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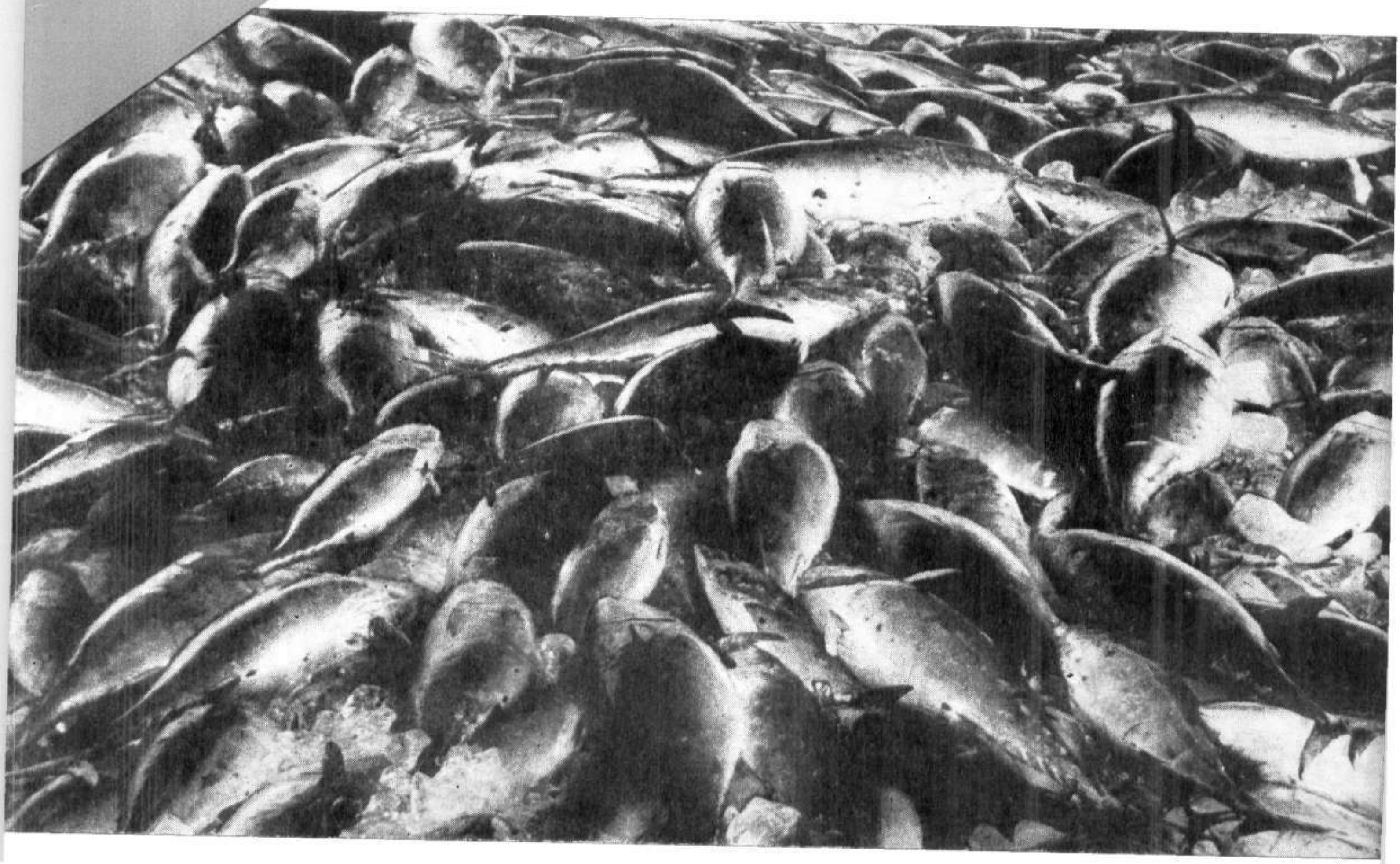

CENTRAL MARINE FISHERIES RESEARCH INSTITUTE

(Indian Council of Agricultural Research)

P.B. No. 2704, Cochin 682 031, India

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CONTENTS

PREFACE

The first four years of the present decade has seen a concerted effort on the part of the government as well as the fishing industry to consider tuna resources of the Exclusive Economic Zone of India and contiguous high seas as potentially important. The report by Silas and Pillai (1982) entitled 'Resources of tunas and related species and their fisheries in the Indian Ocean' has gone a long way in dispelling inhibitions and reservations in many quarters on the availability of tuna resources and the need for developing a tuna harvesting strategy. Recent developments in purse seine fishing in some countries such as Seychelles have indicated the potentialities, but a depressing international market trend for tuna products is still stifling investment in this sector. One silverlining is that today at any fisheries conference or seminar in India, tuna is discussed as a potentially important resource. While for over two decades the Central Marine Fisheries Research Institute has tried to focus attention on this important resource, the Institute itself has been pursuing with limited facilities, research programmes on tuna and tuna-like fishes. The research results embodied in this publication was initiated by me in 1976, as a major project programme at the Institute and gradually built up for critically examining the coastal species of tuna stocks, their biology and fisheries. The research project (FB/PR/3.1) has been carried out from nine centres in which the following has been the involvement of the staff pattern :—

E. G. Silas	Project Leader	Cochin	1976—1985
M. S. Rajagopalan	Associate	Cochin	1976—1979
K. J. Mathew	Associate	Cochin	1976
P. P. Pillai	Associate	Cochin	1978—1985
A. A. Jayaprakash	Associate	Cochin	1981—1985
M. Srinath	Associate	Cochin	1984
I. David Raj	Associate	Cochin	1977
P. Livingston	Associate	Minicoy	1976—1980
Madan Mohan	Associate	Minicoy	1981—1984
G. Gopakumar	Associate	Minicoy	1984 (Part)
C. Muthiah	Associate	Mangalore	1979—1985
V. Balan	Associate	Calicut	1976—1979
R. S. Lal Mohan	Associate	Calicut	1980
T. M. Yohannan	Associate	Calicut	1981—1985
M. D. K. Kuthalingam	Associate	Vizhinjam	1976—1979
Pon Siraimeetan	Associate	Tuticorin	1976—1985
S. Srinivasarangan	Associate	Madras	1981—1985

Technical assistance to the Project was rendered by M. Ayyappan Pillai (1980-1985), J. Narayanaswamy (1980), K. K. Kunhikoya (1981-1985), P. M. Aboobaker (1979-1980), S. Kemparaju (1981-1985), H. Ramachandra (1983-1985), K. Nandakumar (1980), Mohammed Iqubal (1981-1982), P. S. Sadasiva Sharma (1979-1985), C. Manimaran (1981-1985) and K. V. Somaraju (1981-1985).

Some of the associates, due to their preoccupation with other projects, could contribute only in a limited way to the Project. The larger size of the fish and limitations in handling the same in some of the centres due to quick transit from place of landings did pose problems in the proper acquisition of data in the earlier years. In view of this, the data from the different centres used in this report are as follows :

Minicoy	..	1976—1982
Mangalore	..	1979—1982

Calicut	..	1979—1982
Cochin	..	1979—1982
Vizhinjam	..	1980—1982
Tuticorin	..	1979—1982

Initially, the work was mainly confined to Cochin, Tuticorin and Minicoy but with additional staffing and facilities the work was extended to other centres also. In order to standardise collection of data from different centres, suitable proformae were developed for recording field data which are given at the end. For studies on population dynamics, data collected between 1979 through 1982 at selected centres have been used.

Besides the regular monitoring of coastal species resources, special studies were carried out on baitfishes and their biology in the Lakshadweep.

A preliminary account on the status of the tuna fisheries was published earlier (Silas *et al.* 1979). More recently, a case study of the drift gillnet fishery for the larger pelagics at Cochin was published to draw attention to the development in this sector (Silas *et al.* 1984).

This report will bring about for the first time, a large amount of data on coastal tuna resources and at the same time help us to identify major gaps in our knowledge. Purse seining, drift gillnetting, pole and line fishing, longlining and surface trolling are all being undertaken in a very limited or moderate intensity. It is hoped that this report in conjunction with the earlier report by Silas and Pillai (1982) on the Indian Ocean tuna fishery resources will help towards a planned and balanced development of tuna fisheries in this country, both in the small scale and commercial sectors. The research needs highlighted should also meet priority attention in future.

I take this opportunity to sincerely thank my colleagues both scientific and technical who were associated with me in this Project at various stages. I shall look forward for the expertise developed at the CMFRI going a long way in helping towards the rational utilisation of this potentially important resource.

15th April 1985
Cochin

E. G. SILAS
Project Leader (FB/PR/3.1) and Director
Central Marine Fisheries Research Institute,
Cochin

1

TUNA FISHERIES OF THE EEZ OF INDIA—AN INTRODUCTORY STATEMENT

E. G. SILAS

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The tuna fisheries in India is still predominantly an artisanal activity with marginal inputs from the commercial sector. As part of the National Policy for the judicious exploitation of the fishery resources of the Exclusive Economic Zone (EEZ) of India, further emphasis is to be given to the development of tuna fisheries, both in the coastal waters and in the high seas. Despite the fact that there has been a noticeable increase in the landings of coastal tunas during the last two decades, the tuna stocks remain to be one of the least exploited pelagic resource from the EEZ of India. The impact of modern technology was mainly by way of introduction of synthetic fibres for the gear and mechanisation of the crafts which enabled the traditional fishermen to develop their fishing practices in a steady state condition, but the developments in the post harvest technology, especially in the processing of products for internal markets and for exports are still lagging behind (Silas *et al.*, 1979 ; Silas and Pillai, 1982 ; 1983 ; 1984).

The present state of affairs of the tuna fishery in the Indian Ocean are indicative that a major international effort is needed for the development of tuna fisheries for the coastal and island states and to effectively manage the tuna resources of the Indian Ocean, without generating conflicts/developing protective interests and exclusive attitudes. Except for the longline tuna fishery by Japan, Taiwan and the Republic of Korea, and purse seine fishery for tuna by Seychelles there is no organised high seas tuna fisheries in the Indian Ocean. There is the possibility of unlimited entry into the tuna fishery, and added to this, estimates of catch and effort expended and information for biological follow up studies are not always available. The major factors to contend with this fishery are the complex nature of the tuna fishery itself, which employs different techniques for harvesting the resources at surface and sub-surface combined with the need for greater mobility of the fishing fleets. Due to the highly migratory habit of tuna the question of standing stocks become important. All these would necessitate a centralised monitoring Agency to estimate the levels of abundance, catch rate and effort expended and to advice the fishing industry. It is in this context that Silas and Pillai (1982) proposed the establishment of the 'ICCIOT' (International Commission for the Conservation and Management of Indian Ocean Tunas) which could design and implement a coherent policy for the Indian Ocean tuna fishery.

An updated picture of the tuna fisheries of the Indian Ocean as for 1983 shows about 105,000 tonnes increase in production from 207,897 tonnes in 1973 to 312,986 tonnes in 1983, a 51% jump. The catch details for 1983 are given in the following Table.

TABLE 1. *Catch details of tunas, tuna-like fishes and billfishes: Indian Ocean* (1983) (MT).

(Source : *IPTP Data Summary No.* 3, March, 1985)

	Total for Indian Ocean	Total for Western Indian Ocean	Total for Easetrn Indian Ocean
Tunas and tuna-like fishes ..	303,616	187,989	115,627
Billfishes ..	9,370	5,889	3,481
	312,986	193,878	119,108

Inspite of the fact that the last two decades have witnessed the augumentation of production of coastal species of tunas and tuna-like fishes in the small scale fishery sector, through mechanisation of the existing crafts, increasing effort through drift gillnet fishery, pole and line (live-bait) fishery and purse seining, tunas remain to be one of the least exploited resources of the Indian seas, and in 1983 it formed only 1.1% of the total marine fish landings in India. Except in the Lakshadweep Islands where there exists pole and line

Gear-wise and species-wise catch details (MT)—1983

Species	Longline Bait	Bait Boat	Purse Seine	Un-classified (Coastal gears ?)
Yellowfin tuna ..	26,568	6,451	10,773	12,935
Bigeye tuna ..	40,536	1	295	328
Albacore tuna ..	16,890	..	..	..
Southern bluefin tuna ..	10,918	..	..	15,938
Skipjack ..	21	21,646	13,462	28,620
Longtail tuna ..	295	..	..	8,605
Little tuna ..	131	993	..	11,139
Frigate tuna ..	..	3,189	..	851
Tuna-like fishes ..	260	938	15	71,818
Blue marlin ..	2,729	..	..	2
Black marlin ..	294	..	1	..
Striped marlin ..	1,693	..	..	..
Sailfish ..	125	..	..	3
Swordfish ..	1,780	..	..	241
Billfishes ..	11,868	..	..	634
Total ..	104,108	33,218	24,546	151,114
% ..	33.26	10.61	7.84	48.29

surface fishery mainly aimed at tunas; there is no organised fishery for tunas in vogue along the mainland of India. Tuna fishery is currently limited to the small scale sector and very little attempt has hitherto been made to exploit the tuna resources of the EEZ of India.

One of the areas where little information is available is on the se. sonal occurrence in different areas of surface species such as skipjack and young yellowfin tuna which support a surface fishery. Further, there exists scope for the augmentation of production in the pole and line fishery in the Lakshadweep Islands by developing a steady source of bait through bait-fish culture and by attracting tunas by fish aggregating devices (FADs). Vast areas of the Andaman Sea is highly productive for the surface species of tunas. *Inter-alia*, if the environmental data such as temperature, thermocline distribution and its seasonal fluctuations in our waters are made known, these would help considerably in the purse seine operations.

It is to be considered that tuna fishing involves operations not only within our EEZ, but also in the contiguous high seas and if necessary under bilateral arrangements with the other nations. For the Indian Ocean area, the projected figure of potential yield for skipjack tuna is 2 25,000 to 400,000 tonnes and for smaller tunas such as *Auxis* spp. 100,000 to 200,000 tonnes (IOFC 1977). In recent years, the production of tunas, tuna-like fishes and billfishes mainly from the longline fishery and fishing from coastal and oceanic sectors is about 312,986 tonnes (1983). The percentage composition of tuna production from the coastal and island waters through pole and line (bait boat) fishing is 10.61%, surrounding nets (purse seining) 7.84%, coastal fishing (drift gillnetting, hooks and lines and trolling) 48.29% and from the high seas by longlining is 33.26%. The recent development of purse seining by the Republic of Seychelles has been a pointer to the resource potential of skipjack that could be exploited from the Indian Ocean.

Mr. Ranjan Misra (Personal communication) informs me that in March-1985 as many as 46 purse seiners are in operation in Seychelles. Of these 27 belong to five companies from France and 19 to five companies from Spain. The operations are on payment of licence fee as well as royalty and other charges such as fixed amount per tonne of catch as transhipment. Concurrently, another system of joint venture with 51% in favour of Seychelles Government and 49% for French companies is under contemplation. The 'total tonnage being taken from the EEZ of Seychelles and immediately surrounding international waters is estimated to be 150,000 tonnes (tunas) per year'. The purse seiners are 50 and 70 meter vessels of 600 and 1100 MT. That this should happen from virtually a zero base in 1981 should be on eye-opener for our planners.

Mr. Misra further informs me that Thailand in 1984 canned about 100,000 MT of tunas and its 1985 target is about 150,000 MT.

These two are extremely significant developments within the last three to four years which we should take note of.

Silas and Pillai (1982) suggested that the production tempo of tuna fisheries development programmes in India should achieve the commercial production target in terms of quantity and value by 1990 as follows:

Groups	Areas of fishery	Proposed production by 1990 (Tons)	Commercial target (million Rs.)
Coastal species of tunas and skipjack	Small scale fishery sector (Drift gillnets, pole and line and others)	45,000	202.50
Young yellowfin and skipjack	Surface fishing (purse seining)	50,000	450.00
Large oceanic tunas and billfishes	Sub-surface fishing (ordinary & deep longlining)	20,000	270.00
	Total	1,15,000	922.50

During the three year period April, 1982 to April, 1985, India has added hardly anything to tuna production, while Seychelles has developed a base for harvesting over 150,000 MT during this period. In the light of this, the target of achieving 115,000 tonnes production in 1990 given by Silas and Pillai (1982) appears to be very modest, but quite feasible with planned development.

By 1990 I feel that, as indicated by Silas and Pillai (1982) the major component that will contribute to this increase will be skipjack tuna which could easily account for about 40,000 tonnes plus from the present level of artisanal fishery at the Lakshadweep of about 3,000 tonnes.

Bulk of the targeted production of skipjack tuna and young yellowfin in the surface fishery by purse seining and the large oceanic species of tunas and billfishes in the sub-surface fishery by longlining will thus have to be achieved through joint venture or chartering arrangements. As may be envisaged, this would be predominently an export oriented development (Silas, 1982).

In this report, three distinct but complementary components or modules were selected for study

(1) Species-wise catch, effort and c/f ;
(2) Biological aspects such as size distribution, length-weight relationship and growth parameters, and
(3) Population dynamics (stock assessment of selected species of coastal and oceanic tunas).

The specific objectives of these modules were to understand the status of the fishery resources, performance of the various parts of the fishery and to estimate the possibilities of expansion of tuna fishery.

The Central Marine Fisheries Research Institute (CMFRI) furnishes the historical data of various species of marine fishes based on a multi-stage stratified random sampling techniques after classifying important groups of fishes (CMFRI, 1983). For detailed biological investigations involving aspects of species composition, size, age, maturity, spawning, food and feeding habits and other parameters, the Project has selected certain centres along the mainland coast and at Minicoy in the Lakshadweep for tuna investigations which would help in monitoring the resources. Basic data used in the present investigations were collected from :

(1) Publications of the Central Marine Fisheries Research Institute on the trends in the marine fish production in India from 1965-1983 (*Mar. Fish. Infor. Serv. T&E Ser.*, Nos. **22** 1980), **32** (1981), **41** (1982) and **52** (1983);
(2) Data collected from selected centres by the scientists on the fishery and biology of different species under the Institute Research Project 'Resources of tunas and billfishes' (FB/PR/3.1) ;
(3) Data on the landings by coastal purse seine vessels ;
(4) Information on the results of exploratory longlining operations by the vessels of the Central Institute of Fisheries, Nautical and Engineering Training and the Fishery Survey of India ; and
(5) Results of exploratory oceanic drift gillnetting and purse seining conducted in the late sixties by CMFRI and the erstwhile Indo-Norwegian Project.

Although for assessing the total catch and to study the trend of production in the different maritime states of India and the country as a whole, the data have been utilised from 1965-83, for estimating parameters of population dynamics, the data from 5 centres collected during the period 1979-82 in the mainland of India and during 1976-82 from the Minicoy Island were taken into consideration.

New Areas for Research and Development

It is also appropriate to indicate in this introductory statement some new areas for R and D programmes. Of those outlined below, some may have to have a national perspective while others have to be dealt with at organisational level. I could think of the following areas needing immediate attention :

1. *Tunas and billfishes as game fishes*

In some parts of the world tunas and billfishes form a lucrative base for tourism and sport fishing. While our priorities in these matters differ from some of the developed countries, in view of our emphasis on the development of tourism, the importance of ocean sport fishing cannot be minimised. There are excellent opportunities along the west coast of India, Gulf of Mannar, the Lakshadweep Sea and Andaman and Nicobar waters where tunas, sailfishes, marlins and swordfish could be taken in rod and tackle. It is important that we also pay some attention to this area and initiate development of facilities such as boats and gear at selected centres such as Port Blair and Mayabundar in the Andamans, Agathi and Minicoy in the Lakshadweep and at some of the mainland centres such as Ratnagiri, Karwar, Cochin and Tuticorin. A beginning has to be made and both Government of

India and State Tourism Department and Port and Fisheries Departments could evolve a suitable strategy for the development of this activity. Along the east African Coast sport fishing activity has been developed in Malindi and it is understood that the island states such as Seychelles and Mauritius are keenly interested in large scale development of sport fishing in the sea. In our waters the most suitable sport fishing grounds would be :

(i) *Andaman Sea* (Between Port Blair and Diglipur) —excellent area for tunas, seerfishes, sailfish, marlins and barracudas.

(ii) *Gulf of Mannar* (Along Tuticorin—Cape Comorin Coast)—excellent area for seerfishes, sailfishes tunas and marlins.

(iii) *Cochin-Mangalore Area*—good area for tunas, sailfish and seerfishes.

(iv) *Lakshadweep* (Agathi, Minicoy and other islands) —good areas for tunas, sailfish, marlin, swordfish and pelagic sharks.

Besides this, other oceanic gamefishes such as the rainbow runner (*Elagatis bipinnulatus*), dolphin fish (*Coryphaena hippurus*), seerfishes or spanish mackerels (*Scomberomorus commerson, S. guttatus, S. lineolatus* and *S. koreanus*), wahoo (*Acanthocybium solandri*) telang queenfish (*Scomberoides commersonianus*), etc. are excellent game fishes and also occur in the aforesaid areas.

2. *Tuna genetics*

Considerable amount of work on the sub-populations of skipjack tuna in the Central Pacific Ocean has been carried out in the past, in order to understand their migratory patterns and localised concentrations. The need for identifying sub-populations of tunas and their genetic differences through serological studies and observations on sperm morphology and other techniques is a prerequisite for delineating stocks and connected management problems.

3. *Satellite tracking and remote sensing*

Telemetric tagging and tracking of tunas by satellite is a new area which needs further study. Migratory pattern of tunas and their areas of concentrations are to a certain extent dependent on the pattern of se. surface temperature differences, chlorophyll distribution, current boundaries, areas of convergence and divergence, ocean fronts, concentration of flotsams and slicks which could be detected in satellite imagery. Scientifically planned data acquisition and mapping out of these features would help us to a greater extent to understand the likely areas of concentration of tunas especially skipjack and young yellowfin tuna.

4. *Magnetic crystals and migration of tunas*

Investigations are being carried out at present for studying the possibility of whether tunas synthesize internal 'magnets' to enable them to navigate accurately over long distances. It has been observed that millions of 'magnetic crystals' occur in the head of tunas (located in the frontal bone in the case of yellowfin, skipjack and little tunas) with 'accurate magnetic map sense'. Intensive studies on this characteristic feature of tunas should be undertaken since they have far reaching implications in understanding the migratory behaviour of tunas.

5. *Tuna culture*

In Japan, bluefin tuna (*Thunnus thynnus*) is being cultured and harvested. The culture is species specific and the product is aimed at supplying choice markets. This species occurs in temperate waters and to what extent tuna could be cultured economically in tropical waters needs to be seen. Perhaps, an attempt should be made in view of the fact that (*a*) faster growth rates are normally achieved in warmer waters and (*b*) possibility of using the by-catch in fishing operations as feed. This could be motivation enough to carry out some trials in India.

6. *Young fish surveys*

Larval and young fish surveys of tunas are of paramount importance to understand the occurrence and distribution of the '*lost year*' group (post-larvae to early juveniles) which would help in demarcating the spawning ground and season of different species. Further, a species-wise knowledge of the swimming layer of early juveniles, young and adults of tunas would contribute in effective management of operation of fishing gears.

7. *Pollution*

It is necessary that the levels of PCBs, organo-chlorine compounds, radio activity and heavy metals be monitored in the meat of tunas and tuna-like fishes. This is important as these fishes are at the apex of the food chain and obtain and accumulate such pollutants through the different trophic levels.

8. *Floating objects*

Little information is available on the destructive role of damaged plastics, floating tar balls and other flotsam on tunas. With intensive fishing operations good quantities of webbing which have been cut off from the nets may also add to the hazard. A critical study about these objects which negatively affect tuna aggregation and their fishery is called for.

9. *Detection of tuna shoals*

While more sophisticated methods of scouting for tuna shoals and the areas of their concentration by the use of sonar and under water acoustics, aerial spotting and satellite imageries may be undertaken, visual sighting particularly with the help of the movement and behaviour of sea birds should not be discounted. It is very necessary that proper logs of sea bird sightings, their concentration and behaviour is entered in the fishing logs so that accumulated data on their occurrence, distribution and behaviour could also help in the scouting of tuna shoals.

10. *Dolphin-tuna association*

In the Pacific, tuna purse seining is also involved with heavy mortality among dolphins, especially the spinner dolphin (*Stenella longirostris*) and spotted dolphin (*S. attenuata*). Available information indicate that so far the dolphin-tuna association as in the Pacific is not present in the Indian Ocean. However, it is an aspect which needs a careful watch so that in the event of such association in any geographical area in the Indian Ocean, precautionary measures should be taken. The conservation and management practices adopted in the Pacific in purse seine net designs for escape of dolphins should be considered in such an eventuality. Relationship between tunas and other fish associates such as the whale shark need study.

11. *Data acquisition and management of tuna fishery*

One of the important aspects in the management of tuna fisheries is the development of a strong data base for resource information, particularly acquisition of fishery data, its processing and dissemination. Special attention should be given for the monitoring and data acquisition of capture by surface and sub-surface gears for assessing and understanding the stock position of young yellowfin, albacore and skipjack tunas vulnerable to purse seine gear. Any increase in the purse seine fishery and its impact on the longline fishery especially for yellowfin and albacore should be properly assessed. The need is to determine the year classes and magnitude of fish available for a viable longline fishery. Regulation is necessary, but it cannot be implemented without an ocean wide data acquisition system and a co-operative management mechanism and data dissemination system.

12. *Utilisation of tunas*

Silas and Pillai (1982) dealt with in detail the post-harvest storage, processing and marketing of tunas both for export and internal marketing. Development of one or more tuna canneries which can each handle 6,000—10,000 tonnes of tunas per annum is an area which requires immediate attention. The financial assistance for building up infrastructure for such canneries and freezing plants may be provided by government agencies such as the Marine Products Export Development Authority and NABARD.

Frozen tuna products consist mainly of frozen whole body, frozen semi-dress, frozen dress and frozen fillets. Production of such frozen products would involve freezing of captured tunas in fish holds capable of holding the fish below -20° or -40°C.

For internal marketing, the quality and shelf life of dried tuna products such as 'Masmin' should be improved. Canned products should find a good market demand in the country. Better quality salted, smoked or sundried tuna meat would find good market demand in the interior and tribal areas. Future development of processing of tuna meat for internal market should be mainly aimed at developing the technology of fresh and frozen products, canned tuna products and other acceptable items such as fish sausage and fish ham.

CONCLUSION

In summing up I would like to mention that the international market for tunas which was depressed during the last three years, creating a crisis and vagaries in further expansion of this industry is now picking up. The future is bright and 1986 should usher in an era of demand for tunas. Such a positive trend is bound to accelerate global production and marketing efforts. This is one more time for positive action and let us not miss the bus.

2

METHODOLOGY AND BRIEF REVIEW OF THE OCEANOLOGICAL FEATURES OF THE INDIAN WATRES

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The centres selected for detailed biological studies were Minicoy in the U.T. of Lakshadweep, Mangalore, Calicut, Cochin and Vizhinjam along the west coast and Tuticorin along the east coast of the mainland. In all these centres, uniform pattern of data collection system was followed as detailed below :

Each centre was visited at least 4 days in a week and the weekly landings were estimated by

$$W = \frac{Ci}{Cj} \times UK$$

where

W = Weekly total catch
Ci = Catch for observed unit in a week
Cj = No. of units observed (effort)
UK = Total units operated during the week.

From the weekly estimates, monthly catches were computed. In the centres where more than one unit was operated, the standard effort between the units was calculated as follows :

$$SE = \frac{C_{i}}{C_{ii}} \times T_{i} + T_{ii}$$

where SE = Standard effort.

C_i = Catch per unit of effort in weight of one standard gear.

(In Minicoy the Pole and line gear and in the mainland the drift gill net)

C_{ii} = Catch per unit of effort of other gears.

T_i & T_{ii} = Total number of units expended their effort during the month in the tuna and allied pelagic fish fishery.

In the case of purse seine catches, random sampling of the units landed were carried out. Each purse seine usually employs carrier boats which bring the catches to the landing site. The catch of carrier boats as well as that of the purse seine boats were noted by random sampling. The average catch of the observed units is then raised to the total number of purse seiners operating on the day and the average catch for the observation days are then raised to the number of fishing days operating in a month. For estimating the catch per unit effort, the total purse seines operated in a month was taken into account.

2. *Brief review of the oceanological features of the Indian Coast*

BOBP (1983) briefly summarised the fishery resources and the prevailing hydrological characters of the coast of India.

The climate of India can be described as a tropical monsoon climate. Investigations conducted in the past has shown that several layers of water masses such as the Indian Ocean central water, the Indian Ocean equatorial water and the Deep water at a depth of 2000 m are recognisable in the region of subtropical convergence at about 40°S. in the Indian Ocean below the surface waters. The transportation of the cold Antarctic bottom water from the polar regions into the Arabian sea and the Bay of Bengal influence the organic productivity of these areas.

It has been estimated that the rate of primary production on the east coast as 0.63 $gC/m^2/day$ on the shelf and 0.19 $gC/m^2/day$ outside the shelf. Along the west coast of India the mean value within 50 m was calculated as 1.24 $gC/m^2/day$ and the daily production rate of the rest of the west coast shelf as 0.47 $gC/m^2/day$ and for the oligotrophic regions outside the shelf as 0.19 $gC/m^2/day$.

The sea surface temperature of the Indian Coast varies from 23°C to 29°C. Along the north western region, a temperature value of 21°C was recorded during winter season (Nov.-Dec.). In the Bay of Bengal, the range of sea surface temperature is 27°C and 29°C. The thermocline fluctuates much on the west coast of India, being recorded at 100-125 m in winter, at 75-90 m between the monsoon and 20-30 m with the progress of the south-west monsoon. In the Bay of Bengal, the thermocline level is usually below 50-55 m and at times goes down to 100-125 m. Off the west coast, large-scale upwelling has been recorded during the south west monsoon and during the north east monsoon, fairly strong convergence was observed on the east coast of India and in the Andaman Sea.

In the Arabian Sea, the average salinity range is between 34‰ and 37‰ and in the Bay of Bengal 30‰ and 34‰. The influx of Red Sea and Persian Gulf water is the causative factor for the high salinity in the Arabian Sea whereas the large river systems emptying into the Bay of Bengal influence the low saline condition there. It was also observed that the waters in the Arabian Sea is somewhat deficient in oxygen at a depth of 200-500 m depth and this layer is subject to movement as a result of upwelling.

3

A CRITIQUE ON NATIONAL TUNA FISHERY

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1. THE COMMON SPECIES OF TUNAS AND BILLFISHES REPRESENTED IN THE FISHERY

Euthynnus affinis	:	Kawakawa
Auxis thazard	:	Frigate tuna
A. rochei	:	Bullet tuna
Sarda orientalis	:	Oriental bonito
Thunnus tonggol	:	Longtail tuna
T. albacares	:	Yellowfin tuna
T. obesus	:	Bigeye tuna
Katsuwonus pelamis	:	Skipjack tuna
Tetrapturus audax	:	Striped marlin
Makaira indica	:	Black marlin
Istiophorus platypterus	:	Sailfish

Of these species, skipjack tuna constitutes more than 76% of the tuna catch in the Lakshadweep Islands. Along the mainland, *E. affinis* contributes to more than 65% of the total tuna landing, followed by *A. thazard* and *A. rochei* (31%). *S. orientalis* constitutes a minor seasonal fishery along the south-west coast of India and *T. tonggol* occurs seasonally in the Gulf of Mannar and along the north-west coast. Among the billfishes, sailfish commonly occur in the inshore regions of Indian seas.

2. FISHING CRAFTS AND GEARS AND THE FISHERMAN POPULATION

The crafts engaged in the tuna fishery are essentially small mechanised and non-mechanised units. The major crafts and gears engaged in the tuna and other pelagic fishery (Table 1) are based on the results of a survey conducted by the Central Marine Fisheries Research Institute on the existing crafts, gears and personnel engaged in the fishing operations along the coast in 1980 (CMFRI, 1981). The state-wise landings of tunas by mechanised and non-mechanised fishing crafts and the artisanal fishery during the period 1982-'83 is presented in Table 2. It would be seen that about 66% of the tuna landings are from non-mechanised crafts. The common crafts and gears employed in tuna fishery at various centres where the Institute is monitoring the resources for detailed fishery and biological investigation are given in Table 3.

In the mainland of India, crafts such as gillnetters, dug-out canoes and catamarans and gears such as drift gillnets, purse seines, hooks and lines, shore seines

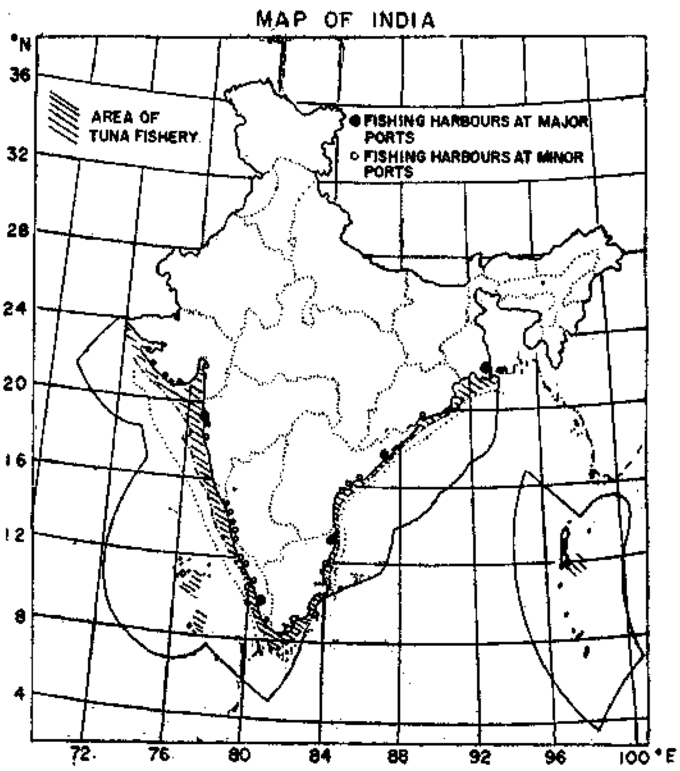

Fig. 1. Operational area of small scale sector fishing boats along the mainland of India and in the Lakshadweep and Andaman Sea.

and surface troll lines are responsible for the major share of tuna landings (Fig. 1). In the Lakshadweep Islands, mechanisation process in the Fisheries develop-

TABLE 1. *State-wise figures of marine fishing crafts, gears and actual fishermen population in India,* 1980 *involved with tuna and other pelagic fisheries*

Items		States and Union Territories									
		West Bengal	Orissa	Andhra Pradesh	Tamil Nadu	Pondi-cherry	Kerala	Kar-nataka	Goa, Damin Diu	Gujarat	Total
Fishing Crafts :											
(*a*) *Mechanised*											
Gill netters	..	247	106	9	324	..	215	23	213	1225	2362
Purse seiners	..	..	..	..	..	..	9	173	39	..	221
Total	..	247	106	9	324	..	224	196	252	1,225	2,583
(*b*) *Non-mechanised*											
Plank built boats		3,972	3,262	11,359	8,957	83	4,376	1,747	1,108	3,040	37,904
Dug out canoes		89	186	1,781	2,210	72	10,415	4,454	1,397	1,080	21,684
Catamarans	..	..	6,276	22,198	31,851	1,595	11,480	23	8	..	73,431
Total	..	4,061	9,724	35,338	43,018	1,750	26,271	6,224	2,513	4,120	133,019
Fishing gears											
Purse seines	..	..	..	..	..	..	9	188	41	..	238
Drift gillnets	..	2,467	10,427	42,375	118,300	1,851	23,307	6,571	3,346	7,383	216,037
Hooks & lines	..	869	15.265	10,752	22,111	720	2,949	1,507	127	2,376	56,676
Shore seines	..	439	2,893	3,042	4,549	84	2,926	3,924	987	..	18,841
Total	..	3,775	28,585	56,169	144,960	2,656	29,191	12,190	4,501	9,759	291,792
Fishermen population											
Full time	..	9,026	20,617	73,506	87,442	5,021	111,970	17,664	6,841	25,616	357,703
Part time	..	9,497	6,262	4,910	4,020	187	11,017	5,558	1,362	6,841	49,654
Occasional	..	1,233	3,845	5,487	5,038	304	8,114	1,783	668	4,070	30,542
Total		19,756	30,724	83,903	96,500	5,512	131,101	25,005	8,871	36,527	437,899

TABLE 2. *State-wise landings of tunas by mechanised and non-mechanised fishing crafts in different States in India* (1982-83)

States		Mechanised* crafts (Nos.)	Tuna landings (tonnes)	Non-mechanised crafts (Nos.)	Tuna landings (tonnes)
West Bengal	..	11,355	..	11,089	..
Orissa	..	11,849	..	21,641	305
Andhra Pradesh	..	34,313	..	91,691	941
Pondicherry	..	4,572	..	8,431	54
Tamil Nadu	..	120,278	1,590	115,675	1,883
Kerala	..	179,276	1,545	169,207	4,760
Karnataka	..	109,428	1,201	18,549	1,042
Gujarat	..	148,078	286	48,349	4
Maharashtra	..	NA**	NA	NA	NA
% Contribution	..	33.95		66.05	

* Mechanisation used both in fishing operation and propulsion or for propulsion only.

** N.A. Data not available at present.

TABLE 3. *Common crafts and gears engaged in tuna and other pelagic fishery in different maritime States of India*

State	Crafts	Gears
ORISSA	Plank built boats ; catamarans ; mechanised boats (Pablo types)	Hooks and lines ; drift gillnets ; mesh size 70-130 mm.
ANDHRA PRADESH	Catamarans ; plank built boats ; mechanised boats (Pablo type)	Drift gillnets mesh size 70-130 mm Hooks and lines.
TAMIL NADU	Mechanised boats (Pablo type) ; catamarans ; Dugout canoes, Mechanised boats (Pablo) ' Tuticorin ' type boats	Drift gillnets, mesh size 90-140 mm ; Hooks and lines ; Troll lines
PONDICHERRY	Mechanised boats (Pablo type) ; Dugout canoes ; Catamarans.	Hooks and lines ; Drift gillnets, mesh size 90-140 mm.
KERALA	*Mechanised boats (14.5 m) ; Mechanised boats (Pablo type) ; Dugout canoes ; Catamarans.	*Purse seines (400-600 × 40-60 m) ; Drift gillnets, mesh size 90-130 mm ; Hooks and lines ; Shore seines.
KARNATAKA	Mechanised boats (14.5 m) ; Mechanised boats (Pablo type) ; Dugout canoes.	Purse seines (400-600 × 40 — 60 m) ; Drift gillnets mesh size 65-135 mm ; Hooks and lines.
GOA	Mechanised boats (14.5 m) ; Mechanised boats (Pablo type) ; Dugout canoes.	Purse seines (600 × 55 m) : Drift gillnets.
MAHARASHTRA	Mechanised boats (small) ; country crafts with OB Engine.	Drift gillnets mesh size 90-130 mm.
GUJARAT	Mechanised boats (small) ; Plank built boats and canoes.	Drift gillnets, mesh size 90-130 mm ; Hooks and lines.
LAKSHADWEEP	Special type mechanised boats (7.93 & 9.14 m) ; with bait tank ; Non mechanised boats (12.5 m)	Pole and line, 3-4 m long ; 35-40 mm at the bottom and 20-35 mm at the top ; polythene line ; barbless hook with lead coating ; troll lines.

* At Cochin from 1980 onwards.

ment commenced in 1959 and since then the fishing fleets had expanded considerably, and at present about 223 mechanised boats are in operation in different islands of the Union Territory. The country craft '*masodis*' which once formed the tuna fishing force in the Lakshadweep are virtually replaced by mechanised crafts. Initially, the boats were supplied to the bonafide fishermen at the subsidised rate of 100% on the cost of engine and 25% on the cost of hull which at present are reduced to 33.3% and 20% respectively (Varghese, 1982). The fishery depends on pole and line (live-bait) fishing and use of troll lines.

3. ANNUAL ALL INDIA PRODUCTION

The trend in the annual all India production during the years 1965-83 as estimated by the Central Marine Fisheries Research Institute is presented in Fig. 2. The average all India tuna catch for the 19 year period was 11,098 tonnes. A progressive trend in the tuna catch was recorded from 1966 (3063 tonnes) which reached a peak of 19,322 tonnes in 1976. After a decline in 1977 and 1978, tuna landings increased in the country and recorded an all-time peak of 26,595 tonnes in 1979

The total landings indicated a downward trend during the period 1980 to 83 and the annual landing of tuna and billfishes in recent years is around 19,000 tonnes.

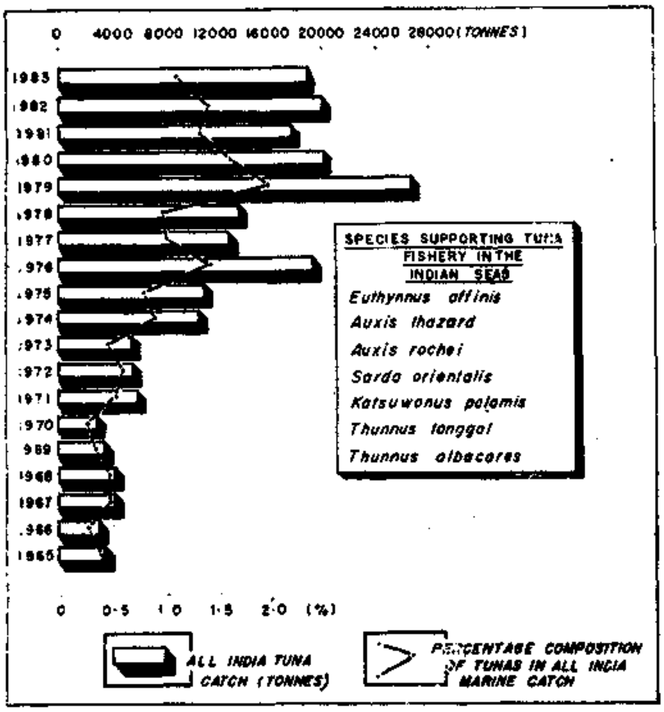

Fig. 2. Trend of All India tuna catch and the percentage composition of tunas in All India marine catch, 1965-'83.

The percentage composition of different species of tunas and billfishes in the total catch during 1981-'82 and 1982-'83 period was as follows:

Species		*Percentage composition* 1981-'82	1982-'83
E. affinis	..	61.62	50.10
Auxis spp.	..	8.25	9.00
T. tonggol	..	0.41	0.10
K. pelamis	..	12.10	10.20
Other species	..	14.02	20.80
Billfishes	..	3.60	9.80

The percentage composition of total tunas in the all India marine fish production ranged from 0.3 in 1970 to 1.97% in 1979. In 1981, tunas constituted 2.4% of the total landings of pelagic groups of fishes in this country: In the Lakshadweep islands, they constituted about 65% of the total marine fish production.

4. Tuna landings along the west and east coasts of India

Production of tunas and billfishes from the west and east coasts of India and from the U.T. of Lakshadweep and Andaman and Nicobar Islands during the years 1965-1983 is shown as percentage of total annual production in Fig. 3. It is discernible that the average annual production of these fishes from the west coast of India alone accounted for about 63.0% of the total catch of tunas in the country, which is mainly contributed by the fishery along the Kerala Coast. The average tuna landings along the east coast during this period was 2501 tonnes forming 24.50% of the all India average tuna production. Tamil Nadu was responsible for about 78% of the production of tunas in the east coast. The rest of the catches are shared by the U.T. of Lakshadweep (12.30%) and Andaman and Nicobar Islands (0.2%).

5. State-wise production

State-wise distribution of tuna landings for the period 1965-'83 is presented in Table 4. The average annual state-wise production of tunas during this period indicate that Kerala State alone accounted for 48% of the total tuna catch in the country, followed by Tamil Nadu (17.60%), Maharashtra (6.67%) and Gujarat (4.2%).

The average annual catch of tunas during 1965-1983 and the trend of tuna fishery in different States are summarised below.

Orissa

The average annual catch in the state of Orissa during 1965-83 was about 97 tonnes and in 1981 it formed 1.5% of the total production of pelagic fishes in the State and in 1982 about 400 tonnes of tunas were landed. *E. affinis* contributed to about 45% of the total tuna catch and the rest by *A. thazard* and other species. Hooks and lines and drift gillnets were the major gears which landed tunas in this State.

Andhra Pradesh

Tuna catch showed a declining trend since 1974, but in 1982 about 820 tonnes were landed in the State, the average tuna landing during 1965-83 period being 440 tonnes. *E. affinis*, *A. thazard* and *A. rochei* constituted the major species although *K. pelamis* has been occasionally landed by hooks and lines. Drift gillnets, hooks and lines and other shore-based gears were responsible for the production of major share of tunas in the State.

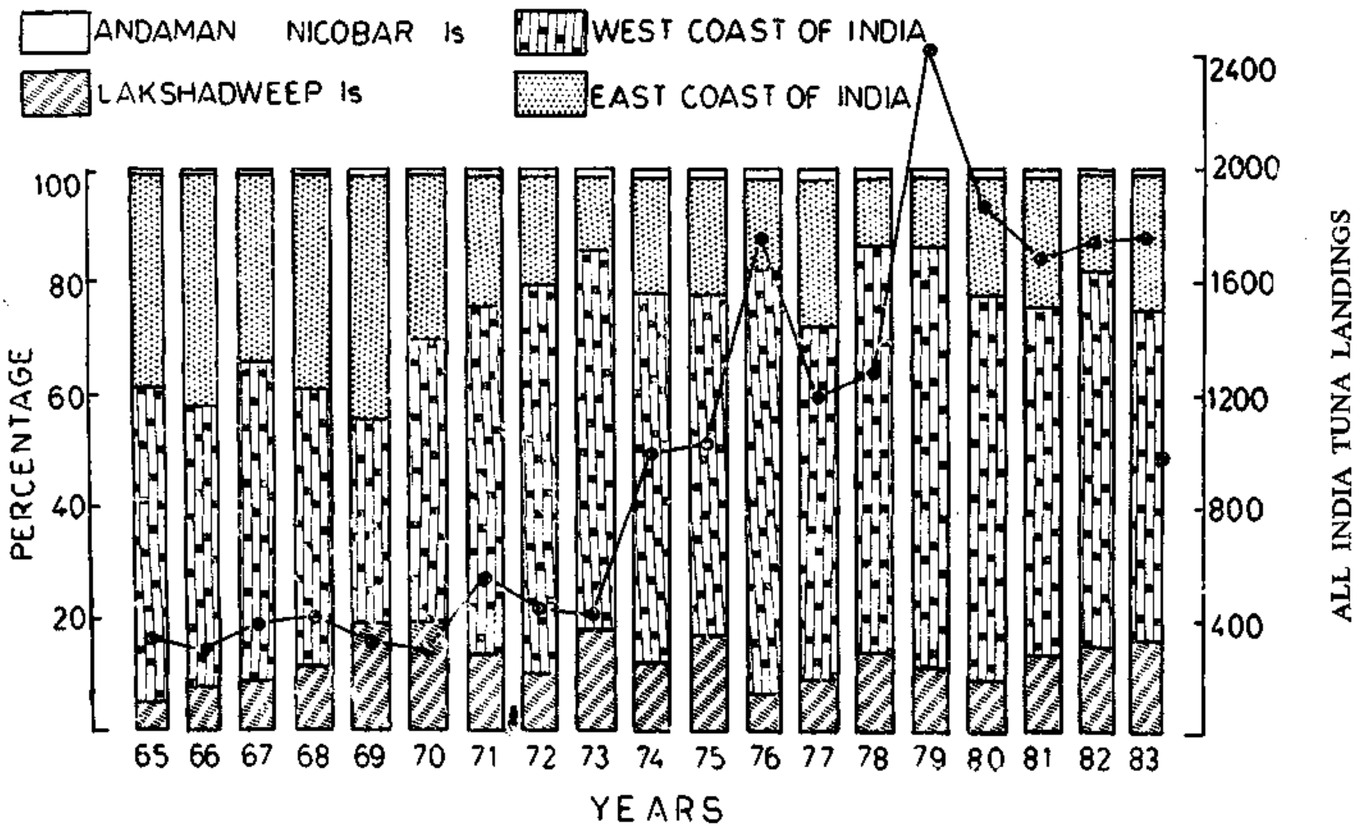

Fig. 3. Trend of landings of tunas along the west and east coasts of India and in the Andaman-Nicobar Islands and Lakshadweep Islands. All India tuna landings (X 10), 1965-'83 is also indicated.

TABLE 4. *Year-wise and State-wise landings of tunas (in tonnes) from 1965 to 1983*

Year		*Orissa	Andhra Pradesh	Tamil-Nadu	Pondi-cherry	Kerala	Kar-nataka	Goa	Maha-rashtra	Gujarat	Andaman & Nicobar Islands	Laksha-dweep	Grand Total
1965	..	121	449	791	1	1,831	69	..	97	6	3	130	3,498
1966	..	89	493	721	7	1,971	11	..	327	..	5	213	3,063
1967	..	..	247	1,177	..	1,445	106	..	873	..	6	377	4,231
1968	..	5	478	1,188	..	1,850	100	..	160	..	5	517	4,303
1969	..	..	193	1,368	2	978	109	..	123	..	7	665	3,445
1970	..	1	135	788	2	1,226	4	2	278	..	9	571	3,015
1971	..	42	293	1,044	16	3,043	515	..	292	1	12	774	6,032
1972	..	28	495	658	1	3,626	134	..	294	1	9	514	5,760
1973	..	46	141	624	..	2,699	120	..	743	268	13	1,020	5,678
1974	..	9	683	1,691	9	5,927	398	..	286	579	7	1,254	10,839
1975	..	16	664	1,785	..	5,845	218	2	274	546	9	1,932	11,285
1976	..	84	334	2,923	1	12,880	576	23	463	734	13	1,291	19,322
1977	..	37	449	3,238	..	6,705	622	107	312	382	37	1,166	13,005
1978	..	609	328	1,169	3	6,545	614	300	1,939	451	57	1,875	13,895
1979	..	31	437	3,211	1	15,391	1,717	742	1,772	442	57	2,794	26,595
1980	..	34	419	4,233	..	10,611	952	356	1,674	277	55	1,760	20,371
1981	..	251	542	3,968	72	5,638	2,520	193	1,320	1,600	42	2,253	18,399
1982	..	409	816	3,214	52	7,281	2,268	6	1,600	358	35	2,966	19,005
1983	..	37	756	3,255	118	5,750	1,795	25	1,248	3,192	35	2,966	19,177

* Catch reported as West Bengal & Orissa.

Tamil Nadu

Tamil Nadu contributed more than 75% of the total tuna production from the east coast of India and the average annual production of tunas in the state during the period 1965-83 was 1980 tonnes. During the period 1979-83 the catches fluctuated between 3000-4000 tonnes. There was a gradual increase in 1973 and in 1981 it constituted 4.2% of the total pelagic fish catches of the state. 70% of the tunas landed was constituted by *E. affinis* followed by frigate and bullet tunas. Drift gillnets formed the major gear which landed tunas in this state followed by hooks and lines, shore seines and troll lines.

Kerala

The state of Kerala has been responsible for more than 70% of the total tuna production from the west coast of the country. Average annual landing of tunas in this State during 1965-83 was 5330 tonnes. Catch of tunas were relatively high since 1974 and a peak catch of 15,390 tonnes were landed in 1979, subsequent to which a declining trend was noticed in this State and in 1983, 5750 tonnes were recorded. This declining trend was reflected in the total all India tuna production as well. Drift gillnets, hooks and lines and shore seines were the major gears which land tunas in this state. Purse seine landings at Cochin contributed hardly 2% of the total catch in this state. The species landed were mainly *E. affinis*, *A. thazard*, but seasonally *A. rochei* and *S. orientalis* also contributed a major share in the tuna landings in this State.

Karnataka

Tuna catch recorded a steady increase since 1975 and the average catch during the period 1965-83 was 676 tonnes. The increased landings since 1978 was partly due to the landings of tunas by purse seiners operating along the Karnataka Coast. In 1981, purse seiners were responsible for 80% of the tuna catch in the State. In general, drift gillnets, hooks and lines and other shore based gears landed tunas. *E. affinis*, *A. thazard* and *T. tonggol* constituted the major species landed in the State.

Goa

Tuna production has been relatively high during 1978-80 and in 1979 about 740 tonnes were landed. The average production of tunas in Goa during 1965-83 is 92 tonnes. *E. affinis* and *T. tonggol* are the major species that support tuna fishery in this state.

Maharashtra

Average annual production of tuna during the period 1965-83 was 739 tonnes. Since 1977, the tuna catch has increased considerably in the State and in 1983 about 1250 tonnes of tunas were landed. *E. affinis* and *T. tonggol* together constituted more than 60% of tunas landed.

Gujarat

Regular landing of tunas has been recorded along the Gujarat Coast since 1973 and the catch reached a maximum of 3192 tonnes in 1983.

Lakshadweep Islands

An average catch of 1317 tonnes of tunas was recorded in the Lakshadweep Islands during 1965-83 in the pole and line (live-bait) fishery and by surface trolling. Skipjack tuna constituted 79.4%, young yellowfin tuna 18.0% and *E. affinis* and *A. thazard* 1.8% of the total tuna catch. However, the availability of bait fishes is the major factor in the success of the Minicoy tuna fishery.

Andaman and Nicobar Islands

Tuna landings fluctuated between 35-57 tonnes and the average catch during the period 1965-83 was about 22 tonnes. Total tuna catches showed a decreasing trend from 1978 onwards and in 1983 only 35 tonnes were landed from around these islands.

5. Seasonal pattern of tuna fishery

The fishing season for the country as a whole is the period October to December; for Maharashtra and Gujarat July to September. On the west coast the peak seasons are October-December for West Bengal and Orissa and January-March for Tamil Nadu and Andhra Pradesh. (BOBP, 1983).

However, the data on seasonal pattern of distribution of average all India tuna landings during the period 1970—83 have been analysed and the results presented in Fig. 4. The average quarterly landings of tunas at an all India level indicate that the two quarters of April to June and October to December are more productive periods. Since on an average of 62% of the landings of tunas are from the west coast of India, the seasonal pattern of distribution of tuna landings at an all India level is chiefly a reflection of the pattern of fishery along the west coast of India.

State-wise average quarterly production of tunas during 1970-83 indicate that it is relatively high during the monsoon months of April to June along the west coast of India and July to October along the east coast. Productive period for tuna fishery was observed to be during April-June for the Kerala State, July-September for the state of Tamil Nadu and October-December for the other maritime States. The bulk of the tuna landings occur in the Lakshadweep Islands during the period November to May (Varghese, 1982).

6. Purse seining in the inshore waters

Coastal tunas netted during the purse seine operations along the inshore waters of Kerala and Karnataka coasts in recent years is presented below :

Base	Catch (tonnes)				Effort (units)		c/f (kg)	
	1979	1980	1981-82	82-83	1981-82	82-83	1981-82	82-83
Cochin (Kerala) ..	—	—	1275	750	21,566	19,347	17.4	1.8
Mangalore .. (Karnataka)	112	751	1767	430	103,905	16,175	17.0	26.6

In 1981, the Danish aided vessel of FSI ' M/V *Matsya Varshini* ' deployed for purse seine survey along the Gujarat Coast, as a part of the World Bank Test Fishing Operations under Gujarat Fisheries Project located good resources of little tunny off Porbandar and Bombay Coast. She netted about 12 tonnes of *E. affinis* in one set from the area 21°08'N and 69° 41'E at a depth of 18 fathoms in September. During the purse seine operations in October, a total of 7 sets were made by her in the area 18°58'N and 72°27'E and the total catch was 9 tonnes of little tuna.

However, added interest has been emerging from the private sector to venture into tuna purse seining. Recently, at Cochin the vessel ' *Simla* ' (20.25 m OAL) rigged for tuna purse seining has netted about 12 tonnes of *E. affinis* and *A. thazard* from off Quilon and Mangalore.

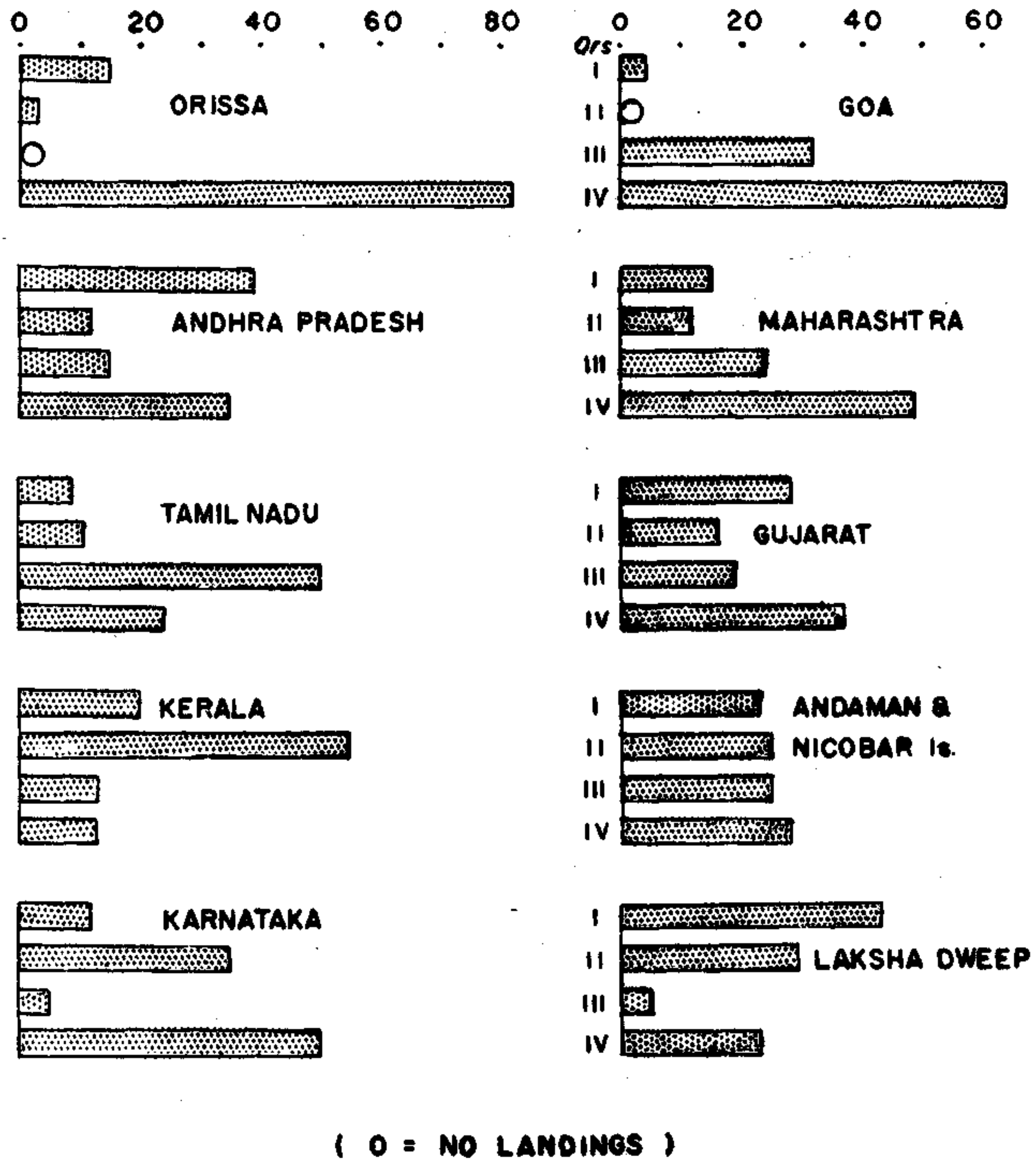

Fig. 4. Seasonal pattern of distribution of tunas (quarterly averages) in different maritime States, 1970-'83.

The State Trading Corporation of India (STC) under the tuna project carried out feasibilty studies on purse seine fishery in the Indian waters during March to June, 1983 in collaboration with ' NORDCO' (funded by SIDA) Canada. It is proposed to conduct large scale purse seine operations for tunas in collaboration with *SEC* (Societa Eserzio Cantieri, Italy) using a tuna purse seiner of 68.79 m OAL and 1055 MT capacity and with helicopter facilities for shoal detection in our EEZ and contiguous high seas.

7. Exploratory tuna longline fishery in India

Considering the availability of tuna resources in the waters around India, the Government of India sought the assistance of FAO of United Nations in 1963 to provide the service of a tuna longline fishing expert to assist in the organisation and training tuna longline fishing in the high seas around India. The fishery survey vessels M/T *Pratap* and *Kalyani IV* and *Kalyani V* which belonged to the erstwhile Exploratory Fisheries Project (Presest ' Fishery Survey of India') were employed for carrying out experimental tuna longline operations. During the period 1964-'65, 14 survey cruises were conducted to train the Indian crew especially in navigation, indigenous construction of the fishing gear and operation of the tuna longline gear. The total catch between April, 1964 and January, 1965 was composed of 70% sharks, 14.7% tunas, 13.2% billfishes and 2.1% other categories (Table 5). (Kawaguchi, 1967).

During 1981, the CIFNET (Central Institute of Fisheries Nautical and Engineering Training) acquired two modern tuna longliners M/V. *Prashikshani* and M/V. *Skipper* I under the Japanese Aid Programme and under Norwegian Aid Programme respectively to impart training for the trainees in the longline fishing technique. The results of tuna longline operational areas covered by M/V. *Prashikshani* during 1981 and 1982 in the oceanic waters of off the south-west coast of India and the Lakshadweep Sea are shown in Figs. 5 & 6. During 1981, the percentage composition of tunas in the total catch was 7.07% which went up to 16.87% in 1982. Incidenc of the pelagic sharks was about 75% of the total catch in both the years (Table 6).

MFV *Matsya Sugundhi*, a longliner cum squid jigging vessel, procured by the Government of India under the Japanese Aid Programme (31.5 m OAL) has been conducting the exploratory longline operations in the oceanic waters of India since 1980. The data regarding the operational details and catch during 1982 and the

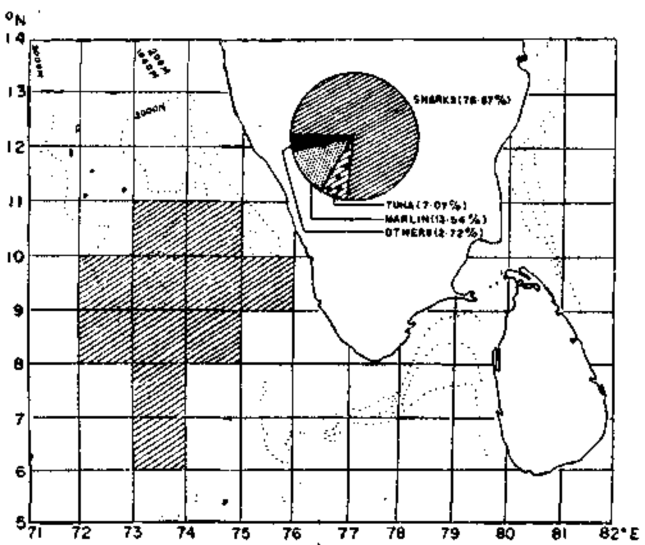

Fig. 5. Operational areas and catch of M. V. *Prashikshani* during 1981.

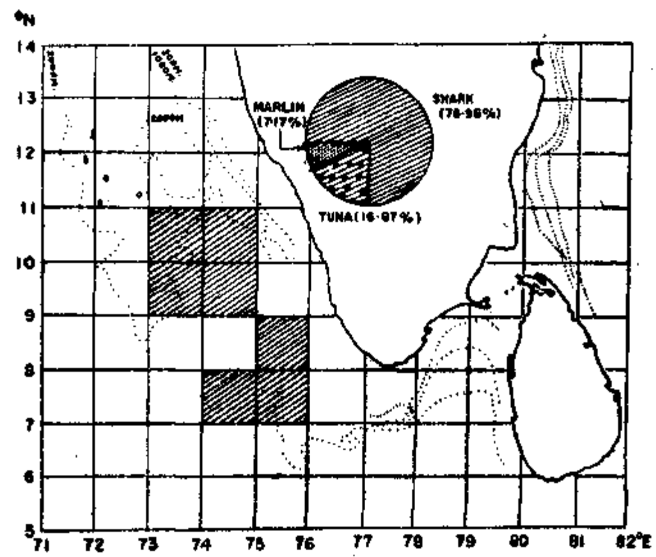

Fig. 6. Operational areas and catch of M. V. *Prashikshani* during 1982.

TABLE 5. *Exploratory tuna long line fishery off the SW coast of India (5°—12° N.) during 1964-'65*

Percentage composition and Hook rate (%)

Species			1964				1965		Total
			April	May	June	Nov.	Dec.	Jan.	
Big eye	..	%	9.20	5.30	0.00	0.00	0.00	4.80	
		HR	0.52	0.20	0.24	0.07	0.02	0.09	
Yellowfin	..	%	10.10	5.90	10.90	5.60	1.20	3.90	12.5
		HR	0.47	0.18	0.00	0.37	2.45	0.12	
N. Bluefin tuna	..	%	3.00	0.00	0.00	2.80	0.00	0.00	
		HR	0.16	0.00	0.00	0.04	0.00	0.00	
Spear fish group	..	%	8.30	11.20	12.70	13.90	19.30	17.30	11.2
		HR	0.43	0.37	0.28	0.18	0.43	0.41	
Shark group	..	%	68.60	72.90	72.60	77.70	76.00	71.30	74.6
		HR	3.52	2.45	1.60	1.00	1.69	1.67	
Others	..	%	3.20	4.70	3.80	0.00	3.50	2.90	1.4
		HR	0.04	0.12	0.08	0.00	0.08	0.07	

TABLE 6. *Details of tuna long-line operations by M. V. Prashikshani during the years* 1981-1982*

Year & Month			Effort (No. of Hooks)	Total Catch (kg.)	Catch composition (HR)				Total HR
					Tunas	Marlins	Pelagic sharks	Others	
1981	January	..	4,000	2,456	0.26	0.52	5.77	..	6.55
	February	..	4,000	2,456	0.28	0.28	1.65	..	2.20
	March	..	8,400	3,386	0.26	0.53	1.05	0.24	2.08
	April	..	5,800	1,256	0.08	0.08	1.64	0.25	2.07
	May	..	7,050	1,668	0.06	0.36	0.89	0.06	1.37
	June	..	250	..	..	..	..	..	..
	July	..	..	..	..	..	..	..	..
	August	..	5,750	700	0.03	..	0.49	..	0.52
	September	..	5,550	1,767	0.02	..	1.13	..	1.15
	October	..	2,200	1,022	0.36	0.59	1.00	..	1.95
	November	..	3,100	847	0.04	0.09	0.81	..	0.94
	December	..	2,700	1,167	0.04	0.29	1.07	..	1.40
	Total		48,800	16,725	1.43	2.74	15.50	0.55	20.23
1982	January	..	3,625	1,923	0.07	0.43	0.76	..	1.26
	February	..	..	..	..	..	..	..	..
	March	..	500	..	..	..	..	..	..
	April	..	..	..	..	..	..	..	..
	May	..	350	..	..	..	..	..	..
	June	..	850	355	..	..	1.76	..	1.76
	July	..	2,425	1,469	..	0.10	2.37	..	2.47
	August	..	1,450	207	..	..	0.18	..	0.18
	September	..	400	44	1.20	..	0.30	..	1.50
	October	..	3,300	4,237	0.001	0.005	0.05	..	0.06
	November	..	1,700	275	..	..	0.30	..	0.30
	December	..	..	..	..	..	..	..	..
	Total		14,600	8,600	1.27	0.54	5.72	..	7.53

* *Source* : CIFNET News letters Vol. I(1) ; II (1) ; III (1)

TABLE 7. *Details of tuna long-line operations by MFV Matsya Sugundhi during the year* 1981*

Year and Month		Effort (No. of hooks)	Total catch (Number)	Hooking rate (%)					Total
				Grey dog shark	Hammer-head shark	Dolphin fish	Marlins	Rock-cod	
1981	October ..	675	11	1.63	..	..	..	..	1.63
	November ..	1500	10	0.67	..	..	..	..	0.67
	December ..	2925	173	5.33	0.44	0.03	0.07	0.03	5.91
	Total ..	5100	194	3.47	0.25	0.02	0.04	0.02	3.80

* *Source*: 'Results of Exploratory Survey of Fisheries Resources of Wadge Bank' Progress Report No. 1, EFP, Bombay.

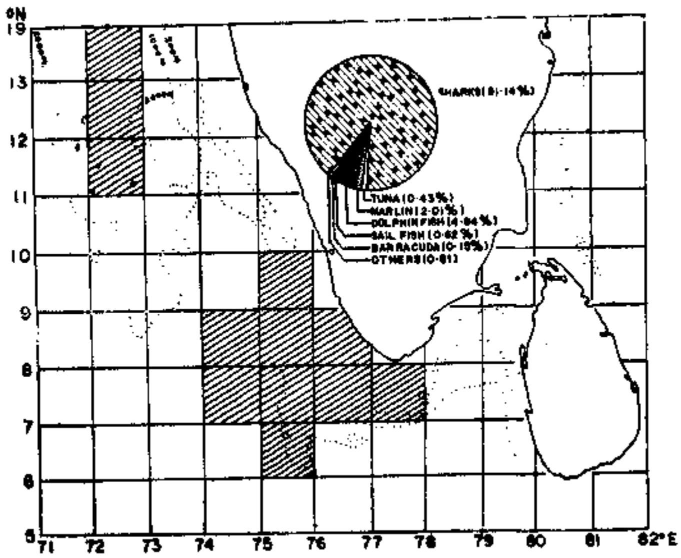

Fig. 7. Operational areas and catch of M. F. V. *Matsya Sugundhi* during 1982.

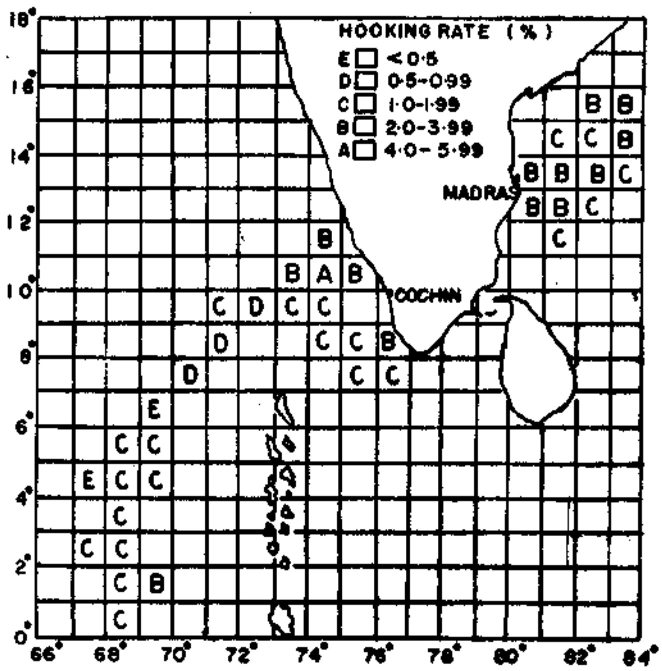

Fig. 8. Area-wise hooking rate in percentage of M. F. V. *Matsya Sugundhi* by tuna longlining, during 1983-84.

TABLE 8. *Details of tuna long-line operations by 'MFV Matsya Sugandhi', during the year* 1982*

Year & Month		Effort (No. of Hooks)	Total catch (Nos.)	Hooking rate (%)						Total HR
				Tuna	Sharks	Marlins	Dolphin fish	Sailfish	Others	
1982	January ..	2,475	44	0.04	0.69	0.08	0.08	0.04	0.85	1.78
	February ..	..	..	..	..	..	..	..	..	..
	March ..	..	..	..	..	..	..	..	..	..
	April ..	..	..	..	..	..	..	..	..	..
	May ..	300	7	..	2.33	..	..	..	..	2.33
	June ..	1,635	69	..	4.22	..	..	..	..	42.2
	July ..	3,000	121	..	3.71	..	0.16	..	0.16	4.02
	August ..	4,257	180	..	4.15	0.04	..		0.02	4.21
	September ..	4,605	142	..	2.64	..	0.43	..	..	3.08
	October ..	3,825	80	..	1.91	0.16	..	..	0.03	2.09
	November ..	7,530	111	..	1.36	0.09	0.01	..	..	1.46
	December ..	7,005	244	0.07	2.54	0.15	0.57	0.12	0.03	3.48
		34,632	998	0.02	2.47	0.08	0.19	0.03	0.09	2.88

* *Source*: 'Results of Exploratory Survey of Fisheries Resources of Wadge Bank' Progress Report No. 2 & 3, E F P, Bombay.

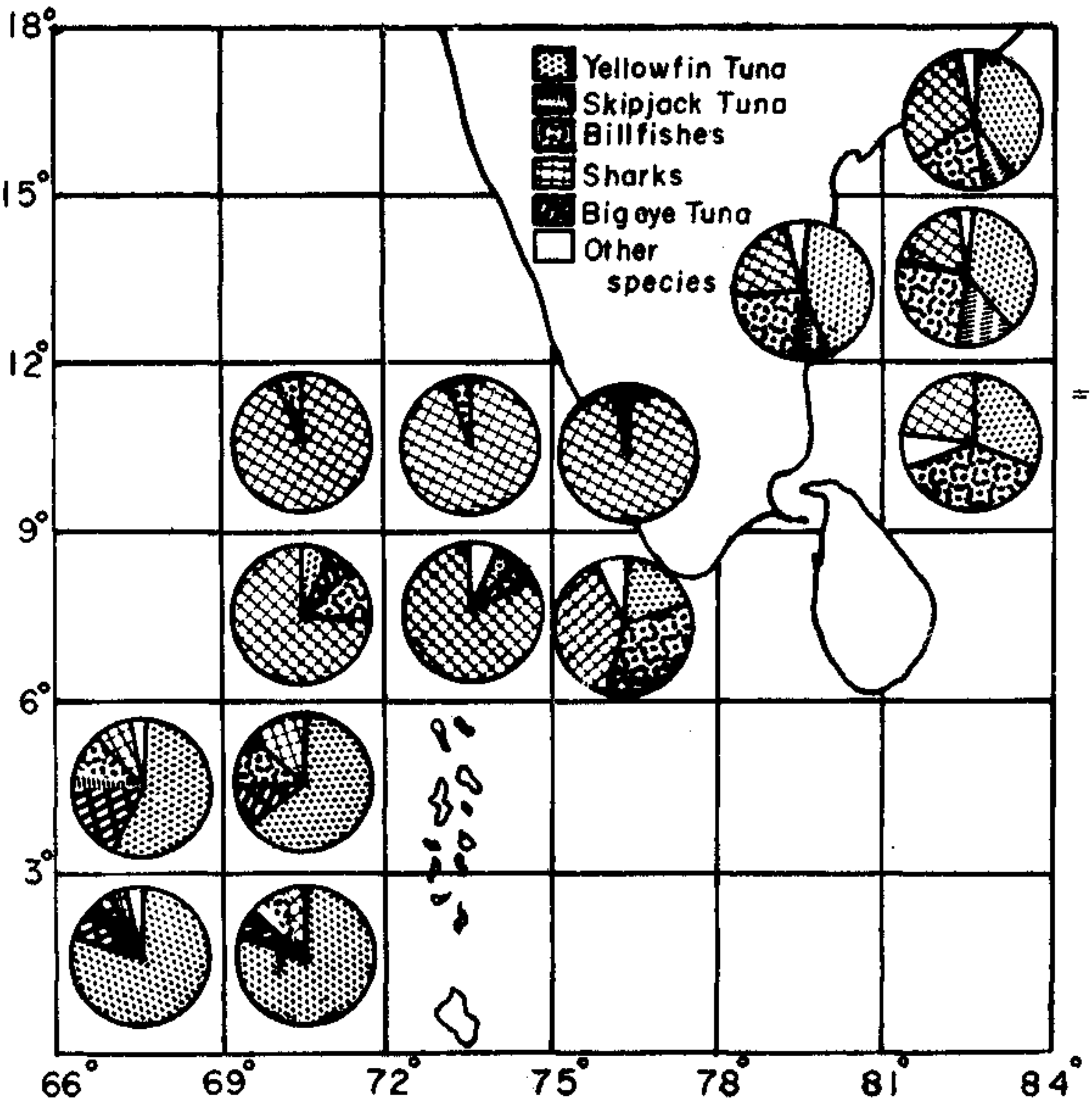

Fig. 9. Composition of tuna longline catch by M. F. V. *Matsya Sugundhi* during 1983-'84.

area of operation are presented in Fig. 7. It was observed that the composition of pelagic sharks in the total catch was 91.1% and tunas 0.43% (Tables 7 & 9). Recently, Varghese *et al.* (1984) summarised the results of tuna longlining operations by *Matsya Sugundhi* from the southwest coast between 7° and 12°N; equatorial waters and from the east coast upto 18°N. Area-wise hooking rate and the composition of longline catches obtained during the survey are presented in Figs. 8 and 9. According to them, of the total of over 83,000 hooks operated, 47,000 were off the southwest coast, 20,000 in the equatorial waters between 0° and 6°N and 16,000 off the east coast. The aggregate catch composition of big eye tuna was 1.69%, yellowfin tuna 21.5%, skipjack tuna 2.01%, marlin 4.38%, sailfish 4.23%, swordfish 0.79%, pelagic sharks 64.24% and other varieties 1.16%. In total, tunas were in higher percentage (85%) from the equatorial waters followed by 53% from the east coast and only 0.03% from the west coast.

8. Exploratory purse seining and gillnetting in the oceanic waters of India

For the first time in the oceanic waters tuna purse seining and oceanic gillnetting has been conducted by CMFRI and the erstwhile Indo-Norwegian Project (Silas, 1969). The results of observation and the biological aspects on different species of tunas caught during the operations are dealt with elsewhere in this publication.

4

POPULATION DYNAMICS OF TUNAS : STOCK ASSESSMENT

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1. Data base : Methods of sampling and analysis

Crafts and gears employed in the fishery and the system of collection of data at different centres along the west and east coasts in the mainland of India and from Minicoy Is. were dealt with earlier. In the manner described, the following informations were collected :

— Numbers landed by fishing gear ;
— Estimated total tunas landed by weight by fishing gear ;
— Estimated weight of sampled landings ;
— Species composition of sampled landings, and
— length and weight of tunas in sampled landings.

Data collected were summarised at the end of the month by fishing gear and species. Samples of length frequencies obtained during the month by a particular fishing gear and species were summarised to calculate the weighted per cent length frequency distribution of total landings for that month.

Although the fishery and biological data have been collected on species such as *E. affinis*, *A. thazard*, *A. rochei*, *S. orientalis*, *T. tonggol*, *T. albacares* and *K. pelamis* from 1976 till date, time-series data representing all the months are available in the case of *E. affinis* and *A. thazard* in the mainland of India and *K. pelamis* and *T. albacares* in the Minicoy waters during 1976-'82. In the case of the former two species, data collected from five centres along the mainland during the four year period (1979-'82) were pooled, annual averages taken and raised to all India level. Fishery and biological data on skipjack and yellowfin tuna during the period 1976-'82 were pooled and annual averages estimated for computation.

Estimation of growth parameters

In the present study, the growth (in length) of different species was assumed to follow the von Bertalanffy's (1938) growth equation :—

$$L_t = L_\infty \left(1-e^{-K(t-t_0)}\right), \quad \ldots\ldots\ldots (1)$$

(Where L_t, L_∞, K and t_0 have their usual meanings) an assumption made by several authors for tunas earlier (Josse *et al.*, 1979 ; Cole, 1980 ; Wankowski 1981 ; White and Yesaki, 1982 ; Yesaki, 1983). The parameters L_∞ and K of the equation were estimated using the computer programme developed by Pauly and David (1981) for modal progression (ELEFAN I). In this method, a ' best fit ' growth curve is fitted objectively through the time series of length frequency measurements. The estimated values of L_∞, K and t_0 for the von Bertalanffy's equation for different species of tunas are given in Table 1.

Since the set of estimates at different centres did not show much variation, single set of estimates for each species is obtained and presented in the above Table.

2. Cohort analysis

In the classical stock assessment theory, it is usual to assume that, within any one age group, the decline in number with age follows an exponential curve. For cohort analysis, the exponential curve within any age group is replaced by a ' step function ' by assuming that—

Table 1. *Values of L_∞, K and t_0 computed from different centres*

	L_∞ (cm)	K	t_0**	I	II	III	IV	V+	VI (?)	
				......	......	......	(cm)	......	......	
E. affinis ..	81.00	0.3655	—0.3438	31.43	46.60	57.14	64.44	69.50		
A. thazard ..	63.00	0.4898	—0.2700	29.20	42.20	50.30	55.00			
T. tonggol ..	93.00	0.4898	—0.2400	42.30	61.90	74.00	81.30	85.90		
S. orientalis ..	66.00	1.0005	—0.1300	44.70	58.00	63.00	65.00			
K. pelamis ..	90.00	0.4898	—0.0600	36.00	57.00	69.00				
*T. albacares** ..	145.00	0.3200	—0.3400	50.60	76.40	95.20	108.8	118.30	125.90	131.20

(* *Based on Minicoy data*) ** Computed from Pauly (1979)

PLATE I. Tunas landed by drift gillnets are counted after auction at Cochin Fisheries Harbour.

PLATE II. Tunas landed by drift gillnet stacked at Cochin Fisheries Harbour before transportation.

PLATE III. Tunas are being loaded at Cochin Fisheries Harbour for transportation to distant markets.

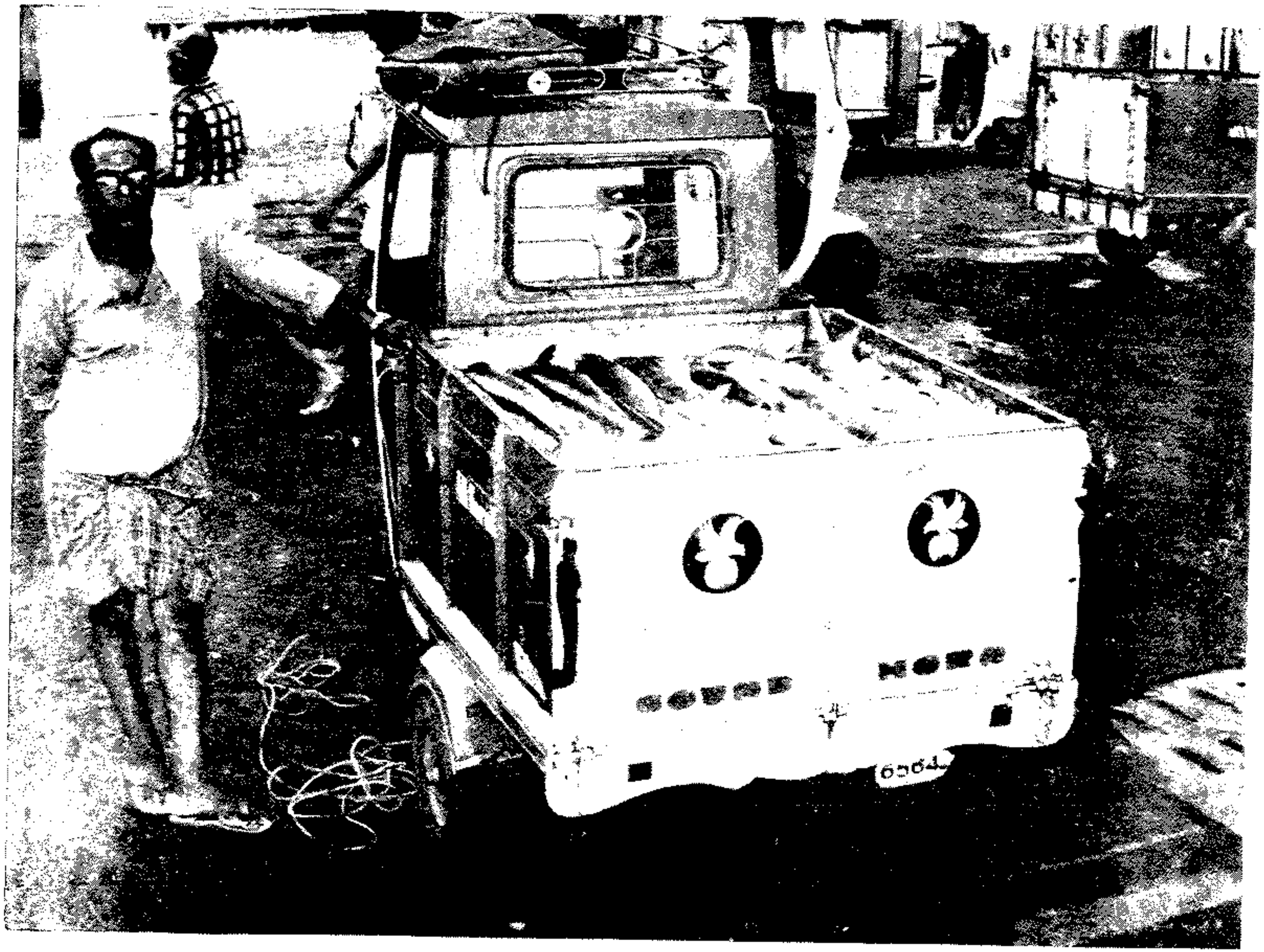

PLATE IV. Tunas and Seerfishes loaded in autocarrier at Cochin Fisheries Harbour for local interior markets.

(1) the whole of the catch for that age group is taken at exactly the middle of the age interval, and

(2) only natural losses occur continuously on an exponential basis.

The analysis of length composition data by adjusting the age-data in order to apply for their length-data, as discussed by Jones (1981) is adopted in the present study.

Further, in this analysis, it is easy to understand what is happening to fish stocks by looking at the numbers of fish caught during successive intervals in their life span. The length of the fish can be used to define the bound areas between successive intervals and each length interval represents a successive interval in the life of the typical year class, though the duration of the interval will vary. In the case of *E. affinis* and *A. thazard*, the length cohort analysis has been applied in order to estimate their numbers in the sea, average numbers and weight in the sea, F, Z and F/Z for each length class under the assumption that the population of these species occurring in the Indian waters represents one unit stock respectively.

3. FORMULATION (Jones, 1981)

The basic equation used in the length cohort analysis was

$$N_t = N_t + \triangle t e^{M \triangle t} + C_t e^{M \triangle t/2} \;\ldots\ldots (2)$$

where $\triangle_t$ = the time required to grow from the beginning to the end of a length interval.

Using von Bertalanffy's (1938) growth equation, the time required to grow from the beginning of a length interval (L_1 cm) to the upper limit of a length interval (L_2 cm) had been determined. In this way,

$$\triangle t = t_2 - t_1 = (1/K)\ [1_n\ (L_\infty - L_1)/\ (L\infty - L_2)] \;\ldots\ldots (3)$$

This equation is a function of L_∞ and K but is independant of t_0.

The equation for $\triangle t$ has been used in conjunction with equation (2) to arrive at a modified equation for analysing length composition :—

$$N_1 = (N_2 X_L + C_{1,2}) X_L \;\ldots\ldots (4)$$

where, $C_{1,2}$ = the number of fish caught during a year with lengths between L_1 and L_2 cm, and

$$X_L = [(L_\infty - L_1) / (L_\infty - L_2)]^{M/2K} \;\ldots\ldots (5$$

N_1 and N_2 represent numbers in the sea with length L_1 and L_2 respectively.

According to Jones (1981), this equation is a function of L_∞, M and K. More particularly, since the '*M*' and '*K*' appear as the ratio M/K, the equation is a function of the two variables, L_∞ and M/K.

The procedure followed was the estimation of a value for the fish reaching the length corresponding to the beginning of the largest length group. Successive application of equation then led to the estimation of the number reaching a particular length for successive smaller specimens.

The difference between a lightly fished and heavily fished stock is emphasized by the consideration of the appropriate input values to use for '*F*' and '*M*' for the oldest animals.

If the oldest age group comprises all individuals, older than a certain age, an input value of F/Z is required. The effect of the estimates among younger ages, of adopting different values of F/Z will depend on whether the stock is heavily exploited or not.

Estimates of the exploitation rate, designated by the ratio F/Z, has been determined for each length interval from the relationship :—

F/Z = Number caught/Number dying

Values of 'F' (instantaneous fishing mortality) corresponding to fishing mortality over a particular time interval was derived at from the relationship :—

$$F \triangle t = (F/Z)(Z \triangle t) \;\ldots\ldots (6)$$

For the calculation of the annual mortality rates, 'Z' and '*F*', it was necessary to take into account the actual time interval $\triangle t$ for length interval. This required input information equivalent to separating the ratio M/K into two separate compartments M and K. Assuming for a given value of M instantaneous mortality rate (Z) was calculated from the relationship

$$Z = M/(1\text{-}F/Z) \;\ldots\ldots (7)$$

The basic input parameters for carrying out cohort analysis are the terminal *F/Z* (the exploitation rate for the largest group) and *M/K*. In the accompanying work sheets the exploitation rate (*F/Z*), total mortality (Z) and fishing mortality rate (*F*) their No. in the sea, Average Number and weight in the sea with respect to *E. affinis* for F/Z (0.70 and 0.50) and $M/K = 1.0$ and *A. thazard* for $F/Z = 0.50$ and 0.80 and $M/K = 1.0$ is presented (Tables 2-5) (Fig. 1).

As presented in the work sheets attached for *E. affinis* applying $F/Z = 0.7$, the total stock was 2.17 lakh tonnes and the average stock 32,000 tonnes. Applying $F/Z = 0.5$ also the average stock was 31,775 tonnes. In the case of *A. thazard*, for $F/Z = 0.5$, the total stock estimated was 7,745 tonnes and the average stock was 925 tonnes.

From the present data it appears that any further increase in the fishing effort in the presently exploited grounds will not lead to increase in the production of these species. The indications are that there will be a steep decline in the catch per Unit of effort. The solution is the expansion of the areas of operations both in the continental shelf waters and in the Lakshadweep and Andaman Sea.

With regard to the stock status of skipjack and yellowfin tuna (young ones), yield per recruit analysis following Beverton and Holt Yield Model was carried out. The instantaneous rate of mortality is estimated following Alagaraja's (1984) method. The data had been collected from the investigations conducted at Minicoy during the period 1976-'82.

The estimation of the growth parameters and the techniques used has been described earlier. Further the corresponding estimates for W∞ were calculated as follows :

Skipjack – W∞ 16.372 kg and for yellowfin tuna it is 49.478 kg.

Estimates of 'Z'

Following the methods presented by Alagaraja (1984) and Srinath (1986 : MS) that portion of the length frequency distribution which resembled the right limb of the catch curve was only considered for estimation of 'Z'. The procedure followed in the estimation of 'Z' was as follows :

Derivations

$\log (N_t + \Delta t / N_t) =$

$$\frac{Z}{K} = \log_e \left[\frac{L_\infty - l_{t+\Delta t}}{L_\infty - l_t} \right] \;\ldots\ldots(8)$$

Estimates of $L\infty$ and K were taken from Table 1. l_t and $l_t + \Delta_t$ were the successive mid values of the length classes, whose frequencies are N_t and $N_t + \Delta_t$. It was considered that 'Z' is constant for the entire size range of the catches in numbers at successive age, Ct and $Ct + \Delta t$ are proportional to Nt and $N_t + \Delta_t$.

Equation (8) can be re-written as :

$$Y_i = \left(\frac{Z}{K} - 1 \right) X_i \;\ldots\ldots\ldots\ldots(9)$$

$$\text{Where } Y_i = \log \left(\frac{N l_t + \Delta t}{N l_t} \right)$$

$$X_i = \log \left(\frac{L_\infty - l_{t+\Delta t}}{L_\infty - l_t} \right)$$

From this, $\frac{Z}{K} - 1$ is given by Y/X. If there are n + 1 length groups considered for estimating Z/K then there will be 'n' ratios of type (9), each one an estimate of $\frac{Z}{K} - 1$. The mean of such ratios gives an average value of $\frac{Z}{K} - 1$ for the length range considered ie., if the first estimate is e_1, the second e_2 .... the last one e_n.

Then,

$$\left(\frac{\bar{Z}}{K} - 1 \right) = \frac{1}{n} \sum_{i=1}^{n} e_i \;\ldots\ldots\ldots\ldots(10)$$

and

$$S^2_{Z/K-1} = \frac{1}{n-1} \sum e_i^2 - \frac{(\sum e_i)^2}{n} \;\ldots\ldots(11)$$

from this the standard error of (Z/K) is given by :

$$S E \left(\frac{Z}{K} - 1 \right) = \frac{1}{\sqrt{n}} \; S_{Z/K-1} \;\ldots\ldots\ldots(12)$$

where, $S_{Z/K-1}$ is the root of (11)

Multiplying $\bar{Z}/K$ by the value of 'K' alredy calculated, the estimates of $\bar{Z}$ and standard error can be estimated. The estimates thus obtained are given in Tables 6 & 7 along with l_c, and l_r where l_c indicates the size at the first capture of the

TABLE 6. K. pelamis : *Yield per recruit*

W∞=16,372 M=0.75
lc=54 M/K=1.54
lr=30 cm
$e^{M(t_r - t_0)}$ =1.861 $\bar{Z}$=2.555

E	Y/R (g)	
0.05	179.1	
0.10	349.4	
0.15	510.6	Ep=0.71
0.20	662.1	
0.25	803.8	
0.30	934.9	
0.35	1,055.3	
0.40	1,164.4	
0.45	1,261.8	
0·50	1,347.1	
0.55	1,419.9	
0.60	1,480.0	
0.65	1,526.9	
0.70	1,560.6	
0.75	1,581.0	
0.80	1,588.2	
0.85	1,582.6	
0.90	1,565.0	
0.95	1,536.0	
1.00	1,498.5	

* Ep=Present exploitation rate.

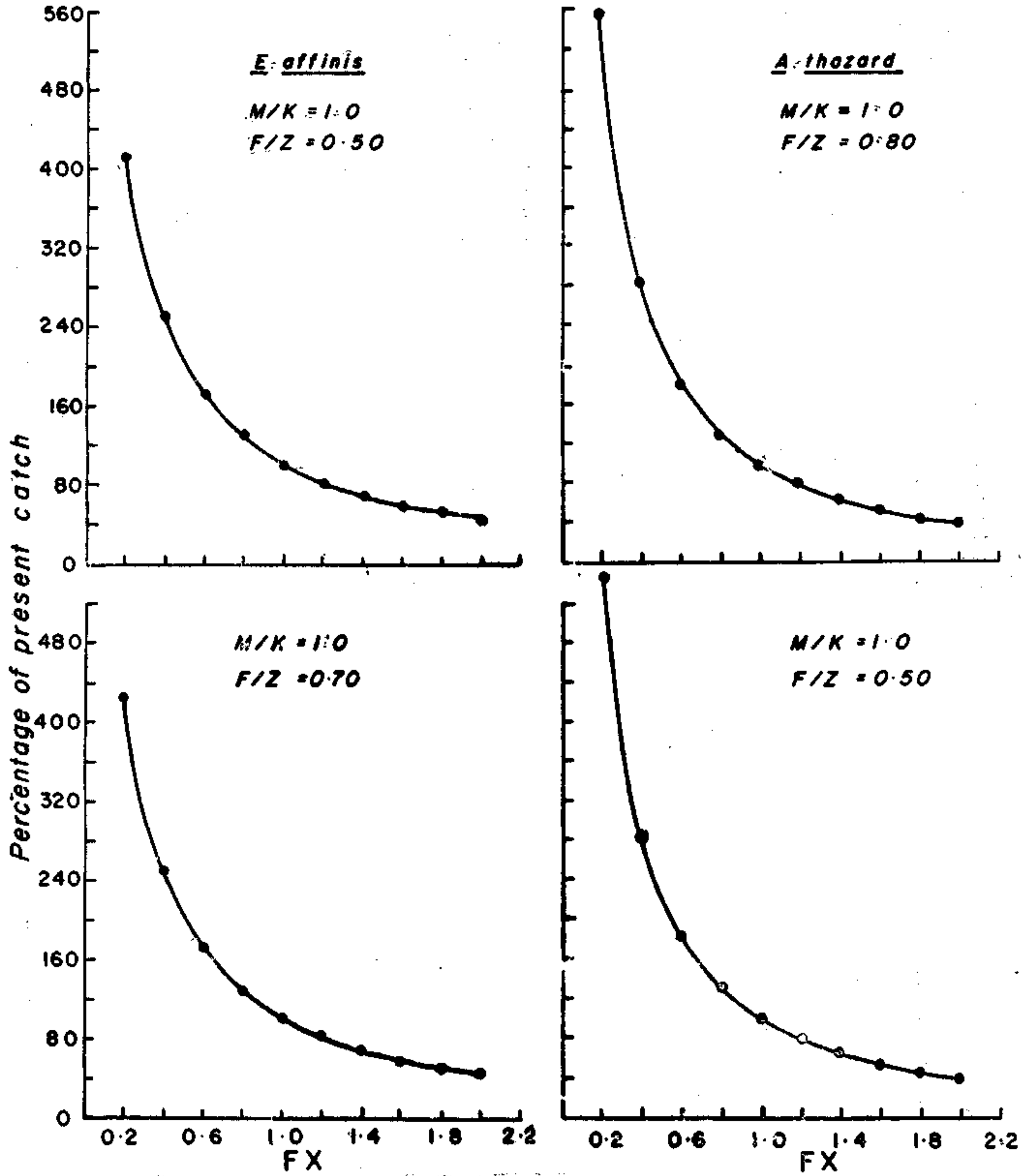

Fig. 1. Effect upon yield of *E. affinis* and *A. thazard* of altering the present level of effort.

TABLE 7. T. albacares : *Yield per recruit*

$W\infty = 49{,}478$ g. $M = 0.49$
$lc = 45$ $M/K = 1.54$
$lr = 30$ cm $\bar{Z} = 3.488$
$e^{M(tr-to)} = 1.426$

E	Y/R (g)	
0.05	485.9	
0.10	927.2	
0.15	1,323.0	
0.20	1,671.9	$\bar{E}_p = 0.85$*
0.25	1,972.7	
0.30	2,224.0	
0.35	2,425.9	
0.40	2,577.3	
0.45	2,678.2	
0.50	2,728.7	
0.55	2,729.7	
0.60	2,683.2	
0.65	2,590.7	
0.70	2,456.6	
0.75	2,285.9	
0.80	2,085.0	
0.85	1,863.3	
0.90	1,631.3	
0.95	1,401.7	
1.00	1,188.9	

* E_p = Present exploitation rate

fully recruited phase and l_r the size at entry to the fishery.

Yield/Recruit of both these species has been calculated following the Beverton and Holt Yield model (1953). For skipjack tuna, calculating ' Z ' as 2.555, $M = 0.75$, M/K as 1.54, $l_c = 54$ cm and $l_r = 30$ cm, the present exploitation ratio calculated was 0.71 based on the equation :—

$$F/Z = \frac{Z - M}{Z} = \frac{2.555 - 0.75}{2.555}$$

This picture represents that the present level of exploitation is not affecting the stock and the capture of this species has not reached the maximum sustainable yield (Fig. 2).

As far as yellowfin tuna (young ones) taken by the pole and line fishery, calculating $\bar{Z}$ as 3.488, $M = 0.49$, $M/K = 1.54$, $l_c = 45$ cm and $l_r = 30$ cm, it was observed that the present exploitation ratio is 0.85 (Fig. 2). However, the pole and line (live-bait) fishery is taking the young yellowfin tunas, and in view of the highly migratory nature of the adults it is emphasized that further expansion of the fishery is possible with regard to these two species by employing efforts in deep longlining, purse seining and by putting in major thrusts on constant supply of bait fishes through mariculture for pole and line (live-bait) fishery as well as use of FADs.

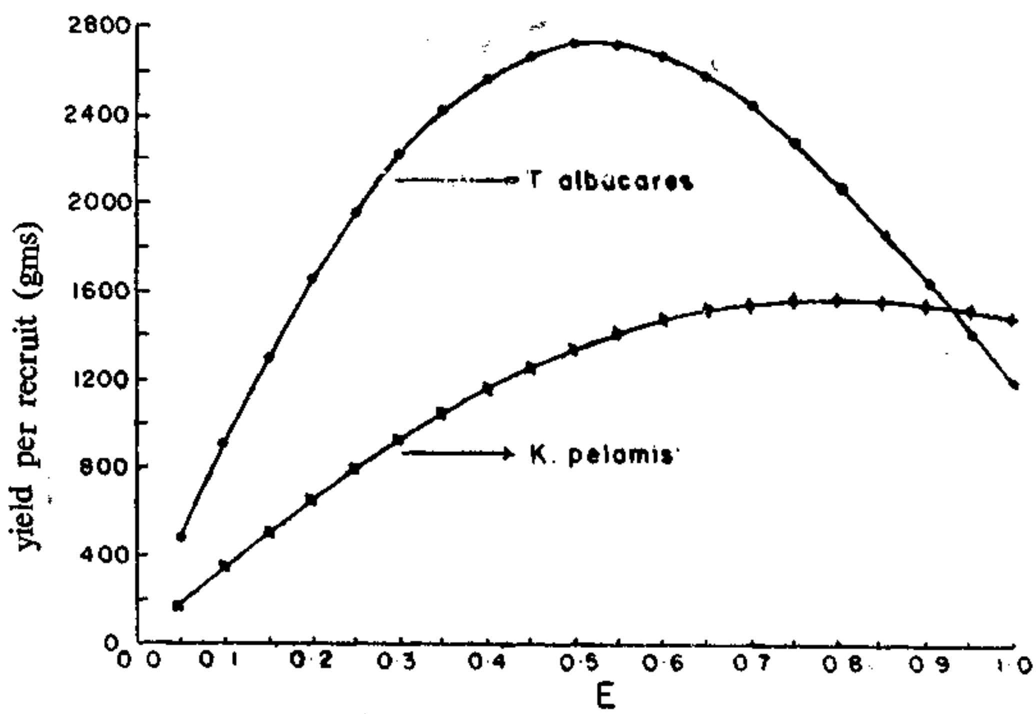

Fig. 2. Yield per recruit of *K. pelamis* and *T. albacares*

TABLE 2. *Exploitation rate, total mortality, instantaneous mortality rate, number in the sea, average number and weight in the sea with respect to* E. affinis

M/K=1.0, F/Z=0.5

Length Class (cm)	Numbers landed (lakhs)	Weight landed (mt)	Numbers in sea (lakhs)	Weight in sea (mt)	Average numbers in sea (lakhs)	Average weight in sea (mt)	*F*	*Z*	*F/Z*
12-14 ..	0.001	0.006	196.884	815.101	15.613	64.639	0.0001	0.3656	0.0030
14-16 ..	0.016	0.010	191.176	1208.233	15.615	98.685	0.0010	0.3665	0.0028
16-18 ..	0.009	0.086	185.453	1696.898	15.612	142.847	0.0006	0.3661	0.0019
18-20 ..	0.012	0.161	179.738	2282.671	15.611	198.265	0.0008	0.3663	0.0022
20-22 ..	0.017	0.288	174.019	2970.511	15.609	266.440	0.0011	0.3666	0.0029
22-24 ..	0.063	1.403	168.297	3753.029	15.607	348.038	0.0040	0.3695	0.0109
24-26 ..	0.407	11.598	162.530	4632.118	15.585	444.136	0.0261	0.3916	0.0667
26-28 ..	0.628	22.499	156.428	5600.118	15.530	555.976	0.0405	0.4060	0.0997
28-30 ..	0.728	32.239	150.123	6650.434	15.460	684.890	0.0471	0.4126	0.1141
30-32 ..	1.565	84.359	143.744	7747.789	15.339	826.787	0.1020	0.4675	0.2183
32-34 ..	1.482	96.474	136.573	8890.880	15.168	987.430	0.0977	0.4632	0.2109
34-36 ..	6.245	481.556	129.547	9988.065	14.714	1134.459	0.4245	0.7000	0.5373
36-38 ..	5.546	503.544	117.923	10707.383	13.998	1270.986	0.3962	0.7617	0.5201
38-40 ..	2.859	303.086	107.261	11369.640	13.466	1427.437	0.2123	0.5778	0.3675
40-42 ..	1.817	223.524	99.480	12236.020	13.153	1617.796	0.1382	0.5037	0.2743
42-44 ..	2.163	304.963	92.855	13092.522	12.874	1815.282	0.1680	0.5335	0.3149
44-46 ..	2.952	478.158	85.986	13929.782	12.496	2024.290	0.2362	0.6017	0.3926
46-48 ..	3.808	700.595	78.468	14438.056	12.001	2208.178	0.3182	0.6817	0.4654
48-50 ..	4.460	927.682	70.287	14619.621	11.279	2346.132	0.3954	0.7609	0.5197
50-52 ..	6.056	1417.074	61.704	14438.757	10.346	2421.004	0.5852	0.9509	0.6155
52-54 ..	6.276	1650.712	51.866	13640.736	9.184	2415.399	0.6834	1.0489	0.6516
54-56 ..	6.988	2040.356	42.233	12331.974	7.837	2288.454	0.8916	1.2571	0.7096
56-58 ..	8.066	2621.359	32.381	10523.724	6.186	2010.554	1.0038	1.6693	0.7810
58-60 ..	7.402	2664.716	22.054	7939.393	4.346	1564.715	1.7030	2.0685	0.8233
60-62 ..	5.722	2271.626	13.063	5186.126	2.639	1047.993	2.1676	2.5331	0.8557
62-64 ..	2.514	1098.631	6.376	2786.522	1.464	639.929	1.7168	2.0823	0.8245
64-66 ..	1.444	691.978	3.327	1593.747	0.831	398.145	1.7380	21.035	0.8262
66-68 ..	0.505	264.615	1.579	827.296	0.481	251.803	1.0509	1.4164	0.7419
68-70 ..	0.430	246.177	0.898	513.758	0.284	162.282	1.5170	1.8825	0.8058
70-72 ..	0.245	152.378	0.364	226.470	0.117	72.861	2.0914	2.4569	0.8512
72-74 ..	0.053	35.539	0.763	51.509	0.209	19.838	1.7916	2.1571	0.8306
74-76 ..	0.006	4.722	0.013	9.444	..	..	0.0000	0.0000	0.5000
Total ..	80.485	19332.114	2863.393	205698.327	318.473	31755.670			

TABLE 3. *Exploitation rate, total mortality, instantaneous mortality rate, number in the sea, average number and weight in the sea with respect to* E. affinis

M/K=1.0, F/Z=0.70

Length class (cm)	Numbers landed (lakhs)	Weight landed (mt)	Numbers in sea (lakhs)	Weight in the sea (mt)	Average numbers in sea (lakhs)	Average weight in sea (mt)	*F*	*Z*	*F/Z*
12-14 ..	0.001	0.006	196.848	814.950	15.610	64.627	0.0001	0.3656	0.0003
14-16 ..	0.016	0.103	191.141	1208.010	15.612	98.667	0.0010	0.3665	0.0029
16-18 ..	0.009	0.086	185.419	1696.584	15.609	142.821	0.0006	0.3661	0.0016
18-20 ..	0.012	0.161	179.705	2282.249	15.608	198.227	0.0008	0.3663	0.0022
20-22 ..	0.017	0.288	173.987	2969.962	15.483	264.301	0.0011	0.3666	0.0030
22-24 ..	0.063	1.403	168.266	3752.335	15.604	347.974	0.0040	0.3695	0.0109
24-26 ..	0.407	11.598	162.500	4631.261	15.581	444.058	0.0261	0.3916	0.0667
26-28 ..	0.628	22.498	156.399	5599.079	15.527	555.883	0.0405	0.4060	0.0997
28-30 ..	0.728	32.240	150.095	6649.196	15.458	684.776	0.0471	0.4126	0.1141
30-32 ..	1.565	84.359	143.717	7746.339	15.334	826.488	0.1021	0.4676	0.2183
32-34 ..	1.482	96.473	136.547	8889.198	15.166	987.281	0.0977	0.4632	0.2114
34-36 ..	6.245	481.555	129.522	9986.154	14.713	1134.356	0.4245	0.7900	0.537
36-38 ..	5.546	503.544	117.899	10705.229	13.996	1270.861	0.3962	0.7617	0.5200
38-40 ..	2.859	303.086	107.238	11367.232	13.462	1426.995	0.2124	0.5779	0.3675
40-42 ..	1.817	223.524	99.458	12233.361	13.151	1617.539	0.1382	0.5037	0.2743
42-44 ..	2,163	304.963	92.834	13089.622	12.872	1815.001	0.1680	0.5335	0.3149
44-46 ..	2.952	478.158	85.967	13926.622	12.492	2023.670	0.2363	0.6018	0.3922
46-48 ..	3.808	700.595	78.449	14434.660	11.963	2201.114	0.3183	0.6838	0.4656
48-50 ..	4.460	927.682	70.269	14615.999	11.277	2345.529	0.3955	0.7610	0.5196
50-52 ..	6.056	1417.074	61.688	14434.934	10.345	2420.744	0.5854	0.9509	0.6157
52-54 ..	6.276	1650.712	51.851	13636.715	9.181	2414.676	0.6836	1.0491	0.6516
54-56 ..	6.988	2040.356	42.219	12327.817	7.834	2287.660	0.8919	1.2574	0.7096
56-58 ..	8.066	2621.359	32.368	10519.441	6.183	2009.626	1.3044	1.6699	0.7811
58-60 ..	7.402	2664.716	22.042	7935.026	4.343	1563.621	1.7042	2.0697	0.8234
60-62 ..	5.722	2271.626	13.052	5181.731	2.637	1046.833	2.1700	2.5355	0.8558
62-64 ..	2.514	1098.631	6.366	2782.143	1.461	638.662	1.7202	2.0857	0.8248
64-66 ..	1.444	691.978	3.318	1589.451	0.828	396.755	1.7441	2.1096	0.7431
66-68 ..	0.505	264.615	1.571	823.146	0.478	250.295	1.0572	1.4227	0.7431
68-70 ..	0.430	246.177	0.891	509.835	0.281	160.627	1.5326	1.8981	0.8074
70-72 ..	0.245	152.378	0.358	222.862	0.114	71.065	2.1442	2.5097	0.8544
72-74 ..	0.053	35.539	0.072	48.303	0.026	17.886	1.9867	2.3522	0.8446
74-76 ..	0.006	4.722	0.009	6.747	..	..	0.0000	0.0000	0.7000
Total ..	80.485	19332.205	2862.065	216616.193	318.468	31728.618			

TABLE 4. *Exploitation rate, total mortality, instantaneous mortality rate, number in the sea, average number and weight in the sea with respect to* A. thazard

M/K=1.0, F/Z=0.50

Length class (cm)	Numbers landed (lakhs)	Weight landed (mt)	Numbers in sea (lakhs)	Weight in sea (mt)	Average numbers in sea (lakhs)	Average weight in sea (mt)	*F*	*Z*	*F/Z*
12-14 ..	0.011	0.413	23.036	84.773	1.843	6.784	0.006	0.496	0.0123
14-16 ..	0.019	0.106	22.122	125.873	1.842	10.482	0.010	0.500	0.0202
16-18 ..	0.058	0.483	21.201	176.602	1.841	15.332	0.032	0.521	0.0605
18-20 ..	0.122	1.423	20.242	236.626	1.832	21.417	0.066	0.556	0.1195
20-22 ..	0.057	0.899	19.223	304.686	1.822	28.886	0.031	0.521	0.0595
22-24 ..	0.022	0.457	18.274	381.918	1.818	37.999	0.012	0.502	0.0240
24-26 ..	0.223	5.992	17.361	467.008	1.806	48.589	0.123	0.613	0.2010
26-28 ..	0.450	15.349	16.254	554.249	1.769	60.334	0.255	0.744	0.3419
28-30 ..	0.254	10.744	14.937	632.145	1.727	73.085	0.147	0.637	0.2308
30-32 ..	0.388	20.092	13.837	717.319	1.689	87.549	0.230	0.719	0.3192
32-34 ..	0.386	24.181	12.623	791.583	1.638	102.700	0.236	0.725	0.3248
34-36 ..	0.957	71.756	11.436	857.817	1.542	115.673	0.621	1.110	0.5589
36-38 ..	1.197	106.275	9.724	863.483	1.378	122.404	0.868	1.358	0.6393
38-40 ..	3.118	325.074	7.852	818.729	1.022	106.612	3.049	3.539	0.8616
40-42 ..	2.785	338.107	4.234	513.993	0.499	60.558	5.583	6.073	0.9194
42-44 ..	0.901	127.304	1.204	169.036	0.144	20.181	6.308	6.798	0.9279
44-46 ..	0.155	25.035	0.227	36.571	0.032	5.094	4.914	5.404	0.9094
46-48 ..	0.043	7.871	0.056	10.321	0.008	1.504	5.232	5.722	0.9144
48-50 ..	0.008	1.725	0.009	1.944	0.001	0.286	6.024	6.514	0.9248
50-52 ..	0.0002	0.044	0.0003	0.084	0.00009	0.019	2.285	2.774	0.8235
52-54 ..	0.00007	0.019	0.0001	0.037	..	..	0.000	0.000	0.5000
Total ..	11.15427	1083.349	233.8524	7744.797	24.25309	925.488			

TABLE 5. *Exploitation rate, total mortality, instantaneous mortality rate, number in the sea, average number and weight in the sea with respect* to A. thazard

M/K=1.0, F/Z=0.80

Length class (cm)	Numbers landed (lakhs)	Weight landed (mt)	Numbers in sea (lakhs)	Weight in sea (mt)	Average numbers in sea (lakhs)	Average weight in sea (mt)	*F*	*Z*	*F/Z*
12-14 ..	0.011	0.413	23.036	84.772	1.843	6.784	0.006	0.496	0.0122
14-16	0.019	0.106	22.122	125.871	1.842	10.482	0.010	0.500	0.0203
16-18 ..	0.058	0.483	21.200	176.600	1.841	15.332	0.032	0.521	0.0605
18-20 ..	0.122	1.423	20.242	236.624	1.832	21.417	0.066	0.556	0.1195
20-22 ..	0.057	0.899	19.223	304.683	1.822	28.889	0.039	0.521	0.0598
22-24 ..	0.022	0.457	18.273	381.914	1.818	37.999	0.012	0.502	0.0240
24-26 ..	0.223	5.992	17.361	467.003	1.806	48.589	0.123	0.613	0.2012
26-28 ..	0.450	15.349	16.253	554.243	1.769	60.333	0.255	0.744	0.3420
28-30 ..	0.254	10.744	14.937	632.138	1.727	73.085	0.147	0.637	0.2308
30-32 ..	0.388	20.092	13.837	717.311	1.689	87.548	0.230	0.719	0.3192
32-34 ..	0.386	24.181	12.623	791.573	1.638	102.699	0.236	0.725	0.3248
34-36 ..	0.956	71.756	11.435	857.807	1.542	115.673	0.621	1.110	0.5589
36-38 ..	1.197	106.275	9.724	863.472	1.378	122.403	0.868	1.358	0.6393
38-40	3.118	325.074	7.852	818.717	1.022	106.611	3.049	3.539	0.8616
40-42	2.785	338.107	4.233	513.980	0.499	60.558	5.584	6.073	0.9194
42-44	0.907	127.304	1.204	169.022	0.144	20.178	6.300	6.799	0.9280
44-36	0.155	25.035	0.227	36.557	0.032	5.091	4.917	5.407	0.9094
46-48	0.043	7.871	0.056	10.307	0.008	1.501	5.245	5.739	0.9146
48-50	0.008	1.725	0.009	1.930	0.001	0.282	6.111	6.601	0.9258
50-52	0.0002	0.044	0.0003	0.071	0.00007	0.015	2.939	3.429	0.8571
52-54	0.00007	0.019	0.00009	0.024	..	..	0.000	0.000	0.8000
Total ..	11.15927	1083.349	233.84739	7744.619	24.25307	925.469			

5

FISHERY AND BIONOMICS OF TUNAS AT COCHIN

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As stated earlier, the Central Marine Fisheries Research Institute furnishes the production figures of various species of marine fishes based on multistage, stratified random sampling techniques. For detailed biological investigations involving aspects of species composition, size, age, growth, spawning, maturity, food and feeding habits and other parameters, the Project has selected some important centres for tuna investigations which would help in monitoring the resources. The fishery and biological aspects collected from 6 centres *viz.*, Mangalore, Calicut, Cochin, Vizhinjam and Tuticorin in the mainland of India, and from Minicoy in the U.T. of Lakshadweep are analysed and results presented in the ensuing section under different modules.

Prior to 1977, tuna catches at Cochin were insignificant with occasional catches in the experimental purse seine operations of the vessels of the Integrated Fisheries Project and in the artisanal fishery from hooks and lines and shore seines. The small mechanised fishing vessels (9.7 m OAL 'Pablo' type boats) commenced operation of effective nylon drift nets in 1977 bringing in good catches of tunas at the Fort Cochin landing centre. The Cochin Fisheries Harbour was commissioned early in 1978 and in 1979 about 160 gillnetters were registered at this centre. Purse seiners also landed tunas at this centre from 1980 although their contribution to the total catch was relatively low.

FISHING AREA

The area of operation of drift gillnetters is generally in the 20-50 m depth zone off Cochin (Fig. 1). The fishermen start from the base by 1600 hrs and reach the fishing ground by 2000 hrs. Setting and hauling time range from 1-2 hrs depending on the size of the net and the amount of catch respectively. Soaking time usually range between 3-4 hrs. The fishermen get back to the Fisheries Harbour to unload their catch between 0600-0900 hrs. In the case of purse seiners, operating during the day, the time taken to complete a haul is 1-3 hours depending upon the catch. The catches are sent to the Fisheries Harbour as quickly as possible through carrier boats.

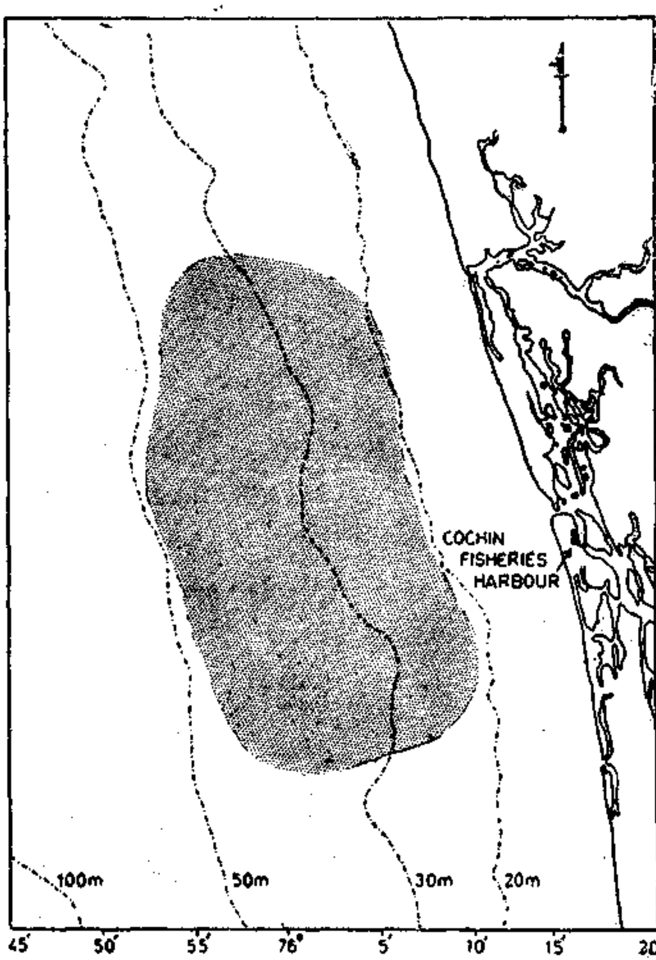

Fig. 1. Operational area of drift gillnetters off Cochin.

CRAFT

The size of the mechanised boats (Pablo type) operating drift gillnets off Cochin range from 7.6-9.7 m (OAL). These boats are fitted with 2 or three cylinder 'Ruston'/

' Bukh '/' Yanmar ' (24-45 HP) engines. These mechanised boats are owned by local persons and fishermen, especially from Kanyakumari District in Tamil Nadu. The crew complement is 3-4 persons.

The purse seiners are of wooden hulls, by and large of 43' in length and a few of 38' also. A few of them have fibreglass hulls. The strength of crew of a purse seiner varies from 20-25. This excludes the crew of the carrier boat (2-3).

Gear

Ninety five per cent of the gear (nylon drift net) are owned by the Tamil Nadu fishermen. The size of the net presently used is 800-1,000 m long and 4-8 m deep. During operation, 9-10 pieces are plied together and suitable floats and sinkers are attached for maintaining buoyancy. The net is fabricated from 6/8/22 nylon monofilament. Usually, the stretched mesh size of the net vary from 7-13 cm.

The purse seine net is of synthetic fibre and usually knotless. This is about 600 m in length with a height of 50 m and with a mesh size of 14-18 mm. About 40-50 brass rings are used for pursing the net.

Effort and *CPUE*

The relationship between effort and catch and CPUE is presented in Fig. 2. During 1979-82, the effort expended was high, amounting to more than 2500 units in the monsoon months of May to August. The effort expended was relatively low during October to January period. In 1979, maximum effort put in was more than 3400 units in the months of May, July and October in 1980 and 1981 during June to August ; and in 1982 in July (3560 units). Although the effort expended were normally low during October to December period, in 1979, lowest effort put in was in June.

Catch

As in the case of effort, catch was also high during the monsoon months, recording values above 300 tonnes per month in all the four years. Lowest catch during this period was recorded during October-December (Fig. 2).

CPUE

The CPUE showed an unimodal trend in 1980 (110 kg) in June, but in all the other years it was multimodal. In 1979, it was bimodal, maximum CPUE being in June (125 kg). In 1981 and '82 major peaks were in April and July and minor peaks observed were in February and September (Fig. 2).

Purse seiners also landed tunas from 1980 in the Fisheries Harbour, Cochin mainly in the pre-monsoon months of 1980, pre-monsoon and post-monsoon months of 1981 and during the premonsoon months of 1982. The CPUE was relatively high during March and May in 1980, in April and November 1981 (56 and 40 kg) and in May (10 kg) in 1982 (Fig. 3).

Catch composition

Euthynnus affinis and *Auxis thazard* were the two species which contributed to the major share of tunas landed at Cochin (Fig. 4). *E. affinis* contributed to about 61%, 77%, 61% and 44% during the years 1979 to 1982 whereas *A. thazard* contributed to 37.8%, 18.7%, 34.0% and 53% of the catch respectively in these years. Others included longtail tuna, oriental bonito, bullet tuna, yellowfin tuna and billfishes such as sailfish and black marlin which were caught sporadically, and their percentage composition in the total catch was below 5% in all these years. In the purse seine catches also *E. affinis* constituted the dominant species (Fig. 3).

Size distribution

The length distribution of different species landed at Cochin Fisheries Harbour showed different pattern during different months.

E. affinis occurred in the size range 20-70 cm in 1979, 22-76 cm in 1980, 22-72 cm in 1981 and 22-70 cm in 1982. Their monthly fluctuations and yearly pooled values are presented in Figs. 5, 6 and 10. During 1979, the major mode was in the size range 52-60 cm, in 1980 it was 48-60 cm, in 1981 in the range 52-60 cm and in 1982 it was in 48-60 cm. Annual pooled values of size groups indicate that the major modes were at 58 cm (1979), 54 cm (1980), 52 cm (1981) and 58 cm (1982). Minor modes were observed at the size 42-48 cm in the years 1980-82. It was also observed that the smaller specimens (20-22 cm size group) of E. *affinis* appeared in the fishery during July-September period of all the four years.

E. affinis taken by the purse seine gear showed a bimodal distribution, the major mode at 52 cm and another mode at 58 cm size (Fig. 14).

The monthly size distribution of *A. thazard* have shown that they occurred in the size range 22-48 cm in the landings at Cochin (Fig. 7). Monthly modes were invariably around 36-42 cm. Annual pooled figure indicates that their major mode was at 38-40 cm size, in the years 1979-82 (Fig. 10).

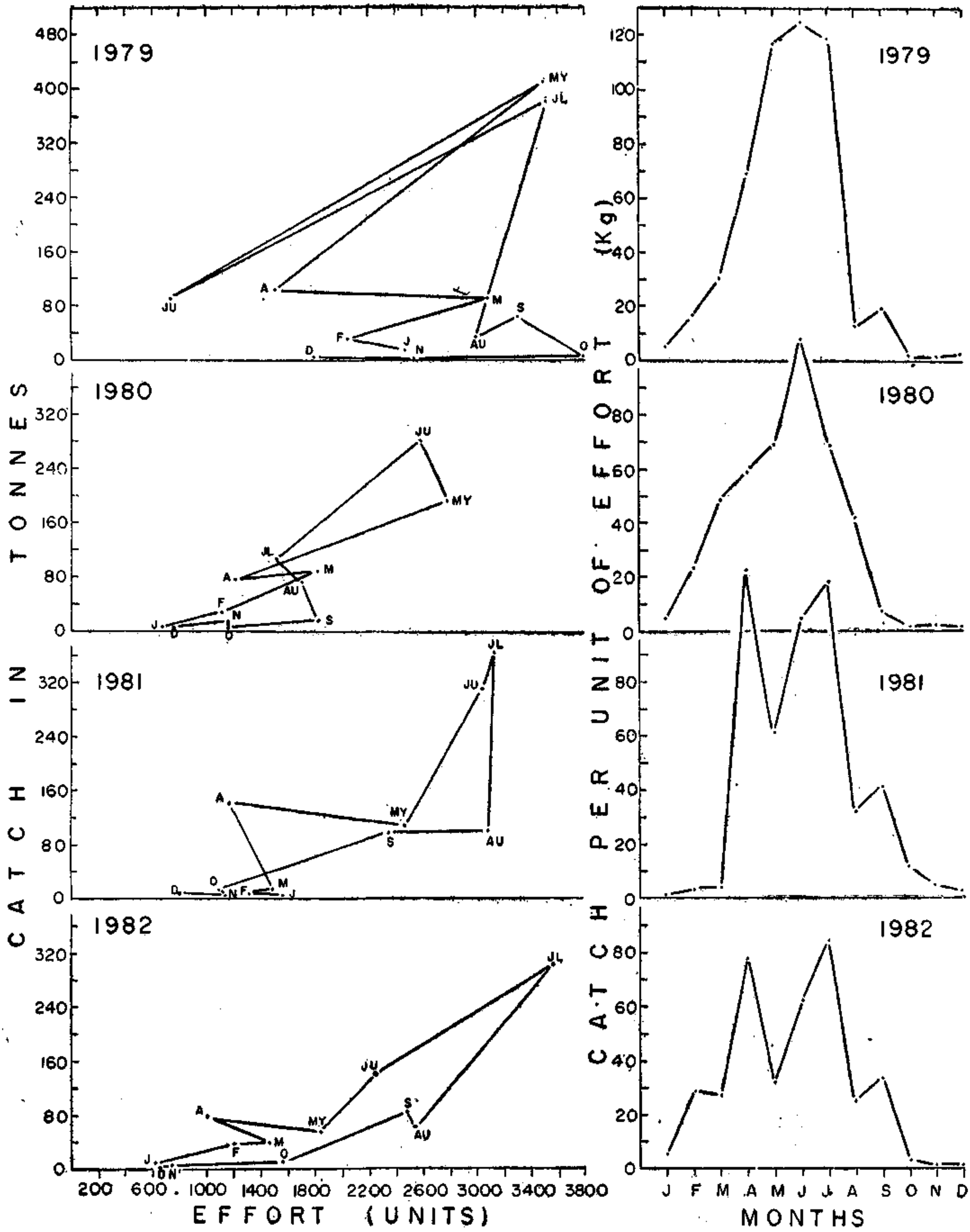

Fig. 2. Catch-effort relationship and catch per unit of effort of tunas in the drift gillnet fishery at Cochin, 1979-'82.

T. tonggol appeared infrequently in the landings and was represented by specimens in the size range 30-72 cm. Although no major mode is discernible, it was 8 and 9). Annual pooled size group distribution indicate bimodal peaks, the major peak at 44-48 cm and the secondary peak at 56-60 cm size group.

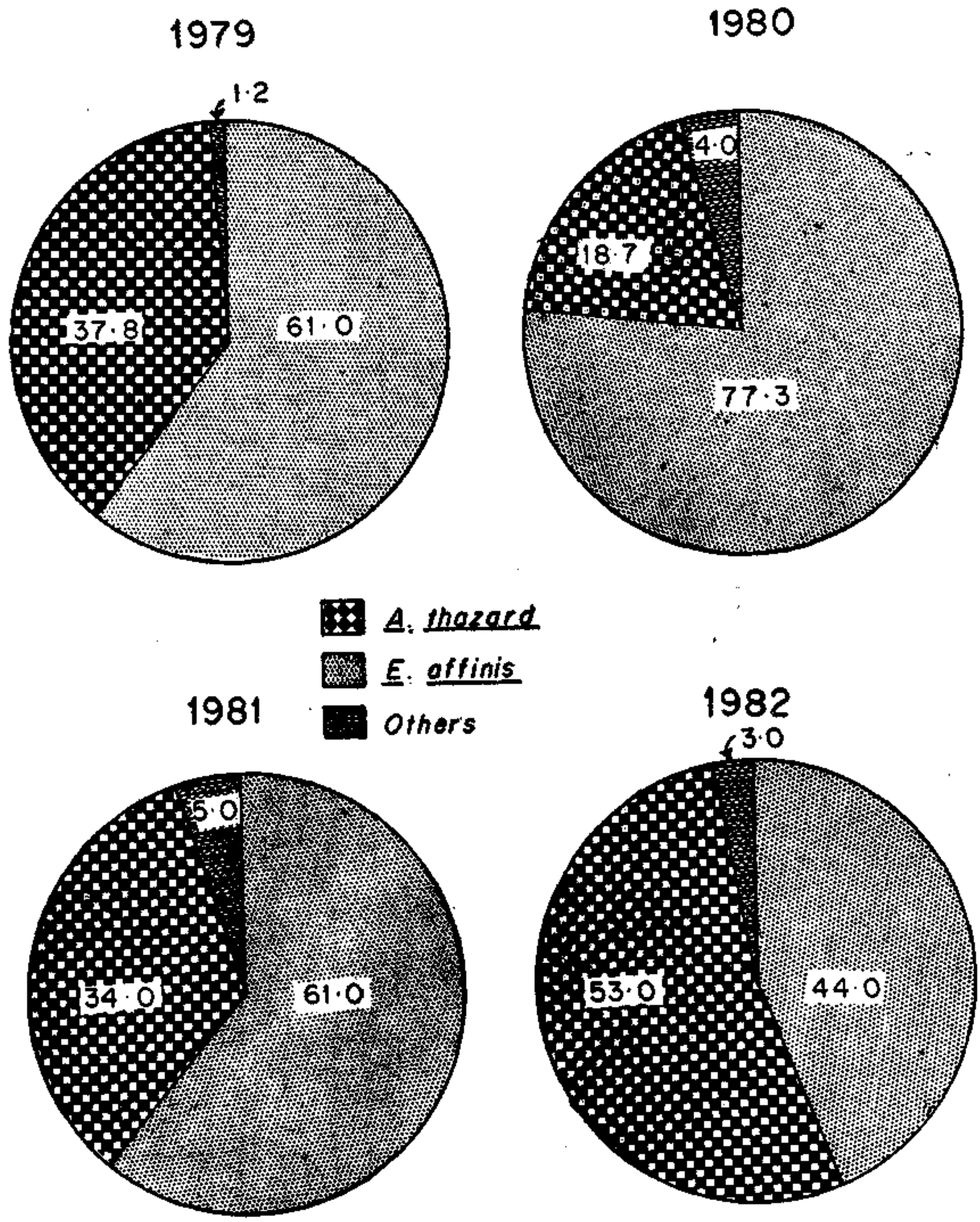

Fig. 3. Percentage composition of different species of tunas and billfishes in the drift gillnet fishery at Cochin, 1979-'82.

observed that relatively small specimens occurred in the January to June period and bigger ones in the later half of all these years. Small sized specimens (30-42 cm) occurred in all the three years in February (Fig.

S. orientalis was met with in the collections during May-November in 1980, May-September in 1981 and May to October in 1982 (Fig. 12). They occurred in the size range 28-60 cm and their major modes were

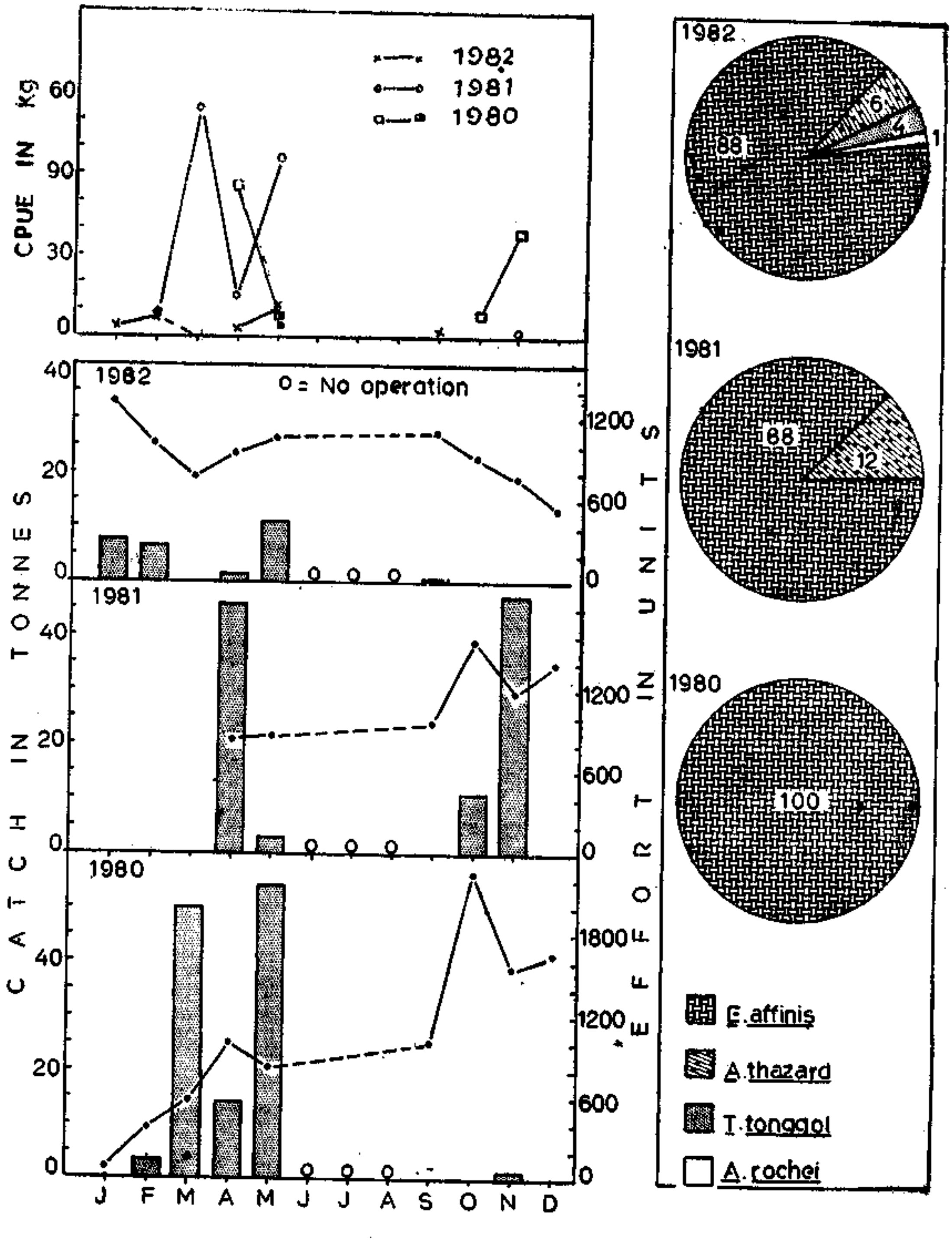

Fig. 4. Catch-effort relationship and catch per unit of effort of tunas and percentage composition of different species of tunas in the purse seine fishery at Cochin, 1980-'82.

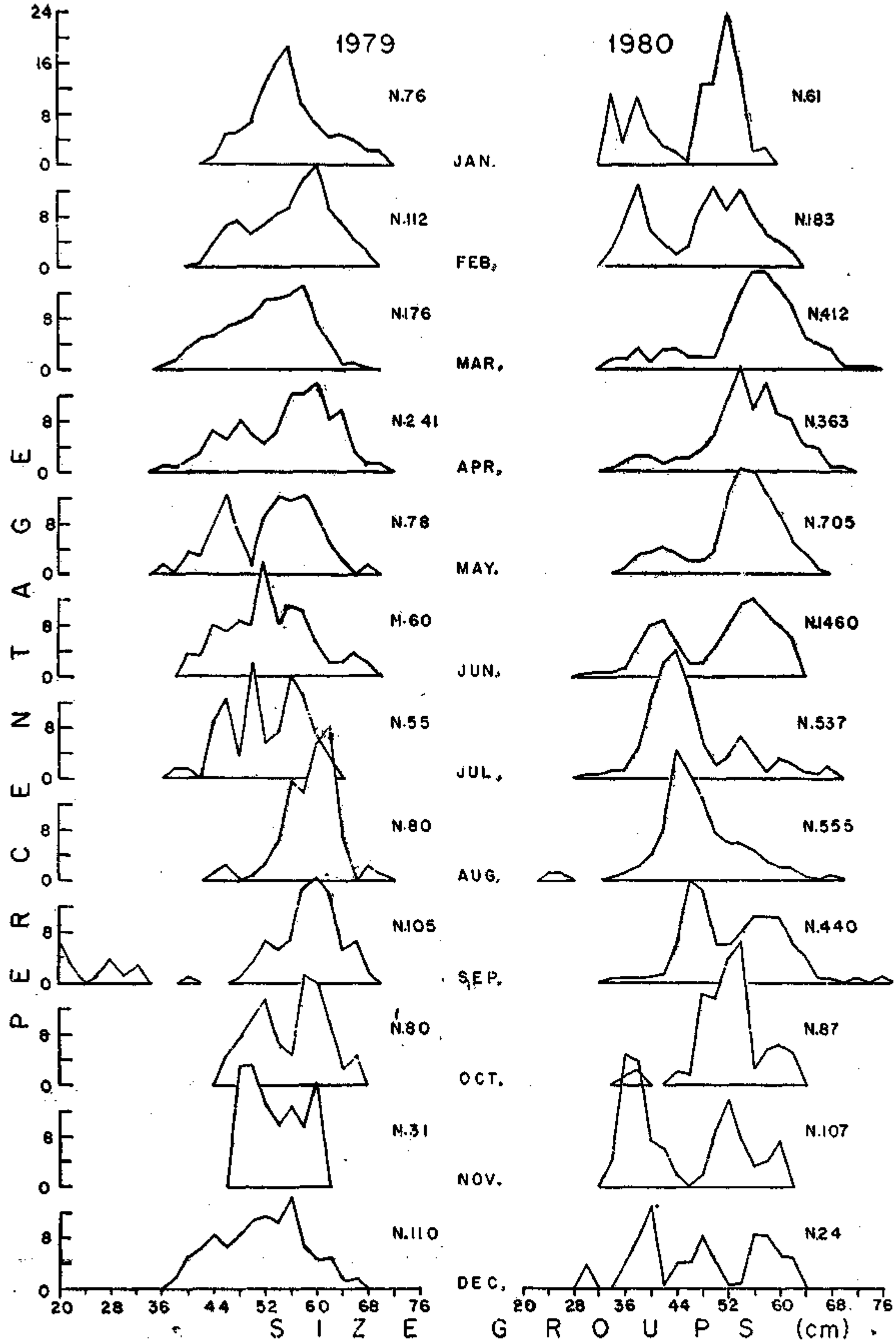

Fig. 5. Monthly length frequency distribution (percentage) of *E. affinis* at Cochin, 1979-'80.

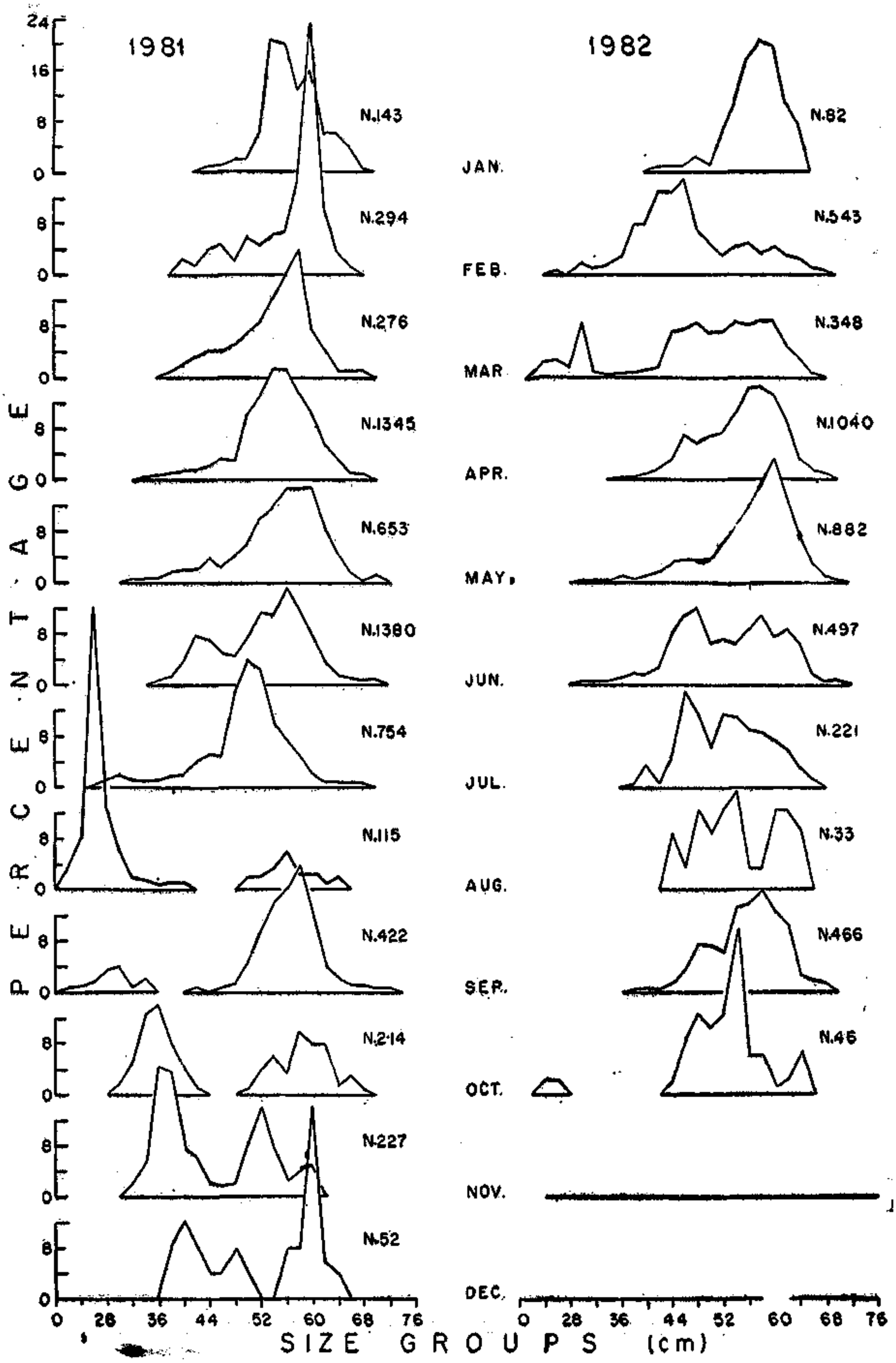

Fig. 6. Monthly length frequency distribution (percentage) of *E. affinis* at Cochin, 1981-'82.

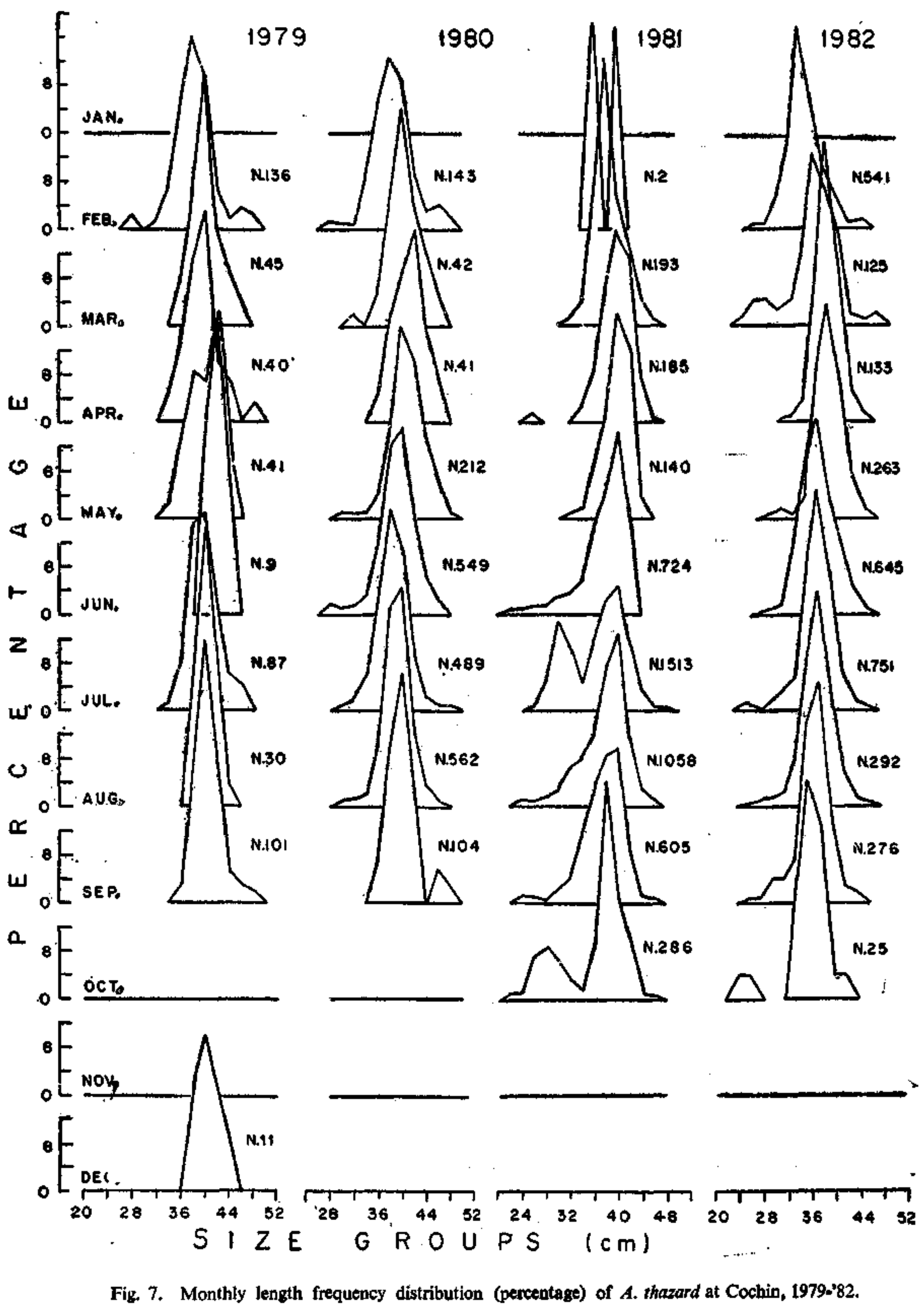

Fig. 7. Monthly length frequency distribution (percentage) of *A. thazard* at Cochin, 1979-'82.

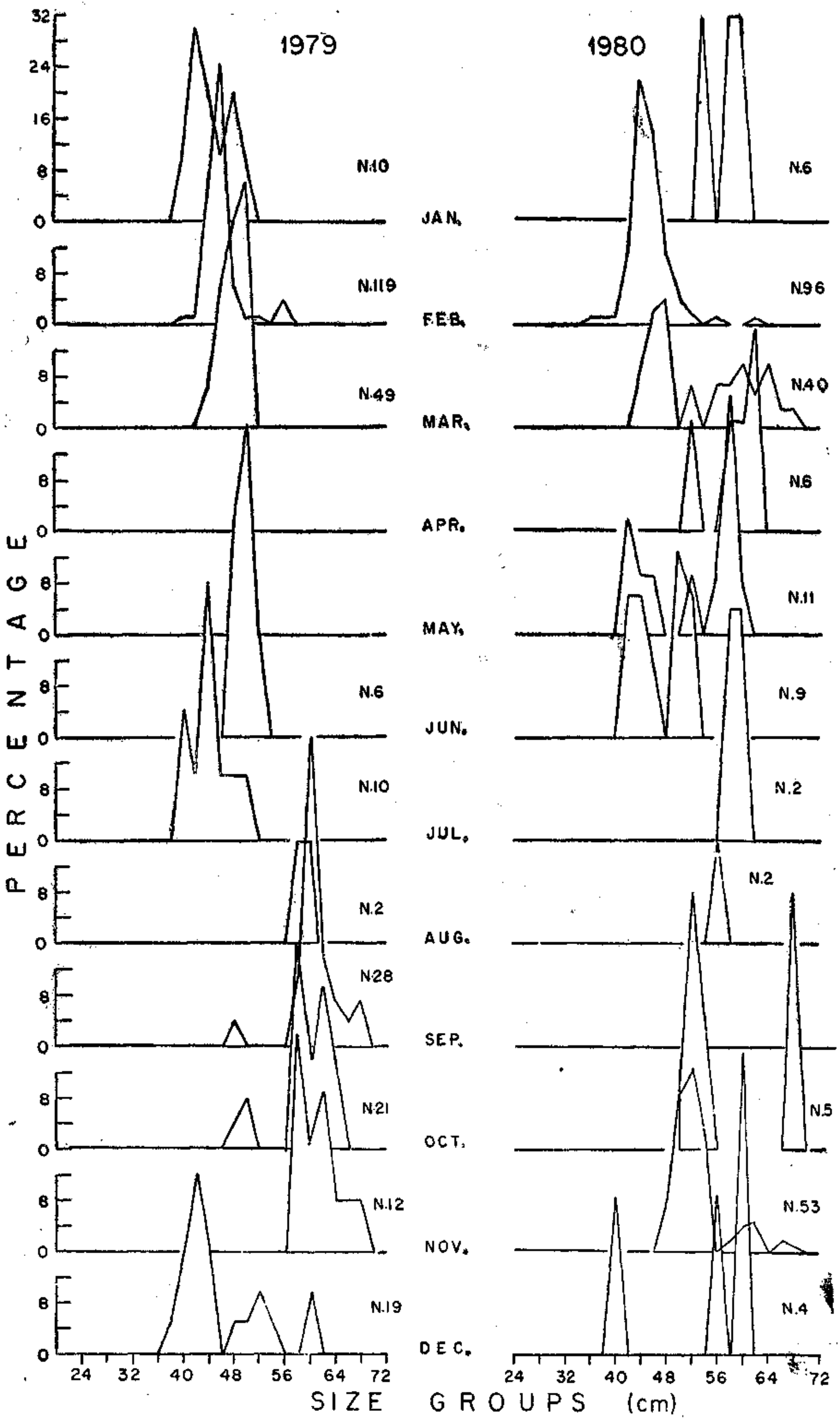

Fig. 8. Monthly length frequency distribution (percentage) of *T. tonggol* at Cochin, 1979-'80.

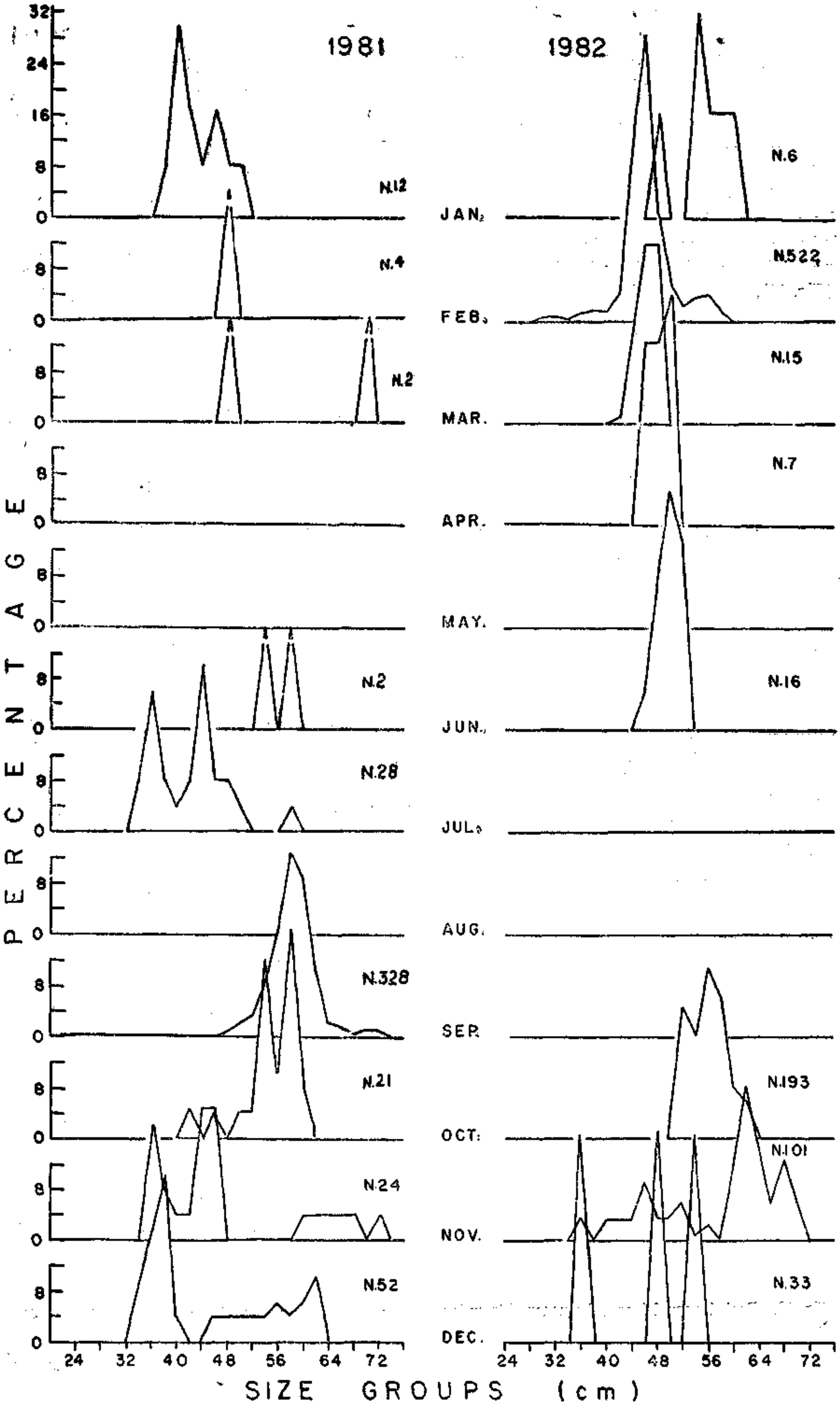

Fig. 9. Monthly length frequency distribution (percentage) of *T. tonggol* at Cochin, 1981-'82.

observed in the samples between 44-50 cm. The smallest specimen (28 cm) was observed in August 1981.

Similar to *S. orientalis, A. rochei* also showed seasonality in the occurrence. They were present in the sample during July to September in 1980, June to August in 1981 and April to October in 1982. They occurred in the size group 18-34 cm and monthly modal distribution indicate that they were dominant in the 26 cm size group in 1980 and '81 and in 26-32 cm size group in 1982 (Fig. 11).

Length-weight relationship

The exponential relationship of length and weight of different species observed at Cochin (Fig. 13) is as follows :

E. affinis	:	$W = 0.0000213\ L^{2.95244}$
A. thazard	:	$W = 0.000015012\ L^{3.04329}$
A. rochei	:	$W = 0.00001487\ L^{3.02648}$
S. orientalis	:	$W = 0.000017739\ L^{2.97361}$
T. albacares	:	$W = 0.0002005\ L^{2.42007}$
T. tonggol	:	$W = 0.0000065689\ L^{3.19058}$

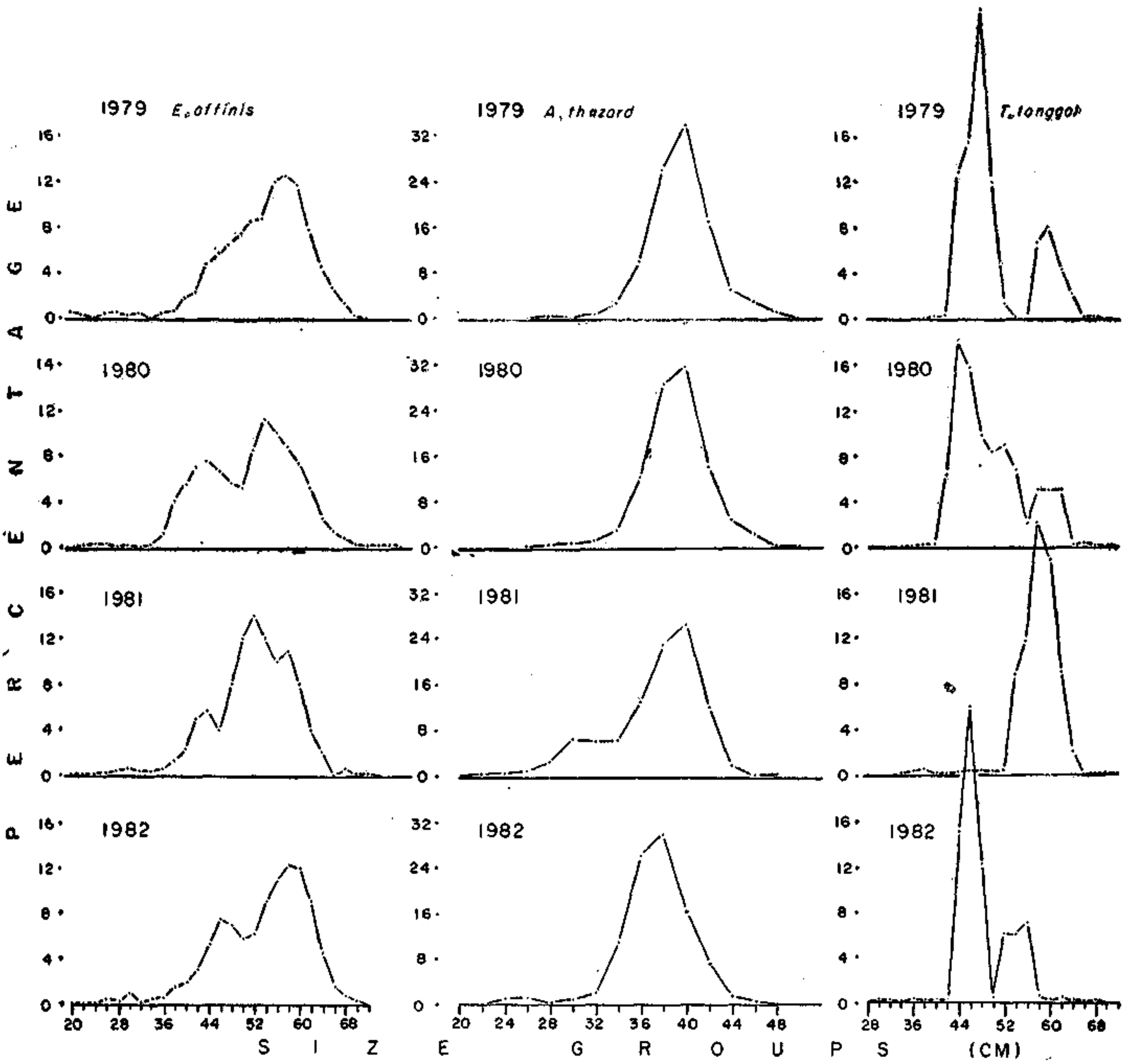

Fig. 10. Pooled annual length frequency distribution of *E. affinis, A. thazard* and *T. tonggol* at Cochin, 1979-'82.

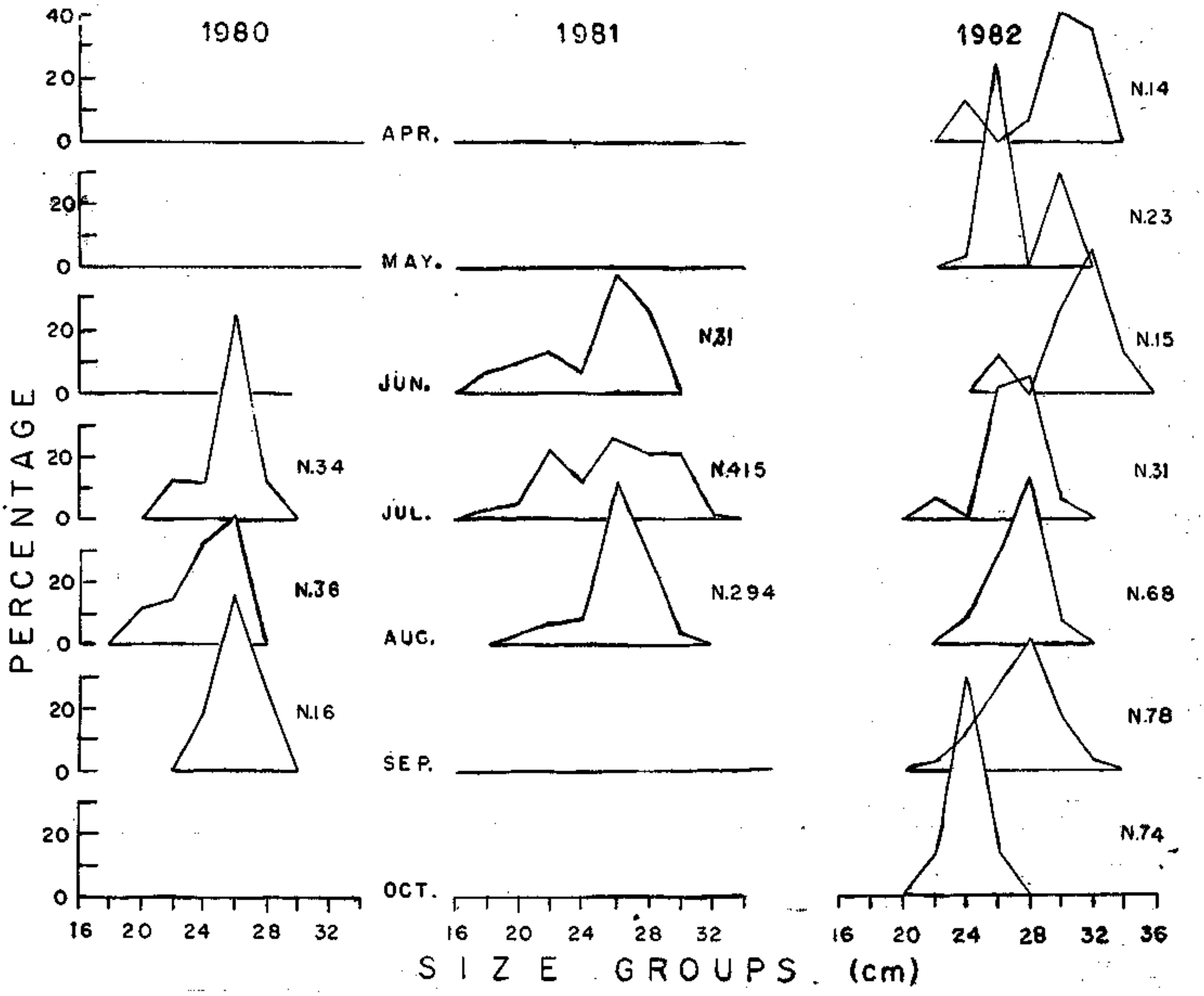

Fig. 11. Monthly length frequency distribution of *A. rochei* at Cochin, 1980-'82.

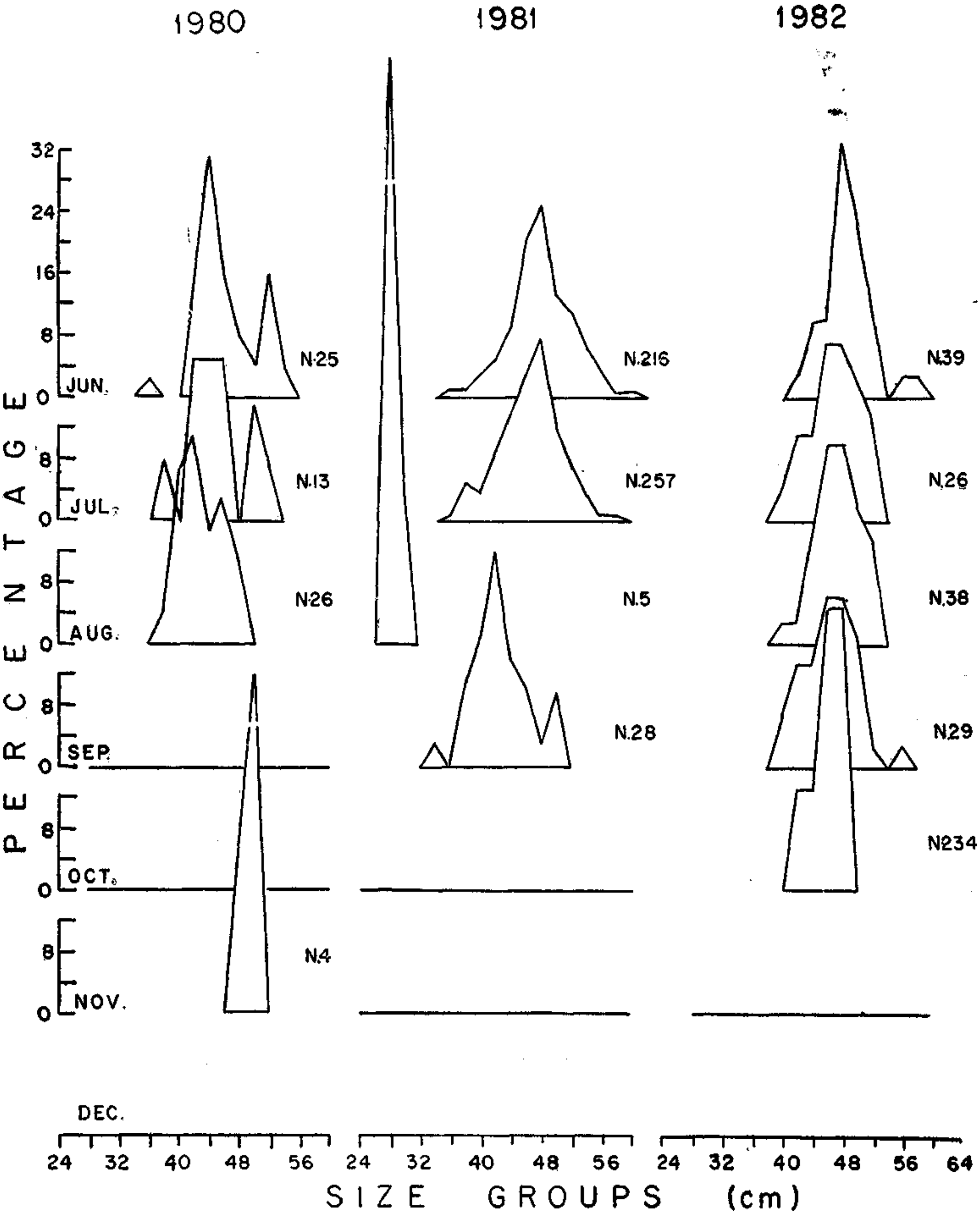

Fig. 12. Monthly length frequency distribution of *S. orientalis* at Cochin, 1980-'82.

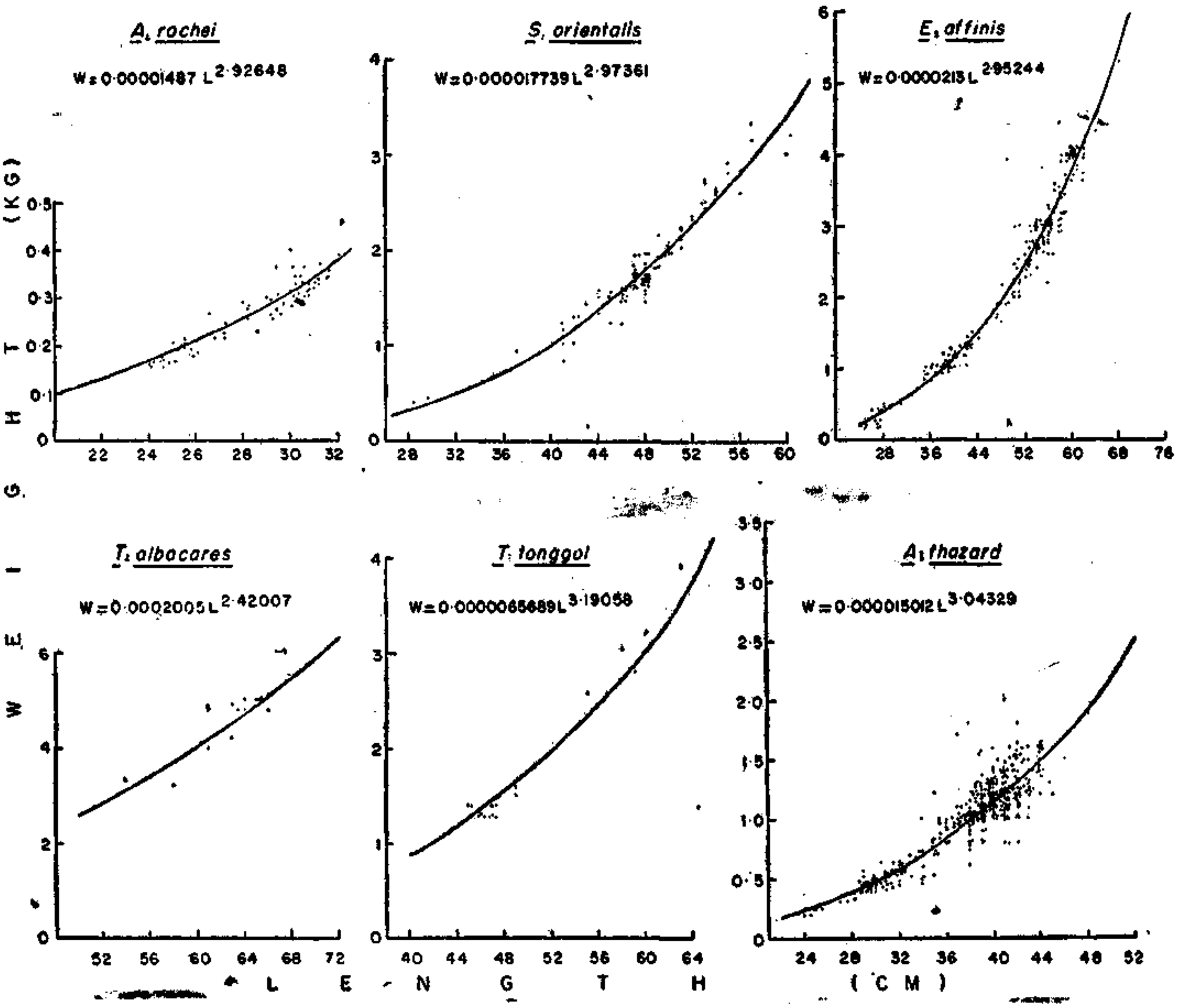

Fig. 13. Length-weight relationship of *A. rochei, S. orientalis, E. affinis, T. abacares, T. tonggol* and *A. thazard* at Cochin, 1979-'82.

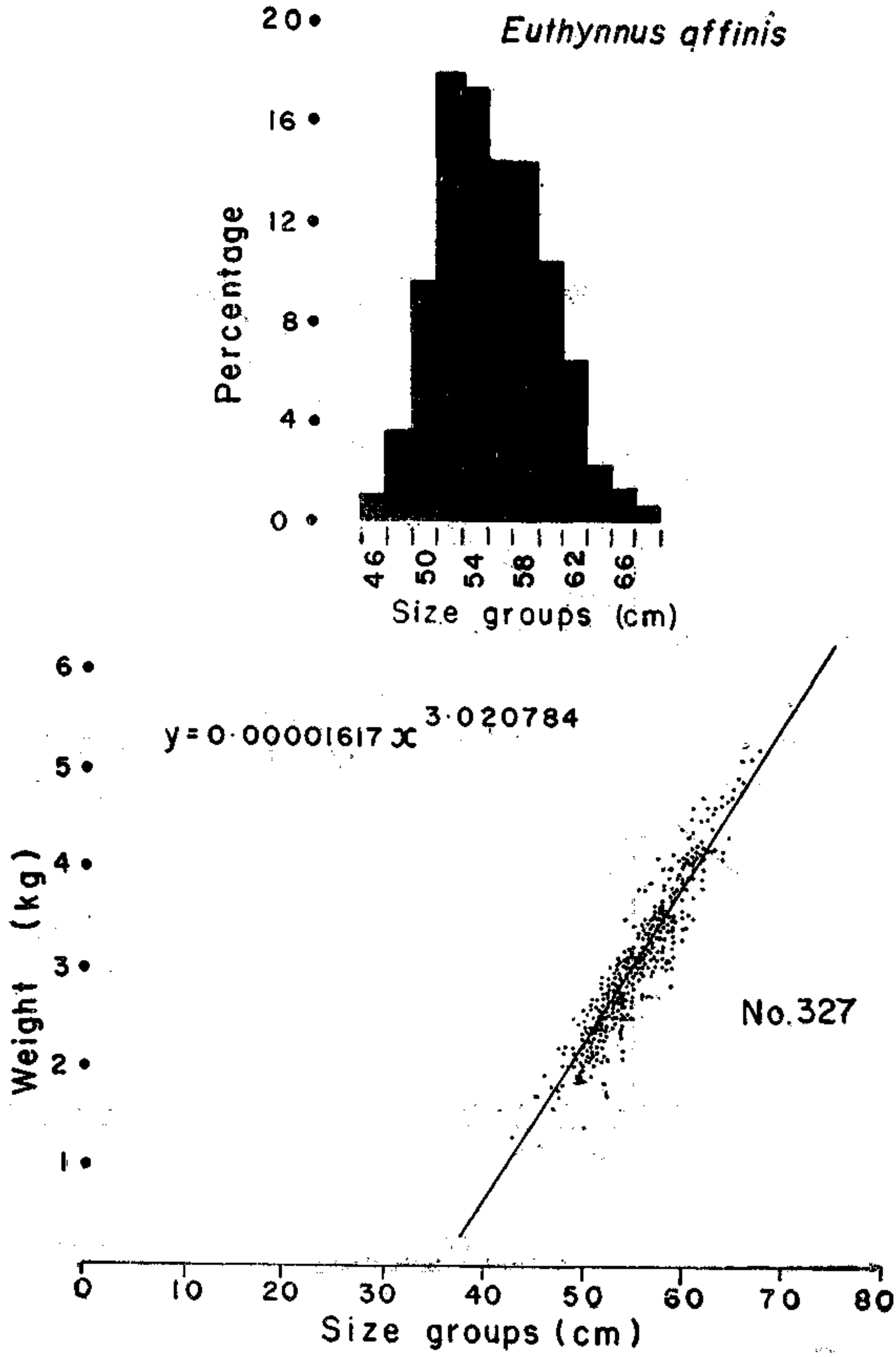

Fig. 25. Length frequency distribution (percentage) and the length-weight relationship of *E. affinis* taken by purse seine at Cochin, 1981-'82.

The results of studies on the length-weight relationship ($W = aL^b$) of *E. affinis* and *S. orientalis* conducted by the earlier authors are presented here for comparison :

Species & locality	Fork length (cm)	a	b	Wt. Unit	Lt. Unit	Source
E. affinis (Indian Ocean)	52-71	0.0166	2.963	gm	cm	Morrow (1954)
E. affinis (Indian Ocean)	12-58	0.0137	3.0249	gm	cm	Sivasubramaniam (1966)
E. affinis (Indian Ocean)	..	0.0138	3.0287	gm	cm	Silas (1967)
E. affinis (South China Sea)	..	0.08853	2.5649	gm	cm	Williamson (1970)
E. affinis (Hawaii)	..	0.0108	3.1544	gm	cm	Tester & Nakamura (1957)
E. affinis (M) (Philippines)	34.4-81.0	0.0334	2.83768	gm	cm	Ronquillo (1963)
E. affinis (F) (Philippines)	33.1-65.2	0.0211	2.94854	gm	cm	Ronquillo (1963)
S. orientalis (Indian Ocean)	..	0.0152	2.958	gm	cm	Sivasubramaniam (1966)

6

FISHERY AND BIONOMICS OF TUNAS AT VIZHINJAM

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Vizhinjam (76°59'E, 8°22'N) is an important fish landing centre owing mainly to its location which affords facilities for operation of boats even during the monsoon season and accessibility to the nearby markets. With the Fisheries Harbour construction underway, the fisheries importance of this area is bound to increase further. Details of common nets employed in the centre and the modes of their operations were described earlier by Nayar (1958), Bennet (1967) and Luther *et al.* (1982). Rao (1964) described the ripe ovaries of some Indian tunas from Vizhinjam and summarised that *E. affinis, A. thazard* and *S. orientalis* spawn in the local waters from April to September and possibly in other months of the year. According to him, the spawn ripe individuals of the above three species indicate the existence of an important spawning ground for them off Vizhinjam.

FISHING AREA

Fishing area for tunas and allied fishes extends from Valia veli in the north to Kollengode in the south within the 40-80 m depth zone (Fig. 1). This area is influenced considerably by the SW and NE monsoons and upwelling, and the concomitant changes in the hydrographical features. Divakaran *et al.* (1983) described the plankton production in the Vizhinjam inshore waters and indicated the availability and abundance of different groups of zooplankton groups in this area.

CRAFTS AND GEARS

At Vizhinjam tunas are mainly caught in the drift gillnets, and hooks and lines. In certain months, shoals of coastal species of tunas come so close to the shore that they are captured in the shore seines operated in the fore-shore waters.

About 60% of the total tuna landings is by the drift gillnets and the rest by the hooks and lines. Both mechanised and non-mechanised crafts are engaged in the operation of both the gears. The tuna landings by other gears such as shore seines and Konchuvala (gillnet) are insignificant.

The crafts used are catamarans and dugout canoes. Four pieces of logs of 6.3 m length are tied together

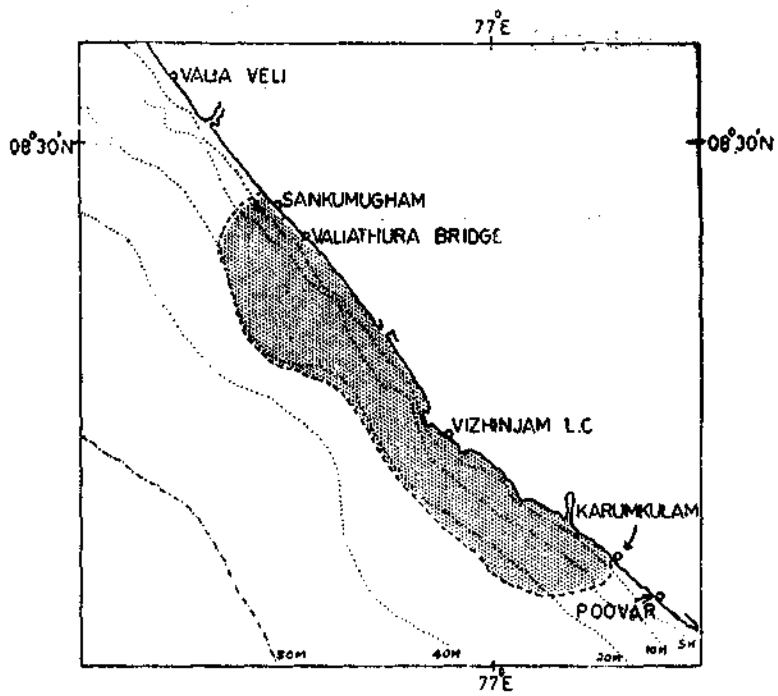

Fig. 1. Operational core area of drift gillnetters and hooks and line fishery at Vizhinjam.

to form one catamaran unit and three fishermen operate one unit. The canoes are dugout, carved from a single log and it has a length of 8 m and depth of 1 m and 3-4 fishermen operate these canoes. Usually drift gillnet operation is suspended during the monsoon months. Of late, mechanised boats of 7.9 m OAL and 16-40 HP are also employed in the fishery.

Drift gillnets are made of nylon yarn. The stretched mesh size is 5-10 cm. The nylon twine has completely replaced cotton and hemp twine as net making materials. The net is preserved by dipping it in a concoction prepared by boiling tamarind in water.

The drift gillnet fishermen leave the shore for fishing by 1600 hrs and they sail in a north by north-west direction. They take 2-3hrs to reach the fishing ground. Generally two hauls are made and the soaking time vary between 2-3 hrs. They return to the shore by about 0600-0800 hrs the next day. The fish catches are auctioned and taken to different markets.

Hooks and line fishery employ longline (choonda) and small hooks (achil). In the longline, fishermen use hooks of size No. 4 and 9 in varying numbers and the line used is nylon (Kangoos). Achil has hooks of size No. 16 and no bait is used. The area of operation is the same for the drift gillnet fishery in a little farther off. The craft used in this fishery is catamaran and manned generally by two fishermen. They leave the shore by 0600 hrs and return at about 1400-1800 hrs. Now a days, catamarans fitted with *Yamaha* outboard engines (8 HP) are popular among the fishermen. The fuel used is diesel and kerosine mixed in equal proportions.

Effort, catch and CPSE

The average standard effort for the period 1979-1982 was 3060 units and the average catch was 258 tonnes of tunas (Fig. 2).

In 1979, maximum standard effort expended was in May (10120 units) and minimum in July. The catch recorded a maximum of 122 tonnes in October with CPSE at 44.50 kg, although during April and July, it was 12.2 kg and 17.0 kg respectively. In 1980, the effort expended was maximum (11,647 units) in June and catch was also highest in that month (207 tonnes) As in the case in 1979, the CPSE in 1980 was highest in October (44.5 kg). In 1981, maximum effort put in was in September (6667 units), but the catch was at its peak in May (147 tonnes), and maximum CPSE was also in May (33.2 kg) with a secondary maximum in November (13.8 kg). In 1982, 12,864 units were in operation in October and the maximum catch recorded was in May (64 tonnes) and maximum CPSE of 27.1 kg was recorded in September.

Based on the pattern of fluctuations in CPSE in the tuna fishery at Vizhinjam, it is observed to be irregular, showing peaks in the monsoon, pre-monsoon and post-monsoon months during the period under report.

Species composition

E. affinis and *A. thazard* were represented in the catches throughout the year. But for *A. rochei, S. orientalis, T. albacares* and billfishes definite periodicity was observed. *A. rochei* appeared in the fishery during pre-monsoon months, *S. orientalis* during pre-and post-monsoon months and *T. albacares* and billfishes during the pre-monsoon months.

In 1979, *E. affinis* contributed to 51.6% and *S. orientalis* and *A. thazard* 27.5% and 14.8% respectively of the total catch (Fig. 3). The percentage composition of *E. affinis* increased during the years 1980, '81 and '82 (55.0%, 68% and 71.6%) while that of *S. orientalis* showed a decreasing trend in these years, their share being 9.8%, 3.1% and 1.2% respectively of the total catch. *A. thazard* constituted 18-20% and billfishes 3-4% of the total catch in all these years.

Length distribution

The data on Length frequency distribution is available for *E. affinis* and *A. thazard* for the years 1981 and 1982 (Figs. 4 & 5).

Annual pooled length distribution of *E. affinis* indicate that in 1981 the major modes were at 26, 38 and 50 cm. A minor mode was present at 58 cm. In 1982, the major modes were at 30, 34, 50 and 58 cm. With regard to *A. thazard* the annual pooled length distribution evinced a biomodal peak in 1981 and 1982 at 30 and 34 cm (Fig. 6).

Monthly variation in size distribution is presented in Figs. 5 and 6, for the two species for the years 1981 and 1982. In 1981 *E. affinis* occurred in the 22-72 cm size group. The major modes increased from January and during August smaller individuals with a peak at 26 cm was recorded. Further increase in the modal classes was evident from September onwards. In 1982, major modes were around 34 and 50 cm. *A. thazard* occurred in the size range 22-50 cm in 1981 and their major modes were around 28, 34, 40 and 42 cm. In 1982, from February to May, modal progress was clearly perceptible and during September, November and December their modes were at 30-32 cm size group.

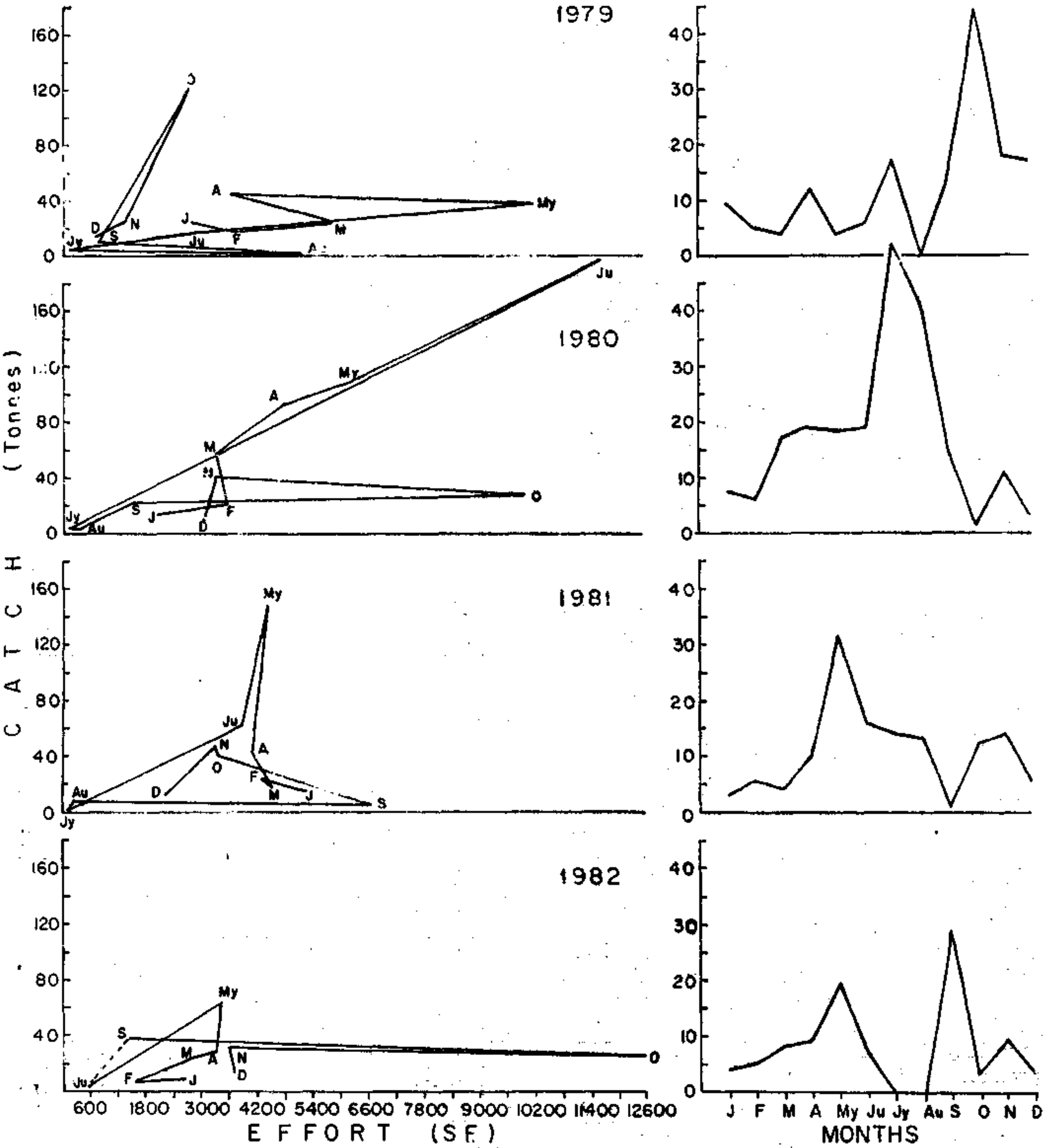

Fig. 2. Catch-standardized effort relationship of tunas at Vizhinjam, 1979-'82.

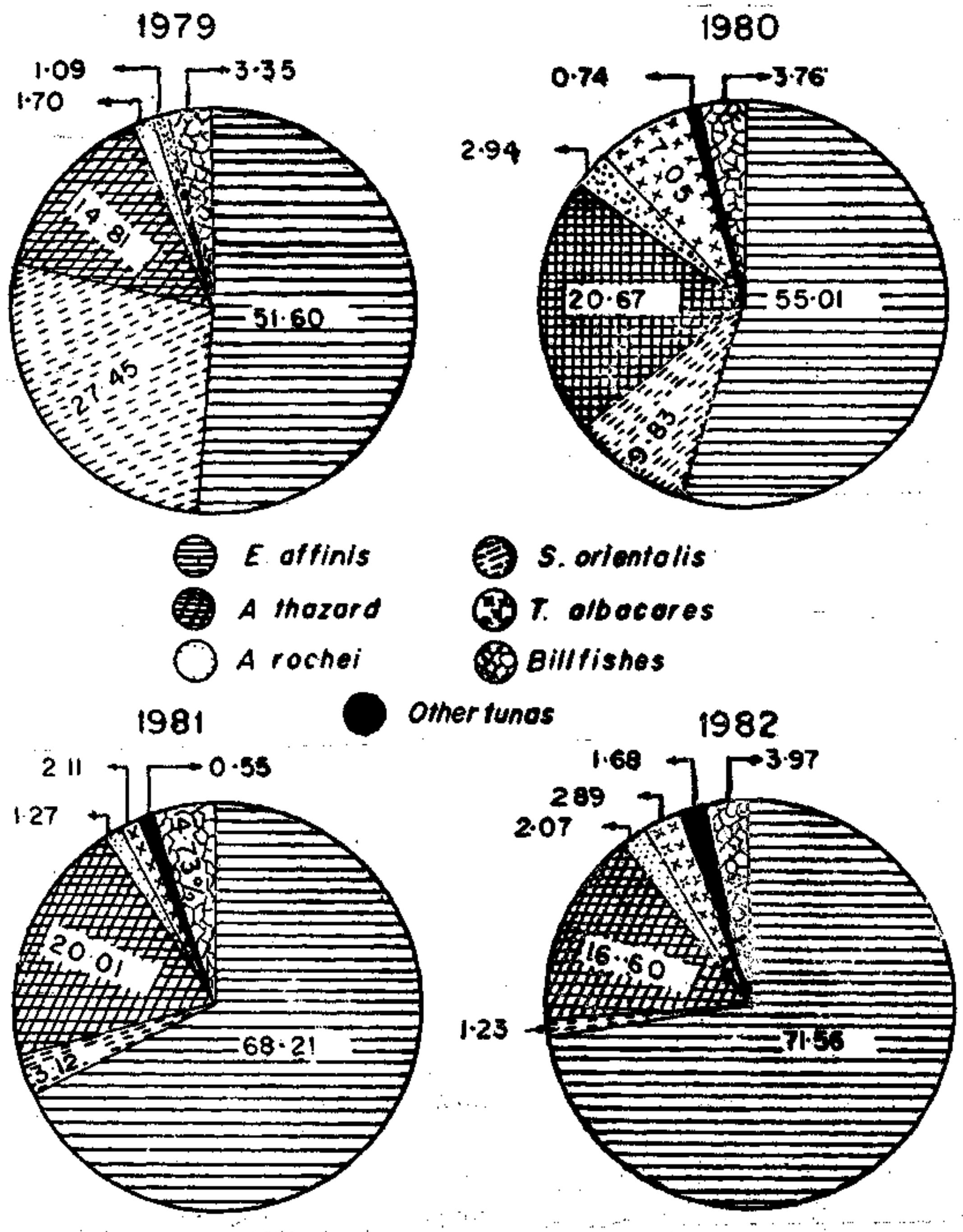

Fig. 3. Percentage composition of different species of tunas and bill-fishes at Vizhinjam, 1981-'82.

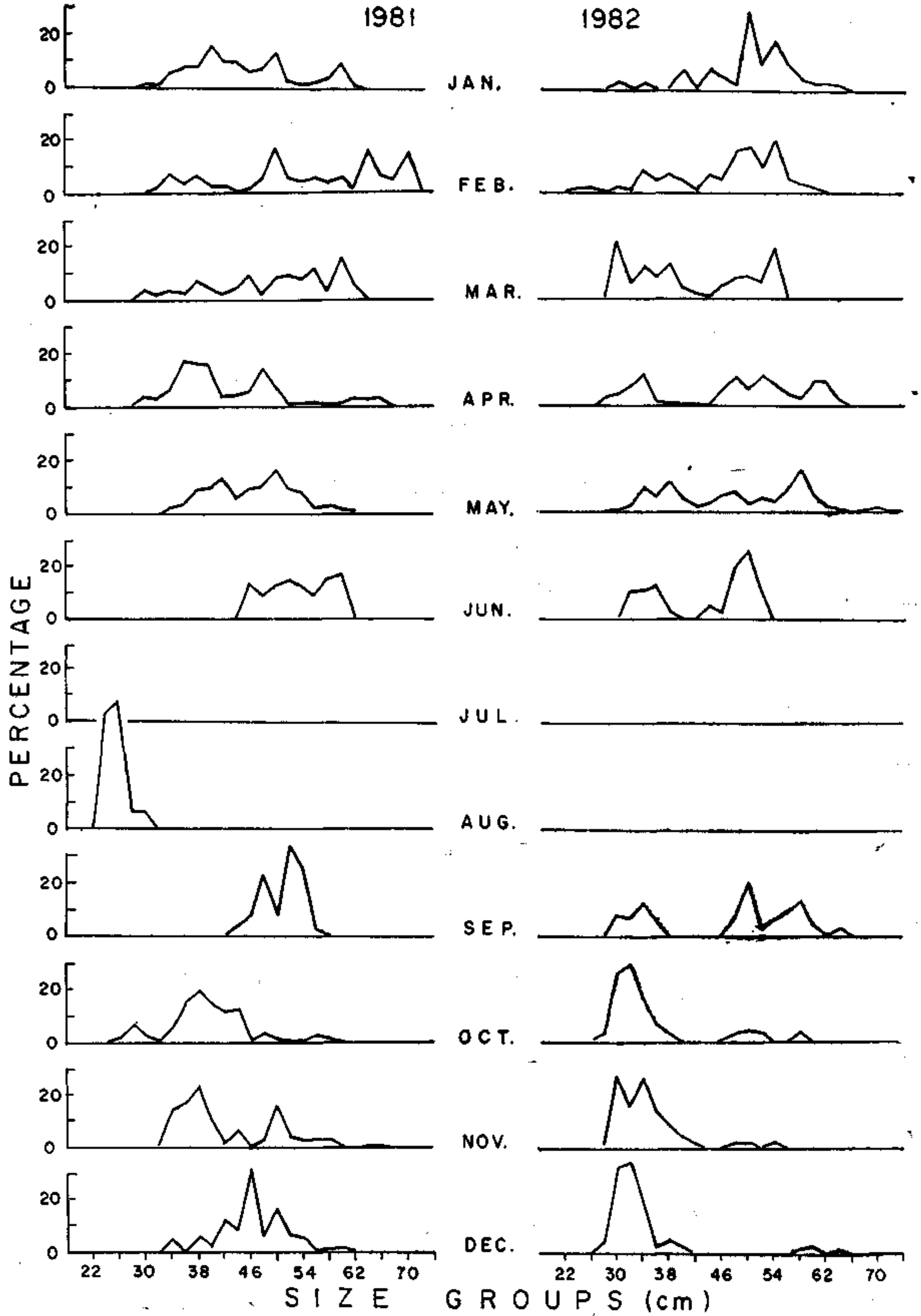

Fig. 4. Monthly length frequency distribution of *E. affinis* at Vizhinjam, 1981-'82.

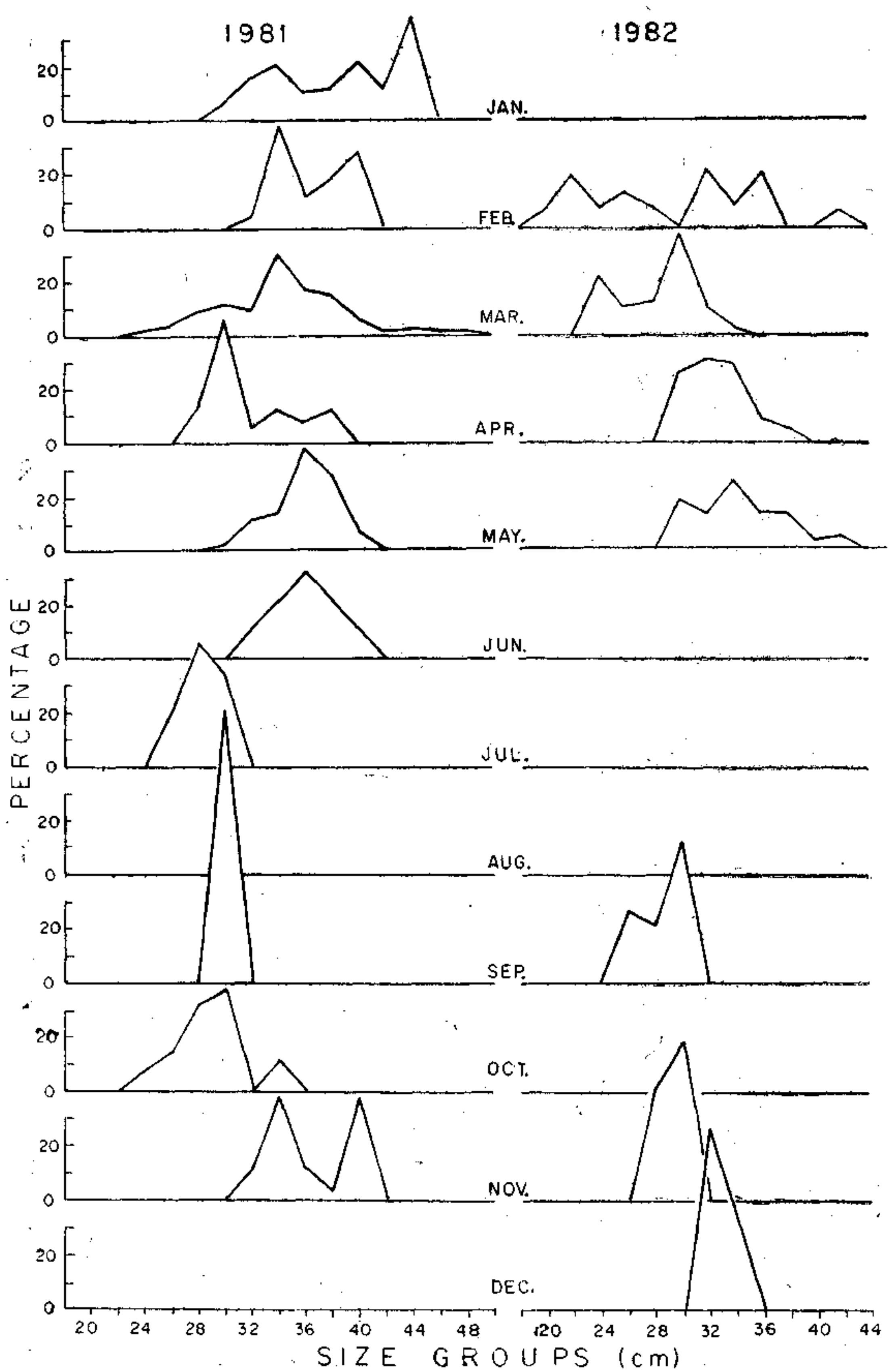

Fig. 5. Monthly length frequency distribution of *A. thazard* at Vizhinjam, 1981-'82.

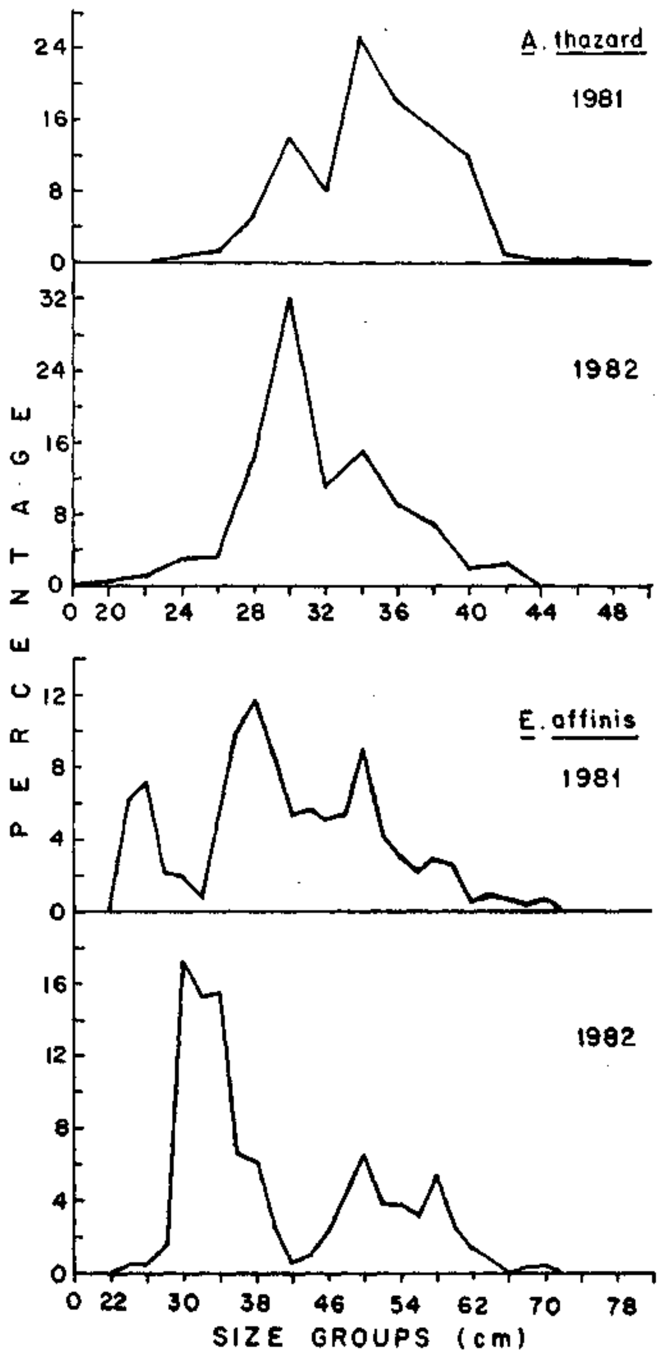

Fig. 6. Pooled annual length frequency distribution of *A. thazard* and *E. affinis* at Vizhinjam, 1981-'82.

7

FISHERY AND BIONOMICS OF TUNAS AT MANGALORE

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Karnataka waters, on the upper part of S.W. coast of India produce an average total of 786 tonnes of tuna annually (1972-'81) forming 0.7% of the state's marine fish catch and 5% of the total tuna catch of India. Of late, the production rate of this resource in the state had gone upto an average of 1,729 tonnes per year (1979-81). This rapid progress was achieved by the introduction of modern fishing techniques such as purse seining, deployment of mechanised crafts for drift gill netting and synthetic materials for gears.

At present, there is no indepth information available on the resource characteristics of tunas and allied forms from Karnataka waters except for those by Silas *et al.*, (1979), Dhulkhed *et al.* (1982) and Muthiah (1982). In view of this, a detailed investigation on the resources of tunas and allied species of Mangalore area (South Kanara District of Karnataka State) was undertaken from 1979 through 1982 and the results are given here. Since purse seiners and mechanised and non-mechanised drift gillnetters equally contributed to the tuna fishery at this centre, the results of observations on the landings of these gears are dealt with separately.

FISHING AREA

Purse seining in Karnataka waters is carried on between Manjeswar in the south and Bindur in the north extending over an area of 150 km (Rao *et al.*, 1982) (Fig. 1). The purse seiners based at Mangalore usually operate between Kasaragod in the south (40 km) and Kaup in the north (45 km). But concentration is seen in the southern region because of competition offered by purse seiners of Malpe in the northern area. Fishing is done from 10-35 m depth and it varies from season to season. During September-January fishing is carried out in the 10-20 m depth because during this season shoals of pelagic species are sighted in good concentration at this depth. After February, operation is extended to waters upto 30-40 m depth because of thinner shoals or non-availability of shoals in the shallow inshore waters (Dhulkhed *et al.* 1982). The operation is suspended during June-August owing to south west monsoon. However, if the monsoon delays and the weather permits fishing is done even upto the middle of June.

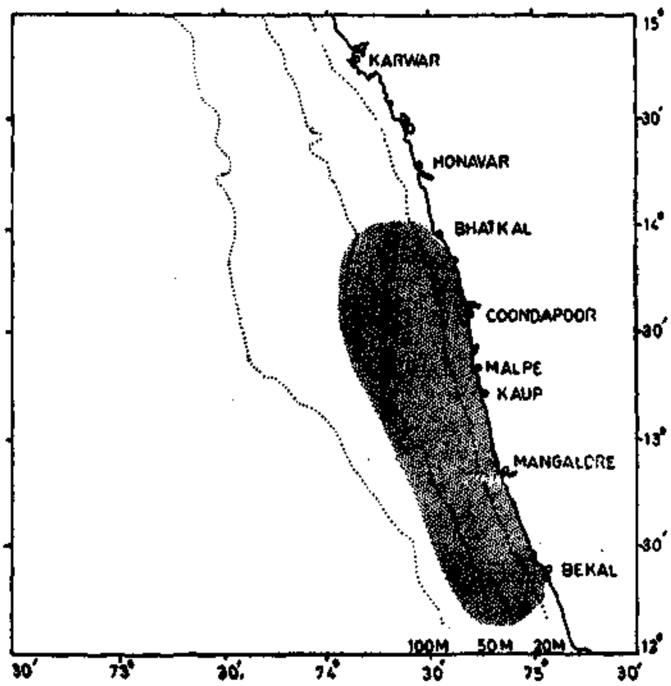

Fig. 1. Operational area of drift gillnetters and purse seiners at Mangalore.

The operation of drift gill nets are restricted to 20-60m depth and the fishing season extends from September to March/April. The areas of operation are off Mangalore, Suratkal, Hejmady, Kaup, Malpe and Gangoli, of which the major areas are off Kaup and off Mangalore (Fig. 1).

The coastal waters of Karnataka spread over a distance of 300 km in two districts *viz.*, South Kanara and North Kanara. Its continental shelf area amounts to 25,000 sq. km and the depth of shelf extends upto 120 m and 88% of the shelf area lies between 0-72 m depth. The bottom area is mostly sandy and muddy upto 60 m depth slightly uneven from 60-90 m depth and rocky coral formation from 90-120 m depth (Anon., 1978). At present only about 20% of the shelf area are exploited (George, 1981). A number of rivers and backwaters enter the coastal waters making the salinity and temperature low during the south west monsoon (August). The salinity shows an increasing trend from September-October and February-May. Suresh and Reddy (1980) have observed that sea water temperature in the Mangalore area showed two peaks, one in April and the other in October, corresponding to the two dry periods and two minima during the periods of south west monsoon and winter season. They also observed that salinity increased from February to May and then decreased recording its lowest in August. In September, salinity values increase and continue upto October followed by a decrease in November and subsequently an increase in December. Lower values of salinity occurred with fall in temperature and with occurrence of rainfall. Upwelling was observed in the deeper water in February/March and in coastal water from May to August. According to them, the coastal waters are rich in nutrients during the south-west monsoon due to the upwelling, river discharge and land drainage. It was observed earlier that currents are directed towards north from October to February and towards south from April-May to September and March appears to be a transition period. The average rainfall in this region is 300 cm of which 75 % fall between May and September.

Constant watch on the purse seine landings was made by making almost daily observations at Bunder (Mangalore) where more than 100 purse seiners land their catches every day. Catch of 10 to 20% of the total boats landed in a day were recorded from which the day's total catches were calculated. Further computing the day's average catch to the total number of fishing days in a month gave the monthly estimated catch. In seasons, whenever there are bumper catches, the purse seine boats usually employ carrier boats to transport fish after a successful haul. Each carrier boat was considered as one unit for computing day's catch in the present study. For CPUE analysis actual number of purse seine units which operated sets were only considered *i.e.*, the total catch for the day or month is divided by the purse units to work out CPUE.

For the purpose of estimation of drift gill net landings, all the six centres were considered as a single unit in view of the fact that all these centres are located within a range of 100 km and the catch composition of species remaining more or less the same. Of the six centres, Kaup and Mangalore where maximum number of units are in operation (more than 60% of the total drift gill nets of South Kanara) were visited twice a week, whereas the other centres namely, Suratkal, Hejmady and Malpe where fishing activities are in lesser magnitude due to fewer number of units in operation were visited once a week and the last centre, Gangoli once a month. Although the sampling from this centre may be inadequate because this centre is far away and due to practical difficulties to visit more often this centre was included for the study in order to give a complete picture of drift gill net fishery of South Kanara. It was noticed that, very often, the drift gill net units shift their operational base because of prolonged poor catch returns from a particular centre or when the operators hear of better catches from neighbouring centres. The methodology of estimation of the catches and standard effort between non-mechanised and mechanised catches was as per that dealt with in Chapter 2.

Crafts and gears

Along the Karnataka Coast, tunas and allied fishes form a minor fishery. In the past, they were taken along with larger pelagics such as seerfishes, catfishes and sharks by 'odubale' a type of drift gill net operated from small dugout canoes. This 'odubale' along with other traditional crafts such as 'rampani' 'kanthabale', and 'pattabale' had contributed upto 75% of the state's annual catches (George, 1981). With the introduction of mechanisation in the state in 1956 for trawling and purse-seining during 1975-76, the operation of 'odubale' by the local fishermen became phased out. This lacunae has been filled by fishermen from Kanyakumari District of Tamil Nadu, who migrate to Karnataka Coast during September to March and employ the drift gill nets, of the size 450-700 m length, landing a good amount of tunas and billfishes. They deploy this gear from Mangalore, Suratkal, Hejmady, Kaup, Malpe and Gangoli along South Kanara Coast. The concentration of these fishermen are more at Kaup and Mangalore because of better market and other infrastructure facilities. The 'odubale' fishery by these fishermen has become so successful in terms of quality fish catches such as sharks, seerfishes, tunas and catfishes, that due to good financial returns the local fishermen are once again being attracted to take up this fishery. The number of 'odubale' units of local fishermen is on the increase now. At present local fishermen employ this gear with motorised canoes with OBE or mechanised boats.

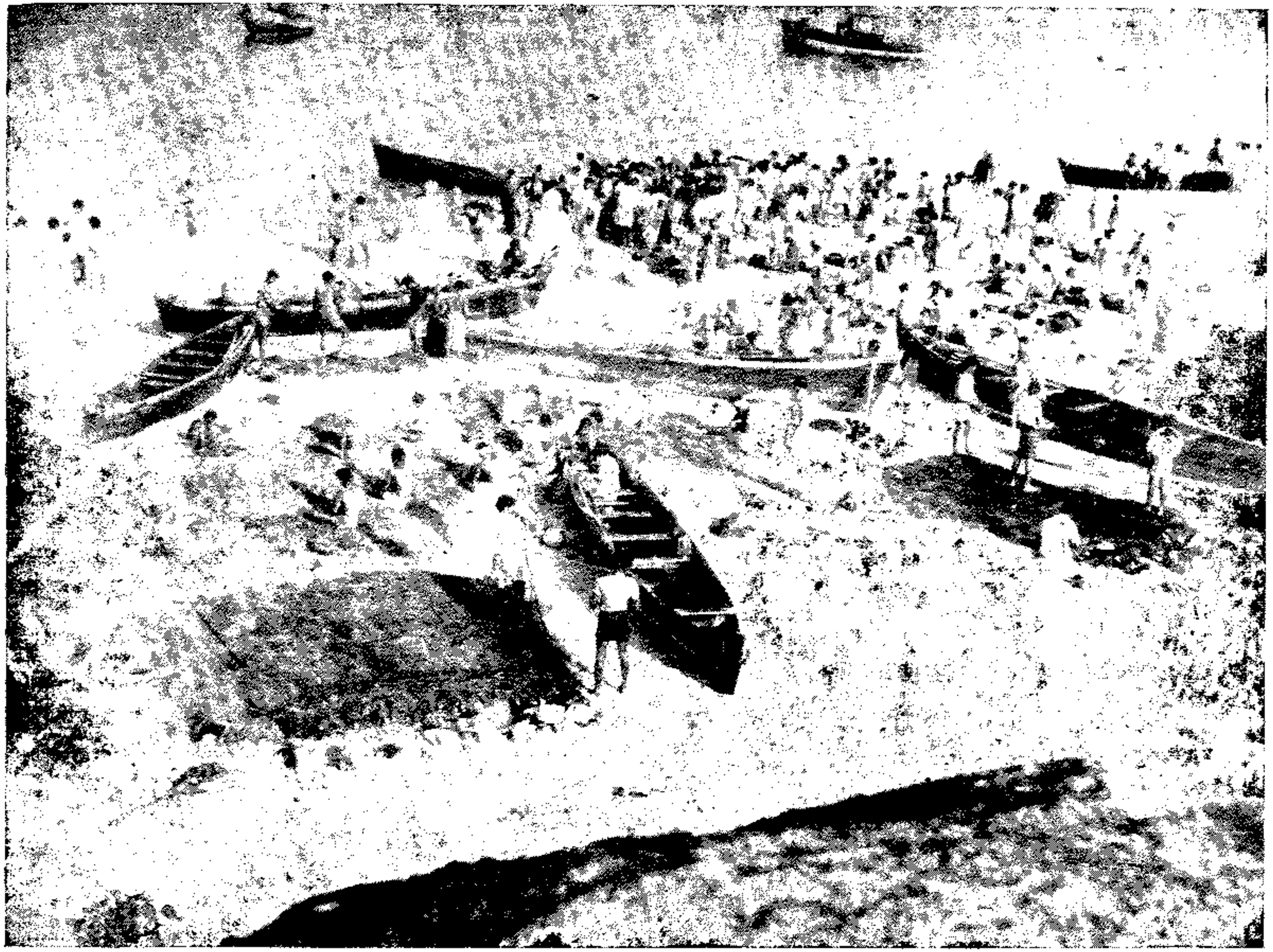

Plate I. Drift gillnet Landing Centre at Kaup, Karnataka State.

PLATE II. Little tuna (*Euthynnus affinis*) landed by drift gillnets at Kaup Landing Centre.

PLATE III. Black marlin (*Makaira indica*) landed by drift gillnet at Kaup Landing Centre.

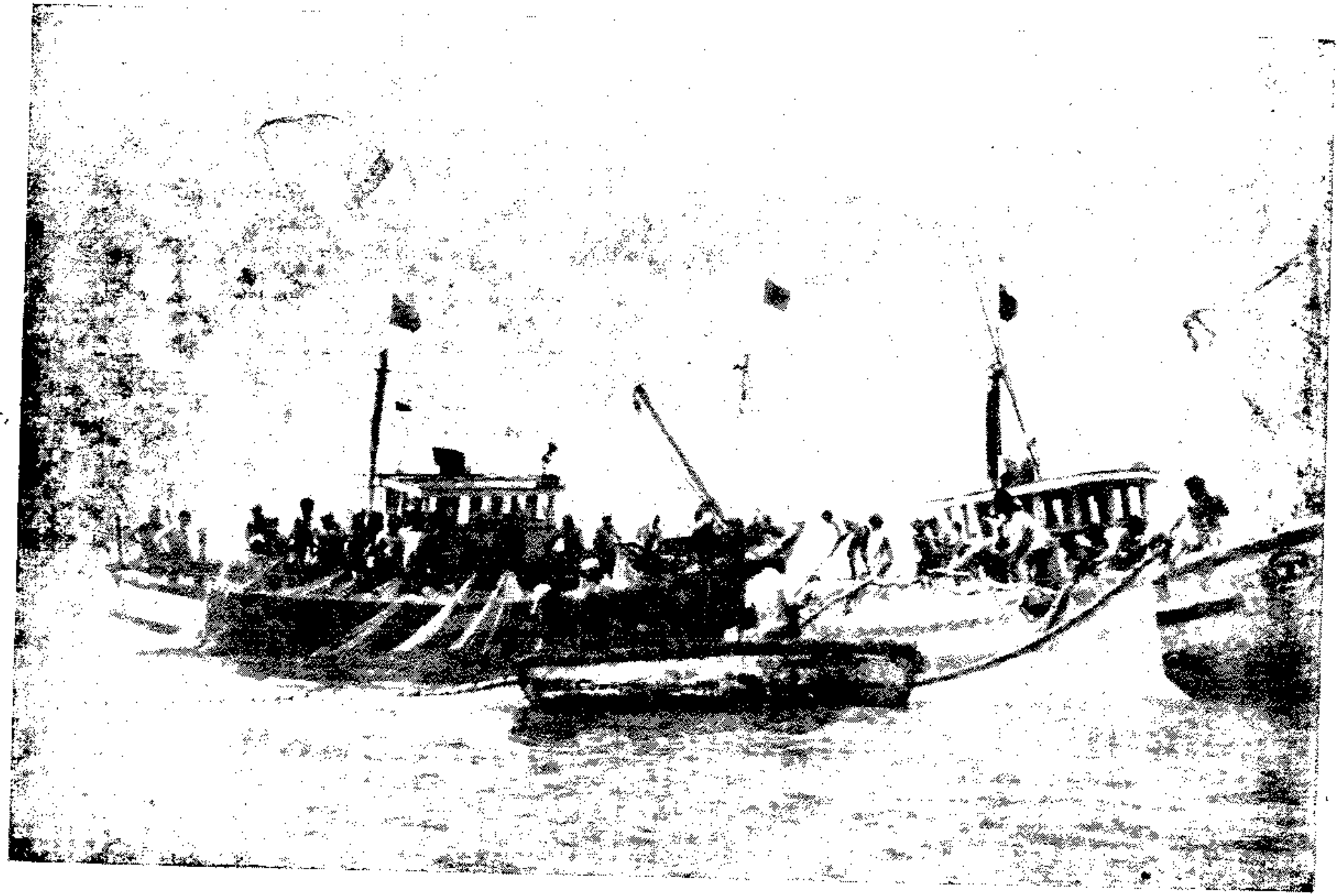

Plate IV. Operation of purse seine, off Mangalore, Karnataka State.

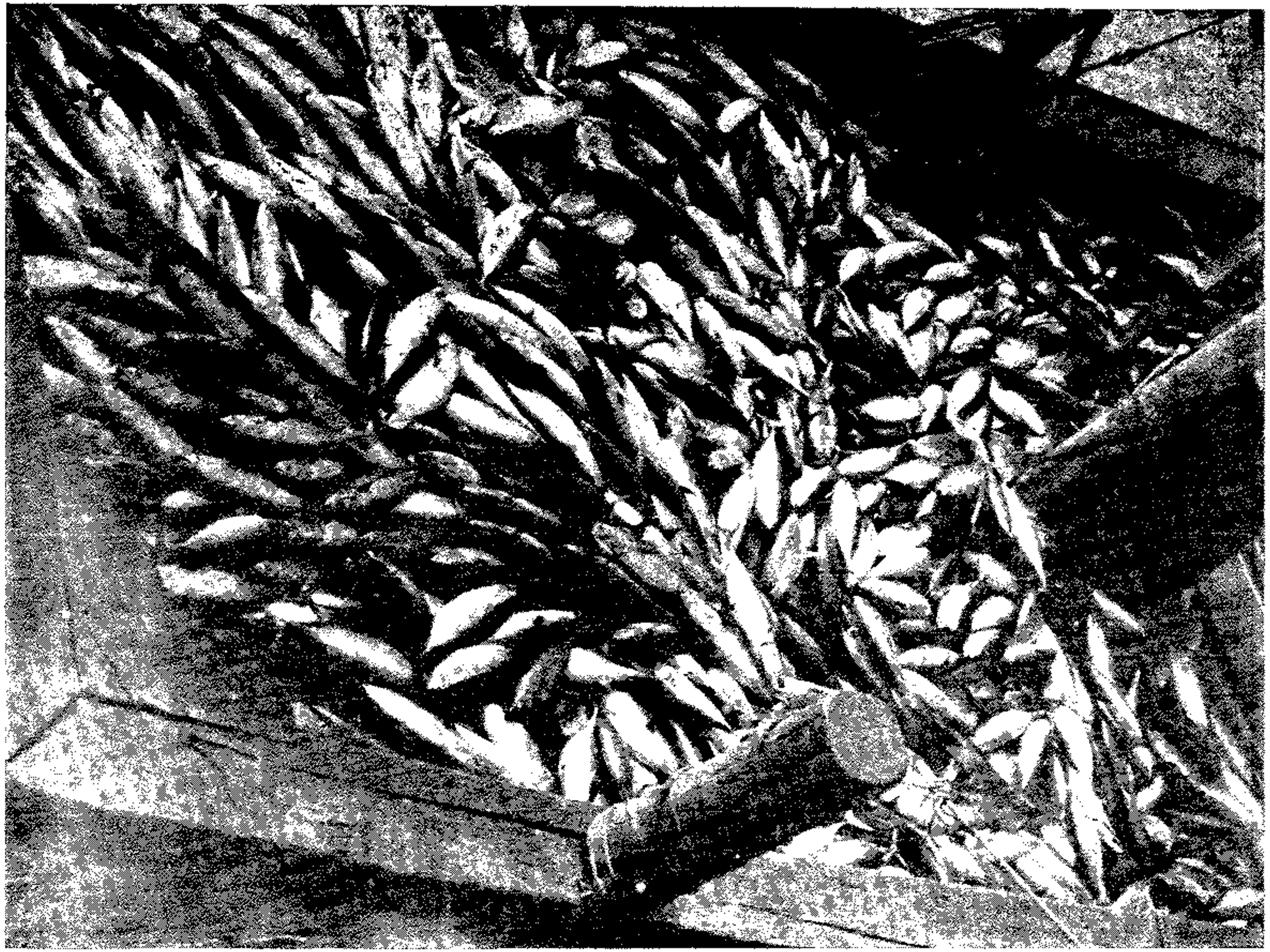

PLATE V. Tunas taken by purse seine boats from off Mangalore, Karnataka State.

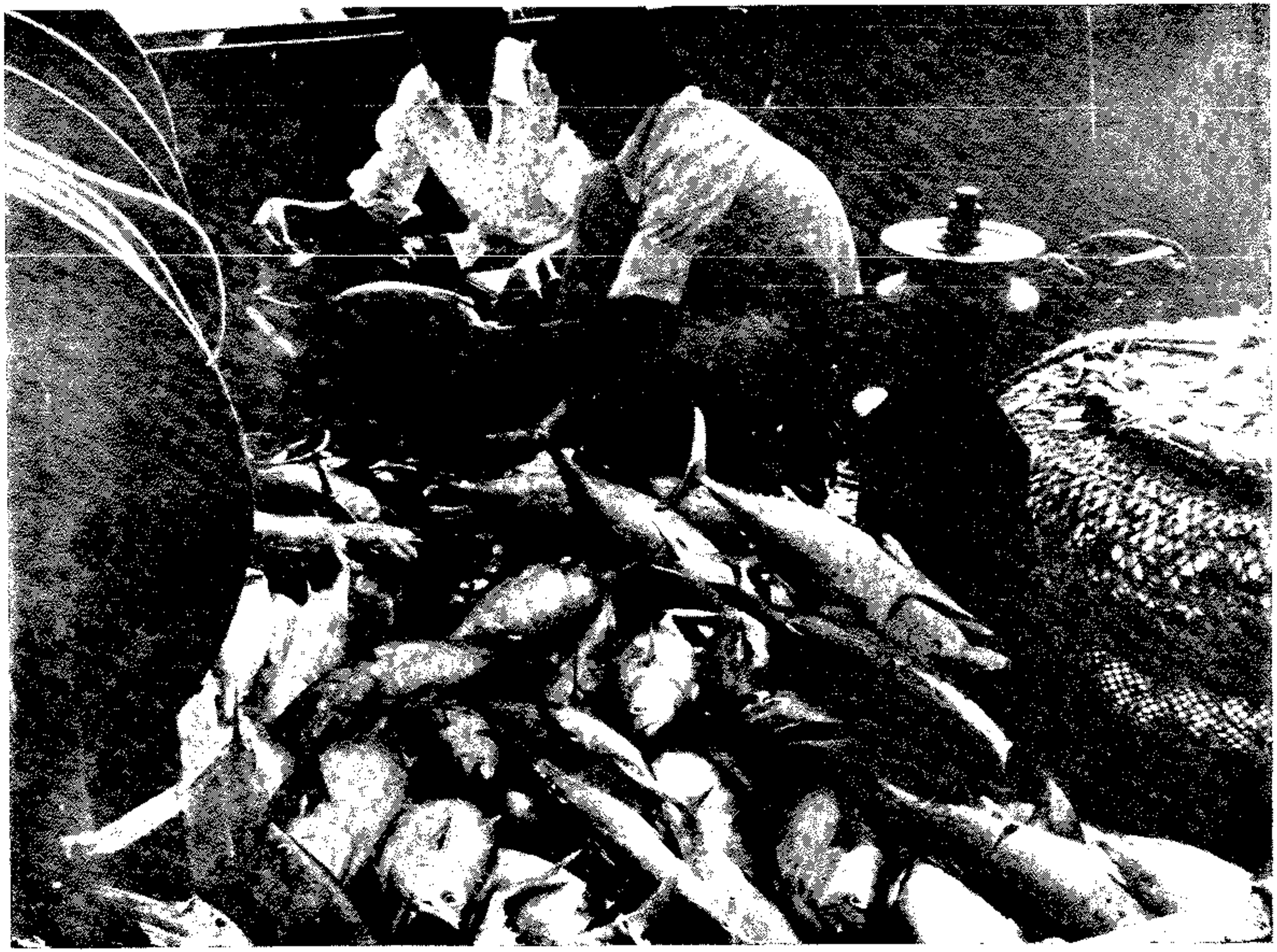

PLATE VI. Little tuna (*Euthynnus affinis*) landed by purse seine boats from off Magalore, Karnataka State.

PLATE VII. Little tuna (*Euthynnus affinis*) catch by purse seine boats, another view.

PLATE VIII. Tuna being loaded for distribution at Mangalore (*Photos* 5-12 by *C. Muthiah*).

'Odubale' operations are restricted to inshore waters. With the advent of mechanisation/motorisation of canoes and boats and the introduction of purse seine in the mid-seventies landings of tunas from the coastal Karnataka have gone up. The annual average catch of tunas and billfishes for the five-year period 1970-'75 (prior to the introduction of purse seine) was 230.5 tonnes, forming 0.2% of the total fish catch of the state, which was increased to 1,166 tonnes in the next five-year period (1976-'81) forming 0.9% in the state's total marine fish catch. About 300 purse seiners and 400 drift gillnetters are engaged in exploiting the pelagics in the state, of which about 250 purse seiners and an equal number of drift gillnetters are under operation in the South Kanara Coast.

Purse seine fishing on a commercial scale was introduced in the Karnataka Coast during 1975-76 and expansion of the purse seine fleet was rapid through the years.

The purse seine unit consists of a main boat made of timber having length from 13 to 14m with diesel engine of 105/120 HP and a 'skiff.' The gear is made up of synthetic nylon of 450 m in length and 33 m height of depth with a mesh size of 14 mm. The upper line of the net is attached with plastic floats and the lower edge to sinker line (lead) and this in turn with purse rings made of brass. The number of crew varies from 18-25. During the season at times of bumper catches, carrier boats, usually trawlers of 8 to 11m length are employed to transport the catch from the fishing area to the landing site. The method of operations of purse seiners has been dealt with earlier (Dhulkhed *et al.*, 1982).

The drift gill net fishing along the South Kanara Coast has been practised with dugout or plank built canoes of 5 to 6 m length propelled by oars or sails and mechanised vessels of 9.7 m length made of timber. Recently the canoes are fitted with Yamaha outboard engine. The net is made of synthetic nylon mostly of pink colour and varying in length from 450 m to 700 m and the height from 6 to 7 m. Usually mechanised vessels use comparatively longer nets in the distant waters. About 20 pieces having 65 to 135 mm mesh size are plied together to make a single net. Wooden floats are attached to the head rope at regular intervals and the foot rope is not weighted during September-December period. From December onwards the foot rope is attached with sinkers of smaller stones.

During September-November, the nets are attached to one end of the canoe or boat. The net is set in the surface waters. After December till the end of the season (March-April) the nets are used as bottom set gill nets with one end attached to the boat which is anchored. The nets are set either against the wind direction or water current so that the fish that swim across get gilled or entangled.

EFFORT, CATCH AND CPUE

Purse seine

The estimated total tuna catch by purse seiners of Mangalore during 1979-'82 was 3,007 t, the annual average being 752 t. The tunas formed 0.4%, 1.73%, 4.65% and 1% respectively of the total fish catch during the above years. The catch showed progressive trends through the years with large fluctuations. In 1979 the catch was 112 t which increased to 508 t in 1980 and leaped to 1,966 t in 1981 and in 1982 it declined to 420 t despite increased effort. The total effort expended also increased progressively from 13,109 units in 1979 to 13,177 in 1980, 16,713 in 1981 and 19,173 in 1982. It may be mentioned here that in Karnataka waters the purse seine effort either decreases or increases in relation to the availability of pelagic fish stocks of mackerel or oil sardine.

The annual catch per unit effort (CPUE) showed an upward trend during 1979, '80 and '81 and a fall in 1982, the values being 8.54 kg, 38.5 kg, 117.69 kg and 21.92 kg respectively with an average annual value of 46.67 kg.

Month-wise effort expended and catch of tunas by the purse-seiners of Mangalore are presented in Fig. 2. It will be seen that in January-April, 1979 there were no tuna landings though the average monthly effort during these months was well above 1,000 units. The maximum effort was in October (2,403 units) and the catch realised was only 7 t. The highest catch of 63 t came in December whereas the effort fell to 1,333 units.

The CPUE of 11.8 kg in May 1979 rose to a maximum of 87.9 kg in June (Fig. 2) and decreased to a minimum in September (1.6 kg) and October (2.9 kg) and again increased to 47.3 kg in December.

In 1980, tunas were caught in almost all months except in December (Fig. 2). March recorded the peak catch (239 t) for the year inspite of a heavy reduction in the effort (510 units). April witnessed a steep fall in the production (6 t). During this year March recorded the highest catches in the pre-monsoon period and October in the post-monsoon period.

In January 1980, the CPUE was about 46 kg which declined to 6.67 kg in February. It attained a maximum

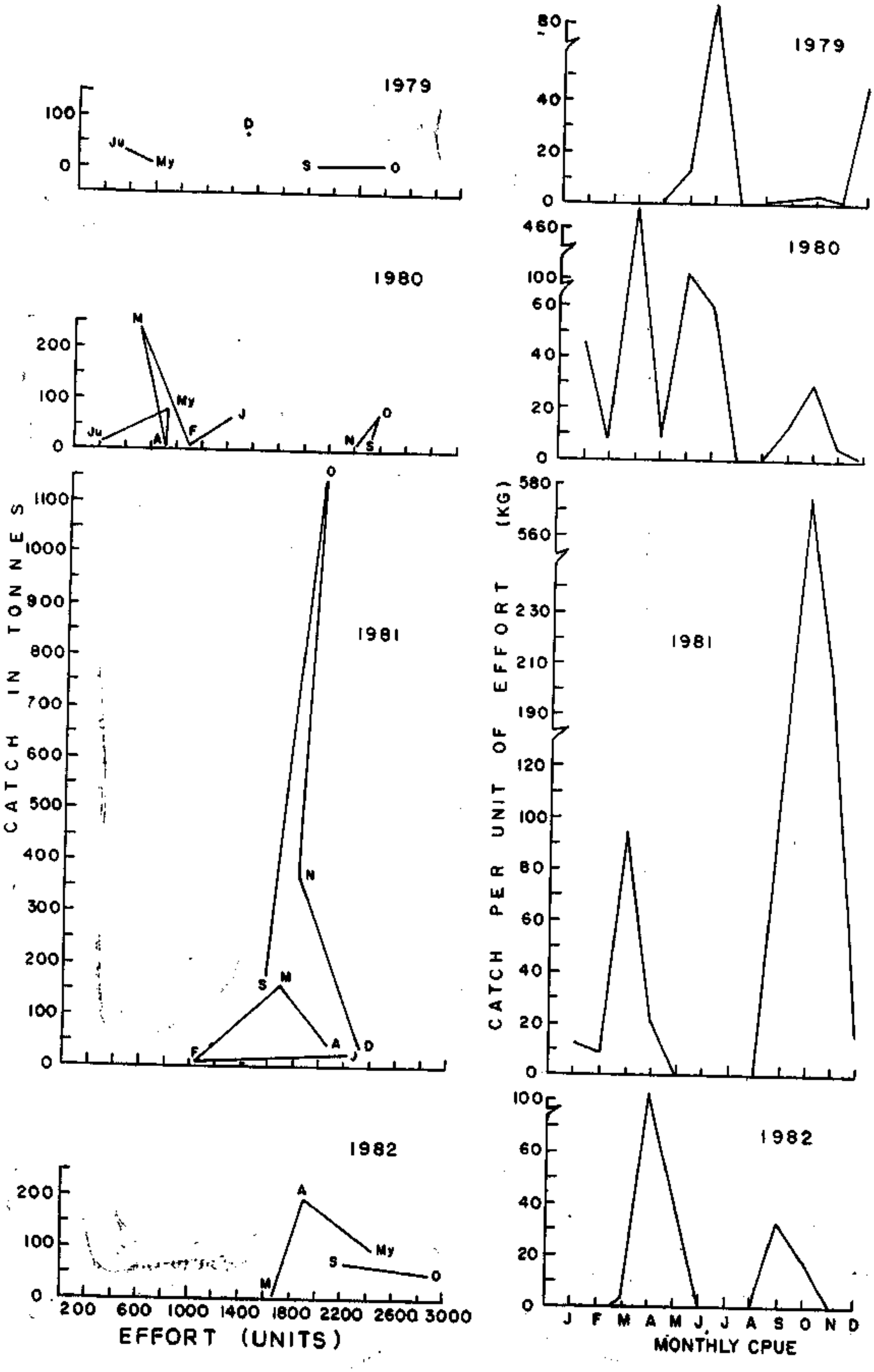

Fig. 2. Catch effort relationship and catch per unit effort of tunas taken by purse seiners at Mangalore, 1979-'82.

in March (468.6 kg) and fell to 8.4 kg in April. It recovered to some extent in May (103.5 kg) followed by a reduction in June (60 kg). In September the CPUE was 11.5 kg which increased to 29.6 kg in October and reduced to a minimum of 4.5 kg in November.

During 1981 tunas were obtained in all months except in May and June (Fig. 2). The trend of catch followed the same pattern as that in the previous year.

During 1981, the CPUE was 11.7 kg in January which showed a marginal decline in February (8.9 kg) followed by a steep increase (95.2 kg) in March and fall (21.2 kg) in April. In September it was higher than in the previous months (110.7 kg) and shot up to an all time record of 566.3 kg in October and then decreasing to 200 kg in November and 16 kg in December.

In 1982, tunas formed a fishery only during March-May and September-October periods though considerable amount of effort was expended during other months. Unlike the previous two years, this year April in the pre-monsoon period and September in the post-monsoon period were productive.

In 1982 the CPUE was 3.5 kg in March which increased to 103.5 kg in April but declined to 38.5 kg in May. September recorded 33 kg which decreased to 17.5 kg in October.

In general post-monsoon period (September-December) seems more productive the catch accounting for 68% of the annual catch with about 53% of the total annual effort and the pre-monsoon period (January-June) recording the rest of the catch and effort.

Drift gillnet

The catch and effort of tunas and billfishes by the drift gillnet units along the South Kanara Coast showed an increasing trend from 1979 to 1981 and a decline in 1982. The catch during 1979 was 107.3 t (for the four month period September-December) for a total effort of 11,342 units, the average monthly catch and effort being 26.8 t and 2,836 units. The total catch was 143.2 t for a total effort of 28,235 units with a monthly average of 20.46 t and 4,034 units in 1980. The catch and effort reached a maximum of 166.2 t (seven months) and 40,314 units in 1981 with an average monthly catch of 23.7 t and effort 5,719 units. In 1982, the catch and effort declined to 119.8 t and 33,958 units respectively the monthly average was 17 t and 4,851 units.

Monthly trend of catch and effort of tunas and billfishes by drift gillnets of South Kanara Coast is given in Fig. 3. It can be seen that during the beginning of the season in September, 1979, the catch was about 24 t for a total effort of 420 units. It reached a peak (37 t) in November with a slightly decreased effort over October and decreased to 21.1 t in December, though the maximum effort of the year was expended in this month (3,855 units).

During January to March period, the fag end of drift gillnet fishery registered very low catch (9.32 t) and effort forming 6.5% and 31.3% of the annual catch and effort respectively and September-December period accounted the rest (Fig. 3). Tunas and billfishes were absent in March when the effort decreased to 1,495 units. This decrease in effort was due to poor catches of high priced fishes such as seerfishes, pomfrets and sharks. The landings in September were at its peak (65.5 t) with a total effort of 2,448 units.

In 1981 very little catches were taken in February, March and April and the effort expended in these months was far less than that in January (7,548 units). A maximum catch of 86.1 t was obtained in October, due to good landings of *E. affinis* and *T. tonggol*. The effort level showed increasing trends from 7,719 units in November to 8,579 units in December.

As in the previous years, the catches were very low in January-March period of 1982 accounting to 1.2 t with 34% of annual effort. The catch was about 15 t for a total effort of 2,043 units which increased to 71.2 t (6,996 units) in October.

Post-monsoon period (September-December) appears the best season when as high as 98% of the annual tuna and billfish catches are caught with about 68% of the annual effort. October forms the peak month with 41% of the annual catch followed by November (25%), September (21%), December (11%) and January-April period, the rest of the catch (2%). It is seen that the drift gillnet fishery commences from September and maximum tuna and billfish catches are obtained in the months of September-December, especially in October, and after December the tuna and billfish landings decreased and reached the minimum at the end of the fishing season March/April.

The annual catch rates during 1979-'82 were 9.5 kg, 5.07 kg, 4.12 kg and 3.53 kg respectively. The average annual catch rate was 4.24 kg (1980'-82 values; the value for 1979 is not included because during this year data is available for only 4 months).

SPECIES COMPOSITION

In general, *Euthynnus affinis* predominated the tuna catches by purse seine (86.88%) followed by *Auxis*

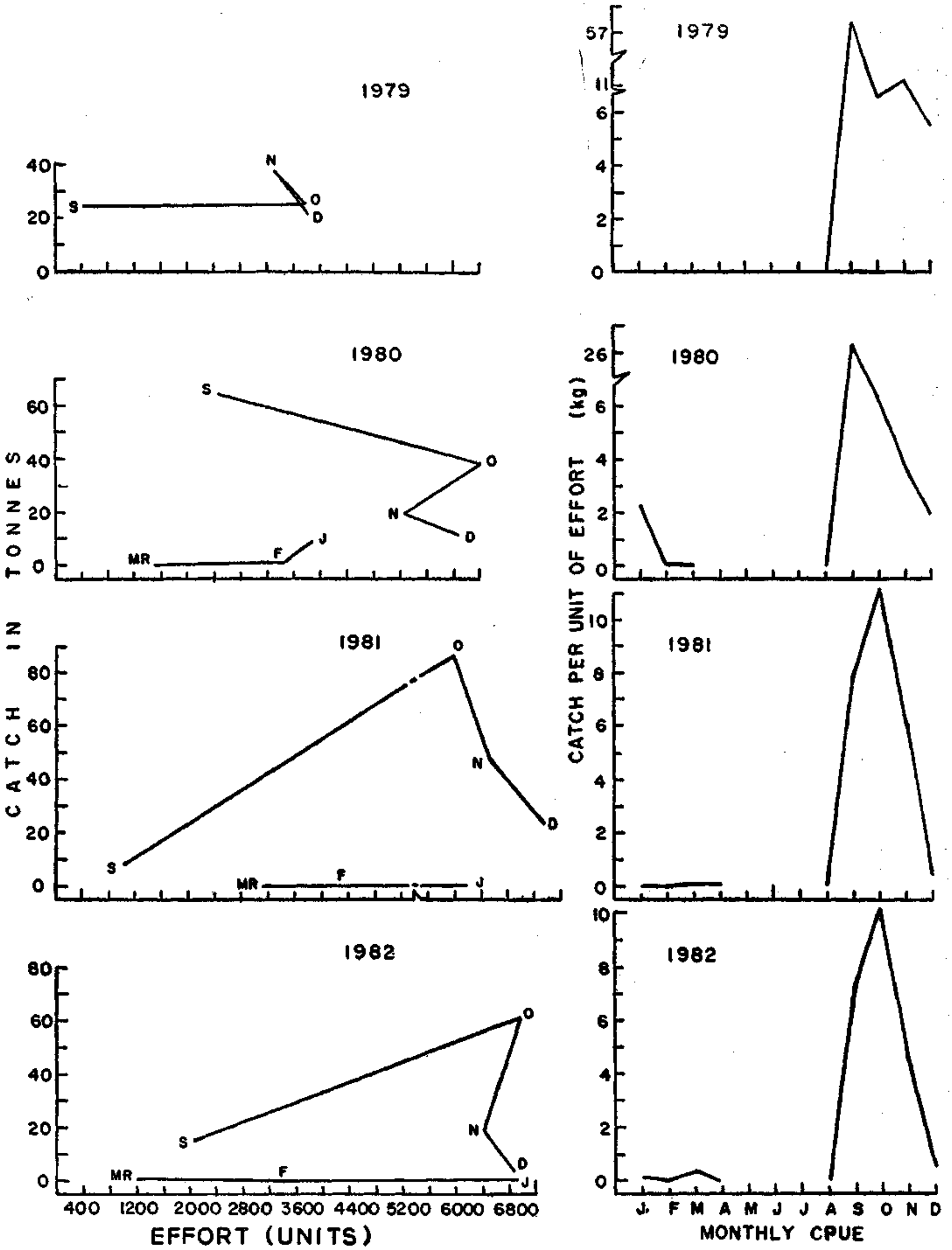

Fig. 3. Catch and effort relationship and catch per unit effort of tunas taken by drift gillnetters at Mangalore area, 1979-'82.

thazard (9.71%) ; *A. rochei* (3.38%) and *S. orientalis* 0.03%) (Fig. 4).

Yearwise estimates indicate that during 1979, *E. affinis* was the chief species contributing as high as 99% of the tuna catches. They were caught during May, June, September, October and December. Best catches were obtained in December (63 t) at a CPUE of 47 kg and in June 32 t with a cpue of 88 kg. *S. orientalis* was the only other species of tuna taken in small numbers during September-October period.

While *E. affinis* continued to dominate the catches in 1980 forming 89%, *A. thazard* and *A. rochei* made their appearances in the fishery contributing to 4% and 6% respectively. *E. affinis* was caught in all months except in November and December, their landings were at its peak in March, 237 t (with high catch rates 465 kg) and lowest in September (4 t). *A. thazard* was landed in March-May and October ; *A. rochei* in September and November. The maximum catch of *A. thazard* was in October (18 t) and *A. rochei* in September (22.7 t).

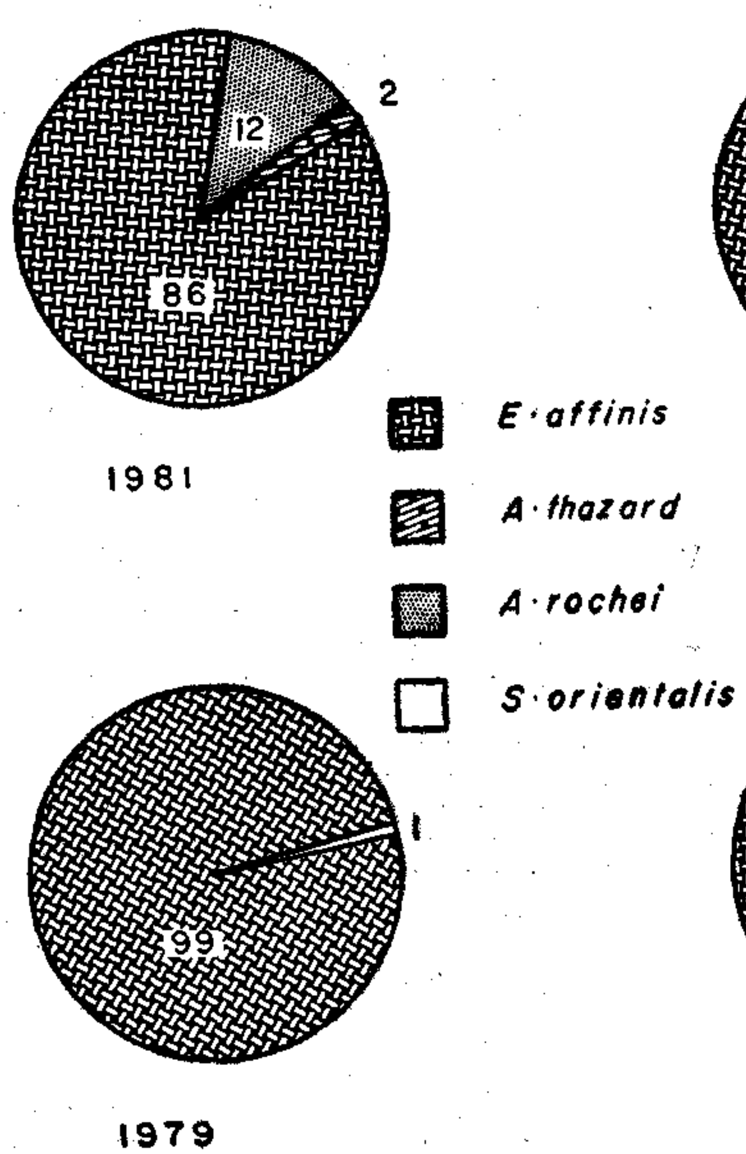

Fig. 4. Percentage composition of different species of tunas in the purse seine catch at Mangalore, 1979-'82.

In 1981 *E. affinis* dominated the landings although their percentage had decreased to 86% and that of *A. thazard* had increased to 12% and *A. rochei* had decreased to 2%. *E. affinis* was obtained in all months except in May-June. October witnessed bumper landings (1,038 t) with cpue of 515 kg. *A. thazard* catches were better in October-November and *A. rochei* in September.

During 1982 the percentage of *E. affinis* had further dropped to 82%, and *A. thazard* and *A. rochei* contributed each 9% to the total catch of tunas. *E.affinis* was caught during March-May and September-October. Higher landings were in March (196 t).

In the drift gillnet catches *E. affinis* was the single major species. It contributed 53.38% to the tuna and allied fish landings followed by *T. tonggol* (16.05%), *M. indica* (13.05%), *A. thazard* (9.52%), *I. platypterus* (6.15%), *A. rochei* (1.47%) and *S. orientalis* (0.39%), mainly during the September-December period. Relatively high catches of *E. affinis* and *A. thazard* were in October, *T. tonggol*, *M. indica* and *I. playtpterus* in November, *A. rochei* and *S. orientalis* in December.

During 1979 *E. affinis* was the major species contributing 57.71% followed by *M. indica* 13.30%, *I. platypterus* 10.65%, *T. tonggol* 9.03% and *A. rochei* 6.85%. *S. orientalis* and *A. thazard* were of very minor importance (Fig. 5). In 1980 the catches were dominated by *E. affinis* (67.38%), *M. indica* (17.05%) and *I. platypterus* (9.73%) compared to 1979, the percentage of *E. affinis* and *M. indica* had shown an increase where as *T. tonggol* a decrease and *I. platypterus* remained the same. The landings of *S. orientalis*, *A. thazard* and *A. rochei* were very meagre. In 1981 the catches were constituted by *E. affinis* (49.05%), *T. tonggol* (25.05%), *M. indica* (11.19%), *A. thazard* (10.13%) and *I. platypterus* (4.16%) in the order of abundance. When compared to the previous year, a decrease was noticeable in the catches of *E. affinis*, *M. indica* and *I. platypterus* whereas there was an increase in the case of *T. tonggol* and *A. thazard*. In 1982 the catches were predominated by *E. affinis* (38.79%), *A. thazard* (26.44%) *T. tonggol* (21.84%) and *M. indica* (11.12%) in the order of abundance. During this year the percentage of *E. affinis*, *I. platypterus* had shown a decrease while the catches of *A. thazard* and *T. tonggol* were better than in 1981.

Size composition

E. affinis

In the purse seine catches in 1979, *E. affinis* was composed of fish from 20 to 66 cm with modal sizes at 24, 44 and 56 cm (Fig. 6). In June there were two modes at 44 and 56 cm and a minor mode at 50 cm. In september small fish (24-26 cm) formed the bulk of the catches besides a few big fish (50-54 cm). Modal groups at 54-56 cm dominated the catches in December. In 1980 the catches were supported mainly by fish ranging from 42 to 62 cm and stray occurrence of small fish (24 cm) in October and older fish (70 cm) in March and April. The length frequency of catches exhibited bimodal distribution with modal sizes at 44 and 54 cm in March and April, at 42 and 56 cm in May and at 52 and 56 cm in June whereas it was trimodal in September with modes at 46, 56 and 62 cm. In October once again catches showed two modes at 46 and 56 cm. During 1981 catches comprised of fish with size range of 30-72 cm. During January-April period catches were constituted by 46-62 cm with modal size between 52 and 54 cm. A few individuals of 36 and 66 cm of size occurred during this period. September and October catches showed multimodes of which the chief one was at 44 cm in September and at 56 cm in October. Small fish (30-38 cm) exclusively supported the fishery in November. Catches in 1982 were represented by fish ranging in size from 42 to 72 cm. In March it showed two modes, the major one at 58 cm and a minor one at 48 cm. In April in addition to a mode at 58 cm, older fish (70 cm) were noticed in small numbers. Catches in May had modes at 48, 56 and 60 cm.

In the drift gill net catches in 1979 the length of *E. affinis* varied from 24 to 64 cm (Fig. 7). The catches in September were dominated by fish with modal lengths at 26, 46 and 58 cm. Small fish (26-40 cm) continued to appear in the catches till November and these fish were the mainstay of the fishery during this period (September-November) except stray occurrence of medium sized fish (56-64 cm). In December in addition to small fish with modal length at 36 cm medium sized fish with modal length at 58 cm formed the bulk of the catches.

The catches during 1980 had size range from 20 to 70 cm. In January the catches were in the size between 50 and 68 cm with the mode at 58 cm. The catches were very poor in February and were formed of 62-64 cm size groups. In September the catches were good and the predominant sizes were between 50 and 56 cm. In October the catches were dominated by fish with modal lengths at 48 and 54 cm followed by younger fish (20-38 cm) with modal sizes at 28 and 38 cm. The catches in November were constituted by fish with modal lengths at 32, 46, 50 and 54 cm whereas younger fish in the modal sizes at 24 and 30 cm comprised the catches in December. In 1981 the fish were in 22-70 cm size range. The catches in September were represented by multimodal size groups with the major modes at 24, 34, 46, 54 and 60 cm. October had prominent

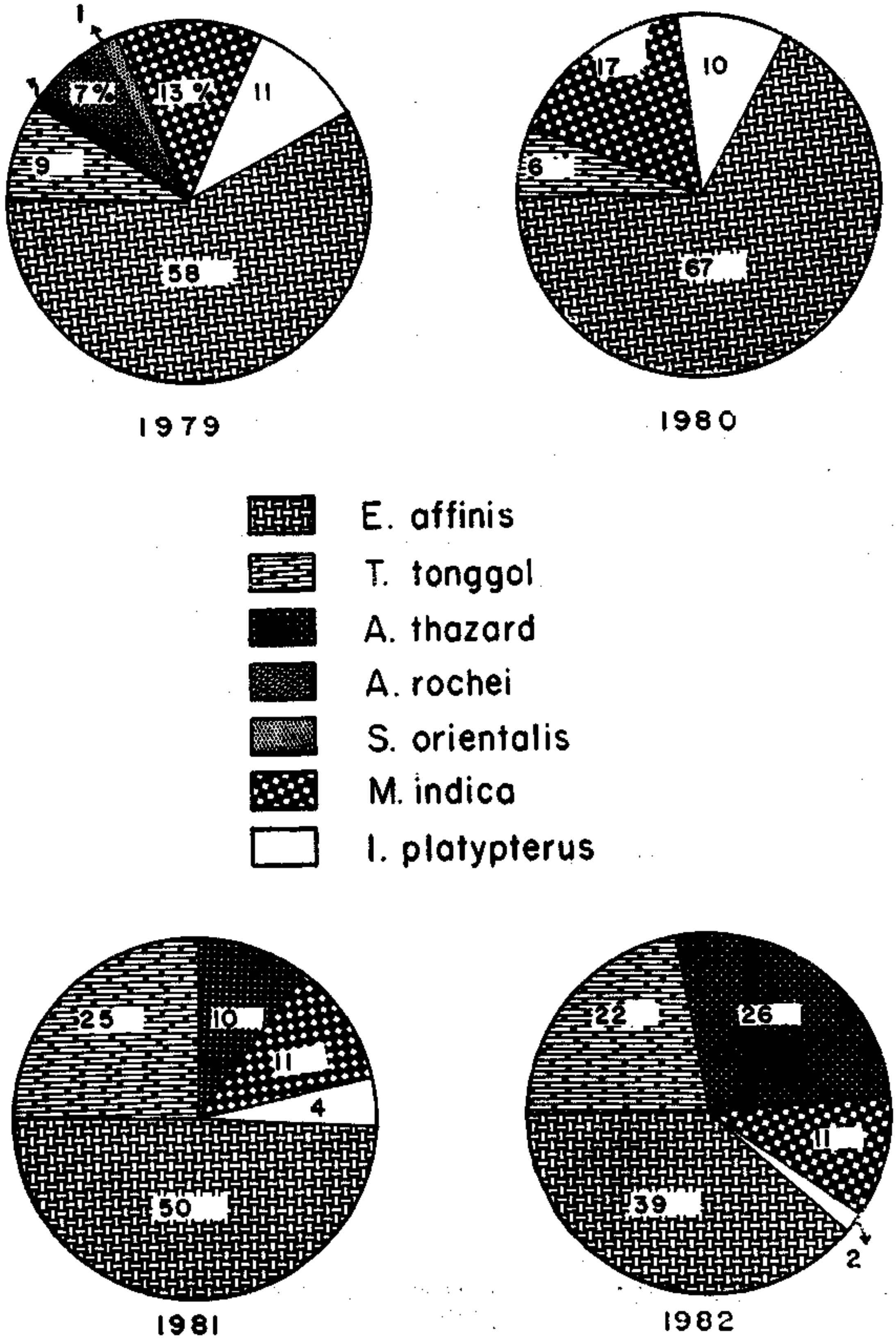

Fig. 5. Percentage composition of different species of tunas in the drift gillnet catch at Mangalore 1979-'82.

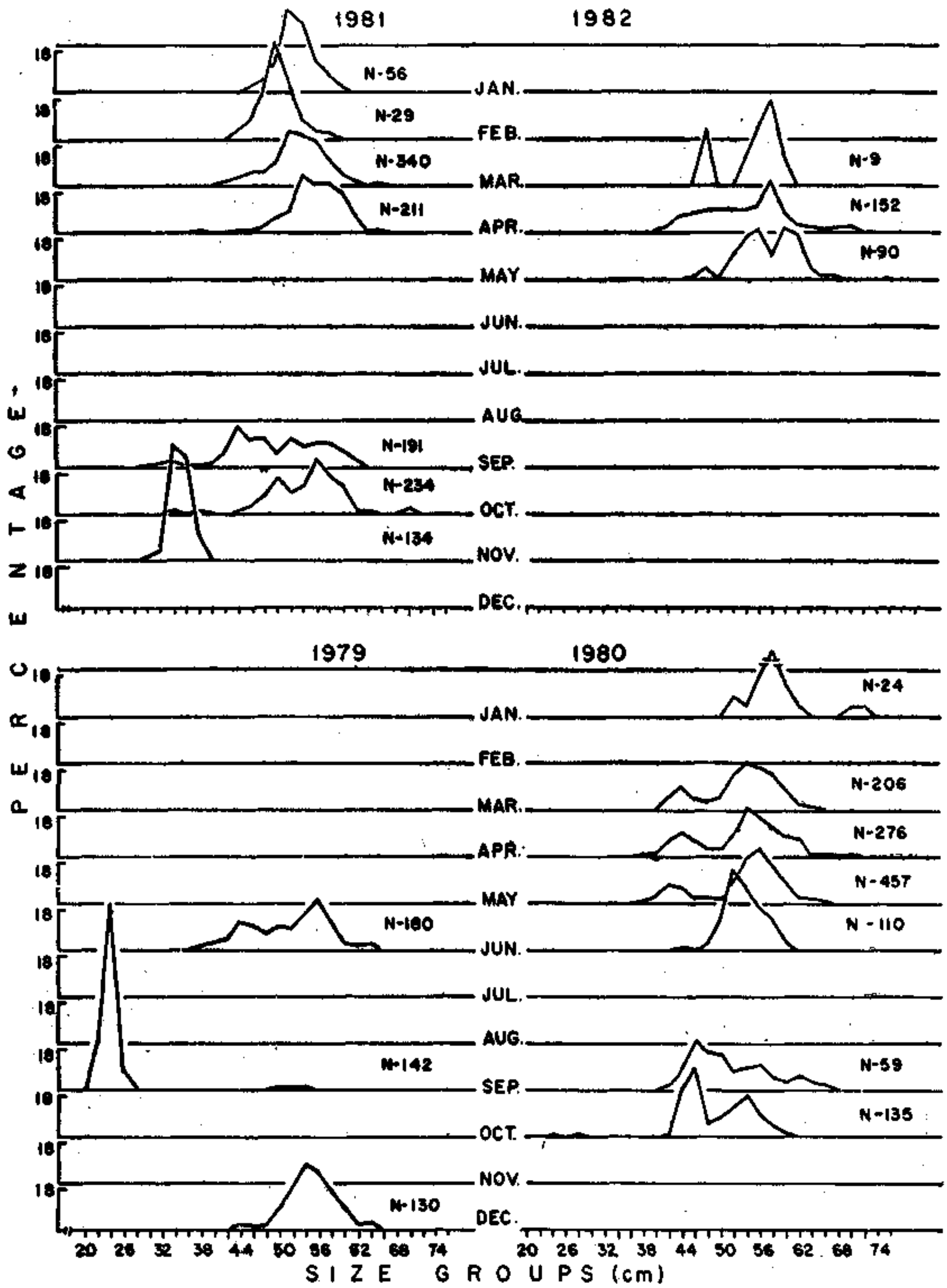

Fig. 6. Monthly length frequency distribution of *E. affinis* taken by purse seiners at Mangalore, 1979-'82.

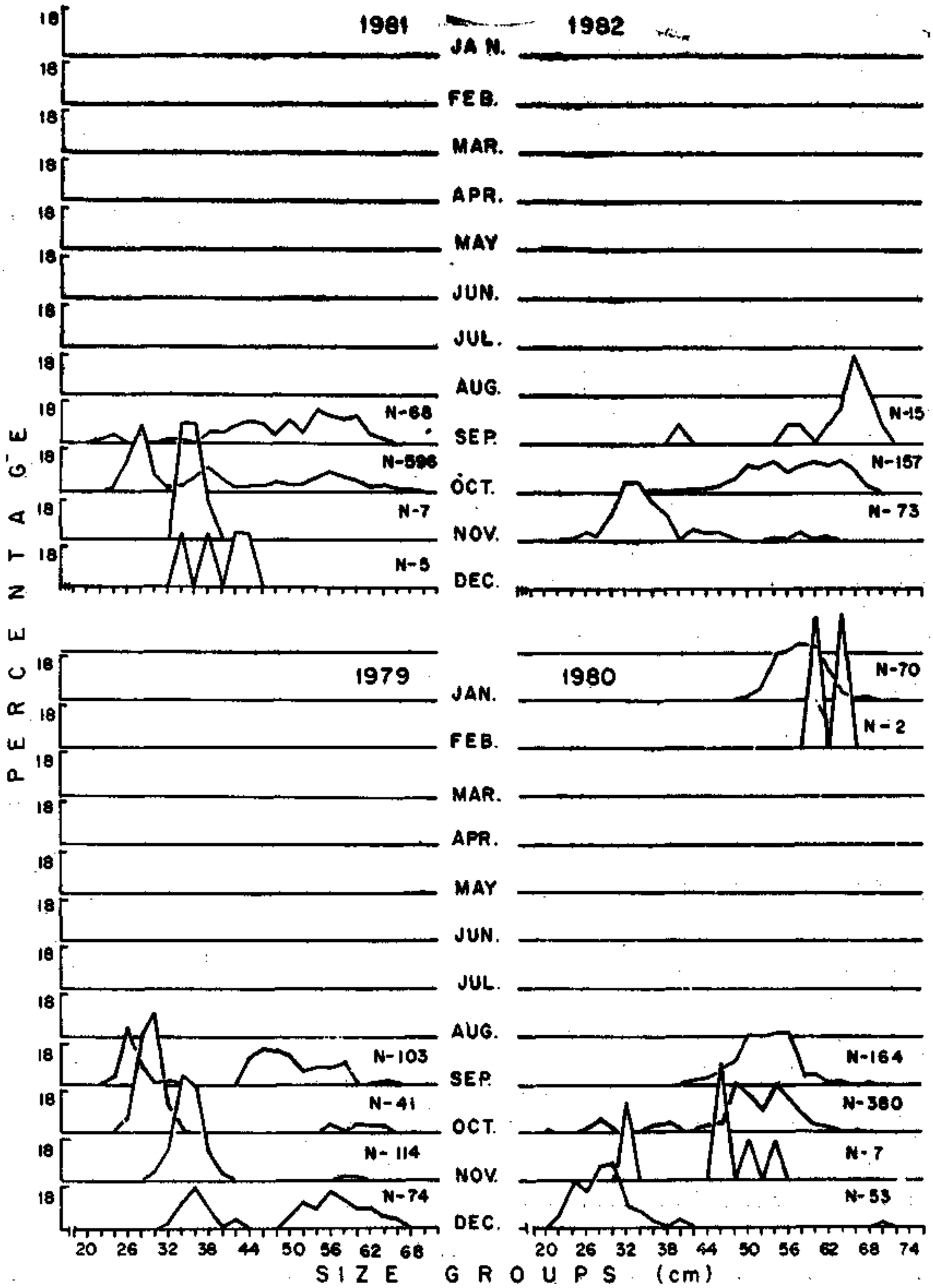

Fig. 7. Monthly length frequency distribution of *E. affinis* taken by drift gillnetters at Mangalore, 1979-'82.

modes at 28, 38 and 56 cm. Catches in November were composed of fish in the range of 34-38 cm. In December the catches were very poor and were represented by fish of 34-56 cm. In 1982 the size range was 24-70 cm. Modes were seen at 40, 56 and 66 cm in September and at 54 and 64 cm in October. Younger fish (24-38 cm) with modal groups at 32-34 cm formed the major portion of the catches in November followed by 40-48 cm and 54-58 cm size groups.

T. tonggol

During 1979 the catches of *T. tonggol* in the drift gill net were very poor and had size range of 36-72 cm (Fig. 8). The sizes were at 62 and 66 cm in September and 54 and 66 cm in October. Five modes at 36, 42, 50, 54 and 60 cm were recorded in November. In December the fish were mostly of medium size (54-60 cm). In 1980 the size range was from 34-74 cm. During January-February the fishery was poor and the sizes were at 60 cm in January and 68 cm in February. In October the catches were good and consisted of fish from 34-66 cm with modal lengths at 48 and 54 cm. The fishery was poor in November and the lengths were at 46, 52 and 70 cm. Fishery in October was mainly supported by modal groups at 58 and 70 cm. Small fish with modal length at 40 cm were also caught in small quantities during this month. In 1981 the size ranged from 26 to 78 cm. Younger fish (26-36 cm) with modal size at 30 and 34 cm entered the fishery in large numbers during October. The other prominent modal groups in other months were at 46,56 and 64 cm. Medium size (58-66 cm) and large size (68-78 cm) with modal lengths at 60 and 72 cm dominated the catches in November and small fish (34-38 cm) with a mode at 34 cm were also noticed during the month. The catches in December showed multimodes at 42, 52, 56, 66, 72 and 76 cm.

During 1982 the size range was from 28-80 cm. In January catches consisted of fish (38 to 56 cm) with modal length at 42 cm. In September the fishery was poor and the sizes were at 44, 52, 62 and 66 cm. The fishery in October was good and had modal groups at 28, 40, 54, 58 and 66 cm. In November the fishery was fairly good and the catches showed wide ranges from 32 to 80 cm with modal groups at 40, 48, 60 and 70 cm. Sizes in December were at 44, 70 and 76 cm.

A. thazard

In 1980 the size composition of catches of *A. thazard* in the purse seines showed a range of 34-48 cm (Fig. 9). In March sizes were at 44-46 cm. Catches in April had size range of 36-46 cm with modes at 38 and 46 cm and 40-48 cm in May with a single mode at 46 cm. In October the catches were dominated by modal group at 38 cm. During 1981 the fishery showed a range of 20-40 cm. The catches were represented by bimodal groups at 34 and 42 cm in September and 36 and 40 cm in October. During November small fish with modal length at 26 cm predominated the catches followed by 30 and 38 cm modal groups. In 1982 the size range was from 28-36 cm in October and the dominant mode was at 36 cm.

In the drift gill net landings, during 1979, the size of *A. thazard* varied from 32-42 cm (Fig. 10). In October the catches were very poor and the size was at 40 cm. Modal groups at 40 cm dominated the catches in November and 38 cm in December. In 1980 the size range was from 20-42 cm. Small fish of 20-28 cm formed the major component of the fishery during September-December period. During 1981 sizes were from 22 to 44 cm. Catches in September were constituted by fish with a modal group at 34 cm. In October fish of 40 and 36 cm sizes formed major portion of the catches followed by young fish (22 cm). During 1982 the size range was from 20-46 cm. In September catches had size range of 38-46 cm and showed a major mode at 40 cm. The size range in October was wide from 20-44 cm with two modes at 28 and 36 cm.

A. rochei

During 1980, purse seine catches of *A. rochei* in September had a size range of 20-28 cm with a dominant mode at 24 cm. In October the fish were small (20- 26 cm) and had showed a prominent mode at 22 cm. During September-October period of 1981 the catches comprised of fish ranging in size from 24-32 cm with a single mode at 26 cm. In 1982 catches of September showed a size range of 24-30 cm with a mode concentration at 26 cm as in the previous year. In October the fish were of small size (18-20 cm) with a mode at 18 cm (Fig. 11).

In the drift gill nets, in December 1979 the catch of *A. rochei* consisted of fish with a size range of 20-26 cm and a single mode occurred at 22 cm (Fig. 12). During 1982 the catch in September had the size range 26 to 30 cm with a single mode at 26 cm. In October the catches were constituted by small fish (18-28 cm) with mode around 22 cm.

S. orientalis

In the purse seine catch in 1979 this species had a size range of 26-30 cm with a mode at 28 cm (Fig. 13). In the drift gill-net catches in September 1979 this species showed a size of 26-32 cm with a modal group at 38 cm (Fig. 14). This modal group continued to

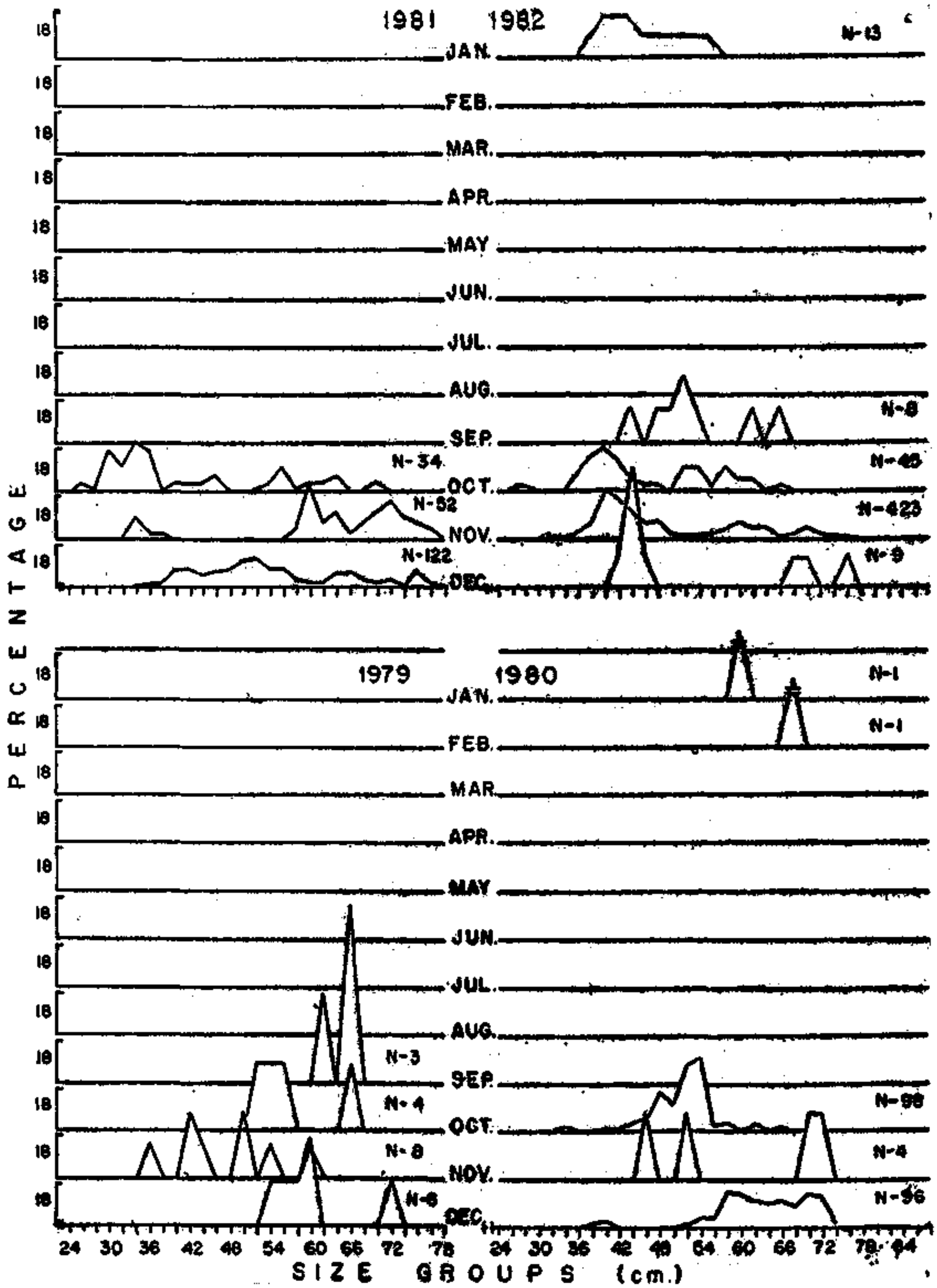

Fig. 8. Monthly length frequency distribution of *T. tonggol* taken by drift gillnetters at Mangalore, 1979-'82.

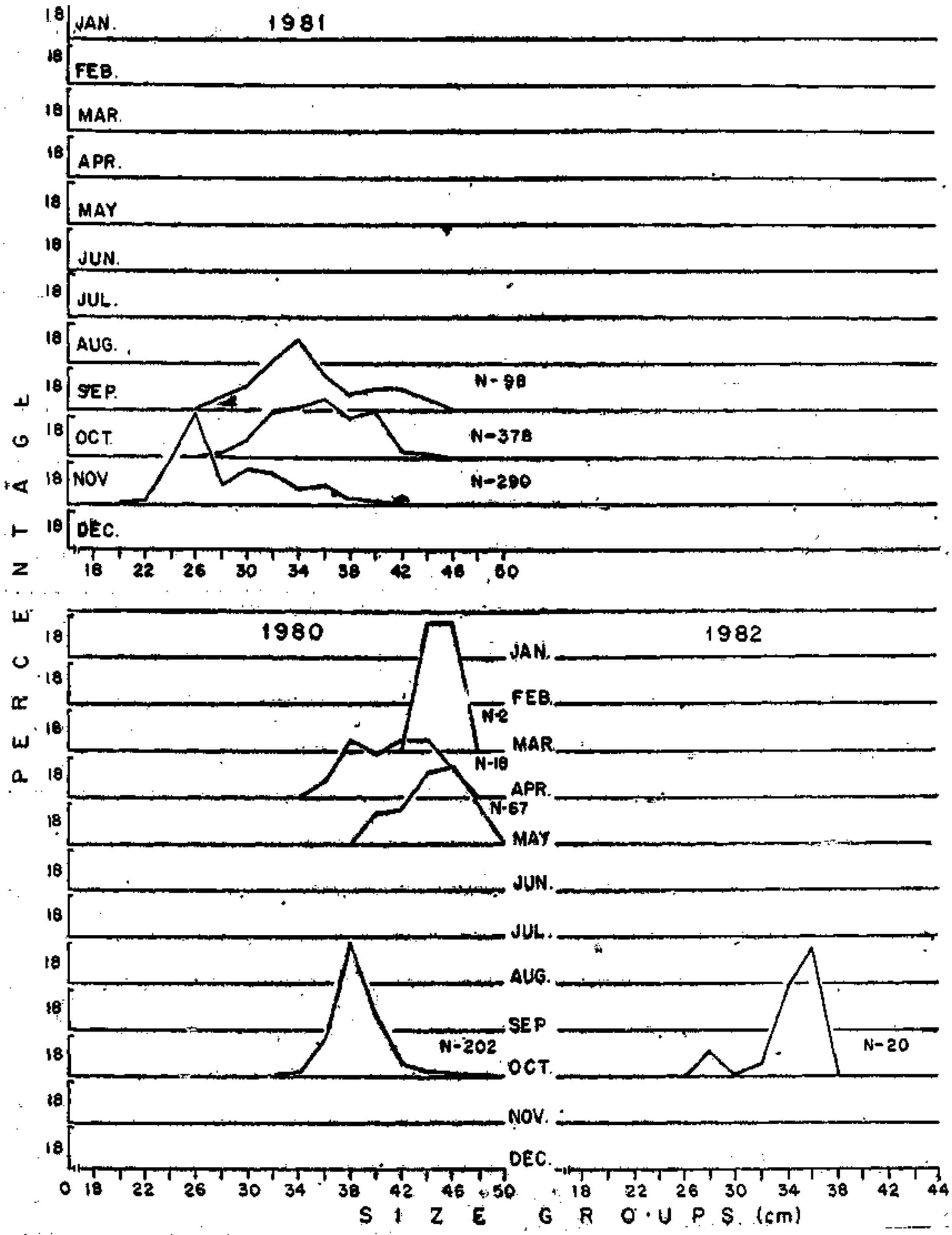

Fig. 9. Monthly length frequency distribution of *A. thazard* taken by purse seiners at Mangalore, 1980-'82.

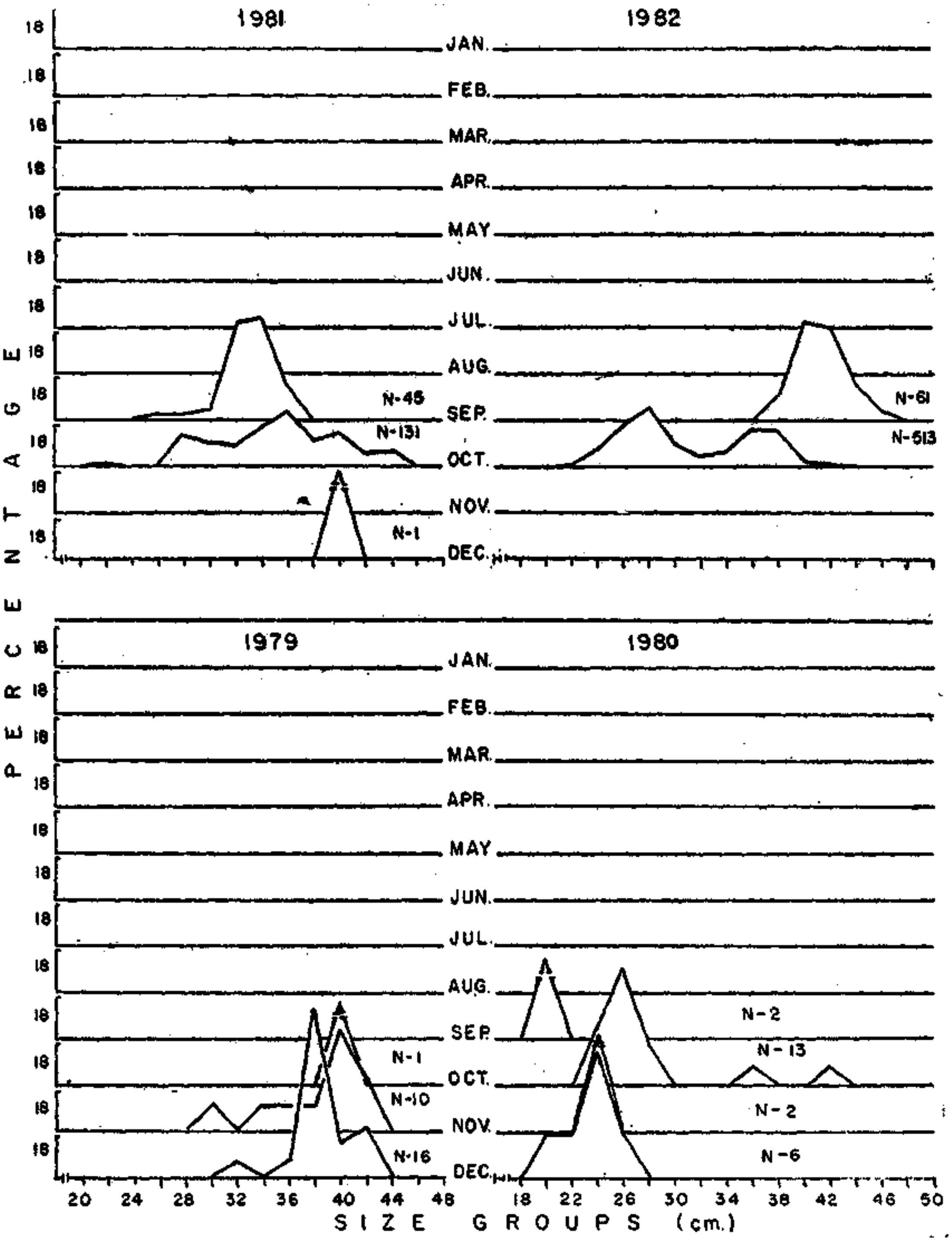

Fig. 10 Monthly length frequency distribution of *A. thazard* taken by drift gillnetters at Mangalore, 1979-'82.

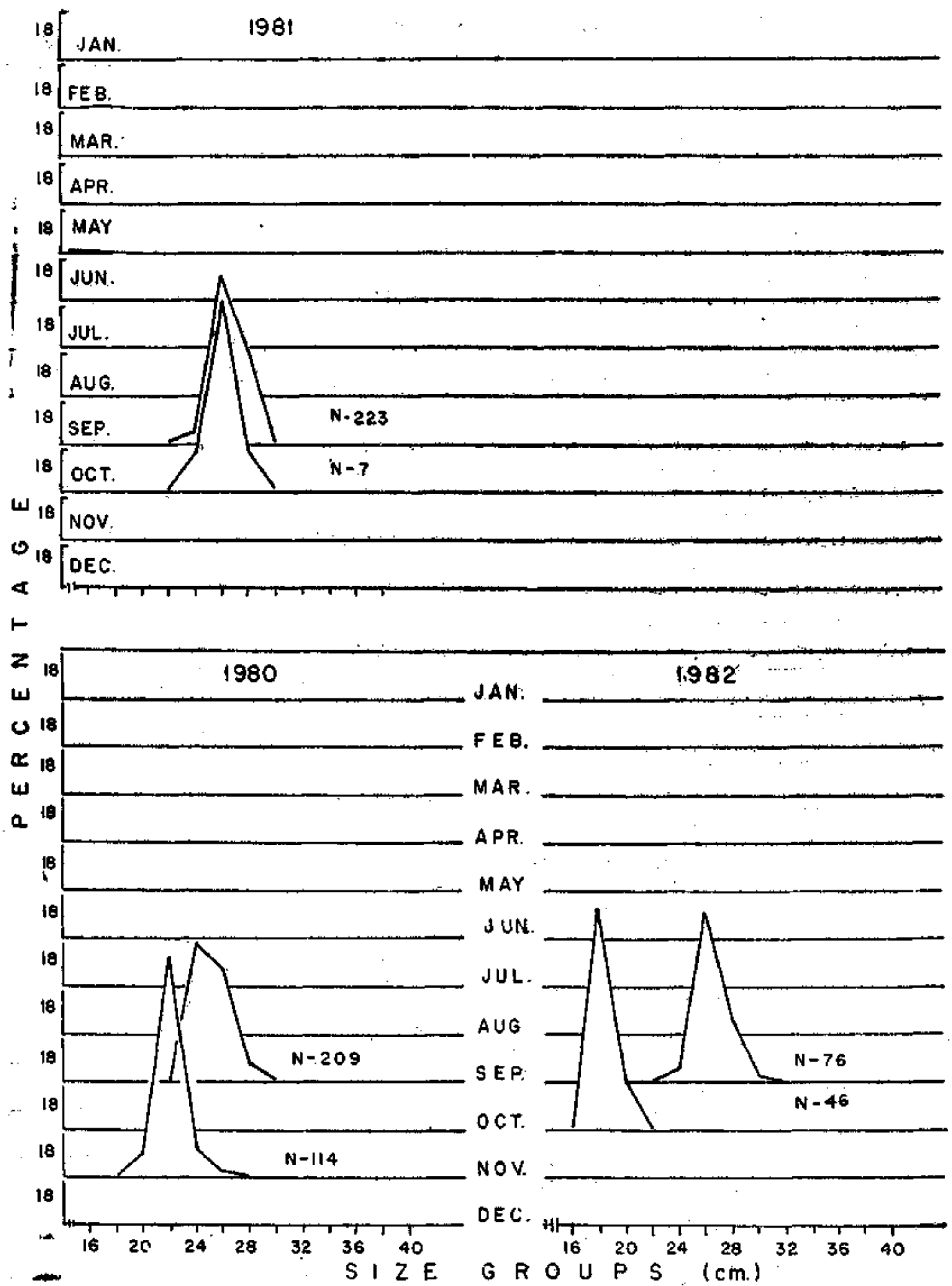

Fig. 11. Monthly length frequency distribution of *A. rochei* taken by purse seiners at Mangalore, 1980-'82.

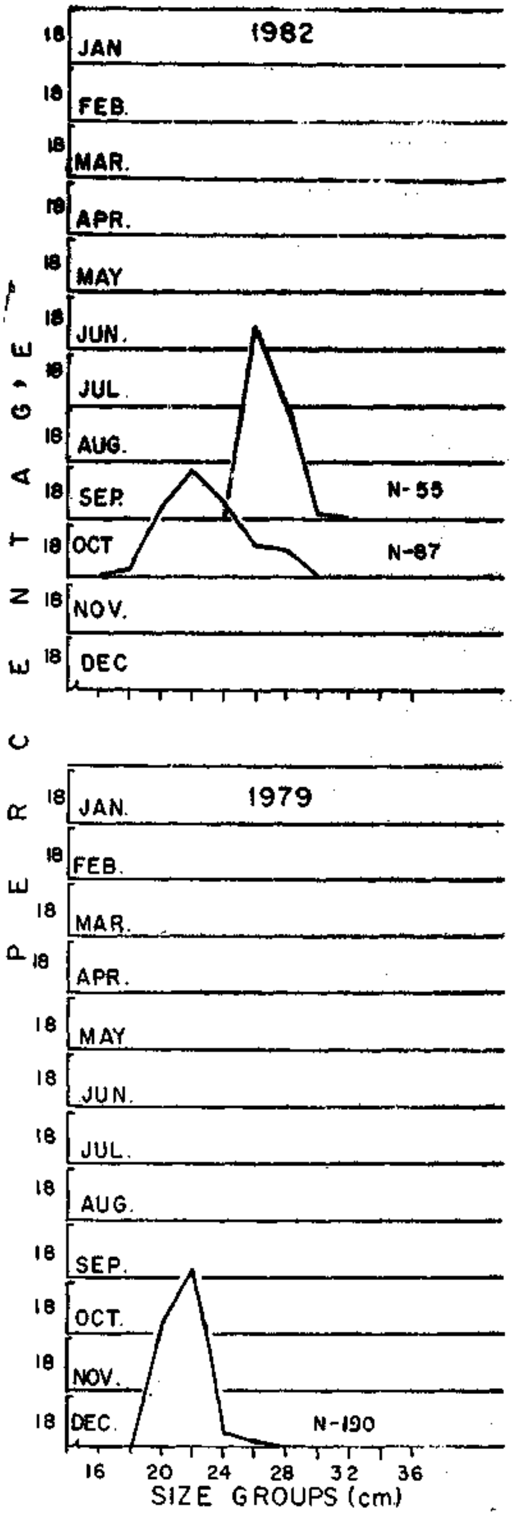

Fig. 12. Monthly length frequency distribution of *A. rochei* taken by drift gillnetters at Mangalore, 1979 and '82.

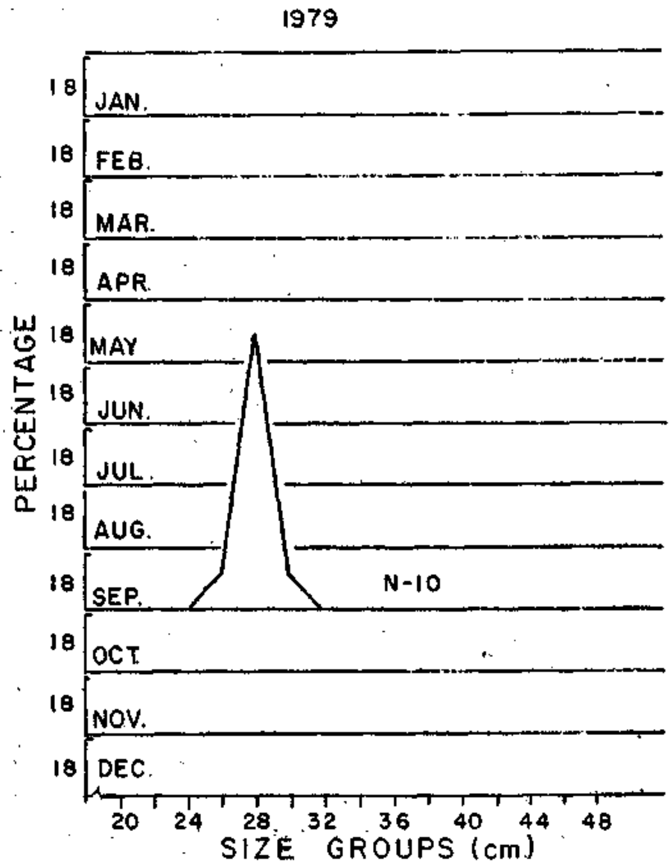

Fig. 13. Monthly length frequency distribution of *S. orientalis* taken by purse seiners at Mangalore, 1979.

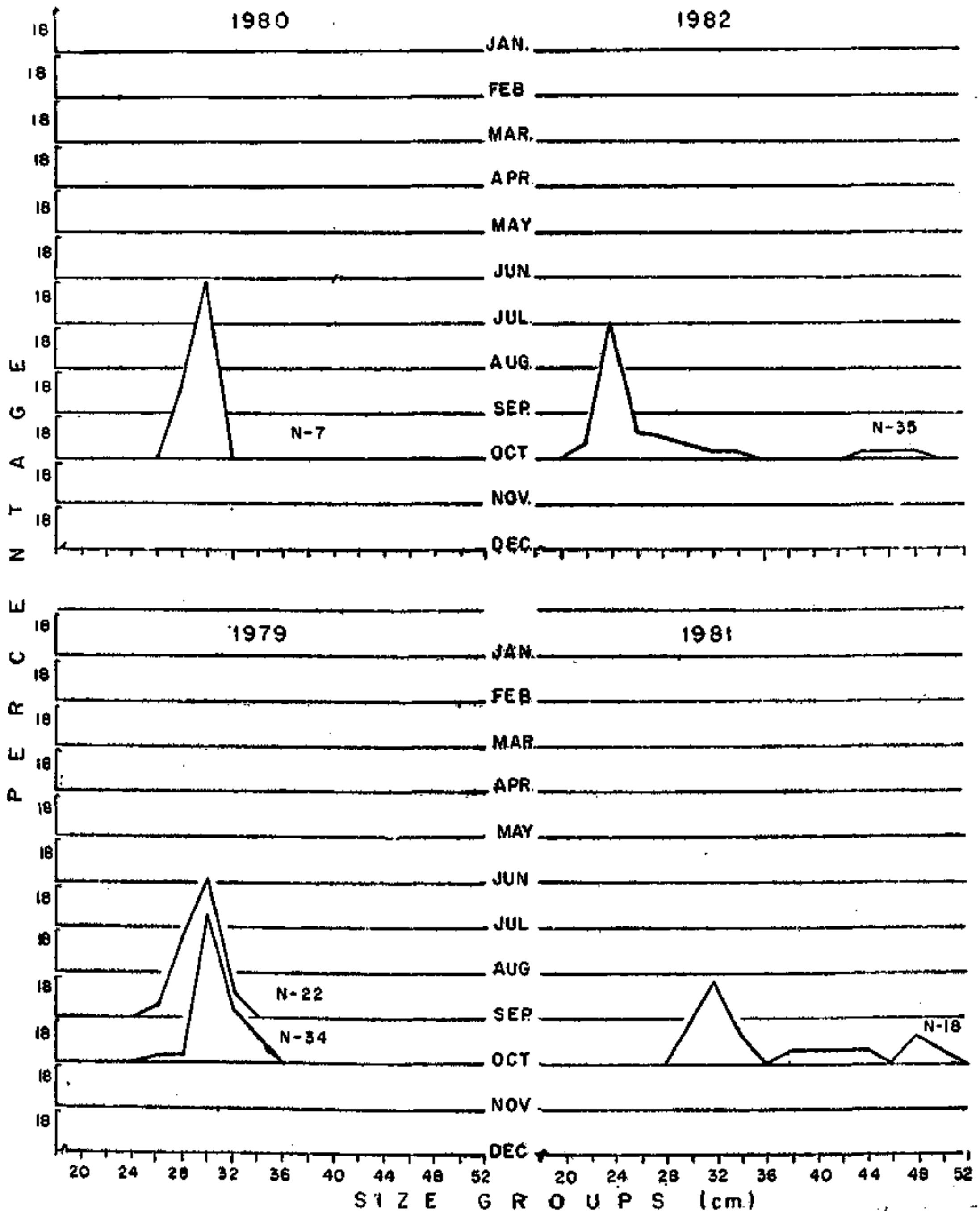

Fig. 14. Monthly length frequency distribution of *S. orientalis* taken by drift gillnetters at Mangalo re, 1979-'82.

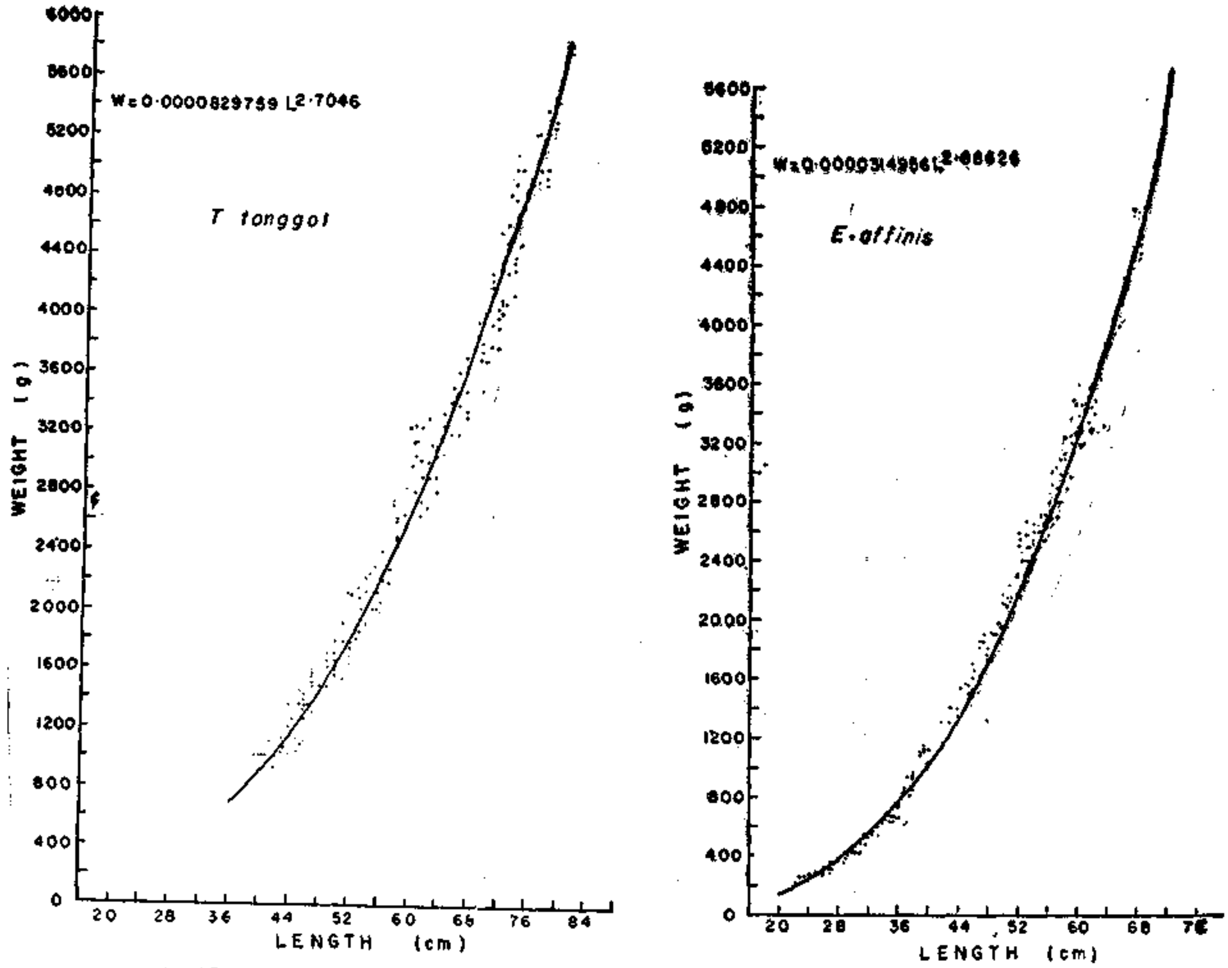

Fig. 15. Length-weight relationship of *T. tonggol* and *E. affinis* at Mangalore, 1979-'82.

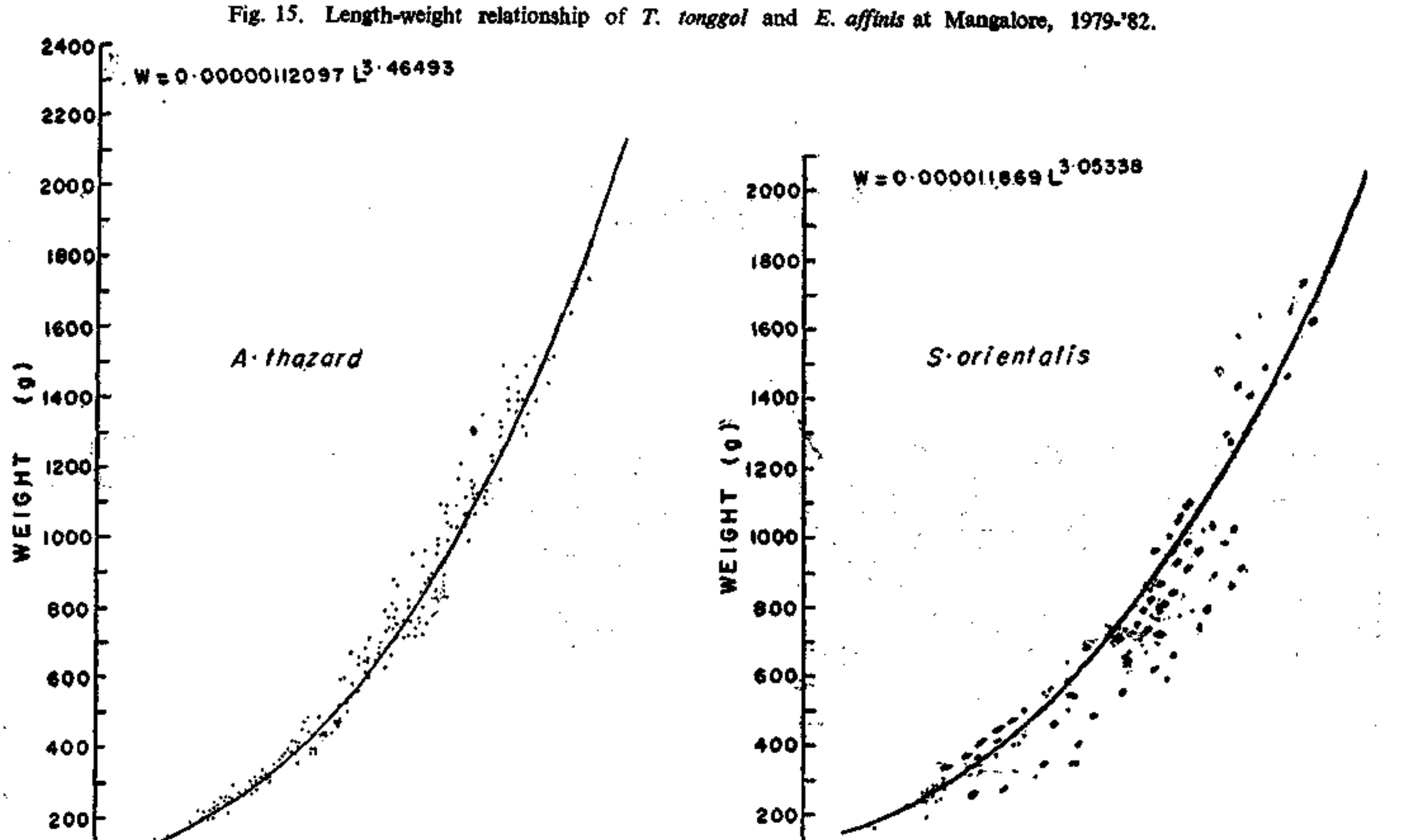

Fig. 16. Length-weight relationship of *A. thazard* and *S. orientalis* at Mangalore, 1979-'82.

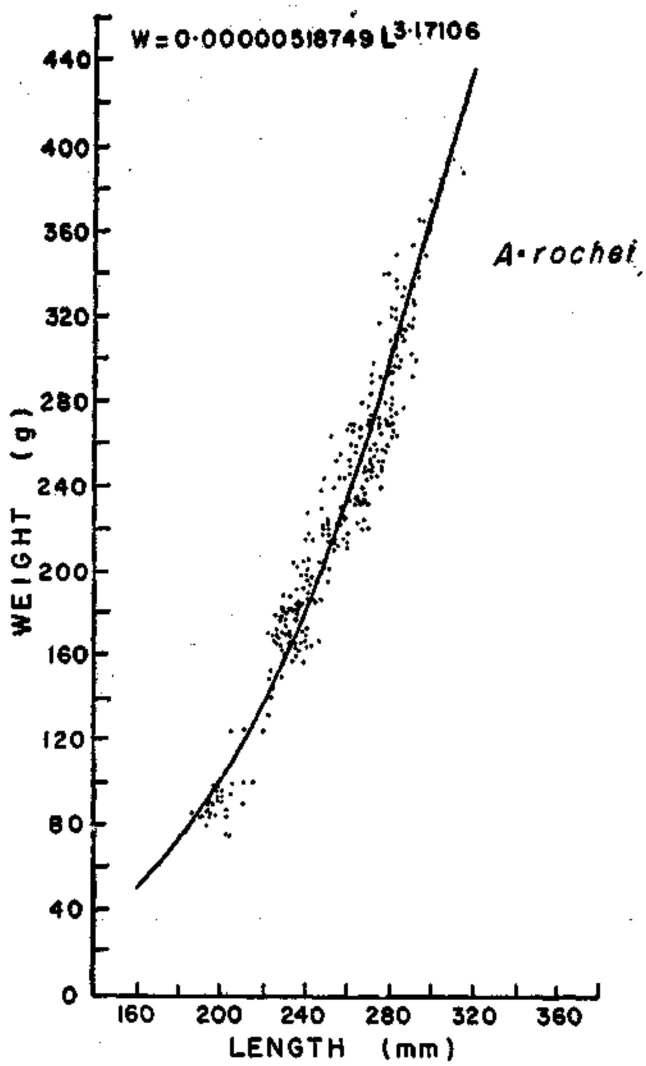

Fig. 17. Length-weight relationship of *A. rochei* at Mangalore, 1979-'82.

dominate during October also when the overall size ranged from 26 to 38 cm. In 1980 the catches in September were composed of small fish (28-30 cm) with a mode at 30 cm. During October, 1981 wide size-range was noticed (30-50 cm) and the modes were at 32, 44 and 48 cm. In 1982 the catches had the size range from 22 to 46 cm of which young fish with mode at 24 cm predominated the catches.

The length-weight relationships of the different species of tunas landed at Mangalore area (Fig. 15-17) are as follows :

E. affinis	$W = 0.0000314956\ L.^{2.88626}$
A. thazard	$W = 0.00000112097\ L^{3.46493}$
A. rochei	$W = 0.00000518749\ L^{3.17106}$
S. orientalis	$W = 0.000011869\ L^{3.05338}$
T. tonggol	$W = 0.0000829759\ L^{2.7046}$

8

MATURATION AND SPAWNING OF *EUTHYNNUS AFFINIS*, *AUXIS THAZARD* AND *AUXIS ROCHEI* IN THE MANGALORE INSHORE AREA DURING 1979-82

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A perusal of the literature on the spawning habits of tunas of the Indian waters indicates that except for the observations on these aspects by Rao (1964) and Silas (1969) information on the above lines on *Euthynnus affinis*, *Auxis thazard* and *Auxis rochei* is wanting.

With the advent of purse seiners in the mid-seventies and the operation of mechanised gill netters off late along the Karnataka Coast, the resources of the above species have come within the reach of the indigenous gears and have gained commercial importance. In order to have a clear picture on the reproductive potential of the population of these species, investigations were carried out on the maturation and spawning aspects of the above three species from 1979 through 1982 in the inshore waters along Mangalore Coast and the results are presented.

Material for the study was collected from the purse seine landings at Mangalore as well as from the drift gill net catches at Kaup (Fig. 1). Fork length and weight to the nearest 10 g of each specimen were recorded. Ovaries were weighed to the nearest gram and later they were preserved in 5% formalin for further studies.

ICES scale was followed for determining the maturity stages *viz.*, immature (I & II), maturing (III), mature (IV & V), ripe (VI) and spent (VII) (Wood 1936).

For the purpose of fecundity study, fishes in stages IV& V alone were considered. 38 ovaries of *E. affinis*, 69 ovaries of *A. thazard* and 85 ovaries of *A. rochei* were examined during the present study. Moisture was removed from the ovaries with blotting paper and they were then weighed in an electric monopan balance to the nearest 0.5 g. A small portion of the ovary was separated and weighed to the nearest 0.001 g employing an analytical monopan electric balance. The weighed portion was placed on a microslide and a drop of glycerin was added to the sample before the ova were teased out. Mature ova were counted and the total fecundity was estimated employing the following formula :

$$\frac{\text{Total weight of the ovary}}{\text{Weight of the sample}} \times \text{No. of ova in the sample}$$

The relationship between fecundity and length and weight was calculated by the least square method :

$$F = Y + aL^b$$

where Y = the factor to be estimated, L = the variable, a = a constant and b = regression co-efficient.

Relative condition (Kn) was calculated as per the method described by LeCren (1951). Gonado-Somatic Index (G.S.I.) was estimated applying the method of June (1953).

Study on the sex ratio was undertaken employing the X^2 method of Fisher (1970).

MATURITY

Euthynnus affinis

The relationship between the maturity and length was based on 183 and 198 females respectively. The percentage occurrence of mature fish in various size groups is given in Fig. 2. It is seen that mature females were observed when they were in 39 cm length and those of males at about 44 cm. Fish measuring more than 60 cm in length were all mature. The 50% maturity, representing the mean length for minimum size maturity in the case of females was at 43 cm. Males in the 36-42 cm size groups were not represented in the samples examined. The mature males were above 42 cm size and 70% of the males were mature (stage

IV and V) at 44 cm. The minimum size at maturity of females and males at 43 and 44 cm respectively closely corresponds to the lengths as evidenced from the relative condition. In the Philippine waters the smallest female in mature condition was recorded at 38.5 cm (Ronquillo, 1963) and in spent condition at 47.7 cm (Bunag, 1958). In the Indian Ocean, they

Auxis thazard

Fig. 2 presents the percentage occurrence of mature females and males based on the examination of 410 and 336 females and males respectively. It is evident that the mature stages in both sexes appear for the first time in the 28 cm size group. With growth, the percentage increased progressively till 40 cm when

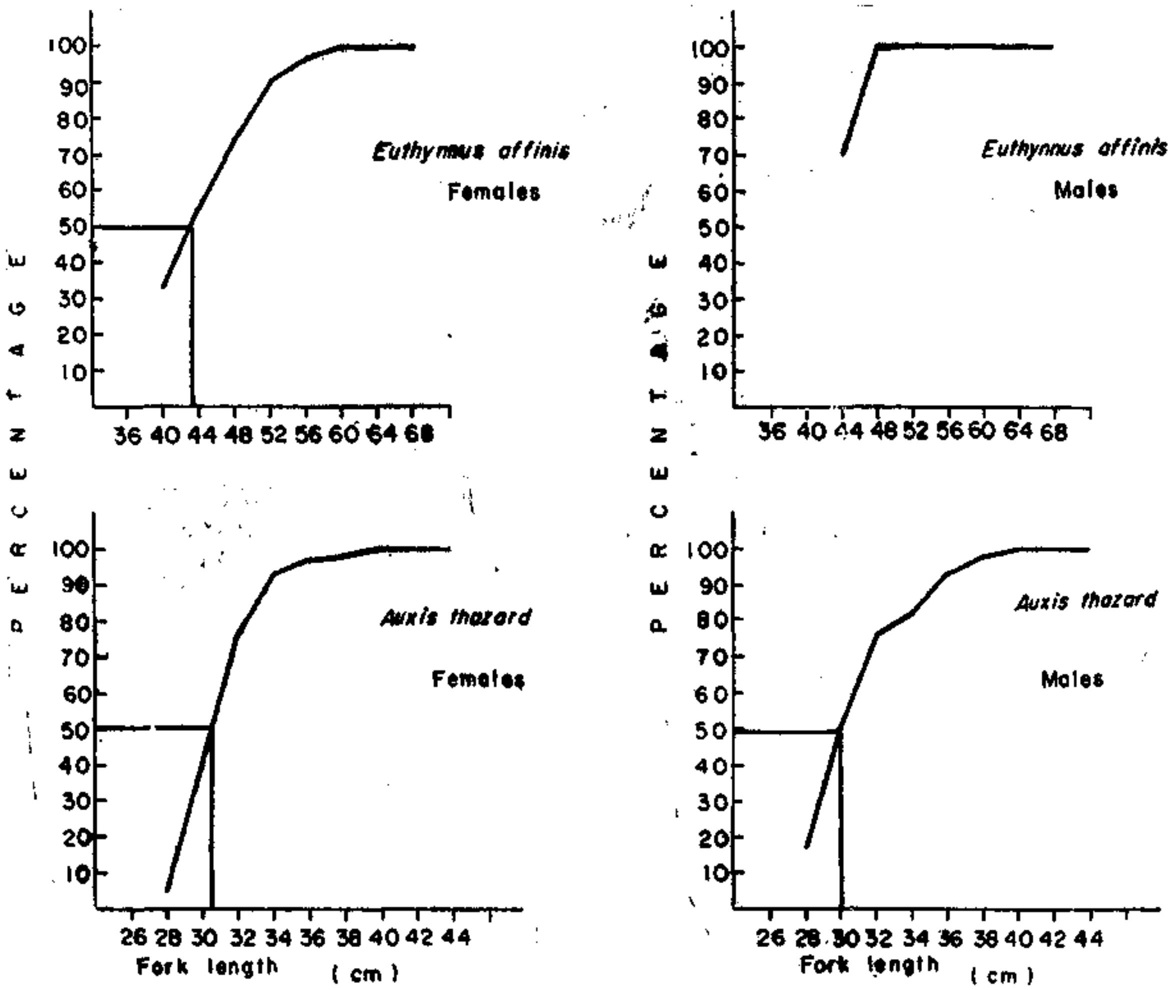

Fig. 1. Percentage occurrence of mature females and males of *E. affinis* (upper panel) and *A. thazard* (lower panel) at Mangalore.

attained maturity between 50 and 65 cm in TL (Ommanney, 1953) and 55 and 60 cm TL (Williams, 1956, 1963). Rao (1964) has recorded a female of 48 cm in ripe running condition off Vizhinjam along the southwest coast of India. According to Williamson (1970), *E. affinis* attains maturity at around 50 cm in the South China Sea. The present observation of minimum size of maturity of 43 cm for females is similar to the findings by Ronquillo (1963).

all fishes were found to be mature. The size at minimum maturity at 50% level was 30.5 cm for females and 30 cm for males. Rao (1964) has recorded a female of *A. thazard* of 41.6 cm in ripe running condition from Vizhinjam. Gonadial studies by Tester and Nakamura (1957) indicated that *A. thazard* matures at a size of about 35 cm. The present study indicates that the minimum size at first maturity with regard to males and females are when they attain the length of

30 cm and 30.5 cm, this finding is in agreement with that of Yasui (1975).

Auxis rochei

For determining the minimum size at maturity 292 and 354 males and females in the size range of 20-32 cm were considered (Figs. 3, 4). Mature fish occurred for the first time at a length of 23 cm in both sexes and all fish beyond 26 cm were mature. The length at which 50% of the females attain maturity was at 23.8 cm and for males at 24 cm. Yoshida and Nakamura (1965) observed milt flowing from the vent of males of *A. rochei* ranging from 29.2 to 32.9 cm in fork length. Rodriquez-Roda (1966) reported that the size of *A. rochei* at first spawning was 35 cm for the females and 36.5 cm for the males.

FECUNDITY

Euthynnus affinis

Fecundity varied from 2,01,542 (47 cm FL) to 15,69,733 (67 cm FL) ova. The smallest matured female (39.4 cm) had 4,47,326 ova. The fish which had the highest no. of ova measured 67 cm and the gonad was in fully ripe condition, occupying the whole body cavity and the weight of the ovary was nearly 0.5 kg. Fecundity varied in fish of the same length but, increased with length. The relation between length (L) and fecundity (F) is given in Fig. 5. The linear expression observed was :

$\text{Log } F = -3.66219 + 2.36111 \text{ Log } L$, and the correlation coefficient $r = 0.725$

The relation between body weight (W) and fecundity (F) of *E. affinis* is plotted in Fig. 5 and the regression observed was :

$\text{Log } F = -0.70091 + 1.03108 \text{ Log } W$, and the correlation coefficient $r = 0.851$.

The only information about fecundity of *E. affinis* in the Indian Seas is that by Rao (1964) from Vizhinjam, who reported that *E. affinis* spawned 2,10,000 to 6,80,000 ova per spawning and 7,90,000 to 25,00,000 ova for the spawning season. He also indicated that the production of ova increased with the length of the fish.

Auxis thazard

Fecundity ranged between 78,803 (31.5 cm FL) and 7,17,895 (39 cm FL) ova. As in the case of *E. affinis* the fecundity in *A. thazard* showed fluctuations in the fish of the same length, but generally it showed an increase corresponding with increase in length. The relation between fecundity (F) and length (L) (Fig. 6) could be expressed as :

$\text{Log } F = -9.77991 + 4.75748 \text{ Log } L$, and the correlation coefficient $r = 0.907$.

The relation between body weight (W) and fecundity (F) (Fig. 6) was :

$\text{Log } F = 1.270675 + 1.27111 \text{ Log } W$ and the correlation coefficient $r = 0.853$.

Rao (1964) reported that an individual of 44.2 cm produced 2,80,000 eggs per spawning and 1.37 million eggs in the spawning season. Silas (1969) estimated the fecundity based on 9 ovaries and it was 1,97,000 to 1.056 million eggs per spawning at an average of 6,01,000 ova per spawning.

Auxis rochei

Fecundity ranged from 52,570 (25.2 cm size) to 1,62,777 (33.7 cm size) eggs. Though variations were observed in fishes of the same size, the fecundity increased with the length of the fish as in *E. affinis* and *A. thazard*. The relationship between fecundity (F) and length (L) is shown in Fig. 6. The relationship was :

$\text{Log } F = -1.70881 + 1.50244 \text{ Log } L$ and the correlation coefficient $r = 0.958$.

The relation between fecundity (F) and body weight (W) was :

$\text{Log } F = 0.02921 + 0.79045 \text{ Log } W$ and the correlation coefficient $r = 0.890$ (Fig. 6).

There is no published information on the fecundity of *A. rochei* except that by Silas (1969). Based on 4 ovaries he estimated the fecundity to vary from 31,000 to 1,03,000 ova with an average of 52,000 ova per spawning.

SPAWNING SEASON

Euthynnus affinis

184 males and 202 females respectively were considered for this study. The percentage occurrence of various stages of maturity for males and females is given in Tables 1 and 2. Fish with ripe gonads (stage VI) were encountered during September-October. Their percentage was relatively high during October when the ripe individuals were invariably observed in the catches over the years. Fish in stage V occurred during December and February-March. Spent fishes in large numbers were encountered in the catches during September-October and a few during January-March, which indicate that the peak months of spawning of *E. affinis* was September-October and to a certain extent prolongs upto March. Further supporting evidences from the study of the relative condition and

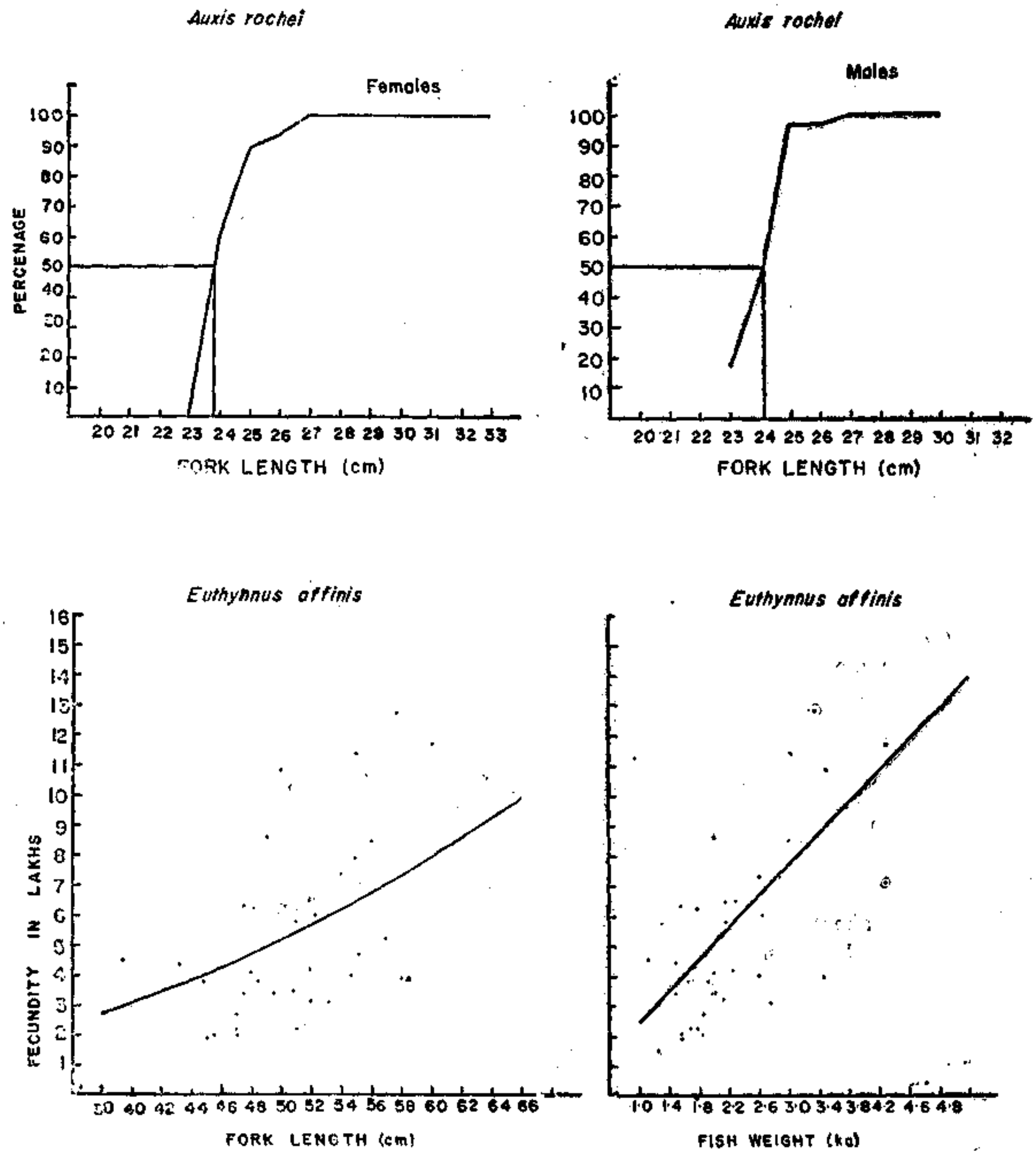

Fig. 2. Percentage occurrence of mature females and males of *A. rochei* (upper panel) and fecundity in relation to fork length and weight (kg) of *E. affinis* (lower panel) at Mangalore.

Gonado-Somatic Index confirm this finding. The availability of ripe *E. affinis* in large numbers in the gill net catches in the inshore waters of Mangalore during October every year provides further support to the observation that this species appears to approach the coastal waters for spawning.

April to September with occasional spawning in other months. Jones (1960) based on the capture of juveniles of *E. affinis* during January, May, June, September, October and November observed a rather protracted spawning season. The present findings also confirm the above observations.

TABLE 1. *Percentage of different maturity stages of males of* E. affinis *in various months*

Month	No. of specimens	Maturity stages						
		I	II	III	IV	V	VI	VII
January	2	..	..	..	..	..	..	100.00
February	3	..	..	..	..	..	..	100.00
March	3	33.30	..	..	33.30	33.30	..	..
April	9	11.10	..	22.20	66.70	..	..	..
May	8	..	..	12.50	87.50	..	..	..
June	5	..	..	..	40.00	60.00	..	..
July	No samples	..	..	..	..	..	..	..
August	No samples	..	..	..	..	..	..	..
September	22	..	..	9.10	50.00	18.20	4.50	18.10
October	110	3.60	3.60	3.60	42.70	34.50	6.40	5.40
November	20	100.00	..	..	..	..	..	..
December	2	50.00	..	..	..	50.00	..	..

TABLE 2. *Percentage of different maturity stages of females of* E. affinis *in various months*

Month	No. of specimens	Maturity stages						
		I	II	III	IV	V	VI	VII
January	No samples	..	..	..	..	..	..	..
February	2	..	..	..	..	50.0	..	50.0
March	6	..	33.3	16.7	16.7	16.7	..	16.7
April	3	..	..	33.3	66.7	..	..	..
May	10	10.0	10.0	20.0	60.0	..	..	..
June	3	..	..	..	..	66.7	..	33.3
July	No samples	..	..	..	..	..	..	..
August	No samples	..	..	..	..	..	..	..
September	20	..	..	25.0	40.0	5.0	..	30.0
October	134	3.0	6.0	5.2	47.8	14.2	14.2	9.7
November	24	100.0	..	..	..	..	..	..
December	No samples	..	..	..	..	..	..	..

The protracted spawning extending from October-November to April-May in *E. affinis* has been reported by Ommanney (1953) from western Indian Ocean. Rao (1964) stated that it spawned off Vizhinjam from

Auxis thazard

In the Mangalore inshore area *A. thazard* were observed only during September-December period of each year. The percentage occurrence of various

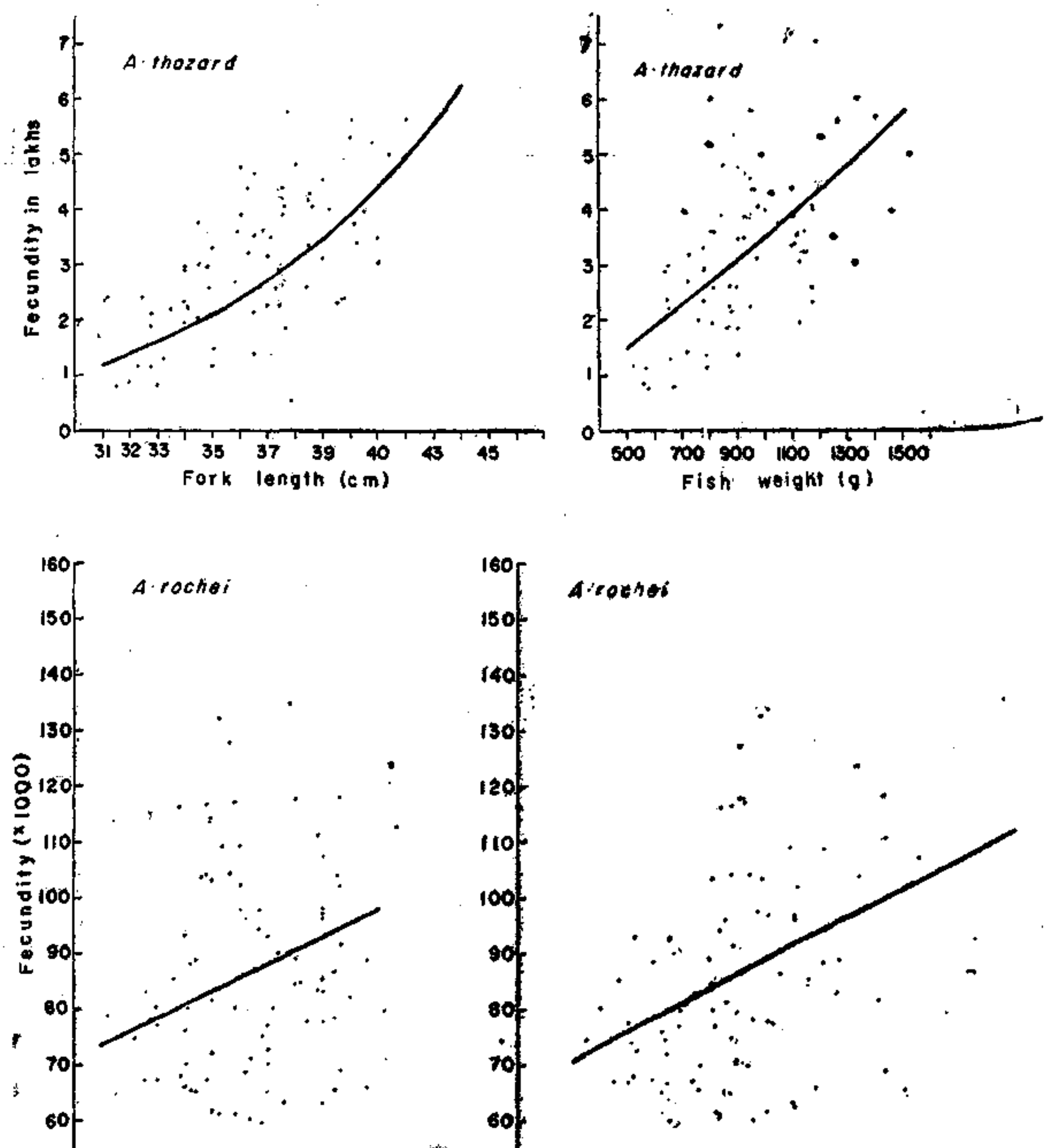

Fig. 3. Fecundity in relation to length and weight of *A. thazard* (upper panel) and *A. rochei* (lower panel) at Mangalore.

stages of maturity for males and females during different months is presented in Tables 3 and 4. Males and females in ripe condition were common in the catches during October-November period whereas spent fishes were recorded from October to December which indicates spawning of this species in the above months. Jones and Kumaran (1963) based on the capture of larval *A. thazard* observed that this species spawns during December-January in the area between 3° and 24° S at long. 50°E and during January-April in the Laccadive Sea. Rao (1964) observed that majority of this species were in the ripe and some in spent condition during August and September with a preponderance of spent specimens in November. The present observation is in conformity with the findings of Rao (1964).

TABLE 3. *Percentage of different maturity stages of males of* A. thazard *in various months*

Month	No. of specimens	Maturity stages						
		I	II	III	IV	V	VI	VII
January	No samples	..	..	..	..	..	..	..
February	No samples	..	..	..	..	..	..	..
March	No samples	..	..	..	..	..	..	..
April	3	..	33.3	..	33.3	33.3	..	..
May	3	..	100.0	..	..	..	..	..
June	No samples	..	..	..	..	..	..	..
July	No samples	..	..	..	..	..	..	..
August	No samples	..	..	..	..	..	..	..
September	50	..	4.0	..	26.0	28.0	4.0	38.0
October	196	14.3	13.3	16.3	15.8	12.8	9.7	17.9
November	85	75.3	8.2	5.9	2.4	..	..	8.2
December	No samples	..	..	..	..	..	..	..

TABLE 4. *Percentage of different maturity stages of females of* A. thazard *in various months*

Month	No. of specimens	Maturity stages						
		I	II	III	IV	V	VI	VII
January	No samples	..	..	..	..	..	..	..
February	No samples	..	..	..	..	..	..	..
March	2	..	100.0	..	..	..	..	..
April	1	..	..	..	..	..	..	100.0
May	1	..	100.0	..	..	..	..	..
June	No samples	..	..	..	..	..	..	..
July	No samples	..	..	..	..	..	..	..
August	No samples	..	..	..	..	..	..	..
September	43	2.3	4.7	7.0	44.2	21.0	4.7	16.3
October	240	4.6	24.6	5.0	30.4	11.7	10.0	13.8
November	116	62.1	18.1	4.3	0.9	..	..	14.6
December	6	100.0	..	..	..	..	..	..

Auxis rochei

A. rochei was observed in the Mangalore inshore waters during the September-December period only. Mature (stages IV & V), ripe and spent fishes occurred during this period and in a high percentage of occurrence in September (Tables 5 & 6) indicating that the spawning of this species is around September.

No information is available with regard to the spawning season of *A. rochei* from Indian waters. Jones and Kumaran (1963) opined that the areas between Madagascar and the coast of Africa are the possible spawning grounds for this species. Their assumption was based on the collection of 20 larval *A. rochei* in the *Dana* collection from the Indian Ocean. *A. rochei* is reported to spawn in August off Kaena Point, Oahu (Yoshida and Nakamura, 1965) and in late June in the waters off Kochi Perfecture and off Taiwan (Hamada *et al.*, 1973). Rodriquez-Roda (1966) had noted that one fourth of the females sampled during September had spent gonads.

TABLE 5. *Percentage of different maturity stages of males of* A. rochei *in various months*

Month	No. of specimens	Maturity stages						
		I	II	III	IV	V	VI	VII
January	No samples	..	..	..	..	..	..	..
February	No samples	..	..	..	..	..	..	..
March	No samples	..	..	..	..	..	..	..
April	No samples	..	..	..	..	..	..	..
May	No samples	..	..	..	..	..	..	..
June	No samples	..	..	..	..	..	..	..
July	No samples	..	..	..	..	..	..	..
August	No samples	..	..	..	..	..	..	..
September	156	..	0.6	..	29.5	30.1	7.7	32.1
October	27	29.6	37.0	3.7	3.7	..	3.7	22.2
November	60	5.0	90.0	..	..	..	..	5.0
December	21	100.0	..	..	..	..	..	..

TABLE 6. *Percentage of different maturity stages of females of* A. rochei *in various months*

Month	No. of specimens	Maturity stages						
		I	II	III	IV	V	VI	VII
January	No samples	..	..	..	..	..	..	..
February	No samples	..	..	..	..	..	..	..
March	No samples	..	..	..	..	..	..	..
April	No samples	..	..	..	..	..	..	..
May	No samples	..	..	..	..	..	..	..
June	No samples	..	..	..	..	..	..	..
July	No samples	..	..	..	..	..	..	..
August	No samples	..	..	..	..	..	..	..
September	217	..	..	0.9	36.0	44.7	1.4	17.0
October	15	..	73.3	..	..	..	..	26.7
November	53	5.7	92.3	..	..	..	..	1.9
December	38	100.0	..	..	..	..	..	..

SPAWNING PERIODICITY

Euthynnus affinis

The ova diameter frequency polygon of *E. affinis* depicting the development of ova through various stages of maturity is presented in Fig. 2. One micro-division indicates 0.0175 mm. In stage I evidently ova were immature and yolkless and 5-8 md size. In stage II the eggs were immature, transparent and commencement of deposition of yolk granules around the nucleus and spreading towards the periphery had been the fully mature ova. Each ovum had perivitelline space and the transparency had commenced at the periphery. This mode was clearly separated from four modes at 16, 22, 16 and 12 md. Ova of the first two modes *viz.*, at 26 and 22 md were in the process of attaining maturity since all the ova appeared completly opaque, and ova of other two modes at 16 and 12 md represented maturing and immature eggs respectively. In stage V three modes could be observed at 36, 22 and 12 md representing fully mature, maturing and immature eggs. The ripe ovary (stage VI) indicated

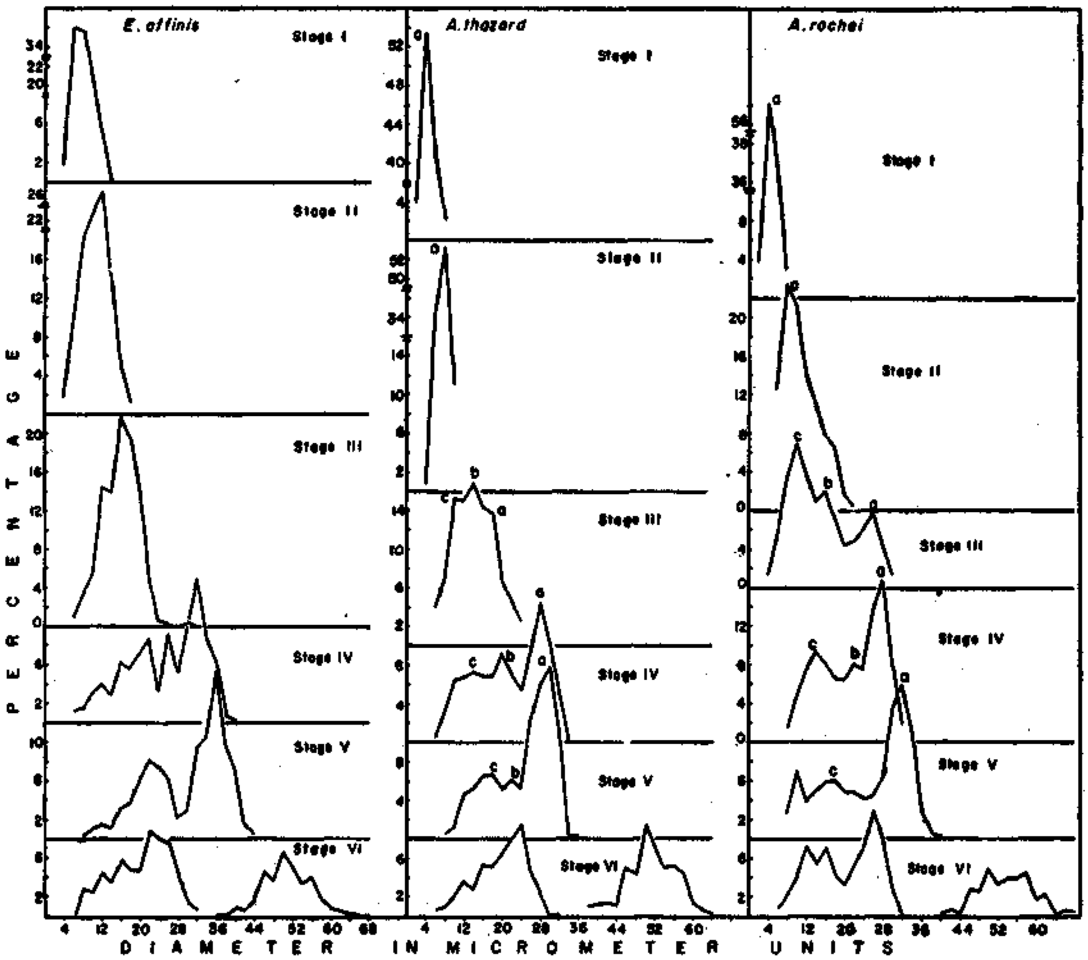

Fig. 4. Ova diameter frequency polygon of *E. affinis*, *A. thazard* and *A. rochei* at Mangalore.

observed. A mode at 12 md was seen in this stage. Differentiation of ova from the egg could be seen in stage III forming two modes at 16 md and 12 md while the former mode representing the maturing group of ova had yolk layering almost 3/4 of each ovum area, the latter mode is represented by immature eggs. In stage IV there was a major mode at 32 md comprising multimodes. One group of modes *viz.*, 56, 50, 46 and 40 md collectively represented the ripe ova. All the ova in these groups were transparent and vacuolated. The average diameter of ova in this group was 52.47 md (0.80 mm) in preserved material whereas they measured 56.15 md (0.89 mm) in samples drawn from fresh ovaries. Each ripe ovum possessed a single round and yellowish oil globule measuring 15 md (0.24 mm) in both preserved and fresh material. The other groups of modes in the ripe ovary at 22 md represented mature ova ; at 16 md maturing ova and 12 and 8 md immature ova. Since these two groups of modes were separated from each other this would indicate that the ripe ova may be extruded soon in the ensuing spawning. Based on the ova diameter studies June (1953) and Bunag (1958) have shown that in several species of tuna all the ova destained to be spawned during the spawning season do not mature at once, but are developed and spawned in batches. Rao (1964) and Bunag (1958) reported that *E. affinis* spawns more than one batch of eggs during a spawning season. The present investigation is also in confirmity with the above findings. Rao (1964) reported that the ripe ovum of *E. affinis* measured 0.99 mm and 0.81 mm in fresh and preserved materials respectively and the oil globules measured 0.25 mm. Bunag (1958) speculated that the ripe eggs would probably be between 0.88 and 1.11 mm in diameter.

Auxis thazard

In Fig. 7 the size distribution of ova from various stages of maturity in *A. thazard* are plotted. In stage I and II the ova were immature coming under a single mode 'a' which is at 4 and 8 md respectively. In stage III, two modes 'a' at 18 and 'b' at 14 md representing ova are discernible, in addition to another mode 'c' at 10 md comprising of immature ova. In stage IV, mode 'a' shifted to 28 md and 'b' to 20 md and 'c' to 14 md representing three groups of ova *viz.*, mature, early mature and maturing. In stage V, mode 'a' progressed to 30 md, 'b' to 22 and 'c' to 18 md. The ova diameter studies show that in some ovaries of stage V the mature ova seem to, appear much smaller in size than the mature ova of some ovaries of stage IV. In the former the ovaries appeared granulated and the mature ova ranged from 25-31 md in diameter with an average of 27.7 md. The ovum vacuolation process seems to commence uniformly over the entire ovum rendering it semitranslucent. In the latter, the ovary appeared to have a granulated appearance and the mature ova varied from 27-37 md (average 31.7 md) in diameter. The periphery of the ovum looked transparent while major portion was opaque. In stage VI, the fully ripe ova have modes at 56, 50 and 46 md. Besides these ripe ova groups, the other groups representing mature, maturing and immature eggs have modes at 24, 16 and 12 md respectively. The above observations conclusively show that in this species also as in the case of *E. affinis* the spawning extends over a prolonged period and the eggs are released in successive batches as indicated by Rao (1964).

In fresh material, the ripe ova were spherical and tinged pinkish. The average diameter of the ova measured 0.87 mm and 0.80 mm in fresh and preserved material respectively. Each ripe ovum contained a single oil globule the average diameter of it was 0.23 mm. Rao (1964) stated that the average diameter of ova in ripe ovaries as 0.97 mm and 0.86 mm in fresh and preserved material respectively and oil globule measuring at an average of 0.22 mm. Yoshida and Nakamura (1965) observed that the residual eggs of *A. thazard* measured between 0.75 mm and 1.30 mm with an average size of 1.08 mm.

Auxis rochei

Ova diameter frequency polygons of different maturity stages of *A. rochei* are given in Fig. 27. In stage I immature eggs formed a mode 'a' at 4 md and in the subsequent stage it shifted to 8 md. In stage III the ova got differentiated into three batches forming modes 'a' at 26 md 'b' at 16 md and 'c' at 10 md representing mature, maturing and immature ova groups respectively. In stage IV, mode 'a' shifted to 28 md ; 'b' to 22 md and 'c' to 14 md. In stage V mode 'a' and 'c' could be seen at 32 md and 18 md respectively whereas mode 'b' disappeared. This may be due to the fast growth of this group of ova and got included with mature group 'a'. Besides this, another fresh batch of ova with mode 'd' at 10 md was also observed. In stage VI the ripe ova measured between 40 and 68 md and had distinct modes at 42, 46, 50, 58 and 62 md. These modes were clearly separated from the mature ova with mode at 26 md, the maturing groups of ova at 16 md and immature group of ova at 12 md. The presence of ripe ova group besides the mature, maturing and immature ova groups indicates that the spawning in this species is similar to that of *E. affinis* and *A. thazard*, by releasing eggs in batches and as such the spawning is extended over a protracted period. The ripe ova of *A. rochei* on an average measured 0.84 mm in the preserved material. Each ovum possessed a single round oil globule, saffron in colour and measured on an average about 0.20 mm.

Relative Condition (Kn)

Euthynnus affinis

Mean Kn values for different months and in relation to various sizes in respect of 82 males and 70 females are shown in Fig. 8 and 9. It can be seen that in both sexes Kn values showed a peak in June followed by an

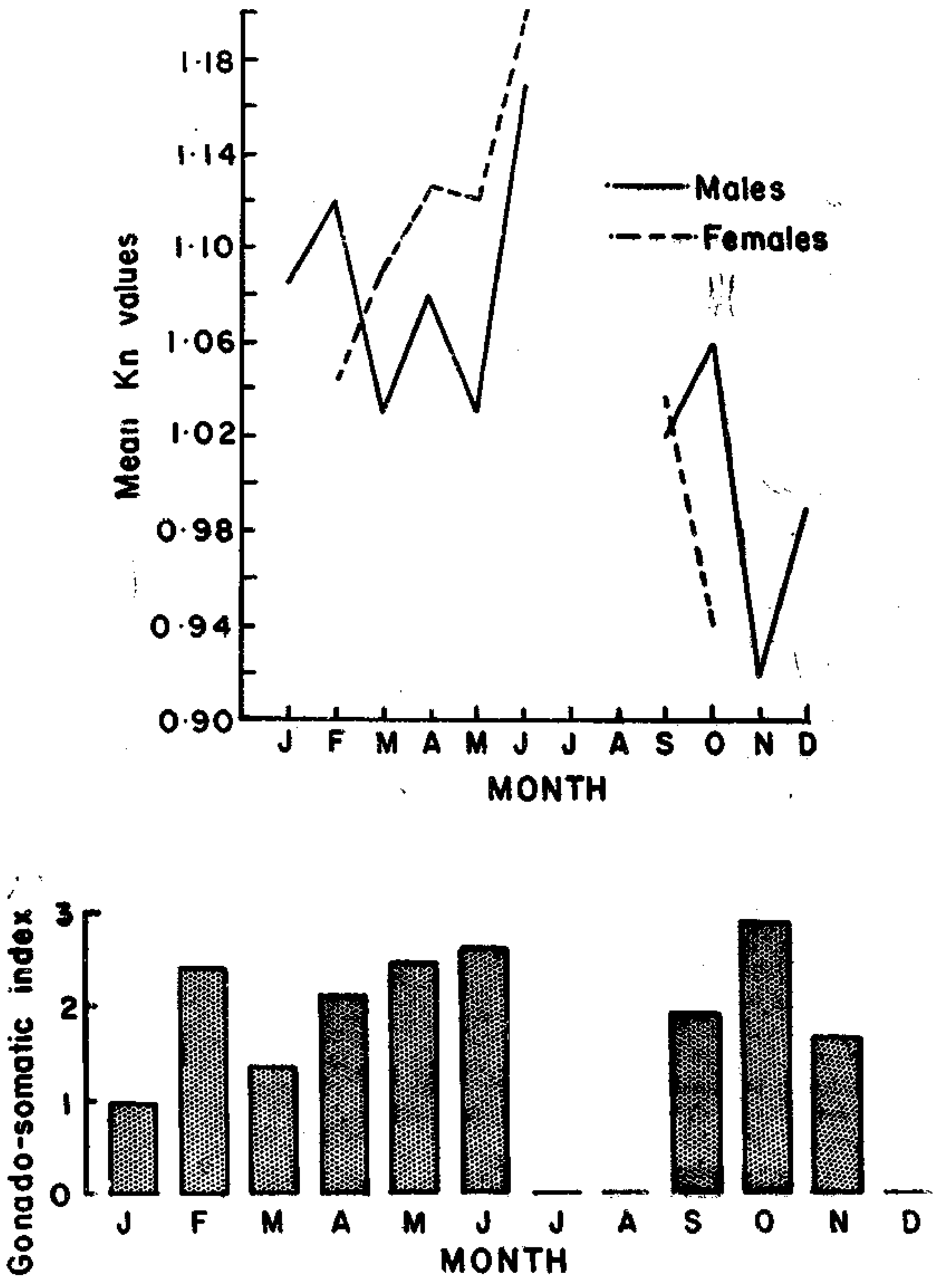

Fig. 5. Mean Kn values of males and females of *E. affinis* in different months (top) and gonadosomatic index values of males and females of *E. affinis* in different months (bottom) at Mangalore.

abrupt fall in September and attaining a minimum in October-November. Thereafter, in males the values increased till February and dropped slightly in March. Again there was another increase in April and fall in May. In females the values showed increasing trend from February. Higher Kn value in June appears to be due to accumulation of fat in the body prior to maturation and the low values in September-December are an indication of the onset of spawning. The low values in February in the case of females and March in the case of males may be attributed to spawning of another batch of ova as it is evident from the ova diameter studies that in this species spawning is fractional.

High Gonado-Somatic Index values (Fig. 8) are based on the study of 80 males and females in October, February and May-June may be attributed to the full development of gonads and it is indicative that this species spawns during the above months.

Mean Kn values derived out of 183 and 198 males and females respectively for different size groups are given in Fig. 9. It may be seen that the values for females showed a gradual rise from 34 cm size group onwards, reaching a peak in 40 cm size group. A decreasing trend in the values was seen from the next size and attaining the lowest in the 46 cm size group. Since fish in 34 cm size groups are immature, the high values in the 40 cm size might be due to the accumulation of fat prior to spawning and the decreasing trend in the 42-46 cm size could be due to spawning activity. The rise in the values in 52, 58 and 64 cm size and the immediate fall in the next size groups in 54 and 62 cm seems to be associated with later successive spawnings.

In males (Fig. 9), the Kn values showed an increasing trend in the 36 cm and drop in 38 cm groups. Again an increase in 40 cm size followed by a slight fall in 42 cm and rise in 44 cm and thence a decreasing trend is evident. As seen in the case of females, the males upto 40 cm were immature. Hence the rise in the 44 cm size might be related to the building up of gonad activity and the decreasing trend after this size might indicate the first spawning. The rise in 56 cm and 60 cm and drop in 58 and 64-66 cm size might be due to the preparations prior to maturity and spawning activity respectively.

Auxis thazard

Fig. 10 show the mean Kn values for different size groups derived from 389 males and 401 females. Kn values for immature females in the 20-22 cm size groups were very low. An increase in the values in the next size (24 cm) and a decline in the 26 cm size seem

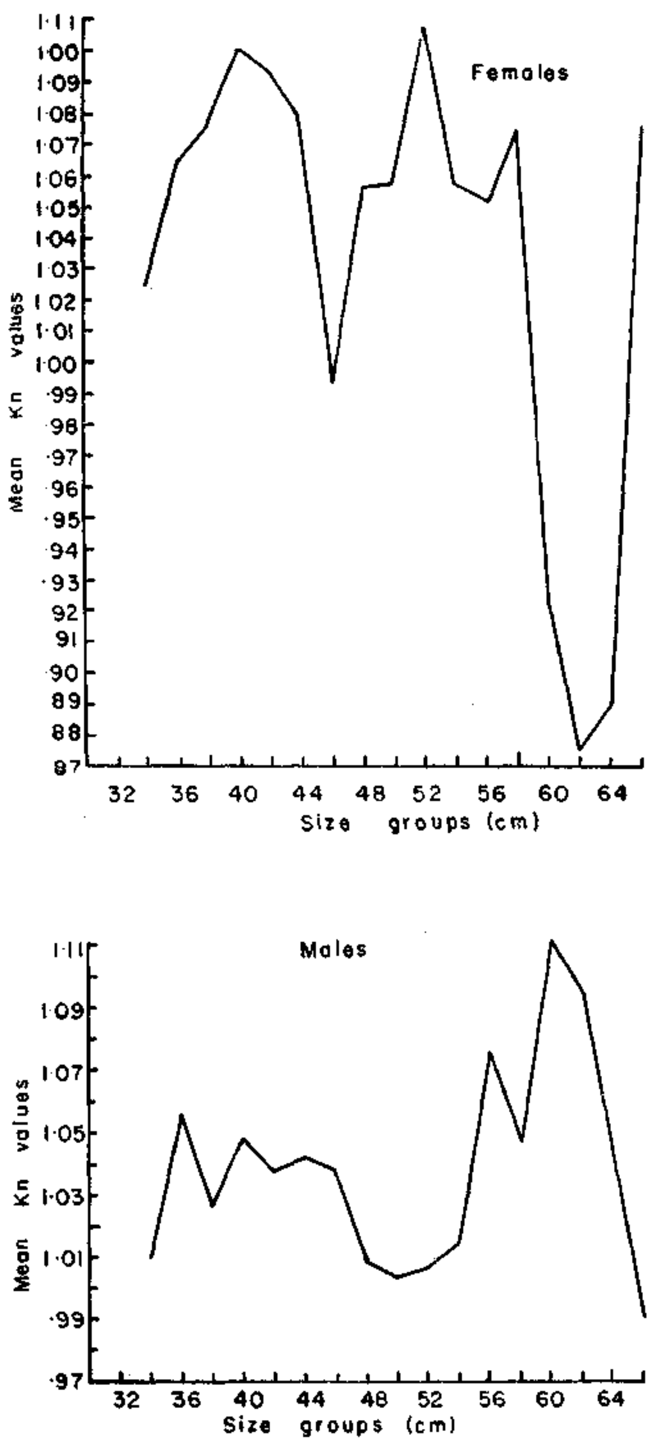

Fig. 6. Mean Kn value of females (top) and males (bottom) of *E. affinis* in different size groups at Mangalore.

to be associated with factors other than maturation of gonads, since fish in these sizes were already in maturing stage. Next to this size, values showed steady increase upto 30 cm indicating that the fish ings. The fluctuation in the Kn values for males follows a similar pattern as observed in the case of females except that the full growth of gonads in males is indicated at 28 cm size.

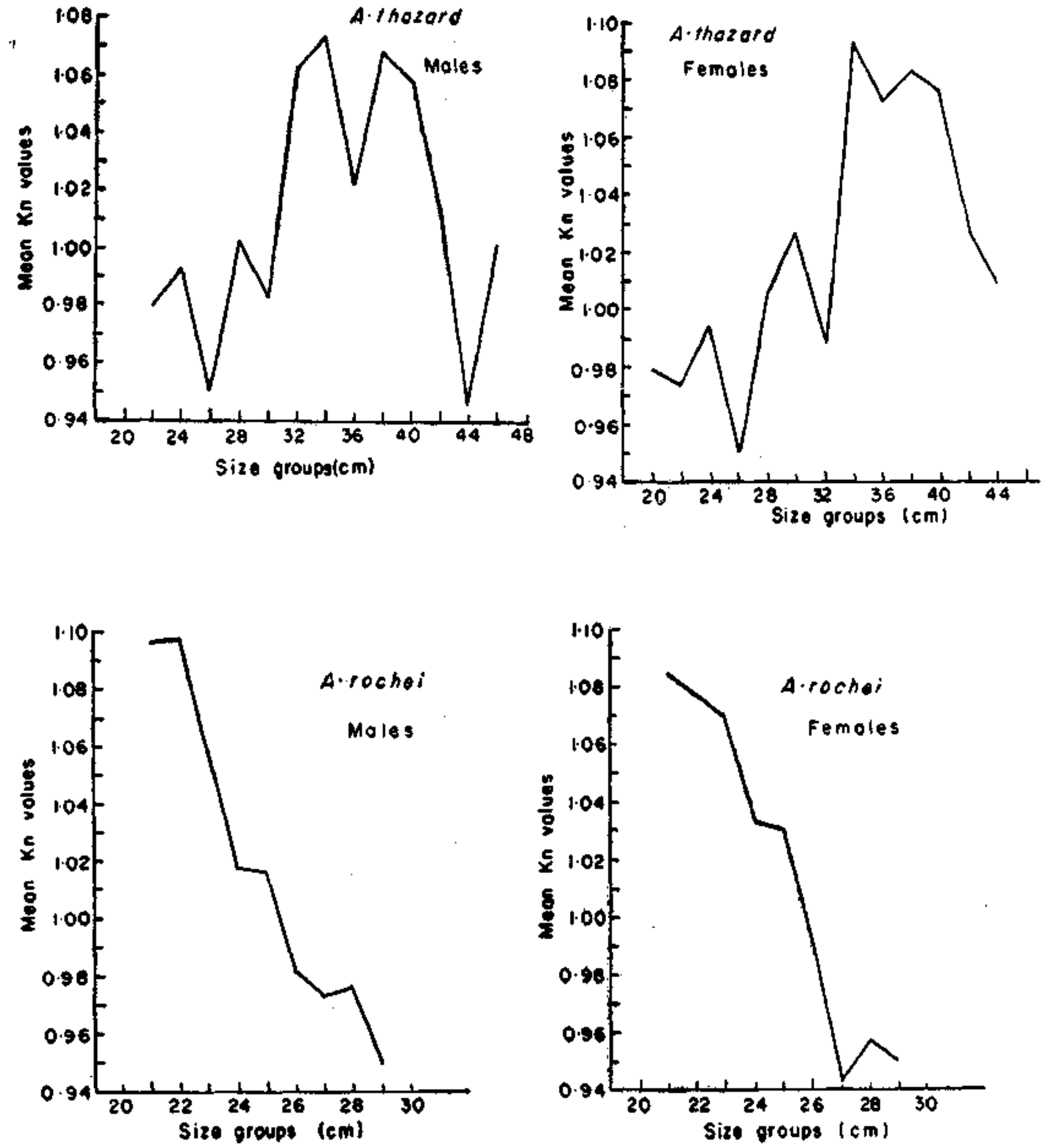

Fig. 7. Mean Kn values of males and females of *A. thazard* (upper panel) and *A. rochei* (lower panel) in different size groups at Mangalore.

accumulate fat in the body prior to spawning. The abrupt decrease in fish measuring at 32 cm size is indicative of the commencement of spawning. The Kn values were on the rise again in 34 and 38 cm sizes followed by decrease in their next size groups (36 and 40 cms) which may be related to the subsequent spawnings.

Auxis rochei

Mean Kn values for various length groups calculated from 158 males and 221 females are shown in Fig. 10. It is seen that the values in females were high in the 21 cm size groups and showed a trough in the 24-25 cm and 27 cm size groups. Since fish upto 22 cm were in immature stages of maturity and the occurrence of a few individuals in ripe gonads in the 23 cm size group indicates that the inflexion in the 24-25 cm and again in the 27-28 cm size might be due to successive spawning activities of the fish. The fluctuation in the Kn values for males follow a similar pattern as observed in the case of females.

Sex Ratio

Euthynnus affinis

Sexes could be differentiated in fish measuring more than 34 cm. A total of 405 specimens were examined for sex ratio analysis, of which 198 were males and 207 females. The male to female ratio was 1 : 1.05 showing no significant departure from the normal expected value.

The results indicated that the observed proportion of males in different months is not significant (Table 7). Further, the analysis of sex ratio (Table 8) in different size groups revealed that there was no significant departure from the 1 : 1 ratio upto 50 cm size, however, significant departure at 5% level was noticed in the 52 and 54 cm indicating the preponderance of females. In the case of males it was in fishes measuring 62 and 66 cm. Williamson (1970) observed that sexes were equally distributed from 38 to 49 cm group where from 50 to 73 cm groups the males dominated.

TABLE 7. *Results of Chi-square test for the proportion of males of* E. affinis *in the monthly samples during* 1979-'82

Month	No. of specimens	Males	Females	Chi-square	Significant or not significant at 5% level
January	2	2	..	2.00	NS
February	5	3	2	0.20	NS
March	9	3	6	2.00	NS
April	12	9	3	3.00	NS
May	18	8	10	0.22	NS
June	8	5	3	0.50	NS
July	No sample	—	..	..	..
August	No sample	..	..	..	..
September	47	26	21	0.53	NS
October	258	120	138	1.26	NS
November	44	20	24	0.36	NS
December	2	2	..	0.20	NS

Degrees of freedom : 1 in all cases; NS = No significant; S = Significant.

TABLE 8. *Results of Chi-square test for the proportion of male in various size groups of* E. affinis *during* 1979-'82

Length group	No. of specimens	Males	Females	Chi-square	Significant or not at 5% level
34	24	13	11	0.17	NS
36	23	8	15	2.13	NS
38	15	7	8	0.06	NS
40	3	2	1	0.33	NS
42	4	1	3	1.00	NS
44	30	11	19	1.20	NS
46	22	10	12	0.18	NS
48	29	14	15	0.03	NS
50	31	11	20	2.61	NS
52	29	9	20	4.17	S
54	44	15	29	4.45	S
56	39	21	18	0.23	NS
58	31	18	13	0.81	NS
60	26	17	9	2.46	NS
62	16	13	3	6.25	S
64	13	9	4	1.92	NS
66	12	11	1	8.33	S
68	5	4	1	1.80	NS
70	2	2	..	1.00	NS

Auxis thazard

Differentiation in sexes could be made from 24 cm size onwards. Out of 774 fishes examined, 359 were males and 415 females (ratio 1 : 1.16) and it was significant at 5% level. The proportion of males during various months (Table 9) show that the females

TABLE 9. *Results of Chi-square test for the proportion of males of* A. thazard *in the monthly samples during* 1979-'82

Month	No. of specimens	Males	Females	Chi-square	Significant or not significant at 5% level
January	No samples	..	..	..	..
February	No samples	..	..	..	..
March	2	..	2	2.00	NS
April	4	3	1	1.00	NS
May	5	4	1	1.80	NS
June	No samples	..	..	..	..
July	No samples	..	..	..	..
August	No samples	..	..	..	..
September	96	53	43	1.04	NS
October	459	213	246	2.37	NS
November	202	86	116	4.46	S
December	6	..	6	6.00	S

dominated during October and November (significant at 5% level) and this period coincides with active spawning of this species. Significant deviation at 5% level was noticed (Table 10) in the 28 and 38 cm due to the predominance of females. Sivasubramaniam (1973) reported that in Sri Lanka waters, *A. thazard* showed no noticeable differences from expected ratio except in one area along the southwest coast of the island where the ratio was 1 : 1.5.

Auxis rochei

Sexes could be differentiated in fish measuring 21 cm size onwards. Out of 664 fish sampled, 326 were males and 336 females, the male to female ratio being 1 : 1.02 and found to be not significant. Monthwise sex ratio (Table 11) show that during October and December there was significant departure from 1 : 1 ratio at 5% level and this was due to the predominance of male. However, lengthwise, both sexes (Table 12) were equally distributed. Hamada *et al.* (1973), reported that both sexes of this species were equally represented in the waters of Kochi and Tohoku Perfecture, Japan and also off Taiwan. Studies by Rodriquez-Roda (1966) from Barbate, Tarifa and La Linea in Spanish waters showed no significant departure from 1 : 1 ratio except at La Linea where males dominated.

TABLE 10. *Results of Chi-square test for the proportion of males in various size groups of* A. thazard *during* 1979-'82

Length group	No. of specimens	Males	Females	Chi-square	Significant or not at 5% level
20	1	..	1	1.00	NS
22	5	2	3	0.20	NS
24	60	26	34	1.07	NS
26	122	64	58	0.30	NS
28	66	24	42	4.91	S
30	92	39	53	2.13	NS
32	75	38	37	0.01	NS
34	78	38	40	0.05	NS
36	108	41	67	6.26	S
38	83	40	43	0.05	NS
40	38	17	21	0.21	NS
42	13	6	7	0.08	NS
44	5	1	4	1.80	NS

TABLE 11. *Results of Chi-square test for the proportion of males of* A. rochei *in the monthly samples during* 1979-'82

Month	No. of specimens	Males	Females	Chi-square	Significan or not at 5% level
January	No samples	..	..	..	..
February	No samples	..	..	..	..
March	No samples	..	..	..	..
April	No samples	..	..	..	..
May	No samples	..	..	..	..
June	No samples	..	..	..	..
July	No samples	..	..	..	..
August	No samples	..	..	..	..
September	446	216	230	0.44	NS
October	45	30	15	5.00	S
November	114	61	53	0.56	NS
December	59	21	38	4.90	S

TABLE 12. *Results of Chi-square test for the proportion of males in various size groups of* A. rochei *during* 1979-'82

Length group	No. of specimens	Male	Female	Chi-square	Significant or not at 5% level
20	38	14	24	2.63	NS
22	139	74	65	0.58	NS
24	98	46	52	0.36	NS
26	260	124	136	0.55	NS
28	127	69	58	0.19	NS
30	2	1	1	0.00	NS

9

FISHERY AND BIONOMICS OF TUNAS AT TUTICORIN

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In the fishery along Tuticorin Coast in the Gulf of Mannar, seven species of tuna and tuna-like fishes occur. They are the little tunny *Euthynnus affinis* (Cantor), Frigate mackerel *Auxis thazard* (Lacepede), bullet tuna *Auxis rochei* (Risso), oriental bonito, *Sarda orientalis* (Temminck and Schlegel), yellowfin tuna *Thunnus albacares* (Temminck and Schlegel), skipjack tuna *Katsuwonus pelamis* (Linnaeus) and long tail tuna *Thunnus tonggol* (Bleeker). In addition, among the billfishes, the sailfish *Istiophorus platypterus* (Shaw and Nodder) and the striped marlin *Tetrapterus audax* (Philippi) also occur in the fishery.

A comprehensive account on tunas of Indian waters has been given by Jones and Silas (1960) and Silas and Pillai (1982). Some aspects of the biology and fishery of these fishes are dealt with here based on the material collected during the years 1979-'82.

Fishing area

The tuna fishery at Tuticorin has earlier been documented by Silas (1967). Since then there has been shift in the pattern of fishery from a predominantly troll line fishery to gill net fishery (both 'paruvalai' and 'podivalai' of synthetic nylon). Troll line operations are conducted only when the use of gill nets are temporarily suspended and when the fishermen sail to deeper grounds. Fig. 1 shows the operational area of drift gill nets off Tuticorin.

Craft and gear and operational details

Fishing craft is still predominantly the 'Tuticorin type' boat which was described by Silas (1967) in detail.

Based on the data collected during the four years from 1979 to 1982, along the coast of Tuticorin from Vaipar, Tuticorin, Punnakayal, Kayalpatnam and Veerapandianpatnam landing centres, it may be stated that the peak season for tuna fishery is from June to September. Heavy landings were noticed only at Veerapandianpatnam. The stray catches of the juveniles of *E. affinis*, *A. thazard* and *S. orientalis* were mostly caught off Veerapandianpatnam by 'sardine drift gill nets' of mesh size 3.2 cm. The medium size (20 to 30 cm) fishes belong to the species *E. affinis*,

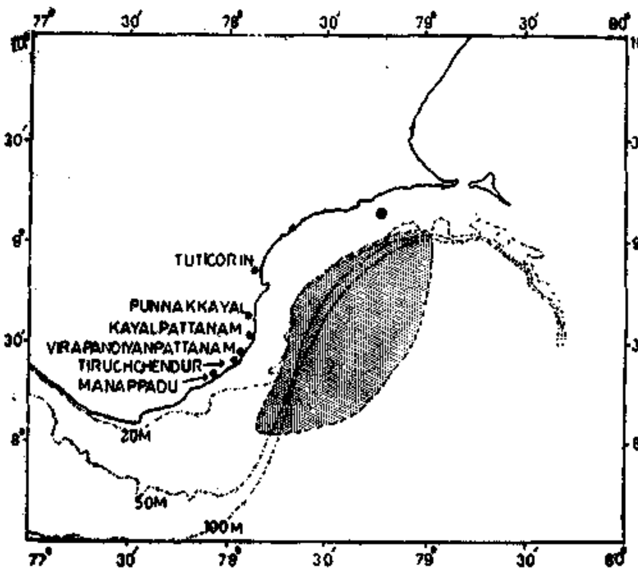

Fig. 1. Operational area of drift gillnetters off Tuticorin.

A. thazard, *S. orientalis* and *A. rochei* and larger sizes of *T. albacares*, *T. tonggol*, *E. affinis*, *S. orientalis*, *K. pelamis*, *A. thazard* and billfishes *I. platypterus* and *T. audax* were caught along with seerfishes and sharks by the drift gill nets called 'Podivalai' of the mesh size 7.0 to 11.5 cm and by 'Paruvalai' of mesh size 12.2-15.0 cm respectively. Occasionally dolphins were also caught by these drift gill nets. The length and depth of a single piece of gill net is about 14-16 metres and 3-4 metres respectively. During operations usually 7-10 pieces are plied together.

E. affinis and *A. thazard* occur round the year. In addition to these three species *viz.*, *T. tonggol*, *T. albacares*, *K. pelamis* and *S. orientalis* occur only during the season (June-September). During the fishing seasons, fishermen from the northern parts of the Gulf of Mannar *viz.*, Vaipar, Vedalai, Mookayoor, Yervadi, Valinockam, Keelakkarai and adjacent villages use to migrate to Veerapandianpatnam with their boats and gears and camp there purely for tuna fishing. Totally 160 number of gill net operational units or even more during seasons were in use from Veerapandianpatnam alone. Of these nearly 90% of the gears were in operation daily depending upon favourable wind when the catches were also proportionately high. The fishing ground is within 30 to 50 metres depth off Veerapandianpatnam (Fig. 1). Totally 60% of the catch is constituted by tuna, followed by seerfishes (15%), sharks (12%) and other fishes such as *Caranx*, catfish, *Sphyraena*, etc.

The fishing ground off Veerapandianpatnam is less than 10 kilometres from the shore and the sailing time to reach the fishing ground is about 2 hrs. Each sail boat has a crew of 5 to 6. They leave the centre by about 1500-1600 hrs and operate the drift gill nets for about 8 hours or even more. Generally only one operation is done and occasionally it is increased by two. Next day morning, after 0600 hrs they start to return to the landing centre and reach the shore before 0800 hours.

Heavy landings of Scombroids, especially tunnies were observed only during the South-West Monsoon season, *i.e.* from June to September. Normally the catch is poor during the North-East Monsoon, due to the turbidity of the water and the difficulty in reaching the ground.

The scombroid fishes especially tunnies were mostly disposed by public auction in the landing centre of Veerapandianpatnam, as soon as they are landed. The fresh fishes were mostly sent to Kerala especially to Quilon, Kottayam and Trivandrum districts in fresh condition packed with ice by lorry and van. In case there is any shortage of ice, there is a steep fall in the price for tuna. When this occurs the fishes are sundried or even pit-cured . In earlier years sundried fish was mostly exported to Sri Lanka (Silas, 1967).

Effort, catch and CPUE

The effort expended in the drift gill net fishery during the year 1979 to 1982 ranged from 4002 to 9438 units, minimum during the year 1979 and the maximum efforts expended during the year 1981 respectively (Fig. 2). The tuna landing was high *i.e.*, 2,797 tonnes during the year 1980 and very low (135 t) during 1982. The latter at Veerapandianpatnam was due to the dispute between the fishermen operating mechanised and non-mechanised boats. The tuna landing was completely nil only in the month of October during the year 1979 and 1982.

During the year 1979, the maximum effort expended was of 896 units in the month of July and the catch of tuna and related fishes was of 186 tonnes. The minimum effort of 169 units have been expended in May 1979 and the catch was nearly 2 tonnes. The minimum catch of tuna (0.2 t) was recorded during February 1979. The tuna landing was high during June, July and August in 1979, being 72 t, 186 t and 98 t respectively. Their landing was very poor during the rest of the months in 1979 (Fig. 2).

The tuna landing was relatively high (2,797 t) during the year 1980, when compared to the corresponding years 1979, 1981 and 1982. During this year, effort was also high (2,219 units) in July and catch of tuna was recorded at 1,177 t. The minimum effort of 190 units was in February and the catch was 1 t only. Unlike that of 1979, the effort and catch were high in the months of July, August and September, during the year 1980, the catch being 1,177 t, 1,112 t and 450 t respectively (Fig. 2).

The effort were high (9,438 units) during the year 1981, when compared to that in 1979, 1980 and 1982, and the annual tuna catch was also estimated to be 1,239 t. Maximum units of 1,920 were operated during the month of July '81 and the catch also recorded to a maximum of 816 t in this month. The minimum effort was expended in October '81 and the catch recorded was 1.5 t. The minimum catch was recorded during the year 1981 in the month of September at 0.03 t. During this month, due to the dispute between the fishermen of mechanised and non-mechanised boats they suspended fishing activities.

When compared to the previous years, the annual tuna landing was poor (135 t) during the year 1982, and the effort expended was 7,654 units. The maximum effort and catch of tuna were recorded only in July '82 and the catch and effort were estimated at 116 t and 1,754 units respectively (Fig. 2.) The minimum tuna catch (0.2 t) and effort (316 units) was recorded in

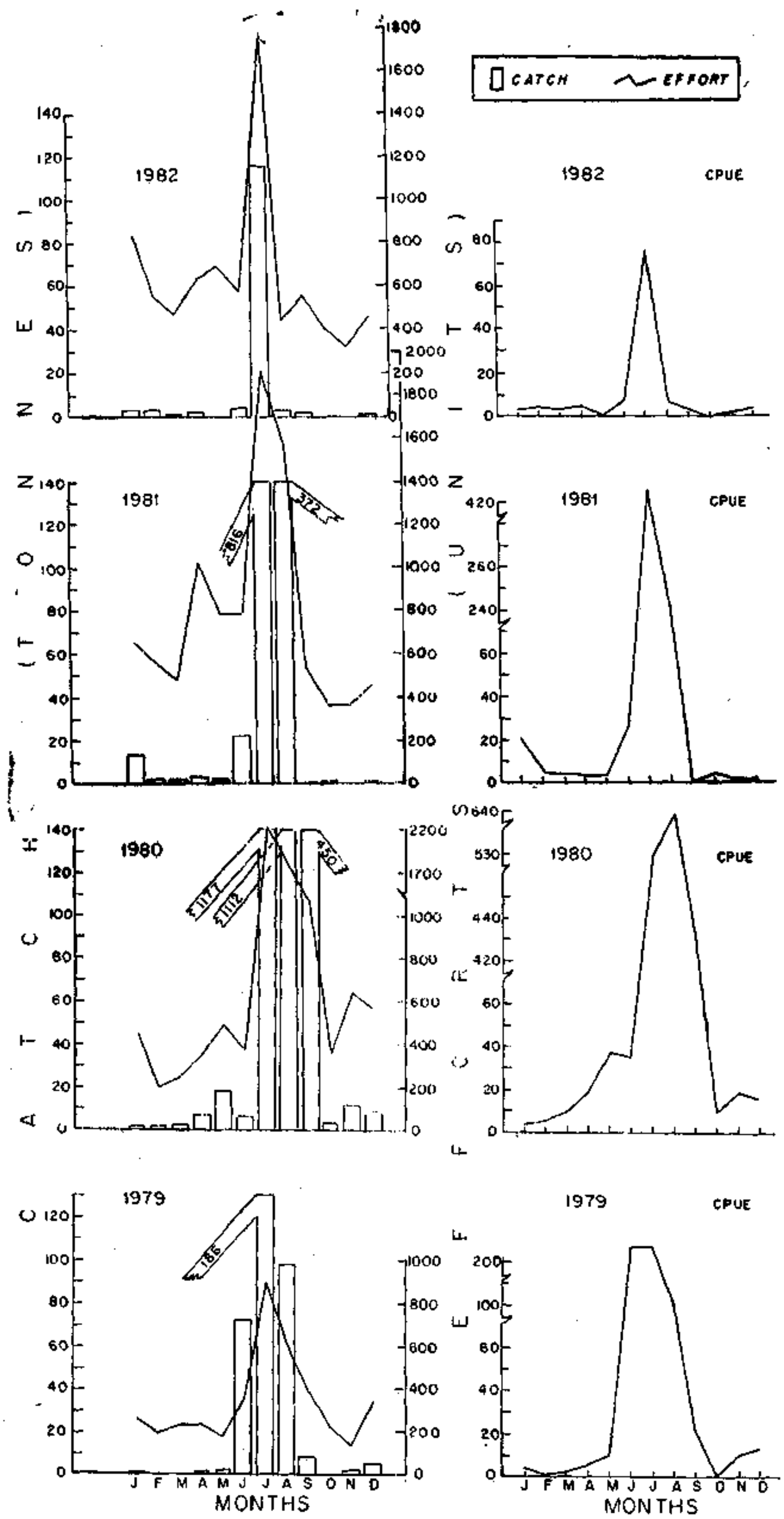

Fig. 2. Catch effort relationship and catch per unit effort of tunas at Tuticorin, 1979-'82.

November '82. But in October '82 the tuna landing was cmopletely nil even though 400 drift gill nets were operated. Totally the tuna landing was very poor during the year 1982, especially in the season June to September.

Species composition

The species composition showed that *E. affinis* formed 57.7%, 14.8%, 28.7% and 79% during the years 1979, 1980, 1981 and 1982 respectively (Fig. 3). *A. thazard* formed 27.8%, 82.6%, 61.3% and 11.1% during 1979, 1980, 1981 and 1982 respectively *S.orientalis* formed 13.7%, 0.9%, 5.3% and 7.0% during 1979, 1980, 1981 and 1982 respectively. The occurrence of *S. orientalis* is only seasonal, from June to September. *T. albacares* occurred as 0.3%, 0.2%, 2.4% and 1.4% during 1979, 1980, 1981 and 1982

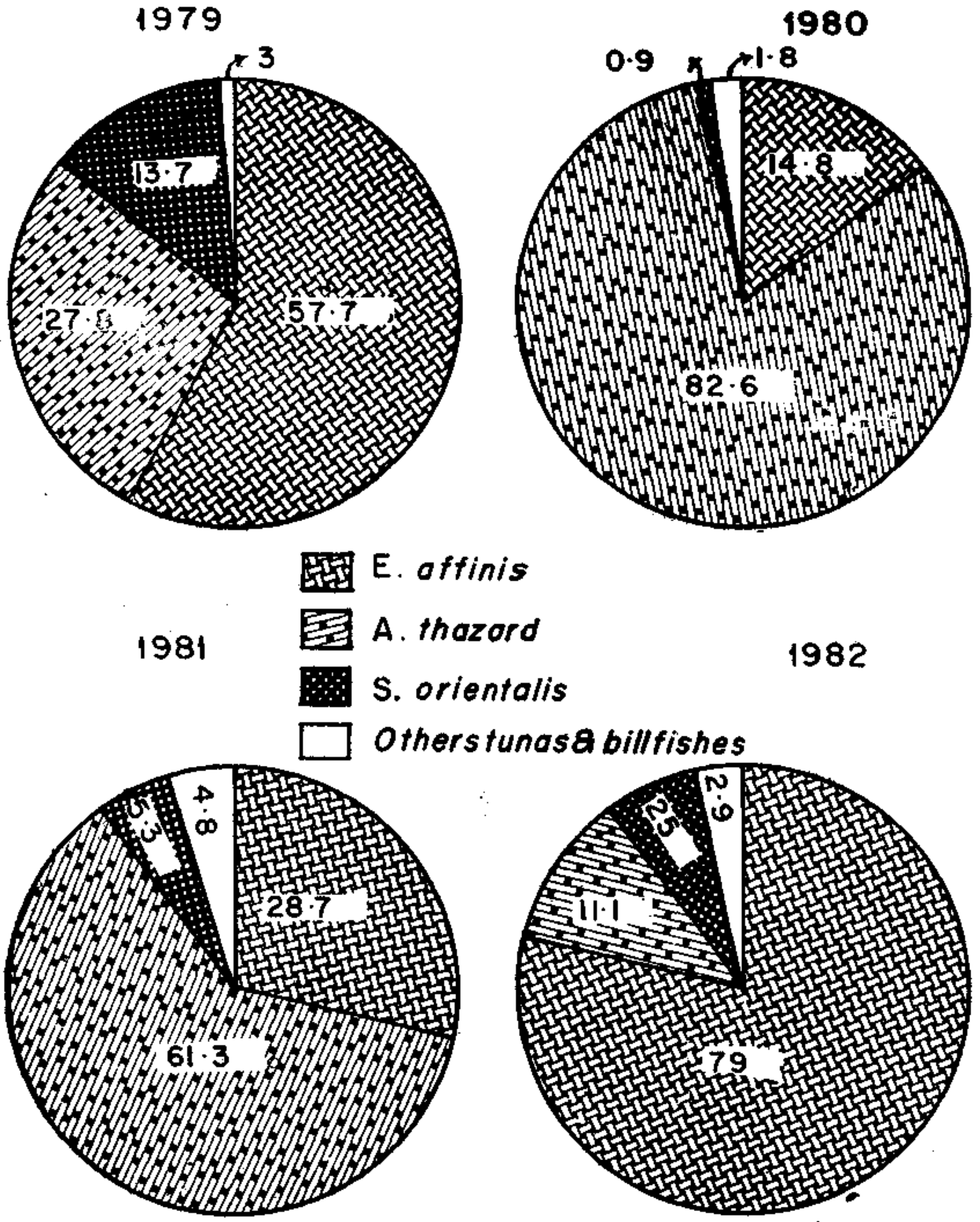

Fig. 3. Percentage composition of different species of tunas at Tuticorin, 1979-'82.

The annual catch per unit effort of tuna and related fishes by drift gill nets during 1979, 1980, 1981 and 1982 was 94, 324, 131 and 18 kg respectively. The minimum annual catch per unit effort was recorded as 18 kg during the year 1982 and the maximum of 324 kg during 1980 (Fig. 2).

respectively. In 1979 *T. albacares* occurred only in August and December; but in 1980, during July, August, September, November and December; in 1981, during June, July, August, October and December and in 1982, during February, July, August, November and December.

T. tonggol was completely absent during the year 1979. It was recorded as 0.08%, 0.02% and 0.06% during the years 1980, 1981 and 1982 respectively. In 1980, it occurred only in June, July and September, in 1981 in July and August; and in 1982 February, June and December.

The occurrence of *K. pelamis* was also sporadic. During 1979, 1981 and 1982 the percentage composition was recorded only as 0.04. During 1979, it occurred only in June; it was completely absent in 1980; in 1981, in July and August; and in 1982, in December.

The species composition of *I. platypterus* was recorded as 0.4%, 1.5%, 2.3% and 1.4% during 1979, 1980, 1981 and 1982 respectively. In 1979, it occurred in June, August and September; in 1980, from June to September; in 1981, in July, August, October and December; and in 1982, in February, April, July, August and September.

Length-weight relationship and sex ratio

Except for the information presented by Silas (1967), there is no published data on the length-weight relation ship of tuna species from the Tuticorin waters. The length-weight relationship of the different species of tunnies such as *E. affinis*, *A. thazard*. *S. orientalis*, *T. albacares*. *T. tonggol* and *K. pelamis* and the billfish I. *platypterus* and their sex ratio were studied.

Length-weight relationship of each fish can be expressed by the formula

$$W = aL^b$$

where W = weight, L = length and a and b are constants. The weight and length were related by using the logarithmic transformation of the formula:

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

where, a and b are constants.

250 specimens of *E. affinis* (12.0 to 74.0 cm F.L. and weighing 0.012 to 5.25 kg) were analysed for length-weight relationship and out of that 165 fish sexed (81 males and 84 females) (Figs. 4 & 5).

The regression equation obtained were as follows:

E. affinis

Pooled .. $\log W = -12.1073 + 3.2944 \log L$
Male .. $\log W = -11.0248 + 3.0176 \log L$
Female .. $\log W = -11.5219 + 3.1819 \log L$

250 specimens of the frigate mackerel *A. thazard* ranging from 12.9 to 53.0 cm (FL) and weighing 0.02 to 3.25 kg were taken for the length-weight relationship study (Figs. 4 & 5). Of these, 118 fish sexed showed 52 males and 66 females.

A. thazard

Pooled .. $\log W = -12.8176 + 3.5139 \log L$
Male .. $\log W = -13.3054 + 3.6566 \log L$
Female .. $\log W = -13.6580 + 3.7733 \log L$

250 specimens of the oriental bonito *S. orientalis*, measuring from 14.0 to 59.6 cm (FL) and weighing 0.028 to 3.75 kg were analysed for length-weight relationship (Figs. 4 & 5). Sixty-nine fish sexed showed 29 males and 40 females.

S. orientalis

Pooled .. $\log W = -12.4968 + 3.4245 \log L$
Males .. $\log W = -7.5065 + 2.2028 \log L$
Female .. $\log W = -7.8291 + 2.3125 \log L$

A total of 44 specimens of northern bluefin tuna *T. tonggol* 45.0 to 73.0 cm (FL) and weighing 2.5 to 5.25 kg were examined for length-weight relationship (Figs. 4 & 6). Nineteen fish sexed showed 11 males and 8 females.

T. tonggol

Pooled .. $\log W = -4.9640 + 1.5440 \log L$
Male .. $\log W = -7.3655 + 2.0881 \log L$
Female .. $\log W = -7.9001 + 2.2319 \log L$

Only 7 specimens of the skipjack tuna *K. pelamis*, have been analyses for length-weight relationship, ranging from 46.6 to 58.0 cm (FL) and weighing 2.75 to 5.0 kg. Of these 3 were males and 4 females (Fig. 6).

K. pelamis

Pooled .. $\log W = -7.7149 + 2.2656 \log L$
Male .. $\log W = -8.0315 + 2.3017 \log L$
Female .. $\log W = -11.1618 + 3.1219 \log L$

Totally 240 specimens of sailfish *I. platypterus* of 66.6 to 267.5 cm (FL) and weighing 1.75 to 55 kg were analysed for the length-weight relationship. Seventeen fish sexed showed 4 males and 13 females (Figs. 4 & 6).

I. platypterus

Pooled .. $\log W = -9.7075 + 2.4947 \log L$
Male .. $\log W = -8.0835 + 2.1790 \log L$
Female .. $\log W = -11.0484 + 2.7787 \log L$

According to Silas (1967), the weight and length were related by using the equation. $\log W = a + b \log L$

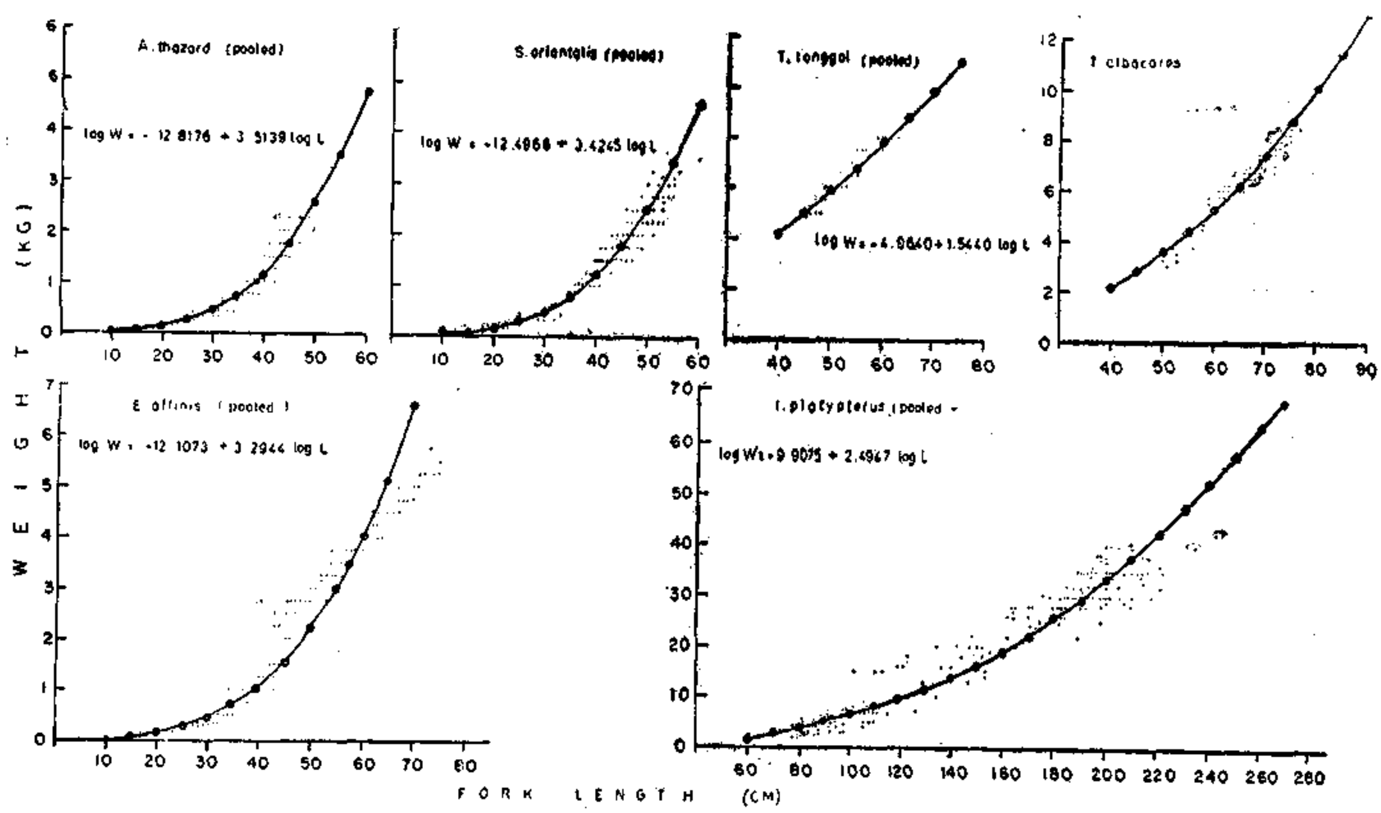

Fig. 4. Length-weight relationship of *A. thazard, S. orientalis, T. tonggol, T. albacares, E. affinis* and *I. platypterus* (pooled) at Tutcorin, 1979-'82.

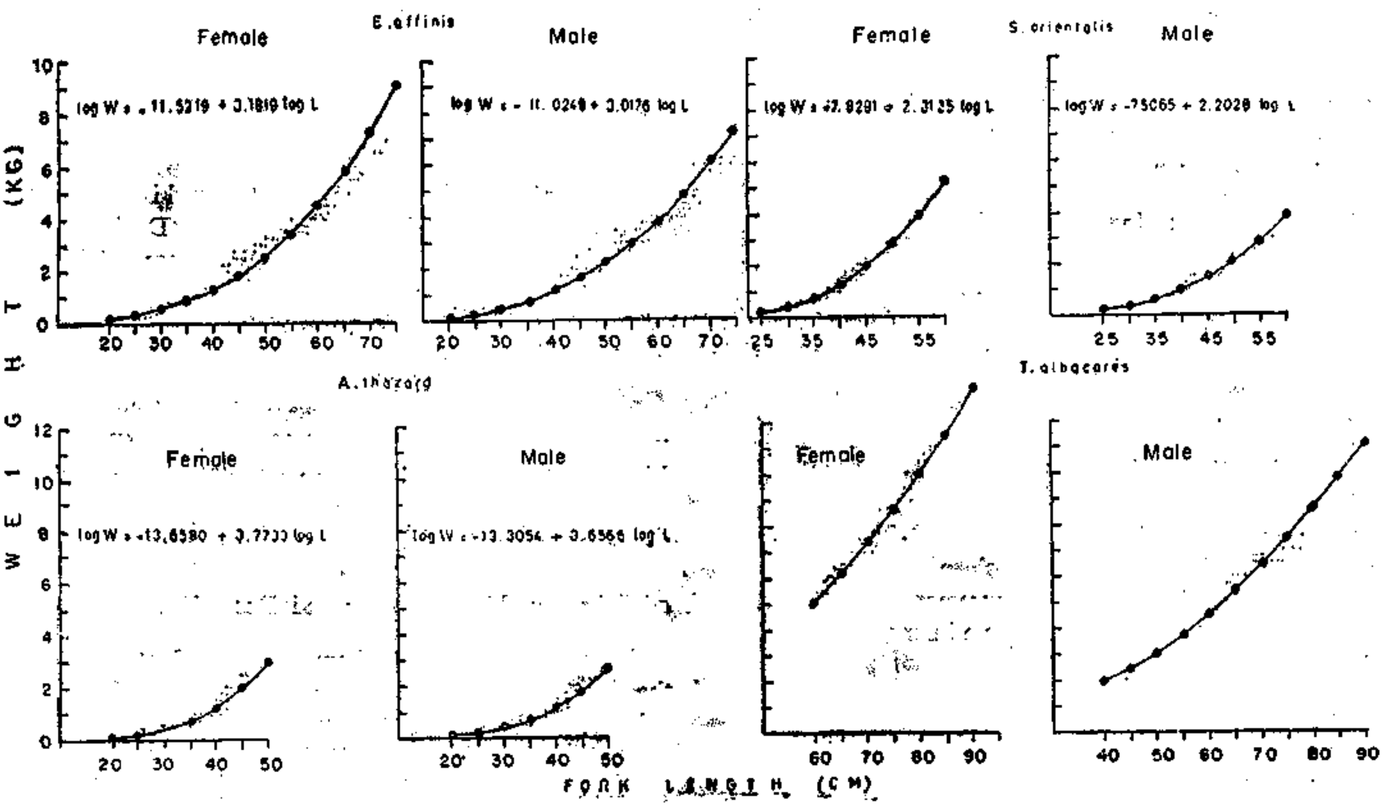

Fig. 5. Length-weight relationship of females and males of *E. affinis, S. orientalis, A. thazard* and *T. albacares* at Tuticorin.

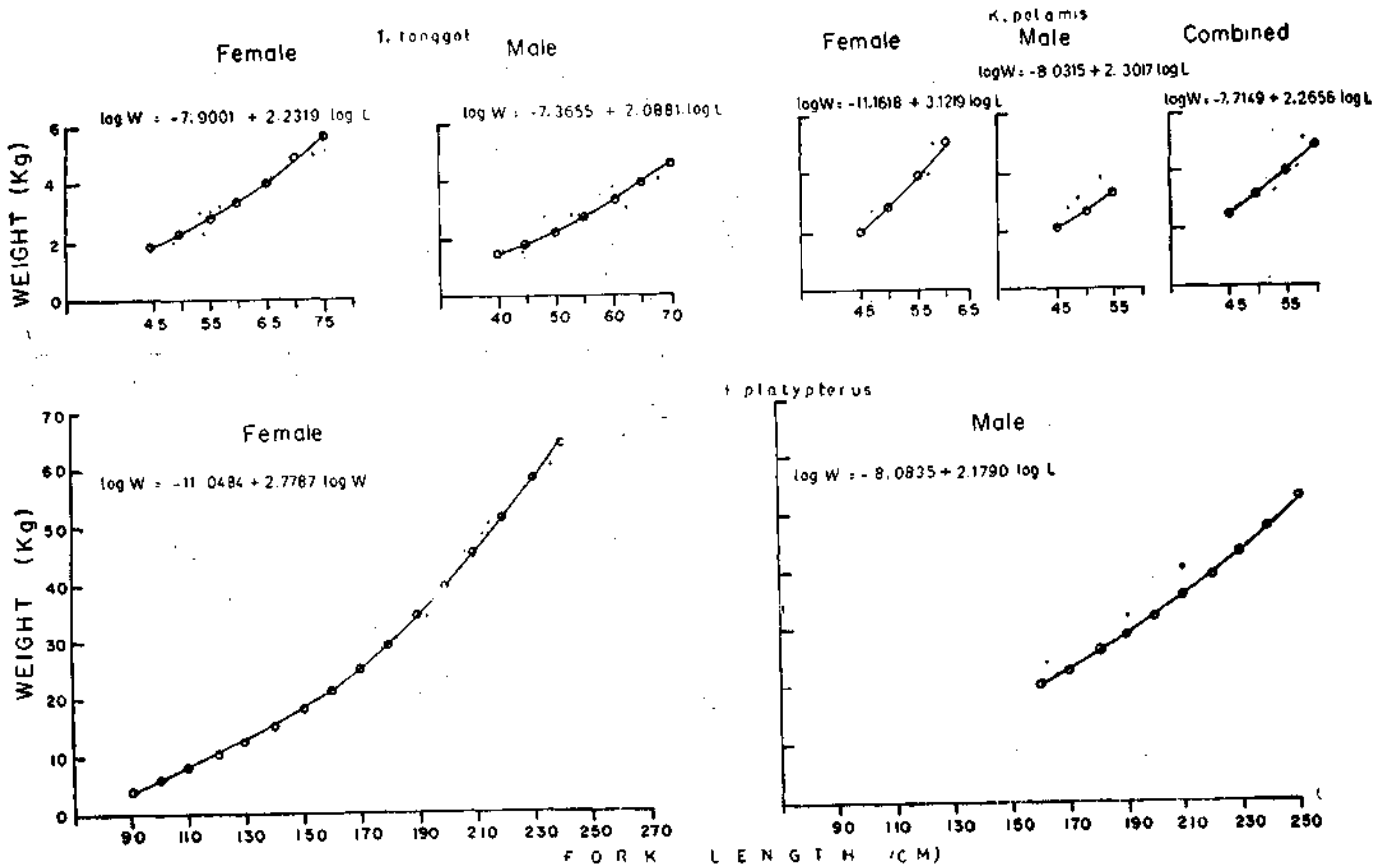

Fig. 6. Length-weight relationship of males and females of *T. tonggol*, *K. pelamis* and *I. platypterus* at Tuticorin.

is almost same and the fit was found to be good in the present study also. The regression equations obtained by him were as follows :

Yellowfin tuna	:	$\log W = -7.3781 + 3.0056 \log L$
Northern bluefin tuna	:	$\log W = -6.1708 + 2.5128 \log L$
Little tunny	:	$\log W = -7.5442 + 3.0287 \log L$

Size distribution

The size distribution of the tunnies in the Gulf of Mannar has been given by Silas (1967) for *T. tonggol* *T. albacares* and *E. affinis*. Six species of tuna and tuna-like species and the sailfish off Tuticorin were selected for taking length measurements. The length measurements were grouped at 2 cm intervals and length frequency curves were plotted.

Totally 12, 90, 155 and 5 specimens in the size range 66.5 to 267.5 cm (FL) of the sailfish, *I. platypterus* were examined for size distribution during 1979, 1980, 1981 and 1982 respectively.

The percentage frequency in the various size groups of the different species are worked out (Figs. 7-14).

For *E. affinis* major modes were observed in the range of 30 to 74 cm during the year 1979. During 1980 major modes were observed in the range of 14 to 68 cm. In 1981, the major modes were in the range from 30 to 68 cm. In 1982, major modes were observed in the range of 30 to 70 cm (Figs. 7 & 8).

In *A. thazard* major modes were observed during the year 1979 in the size range of 18 to 52 cm (Fig. 19). Major modes were in the range of 13 to 40 cm during 1980 (Fig. 64). During the year 1981 major modes were observed in the size range of 18 to 40 cm (Fig. 10). In 1982 no major mode was observed during the months of February, May, October and December.

S. orientalis occurred from June to September in the size range 40 to 54 cm. In 1980, it occurred during July to September and there were 11 modes in the size range of 14 to 44 cm. In 1981, also it occurred from July to September and 9 modes were observed in the range of 26 to 60 cm. During the year 1982, it was

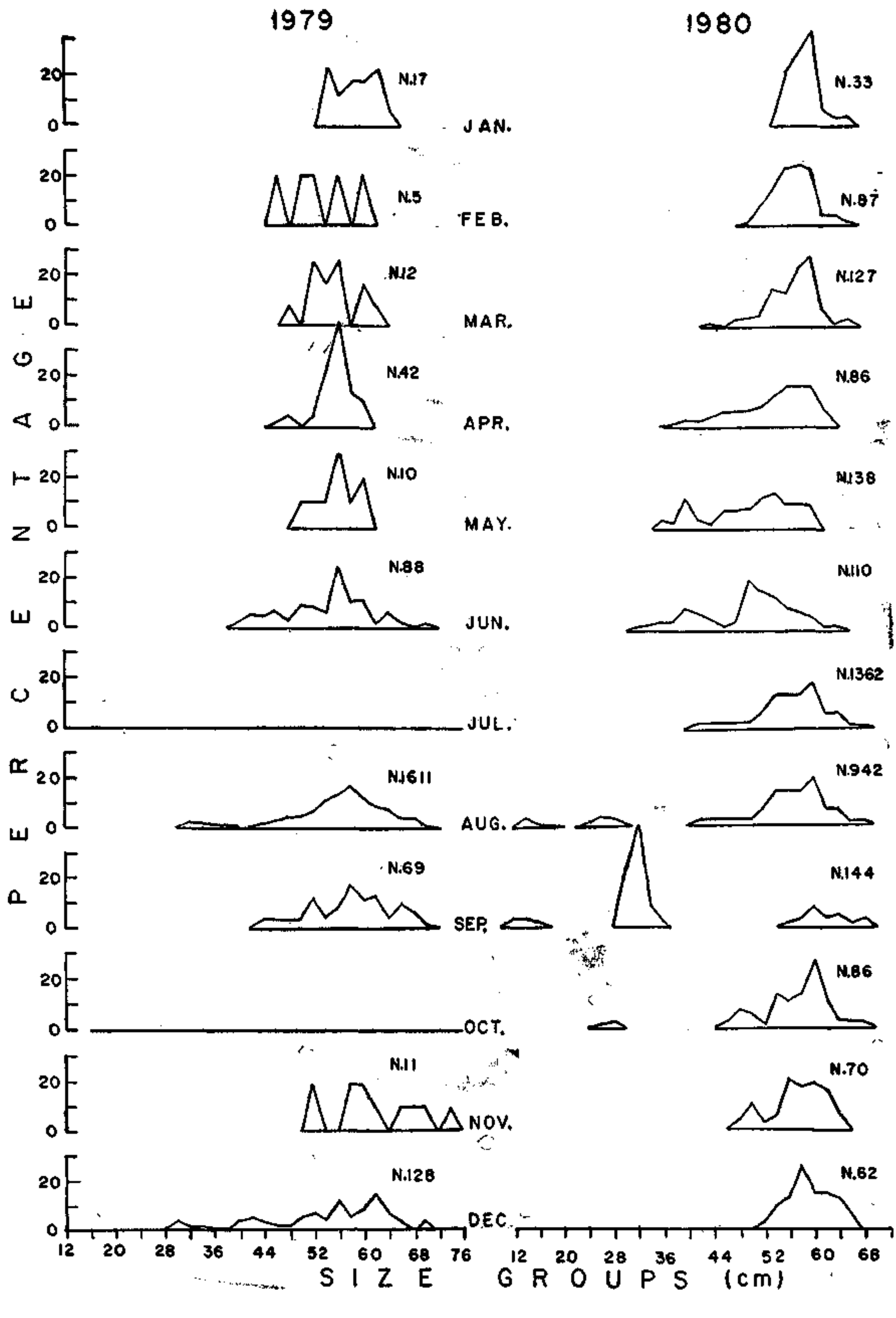

Fig. 7. Monthly length frequency distribution of *E. affinis* at Tuticorin, 1979-'80.

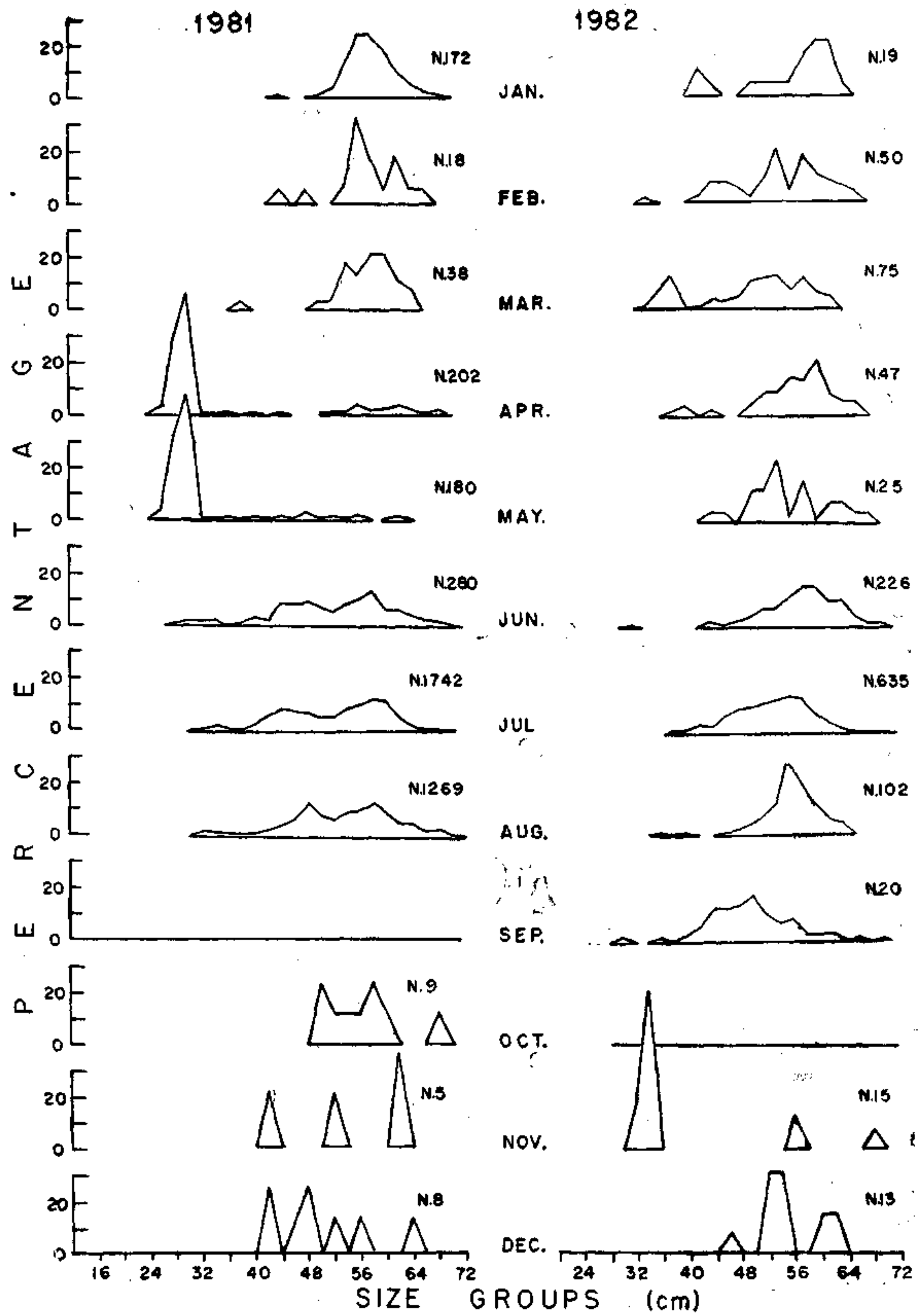

Fig. 8. Monthly length frequency distribution of *E. affinis* at Tuticorin, 1981-'82.

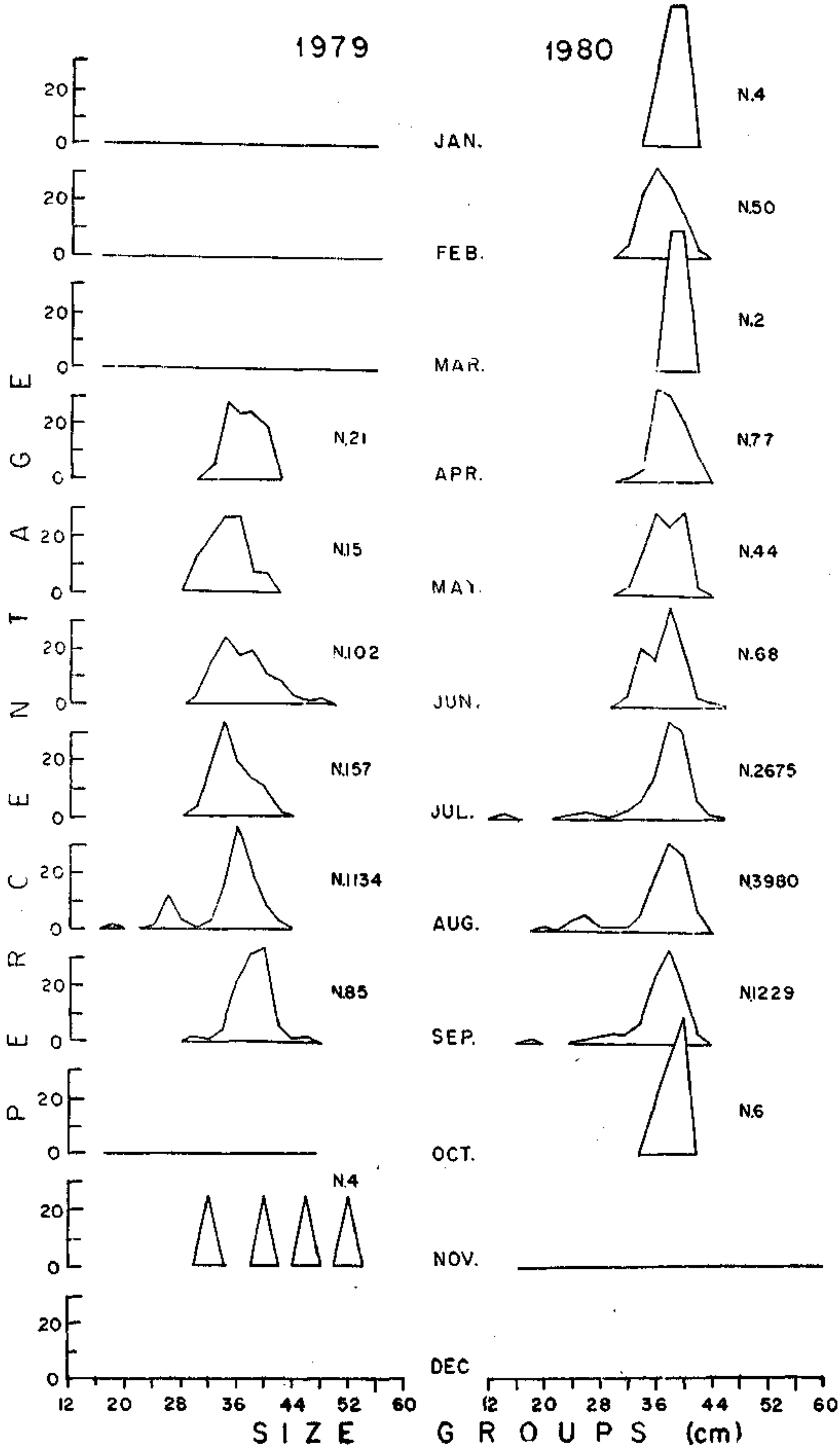

Fig. 9 Monthly length frequency distribution of *A. thazard* at Tuticorin, 1979-'80.

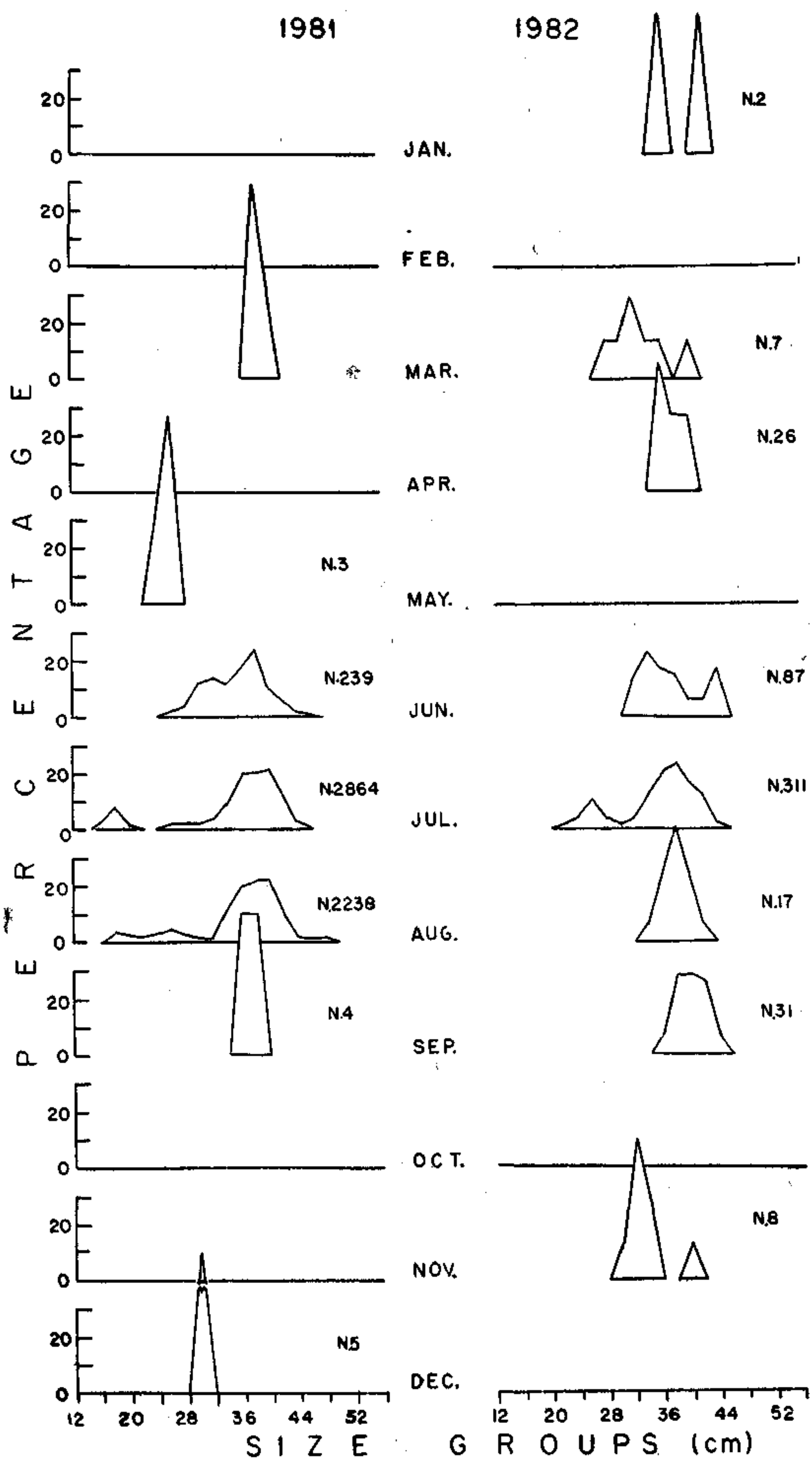

Fig. 10. Monthly length frequency distribution of *A. thazard* at Tuticorin, 1981-'82.

present only during July and only major modes were observed, in the size range 36 to 48 cm (Figs. 11 & 12).

T. albacares occurred in August and September in 1979, 8 modes were observed in the size range of 52 to 74 cm. 15 modes were observed during 1980 in the size range 62 to 88 cm. when the species occurred in the month of July, August, September, November December. A single mode was observed in the month of November (Figs. 13 & 14).

T. tonggol was completely absent in the catches during the year 1979. In June 1980, it occurred in June, July and September with 5 major modes in the range of 44 to 64 cm.

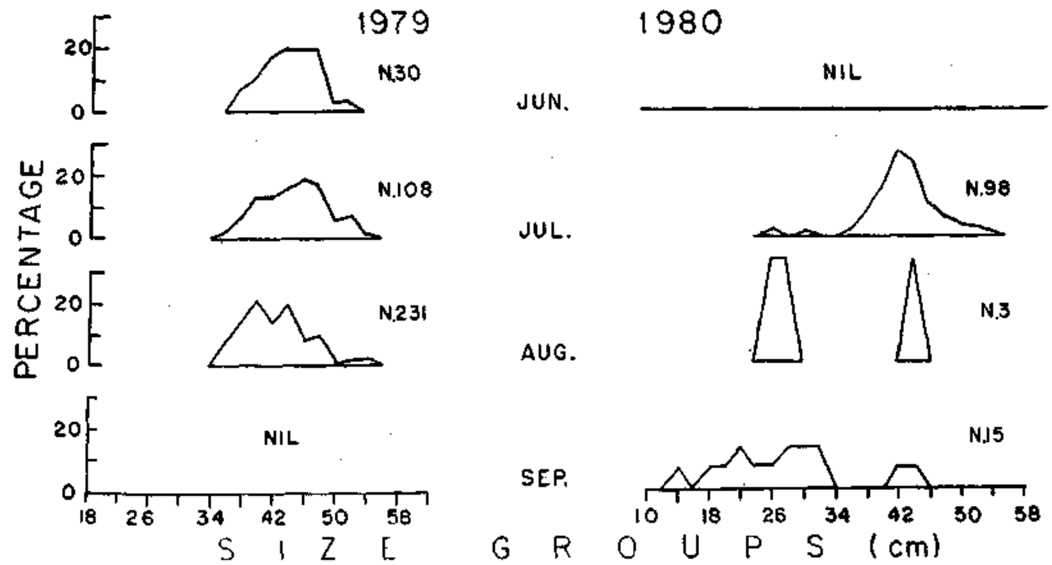

Fig. 11. Monthly length frequency distribution of *S. orientalis* at Tuticorin, 1979-'80.

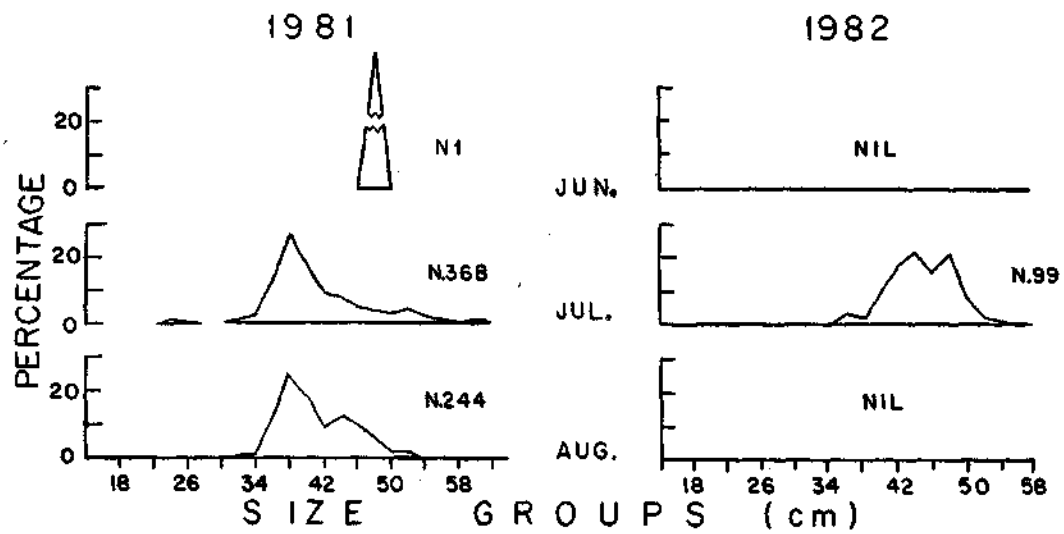

Fig. 12. Monthly length frequency distribution of *S. orientalis* at Tuticorin, 1981-'82.

and December. In 1981 *T. albacares* occurred during June, July, August, October and December. There was a single mode each in June and December. In 1982 it was present during of July, August, November and

In *K. pelamis* which is very rare in the Tuticorin waters only two modes were observed in the range of 56 to 60 cm during the year 1979. In 1981 and 1982 major modes were in August and December respectively.

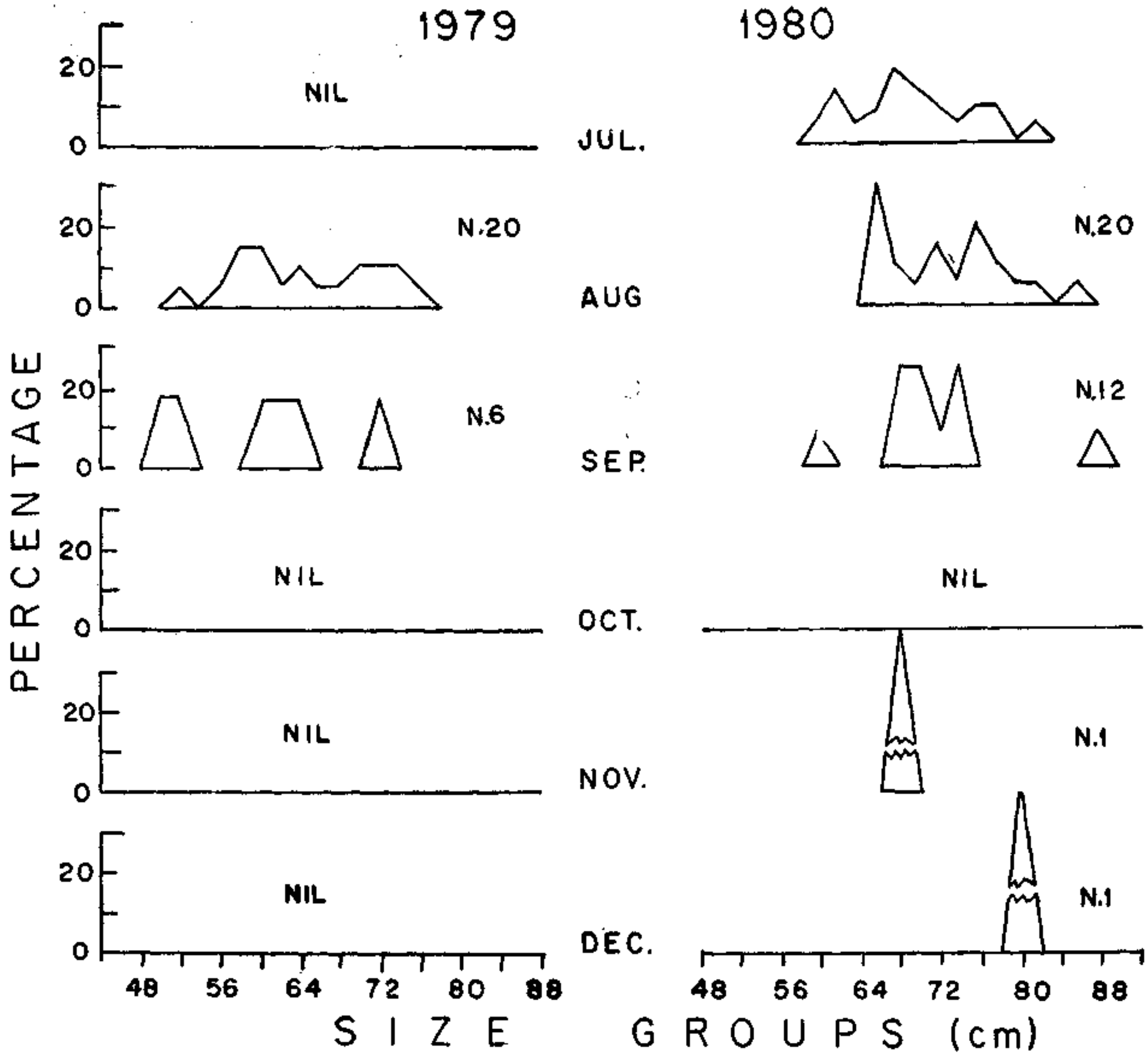

Fig. 13. Monthly length frequency distribution of *T. albacares* at Tuticorin, 1979-'80.

I. platypterus occurred in June, August and September in 1979 in the size range 100 to 250 cm. In 1980, they occurred in the size range of 90 to 220 cm from June to September. In 1981, their size ranged between 60 and 260 cm and they occurred in June, July, August, October and December. During 1982, they were present in February, July, August and September.

The occurrence of young specimens of tunas in the inshore waters off Tuticorin is seasonal and they were regularly present in the catches during July to September since 1976.

The stomach contents of the adults of *E. affinis*, *A. thazard*, *S. orientalis*, *T. albacares*, *T. tonggol* and *K. pelamis* and the sailfish *I. platypterus* in Tuticorin waters were analysed and the results are given below :

E. affinis

10 specimens in the size range 26.5 to 73.3 cm (FL) were examined during 1980 and 1981.

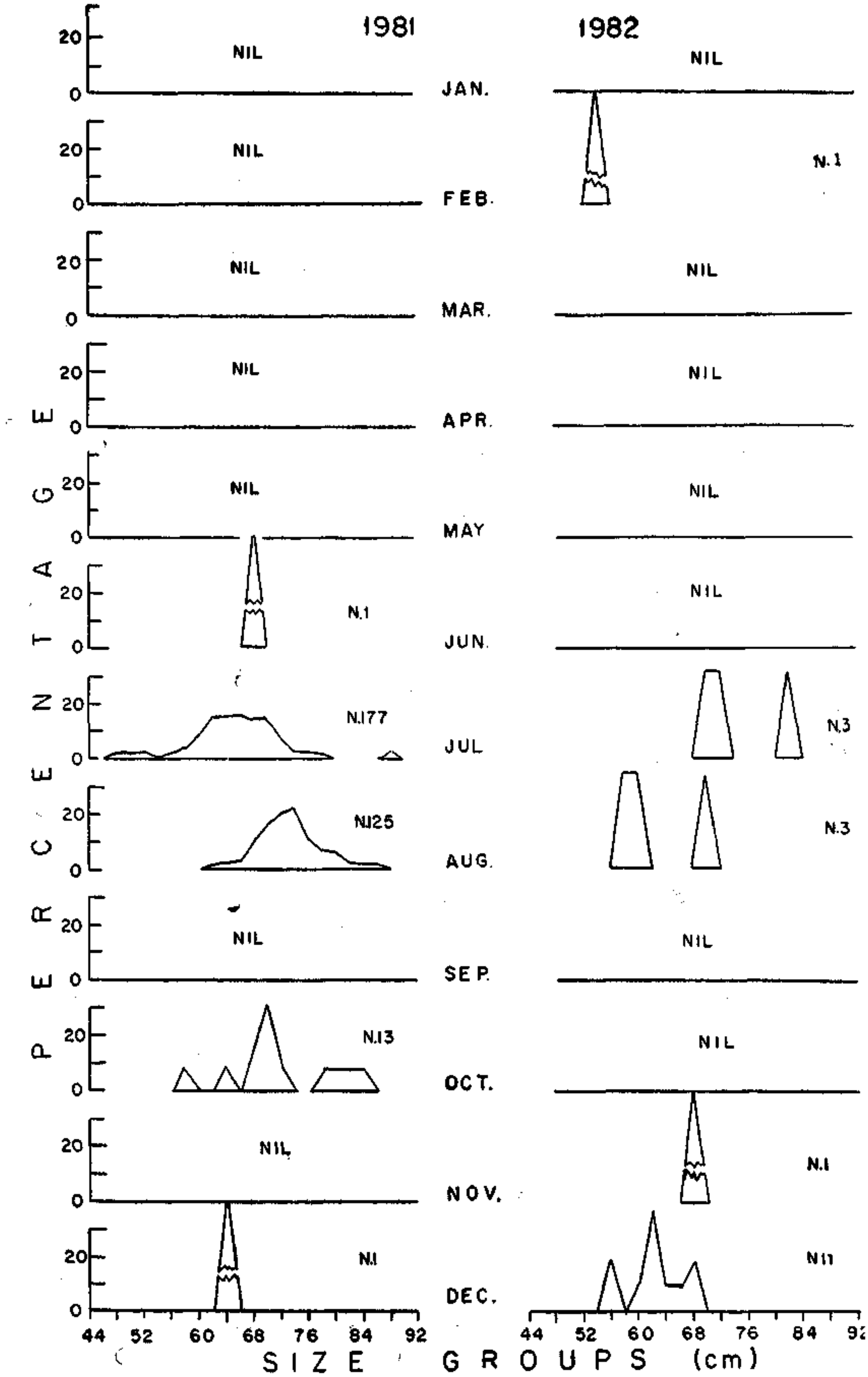

Fig. 14. Monthly length frequency distribution of *T. albacares* at Tuticorin, 1981-'82.

The visual gradings of the fullness of the stomach for the 10 specimens were as follows :

Grading		Percentage
Empty	..	40%
Trace	..	10%
1/4 + or —	..	10%
1/2 + or —	..	20%
3/4 + or —	..	—
Full (gorged)	..	20%

From Table 1 it appears that from the actual volume, *Sardinella* spp. constituted (88%) an important item among the food organisms of *E. affinis.*

TABLE 1. *List of food items of* E. affinis

Constituents		No. of occurrence	Percentage of prevalence	Actual volume ml.	Percentage by volume	Actual No. of food organisms
Sardinella spp.	..	2	20	88.0	47.3	22
Unidentified fish	..	2	20	72.0	38.7	10
Skeletal remains of fish	..	2	20	26.0	14.0	..

A. thazard

28 specimens of *A. thazard* in the size range of 25.0 to 45.5 cm (FL) were examined during 1980 and 1981.

The visual grading of the fullness of the stomach for the 28 specimens was as follows :

Grading		Percentage
Empty	..	78.6
Trace	..	7.1
1/4 + or —	..	7.1
1/2 + or —	..	3.6
3/4 + or —	..	3.6
Full (gorged)	..	—

From Table 2 it will be seen that, when compared to the young the adult feeds on both fish as well as crustacean zooplankton and squids. A major food item of the adult *A. thazard* appears to be *Loligo* sp. (61.0% by volume).

TABLE 2. *List of food items of* A. thazard

Constituents		No. of occurrence	Percentage of prevalence	Actual volume ml.	Percentage by volume	Actual No. of food organisms
Anchoviella commersonii	..	1	5.9	7.0	14.2	1
Fish remains	..	2	11.8	0.7	1.4	..
Squid—*Loligo* sp.	..	1	5.9	30.0	61.0	2
Fish larvae	..	1	5.9	4.0	8.1	46
Copepods	..	2	11.8	2.0	4.1	340
Decapod larvae	..	2	11.8	2.5	5.1	445
Amphipods	..	2	11.8	0.9	1.8	16
Megalopa larvae		1	5.9	1.1	2.2	9
Pteropods	..	1	5.9	Trace	..	1
Unidentified zooplankton	..	2	11.8	1.0	2.0	32

S. orientalis

Altogether 17 specimens of *S. orientalis* in the size range of 23.2 to 42.8 cm (FL) were examined during 1980-'82.

The visual grading of the fullness of the stomach for the 17 specimens was as follows :

Grading		Percentage
Empty	..	53.0
Trace	..	11.8
1/4 + or —	..	5.8
1/2 + or —	..	11.8
3/4 + or —	..	5.8
Full (gorged)	..	11.8

From Table 3 it will be seen that with regard to the preponderance *Sardinella* spp. constituted an important item followed by squids (*Loligo* sp.). But by volume, the young of *A. thazard* of 18.0 cm long (FL) was important.

Kumaran (1964) investigated the food habits of *S. orientalis* and pointed out that the most important single food item was *Anchoviella commersonii* and further he added that the food content of *S. orientalis* is similar to that of *E. affinis* and *A. thazard*, but in the present study it was observed that *S. orientalis* feeds mostly on *Sardinella* spp. 17.6% by prevalence and squids 11.8% by occurrence.

TABLE 3. *List of food items of* S. orientalis

Constituents		No. of occurrence	Percentage of prevalence	Actual volume ml.	Percentage by volume	Actual No. of food organisms
Sardinella sp.	..	3	17.6	64.8	38.3	5
A. thazard (young one)	..	1	5.8	68.4	40.4	1
Squids (*Loligo* spp.)	..	2	11.8	35.6	21.1	6
Skeletal remains of fish	..	2	11.8	0.3	0.2	Trace

T. tonggol

12 specimens of *T. tonggol* in the size range of 44.5 to 73.0 cm (FL) were examined during 1980-'82.

The visual grading of the fullness of the stomach for the 12 specimens was as follows :

Grading		Percentage
Empty	..	58.3
Trace	..	16.7
1/4 + or —	..	16.7
1/2 + or —	..	—
3/4 + or —	..	8.3
Full (gorged)	..	—

From the Table 4 it will be seen that both from the number of actual food organisms as well as the actual volume *Loligo* spp. constituted the most important item of food of *T. tonggol* (72.9%) followed by *Sardinella* spp. (13.2% by volume). The third item was *Sillago sihama* (10.7% by volume).

TABLE 4. *List of food items of* T. tonggol

Constituents		No. of occurrence	Percentage of prevalence	Actual volume ml.	Percentage by volume	Actual No. of food organisms
Loligo sp.	..	1	8.3	68.0	72.9	5
Sardinella spp.	..	1	8.3	12.3	13.2	2
Sillago sihama	..	1	8.3	10.0	10.7	1
Skeletal remains of fish	..	1	8.3	3.0	3.2	Trace

T. albacares

4 specimens of *T. albacares* in the size range of 58.0 to 87.9 cm (FL) were examined in 1980. The visual grading of the fulness of the stomach for the 4 specimens was as follows :

Grading		Percentage
Empty	..	50
Trace	..	—
1/4 + or —	..	25
1/2 + or —	..	—
3/4 + or —	..	—
Full (gorged)	..	25

From Table 33 it will be seen that both from the number of occurrence as well as the actual volume, the juveniles of *A. thazard* constitute an important item of food of *T. albacares*.

TABLE 5. *List of food items of* T. albacares

Constituents		No. of occurrence	Percentage of prevalence	Actual volume ml.	Percentage by volume	Actual No. of food organisms
A. thazard (young ones)	..	1	25	80.0	80.8	12
Unidentified fish	..	1	25	19.0	19.2	3

K. pelamis

4 specimens of *K. pelamis* in the size range of 48.5 to 58 cm (FL) were examined in 1979 and '82.

The visual grading of the fullness of the stomach for the 4 specimens was as follows :

Grading		Percentage
Empty	..	50
Trace	..	—
1/4 + or —	..	—
1/2 + or —	..	—
3/4 + or —	..	25
Full (gorged)	..	25

From Table 6 it is evident that both from the number of actual food organisms as well as the actual volume, *Sardinella* spp. followed by juveniles of *A. thazard* (36.4% by volume) constituted important items of food.

TABLE 6. *List of food items of* K. pelamis

Constituents		No. of occurrence	Percentage of prevalence	Actual volume ml.	Percentage by volume	Actual No. of food organisms
Sardinella spp.	..	1	25	85.0	63.7	14
A. thazard (juveniles)	..	1	25	48.7	36.4	2

I. *platypterus*

5 specimens of *I. platypterus* in the size range of 66.5 to 234.6 cm (FL) were examined during 1980 and '81.

The visual grading of the fullness of the stomach for the 5 specimens was as follows :

Grading		Percentage
Empty	..	40
Trace	..	—
1/4 + or —	..	—
1/2 + or —	..	20
3/4 + or —	..	20
Full (gorged)	..	20

From Table 7 it will be evident that both from the actual number of food organisms as well as the actual volume, *Sardinella* spp. constituted the important item of food (50.5% by volume) of *I. platypterus* followed by *Loligo* sp. (28.6% by volume) and *Kovala koval* (20.9% by volume).

TABLE 7. *List of food items of* I. platypterus

Constituents		No. of occurrence	Percentage of prevalence	Actual volume	Percentage by volume	Actual No. of food organisms
Sardinella spp.	..	1	20	60.0	50.5	4
Kovala koval	..	1	20	24.8	20.9	2
Loligo sp.	..	1	20	34.0	28.6	2

10

ON THE OCCURRENCE, SIZE DISTRIBUTION, MORPHOMETRY AND FEEDING HABITS OF THE JUVENILES OF *EUTHYNNUS AFFINIS* (CANTOR), *AUXIS THAZARD* (LACEPEDE), AND *SARDA ORIENTALIS* (TEMMINCK AND SCHLEGEL), ALONG THE TUTICORIN COAST, GULF OF MANNAR

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Very little information is available on the fishery and bionomics of juvenile tunas from Indian waters. In the present account the juveniles of three species of tuna-like fishes occurring in the fishery along the Tuticorin coast have been studied and the results presented. Morphometric and meristic characteristics, the biology as well as the food and feeding habits of *E. affinis*, *A. thazard* and *S. orientalis* are dealt with in the report.

Based on the data collected during the years 1976-'78 it may be stated that the peak season for tuna fishery at Tuticorin was from June to September. Heavy landings were noticed only at Veerapandianpatnam. Stray catches of the juveniles of *E. affinis*, *A. thazard* and *S. orientalis* were collected from Veerapandianpatnam, Kayalpatnam, Punnakayal and Tuticorin from the sardine gill net operations ('salavalai' of mesh size 3 to 3.2 cm) off Manapad from the 30-50 m depth zone.

During the year 1976, 1977 and 1978 seasons, 106, 115 and 106 specimens of the juveniles of *E. affinis*, *A. thazard* and *S. orientalis* in the size range of 6.2 to 19.8 cm, 12.9 to 19.6 cm and 9.8 to 19.9 cm in fork length and weighing from 3 to 100 gm, 20 to 100 gm and 7 to 95 gm respectively were recorded and examined Table 1. The specimens were collected during the fishing season July to September (Fig. 1).

Size distribution

The size range of the juveniles of *E. affinis* ranged from 6.2 to 19.8 cm (FL). The size range of *A. thazard* was recorded at 12.9 to 19.6 cm and *S. orientalis* from 9.8 to 19.9 cm. Most of the specimens come under the size group 12-16 cm (FL). The size distributions of the juveniles of *E. affinis*, *A. thazard* and *S. orientalis* are shown in Figs. 2 & 3. The percentage composition of *E. affinis* recorded was 13.3, 27.5 and 36.3 during the year 1976, 1977 and 1978 respectively. *A. thazard* recorded as 64.5, 31.5 and 49.1 per cent during 1976, 1977 and 1978 respectively. The percentage of *S. orientalis* was 22.2, 41.0 and 14.6 during the year 1976, 1977 and 1978 respectively (Fig. 4).

Length-weight relationship

The length-weight relationship of early juveniles of *E. affinis*, *A. thazard* and *S. orientalis* in the size

TABLE 1. *Occurrence of juveniles of*, E. affinis, A. thazard, and S. orientalis *at Tuticorin*, 1976-'78

Species	1976			1977			1978		
	July	August	September	July	August	September	July	August	September
E. affinis	..	42	1	..	26	..	..	36	1
A. thazard	30	17	..	15	14	..	20	19	..
S. orientalis	..	39	..	..	48	..	..	19	..

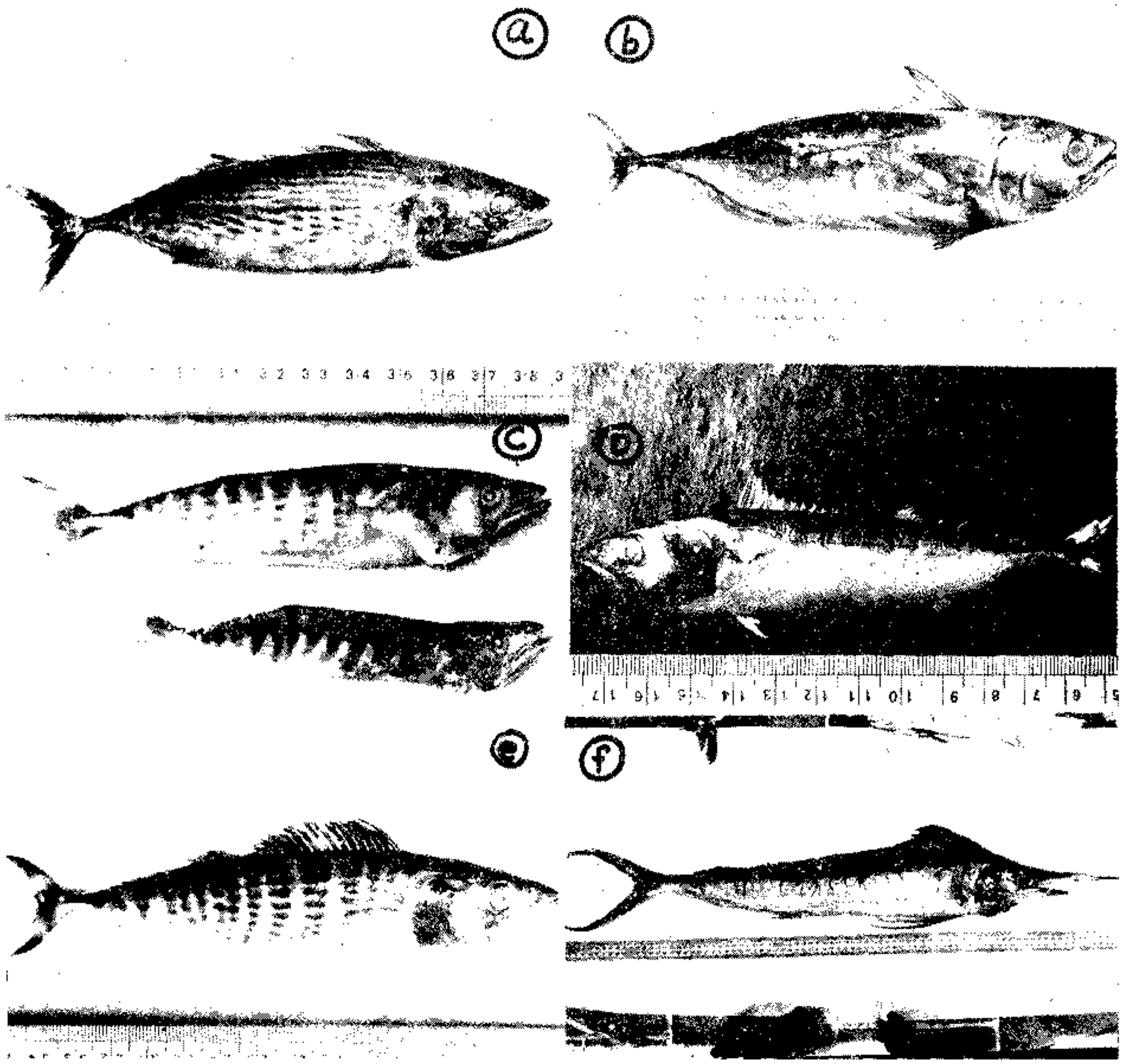

PLATE I. Young specimens of tunas and sailfish landed at Tuticorin. *a, c* and *e*. *Sarda orientalis*. *b*. *Euthynnus affinis*. *d*. *Auxis thazard*. *f*. *Istiophorus platypterus*.

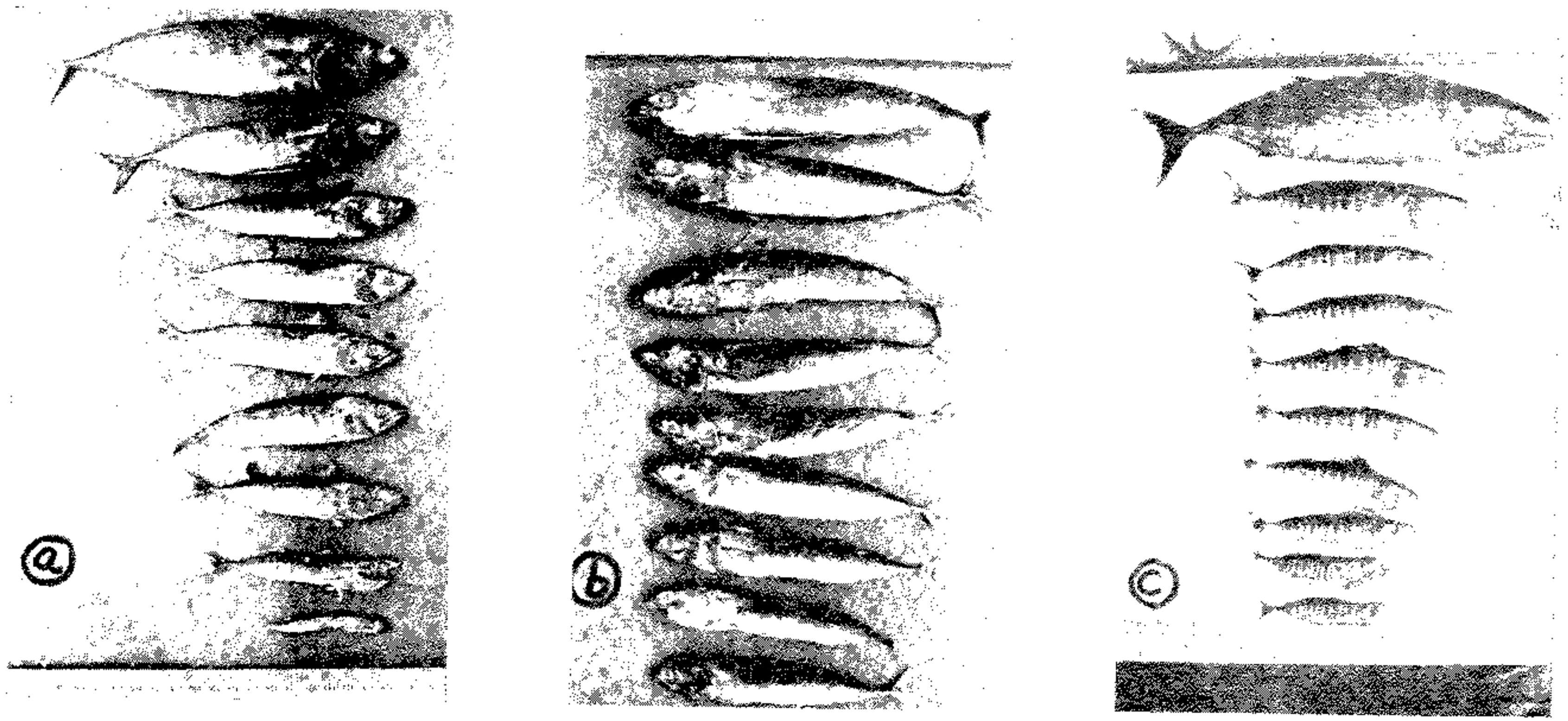

PLATE II. Juveniles and young specimens of tunas landed at Tuticorin. (a) *Euthynnus affinis*. (b) *Auxis thazard*. (c) *Sarda orientalis*.

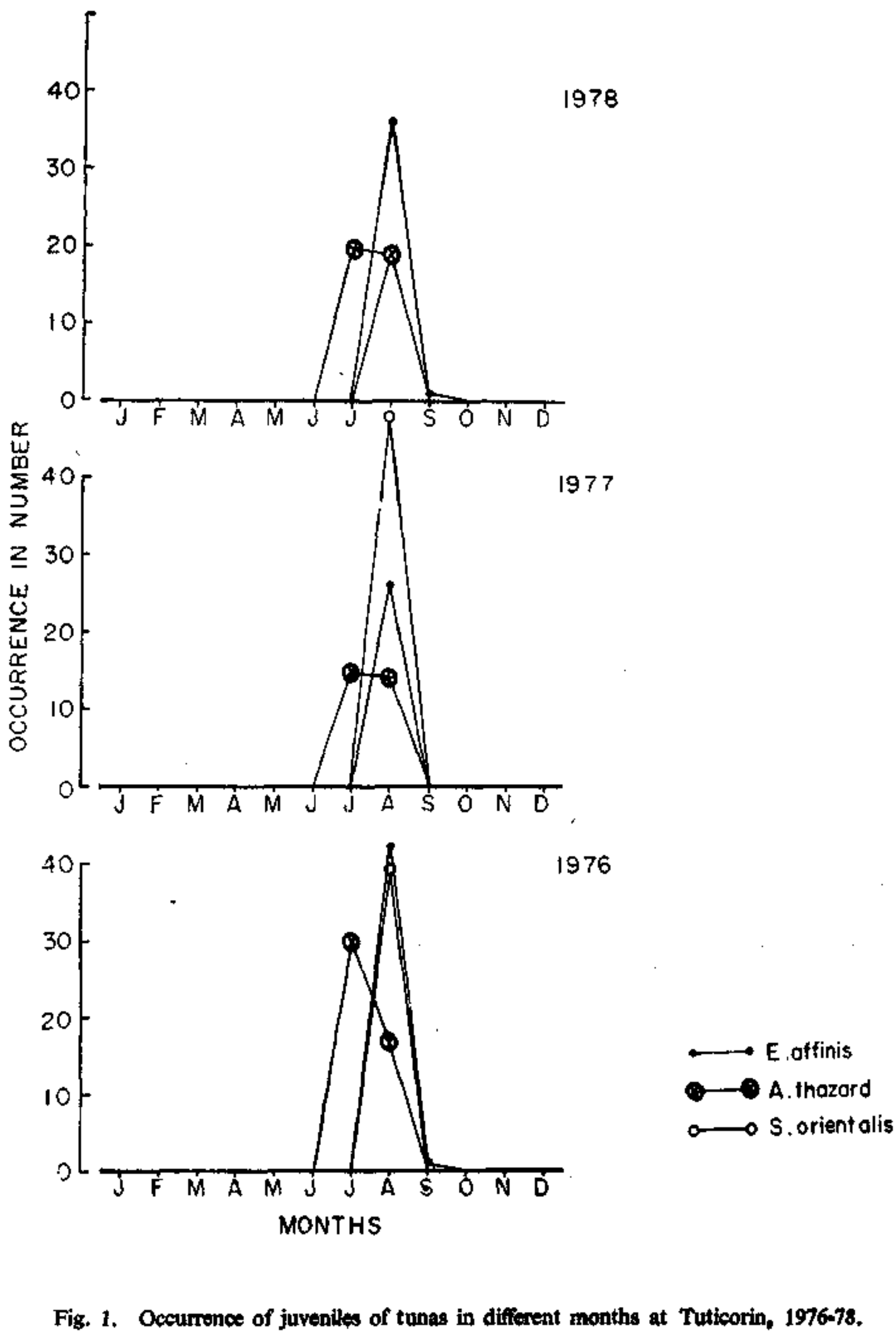

Fig. 1. Occurrence of juveniles of tunas in different months at Tuticorin, 1976-78.

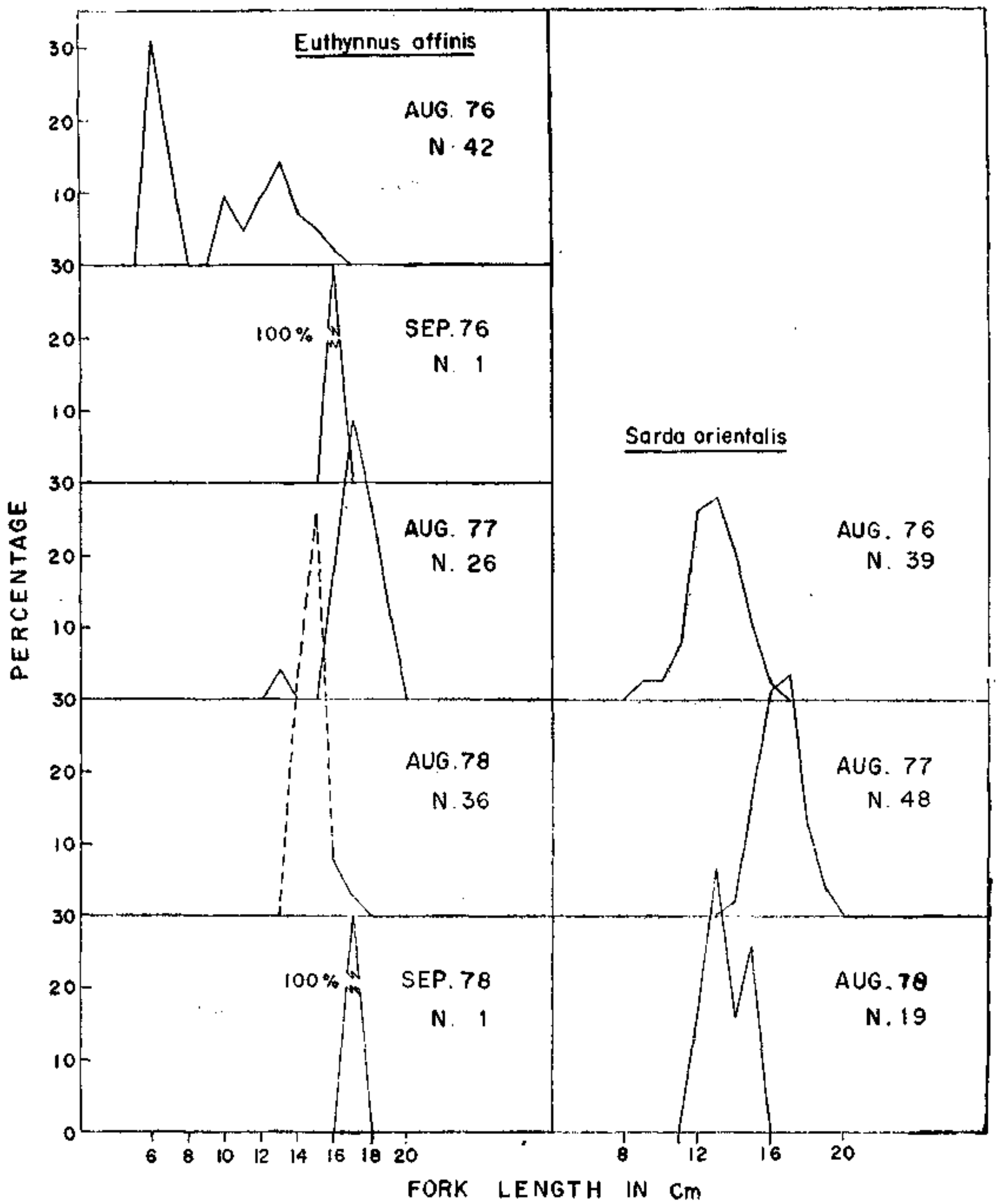

Fig. 2. Monthly length frequency distribution of the juveniles of *E. affinis* and *S. orientalis* at Tuticorin.

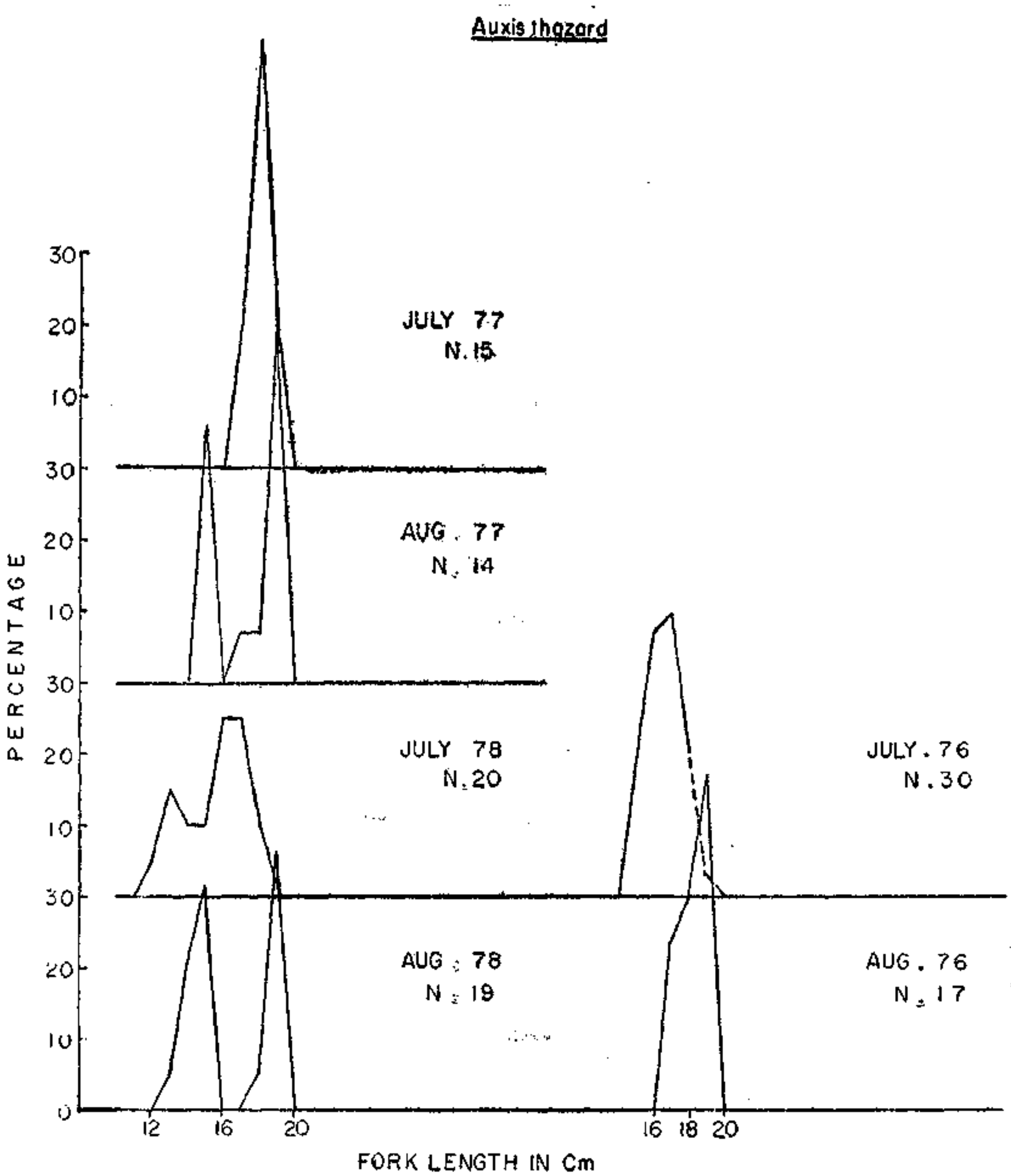

Fig. 3. Monthly length frequency distribution of the juveniles of *A. thazard* at Tuticorin.

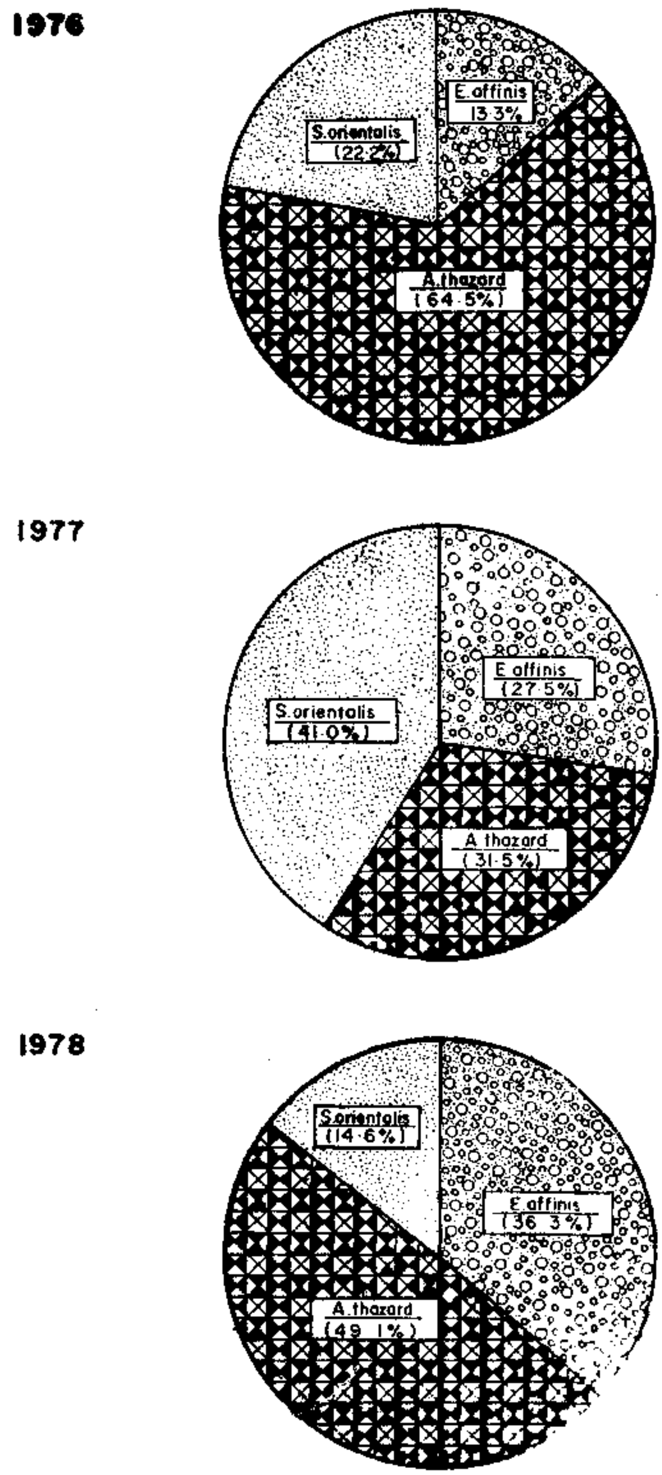

Fig. 4. Percentage composition of the juveniles of tunas at Tuticorin, 1976-'78.

range 6.2 to 19.9 cm in fork length are presented in Fig. 5.

Applying the formula $W = {}_{c}L^{n}$ the calculated length-weight relationship of the present materials of *E. affinis*, *A. thazard* and *S. orientalis* were found to be $W = 0.001039807.\ L^{3.85887}$, $W = 0.002208062.\ L^{3.56754}$ and $W = 0.003136932.\ L^{3.45514}$ respectively. In each case the fit was found to be good.

It may be noted, however, that the rate of increment in weight per unit length of tuna is very slow upto a size of 6 to 12 cm, after which the growth rate increases rapidly (Fig. 5).

The correlation between the different characters of the juveniles of *E. affinis*, *A. thazard* and *S. orientalis* are given in the form of trellis diagram (Fig. 6).

In this diagram, the values of the correlation between the different characters have been given in the form of symbols : '+', '—' and '0'. The '+' and '—' are positive values and '0' for negative value. The symbol '+' indicates the values of 0.5 and above but less than 1.0. The symbol '—' indicates the value less than 0.5 and '0' indicates the negative value of the correlation between the particular character. It was observed only in the juveniles of *E. affinis*. It means that the particular character is not showing correlation between the other character. The correlation between the eye diameter and other characters of the juveniles of *E. affinis* were very low and insignificant.

However, for *A. thazard* and *S. orientalis* the correlation between the eye diameter and other characters were found to be positive and significant. But in *E. affinis* it is not significant eventhough it has a positive value. In *A. thazard* (juveniles) also the height of the II dorsal fin is having only the positive values but not significant.

E. affinis

During the year 1976, 1977 and 1978 seasons the juveniles of this species were caught during very restricted periods. The length frequency of the species is presented in Fig. 2.

During the year 1976, 1977 and 1978 seasons over 106 specimens in the size range 6.2 to 19.8 cm in fork length and weighing from 3 to 100 g were examined. The length frequency of 106 specimens in the above size range landed during 1976 and 1978 (from August and September) and in 1977 (August) is presented in Fig. 1.

Meristic counts :

D1. XIV-XVI ; D2 + finlets — + 8 ; A + finlets — + 7 ; gill rackers 6—9 + 16 — 22.

The frequency of gill raker counts are given in Table 3.

TABLE 2. *Frequency of gill raker counts of* A. thazard

Counts		Upper limb 7	8	9	10	No. of specimens	Lower limb 19	20	21	22	23	24	25	26	27	specimens
No. of specimens	..	2	20	91	2	115	1	..	2	5	33	41	24	7	2	115
%	..	1.7	17.4	79.2	1.7		0.9	..	1.7	4.3	28.7	35.7	20.9	6.1	1.7	

Counts		Combined frequency 27	28	29	30	31	32	33	34	35	36	No. of specimens
No. of specimens	..	1	..	1	2	11	33	38	21	6	2	115
%	..	0.9	..	0.9	1.7	9.6	28.7	33.0	18.3	5.2	1.7	

A. thazard

During the year 1976, 1977 and 1978 seasons the juvenile specimens were caught only during a very restricted period. The frequency of the specimens landed during the months of July and August are shown in Fig. 2. The specimens caught measured from 12.9 to 19.9 cm in fork length and weighed from 20 to 100 g.

Meristic counts

D1 X-XI ; D2 + finlets — + 7 — 8 ; A + finlets — + 7 (only) gill rakers 7 — 10 + 19 — 27.

The frequency of gill raker counts are given in Table 2.

S. orientalis

Juveniles of *S. orientalis* were recorded in very few numbers only in the month of August during the year

TABLE 3. *Frequency of gill raker counts in* E. affinis

Counts		Upper limb				No. of	Lower limb							No. of
		6	7	8	9	specimens	16	17	18	19	20	21	22	specimens
No. of specimens	..	11	72	4	1	88	1	1	7	68	9	..	2	88
%	..	2.5	81.8	4.6	1.1		1.1	1.1	8.0	77.3	10.2	..	2.3	

Counts		Combined frequency							No. of
		23	24	25	26	27	28	29	specimens
No. of specimens	..	1	5	9	62	5	5	1	88
%	..	1.1	5.7	10.2	70.5	5.7	5.7	1.1	

1976, 1977 and 1978, taken by sardine gill nets. The length frequencies of the specimens landed for the months of August during the above period are shown in Fig. 2. The specimens caught measured from 9.8 to 19.9 cm in fork length and weighed from 7 to 95 g.

Meristic counts

D1 XVII – XIX ; D2 + finlets – + 7 – 9 ; A + finlets – + 5 – 7 ; gill rakers ; 2 – 5 + 5 – 9.

The frequency of gill raker counts is presented in Table 4.

TABLE 4. *Frequency of gill raker counts of* S. orientalis

Counts		Upper limb				No. of	Lower limb					No. of
		2	3	4	5	specimens	5	6	7	8	9	specimens
No. of specimens	..	3	5	95	3	106	1	..	15	89	1	106
%	..	2.8	4.7	89.6	2.8		0.9	..	14.2	84.0	0.9	

Counts		Combined frequency						No. of specimens
		8	9	10	11	12	13	
No. of specimens	..	1	2	2	14	84	3	106
%	..	1.0	1.9	1.9	13.2	79.2	2.8	

Food and feeding habits :

In waters around Sri Lanka, *E. affinis* are found in schools with *A. thazard*, and presumably these two species are directly competing for food (Williams 1963). The feeding habits of *E. affinis* may vary throughout the year (Kishinouye 1895). According to Magnuson and Heitz (1971), the gill raker gap is greater in *S. orientalis*. Therefore, it would be expected that the diet of *A. thazard* would contain a large proportion of smaller organisms than that of *S. orientalis*.

E. affinis

Totally 88 specimens were examined during 1976-1978. The visual grading of the fullness of the stomach for the 88 specimens was as follows :

Grading		Percentage
Empty	..	76.1
Trace	..	11.4
1/4 + or –	..	4.5
1/2 + or –	..	4.5
3/4 + or –	..	1.2
Full (gorged)	..	2.3

From Table 5 it will be seen that both from the number of occurrence as well as the actual volume, *Anchoviella commersonii* constituted the most important food item with zooplanktonic crustaceans next in importance. Young-ones of *E. affinis* feed on zooplankton as well as small fishes like *Stolephorus*. Feeding pattern is not different from that of the adult.

TABLE 5. *Food items of* E. affinis *(juveniles)*

Constituents		Occurrence No.	%	Actual volume (ml)	Percentage by volume	Actual No. of food organisms
Anchoviella commersonii	..	4	4.6	8.8	48.0	5
Skeletal remains of fish	..	3	3.5	3.0	16.4	..
Crustacean food (plankton)						
Decapod larvae	..	5	5.7	0.4	2.2	70
Mysids	..	2	2.3	0.4	2.2	12
Phyllosoma	..	1	1.2	1.0	5.5	6
Megalopa	..	3	3.5	2.4	13.1	42
Stomatopods	..	1	1.2	..	..	2
Amphipods	..	1	1.2	0.4	2.2	8
Lucifer	..	1	1.2	0.1	0.5	3
Other crustacean remains	..	2	2.3	1.0	5.5	..
Unidentified zooplankton	..	5	5.8	0.8	4.4	30

A. thazard

Altogether 115 specimens were examined during 1976-1978. The visual grading of the fullness of the stomach for 115 specimens was as follows :

Grading		Percentage
Empty	..	47.0
Trace	..	10.4
1/4 + or −	..	37.3
1/2 + or −	..	3.5
3/4 + or −	..	0.9
Full (gorged)	..	0.9

From Table 6 it is clearly seen that when compared to *E. affinis* (juveniles) it feeds mainly on the zooplanktonic organisms and both from the number of occurrence as well as the actual volume, copepods constituted the predominant item among the food organisms of *A. thazard* (juveniles). Decapod larvae were observed to be the second important food item of them.

Young-ones of *A. thazard* are exclusively plankton feeders unlike the adults. They feed mainly on crustaceans, copepods and decapod larvae.

TABLE 6. *Food items of* A. thazard *(Juveniles)*

Constituents		Occurrence No,	%	Actual volume	Percentage by volume	Actual No. of food organisms
Crustaceans :						
Copepods	..	59	51.3	25.8	56.8	15688
Decapods	..	50	43.5	7.9	17.4	988
Megalopa	..	8	7.0	2.2	4.9	27
Lucifer	..	6	5.2	0.1	0.2	27
Amphipods	..	13	11.3	2.5	5.5	70
Mysids	..	1	0.9	0.1	0.2	9
Stomatopods	..	2	1.7	1.1	24	6
Ostracods	..	3	2.6	0.1	0.2	18
Cladocerans	..	1	0.9	Trace	Trace	6
Mollusca :						
Gastropods	..	2	1.7	Trace	Trace	3
Lamellibranchiates	..	9	7.8	0.2	0.4	48
Ascidian :						
Appendicularians	..	2	1.7	0.4	1.0	25
Fish eggs & larvae :						
Fish eggs	..	12	10.4	0.7	1.5	16
Fish larvae	..	9	7.8	1.8	4.0	25
Unidentified zooplankton	..	27	23.5	2.5	5.5	244

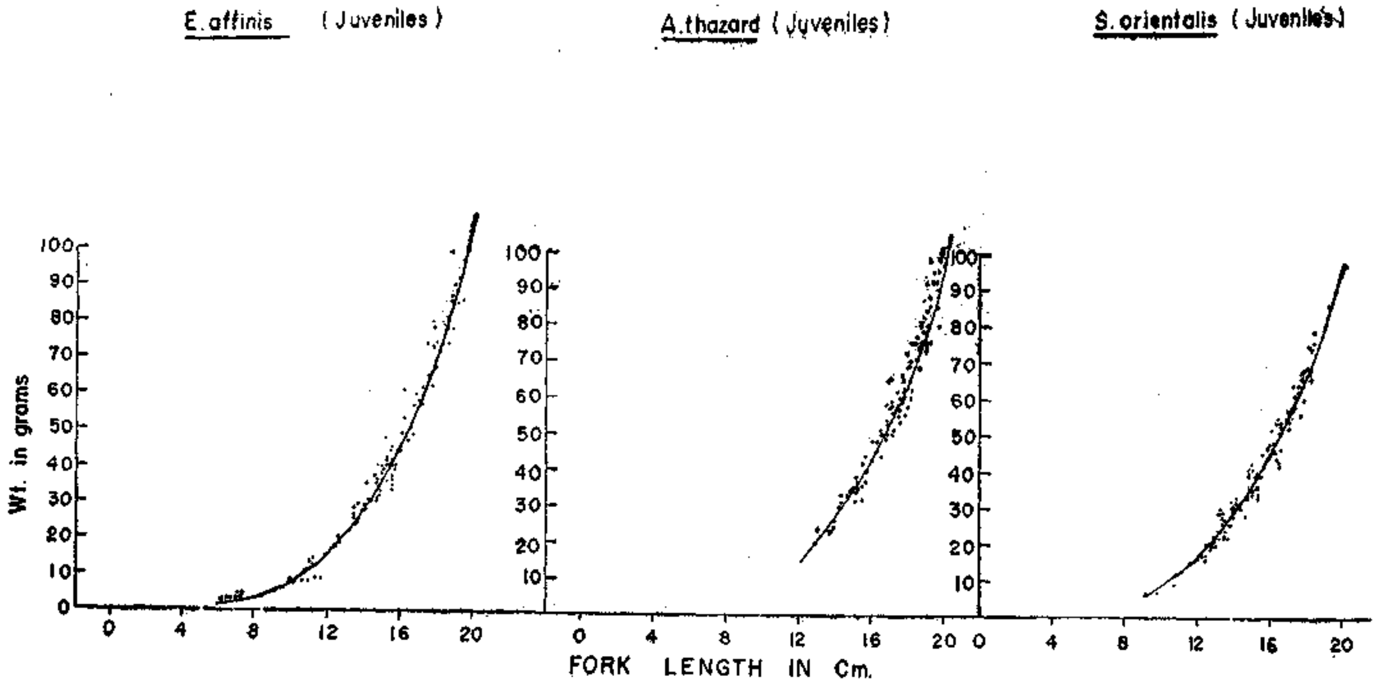

Fig. 5. Length-weight relationship of the juveniles of *E. affinis*, *A. thazard* and *S. orientalis* at Tuticorin.

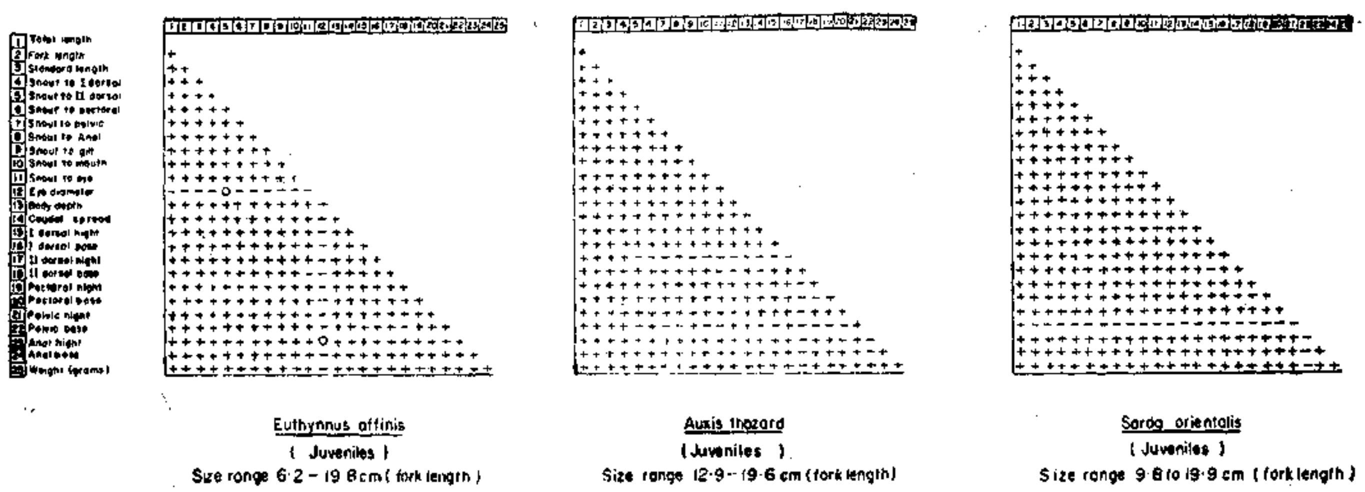

Fig. 6. Correlation matrix of different characters of the juvenile of tuna from the Tuticorin waters of Tamilnadu Coast in the Gulf of Mannar.

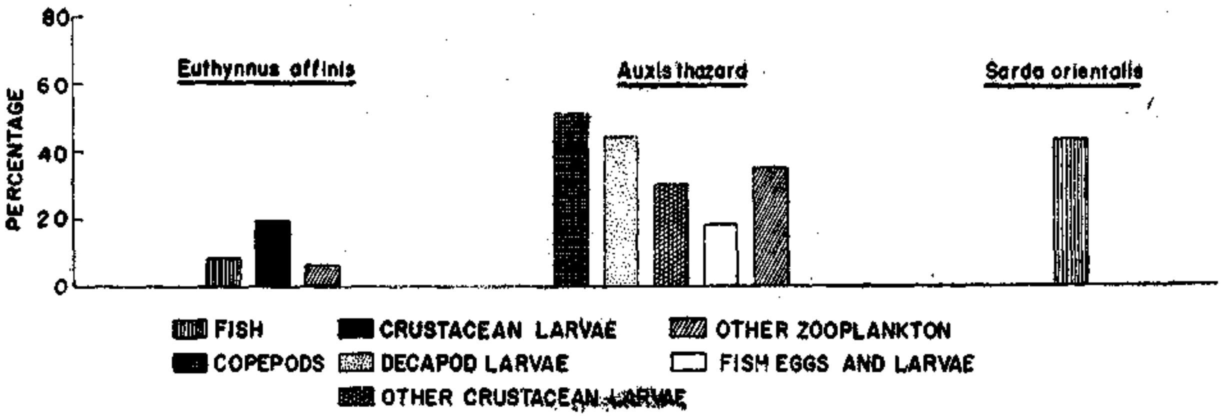

Fig. 7. Percentage composition of the occurrence of major food constituents of the juveniles of *E. affinis*, *A. thazard* and *S. orientalis* at Tuticorin.

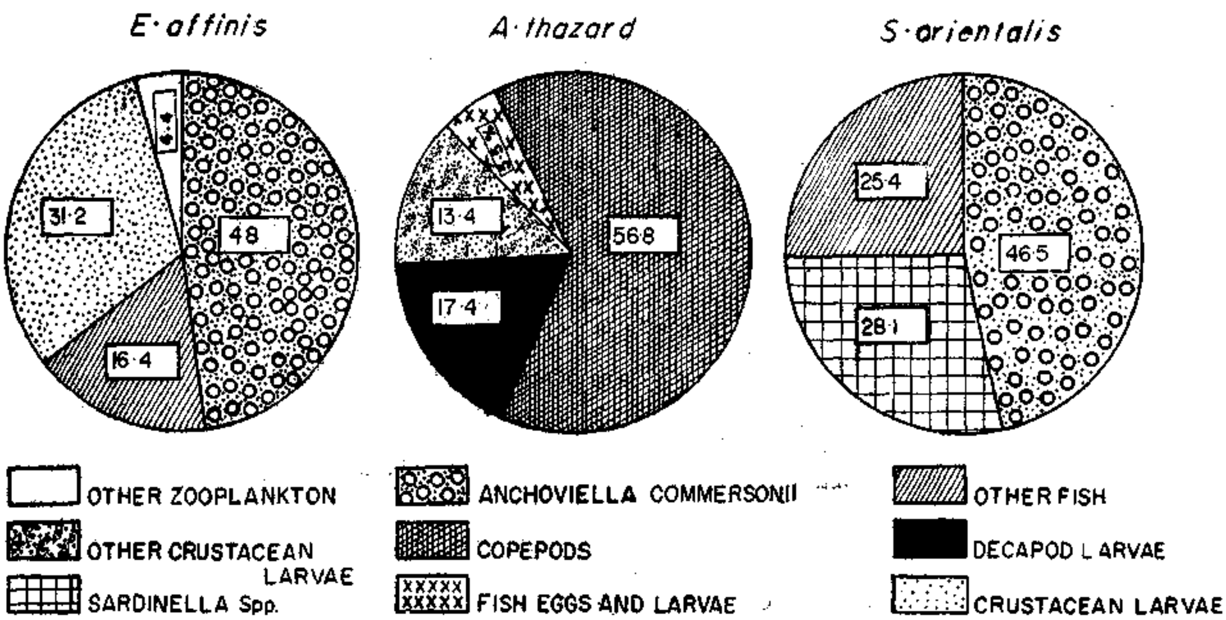

Fig. 8. Volumetric composition of the stomach contents of the juveniles of *E. affinis*, *A. thazard* and *S. orientalis* at Tuticorin.

S. orientalis

Totally 106 specimens were examined during 1976-1978. The visual grading of the fullness of the stomach was as follows :

Grading		Percentage
Empty	..	59.4
Trace	..	13.2
1/4 + or −	..	17.0
1/2 + or −	..	3.8
3/4 + or −	..	1.9
Full (gorged)	..	4.7

Unlike that of *E. affinis* and *A. thazard*, *S. orientalis* (juveniles) feed mainly on fishes. From Table 7 it will be seen that both from the number of occurrence as well as the actual volume, *Anchoviella commersonii* constituted the most important food item and *Sardinella* spp. comes in the next among the food organisms of *S. orientalis* (juveniles). Young ones of *S. orientalis* are carnivorous and not plankton feeders.

The percentage of occurrence and volumetric composition of major food constituents of *E. affinis*, *A. thazard* and *S. orientalis* are presented in Figs. 7 & 8.

TABLE 7. *Food items of* S. orientalis *(juveniles)*

Constituents		Occurrence number	Occurrence Percentage	Actual volume (ml)	Percentage by volume	Actual No. of food organisms
Vertebrates (Fishes) :						
Sardinella spp.	..	2	1.9	13.5	28.1	4
Anchoviella commersonii	..	19	17.9	22.3	46.5	22
Unidentified fish	..	4	3.8	4.0	8.3	6
Fish remains	..	21	19.8	8.2	17.1	Trace

11

FISHERY AND BIONOMICS OF TUNAS AT CALICUT

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Fishing operations by drift nets were in vogue off the Malabar region on a medium scale since the beginning of this century. Four types of drift nets operated aboard the canoes or non-mechanised boats were extant since that time ; they were : (1) a thick large-meshed and heavy (325 mm mesh size) hemp drift net locally called 'Sraavu vala' (shark nets) employed for the apture of large sharks, sawfish, billfishes, etc. from deep waters, (2) a thin big-meshed (12-20 cm mesh) hemp drift net called 'Thirandi vala' (Rayfish net) used mainly for the capture of rayfishes, skates and sawfish from the nearshore waters, (3) a small-meshed (7-8.5 cm) cotton-made or hemp drift net called 'Kandadi vala' used for the capture of small sized cybiids, *Chirocentrus*, pomfrets, sharks, sawfish, tachysurids, large carangids and mackerel and, (4) a slightly bigger meshed hemp drift net called 'Odu vala' (9-12 cm mesh) used for the capture of big-sized fishes such as cybiids, tunas, tachysurids, pomfrets, *Chirocentrus*, carangids, chorinemids, *Rachycentron*, sphyraenids, and medium-sized sharks.

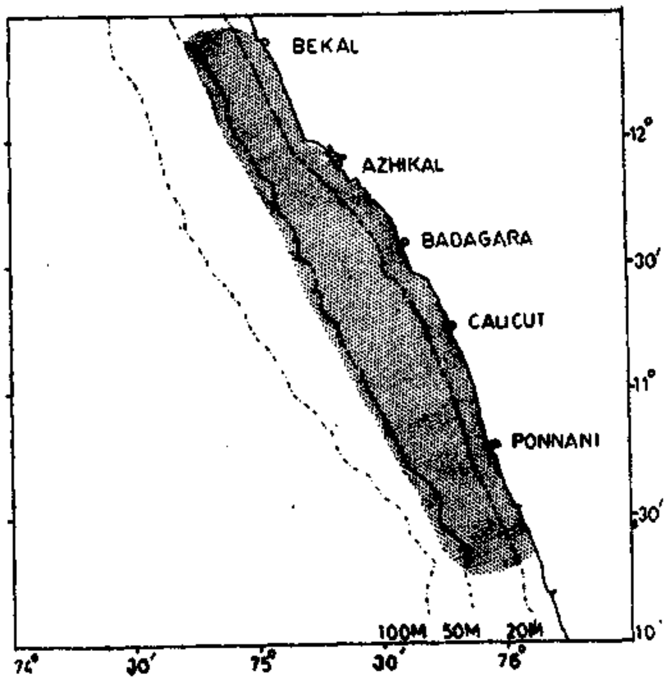

Fig. 1. Operational area of drift gillnetters off Calicut.

After the thirties of this century, the 'Sraavu vala' became obsolete. The 'Thirandi vala' and 'Kandadi vala' operations were continued till about the end of the fifties only, all along the Kerala Coast. Hence the big-meshed hemp 'Odu vala' gained importance since the sixties and continues so till date with the change that the hemp has been replaced by nylon webbing. At the Calicut centre itself 40 or 50 such hemp drift net units were in operation. Similarly a good number of them are under operation at Chowghat, Tanur, Beypore, Pudiappa, Quilandy, Badagara, Mahe, Tellicherry, Cannanore, Palayangadi, Kasaragod in Kerala (Fig. 1) and Ullal and Malpe in Karnataka with the aid of non-mechanised canoes. These units were operating largely during the post-monsoon months *i.e.*, till the end of February or March and occasionally during the pre-monsoon period (from March till end of May). The maximum number operated was from September to January.

A few mechanised boats with nylon drift nets have been operating since the seventies by migrant fishermen from Kanyakumari, Tamil Nadu off the Kerala and Karnataka coasts. At Calicut and Cochin also, these migrant fishermen regularly operated the drift net (nylon) units despite severe protests from the local fishermen. Their industrious seafaring fishing efforts gave a boost to the drift net operations all along the

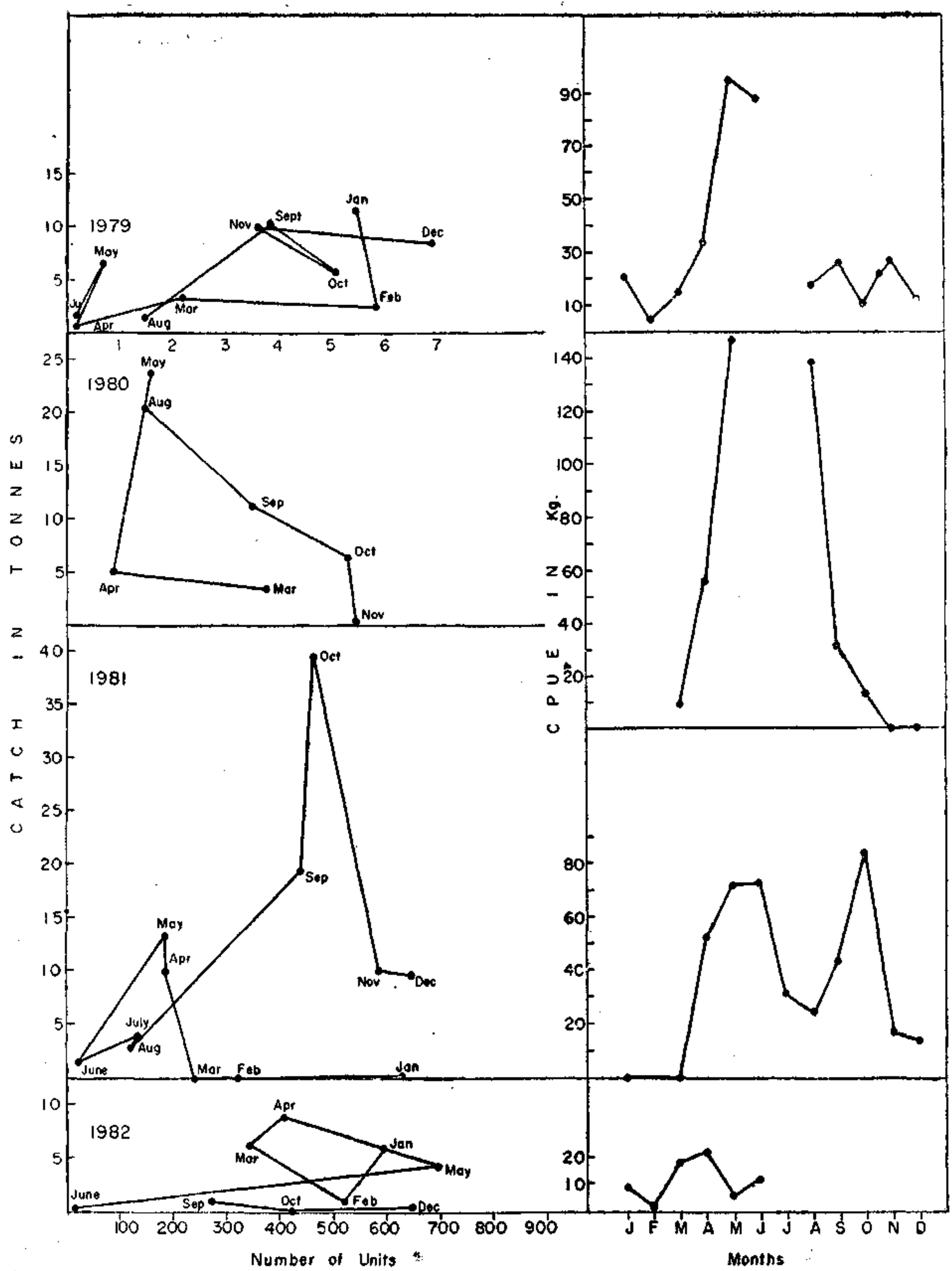

Fig. 2. Catch—effort relationship and catch per unit effort of tunas at Calicut, 1979-'82.

west coast and consequently the following major developments took place in the drift net fishery :

(1) The use of mechanised boats for drift net fishing as well as use of towing up and down the fishing grounds, eight or ten non-mechanised drift netter canoes at a stretch on a single fishing day (from the afternoon to the ensuing forenoon). This has effectively extended the operational range of the canoes to the deeper shelf waters where normally fishes such as the tunas and related spp., billfishes, cybiids, and other large pelagics occur.

(2) It has caused an overall increase in the number of drift net units operating during all fishing days.

(3) It has caused a recent increase in the size dimensions of the drift nets to cope up with the operations at greater depths, also replacing the cotton-made and the hempen nets with the nylon ones.

(4) Consequent on the coverage of deeper, richer and productive waters catches by the mechanised gill netters have now a days recorded considerable improvements. All these have widened the spectrum of our knowledge of the abundance and distribution of the various larger fishes which are not normally available to the less developed artisanal gears operating in the inshore waters. Hence, they in a cumulative way, have helped in the development of our gill net fishery for the tunas, billfishes and larger pelagics.

Effort, catch and cpue

In Calicut the tuna fishery starts in the month of September and lasts until February and sometimes until April. The gear employed is drift net which is mainly used for seerfishes. During the period under consideration the tuna fishery at Calicut yielded an annual catch ranging from 25 to 111 tonnes with an average of 76.7 tonnes (Fig. 2). Maximum catch was recorded in the year 1981 and minimum in 1982. Best returns per boat (31.78 kg) were realised in the year 1977 and in 1982 the cpue was the lowest (6.59 kg).

Species composition

E. affinis constituted more than 90% of the catch of tunas, while *A. thazard*, *T. tonggol* and *S. orientalis*, also occurred in the catches (Fig. 3).

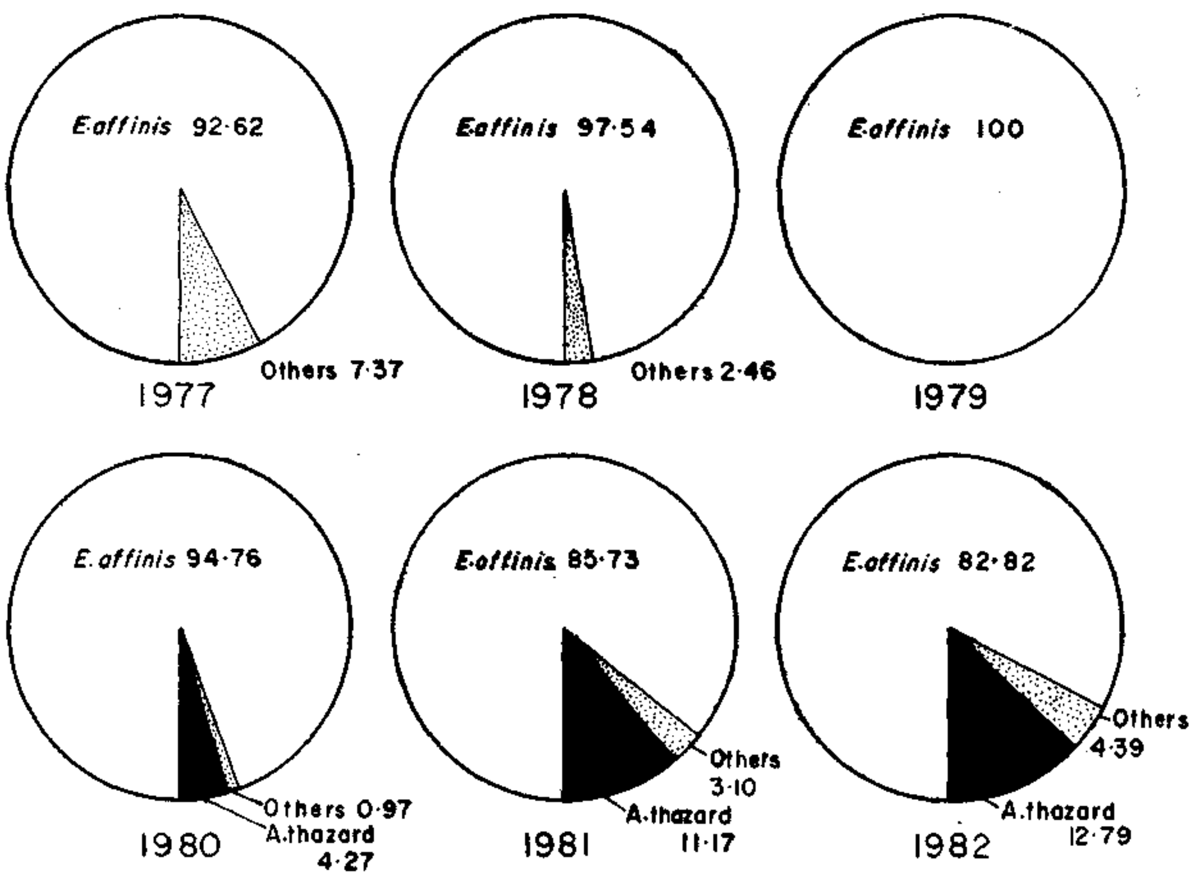

Fig. 3. Percentage composition of tunas at Calicut, 1979-'82.

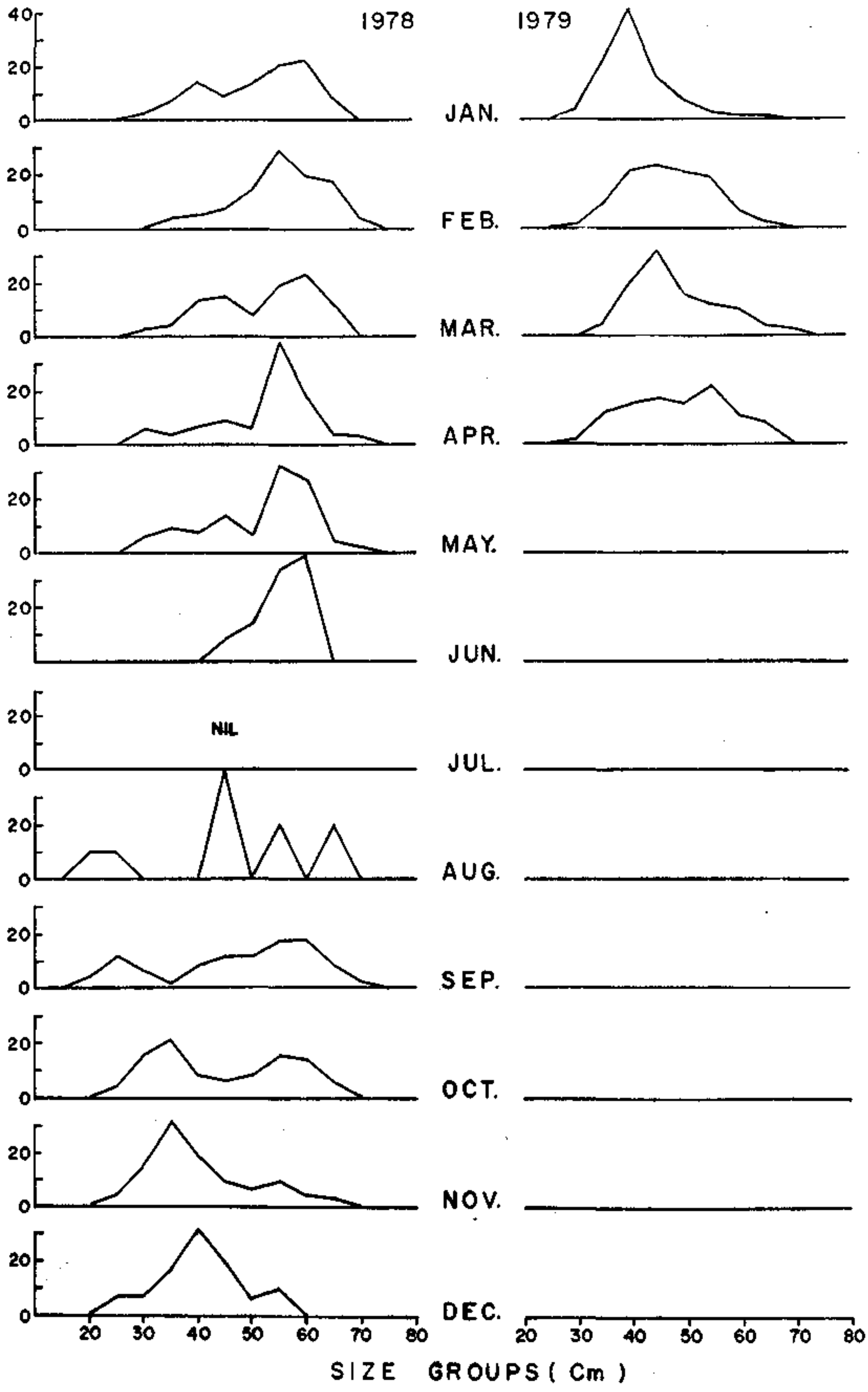

Fig. 4. Monthly length frequency distribution of *E. affinis* at Calicut, 1978-'79.

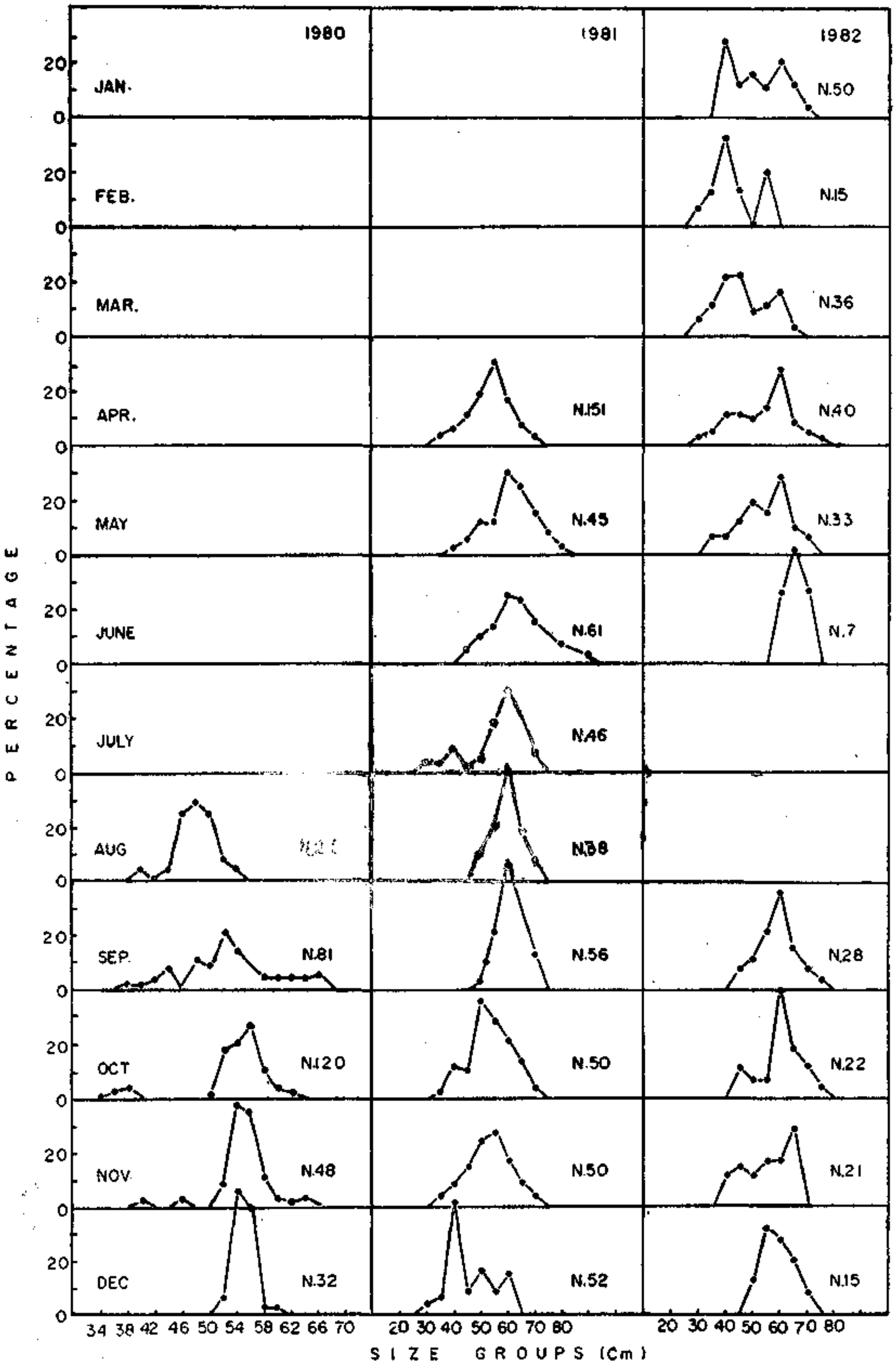

Fig. 5. Monthly length frequency distribution of *E. affinis* at Calicut, 1980-'82.

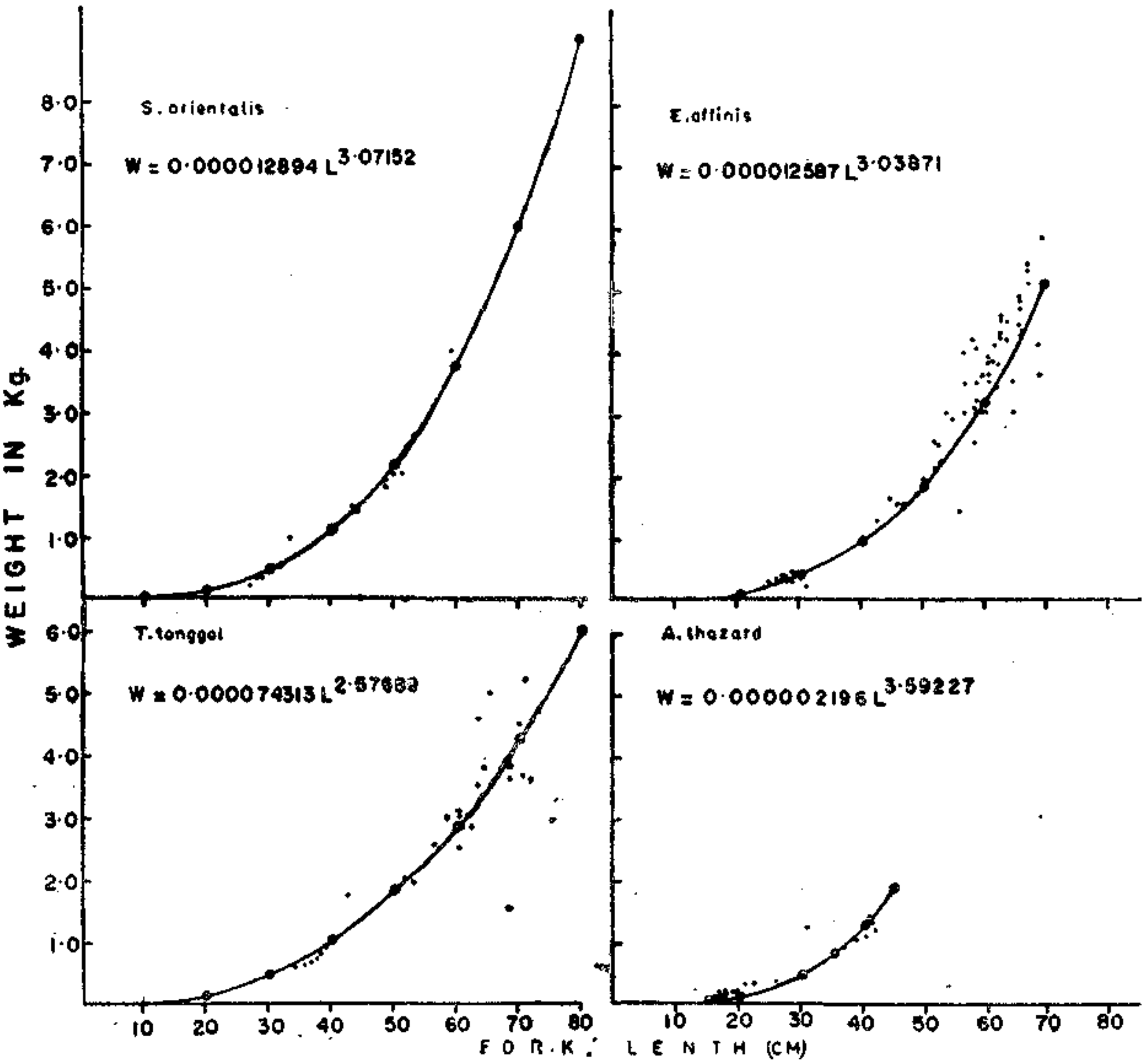

Fig. 6. Length-weight relationship of *S. orientalis, E. affinis, T. tonggol* and *A. thazard* at Calicut.

Length frequency distribution

E. affinis landed at Calicut had a length ranging from 20-70 cm (Fig. 3). In January 1978 the modes were at 40 cm and 60 cm. The mode at 60 cm persisted till September. The mode of 40 cm shifted to 45 cm in March and persisted till August. Another mode at 55 cm which appeared in February persisted till December. A mode at 25 cm appeared in September and shifted to 40 cm by December and to 45 cm by March 1979. A mode at 48 cm which appeared in August, 1980 shifted to 54 cm by December. In 1981 April the mode was at 55 cm which shifted to 60 cm in May and persisted till September. In October a mode appeared at 50 cm and shifted to 55 cm by November. In December, 1981 another mode appeared at 40 cm and shifted to 50 cm by May 1982 (Fig. 5).

The mode at 25 cm in September, 1978 which shifted to 45 cm by March 1979 showed a monthly average growth rate of 3.33 cm. The mode at 48 cm in August 1980 which shifted to 54 cm by December 1980 indicates an average monthly growth rate of 1.5 cm. The mode at 55 cm in April 1981 which shifted to 60 cm by September 1981 indicates a monthly average growth rate of 1 cm. The mode at 40 cm in December 1981 which shifted to 50 cm by May, 1982 indicates a monthly growth rate of 2 cm. Thus after 45 cm the growth may be about 1.5 cm per month as against 3.33 cm before that size.

The fishery is supported by *E. affinis* of size above 40 cm and below 60 cm.

Length-weight relationship

Length-weight relationship of *E. affinis*, *S. orientalis*, *T. tonggol* and *A. thazard* were estimated and the results are given in Fig. 6. The correlation coefficients are also given. Their values range from 0.96-0.99 indicating almost perfect correlation. The values for different species studied are as follows :

E. affinis $W = 0.0000\,1365\ L^{3.08871}$

S. orientalis $W = 0.0000\,12894\ L^{3.07152}$

T. tonggol $W = 0.0000\,74313\ L^{2.57889}$

A. thazard $W = 0.00000\,2196\ L^{3.59227}$

12

FISHERY AND BIONOMICS OF TUNAS AT MINICOY ISLAND

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The Union Territory of Lakshadweep is represented by twenty islands out of which only ten are inhabited. Oceanic species of tunas such as skipjack (*Katsuwonus pelamis*) and yellowfin tuna (*Thunnus albacares*) are available in Lakshadweep area from October to May every year. They are being exploited from Minicoy waters by pole-and-line tuna fishing using live bait. Since 1960, pole-and-line fishing has been adopted in the other islands of Amini group with the introduction of mechanised boats. The seventies has seen an almost complete transition of replacement of the 'Odum' (traditional tuna fishing boats) with mechanised boats fitted with bait tanks at Minicoy Islands. Thus tuna fishing became popular in the Union Territory which is now fetching a good amount to the islanders and helping in the improvement of the economy of these islands.

The earliest accounts about tuna fishing of Minicoy were that by Hornell (1910) and Ellis (1924). Later Mathew and Ramachandran (1956), Jones (1958) and Jones and Kumaran (1959) have described tuna fishery of this island in detail. Varghese (1970) compared the landing of the mechanised boats with that of non-mechanised boats and suggested for the speedy mechanisation of the fishing fleet of Minicoy island. Puthran and Pillai (1972) described tuna fishing methods in Minicoy waters and suggested for steady supply of live-bait fish during tuna fishing season, introduction of big size vessels to serve as mother ship and equip present fishing fleet with fish finding devices. Varghese (1982) summarised the fishing practices and the development of fishery in the Lakshadweep Island.

There is no clear indication from the published literature regarding the introduction of pole-and-line fishing at Minicoy. It is believed that this fishery is being in practice from time immemorial. Before 1960, locally built non-mechanised boats (*Masodi*) were used for pole-and-line fishing which were unable to go beyond ten km from the islands. Gradually mechanised boats were introduced in the island and with the result of this now twenty mechanised boats are in operation at Minicoy.

FISHING AREA

The area of operation of Minicoy tuna fishery is spread over a stretch of the oceanic waters extending from the island up to about 22 km around (Fig. 1). A clear cut difference in the fishing areas operated during different periods is discernible. During monsoon months, the boats usually fish in the nearby waters lying within the 5 km zone. During non-monsoon months, they operate far off up to the distance of 20-22

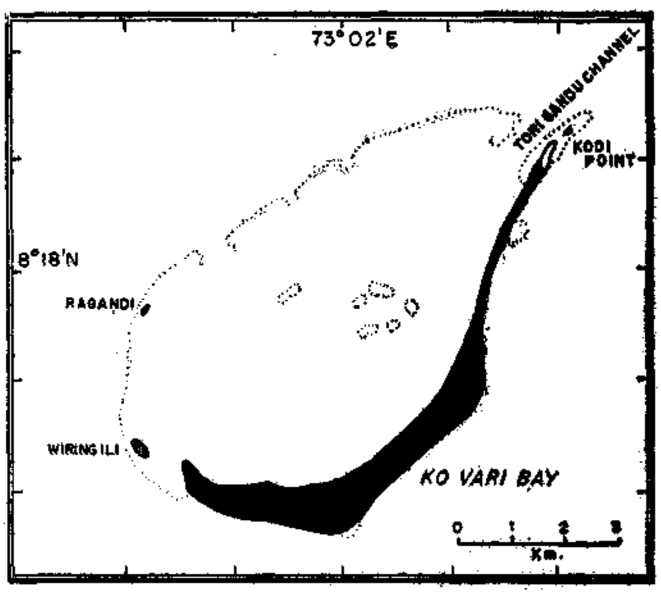

Fig. 1. The lagoon at Minicoy.

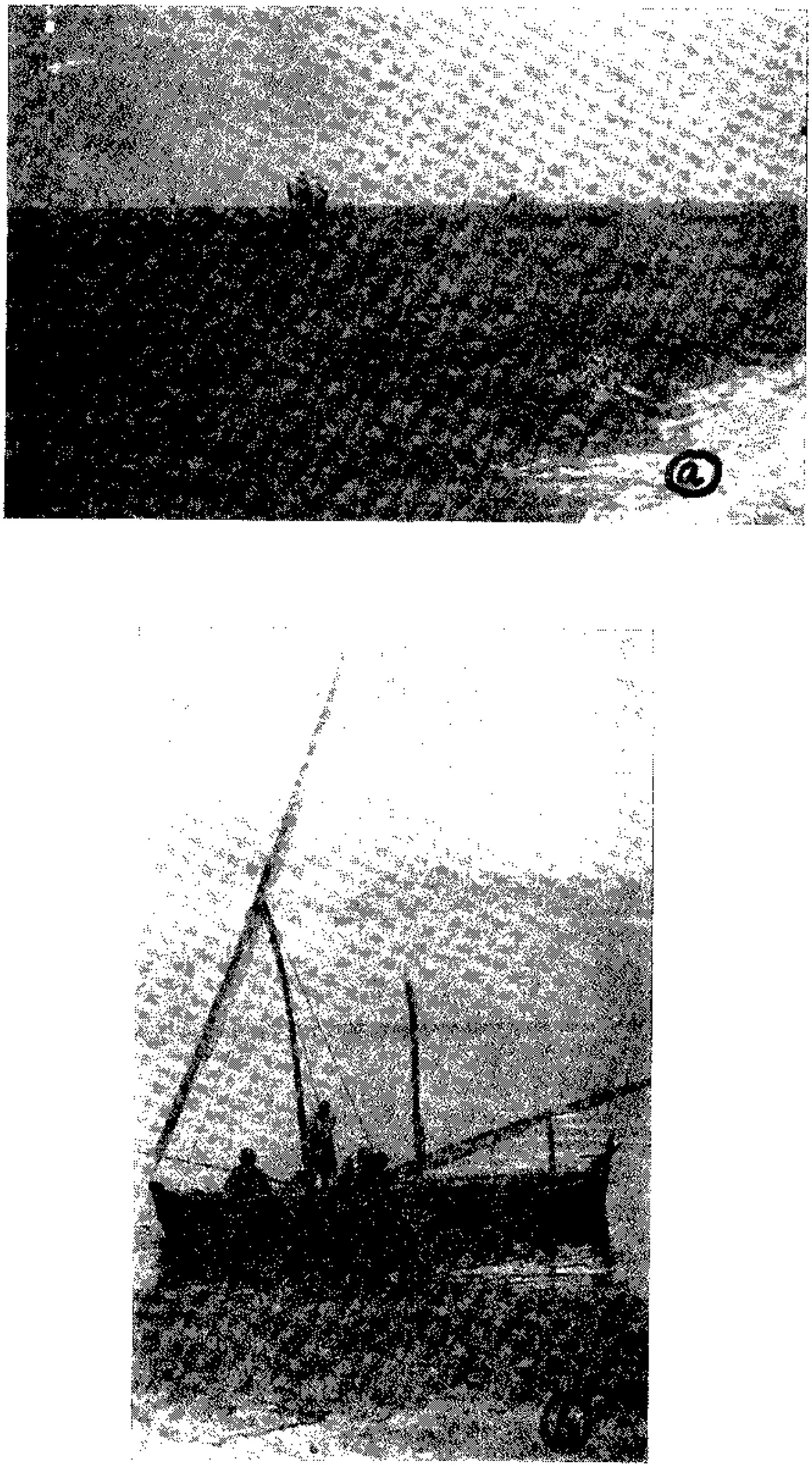

PLATE I. (*a*) Tuna fishing by pole and line in the open sea off Minicoy. (*b*) Non-mechanised tuna fishing boat (*Odum*) at Minicoy.

PLATE III. (*a*) Mechanised pole and line tuna fishing boat at Minicoy. (*b*) 'Masmin'—tuna product at Minicoy.

km from the island. The daily fishing course of the island is stereotyped, and the north-eastern ground of the island is exploited much.

Crafts

Prior to 1960 only non-mechanised boats were used for tuna fishing and the details of the boat are given by Jones and Kumaran (1959). But now these boats are used only during south-west monsoon period for troll line fishing from the eastern side of the island. The first mechanised fishing boat was introduced to Minicoy in 1959.

Mechanised boats of two sizes i.e. 7.93 metres and 9.14 metres long are being used for pole-and-line tuna fishing. Engine of 10 to 40 BHP is fitted in the middle of the boat and is surrounded on all the sides with wooden planks. This engine room is covered by a roof consisting of two pieces of wooden planks.

Bait tank of $1.6 \times 0.8 \times 0.8$ metre size is fitted in front of the engine room. Live-bait fishes are taken to fishing ground by keeping them in the water tight bait tank in which sea water is circulated through the tank with the help of special water circulation device. The temperature, dissolved oxygen level and salinity are maintained at the same time at the optimum level with the help of sea water circulation in the bait tank. The bait tank is divided into two parts by fitting a partition in the middle of the tank which can be removed easily. The partition helps in collection of bait fishes from the tank at the time of chumming.

Quarter deck which is about one metre broad is provided on the top of the quadrant. This serves as platform at the time of pole-and-line fishing. The space between the engine room and fishing platform which is somewhat deeper is used as fish hold. A partition is provided in the middle of fish hold and is covered with removable wooden planks. A hand pump which is fitted on right side of engine room is used for drawing out dirty water from the fish hold.

Pole and line

Bamboo poles of 3 to 4 metres in length and 35 to 40 mm diameter which are straight, strong and flexible are used as poles. A line of nylon twine or polythene line is attached at the tip of the pole. Barbless, lead coated hooks of small and big size are used. One end of the hook is flattened to avoid it from slipping from the knot due to the weight of the fish. The total length of the line along with the hook from the pole end is almost equal to that of the pole. The hook is kept fixed to the base of the pole when it is not in use.

Bait collection

Bait fishes are collected from Minicoy lagoon either in the morning of the fishing day or the previous day evening.

Bait fishes are caught by luring them with the help of some type of bait which is made up of crushed crabs, tuna meat or other fish's meat. This crushed bait is thrown over bait net lowered into the lagoon from the side of the tuna boat by four persons. Bait fishes after being attracted, come up and gather over the net. Two persons hold two poles as near as possible to the boat vertically. One person rubs the bait, either crab or tuna meat on a coir padding at the end of a bamboo pole and the other person standing on the side pushes pole up and down in the lagoon water. By doing this fine particles of meat will spread in all directions which attracts bait fishes from coral colonies to come out and gather over the net. When sufficient quantity of bait fish gathers over the bait net, it is quickly raised and bait fishes are transferred into live bait tanks.

For another method of bait fish collection, poles are removed from the bait net and two corners of the net are tied to two small wooden poles which are fixed in the lagoon. The two other corners of the net are anchored at the bottom of the lagoon with the help of coral stones which provides the net a slanting position. A 15 to 20 metre long rope with a row of coconut palm leaves closely tied all along is drawn by 4 to 5 persons by making a very narrow circle towards the anchored net. Bait fishes get scared and try to run out of this circle by moving towards the anchored net and finally get trapped in the bait net.

Scouting for shoals

Following methods are used to locate fishable tuna shoals.

(1) *Presence of bird flocks ;* In Minicoy waters fishermen are mostly dependent upon the presence of sea birds for locating tuna shoals (Silas 1969). As soon a sa bird flock is sighted, tuna fishing boats rush to that area for fishing. The size of the tuna school is judged by the spread of the bird flock rather than by the number of birds involved. Presence of a compact group of birds indicates availability of small school while a flock scattered over a large area suggests a large fish school. If a bird flock is flying high it is believed that tuna school is moving very fast. But if tuna shoals are almost stationary while feeding on small fishes present in the area, then bird flock will be flying quite low and also be diving for feeding.

(2) *By troll and line operation:* When birds are not sighted in the area, fishermen operate their troll line gear on their way to tuna fishing grounds. As soon as tuna strike a trolling jig, the person operating the line informs the captain of the boat who slows down the boat immediately. This indicates the presence of sub-surface tuna shoals. This type of tuna shoals take some time for chumming.

(3) *Breezing shoals:* When a skipjack school swims on the surface without actively feeding on small fishes, it appears as black spots from the tuna fishing boat. Big-sized black spot denotes the presence of a big tuna shoal.

(4) *Jumping shoals:* In Minicoy waters, tuna shoals are observed jumping out of sea water from December to March when temperature of sea water is comparatively lower than other months of the fishing season. It is very interesting to observe this type of shoals which are found quite near the Minicoy island in the morning hours. Sometimes these shoals are associated with dolphins. Since dolphins also jump during morning hours, tuna shoals also follow the behaviour pattern.

(5) *Tuna shoals associated with floating objects:* Some tuna shoals are found associated with floating objects. Floating objects are mostly wooden logs. The presence of flotsam makes the task of the fishermen easy in locating tuna shoals. Generally good quantities are fished from near the floating objects. These are found in all directions of Minicoy upto ten km distance. Generally these shoals are composed of juveniles of skipjack and yellowfin tuna which are accompanied with the sharks and *Coryphyaena* spp.

CHUMMING

When a tuna shoal is located the tuna fishing boat is steered towards the shoal. Before the 'Chummer' starts throwing bait, all preparations are made and fishermen on board get ready to react quickly. Bait fishes are thrown overboard by the 'chummer' and the reaction of the tuna shoal is noticed. If tuna shoal exhibits good bait biting, bait fish are thrown continuously and thin but regular bait line is maintained. Tunas are chummed near the fishing platform of the fishing boat. Water splashers start splashing water over the bait fishes to hide them and hooks together. Sometimes a tuna feed on the live bait, but do not bite the hooks. In such cases bait fish is attached to the tip of the hook and tuna are chummed.

FISHING OPERATIONS

When tuna shoals are chummed near the fishing boat, actual tuna fishing operation commences. Crew take their position on the fishing platform and lower their hooks just below the sea surface. When tuna bites the hook, the fish is lifted up out of sea water with a slight jerk to the body and with the help of a second jerk the tuna is released from the hook and falls inside the boat. A special skill is required for operating pole and line and usually only trained personnel are taken on board. Whenever tuna feeding on bait and biting the hook is very quick, the angling of tunas will also be fast and sometimes a tuna fishing boat is loaded with tunas within half an hour. During the peak tuna fishing season a fishing boat can make 2 or 3 trips in a day and everytime return with good catches.

TROLL LINE

Big size hooks are used during the south-west monsoon season for tuna fishing. While some fishermen prefer naked hooks when fishing others prefer hooks covered with feathers. Since troll line fishing is conducted in deeper waters nylon twine or polythene thread are used as line of various length.

From June onwards climatic conditions does not favour pole and line fishing. Sea towards the western side of the island becomes rough and it is difficult for mechanised fishing boats to cross the lagoon reef and go out in the open sea. Moreover bait fishes are also not available during this period.

Therefore non-mechanised boats operate troll line from the windward side of Minicoy Island where the sea will be very calm. Upto 10 persons go in a boat and after reaching the fishing grounds each crew operate troll line. Usually catches during monsoon period by troll lines are very poor since this is the lean period for tuna fishing season at Minicoy. The main feature of this fishing is that billfishes and big sized yellowfin are also caught during this period.

EFFORT, CATCH AND CPUE

During 1976 high value of standard effort was recorded from January to April and November to December; maximum effort in December and minimum in July. Next year it was high from February to April and December, maximum in February and minimum in June. In 1978 high effort was recorded for January, April, November and December, the maximum during December and minimum in July. During 1979 effort was recorded high in March, April and December, maximum being in December and minimum in July. In 1980 during March, April and December high values were recorded, maximum being in March and minimum in June. During 1981 high values were recorded from January to March and in December, maximum being

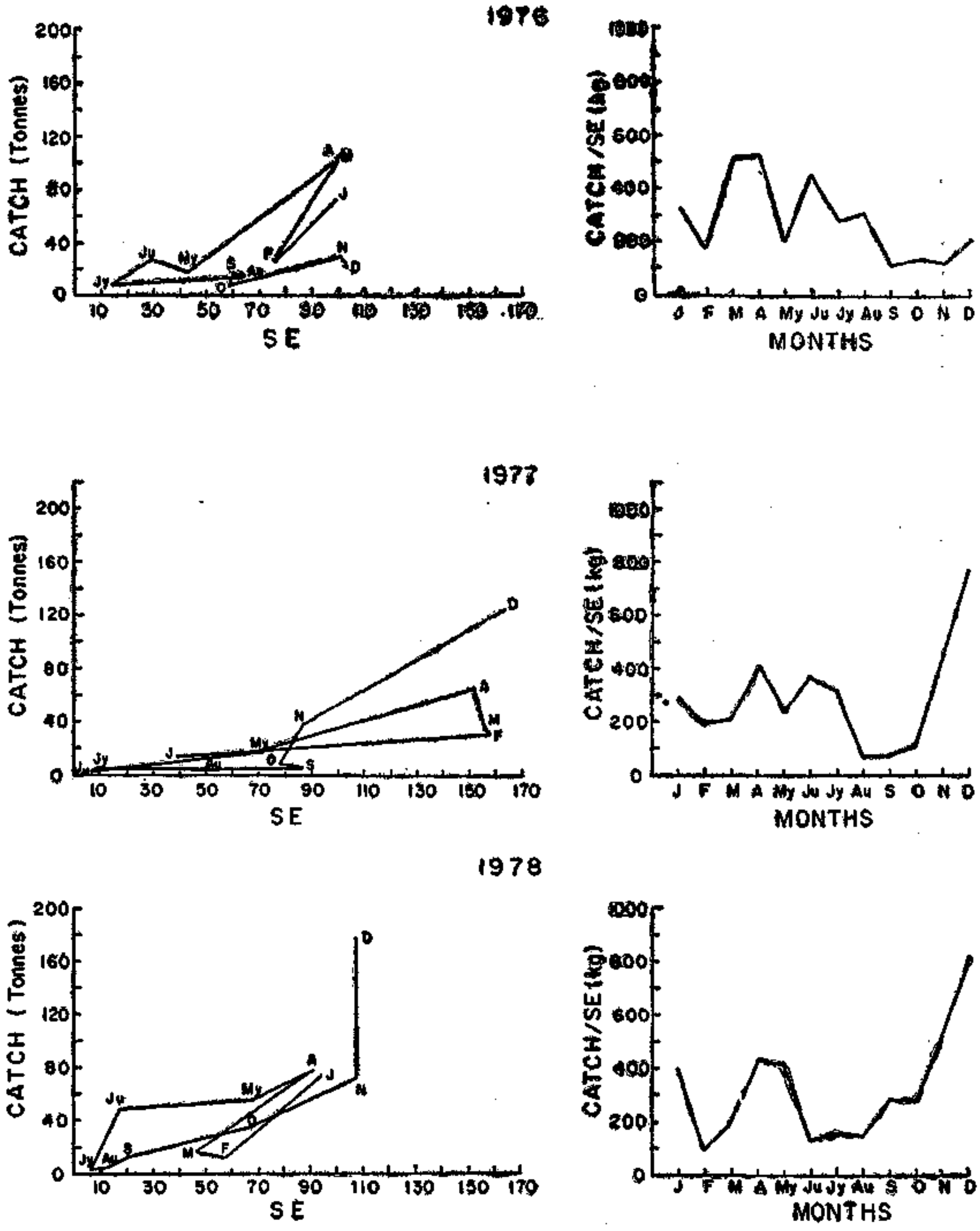

Fig. 2. Catch-standard effort relationship of tunas at Minicoy, 1976-'78.

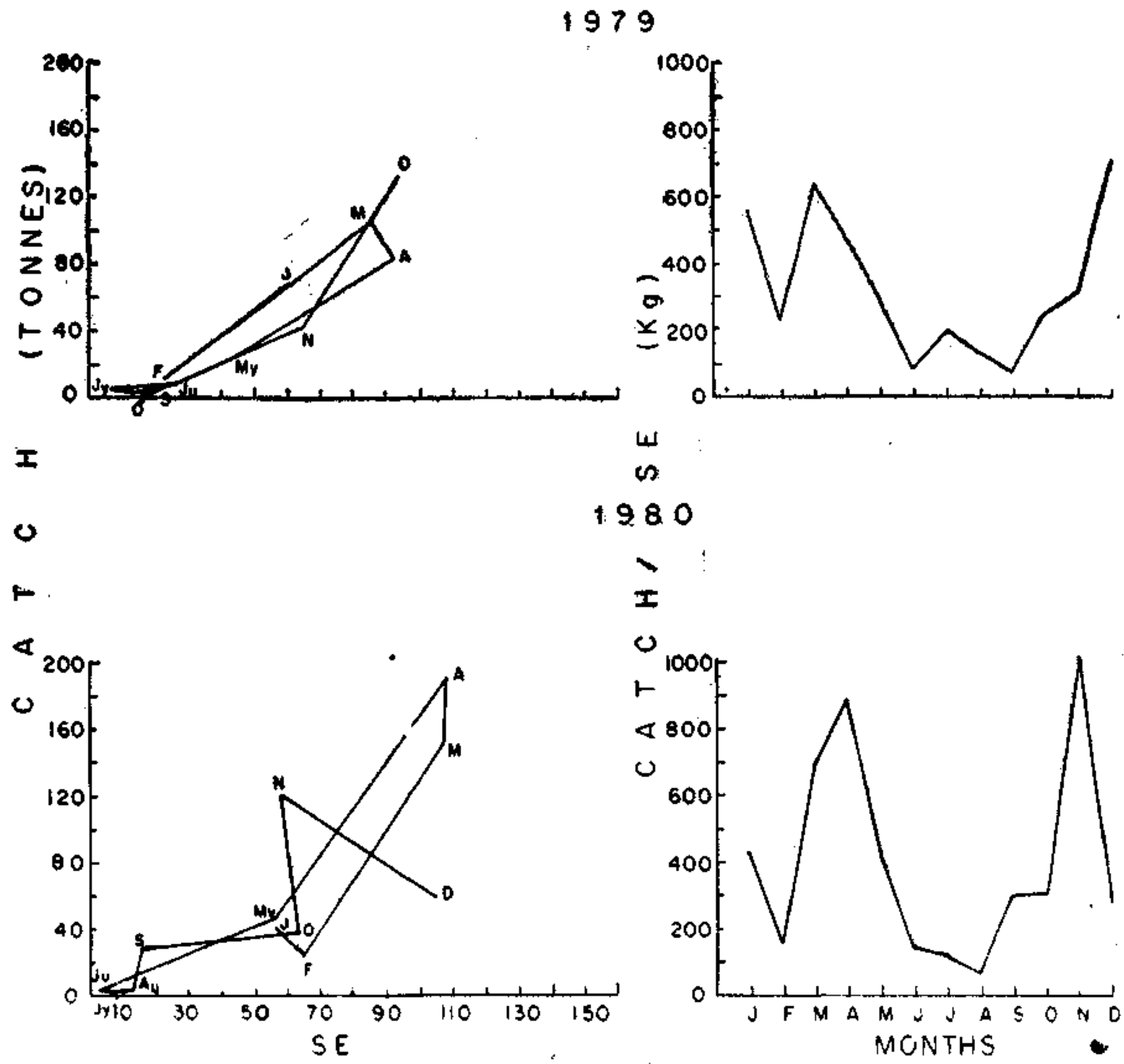

Fig. 3. Catch-standard effort relationship of tunas at Minicoy, 1979-'80.

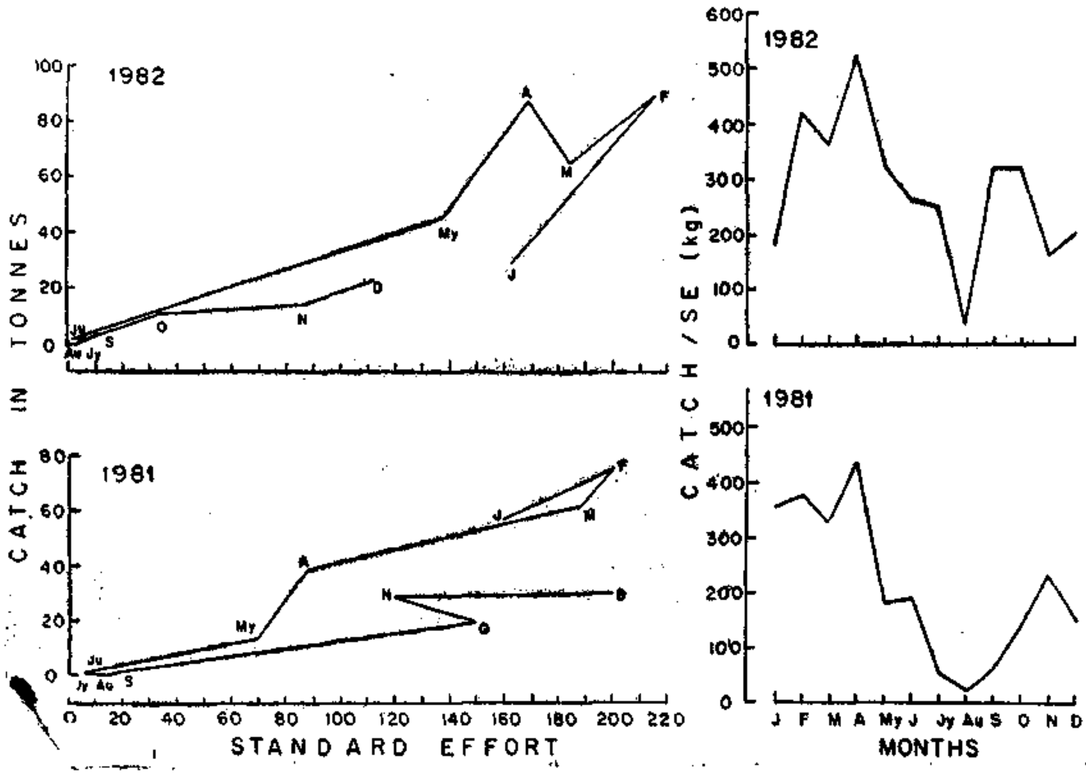

Fig. 4. Catch-standard effort relationship of tunas at Minicoy, 1981-'82.

in February and minimum in June. In 1982 from January to May high values of effort were recorded, maximum being in February and minimum in August.

Tuna catches have exhibited variations at Minicoy from 1976 to 1982 (Figs. 2-4). While tuna catches were 421.8 tonnes during 1976, it was about one hundred tonnes less during next year. But during 1978 tuna catches improved and 509 tonnes were landed at Minicoy. Next year catches were almost similar to that of 1978 catches. But during 1980 record catches of 675 tonnes were landed which was the highest annual production at Minicoy for the period from 1976 to 1982. In 1981 only 324.4 tonnes were landed, which did not show any improvement in 1982.

During 1976 catches were relatively high during January to April when maximum catches of 104 tonnes were recorded in March (Fig. 85). In 1977, high catches were from January to March and December with maximum catch of 126 tonnes in December and lowest in July. In 1978 good catches were recorded in January, April, May and December and a maximum catch of 178 tonnes was recorded in December and lowest in July. In 1979, there were good catches in January, March, April and December. In 1980 maximum catches of 190 tonnes were observed in April and lowest in July. In 1981, there were good catches from January to April with the maximum catch of 75 tonnes in February and lowest in August. In 1982 the maximum catch was recorded in February and lowest in August.

From the above it is clear that the tuna fishing season at Minicoy commences from November and lasts upto May.

As can be seen from the Figs. 2-4, during 1976 catch per standard effort was high from March to June and 530 kg was recorded during April. Next year it was high from January to June and in December. For this year maximum CPSE of 770 kg was recorded in December and lowest from July to September. In 1978, CPSE was good in January, April, May and December and CPSE was maximum in December (820 kg) and lowest in February. Next year again maximum CPSE was recorded in December (710 kg) when it was good in January, March and December and lowest in June. In 1980 CPSE was high in January, April and November and maximum CPSE of 1010 kg was recorded during November and lowest 70 kg in August. In 1981 it was high from January to April and November when maximum CPSE was recorded in April and lowest 24 kg in August. In 1982 CPSE

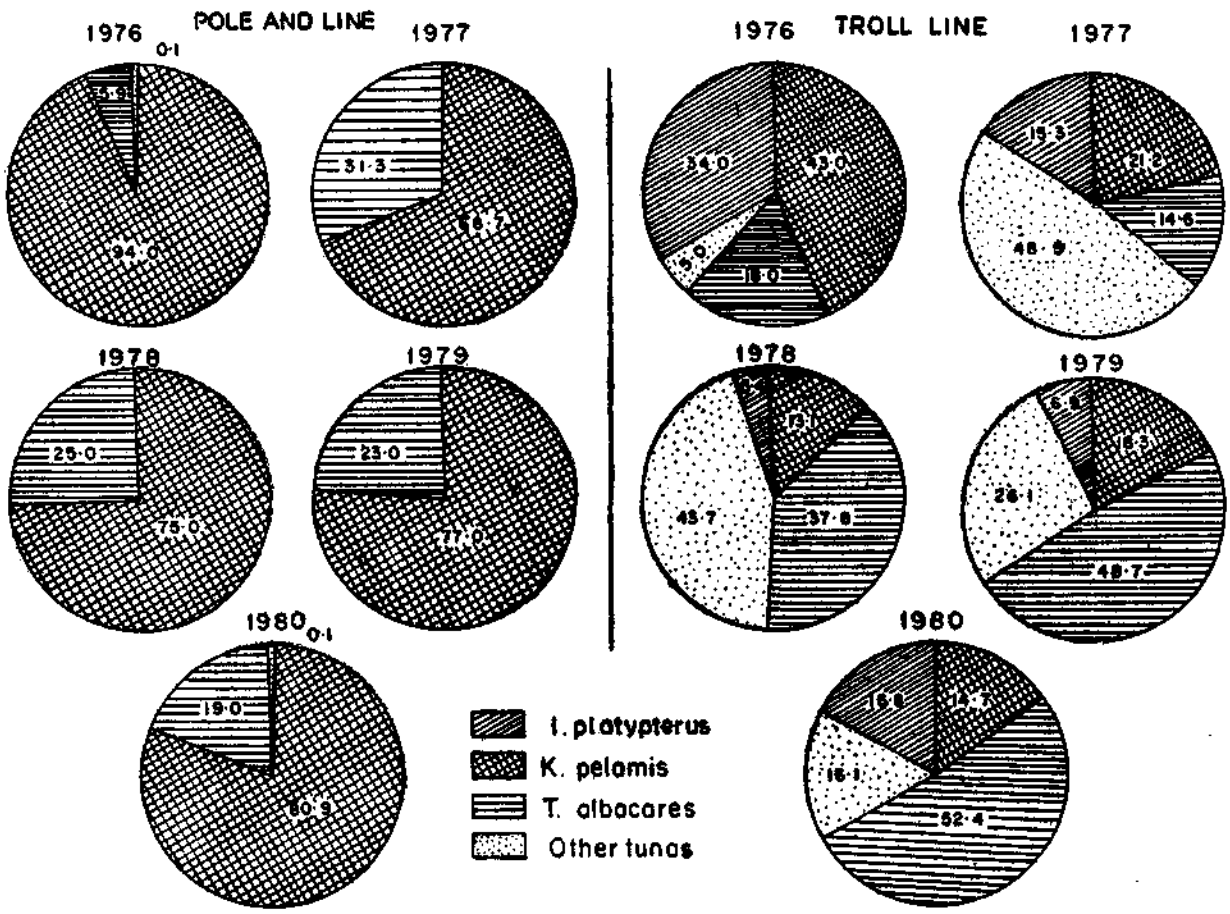

Fig. 5. Percentage composition of tunas in the pole and line, and troll line fishery at Minicoy, 1976-'80.

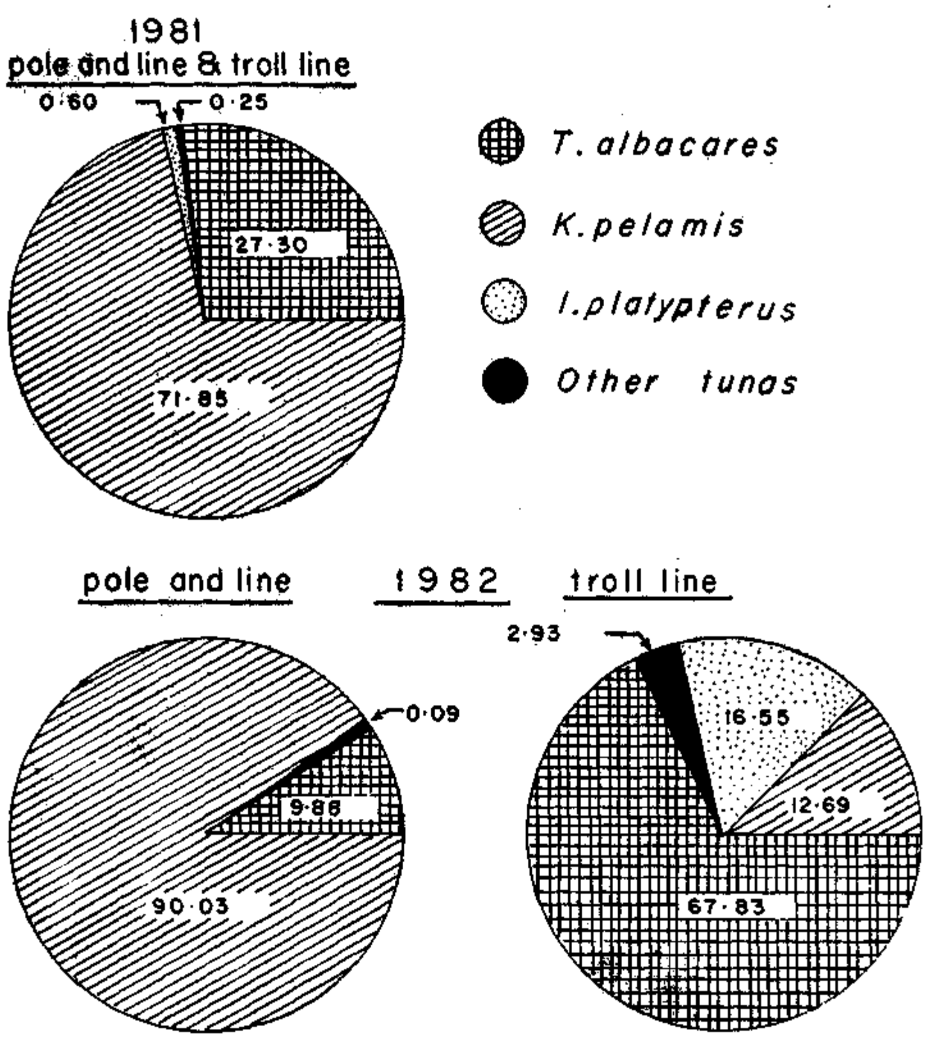

Fig. 6. Percentage composition of tunas in the pole and line, and troll line fishery at Minicoy, 1981-'28.

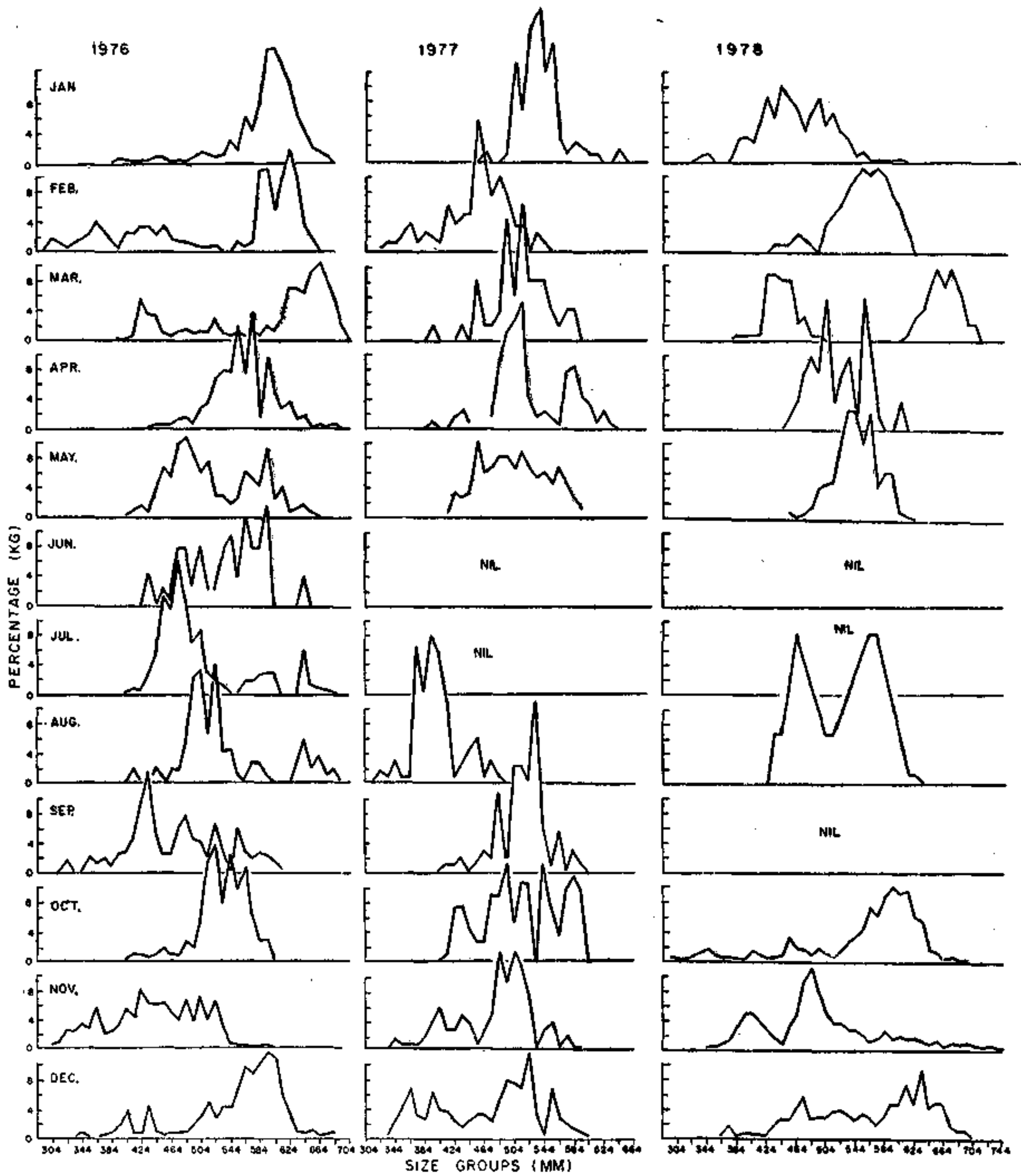

Fig. 7. Monthly length frequency distribution of *K. pelamis* at Minicoy, 1976-'78.

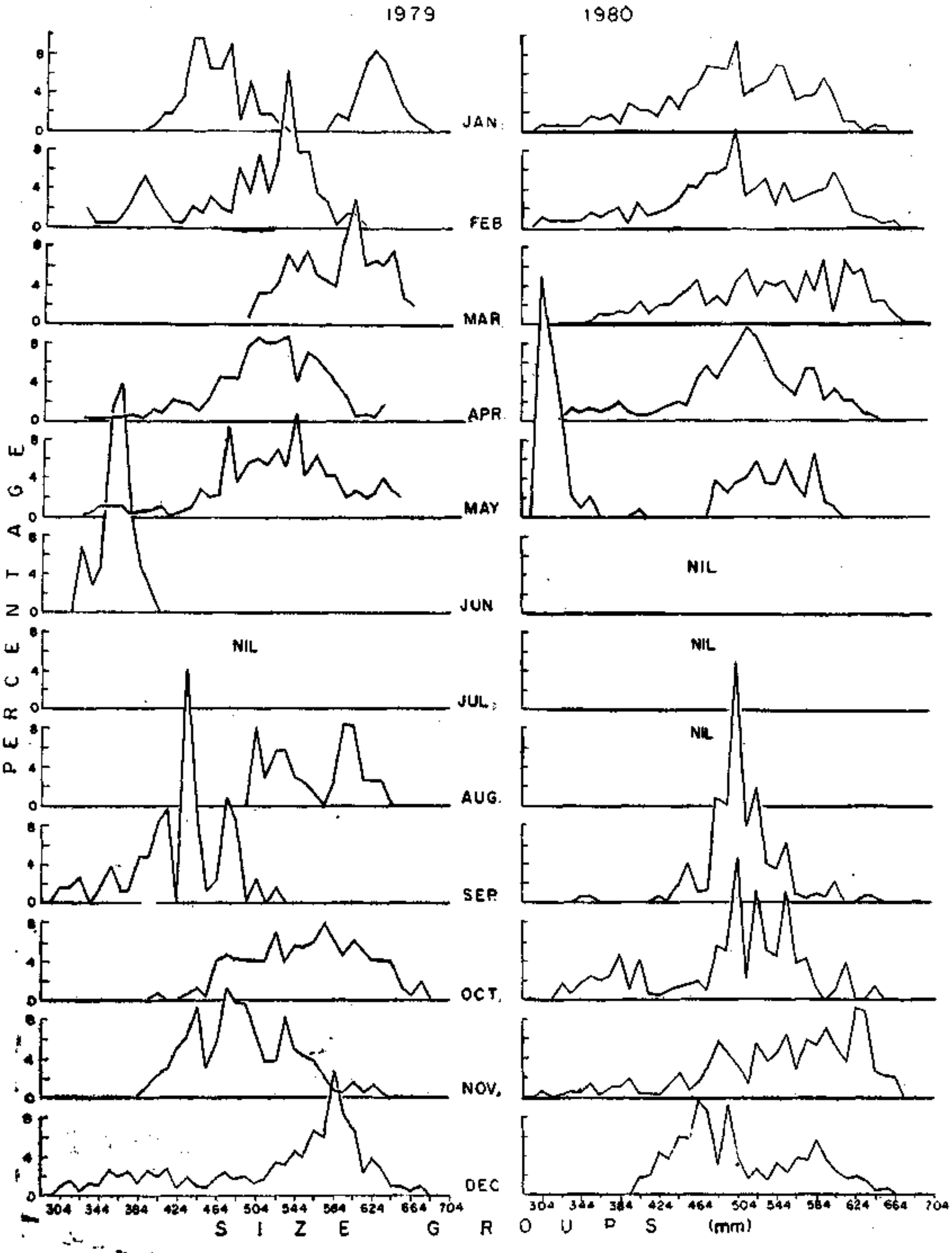

Fig. 8. Monthly length frequency distribution of *K. pelamis* at Minicoy, 1979-'80.

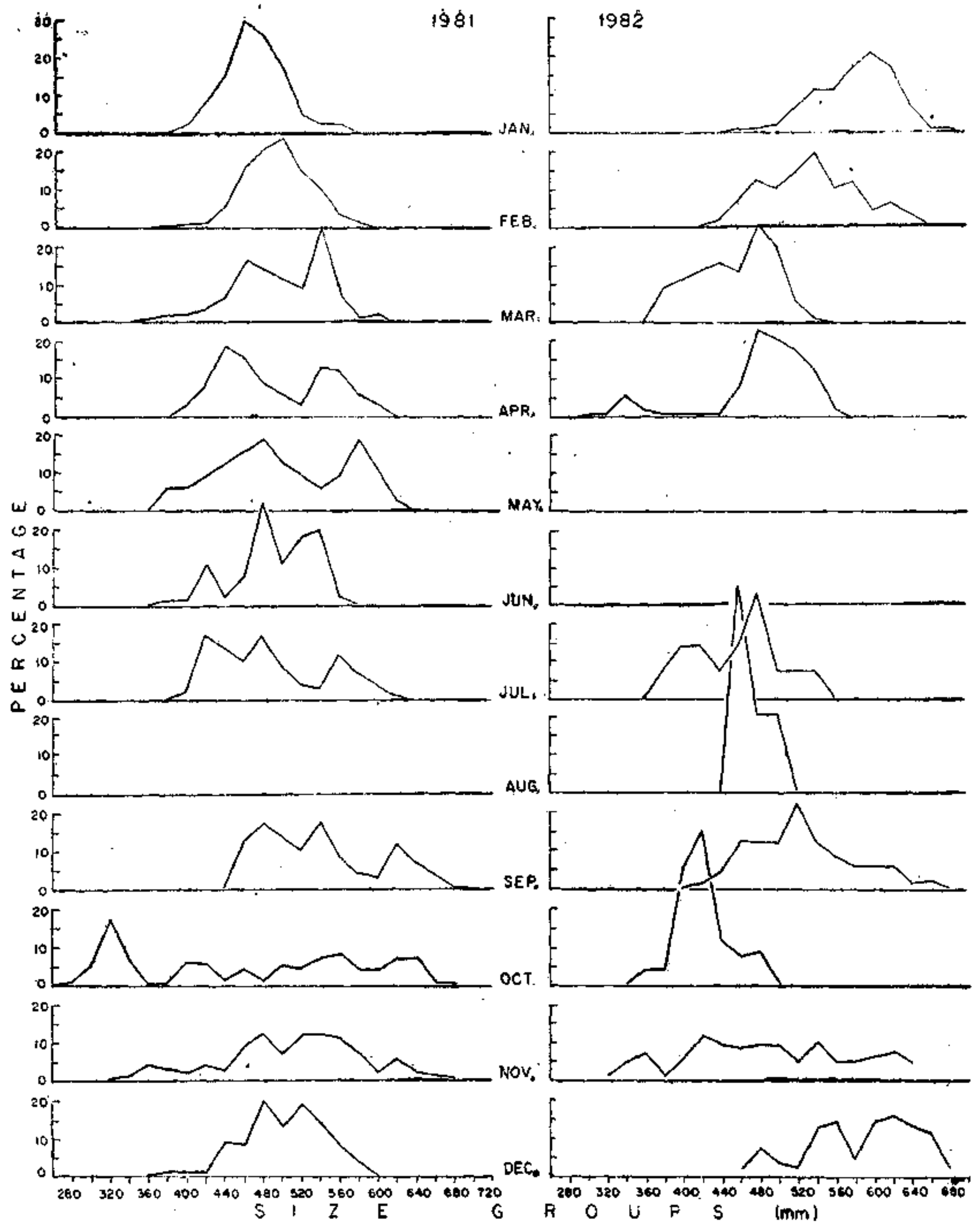

Fig. 9. Monthly length frequency distribution of *K. pelamis* at Minicoy, 1981-'82.

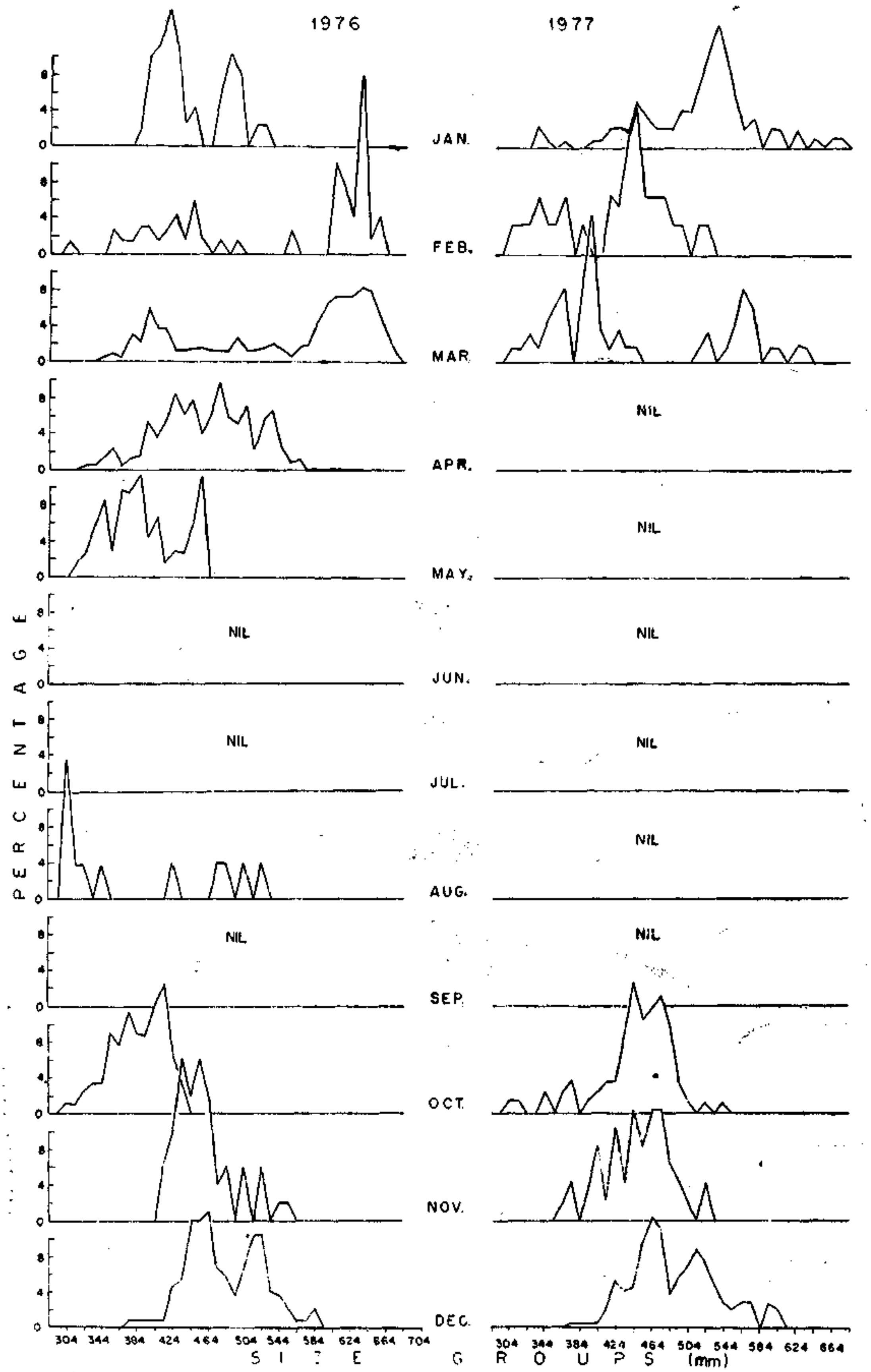

Fig. 10. Monthly length frequency distribution of *T. albacares* at Minicoy, 1976-'77.

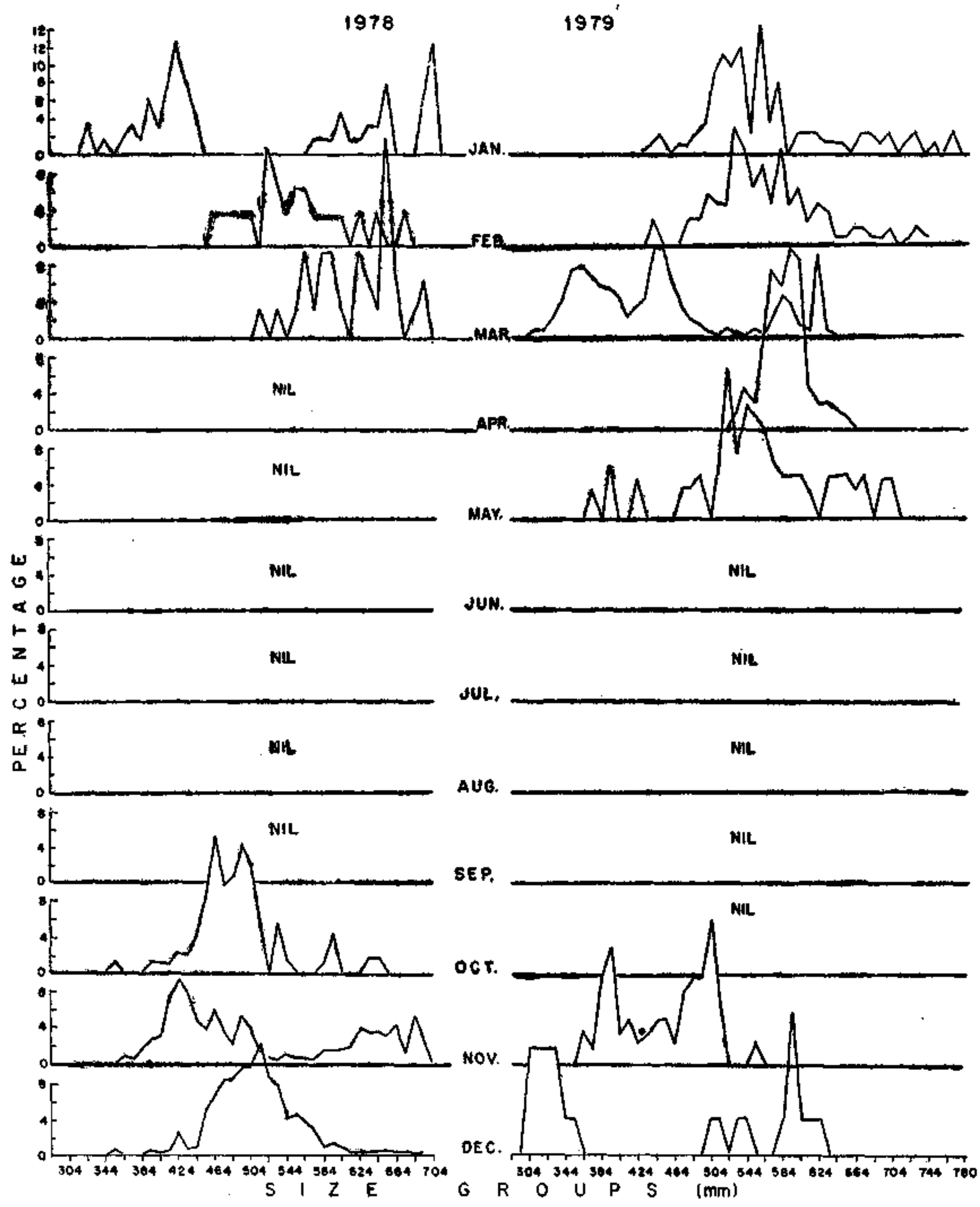

Fig. 11. Monthly length frequency distribution of *T. albacares* at Minicoy, 1978-'79.

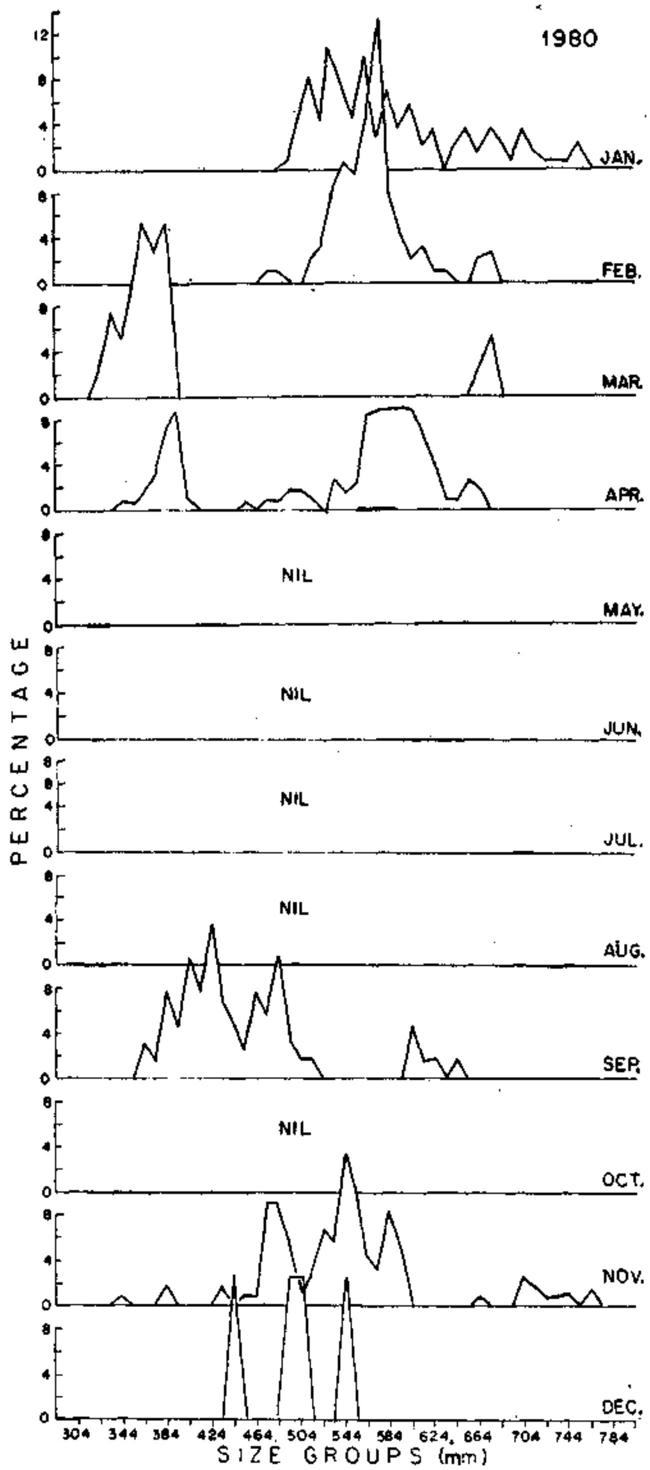

Fig. 12. Monthly length frequency distribution of *T. albacares* at Minicoy, 1980.

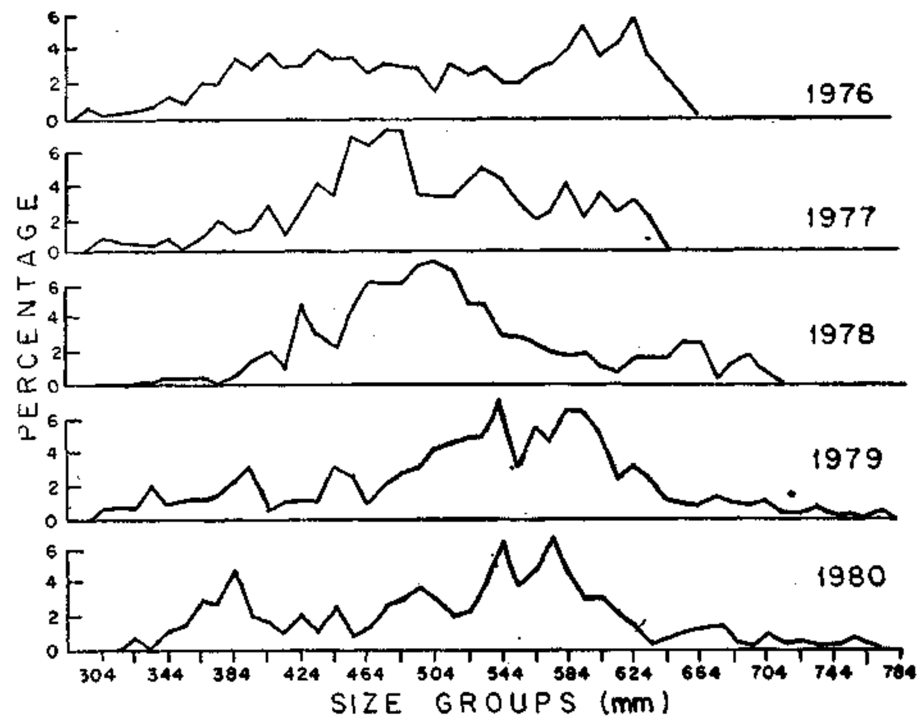

Fig. 13. Pooled annual length frequency distribution of *T. albacares* at Minicoy, 1976-'80.

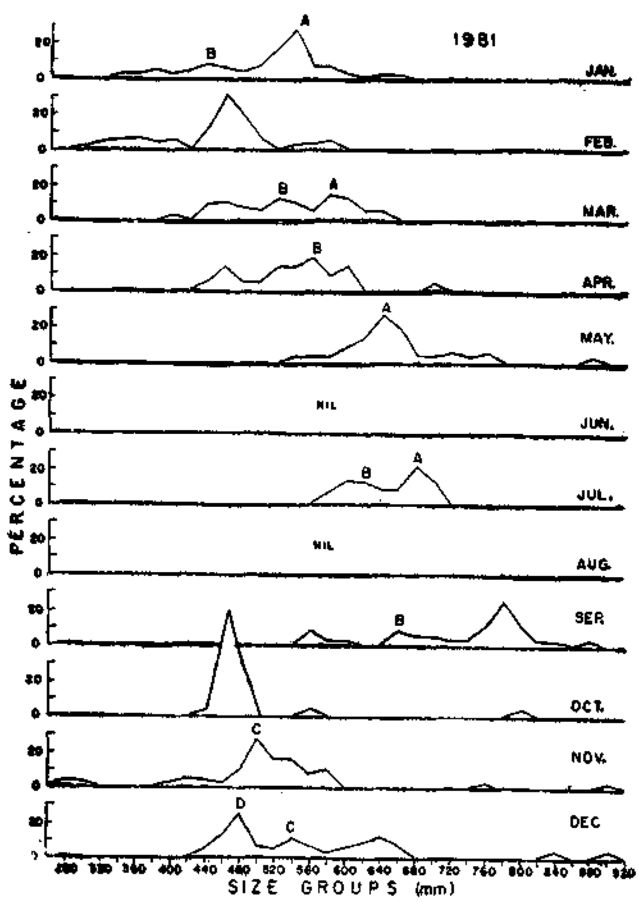

Fig. 14. Monthly length frequency distribution of *T. albacares* at Minicoy, 1981.

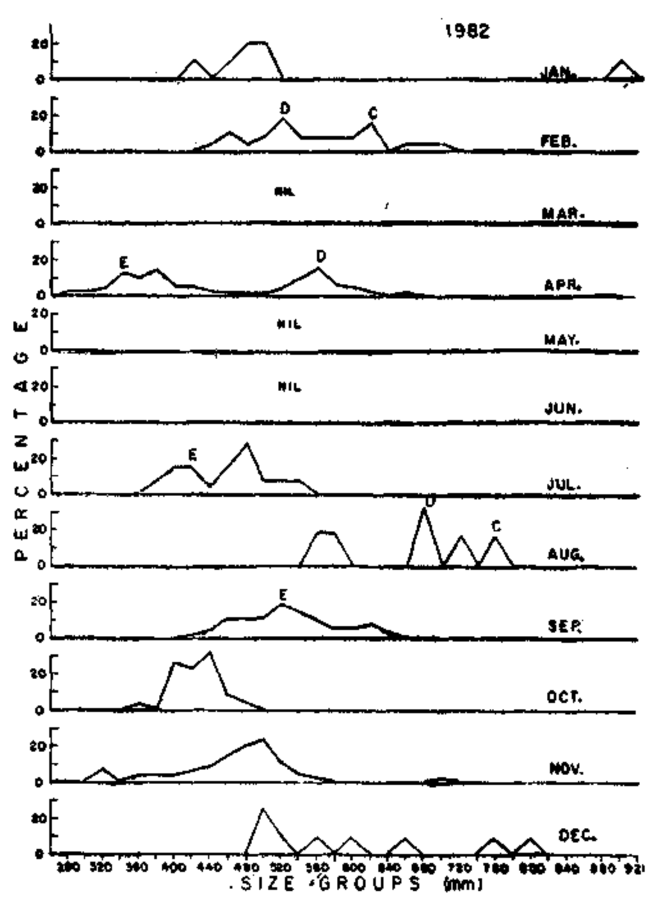

Fig. 15. Monthly length frequency distribution of *T. albacares* at Minicoy, 1982.

was high from February to May and in September and October. Maximum value of 522 kg was recorded in April and lowest 38 kg in August.

SPECIES COMPOSITION

Pole and line catches: It is evident from the fig. 5 that during 1976 *Katsuwonus pelamis* accounted for 94% of the total tuna catch followed by *Thunnus albacares* 5% and other tunas 1%. During 1977 the percentage of yellowfin increased by contributing 31.3% and skipjack with 68.7%. In the ensuing year skipjack contributed 75% and yellowfin 25%. In 1979 skipjack formed 77% of the tuna catch and yellowfin 23%. During 1980 there was a little increase in skipjack catch 80.9% followed by yellowfin 19% and other tunas 0.1%. In 1981, the catch of skipjack shoed a decline while that of yellowfin improved (Fig. 6). During 1982 *Katsuwonus pelamis* accounted for 90% and yellowfin 10%.

Troll line catches: Yellowfin tuna predominated in the troll line catches followed by billfishes from 1976 to 1982 (Figs. 5 & 6).

SIZE DISTRIBUTION

In *K. pelamis* the size ranged from 304-704, 304-664, 320-744, 304-684, 304-664, 260-700 and 280-680 mm during 1976-'82 respectively. The monthly progression of the various modes are given in figs. 7-9.

In *T. albacares* the size ranged from 304-664, 304-624, 324-684, 304-664, 324-764, 260-920 and 260-920 mm during 1976-'82 respectively. Monthwise progression of the modes are given in figs. 10-15.

13

LENGTH-WEIGHT RELATIONSHIP OF SKIPJACK, *KATSUWONUS PELAMIS* (LINNAEUS) AND YELLOWFIN TUNA *THUNNUS ALBACARES* (BONNATERRE) FROM MINICOY WATERS

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One of the major objectives of the research programme on tunas at Minicoy Island, is to collect data on length frequency distribution of skipjack, *Katsuwonus pelamis* and yellowfin tuna *Thunnus albacares* which are caught by pole and line fishing. In order to utilize these length frequency data and to convert catch data from kilograms to number of fish for the purposes of estimating average weights and the population sizes, it becomes essential to estimate the length-weight relationship of these species.

1. SKIPJACK TUNA

Data on length and weight of skipjack were collected from Minicoy fish landing centre during 1981-1982. Fish were measured and weighed in fresh condition. Fork length was measured in millimetres and weight was recorded to the nearest 50 grams. Sex and maturity stages of individual fish were also recorded.

Length-weight relationship of each fish is expressed by the formula

$$W = aL^b$$

where W = weight, L = length and *a* and *b* are constants. Logarithmic transformation of the formula gives a straight line relationship of the form

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

Log a and the regression coefficient (b) were estimated by the least square method. Through analysis of covariance procedure, the coefficient of determination r^2 and the residual mean squares or variance and M.S. were also computed for each regression equation.

A total of 440 fish, of which 220 were males were analysed for this study. Males ranged in fork length from 360 to 660 mm and the 220 females from 360 to 670 mm. The following basic statistics were estimated from the logarithmic lengths and weights for deriving the regression equations separately for the males, females and both sexes combined.

Statistics	Groups		Both sexes combined
	Males	Females	
N ..	220	220	440
sx ..	592.111743	594.437869	1186.549612
sy ..	732.061668	738.150002	1470.211670
sx^2 ..	1594.342638	1606.690249	3201.032887
sy^2 ..	2444.776084	2483.485438	4928.261522
sxy ..	1972.709421	1996.291708	3969.001129

sx, sy = Sums of x and y ; sx^2, sy^2 and sxy = Sums of squares and products.

Corrected sums of squares and products as well as the estimates of regression coefficient b and standard error for males, females and both sexes combined are as follows :

Statistics	Groups		Both sexes combined
	Males	Females	
D.F. ..	219	219	438
sx^2 ..	0.72304	0.5248	1.2479
sxy ..	2.4262	1.8175	4.2437
sy^2 ..	8.8020	6.8294	15.6264
b ..	3.355656	3.462785	3.39301
D.F. ..	218	218	437
S.S. ..	0.66079	0.53057	1.19486
M.S. ..	0.0030	0.0024	0.0027
S.E. ..	0.6473	0.6804	0.0466

D.F. = Degree of freedom ;
sx^2, sy^2 and sxy = Corrected sums of squares and products ;
b = Regression coefficients ;
S.S. = Sum of squares ;
M.S. = Mean squares ;
S.E. = Standard error of regression coefficients.

By using the above statistics following relationship for males and females separately was obtained.

Males $\quad \text{Log } W = -5.70392 + 3.35566 \text{ Log } L$

Females $\quad \text{Log } W = -6.00119 + 3.46279 \text{ Log } L$

which is equivalent to

Males $\quad W = 0.00000198 \ L^{3.35566}$

Females $\quad W = 0.000001 \ L^{3.46279}$

The value of '*r*' which is a measure of the degree of association between the L and W (Correlation coefficient) for males was 0.961743 and for females 0.968386. The coefficient of determination r^2 which is the proportion of the variation in W explained by the fitted regression and square root of this quantity, for the males was 0.9249 and for females 0.92227.

The result of analysis of covariance to test the significance of differences in the regressions of y and x are presented below :

Source of variation	Degree of freedom	Sum of squares	Mean squares	Observed F	5% F
Deviation from individual regression within sexes ..	436	1.19136	0.00273	1.28208*	3.92-3.84
Differences between regression ..	1	0.00350	0.00350		
Deviation from average regression	437	1.19486	0.00273		

* Not significant.

From the table it becomes clear that there is no significant difference in the regression coefficient between males and females. Even in the adjusted means also, no significant difference could be observed. Therefore, the data for both males and females were pooled together and a common length-weight relationship was fitted.

$$\text{Log } W = -5.80855 + 3.39301 \text{ Log } L$$

which is equivalent to

$$W = 0.00000155 \ L^{3.39301}$$

The regression lines for males and females and for both sexes combined are shown in Fig. 1 & 2.

In the report by Chatwin (1959) a very low exponential value of 2.626 was obtained for skipjack from off northern Chile area. It was pointed out by him that the estimate was based on two samples of fish with a very narrow range of total lengths which was not representative of the range in the catch. He emphasized that it would be desirable to obtain a further estimate based on a larger range of total length. Hennemuth (1959) calculated regression coefficient value from 3.144 to 3.555 based on 1280 fish with length range from 414 to 697 mm in different areas of the Eastern Pacific Ocean north of the equator. The total pooled regression equation by him was :

$$Y = -8.250 + 3.336 X$$

Nakamura and Uchiyama (1966) found the value of *b* to be 3.36836 from the Central Pacific Ocean. Batts (1972) calculated the length-weight relationship for 644 skipjack from North Carolina waters. Fish length in his studies ranged from 263 to 757 mm while weights were from 0.29 to 9.73 kg. He calculated the value of regression coefficient to be 3.3533 and noticed that this value agreed well with length-weight relationship of skipjack reported by Nakamura and Uchiyama (1966).

Blackburn and Servanty (1981) measured 607 skipjack with length range of 410 to 645 mm from east coast of Australia and calculated the following relationship.

$$\text{Log } W = -6.0762 + 3.5202 \text{ Log } L$$

The coefficient of determination r^2 was 0.856 and standard error of the first and second constant in the equation were 0.1595 and 0.0586. Their equation was equivalent to

$$W = 0.000000839 \ L^{3.5202}$$

They found that regression from east Australia and eastern Pacific are significantly different at the 5% level of probability. They reported that the two groups of skipjack tuna probably belong to different populations.

In the present study regression equation was calculated for males and females separately and the value of *b* for males was 3.35566 and for females 3.46279. Testing for significant difference between the two regression equations was performed. The F value in testing for equal slopes was found to be non-significant. Thus the two regression lines were found coincidental and therefore no significant difference is present between the length-weight relationship of male and female fish. So it is appropriate to pool all the data and the common value for regression coefficient was found as 3.39301.

Similar studies on the length-weight relationship of skipjack tuna have been conducted during the period

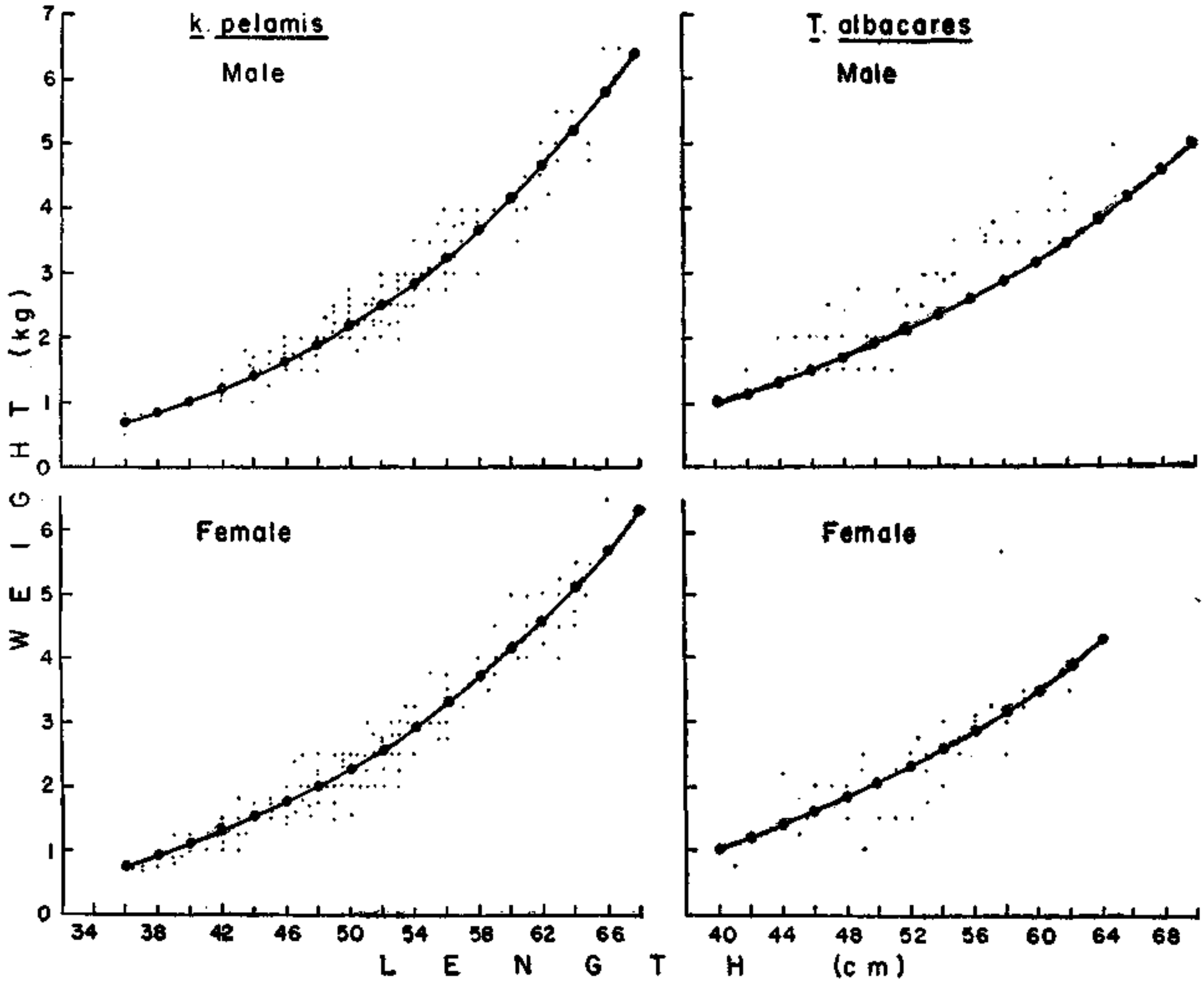

Fig. 1. Length-weight relationship of males and females of *K. pelamis* and *T. albacares* at Minicoy 1980-'82.

1978-80 and the relationship emerged was with 'r' value of 0.9615.

$$W = 0.000000002093\ L^{3.30212}$$

The standard error of common regression coefficient in the equation is 0.04669 and the value of coefficient of determination r^2 as 0.9235.

There is no previous published information on length-weight relationship of skipjack from Indian waters for comparison with the results of the present study. However, Marcille and Stequert (1976) have examined 848 specimens of skipjack taken by bait boats from Madagascar within the size range 41-62 cm and according to them the value of constant 'b' is 1.131×10^{-5} and the coefficient of allometry 'a' was 3.158. They arrived at the conclusion that the calculated weight of 55 cm fish is 3.54 kg.

2. Yellowfin tuna

The length-weight relationship of yellowfin tuna, *Thunnus albacares* from several fishing areas of the Eastern Tropical Pacific Ocean been published by Chatwin (1959). But there is no published information on this aspect from Minicoy waters, where yellowfin forms 5 to 20 % of the total tuna catch every year.

Present investigations are based on 134 yellowfin tuna taken in the pole and line fishery out of which 67 were males and 67 females. Males ranged in fork

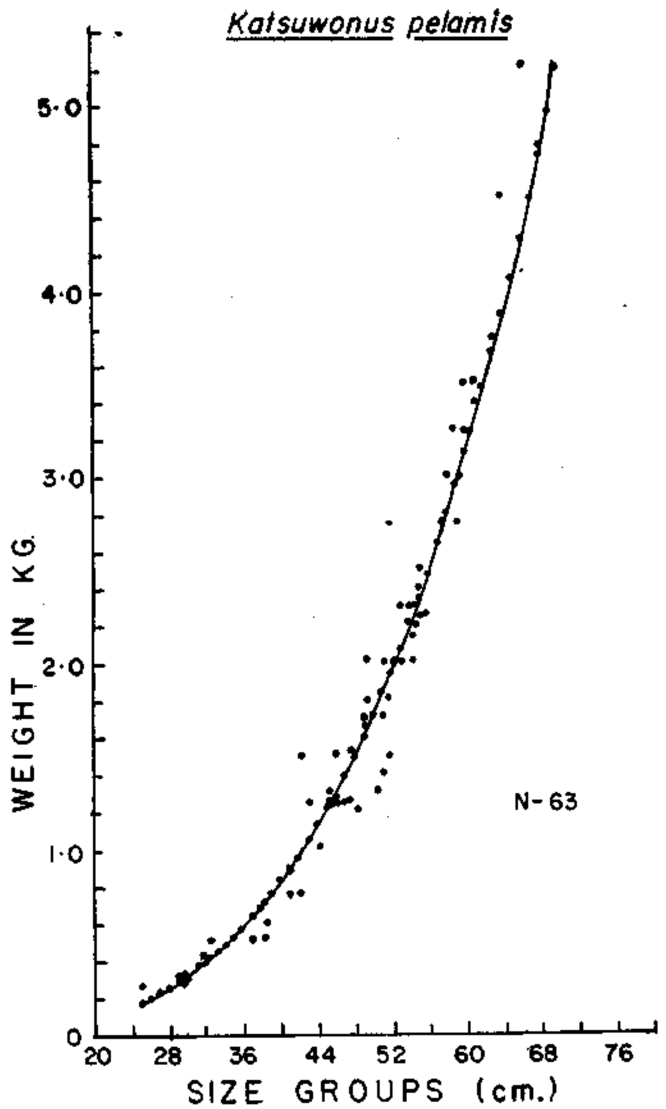

Fig. 2. Length-weight relationship of *K. pelamis* at Minicoy (pooled), 1980-'82.

length from 420 mm to 680 mm and females between 410 mm and 620 mm. Fork length in millimetres, total weight in grams, sex and maturity stages of individual fish were recorded in fresh condition.

The following basic statistics were estimated from the logarithms of length and weight for deriving the regression equations separately for the males, females and both sexes combined.

Statistics	Groups		Both sexes combined
	Males	Females	
N ..	67	67	134
sx ..	417.727836	417.150184	834.878020
sx^2 ..	2605.167765	2597.768107	5202.935872
sy ..	516.945556	509.704716	1026.650272
sy^2 ..	3997.080792	3884.822076	7881.902868
sxy ..	3225.220016	3175.109956	6400.329972

sx, sy = Sum of x and y :
sx^2, sy^2 and sxy = Sums of squares and products.

Corrected sums of squares and products as well as the estimates of regression coefficient *b* for males, females and for both sexes combined are as follows :

Statistics	Males	Females	Both sexes combined
D.F. ..	66	66	132
sx^2 ..	2.196905	1.626134	3.823039
sxy ..	0.741721	0.540107	1.281828
sy^2 ..	8.532913	7.226591	15.759504
b ..	2.961902	3.010763	3.001012
D.F. ..	65	65	131
D.D. ..	8.2829	7.0472	15.3297
M.S. ..	0.1274	0.0358	0.0810

D.F. = Degree of freedom :
xy, x^2, y^2 = Corrected sums of products and squares :
b = Regression coefficient :
S.S. = Sum of squares :
M.S. = Mean squares.

By using the above statistics the following equations for males and females separately were obtained.

$$\text{Males} \quad \text{Log W} = -10.751095 + 2.961902 \text{ Log L}$$

$$\text{Females} \quad \text{Log W} = -11.137845 + 3.010763 \text{ Log L}$$

The results of analysis of covariance to test the significance of differences in the regressions of x and y are presented in the following table :

Source of variation	Degree of freedom	Sums of squares	Mean squares	Observed F	5% F
Deviation from individual regression within sexes ..	130	15.3301	0.1179	0.0034 *	3.92-3.84
Differences between regressions ..	1	0.0004	0.0004		
Deviation from average regression	131	15.3297	0.1046		

* Not significance.

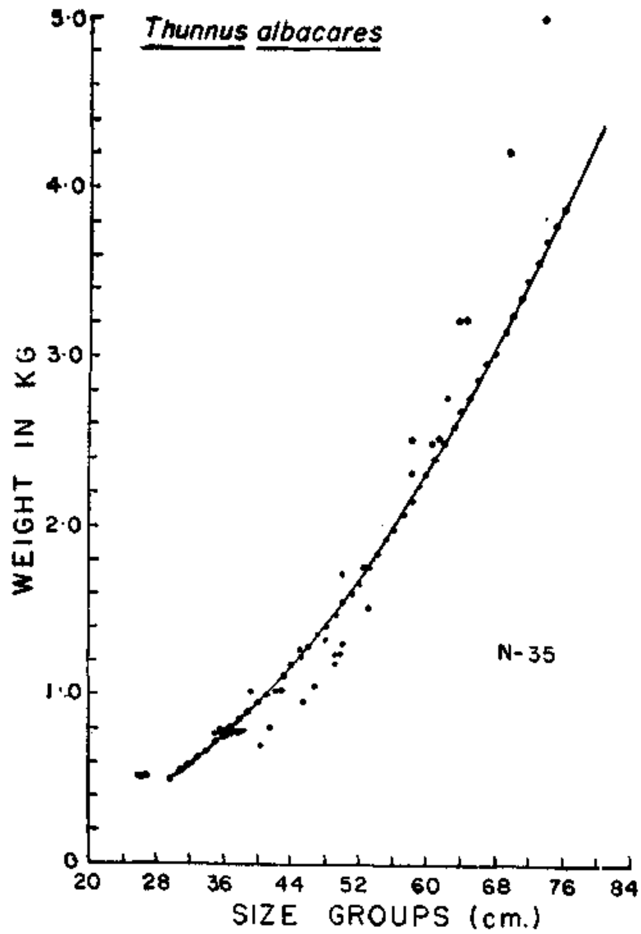

Fig. 3. Length-weight relationship of *T. albacares* at Minicoy (pooled), 1980-'82.

As is clear from the table there is no significant difference in the regression coefficient between males and females (Fig. 1). Therefore, the data for both males and females were pooled together and a common length-weight relationship equation was fitted as below (Fig. 3).

$$\text{Log } W = -11.036032 + 3.001012 \text{ Log } L$$

The value of '*r*' which is a measure of the degree of association between the length and weight (Correlation coefficient '*r*') for the males was 0.8732 and for females 0.8230.

Studies on the similar lines have been conducted to find out the length-weight relationship of yellowfin tuna during 1978-80. The relationship obtained was

$$W = 0.000001655 \ L^{2.21160}$$

and the '*r*' value was 0.9139.

Chatwin (1959) calculated the length-weight relationship of yellowfin tuna, *Thunnus albacares* from the Eastern Pacific Ocean. He estimated the value of regression coefficient to be 3.020 from all the areas he sampled.

The results of the present study reveal that there is no significant difference in the regression coefficient between males and females. Therefore data are pooled together and common equation is fitted. The value of regression coefficient for the pooled data is 3.001012 which is almost equal to the value given by Chatwin (1959).

14

AGE AND GROWTH OF *KATSUWONUS PELAMIS* (LINNAEUS) AND *THUNNUS ALBACARES* (BONNATERRE) FROM MINICOY WATERS

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1. SKIPJACK TUNA

The earliest estimate of growth of skipjack tuna in the Pacific Ocean was that of Aikawa (1937) who examined 20 specimens from the islands off the southern part of Izu Peninsula in the western Pacific and later Aikawa and Kato (1938) examined 20 specimens from the Palau Island area. Kawasaki (1955) estimated the growth of skipjack from the south western sea off Japan, based on the progression of modal groups. In a later publication Kawasaki (1963) gave additional estimates of growth rates based on the data from the area off north eastern Japan. Yokota *et al.* (1961) estimated the growth rates based on modal progression of skipjack from the Sulu Sea. Brock (1954) studied the growth of skipjack in the area of the Hawaiian islands by examining the progression of modes computed from length frequency studies. Rothschild (1967) estimated the parameters of growth for this species on the basis of 35 recoveries of fish tagged in Hawaiian waters in 1958 which were at liberty upto 420 days. In the eastern Pacific, Schaefer *et al.* (1961) examined the growth of skipjack tagged during 1955-1959. In another publication, Schaefer (1961) reported the results of growth studies of skipjack tuna in the Pacific, north of 15.N. on estimates from modal progression. Batts (1972) estimated age and growth of skipjack from north Carolina, from annuli in cross sections of dorsal spines. A review and critique of the methods and results of numerous investigations of growth rate in adult skipjack has been made by Josse *et al.* (1979). Wild and Foreman (1980) have counted the increments on otoliths of skipjack from the Revillagigado Islands and off Baja California which were tagged, injected with tetracycline, released and captured. Matsumoto and Skillman (1984) have tabulated the growth parameters for the von Bertalanffy growth equation and compiled the lengths at various ages from different investigations on skipjack.

From the Indian ocean, Shabotiniets (1968) calculated the length at different ages of skipjack from Madagascar area based on the growth marks in the first spine of the first dorsal fin. The only published information on the age and growth of skipjack tuna from Indian waters is that by Appukuttan *et al.* (1977) based on data collected from 1966 to 1969 from Minicoy waters.

Random samples of skipjack tuna, *katsuwonus pelamis* caught by pole and line tuna fishing off Minicoy were selected for taking length measurements. Length was measured from the tip of the snout to the caudal fork (Fork length) upto the nearest half centimetre. Care was taken not to include any specimen where the tail portion was suspected to be broken. The length measurements were grouped at two cm intervals and length frequency curves were plotted.

Length frequency distribution and progression of modal groups

These studies are based on 1140 specimens measured during 1981 and 752 in 1982. The fork length of the individual fish ranged from 280 to 680 mm. The results are plotted in the form of length frequency curves.

The analysis of data revealed certain regular modes together with some minor modes. The identity of some of the smaller modes appeared doubtful, and in the description given below they are mentioned as such and growth rate has been calculated only by tracing a few conspicuous modes in the length frequency curves.

In April 1981, two modes (A and B) may be seen at 440 and 540 mm (Fig. 9: See paper 12). In May two modes can be recognised at 480 and 580 mm. In June three modes are observed at 420, 480 and 540 mm. While the mode at 480 mm of June can be traced back as mode A of April indicating a growth of 4 cm, mode at 540 mm and 420 mm could not be traced back. In July, modes are seen at 420, 480 and 560 mm. Samples were not available in August. In September mode A of June progressed to 540 mm and mode B of April appeared at 620 mm with a growth of about 10 cm increment in six months. In October mode A progressed by 2 cm and a new mode C appeared at 320 mm which could be considered as an addition of new individuals to the fishery. Three small modes also appeared at 400, 460 and 500 mm. In November five modes at 360, 420, 480, 500 and 620 mm can be seen but only one of them could be traced back *i.e.*, mode B of September which did not show increment in growth.

Following the progress of the modes during the course of another year in January 1982 mode A of October, 1981 appeared at 600 mm with a growth of 4 cm. In February, mode A showed growth of 2cm and progressed to 620 mm. In March two modes were observed at 440 and 480 mm. Mode C at 440 mm which was evidently not represented in the immediate preceding four months appeared again with growth of 10 cm in four months. In April, the modes were at 340 and 480 mm. Again the appearance of a fresh mode at 340 mm (mode D) in April reveals the recruitment of new individuals to the fishery. There were no samples during May and June. In July two modes can be seen at 400 and 480 mm. Mode at 400 mm is due to 6 cm growth of mode D of April, at 340 mm and mode at 480 mm is due to 4 cm growth of mode C of April. In August there is only one mode at 460 mm which could not be traced back. In September two modes are seen at 460 mm and 520 mm. Mode at 460 mm can be traced back to mode D of July at 400 mm and mode at 520 mm is due to 4 cm growth of mode C of July at 480 mm. In October there are two modes at 420 and 480 mm. Mode D of September has progressed by 2 cm and a new mode has come up at 420 mm. In November, mode C of September has again appeared at 540 mm. There are four other modes at 360, 420, 500 and 620 mm. Mode at 360 mm is because of the entry of new individuals to the fishery. In December three modes can be seen at 480, 560 and 620 mm. While mode at 480 mm can be traced back at 480 mm in October which did not show any growth increment, mode C of November progressed by 2 cm.

Age and Growth

The determination of the age at the time of recruitment to the fishery has been a problem. Appukuttan *et al.* (1977) have given the length of one year old skipjack as 406 mm at Minicoy while other workers have given different sizes of one year old skipjack: Aikawa and Kato (1938) as 270 mm; Brock (1954) as 523 mm; Yokota *et al.* (1961) as 370 mm; Schaefer (1961) as 304 mm; Rothschild (1966), Joseph and Calkins (1969) as 304 mm and Batts (1972) as 406 mm.

Yoshida (1971) while studying the growth rate of juveniles of skipjack tuna from Hawaii and South Pacific Ocean has stated that larval skipjack tuna grow 9 cm during the first month and thereafter 2 cm per month for the next 11 months. Thus he calculated length of one year old skipjack as 31 cm. Fish in 35 cm length form a prominent mode during winter Hawaiian skipjack fishery (Rothschild 1965).

It can be seen from fig. 9 (see paper 12) that prominent mode of the smallest fish appeared at 320 mm in October 1981 and at 360 mm in November 1981. Again mode of smallest fish appeared at 340 mm in April 1982 and at 360 mm in November 1982. The occurrence of 360 mm fish in the month of November of both the years is significant pointing to the possibility that they are one year old. Presuming one month old skipjack to be 10 cm long, the growth rate during first year will be about 23.6 mm per month during the rest of the 11 months assuming that the one year old skipjack is 360 mm. During 1981, the mode of the smallest fish seen at 320 mm progressed to 560 mm by December 1982. Thus in 14 months, the mode has progressed by 240 mm *i.e.*, a monthly growth rate of 17.14 mm. In the same way mode D of April 1982 at 340 mm could be followed upto December 1982 at 480 mm and thus in 7 months it progressed by 140 mm with monthly growth rate of 17.5 mm. Mode A of April 1981 at 440 mm could be followed upto March 1982 when it attained 620 mm length in 11 months with monthly growth rate of 16.3 mm. Mode B at 540 mm in April 1981 could be followed upto November 1981 when it attained 620 mm in 7 months *i.e.*, a growth rate of 11.4 mm per month. Thus with age there is a reduction in growth rate. The length of 3 years old skipjack will be about 682 mm. Fish longer than 680 mm were not recorded during these observations.

Fitting von Bertalanffy's growth equation

von Bertalanffy's (1938) growth equation $L_t = L_\infty (1 - e^{-K(t-t_0)})$ is applied in the present study to estimate the growth parameters.

For assigning ages to certain sizes of fish, it is essential to estimate the size at birth. Earlier workers have estimated size at age on length frequency data which were utilised to interpret modal progression in time. Hence there is a wide range of such estimations.

Joseph and Calkins (1969) used size at hatching to assign ages to skipjack tuna. Same has been considered for these studies. From the data published by Raju (1964) an average circumference of 3.00 mm of skipjack eggs has been calculated. Jones (1959) has given length of skipjack larvae from 5.08 to 6.17 mm from Minicoy area and from 2.63 mm to 7.08 mm from other areas of Laccadive Sea. So length at hatching has been taken as 3 mm.

The values of other growth parameters were calculated as follows :

$L\infty$ = 900 mm
k = 0.4898 (annual basis)
t = —0.06

Based on these parameters age of skipjack was calculated. For one year old skipjack the size observed was 367 mm, for two years old 573 mm, for three years old 690 mm and for four years old 777 mm. The monthly growth rate for four years were calculated as 30.58 mm, 17.16 mm, 9.75 mm and 7.25 mm respectively.

Discussion

A summary of growth studies in different parts of the world Oceans by various authors are given in Table 1.

A review and critique of the methods and results of the numerous investigations of growth in adult skipjack has been made by Jose *et al.* (1979). They compared their tagging data from Joseph and Calkins (1969) for the eastern Pacific and the tagging data from the Papua New Guinea area for the fish of smaller size (40-60 cm). They found no significant difference in the growth of skipjack from both the areas. An estimate of 17.4 cm per year from modal progression was estimated for the eastern Pacific similar to that obtained from tagging data.

From daily growth increments on otoliths, Uchiyama and Struhsaker (1979) estimated growth of 28.2 cm between one and two years, 10.8 cm between 2 and 3 years from central Pacific and that skipjack from eastern Pacific grew 23.6 cm between 1 and 2 years of age. According to Josse *et al.* (1979) these differences in growth rates among areas are probably not statistically significant.

Age and growth studies of skipjack from the Indian Ocean are very few. Shabotiniets (1968) calculated the size at age of skipjack tuna from Madagascar area based on the growth marks in the first spine of the first dorsal fin. Since he could not validate the marks on spine sections as annuli, the age and growth and length at different ages seems to be doubtful. He stated 40-45 cm long fish to be 3 years old and 40-60 cm 4 years old.

Appukuttan *et al.* (1977) estimated the values of *k* and $L\infty$ from Minicoy waters to be 0.22 and 843 mm when the length of the fish ranged between 350 and 695 mm. They applied three methods i.e. probability plot technique, length frequency and the statistical method and found almost similar results by these methods. Employing the probability plot method they found that fish attains 402.2, 494, 562.6 and 620.5 mm respectively when it is 1 year, 2 year, 3 year and 4 year

TABLE 1. *Size in mm, at given ages in months for various estimates (By* von Bertalanffy equation) *of the growth of skipjack*, Katsuwonus pelamis

Age in months	Aikawa & Kato 1938	Brock 1954 k = 0.95	Yokota 1961	Schaefer 1961 k = 0.44	Kawasaki 1963 k = 0.19	Rothschild 1966 k = 0.77	Joseph & Calkins 1969 k = 0.41	Skillman (MS) k = 0.47	Batts 1972	Appukuttan *et al.* 1977 k = 0.22	Shabotiniets 1968	Present study k = 0.48
0	..	3	..	3	3	3	3	..	..	..	..	3
6	..	323	..	170	131	265	203	..	..	..	..	..
12	270	523	370	304	247	443	366	430	406	407	..	367
18	..	647	..	411	352	564	498	..	..	..	..	..
24	270-370	724	520	498	449	647	605	610	493	493	..	573
30	..	771	..	567	536	703	693	..	..	..	..	..
36	370-460	802	645	623	615	741	764	730	569	562	400-450	690
42	..	820	..	668	688	767	822	..	..	..	..	..
48	460-550	832	750	704	754	785	869	800	638	620	400-600	777
L	800	851	1400	851	1418	823	1075	924	..	843	..	900

old. By length frequency study they observed that fish attains 410, 500, 570, 630 and 680 mm in one year to 5 year old respectively. By fitting Von Bertalanffy growth equation they estimated the length of 1 year 2 year, 3 year, 4 year, 5 year and 6 year old fish as 407.29, 493.34, 562.39, 620.05, 664.08 and 699.41 mm respectively. They calculated monthly growth rate for six years as 33.9, 7.2, 5.8, 4.8, 3.7 and 2.9 mm respectively.

A review of the literature on growth of skipjack tuna (Table 1) reveals that according to the majority of the studies fish grow from 15 to 28 cm between first and second year of its age, 8 to 16.7 cm between 2 and 3 years and 8 to 13.9 cm between 3 and 4 years. The only exception to these results are that by Batts (1972) who observed 7.2 cm growth between 1 and 2 year, 7.6 cm between 2 and 3 years and 6.9 cm between 3 and 4 years and Appukuttan *et al.* (1977) who estimated 8.6 cm between 1 and 2 years, 6.9 cm between 2 and 3 years and 5.8 cm between 3 and 4 years. The results of the present studies show that skipjack grow 21 cm between 1 and 2 years, 12 cm between 2 and 3 years and 8.7 cm between 3 and 4 years.

According to published information from the Pacific and elsewhere monthly growth rate of skipjack during the first year ranged between 20.58 and 43.58 mm, for the second year between 12.5 and 23.3 mm, during third year between 6.6 and 13.91 mm and during fourth year between 4 and 11.58 mm. In majority of the studies these values fell around 30, 15-20, 10-13 and 8 cm during first, second, third and fourth year respectively. But according to Appukuttan *et al.* (1977) the monthly growth increments during the first six years were 33.9, 7.2, 5.8, 4.8, 3.7 and 2.9 mm respectively. While monthly growth rate in their studies from second onwards can be considered, the fall in growth rate from 33.9 mm during first year to 7.2 mm during second year is very low. The results of the present studies show a monthly growth rate of 30.58 mm during first year, 17.16 mm during second year, 9.75 mm during third year and 7.25 mm during fourth year.

Josse *et al.* (1979) in their critical review of the methods and results of numerous investigations of growth rate of skipjack concluded that counting seasonal marks on vertebrae, scales and dorsal spines and following modal progression of length frequencies are the least reliable, that counting daily increments on otoliths is more reliable and that measuring the growth between tagging and recapture is the most reliable. There is no published information on the tagging experiments of skipjack tuna from Indian waters. Although growth rates observed during the present investigation agrees well with many other studies in the Pacific and elsewhere, till tagging experiments are conducted in Indian waters and growth is estimated, age and growth estimated in present studies may be treated with some reservations.

2. Yellowfin tuna

A number of investigations have been made on the age and growth of yellowfin tuna, *Thunnus albacares* caught by pole and line from the Pacific Ocean and elsewhere. Different methods have been applied to estimate age and growth such as analysis of annual marks on scales and vertebrae (Aikawa and Kato 1938 ; Nose *et al.* 1957 ; Yabuta *et al.* 1960 ; Tan *et al.* 1965 ; Yang *et al.* 1969), by the modal progression of length frequencies (Moore 1951 ; Yabuta and Yukinawa 1957 and 1959 ; Hennemuth 1961 ; Davidoff 1963), incremental growth (Diaz 1963) and data from tagging experiments (Blunt and Messersmith 1960 ; Schaefer *et al.* 1961 ; Bayliff 1973). Uchiyama and Struhsaker (1981) and Wild and Foreman (1980) studied the age of yellowfin tuna by counting growth increments from otoliths.

Suzuki (1971) has reviewed the methods and results of age and growth determination by the scales and vertebrae, length frequency model progression and by incremental growth method.

There is no published information on age and growth of yellowfin tuna from Indian seas. This paper deals with age and growth studies of yellowfin tuna at Minicoy by length frequency method and by estimating the parameters of Von Bertalanffy growth equation.

Random samples of yellowfin tuna, *Thunnus albacares* were selected for recording fork length of fish. Care was taken not to include such specimens were tail portion was suspected to be broken. Totally 912 length measurements were recorded from January 1981 to December 1982. The length measurements were grouped at two cm interval and length frequency curves were plotted.

Length frequency distribution and progression of modal groups

The percentage frequency in the various size groups are plotted as length frequency curves in Figs. 14 & 15 (see paper 12).

It can be observed from the Fig. 14 that there are three modes in January at 380 mm, 440 mm (Mode B) and 540 mm (Mode A). In February there is one prominent mode at 460 mm which could not be traced back. In March three modes were observed at 440, 520 and 580 mm, and mode at 520 mm and 580 mm can be traced back as mode B and mode A of January with 8 cm and 4 cm growth respectively. In April there are three modes at 460, 560, and 600 mm. While mode at 560 mm can be traced back as mode B of March with 4 cm growth. In May, mode A which was not represented in April appeared at 640 mm. Samples were not available during June. In July, two modes were observed at 620 and 680 mm. Mode at 620 mm can be traced back as mode B of April which has shown a growth of 6 cm in three months and mode at 680 mm as mode A of May at 640 mm. During August, samples were not available. In September there were 3 modes at 560, 660 and 780 mm. Only one mode at 660 mm can be traced back as mode B of July with 4 cm growth. In October, a new prominent mode (Mode C) appeared at 460 mm which could be considered as entry of new individuals to the commercial tuna fishery. In November there were two modes at 500 mm and 540 mm. Mode at 500 mm is due to 4 cm growth of mode C of October.

Following the progress of the length frequency modes during the course of 1982 (Fig. 15: paper 12), in February three modes were observed at 460, 520 and 620 mm. The mode at 520 mm can be traced back as mode D of December 1981 at 480 mm and mode at 620 mm as mode C of December at 540 mm. Data are not available for March. In April there were three modes at 340, 380 and 560 mm. While mode at 560 mm is due to 4 cm growth of mode D of February, other two modes at 340 mm (Mode E) and 380 mm are because of the entry of new individuals to the fishery. Samples were not available in May and June. In July two modes can be seen at 420 and 480 mm. Mode at 420 mm can be traced back as mode E of April. In August three modes were observed at 560, 680 and 760 mm. Mode at 680 mm can be traced back as mode E of April which was not represented in immediate preceding 3 months. In the same way, mode at 760 mm can be traced back as mode C of February at 620 mm which was not represented during the last 5 months. In September there were modes at 460, 520 and 620 mm. Out of the three modes, only one mode at 520 mm could be traced back as mode E of July at 420 mm. In October two modes at 400 and 440 mm have been represented by the addition of new individuals to the fishery.

Age and Growth

It is clear from the above description that only few modes could be clearly followed for some months. As can be seen from the Fig. 15 (paper 12) that mode of smallest fish at 340 mm (Mode E) in April 1982 could be followed upto September when it attained a length of 520 mm in five months with a monthly growth rate of 36 mm. It is clear from the progression of other modes (Mode A, B, C and D) that the fish grew 40 mm per month in the beginning of the modal progression. Occurrence of 500 mm long fish during November of both the years clearly indicates the fish to be one year old.

Mode A of January 1981 at 540 mm could be followed upto July 1981 when it attained 680 mm length in six months with monthly growth rate of 23.3 mm. Mode B of January 1981 at 480 mm could be followed upto September 1981 when it progressed by 180 mm in 8 months with a monthly growth rate of 22.5 mm. Mode C of October 1981 at 460 mm could be followed upto August 1982 when it grew 300 mm in ten months with a monthly growth rate of 30 mm. In the same way mode D of December 1981 at 480 mm could be followed upto August 1982 with 200 mm growth in 8 months and a monthly growth rate of 25 mm.

It is interesting to note here that yellowfin after attaining 500 mm length, grew at a slower rate. It is evident from the Figs. 14 & 15 (paper 12) that mode B progressed from 520 to 660 mm in 6 months with monthly growth rate of 23.3 mm. Mode A also has shown monthly growth rate of 23.3 mm. So it can be concluded that yellowfin grow 23.3 mm per month between first year and second years of its life and two years old fish will be around 780 mm, as seen in September 1982, when a prominent mode at 780 mm representing two years old fish is present.

Although fork length of fish ranged between 270 and 1370 mm during both the years, fish more than 780 mm could not be used for length frequency analysis as they were caught only as stray numbers.

Fitting von Bertalanffy's growth equation

The growth equation developed by von Bertalanffy (1938) has been used in the present study. The values of the different parameters were calculated by using length data of the year 1981 and the following results were obtained. The length of the individual fish ranged from 270 to 1370 mm.

L_∞ = 145 cm
k = 0.32 (Annual basis)
t_0 = —0.34

Based on these parameters, age of yellowfin tuna from Minicoy waters was estimated as follows :

Age in years	*Fork length in mm*
1	506
2	769
3	952
4	1088
5	1187
6	1259
7	1311

Monthly growth increment for seven years was calculated as 42.16 mm, 21.91 mm, 15.25 mm, 11.33 mm, 8.25 mm, 6.0 mm and 4.33 mm respectively.

Discussion

The earliest study on growth of yellowfin tuna was that of Kimura (1932) who collected weight frequency data from Suruga Bay between 1924 and 1931. Nose *et al.* (1957) converted these weight data given by Kimura (1932) into length and estimated lengths of yellowfin upto five years as 62, 81, 106, 120 and 134 cm respectively.

Aikawa and Kato (1938) estimated age of six yellowfin out of which four were small and two were of large size. They used the 5th and 10th vertebrae to read annual marks on them. Nose *et al.* (1957) converted the weights at estimated ages into lengths and concluded that fish was 54, 70, 85, 100, 115, 130, 145 and 160 cm long from one to eight years respectively.

Schaefer and Marr (1948) calculated the growth of yellowfin tuna based on length frequency records for Pacific Oceans near Costa Rica and opined that fish of one and two years old to be 85 and 115 cm respectively.

Moore (1951) used modal length progression of 4793 fish from Hawaiian waters for estimating age of yellowfin tuna upto 4th year of fishlife. He calculated length of fish from first to fourth year to be 103, 136, 155 and 168 cm respectively.

Annual marks formation on body scales were used by Nose *et al.* (1955) for calculating the ages of 300 yellowfin tuna collected from Tokyo market and later (1957) from several areas of western Pacific. Yabuta and Yukinawa (1957) used length frequency modal progression of 54,473 specimens which were caught from Japanese waters, and estimated the age upto third year to be 100, 133 and 146 cm respectively. In a later publication (1959) they calculated age of yellowfin upto fourth year when fish were 100, 125, 137 and 145 cm long respectively. Yabuta *et al.* (1960) used annulus formation on body scales for estimating ages and stated fish of 92.3, 120.1, 139.9 and 154.1 cm long to be 1, 2, 3 and 4 years old respectively. Hennemuth (1961) estimated yellowfin age by modal length progression method and stated that the estimation of rate of growth and age determination by direct methods for tropical tunas is not reliable. He estimated the length of 1, 2, 3 and 4 years old fish to be 55, 85, 123 and 144 cm respectively. He concluded that the rates of growth of fish from the western, central and eastern Pacific regions were quite similar.

Schaefer *et al.* (1961) reported on the growth of recovered tagged yellowfin tuna from the eastern Pacific Ocean and found that tagging data showed considerably lower growth rate than that obtained from length frequency modal progression for fish of similar age. Blunt and Messersmith (1960) based on the three tagged yellowfin recoveries stated that first specimen with fork length of 601 mm at the time of tagging showed 332 mm growth in 372 days, second 495 mm at the time of tagging with 210 mm in 367 days and third with 570 mm at the time of tagging with 768 mm growth in 842 days.

Diaz (1963) utilized length frequency modal progression for age determination for the fish caught from western coast of America from 1951 to 1956. He estimated length of 1, 2, 3, 4 and 5 years old fish to be 65, 110, 140, 165 and 180 cm respectively. Tan *et al.* (1965) estimated age and growth of 170 yellowfin from Pacific (0°-10°N ; 155°-175°E) by reading annual marks on centra and stated the size of 1, 2, 3 and 4 years old fish to be 50, 82, 115 and 130 cm respectively. Yang *et al.* (1969) utilised annual marks formation on body scales of 200 yellowfin from Pacific Ocean (3°-33°N ; 133°-270°E) during 1965. He estimated the length of 1, 2, 3, 4 and 5 years old fish to be 55, 90, 120, 145 and 160 cm respectively.

From Philippine waters, Yesaki (1983) calculated values of k as 0.29 and L_∞ value as 181 cms. He estimated length of 1.5 years old male as 64 cm and female 66 cm.

Age and growth estimation by reading annual marks on body scales and vertebrae, length frequency modal progression and incremental growth methods for yellowfin tuna have been reviewed by Suzuki (1971). He concluded that there is a general agreement among the tuna researchers that yellowfin tuna grow rapidly in early life and at a similar rate in the major regions of the Pacific Ocean.

During the present investigation by length frequency analysis length of 1 and 2 years old fish has been estimated as 50 and 77.9 cm respectively. But by fitting von Bertalanffy's growth equation length upto seven years was 50.6, 76.9, 95.2, 108.8, 118.7, 125.9 and 131.1 cm respectively.

15

SPAWNING BIOLOGY OF THE SKIPJACK, *KATSUWONUS PELAMIS* (LINNAEUS) FROM MINICOY WATERS

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One of the important technical approaches to investigate the resource characteristics of oceanic species of tunas is to study the phases of its life history. Subsequent to the results of investigations on spawning of skipjack in Minicoy waters by Raju (1964), there is no further information available on this aspect from the area. The present paper deals with the spawning of skipjack, *Katsuwonus pelamis* in Minicoy waters with particular reference to the reproductive process. Ova diameter measurements have been used to demonstrate the developmental changes that take place in the female gonads during the breeding season.

Material for these investigations was obtained from the fish landed by commercial pole and line tuna fishing boats at Minicoy during 1981 and 1982. The fork length in millimetre and weight in kg of the fish were recorded. The body cavity was opened and sex and maturity stage was determined by visual examination. The ovaries along with attached peritonial and vascular tissues were carefully removed from the fish and were preserved in 5% formalin. Ovaries from immature to spent stages were collected for ova diameter measurement studies. For the fecundity studies only mature ovaries were collected.

For ova diameter examination, samples were collected from anterior, middle and posterior part of the ovary. Ova were teased out under a binocular microscope to ensure complete separation from the follicles. For immature ovaries, measurements of 200 ova were taken but for maturing, mature and spent ovaries 300 ova were measured. Measurements were made by an ocular micrometer in a compound monocular microscope and later micrometer divisions were calibrated into millimetres. Almost majority of ova were spherical, even then measurements were made on whatever axis ova fell parallel to the micrometer divisions.

June (1953), Yuen (1955), Otsu and Uchida (1959), Joseph (1963), Raju (1964) and Batts (1972) could not detect any difference in the frequencies of ova diameters selected from different part of the same lobe of the ovary and from right or left ovary. Thus all these workers concluded that ova develop uniformly throughout the ovary and in both ovary lobes of tunas. Therefore, during these present investigations, for fecundity studies ova samples were taken from the middle of either lobe of the mature ovary randomly and all the mature ova were counted. Fecundity was calculated by using the following formula :

$$\text{Fecundity} = \frac{\text{Number of ova in sample X weight of paired ovaries}}{\text{Weight of ova samples}}$$

For determining maturity stages and spawning season 638 specimens of skipjack were examined.

Maturity

Ova diameter of 200 ova for stage I and stage II and 300 ova for stage III and above were taken at random and they were grouped into four ocular micrometer division groups. Ocular micrometer divisions were converted in millimetres and frequency polygons of ova showed typically seven maturity stages (Fig. 1).

Only immature ova with diameter upto 0.14 mm with mode at 0.09 mm are present in stage I. As a matter of fact this group of ova should be called as the 'General Immature Egg Stock' since they are available throughout the year in the ovaries of all stages of maturity.

In stage II one batch of ova is seen separated from the immature ova with a mode at 0.28 mm with the maximum ova diameter of 0.37 mm. This group of ova can be termed as 'Intermediate Group'. At this stage of maturation yolk deposition has started in ova.

In stage III the maturing group of ova which is observed as 'Intermediate Group' in stage II showed

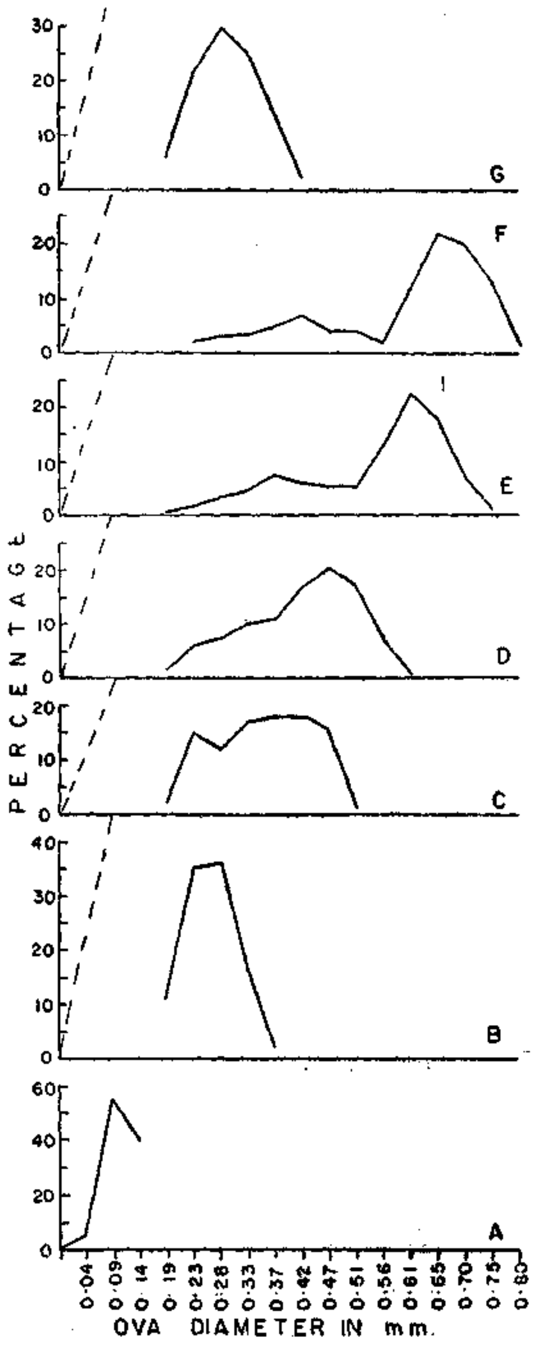

Fig. 1. Ova diameter frequency polygons of *K. pelamis* at Minicoy.

progress in diameter with mode at 0.42 mm with maximum diameter of 0.51 mm. Ova at this stage show thick deposition of yolk.

In stage IV maturing ova showed further increase in size and become mature with mode at 0.47 mm and with maximum diameter of 0.61 mm. The ova are opaque at this stage.

In stage V in addition to the immature stock of ova, two groups of ova *i.e.*, maturing and mature ova show prominent separate modes. While maturing ova did not show much growth, mature ova has grown at a faster rate. The mode at 0.61 mm of ripe ova is evidently the group of eggs which would spawn in near future.

In stage VI range of ripe group of ova diameter was from 0.56 mm to 0.80 mm with mode at 0.65 mm. Although ova at this stage did not show much growth, but they changed from yellowish to orange in colour and also started to become transparent. The one ovary which was examined during these studies did not contain ova with oil globule. Mature ova are easily separated from the follicles and some loose ova were found in the lumina of the ovary.

In the spent ovary stage VII diameter of ova is almost similar to those of in stage II. Very few residual eggs were observed in this ovary. While the absence of the the residual eggs in the ovaries cannot be accepted as proof that the fish has never spawned, their presence shows good evidence that spawning has definitely occurred.

Sex ratio

Ratio of males to females was found to be 1 : 1.18 for the year 1981 and 1 : 0.98 for the year 1982. The ratio for the pooled data for both the years of observations was male 1 : female 1.07. The percentage occurrence of sexes in different months during both the years are given in Table 1. From this it can be seen that during 1981, while the females dominated over males during January, February, April, June, November and December, males dominated in March, May and September. During 1982 females dominated over males in January, February, September and October, while males dominated during the remaining months except November when both the sexes were equally distributed.

Spawning season and frequency

A comparison of the data on the maturity of skipjack over two successive years (1981, 1982) reveals that fish of various maturity stages may be present in any month of the year. For example, fish of maturity stage II to IV were recorded throughout the year.

TABLE 1. *Percentage of males and females of* Katsuwonus pelamis *during* 1981 *and* 1982

Month		1981 Total number of fish	1981 Percentage of Males	1981 Percentage of Females	1982 Total number of fish	1982 Percentage of Males	1982 Percentage of Females
January	..	40	37.50	62.50	51	43.14	56.86
February	..	49	38.78	61.22	32	46.88	53.12
March	..	31	54.84	45.16	30	60.00	40.00
April	..	32	40.63	59.37	67	53.73	46.27
May	..	31	51.61	48.39	..	..	..
June	..	41	46.33	53.67	..	..	..
July	..	..	..	..	..	..	..
August	..	..	..	..	..	..	..
September	..	..	..	..	50	46.00	54.00
October	..	13	69.23	30.77	16	43.75	56.25
November	..	33	45.45	54.55	30	50.00	50.00
December	..	57	47.37	52.63	35	60.00	40.00

Further, females were divided into three major categories based on maturity stages *i.e.*, immature (stage I and II), Maturing (Stage III) and mature (Stage IV and above). The results are given in Tables 2—4 It can be seen from these tables that mature fish occurred almost throughout the commercial pole and line tuna fishing period. During 1981 peak occurrence of mature fish was in January to May. But in 1982 mature fish dominated during all the months except in October.

TABLE 2. *Percentage occurrence of gonads of* Katsuwonus pelamis *in different stages of maturity* (From January 1981 to December 1981)

Month		No. of	Sex	Stages of maturity I	II	III	IV	V	VI	VII
January	..	15	M	..	20.00	40.00	33.33	6.67	..	..
		25	F	..	16.00	36.00	32.00	16.00	..	..
February	..	19	M	..	21.05	47.37	26.32	5.26	..	..
		30	F	..	6.67	43.33	36.67	13.33	..	..
March	..	17	M	..	29.41	17.65	41.18	11.76	..	..
		14	F	..	28.57	21.43	42.86	6.14	..	..
April	..	13	M	..	38.46	46.16	15.38	..	..	..
		19	F	..	36.84	42.11	21.05	..	..	..
May	..	16	M	..	18.75	43.75	31.25	6.25	..	..
		15	F	..	13.33	33.33	33.34	20.00	..	..
June	..	19	M	5.26	36.84	42.11	15.79	..	..	..
		22	F	..	54.55	36.36	9.09	..	..	..
July	..	..	M	..	..	..	..	..	..	..
		..	F	..	..	..	..	..	..	..
August	..	..	M	..	..	..	..	..	..	..
		..	F	..	..	..	..	..	..	..
September	..	..	M	..	..	..	..	..	..	..
		..	F	..	..	..	..	..	..	..
October	..	9	M	44.44	44.45	11.11	..	..	..	..
		4	F	25.00	25.00	50.00	..	..	..	..
November	..	49	Ind.	..	..	..	..	..	..	..
		15	M	26.67	20.00	46.67	6.66	..	..	..
		18	F	11.11	16.67	66.67	5.55	..	..	..
December	..	27	M	..	3.70	62.97	33.33	..	..	..
		30	F	..	10.00	60.00	30.00	..	..	..

M = Male, F = Female, Ind. = Indeterminate

TABLE 3. *Percentage occurrence of gonads of* Katsuwonus pelamis *in different stages of maturity*
(From January 1982 to December 1982)

Month	Number of fish	Sex	Stages of maturity I	II	III	VI	V	VI	VII
January	22	M	..	..	59.09	36.36	4.55	..	..
	29	F	..	..	31.03	58.62	10.35	..	..
February	15	M	..	33.33	66.67	..	..	..	..
	17	F	..	58.82	17.65	5.88	..	..	..
March	18	M	..	27.78	27.78	44.44	..	..	..
	12	F	..	8.33	50.00	41.67	..	..	..
April	36	M	..	..	11.11	19.44	50.00	13.89	5.56
	31	F	..	..	19.35	32.26	38.71	9.68	..
May	..	M	..	..	..	..	..	..	.
	..	F	..	..	..	..	..	..	..
June	..	M	..	..	..	..	..	..	..
	..	F	..	..	..	..	..	..	..
July	..	M	..	..	..	..	..	..	..
	..	F	..	..	..	..	..	..	..
August	..	M	..	..	..	..	..	..	..
	..	F	..	..	..	..	..	..	..
September	23	M	..	8.69	21.74	43.48	26.09	..	..
	27	F	..	..	29.63	44.44	25.93	..	..
October	7	M	28.57	42.86	28.57	..	..	..	..
	9	F	..	22.22	55.56	22.22	..	..	..
November	15	M	..	..	46.67	20.00	26.67	6.66	..
	15	F	..	..	40.00	33.33	26.67	..	..
December	21	M	..	9.52	9.52	23.81	38.10	19.05	..
	14	F	..	..	28.57	28.57	28.57	14.29	..

M = Male, F = Female.

TABLE 4. *Percentage occurrence of female fish in immature, maturing and mature stages during* 1981 *and* 1982

Month		Immature	Maturing	Mature
January	1981	16.00	36.00	48.00
	1982	..	31.03	68.97
February	1981	6.67	143.33	50.00
	1982	17.65	58.82	23.53
March	1981	28.57	21.43	50.00
	1982	8.33	50.00	41.67
April	1981	36.84	42.11	21.05
	1982	..	19.35	80.65
May	1981	13.33	33.33	53.53
	1982	..	..	..
June	1981	54.55	36.66	9.09
	1982	..	..	..
July	1981	..	..	..
	1982	..	..	..
August	1981	..	..	..
	1982	..	..	..
September	1981	..	..	..
	1982	..	29.63	70.37
October	1981	50.00	50.00	..
	1982	22.22	55.56	22.22
November	1981	27.78	66.67	5.58
	1982	..	40.00	60.00
December	1981	10.00	60.00	30.00
	1982	..	28.57	71.43

Fish in spawning stage of maturity (ripe running) and spent condition were very rare in the catches. Here it becomes necessary to point out that scarcity of spawning females in commercial catches at Minicoy does not mean that skipjack is not spawning in Minicoy waters. This has already been shown by Jones (1959) based on skipjack larval collections from Laccadive Sea. The predominance of stage III (maturing) may be because of the entry of fishes in the catches in their recovering stage after spawning. Moreover the assumption about the females moving into deeper waters for spawning and be away from the reach of pole and line fishing cannot be ruled out.

According to Matsumoto and Skillman (1984) 'Gonadial studies in the Pacific Ocean indicated that skipjack tuna spawn throughout the year in tropical waters near the equator and from spring to early fall in subtropical waters with the spawning period becoming shorter with increasing distance from the equator.'

Therefore, the occurrence of mature females throughout the pole and line fishing season and occurrence of young fishes of about 30 cm during January to May and September to December, period clearly indicates that in Minicoy waters also skipjack spawn throughout the year.

The frequency distribution of ova diameter measurements from a ripe and spawning ovary (Stage V and VI) of skipjack reveals that there are three groups of ova *i.e.*, immature, maturing and mature which are clearly separated from each other. It is understood that as the ripe group of ova is spawned out, its place is soon taken up by the maturing group of ova which have already completed more than half of the maturation process. It is clear from the Fig. 1 that mature ova grow at a faster rate than maturing ova. Therefore, when mature ova are spawned out, maturing ova will grow at a faster rate and may be ready for spawning soon, thus having more than one spawning in a year (Brock 1954 ; Bunag 1956 ; and Raju 1964).

FECUNDITY

An examination of the mature ovaries of *K. pelamis* reveals that they contain three groups of ova *i.e.*, immature, maturing and mature. The number of mature eggs was taken to be the fecundity of each individual fish. A total of 23 mature individuals was examined. The length and weight of fish, total number of mature ova and ova per kg of fish body weight are given in the Table 5. Results of other studies on skipjack from different world oceans are given in the Table 5.

TABLE 5. *Fecundity estimates of* Katsuwonus pelamis, *during* 1981-'82

S. No.	Length of fish (cm)	Weight of fish (kg)	Length of ovary (cm)	Weight of ovary (g)	Total number of mature ova	Ova per kg of fish weight
1 ..	46.5	1.8	12.7	46.0	2,12,566	1,18,092
2 ..	48.0	2.0	12.2	42.5	2,21,297	1,10,648
3 ..	48.5	2.0	12.9	38.0	1,82,856	91,428
4 ..	49.0	2.5	11.5	35.0	1,70,555	68,222
5 ..	50.0	2.3	13.0	33.0	1,89,024	82,184
6 ..	50.0	2.6	13.2	53.0	2,94,097	1,13,114
7 ..	50.0	2.5	14.1	52.0	3,29,628	1,31,851
8 ..	51.0	2.3	13.1	53.0	2,74,858	119,503
9 ..	51.5	2.5	13.4	47.0	2,48,988	99,555
10 ..	51.5	2.7	13.3	54.5	2,98,933	1,10,715
11 ..	52.0	2.5	12.2	43.0	2,53,442	1,01,376
12 ..	52.5	2.8	12.7	46.5	3,31,824	1,18,508
13 ..	53.0	3.0	13.8	50.5	3,26,987	1 08,995
14 ..	53.0	2.5	14.4	58.8	3,26,826	1,30,730
15 ..	53.0	3.2	14.6	47.5	2,73,980	85,628
16 ..	53.0	3.0	14.3	46.0	3,05,762	1,01,920
17 ..	53.0	2.8	13.6	51.5	3,06,013	1,09,290
18 ..	54.0	2.5	14.5	5.10	3,74,595	1,49,838
19 ..	54.0	3.5	13.0	52.0	2,67,904	76,544
20 ..	54.0	3.3	14.5	53.5	3,53,742	1 07,194
21 ..	59.0	4.0	13.5	66.0	4,34,412	1,08,603
22 ..	62.0	4.5	14.0	76.0	4,79,484	1,06,552
23 ..	66.0	6.5	15.3	930	6,82,899	1,05,061

TABLE 6. *Observed fecundity estimates for skipjack tuna*

Source & Area	Locality	Number of fish	Fish length range (mm)	Total ova range
Pacific Ocean				
Yabe (1954)	Ryuku Islands	5	460-610	113,364-859,897
Rothschild (1963)	Hawaii	3	440-870	280,000-900,000
Joseph (1963)	Eastern Pacific	42	614-715	210,000-1190,000
Yoshida (1966)	Marquesas Islands	4	430-750	100,000-2000,000
Atlantic Ocean				
Simmons (1969)	Caribbean Sea	13	465-809	262,000-331,000
Batts (1972)	North Carolina	31	498-704	141,000-1200,000
Indian Ocean				
Raju (1964)	Minicoy	63	418-703	151,900-1977,000
Stequert (1976)	Madagascar	64	441-565	87,000-824,000
Present study	Minicoy	23	465-660	170,555-682,899

Relation between fecundity and length and weight of fish

The fecundity observations of 23 skipjack are plotted against the length (Fig. 3). The number of mature eggs increased with the length of the fish. However, it can also be seen that the fecundity of the individual fish of the same length varied considerably.

The regression line is fitted by least square method by applying the following formula :

$$Y = a + bL$$

Where Y is the number of mature ova in thousands, L is the length of fish in mm and *a* and b are constants. The values of *a* and b were estimated and the following equation was obtained. The value of '*r*' was 0.92707.

$$Y = -918.57049 + 23.27525 \; L$$

In order to find whether any relation exists between the weight of the fish and fecundity, fecundity estimates of 23 individual fish are plotted against their respective fish weight (Fig. 2). By the least square method, relation between fecundity and weight of the fish was determined and the following equation was obtained :

$$Y = -20.00365 + 99.48753 \; W$$

where Y = fecundity of the fish and W = weight of fish in kg. The value of '*r*' was 0.90004.

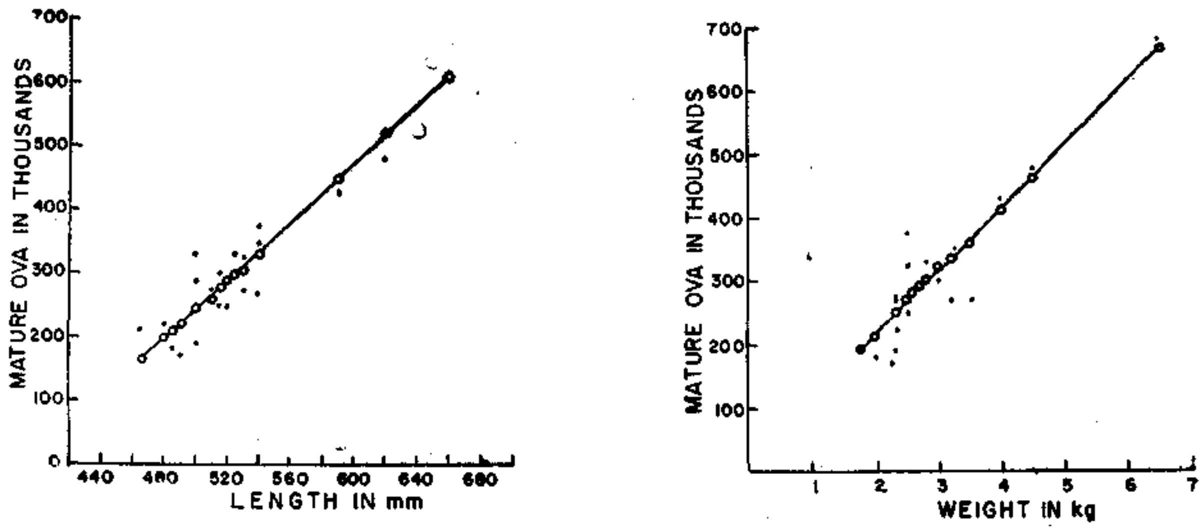

Fig. 2. Fecundity in relation to the length and weight of *K. pelamis* at Minicoy.

Discussion

A number of investigations have been conducted on the spawning of skipjack from the Pacific Ocean and elsewhere. These studies were based on the presence of skipjack larvae, young fishes or on the stage of gonad maturity in the adult fish. Waldron (1963) stated that in the equatorial waters in the Pacific, spawning occurs throughout the year, although there may be identifiable peak periods. According ot him in increasing distances from the equator, the season becomes progressively shorter and spawning occurs during the summer months.

Jones and Silas (1963) stated that no definite range of spawning has been established in any area in the Indian Ocean except that from the Laccadive Archipelago. Based on larval collections by Jones (1959) and gonadial examination by Raju (1964), Jones and Silas (1963) concluded that spawning of skipjack takes place over an extended period from January to April and then from June to early September with the peaks in January and June respectively.

Waldron (1963) opined that the presence of larval skipjack in plankton collection probably provides a more precise estimate of spawning season than does the presence of mature ovaries in the adults. After the studies on skipjack larvae from Laccadive sea by Jones (1959), there is no published accounts on this aspect from this area. Perhaps regular plankton collection throughout the year from the Laccadive sea and Minicoy area may give a better picture.

Since mature fishes are available throughout the pole and line fishing season and regular occurrence of fish below 30 cm clearly indicates that around Minicoy waters spawning of skipjack is protracted and most probably occurs throughout the year.

Waldron (1963) while reviewing the literature on the biology of skipjack stated that the sex ratio of skipjack may depart significantly from 1 : 1 at certain times of the year. Jones and Silas (1963) have also reported in the same way about sex ratio of skipjack from Minicoy area. Orange (1961) reported that in Eastern Tropical Pacific, percentage of males below the length of 75 cm is close to 50 per cent, but percentage of males increases with the length of the fish.

Results of present investigations reveal that during 1981 and 1982 together, females dominated over males but not significantly. Monthly variation in sex ratio was observed during both the years.

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BIOLOGY OF THE BAIT FISHES *SPRATELLOIDES DELICATULUS* (BENNET) AND *S. JAPONICUS* (HOUTTUYN) FROM MINICOY WATERS

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Spratelloides delicatulus is considered to be an excellent bait fish by Hawaiian fishermen (June 1951, Ikehara 1953, June and Reintjes 1953). This species, however, does not contribute to a good percentage of the bait fish catch in Hawaii but whenever *Stolephorus purpureus* is not available as bait sufficiently, sprats are captured and made use as bait (Welsh 1950). *S. delicatulus* is the widely used sprat in the Indo-Pacific. Its poor survival in captivity is the main handicap (Ikehara 1953, June and Reintjes 1953, Wilson 1971, Lee 1973). Occurrence of this species is very seasonal in the Pacific Ocean and is available more during summer months (Welsh 1950, June 1951 Wilson 1963). Hida (1971) noted that *S. delicatulus* was abundant in lagoons of large atolls in Micronesia.

Matsumoto (1937) observed that *S. delicatulus* is the most important bait fish at Saipan where it is found all the year but is scarce in November, December and January. At the peak of the season, one haul of bait captured is enough bait for a day's fishing. Cleaver and Shimada (1950) reported that *S. delicatulus* is a preferred bait species. This species was reported to be abundant in Western Samoa (Van pel 1960). *S. delicatulus* and *S. gracilis* are considered as possible bait fish resources in New Guinea by Kearney *et al.* (1972). Lewis *et al.* (1974) reported that both species are the most attractive bait fishes for skipjack tuna in Papua New Guinea waters.

Wilson (1971) observed that *S. gracilis* is a good live-bait fish but it is not as hardy as *S. delicatulus.* They are not extensively used at Palau. Lee (1973) reported that *S. delicatulus* is an important bait fish in the Fiji waters. The quantity of round herring comprised of *S. japonicus, S. delicatulus* and *S. atrofasciatus* from three major localities in the Ryukyu Islands for 1966 and 1967 was 54.7 and 45 metric tons respectively (Isa, 1972).

Jones (1960, 1964a) reported that *S. japonicus* is used in the Laccadive fishery and stated that it occurs in small schools but is not as abundant as *S. delicatulus.* Thomas (1964) observed that both these bait species are seasonally available and have been observed sometimes in large quantities and are scarce after December.

I. Spartelloides delicatulus

A review of the published literature on bait fishes reveals that there is no information on the biology of *Spratelloides* spp. from Indian waters. The biology the of blue sprat. *S. delicatulus* is presented here based on the material collected from Minicoy lagoon from December 1981 to December 1982. Samples for August, October, November and December were collected from the Minicoy lagoon along with mullets while during other months they were obtained from commercial bait fish catches. Samples were preserved in 5 per cent formalin after collection and were analysed for biological studies. Total length was measured in millimetres and condition of stomach, sex and maturity of individual fish was recorded. The procedures adopted for the analysis of material and data are given in the respective sections.

Distribution and abundance

S. delicatulus (Blue sprat) is found near the inner reef area at Ragandi point on the western side of Minicoy lagoon. They are available in scattered shoals and very rarely occur in large shoals. Blue sprat is easily found only on the shoal sand near the bodies of moving and clear water in the shallow part of the lagoon.

During 1981-82 tuna fishing season (pole-and-line) *S. delicatulus* dominated the bait fish catches of Minicoy and contributed 64.16 per cent. This species was available during all the months of the season and accounted for the bulk of monthly bait catches. This species starts appearing in the lagoon from September onwards when very young juveniles are available which are very fragile at that stage. The fishery of the species entirely depend on its recruitment ot the shallow moving waters of the lagoon.

Length frequency distribution

These studies are based on 1191 specimens collected from December 1981 to December 1982. The total length of the individual fish ranged between 18 and 59 mm. The percentage frequency in the various size groups are plotted in the form of length frequency, curves in Fig. 1.

It can be seen from the figure that several modal groups occurred, but only some of them could be traced with reasonable assurance of accuracy. While the identity of some of the smaller modal groups is doubtful, in the description given below they are described as such and growth is calculated based on only those modes which could be traced for some months.

There are two modes at 27 mm (Mode A) and 31 mm during December 1981. Samples were not available during January 1982. In February three modes at 25 mm, 31 mm and a small mode at 43 mm appeared. While mode at 31 mm could be traced back as mode A of December 1981 with 4 mm growth, other two modes could not be traced back. Next month four modes appeared at 25 mm (Mode B), 31 mm, 35 mm and one small mode at 41 mm. Only one mode at 35 mm could be traced back as mode A of February with 4 mm growth. Samples were not available during May, June and July. During August only one mode appeared at 51 mm which could be traced back as mode A of March with 16 mm growth in five months. Samples were not available during September. During October four modes could be seen at 29 mm, 37 mm, 41 mm and 45 mm. While mode at 41 mm could be traced back as mode B of March which was evidently not represented in the immediate preceding six months. In December, three modes at 41 mm, 45 mm and 49 mm appeared but only one mode at 49 mm could be traced back as mode B of October with 8 mm growth.

Age and growth

As can be seen from fig. 1; both the modes A and B could be followed upto few months only. Mode A of December 1981 could be followed upto August

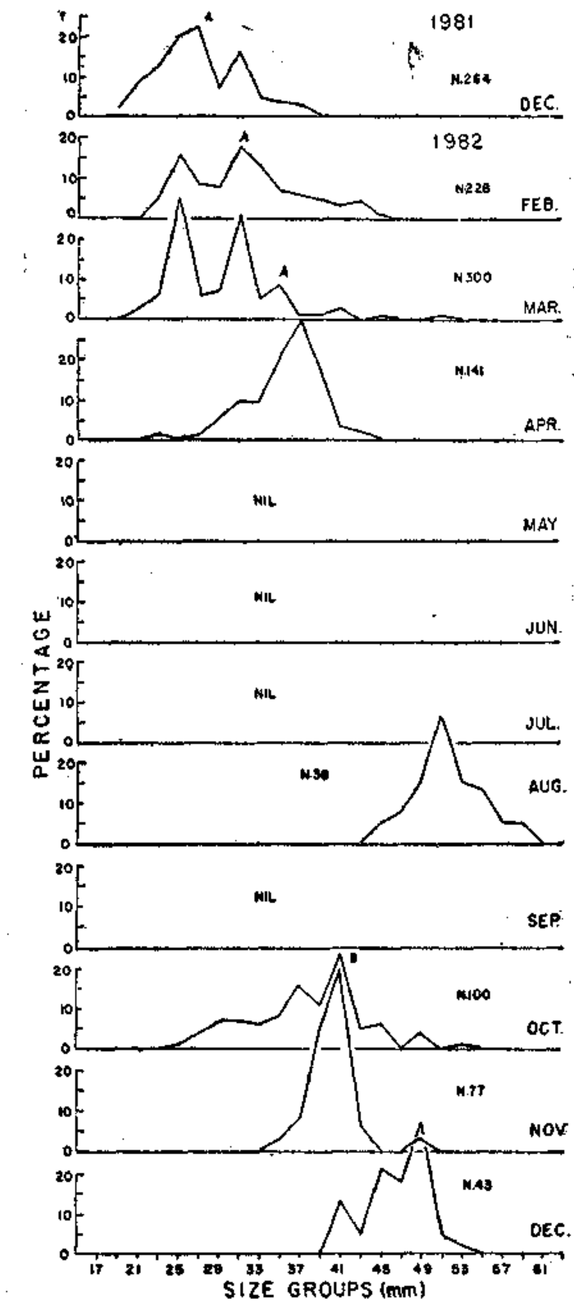

Fig. 1. Length frequency distribution of *S. delicatulus* at Minicoy, 1981-'82.

1982 when it grew from 27 mm to 51 mm *i.e.*, 24 mm in 8 months with monthly growth rate of 3 mm. Mode B of March at 25 mm could be followed upto December 1982 at 49 mm with growth of 24 mm in

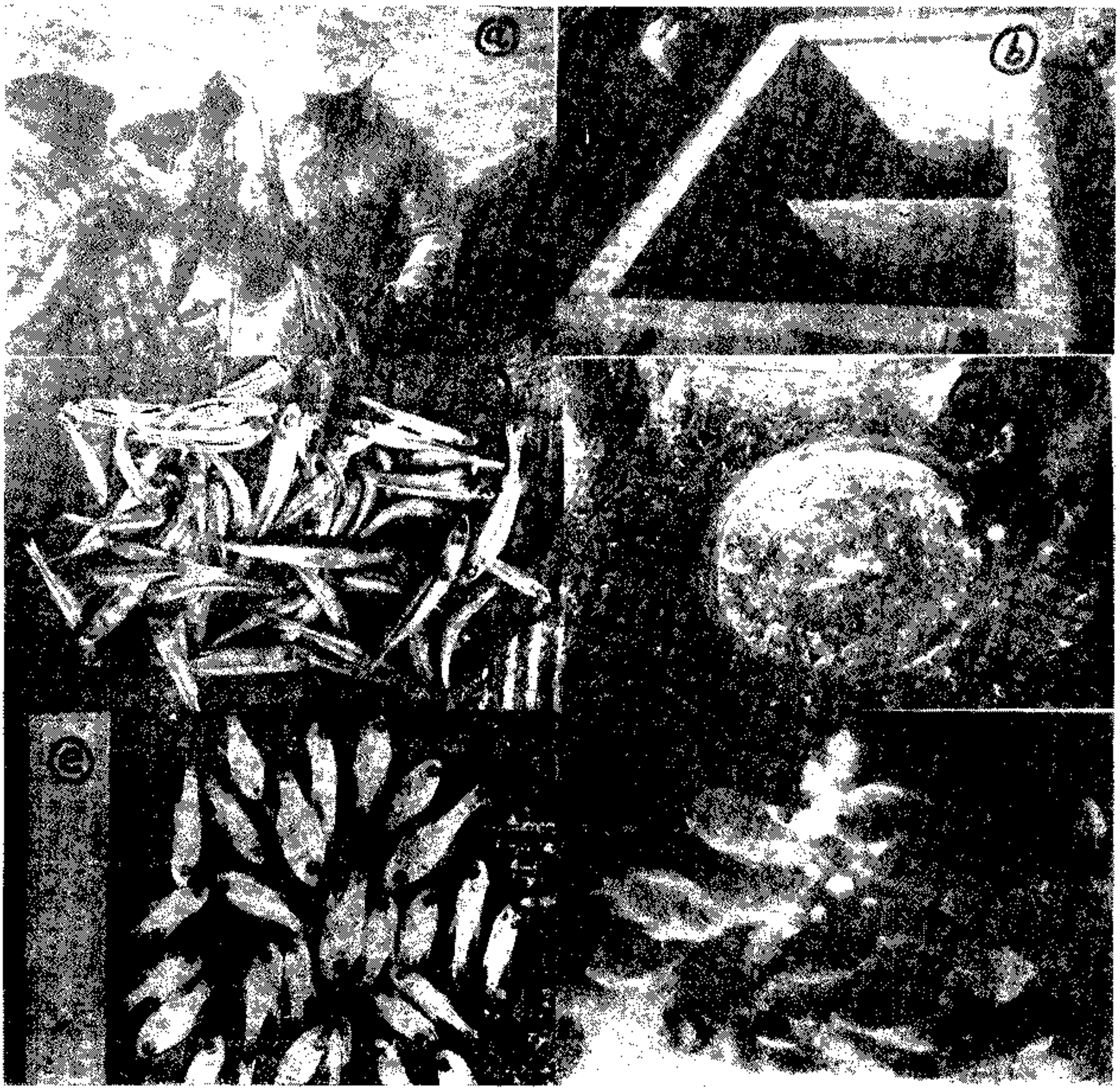

PLATE I. (*a*) Live-bait fishes being transferred to tank. (*b*) Bait tank with bait fishes. (*c*) *Pranesus pinguis*. (*d*) *Spratelloides delicatulus*. (*e*) *Apogon* sp. (*f*) *Chromis caeruleus*. (*Photos* 15-18 by *Madan Mohan*)

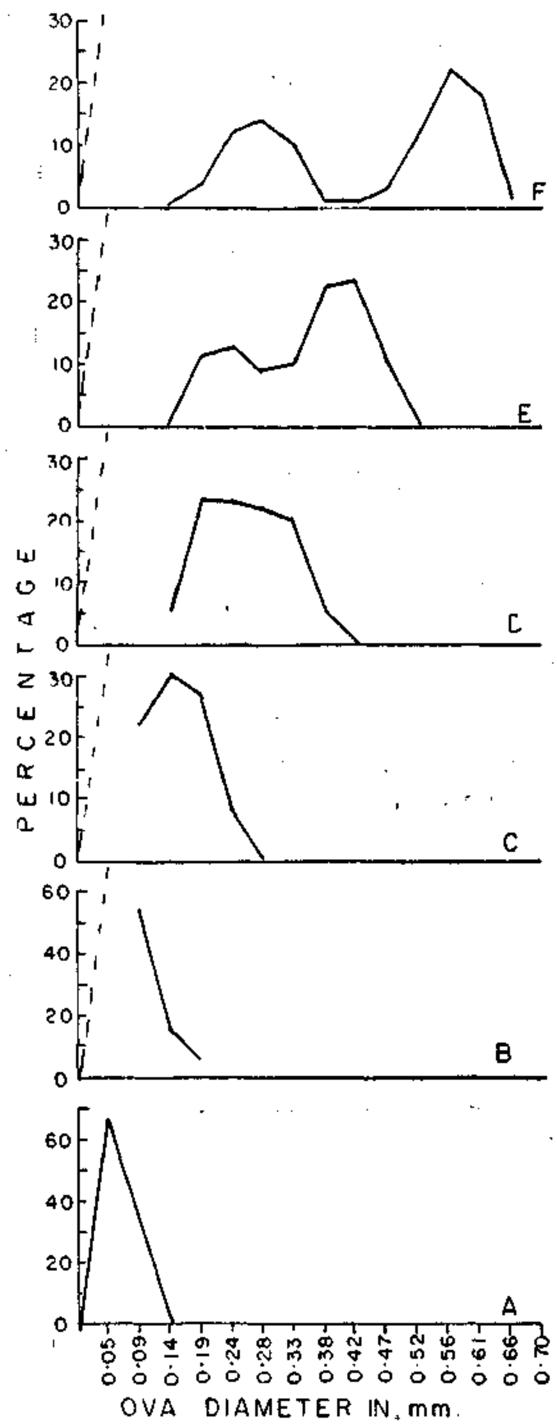

Fig. 2. Ova diameter frequency polygons of *S. delicatulus* at Minicoy, Dec. 1981-Dec. '82.

9 months with monthy growth rate of 2.66 mm. Therefore, both the modes have shown a monthly growth rate of about 3 mm.

Jones (1964) stated that *S. delicatulus* enters the Minicoy lagoon in very large shoals before the monsoon and remains there upto about November. As can be seen from the figure, all the fish collected during August were adults and their gonadial examination revealed that all were mature. Even during October, November and December majority of the fishes collected were mature. Every year the young ones of this species of about 15 mm start appearing from September onwards and during bait fish collections from about November only young fishes are caught and used as bait. During the present investigation samples during August, October, November and December were collected from near the shore and not from Ragandi point from where this species is usually caught.

Maturity and spawning

The maturity stages of individual fish were classified by microscopic examination of ova.

Since ovaries are small in size, ovary as a whole was teased and measurements of 200 ova from immature and maturing ovary and 300 ova from ovary of stage IV and above of maturity stage were taken. Ova were grouped into four ocular micrometer division groups. Ocular micrometer divisions were converted in millimetres and frequency polygons of ovaries, typically seven maturity stages were drawn (Fig. 2). As can be seen from the Figure only immature ova with diameter from 0.01 to 0.14 mm with mode at 0.05 mm are present in stage I of ovary. This group of ova is present in the ovaries of all stages and throughout the year.

In stage II one batch of ova is seen getting separated from the immature ova with mode at 0.09 mm.

In stage III the maturing group of ova progressed in diameter with mode at 0.19 mm. At this stage yolk deposition has started in the big size ova. Some of the ova in which yolk deposition has started are translucent while majority of ova are transparent.

In stage IV three types of ova *i.e.*, immature, maturing and mature can be clearly distinguished. Maturing ova of stage III has shown fast growth with mode of maximum diameter of ova at 0.33 mm.

In stage V mature ova of stage IV has shown further increase in diameter with the mode of ripe ova at 0.42 mm. Ripe ova have become clearly separated from the maturing stock. The mode at 0.42 mm is clearly the group of ova which will be spawned in near future.

In stage VI ripe group of ova ranged in diameter from 0.47 mm to 0.71 mm with mode at 0.56 mm. Ripe ova have shown faster growth than maturing ova. They are yellow in colour and in few of them oil globule is visible. Some of the ova became transparent and are easily separated from the follicles with some loose ova in the lumina of the ovary.

Spent ovary was not available for analysis during these studies.

Spawning season

357 specimens of *S. delicatulus* from December 1981 to December 1982 were examined to study the percentage occurrence of gonads in different stages of maturity. The details are given in Table 1.

In December 1981 stages II to IV were present and stage II dominated over other stages. In February 1982 stages I to stage IV were available stage III being the predominant one followed by stage II. In March stage II to VI were present and stage III dominated followed by stage IV. In April stages I to VI were available and again stage III dominated followed by stage IV. Samples were not available for study during September. In October stages III to VI were available and stage V dominated followed by stage VI. In November stages IV to VI were present and VI dominated followed by stage V. In December stage III to VI were available, stage IV being predominant followed by stage V.

Further fish were divided in three major groups based on maturity stages *i.e.*, immature (Stage I and II), maturing (Stage III) and mature (Stage IV and above). The results are given in Table 2. It can be seen from the Table that maturing fishes dominated over others during December 1981, February and March. But from April onwards mature fishes dominated with very high percentage. From the above it is clear that mature *S. delicatulus* starts appearing in good numbers from April onwards. During August the percentage of mature fish was very high and thence onwards they were available in good quantities. Jones (1964) stated that *S. delicatulus* enters the Minicoy lagoon in very large shoals before the monsoon and

TABLE 1. *Percentage occurrence of gonads of* S. delicatulus *in different stages of maturity* (from December 1981 to December 1982)

Month	No of fish	Sex	Stages of maturity						
			I	II	III	IV	V	VI	VII
1981									
January	22	M	..	54.55	27.27	13.64	4.54	..	..
December	10	F	..	90.00	10.00	..	..	..	..
1982									
January	..	M	..	..	..	..	..	..	..
	..	F	..	..	..	..	..	..	..
February	29	M	6.89	31.03	34.48	27.58	..	..	..
	17	F	5.88	29.41	64.70	..	..	..	..
March	22	M	..	18.18	50.00	22.72	9.09	..	..
	8	F	..	12.50	37.50	37.50	..	12.50	..
April	39	M	2.56	10.26	15.38	43.59	17.95	10.26	..
	22	F	..	9.09	72.73	9.09	..	9.09	..
May	..	M	..	..	..	..	..	..	..
	..	F	..	..	..	..	..	..	..
June	..	M	..	..	..	..	..	..	..
	..	F	..	..	..	..	..	..	..
July	..	M	..	..	..	..	..	..	..
	..	F	..	..	..	..	..	..	..
August	19	M	..	..	10.53	47.37	36.84	5.26	..
	19	F	..	..	..	..	57.89	42.10	..
September	..	M	..	..		..	..	..	..
	..	F	..	..	..	..	..	..	..
October	36	M	..	..	8.33	19.44	30.55	41.67	..
	21	F	..	..	28.57	19.04	47.62	4.76	..
November	10	M	..	..	..	40.00	10.00	50.00	..
	40	F	..	..	..	32.50	50.00	17.50	..
December	22	M	..	..	18.18	36.36	36.36	9.09	..
	21	F	..	..	14.28	52.38	33.33	..	..

M = Male, F = Female

TABLE 2. *Percentage occurrence of* S. delicatulus *in immature, maturing and mature stages from December* 1981 *to December* 1982

Month		Immature	Maturing	Mature
1981				
December	..	..	87.50	12.50
1982				
January	..	..	..	..
February	..	6.52	76.09	17.39
March	..	..	63.33	36.67
April	..	1.64	45.90	52.46
May	..	..	..	..
June	..	..	..	..
July	..	..	..	..
August	..	..	5.26	94.74
September	..	..	..	..
October	..	..	15.79	84.21
November	..	..	..	100.00
December	..	..	16.28	83.72

remains there upto about November. The occurrence of mature specimens from August onwards in near shore area of the lagoon indicates that spawning in this species takes place during the south-west monsoon period and extends upto December. This may be the reason that from October to April only young blue sprat occurs in bait fish catches.

Frequency of spawning

The frequency distribution of ova diameter measurements from the ripe and spawning ovary (Stage V and VI) of *S. delicatulus* reveals that at this stage of maturity the ovary contains three groups of ova *i.e.*, immature, maturing and mature (Fig. 2). From the figure it can be seen that in the ovary of stage VI ripe ova almost get separated from the maturing ova. From stage III onwards mature ova has shown faster growth than maturing ones. Therefore, when ripe ova are spawned out their place is soon taken by maturing ova which have already completed more than half the maturation process. When ripe ova are spawned, maturing ova will grow faster and will be ready to spawn soon. The occurrence of juvenile fishes for a longer period also suggests that *S. delicatulus* may spawn more than once in a spawning season.

Sex ratio

For the period under study the ratio of males to females was found to be 1 : 0.79. The percentage occurrence of sexes in different months are given in Table 3. From the table it can be seen that males dominated over females throughout the period except in November when females dominated. During August, the percentage of both the sexes was equal.

TABLE 3. *Percentage of males and females of* S. delicatulus *from December* 1981 *to December* 1982

Month		Total No. of fish	Males (%)	Females (%)
1981				
December	..	32	68.75	31.25
1982				
January	..	..	..	..
February	..	46	63.04	36.96
March	..	30	73.33	26.67
April	..	61	63.93	36.07
May	..	..	..	..
June	..	..	..	..
July	..	..	..	..
August	..	38	50.00	50.00
September	..	..	..	..
October	..	57	63.16	36.84
November	..	50	20.00	80.00
December	..	43	51.16	48.84

Fecundity

For fecundity studies ovary as a whole was teased and total number of mature ova were counted. A total of 15 ripe ovaries was examined and as can be seen from the Table 4 that number of mature eggs increased with the length of the fish. However, it may also be seen from the table that the fecundity of fish of the same length showed considerable variations.

TABLE 4. *Fecundity estimates of* S. delicatulus, *during* 1982

Serial No.		Length of fish mm	Total No. of mature ova	Stage of maturity
1	..	40	286	VI
2	..	40	317	VI
3	..	43	407	VI
4	..	49	638	V
5	..	49	653	VI
6	..	50	467	VI
7	..	50	566	VI
8	..	50	689	VI
9	..	51	547	V
10	..	53	453	V
11	..	53	624	VI
12	..	54	760	V
13	..	56	943	VI
14	..	58	769	VI
15	..	58	1005	V

Food and feeding

Preserved stomachs of a total of 367 specimens of *S. delicatulus* were examined for food and feeding habits. The degree of distension of stomachs was recorded depending on their fullness in the following categories (1) Empty, (2) 1/4 full, (3) 1/2 full, (4) 3/4 full, (5) Full and (6) Gorged. Specimens with gorged, full and 3/4 full stomachs were considered to have actively fed, whereas those with half full as moderately fed and with 1/4 full stomachs as poorly fed.

The empty stomachs (189 Nos.) occurred in a high percentage (51.50%) of the 367 stomachs examined. Their percentage was high during April, October, November and December. Actively fed fishes were available in high percentage during December 1981, February, March and August. Moderately fed fishes occurred in good percentage during all months of the observations except in April and September.

The food of the species mainly consisted of crustaceans represented by post larvae of decapods, harpacticoid and calanoid copepods, mysids and gammarids. Fish eggs and algal filaments were also observed rarely.

Behaviour

Blue sprat like other members of the family Dussumieriidae is a schooling species. The size of the school is usually small. They are found in scattered shoals and are observed in the same type of habitat *i.e.*, sandy bottom area of inner reef flat throughout the season of availability.

The analysis of data reveals that during tuna fishing season only young specimens of *S. delicatulus* are caught and used as bait. Samples during August onwards were collected from the shore area of the lagoon along with mullets and *Atherina* spp. Majority of the fishes collected from the shore area were in 'mature stage' while they were not available in bait fish catches at all. Mature specimens collected from shore area would have migrated from the reef area along with strong currents. The absence of spent specimens of this species and mature fishes from bait catches clearly suggests that spawning of this species takes place elsewhere, most probably outside the reef area and not in the lagoon.

Jones (1960) during the third cruise of R. V. *KALAVA* in the Laccadive sea observed that millions of *S. delicatulus* assembled under ship's light when the ship was anchored just outside the reef off Bitra Island (Lat. 11° 38'N, Long. 72° 13'E) and in few numbers next day outside the reef of Agathi Island (Lat. 10° 51' N, Long. 72° 28'E). Wilson (1977) reported that Palauan fishermen occasionally encountered blue sprats some distancea way from the Island. Although *Herklotsichthys punctatus* was used as bait while catching tuna 11 km off Kayangel, the food contents of skipjack caught from the same shoal consisted of large amount of *S. delicatulus*.

II. Spratelloides japonicus

Spratelloides japonicus was originally described as *Atherina japonicus* by Houttuyn in 1782. But Weber and be Beaufort (1951) named this species as *Spratelloides gracillis.* Munro (1955) named it as *Spratelloides japonicus* and this was followed by Jones (1960). Baldwin (1977) in his revirew of the use of live-bait fishes in the Tropical Pacific has mentioned both *Spratelloides gracilis* and *Spratelloides japonicus* seperately while Jones (1960, 1964) has synonimized *S. gracilis* with *S. japonicus.* In the present context *S. gracilis* has been considered a synonym of *S. japonicus.*

Baldwin (1977) presented the distribution of this species in the different world oceans. Jones (1960) has given its distribution as Red Sea, Laccadives and coasts of India and Ceylon to Indonesia, Philippines, Japan, Fiji and Tahiti.

Wilson (1971) noted that *S. japonicus* is a good live bait fish but not as hardy as *S. delicatulus* and not extensively used at Palau, while Lee (1953) noted that it is important in the Fiji fishery, but its survival is very poor.

Isa (1972) reported *S. japonicus* as an important bait fish in the Ryukyu Islands fishery. Kikawa (1977) stated that in Nuguria Islands *S. japonicus* and *S. delicatulus* were represented in the bait fish catches made with the stick held lift nets. *S. japonicus* was more abundant than *S. delicatulus.* Most of them were juveniles, ranging in length from 25 to 40 mm. Wilson (1977) reported that *Spratelloides* spp. are very common in Ponape and they were most frequently taken by the Okinawan fishermen. Smith (1977) stated that in Papua New Guinea, sprats rank second to anchovies in terms of overall abundance and contribution to the bait fish fishery. *Spratelloides gracilis* (= *S. japonicus*) and *S. delicatulus* with their brilliant colouration and rapid swimming action, are very attractive and proved to be excellent bait.

Jones (1960, 1964) noted that *S. japonicus* is used in the Laccadive fishery and that it occurs in small schools but is not as abundant as *S. delicatulus.* Both species are seasonally available and have been observed on occasion in large quantities, but after December they are scarce (Thomas 1964).

There is no hitherto published information on the biology of *S. japonicus* from Indian waters. A review of the published literature on bait fish biology also reveals that no available information is present in this regard from elsewhere. Therefore, a preliminary Account of the biology of the silver sprat, *S. japonicus* is presented here based on analysis of the collections from Minicoy waters.

Samples for the present investigation were collected from Minicoy bait fish catches during 1981-82 tuna pole-and-line fishing season. Though the species was available as stray catches during all the months of the season, it contributed 20.5 per cent of the total bait catches in February 1982 and 10.5 per cent in January. Samples were preserved in 5 per cent formalin and were analysed later for biological studies.

Length-weight Relationship

54 males ranging from 42 to 62 mm and 34 females ranging from 45 to 60 mm in total length were considered for these studies. $W = aL^b$ could be fitted to the data, where W is the weight of fish, L is the total length of the fish, *a* and *b* are two constants. Logarithmic transformation of the formula gives a straight line relationship to the form

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

Log *a* and the regression coefficient (*b*) were estimated for the males and females separately by using least square method and the following relationship were obtained.

$$\text{Males Log } W = -1.5743 + 2.0782 \text{ Log } L$$

$$\text{Females Log } W = -1.6707 + 2.0938 \text{ Log } L$$

The coefficient of correlation ('*r*') for the males was 0.878 and for females 0.938.

In the analysis of covariance to test the significance of differences in the regressions of y and x was attempted and it was found that there is no significant difference in the regression coefficient between males and females. Therefore, the data for both males and females were pooled together and a common length weight relationship was fitted as below.

$$\text{Log } W = -1.4380 + 2.0400 \text{ Log } L$$

Regression lines for males and females separately are given in Figs. 3 & 4.

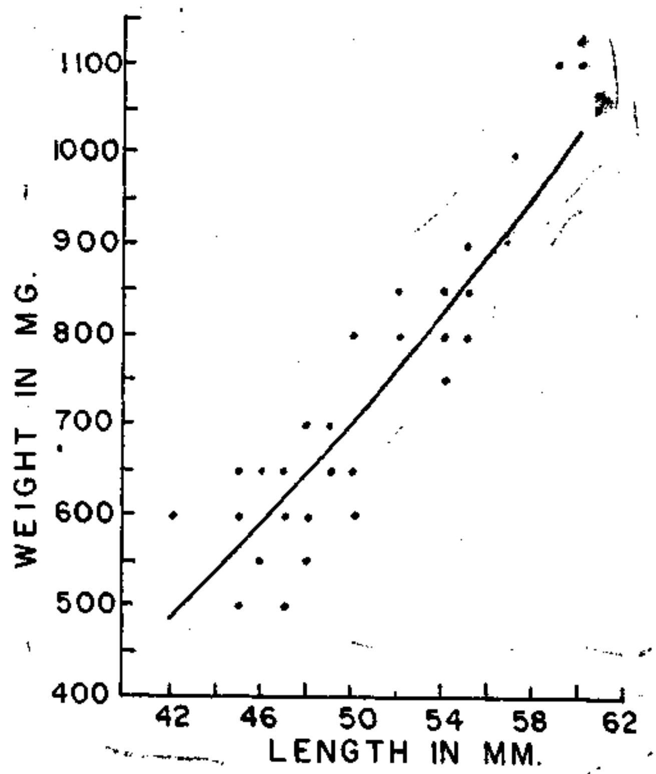

Fig. 3. Length-weight relationship of males of *S. japonicus* at Minicoy.

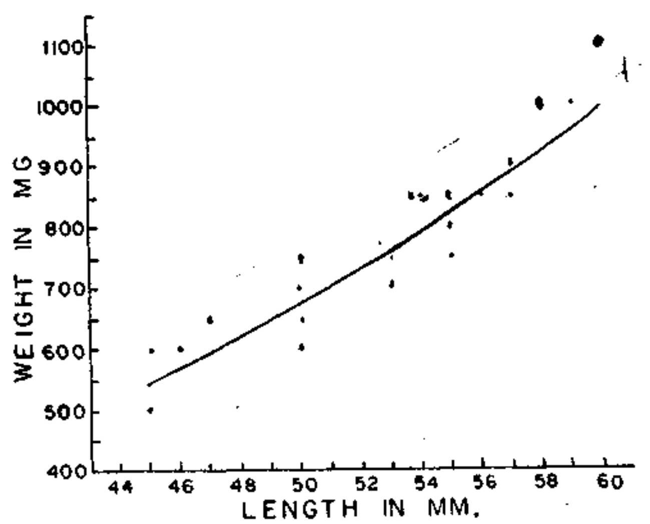

Fig. 4. Length-weight relationship of females of *S. japonicus* at Minicoy.

Distribution and abundance

S. japonicus (Silver sprat) are found in the deeper parts of the Minicoy lagoon north of Ragandi point area. They are found associated with corymbose corals. During high tide period fishes gather on the top of the coral heads and it is easy to catch them at that time since they will form small schools. During high tide, fish moves in deeper waters little away from the corals.

During 1981-82 pole-and-line tuna fishing season, 263 kg of *S. japonicus* which made 9.40 per cent of the total bait fish catches, were caught at Minicoy and used as bait. It was available in good percentage during January (10.50%) and February (20.50%). This species is caught from December onwards when they start appearing in the western part of Minicoy lagoon. Its availability is very erratic and rarely they are caught in bulk.

Length frequency distribution

During the course of these investigations, the total length of the individual fish ranged between 35 and 60 mm. The percentage frequency in the various size groups are plotted in the form of length frequency curves in Fig. 5.

As can be seen from the figure that there are two modes at 42 mm (A) and 46 mm (B) during December 1981. Samples were not available during January

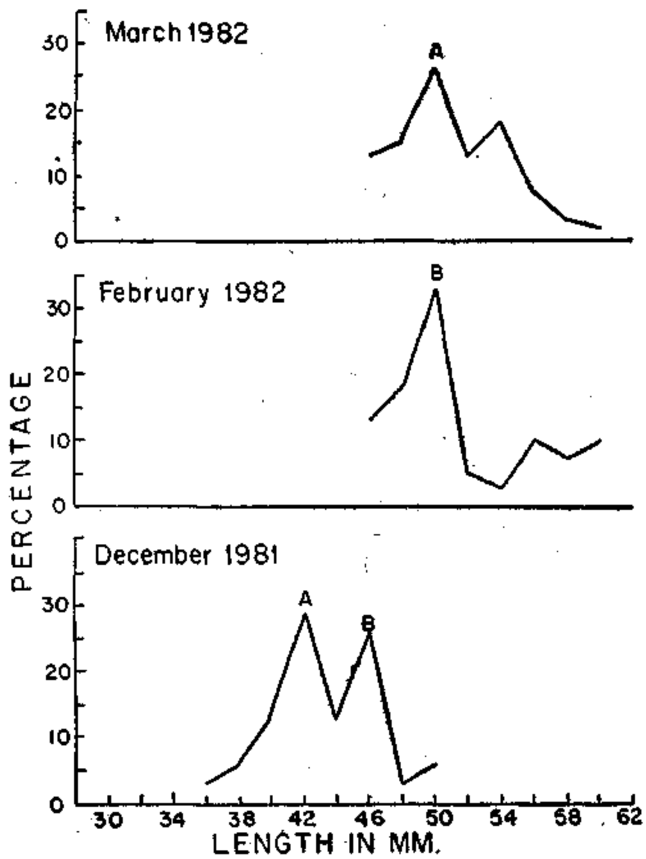

Fig. 5. Monthly length frequency distribution of *S. japonicus* at Minicoy, Dec. 1981-March '82.

1982. In February two modes at 50 mm and 56 mm appeared. Mode at 50 mm can be traced back as mode B of December at 46 mm with 4 mm growth. In March, two modes at 50 mm and 54 mm appeared. Mode at 50 mm can be traced back as mode A of December at 42 mm with 8 mm growth.

Age and growth

Length frequency data of *S. japonicus* are available only for four months due to its seasonal availability. It is interesting to note here that like *S. delicatulus*, its total length ranged from 35 to 60 mm. This species also has shown growth from 42 to 50 mm at the rate of about 3 mm per month.

Maturity and spawning

The maturity stages of individual fish were classified by microscopic examination of the ova of different maturity stages and the procedure is as that followed for *S. delicatulus*.

It can be observed from Fig. 6 that in stage I of the ovary only immature ova which ranged from 0.01 to 0.09 mm with mode at 0.05 mm are present. These immature ova are present in the ovaries of all stages and are shown in figure in broken lines.

In stage II, ova range from 0.01 to 0.19 mm with mode at 0.09 mm.

In stage III, it can be seen that one group of ova is getting seperated from immature stock of ova which ranged from 0.04 to 0.33 mm with mode of maturing ova from 0.19 mm to 0.23 mm. In the bigger size of ova, yolk deposition has started and they look translucent but majority of ova are transparent.

In stage IV maturing ova have shown some progress. Mature ova have their mode from 0.23 to 0.28 mm. Majority of the ova are translucent and can be clearly distinguished from the maturing stock.

In stage V, mature ova have shown faster growth and at this stage of ovary three groups of ova namely immature, maturing and ripe can be clearly distinguished from each other. From the figure it can be seen that ripe ova range from 0.28 to 0.52 mm with clear mode at 0.38 mm while maturing ova have mode from 0.19 to 0.23 mm. Ripe ova with mode at 0.38 mm are the group of ova which will spawn in the near future leaving behind maturing stock.

Spawning season

Sexwise monthly distribution of maturity stages of *S. japonicus* is shown in the Table 5. During December

TABLE 5. *Percentage occurrence of gonads of* S. japonicus *in different stages of maturity during* 1981-82 *season*

Month	No. of fish	Sex	Stages of maturity						
			I	II	III	IV	V	VI	VII
1981									
December	17	M	..	41.18	52.94	5.88	..	..	..
	14	F	7.14	85.72	7.14	..	..	..	..
1982									
February	23	M	..	..	56.52	21.74	13.04	8.70	..
	16	F	..	6.25	37.50	12.50	37.50	16.25	..
March	31	M	..	..	41.93	48.39	3.23	6.45	..
	21	F	..	9.52	47.62	14.29	19.05	9.52	..

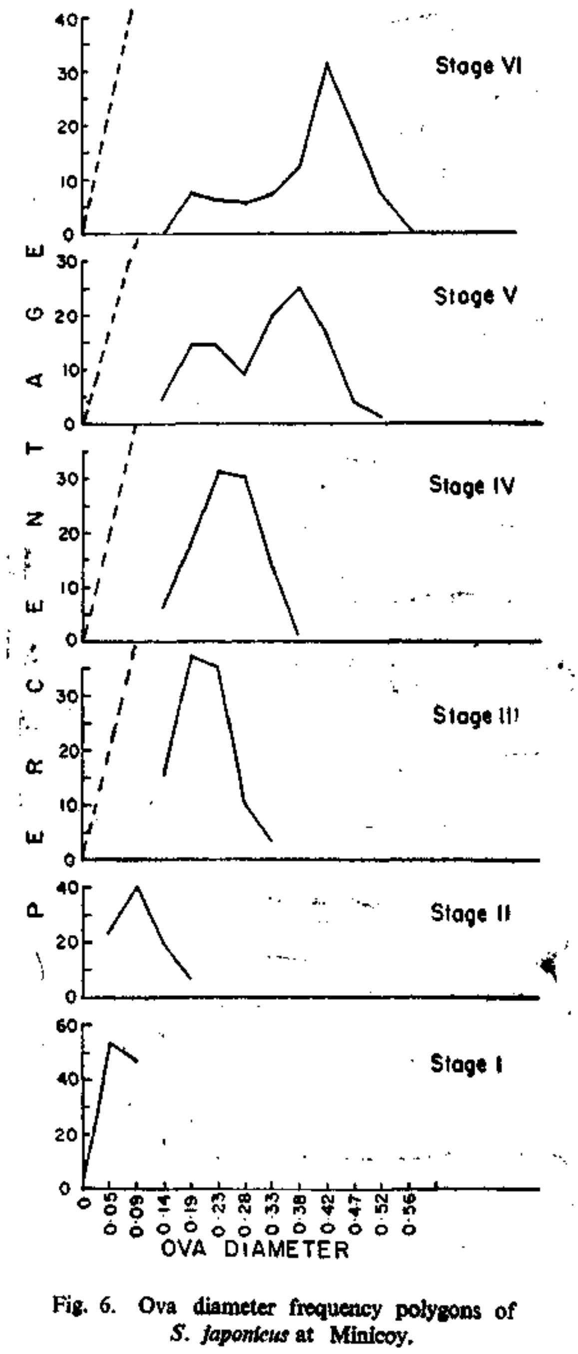

Fig. 6. Ova diameter frequency polygons of *S. japonicus* at Minicoy.

1981 fish from stages I to IV were available. But in February and March 1982 fish from stages II to VI in maturity were available. Even during February and March maturing fishes dominated over mature fishes.

Since this species is usually available for few months every year at Minicoy, it is rather difficult to state anything about its spawning season. But presence of mature fishes from February shows that this species may certainly be spawning from March onwards. Nature of the ovary suggests that fish may spawn more than once in a spawning season. Therefore, because of the occurrence of juveniles of this species from December onwards, it can be stated that *S. japonicus* has an extended spawning season at Minicoy.

Frequency of spawning

As can be seen from Fig. 6 that ovary in the ripe maturity stage contains three types of ova namely immature, maturing and ripe. Immature ova are available in plenty due to continuous proliferation of ova in the ovary. Maturing and mature ova have separate distinct modes. From stage IV onwards mature ova have shown faster rate of growth than the maturing ones and in ripe ovary they are almost ready for spawning. While this batch of ripe ova is spawned out, their place will be soon occupied by maturing ova which have already completed more than half of maturation process. These ova will show faster rate of growth and soon will be ready for spawning. Therefore, it can be stated that like *S. delicatulus* this species also spawns more than once in a spawning season.

Sex ratio

Percentage of males in comparison to females was found to be higher during all the months of observations (Table 6). Even for the season as a whole, males dominated over females. Ratio of males to females was calculated as 1 : 0.72.

TABLE 6. *Sex ratio of* S. japonicus *at Minicoy during* 1981-82 *season*

Month		Total No. of fish	(Males %)	Females (%)
1981				
December	..	31	54.84	45.16
1982				
February	..	39	58.97	41.03
March	..	52	59.62	40.38
Total	..	122	58.20	41.80
Sex ratio	..		1	0.72

Fecundity

Since the ovary of *S. japonicus* is very small in size, ovary as a whole was teased on a slide and mature ova were counted with the aid of a binocular microscope. Fifteen ripe and spawning ovaries were selected for these studies and counts were made. Total length of fish, weight of fish, total number of mature ova and stage of maturity are given in Table 7. It can be seen

TABLE 7. *Fecundity estimates of* Spratelloides japonicus

Serial No.		Total length of fish in mm	Weight of fish in mg	Total No. of mature ova	Stage of maturity
1	..	45	500	381	V
2	..	45	600	425	V
3	..	50	750	512	V
4	..	50	700	538	V
5	..	50	750	563	V
6	..	53	750	742	V
7	..	55	750	637	V
8	..	55	750	674	VI
9	..	57	700	934	V
10	..	57	900	986	V
11	..	57	900	1,009	V
12	..	57	850	1,123	V
13	..	58	1,000	1,011	VI
14	..	59	1,100	1,133	VI
15	..	60	1,100	1,181	V

from the table that the number of mature ova increased with increase in fish length. Even then, fish of the same length showed variations in total number of mature ova.

Food and Feeding

A total of 132 specimens of *S. japonicus* were examined for food and feeding studies. The degree of distension of stomachs was recorded depending on the fullness in the following categories (1) Empty, (2) 1/4 Full, (3) 1/2 full, (4) 3/4 Full, (5) Full and (6) Gorged.

The empty stomachs occurred in high percentage (79.51%) of the total stomachs examined (Table 8). Their percentage was high during all the months of observations. Half full contributed 17.21% and full stomachs 3.28 per cent.

S. japonicus mainly subsists on crustaceans. These were represented mostly by harpacticoid and calanoid copepods and post larvae of decapod crustaceans. Gammarids and fish eggs were recorded in very few numbers.

Behaviour

Like other members of the family Dussumiieridae, *S. japonicus* is also a schooling species. It can be seen in small schools swimming over the coral heads in deeper waters.

Usually young ones of the species are used as bait at Minicoy. Whenever they are available in good numbers, they are preferred as bait. During 1981-82 tuna pole-and-line fishing season, 25,134.5 kg of tunas were caught by using 263 kg of *S. japonicus* as bait. When its efficiency in attracting tuna was compared with other bait fishes of the season, it proved to be most efficient with catch per unit bait of 95.57 kg.

This species possesses all desirable qualities which are essential for a bait fish such as small size, silvery on body sides, slender, hardy during transportation and efficient in chumming tunas during tuna fishing operations.

TABLE 8. *Percentage occurrence of stomachs of* Spratelloides japonicus *in various degrees of fullness during* 1981-'82 *season at Minicoy*

Month		Empty	¼th full	½ full	¾th full	Gorged	Sample number
1981 December	..	77.42	..	22.58	..	..	31
1982 February	..	71.79	..	20.51	..	7.70	39
1982 March	..	86.54	..	11.54	..	1.92	52
Total numbers	..	97	..	21	..	4	122
Percentage	..	79.51	..	17.21	..	3.28	

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EXPLORATORY FISHING BY OCEANIC DRIFT GILLNETTING AND PURSE SEINING IN THE LAKSHADWEEP

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With a view to develop the oceanic pelagic fisheries, it was planned as early as 1965 to conduct exploratory fishing in the offshore and oceanic areas by drift gillnetting and purse seining. During the cruises of *R. V. Varuna* it was possible to plan out the operation of drift gillnet fishing which was started in January 1965 and continued as and when possible upto the end of January 1968. Purse seining for tunas was also conducted by *R. V. Varuna* and *M. V. Tuna* of the erstwhile Indo-Norwegian Project. Although during the cruises scouting for tuna was conducted by sonar (ASDIC) (horizontal range 1500 m) and echosounders, it was found that visual scouting was more effective. The characteristic sonic spires in the Deep scattering layer between 300 and 450 metre were observed and it is presumed that these could be due to the presence of larger tunas such as bigeye and possibly billfishes at that depth. A brief summary of the results of the operations has been presented earlier (Silas 1969).

EXPLORATORY DRIFT GILLNETTING

A number of units of drift gillnets made of nylon was used at each operation, each unit being 25.85 m long and 6.10 m broad. In a single unit the mesh size was the same and units with mesh size 2.5, 5.5, 10.0, 12.5 and 17.0 cm were used. The smaller mesh sizes were selected specially for collecting juvenile of pelagic fishes.

The area of operation is presented in Fig. 1. The nets were operated in the Lakshadweep Sea as well as in the continental shelf off the south-west coast. A summary of the total operational details is as follows :

No. of fishing operation	= 86
Total soaking time	= 794.50 hrs.
Total catch	= 2,522.0 kg.
Av. catch/fishing operation	= 29.33 kg.
Total catch of tunas	= 853 kg.

The number of units of nets varied from 14 to 45. The maximum soaking time of the net for a single operation was 15.00 hrs. and the minimum 4 hrs. and 10 minutes. Mostly handling was done manually, but on a few occasions a line hauler fixed on the port side was used. The effective fishing depth was from surface to between 4 and 5 m.

The number of specimens, size range, percentage composition, and average weight of tunas (squids and other pelagics such as horse mackerel and *Coryphaena* sp are not considered here) were as follows :

	No. of specimen	Fork length (cm)	% composition (by weight)	Total (weight kg)	Average weight (kg)
A. rochei ..	141	191-290	2.8	24	0.168
A. thazard ..	153	201-510	13.5	115	0.750
E. affinis ..	238	281-620	62.1	531	2.232
S. orientalis ..	21	281-520	3.2	27	1.309
K. pelamis ..	38	421-650	14.9	127	3.347
T. tonggol ..	1	447	0.5	4	..
T. albacares ..	7	500-650	3.0	25	3.500

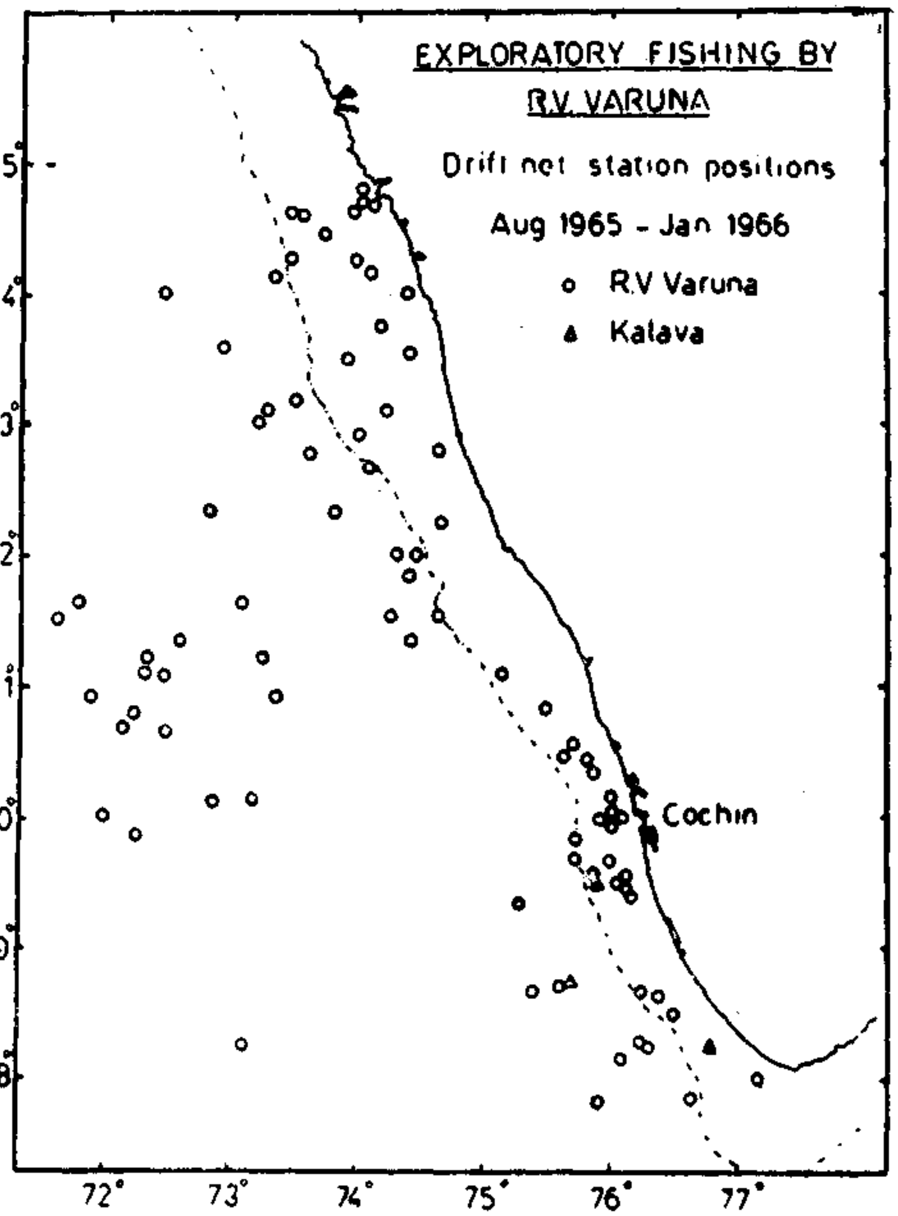


Fig. 1. R. V. *VARUNA* station positions of experimental oceanic drift gillnetting conducted during Aug. 1965-Jan., '66.

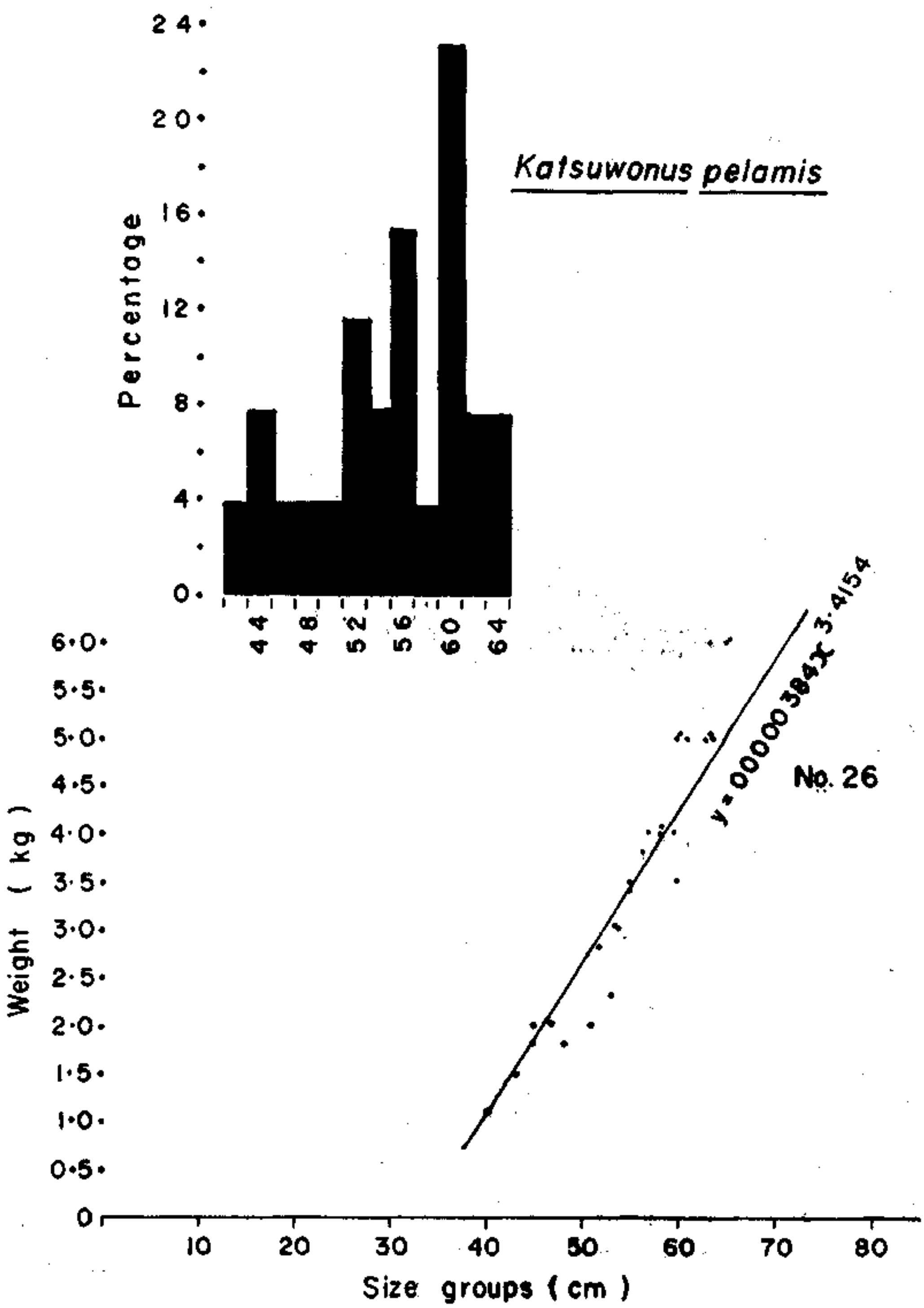


Fig. 2. Length frequency distribution (percentage) and the length-weight relationship of *K. pelamis* taken during the oceanic drift gillnetting.

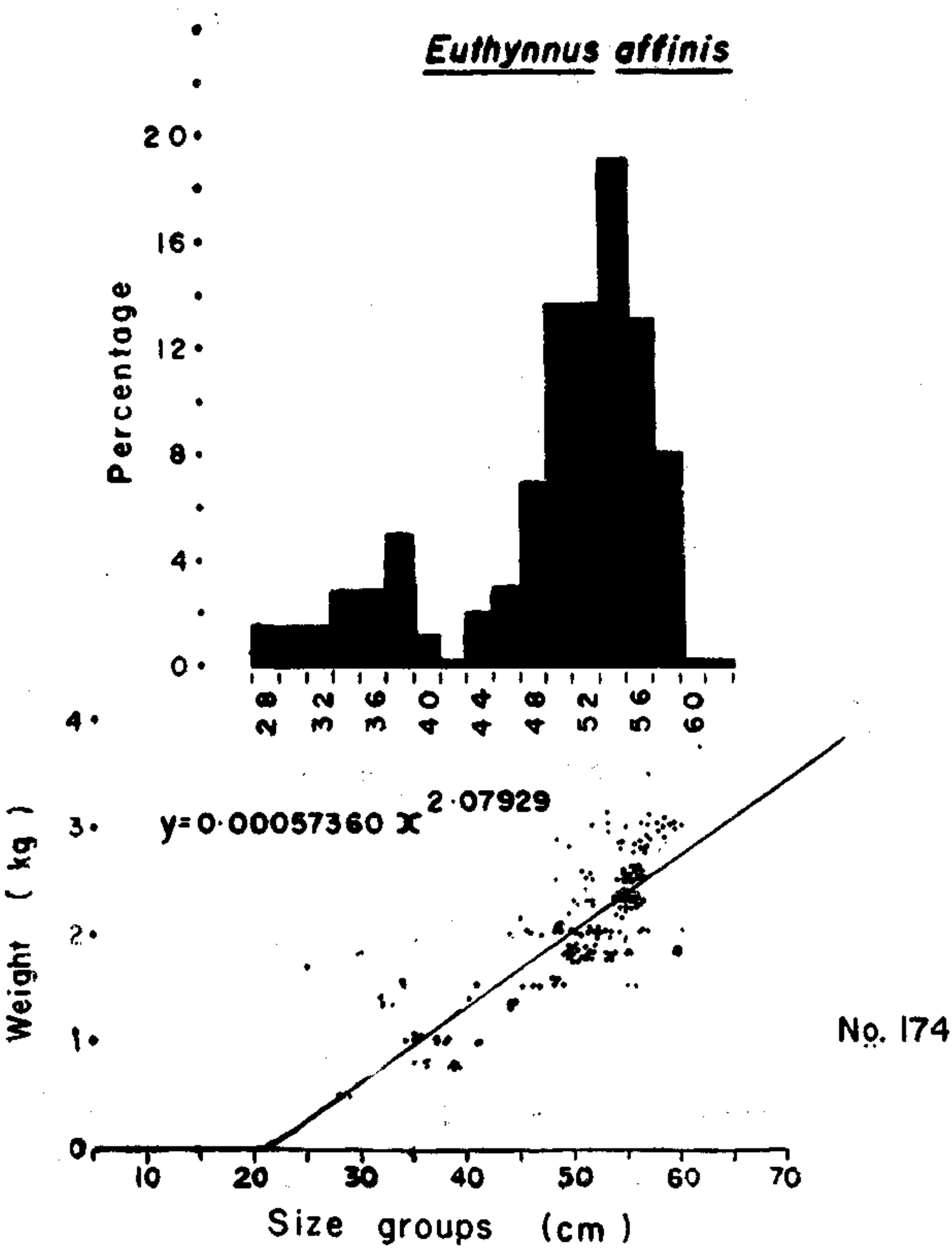


Fig. 3. Length frequency distribution (percentage) and the length weight relationship of *E. affinis* taken during the oceanic drift gillnetting.

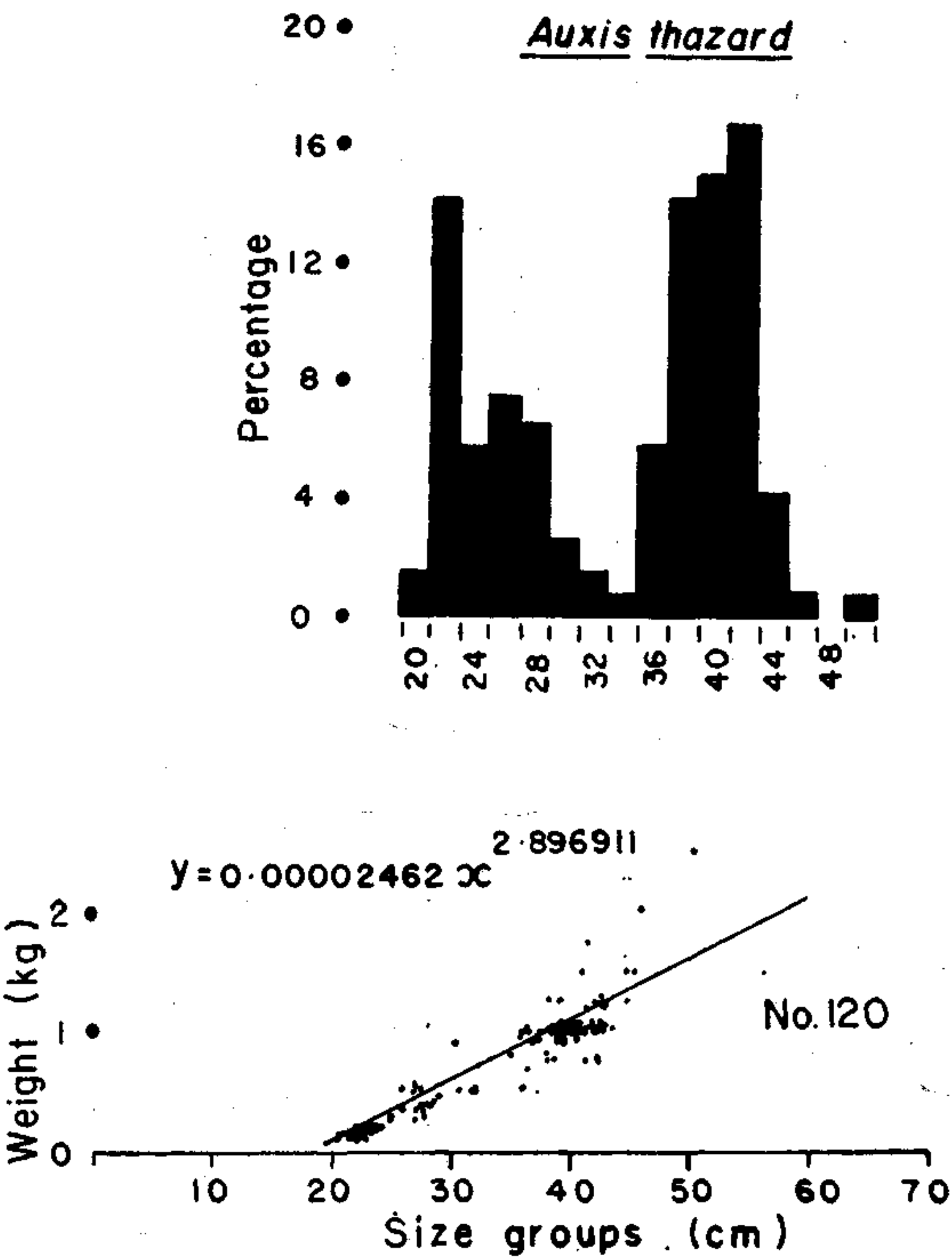


Fig. 4. Length frequency distribution (percentage) and the length-weight relationship of *A. thazard* taken during the oceanic drift gillnetting.

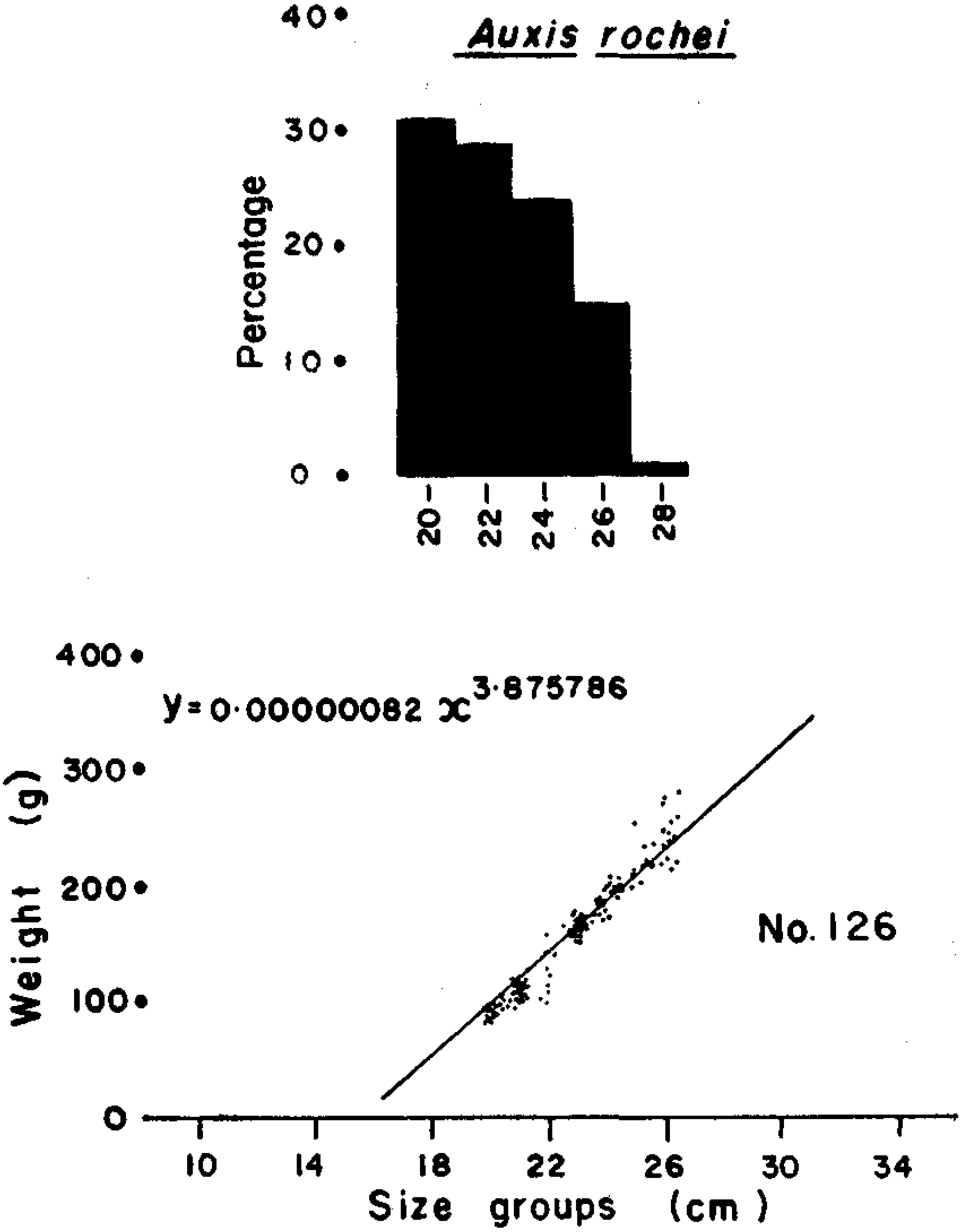


Fig. 5. Length frequency distribution (percentage) and the length-weight relationship of *A. rochei* taken during the oceanic drift gillnetting.

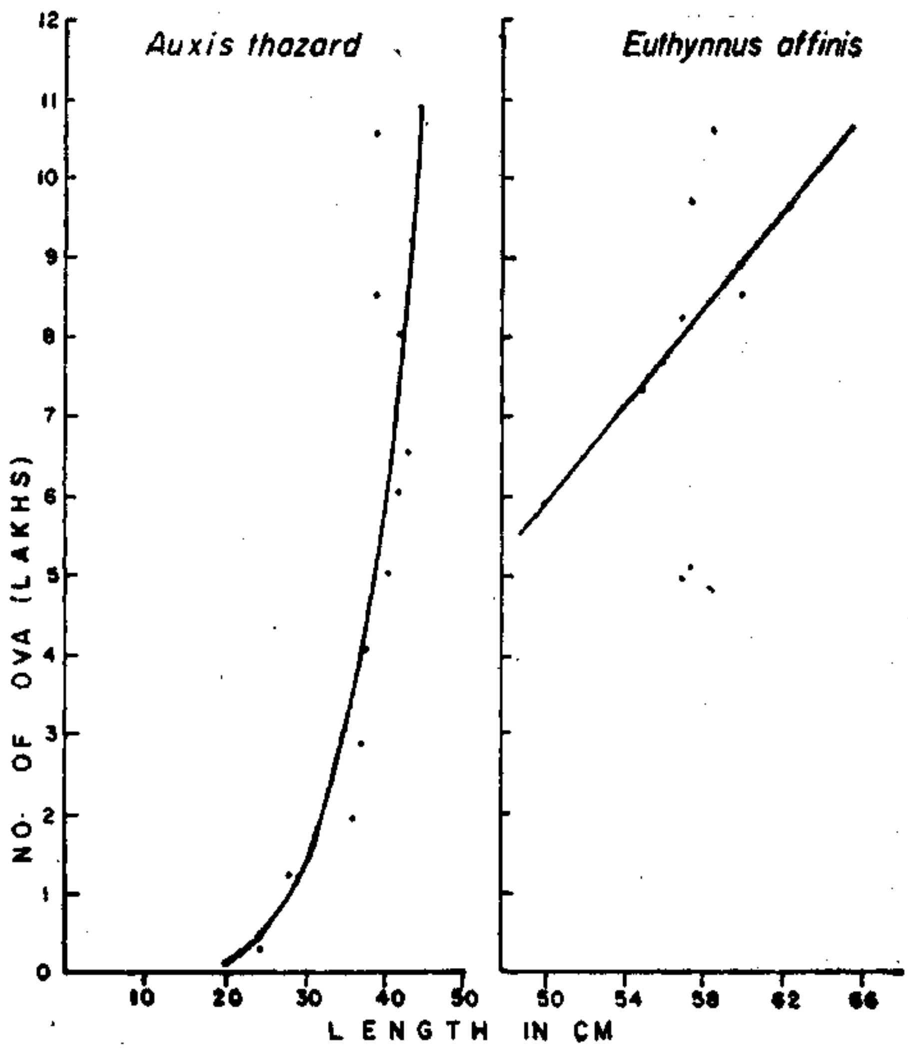


Fig. 6. Fecundity in relation to the total length of *A. thazard* and *E. affinis* taken during the oceanic drift gillnetting.

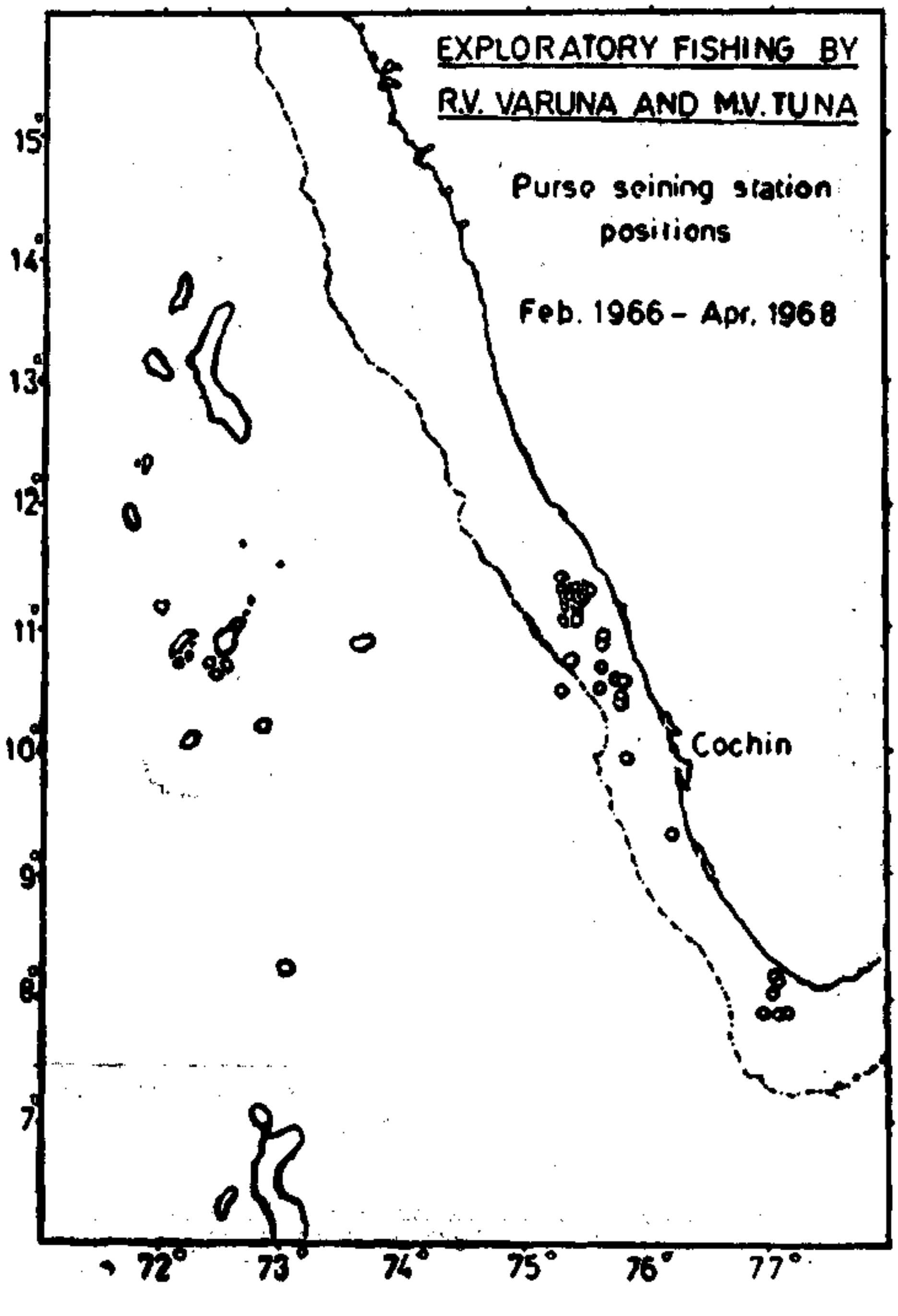


Fig. 7. R. V. *VARUNA* and M. V. *TUNA* station positions of experimental purse seining conducted during Feb., 1966-April, 1968.

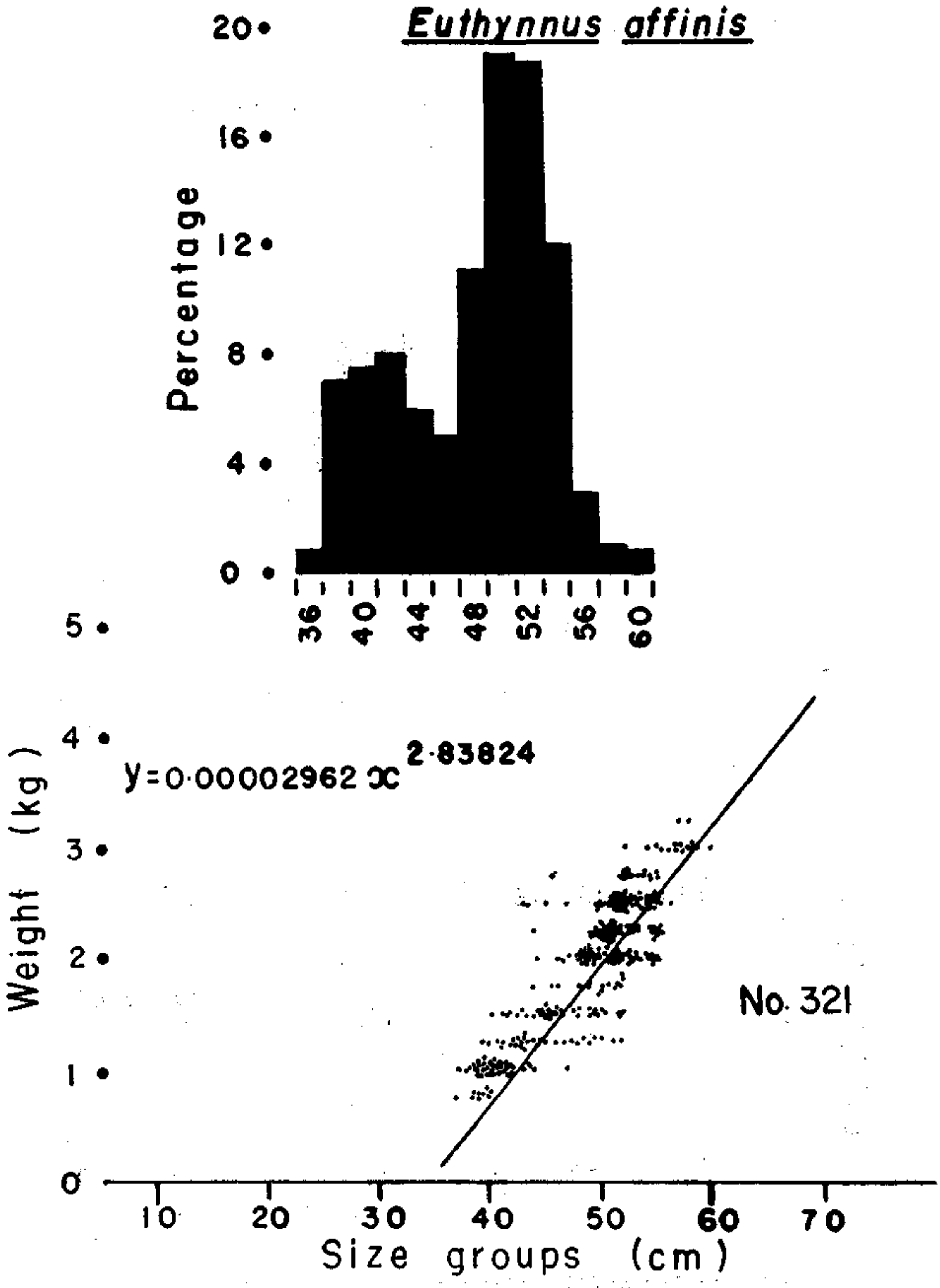
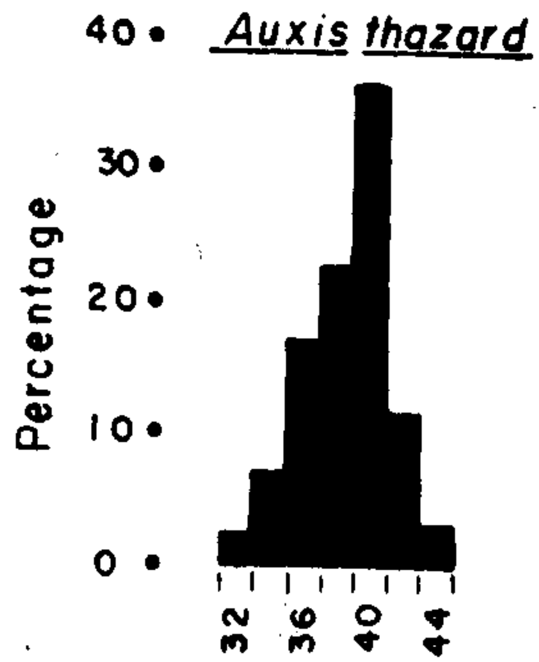


Fig. 8. Length frequency distribution (percentage) and the length-weight relationship of *E. affinis* taken during purse seining.



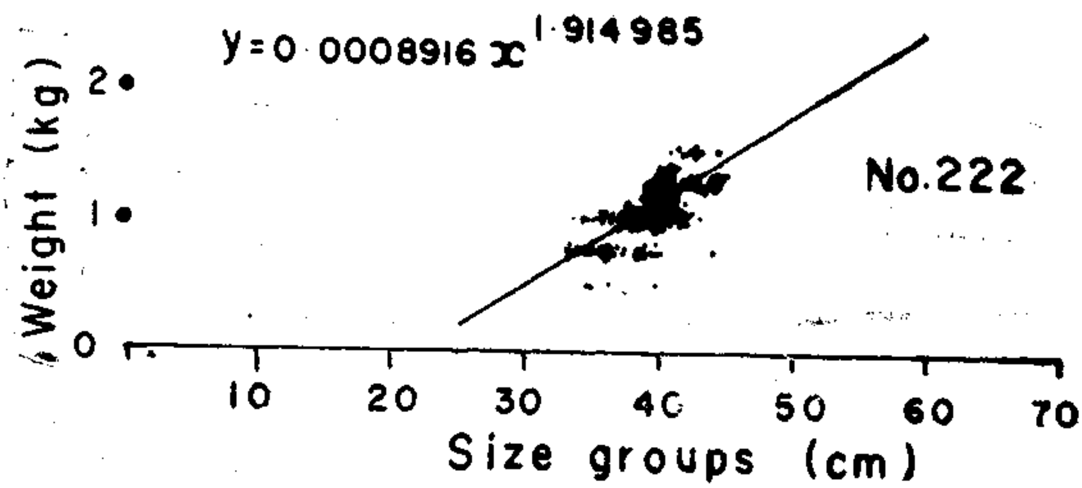


Fig. 9. Length frequency distribution (percentage) and the length-weight relationship of *A. thazard* taken during purse seining.

Length frequency of tunas collected during the drift gillnets and their length-weight relationship is presented in Fig. 2-5. The length-weight relationship of different species were as follows :

E. affinis	y	=	$0.00057360\ x^{2.07929}$
A. thazard	y	=	$0.00002462\ x^{2.896911}$
A. rochei	y	=	$0.00000082\ x^{3.875786}$
S. orientalis	y	=	$0.00039446\ x^{2.17519}$
K. pelamis	y	=	$0.00000384\ x^{3.41541}$

Other aspects of biology especially the fecundity (Fig. 116) worked out for different species is presented below :

	No. of ovaries examined for counts	Estimated number of ova Range	Mean
A. rochei	4	31236 — 102902	52000
A. thazard	9	197223 — 1056468	601400
E. affinis	7	493617 — 1393882	866900
S. orientalis	4	268930 — 403603	354100
K. pelamis	1	26873	268400

Exploratory purse seining

Purse seine fishing for tunas in the Lakshadweep sea was first carried out by *R. V. Varuna* in February, 1966, but was not successful. Later, in March 1967, *R. V. Varuna* and *M. V. Tuna* conducted purse seine operations with a net of 540 m long, 67 m depth and 10 mm mesh size. Although skipjack shoals were encircled, they sounded faster and not a single fish was caught. It was observed that, for successful operations, in the oceanic areas nets of larger dimensions should be employed which could operate in relation to the thermocline. The same purse seine net was successfully operated on the shelf areas where good catches were obtained, the maximum exceeding 10 tonnes in a single operation (Fig. 7).

Out of a total of 38 purse seine operations carried out by *R. V. Varuna* and *M. V. Tuna*, the number of positive stations with tuna were only 10 for which the effort expended in hours was 39.50. The total catch amounted to 19,436 kg. The average duration of the positive operations being 3.95 hours the average catch in kg per positive operations was 1943.8 kg and catch/hour for positive hauls worked out to about 494 kg. However, these investigations have proven beyond doubt that in the coastal waters, the nets of the type used could be successfully operated and much higher catch rates could be expected.

The catch was mainly compossed of *E. affinis* and *A. thazard*. *E. affinis* occurred in the size range 32-58 cm and *A. thazard* 32-46 cm. Their length frequency distribution and the length-weight relationship is presented in Figs. 8 & 9. The length-weight relationship of the two species calculated were as follows :

E. affinis	y	=	$0.00002962\ x^{2.6324}$
A. thazard	y	=	$0.00089160\ x^{1.191498595}$

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OBSERVATIONS ON THE FISHERY AND CERTAIN ASPECTS OF THE BIOLOGY OF YELLOWFIN TUNA, *THUNNUS ALBACARES* (BONNATERRE) TAKEN BY LONGLINE GEAR IN THE EEZ OF INDIA

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The two oceanic species of tunas that are exploited by India at present are the skipjack and yellowfin (mainly young ones) tunas. The distribution of yellowfin tuna in the area extends from the oceanic waters to the marginal range of neritic provinces, and the exploitation of this species is chiefly along the fringe of its distribution. In the case of the yellow fin tuna, the juvenile and immature fishes enter the surface fishery in the insular ranges and the adults are mainly confined to the sub-surface waters in the oceanic area where they contribute to the tuna longline fishery.

The present communication is based partly on the information available in the publications and partly on the results of observations on the fishery and biology of yellowfin tuna carried out by the authors on the long line catches from the oceanic waters of India. Some aspects of the biology of this species, estimated based on the data collected from the fishery by surface gears are also included in the text in order to facilitate comparison of biological parameters.

FISHERY

Recently, BOBP (1985) presented an estimation of the landings of yellowfiin tuna by the longline fishery by the Japanese, Taiwanese and Korean longliners from the waters close to India, Maldives and Sri Lanka for the years 1977-'82. Recent trend of the catch rate of this species is presented in Table 1.

TABLE 1. *Yellowfin tuna catches and their mean size, by the longline fishery from the area 0°-10°N ; 70°-80°E*

Area and particulars			1979	1980	1981	1982
0°-5°S	Hooks	(Nos)	971,916	176,500	464,800	290,800
70°-75°E	Catch	(Nos)	6,249	695	2,813	1,188
	HR	(%)	0.64	0.39	0.61	0.41
0°-5°N	Hooks	(Nos)	306,452	11,500	..	76,000
70°-75°E	Catch	(Nos)	3,007	33	..	52
	HR	(%)	0.48	0.29	..	0.07
0°-5°N	Hooks	(Nos)	1,232,134	423,971	136,700	499,500
75°-80°E	Catch	(Nos)	7,083	1,742	386	946
	HR	(%)	0.57	0.42	0.28	0.19
5°-10°N	Hooks	(Nos)	584,511	..	12,000	..
75°-80°E	Catch	(Nos)	8,821	..	..	..
	HR	(%)	1.50	..	..	..
Total Hooks		(Nos)	3,095,013	611,971	615,500	866,300
Total catch		(Nos)	25,160	2,470	3,199	2,186
HR		(%)	0.81	0.40	0.53	0.25
Mean size	(kg)		31.12	31.00	31.00	33.60

It is evident from the production rate presented in Table 1, that peak production of yellowfin tuna in commercial fishery was in 1979 (783 tonnes) which declined in the later years (1980=77 tonnes ; 1981=99 tonnes ; 1982=73.4 tonnes).

The pioneering attempt by India to conduct exploratory longline fishery in the oceanic waters off the south-west coast of India (5°N-12°N) was during the period 1964-65. Fourteen fishing operations were conducted during the months of April, May, June, November and December in 1964 and in January in 1965. The fishery survey vessels '*M. T. Pratap*', '*Kalyani IV*' and *Kalyani V* which belonged to the erstwhile Deep Sea Fishing Organisation of the Government of India (present Fishery Survey of India) were employed for carrying out experimental tuna longline operations. The results of the operations including the effort expended, catch and hook-rate are presented in Table 6. Maximum percentage composition of yellowfin tuna in the area 5°N-12°N was recorded in the month of April (10.1) although high hook-rate was observed in December (2.45%) (Kawaguchi 1967).

M. V. '*Prashikshani*', the training vessel of the Central Institute of Fisheries Nautical and Engineering Training (CIFNET) commenced operation for training in longline fishery from January, 1981, mainly in the oceanic waters in the depth range of 2000-2500 m off Lakshadweep Islands. A brief account of the effort expended, total catch of tunas and by-catch taken during the operation of the vessel in the Lakshadweep Sea has been presented earlier (Pillai 1981). The areas of operation of M.V. '*Prashikshani*' and catch composition are presented in Figs. 5 and 6 (paper 3) and the total effort expended and catch of tunas, marlins pelagic sharks and other fishes during 1981 and 1982 are given in Table 6 (paper 3). In 1981, the effort expended (number of hooks) was high during the months March, April and May (500 hooks). Whereas in 1982, maximum effort was put in during January, July and October (200 hooks). The hook-rate of tunas in 1981 (698 Nos) was 1.43 per cent which was declined in 1982 (185 Nos) to 1.27 per cent. Yellowfin tuna constituted ninety per cent of the catch of tunas in both the years.

"*Matsya Sugundhi*", the survey vessels of the Fishery Survey of India conducted exploratory tuna longline operations under the 'Wadge Bank Programme' from 1981. The areas and results of surveys of this vessel during October to December, 1981 ; 1982 and 1983-84 are presented in Figs. 7-9 and Tables 7 & 8 (paper 3).

In 1983, operation of this vessel was in the waters close to the inshore region. Joseph (1984) briefly summarised the surveys conducted by '*Matsya Sugundhi*' during October, 1983 to March, 1984 in the Arabian Sea and Bay of Bengal. Five voyages were conducted by this vessel of 20-40 days duration, of which four were in the Arabian Sea between 8°N and 9°N and 68°E and 72°E. In the Bay of Bengal, the survey of 40 days period covered the area between 8° and 16°N. The catch from the equatorial area consisted of 85 per cent tunas (bigeye, yellowfin and skipjack) and from the east coast 53 per cent (yellowfin and skipjack tunas). Hook-rate upto 2.5 per cent was realised in the case of yellowfin tuna from the equatorial waters.

Varghese *et al.* (1984) presented in detail the total effort expended, catch and hook-rate of tunas and other fishes in the exploratory longline fishery surveys by '*Matsya Sugundhi*', during the same period from the south-west coast of India, equatorial waters and from the east coast. The aggregate percentage composition of yellowfin tuna in the total catch from the west coast was 2.03, from the east coast 43.82 and from the equatorial waters 73.62, and the respective hook-rates from the above three areas were 0.05 per cent, 0.96 per cent and 1.14 per cent.

Region-wise hook-rate of yellowfin tuna during the survey were as follows :

Area		Hook-rate (%)
8°-9°N.	74°-75°E	0.1
" " "	75°-76°E	0.1
" " "	76°-77°E	0.6
7°-8°N.	75°-76°E	0.3
5°-6°N.	68°-69°E	1.1
" " "	69°-70°E	0.6
4°-5°N.	67°-68°E	0.3
" " "	68°-69°E	0.6
" " "	69°-70°E	1.0
3°-4°N.	67°-68°E	0.0
" " "	68°-69°E	0.9
" " "	69°-70°E	0.4
2°-3°N.	67°-68°E	1.7
" " "	68°-69°E	1.5
1°-2°N.	68°-69°E	1.3
" " "	69°-70°E	2.5
0°-1°N.	68°-69°E	0.9

Sivasubramaniam (1985) observed that the longline catches of yellowfin tuna from the inshore waters of Sri Lanka were high during the north-east monsoon period. According to him, in the oceanic waters of

Sri Lanka the catch rates were high during the first quarter and first half of the second year. Catch rates rapidly declined during the second quarter in the area close to the equator. Peak catches were observed in the exploratory longline fishery survey from the oceanic waters of the south-west coast of India in November-December period. Maximum catch of young yellowfin tuna by the pole and line fishery at Minicoy was also recorded during the north-east monsoon period.

Morphometry

In the present study, data on the morphometric characters collected from 29 specimens of yellowfin tuna, ranging in length from 87.0 and 160.0 cm taken by the longline fishery from the oceanic waters of India in 1984 have been analysed and the summary results presented in Table 2. The regression of different morphometric characters on the fork length, and the correlation matrix of the characters of *T. albacares* are presented in Tables 3 and 4.

Length composition

Very little information is available on the length composition of yellowfin tuna from the oceanic waters around India. Silas *et al.* (1979) stated that the size range of this species caught along the south-west coast of India is 63-78 cm. In the Minicoy Island they were present in the live-bait pole and-line fishery in the size range 28-66 cm. Sivasubramaniam (1985) observed

TABLE 2. *Summary of morphometric data of* T. albacares (in cm) (N 29)

Characters		Maximum	Minimum	Mean	Standard deviation
Total length	..	160.0	87.0	106.067	22.35
Fork length	..	143.0	77.5	96.087	18.938
Standard length	..	133.0	73.0	89.203	17.390
Snout to eye	..	13.3	8.0	9.479	1.570
Eye diameter	..	4.2	3.1	3.595	0.877
Snout to D1	..	38.0	24.0	28.431	4.374
Snout to pectoral	..	38.8	22.2	27.305	4.384
Height of pectoral	..	31.7	21.2	24.790	3.152
Base of pectoral	..	9.9	4.0	6.495	1.264
Height of D1	..	18.1	9.0	11.528	2.374
Snout to D2	..	73.5	43.0	50.954	8.710
Height of D2	..	29.0	11.0	15.464	5.950
Base of D2	..	12.0	5.6	7.867	1.516
Snout to anal	..	81.3	47.7	57.367	9.626
Height of anal	..	40.3	10.7	16.918	8.107
Caudal fork	..	50.0	26.0	32.446	7.717
Snout to pelvic	..	43.0	25.3	30.582	4.882
Length of pelvic	..	15.2	8.8	10.692	1.886
Girth	..	37.2	20.0	24.508	4.676

TABLE 3. *Regression of different morphometric characters on the fork length of* T. albacares (N. 29)

Characters		*a*-value	*b*-value
Total length	..	24.276	0.858
Standard length	..	7.987	0.852
Snout to Eye	..	2.344	0.075
Eye diameter	..	2.558	0.011
Snout to D1	..	8.329	0.211
Snout to Pectoral	..	7.756	0.208
Height of Pectoral	..	10.761	0.147
Base of Pectoral	..	0.872	0.059
Height of D1	..	0.396	0.115
Snout to D2	..	10.679	0.422
Height of D2	..	—12.600	0.302
Base of D2	..	1.457	0.067
Snout to Anal	..	12.760	0.468
Height of Anal	..	—19.982	0.387
Caudal fork	..	—2.760	0.369
Snout to Pelvic	..	6.033	0.252
Length of Pelvic	..	2.179	0.089
Girth	..	3.240	0.223

TABLE 4. *Correlation matrix of various morphometric characters of* T. albacares

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
1. Total length	..																		
2. Fork length	..	+																	
3. Standard length	..	+	+																
4. Snout to eye	..	+	+	+															
5. Eye diameter	..	0	0	0	0														
6. Snout to D1	..	+	+	+	+	0													
7. Snout to pectoral	..	+	+	+	+	0	+												
8. Height of pectoral	..	+	+	+	+	0	+	+											
9. Base of pectoral	..	+	+	+	+	0	+	+	+										
10. Height of D1	..	+	+	+	+	0	+	+	+	+									
11. Snout to D2	..	+	+	+	+	0	+	+	+	+	+								
12. Height of D2	..	+	+	+	+	0	+	+	a	a	a	+							
13. Base of D2	..	+	+	+	+	0	+	+	a	+	a	+	a						
14. Snout to anal	..	+	+	+	+	0	+	+	+	+	+	+	+	+					
15. Height of anal	..	+	+	+	+	0	+	+	+	+	+	+	+	a	+				
16. Caudal fork	..	+	+	+	+	0	+	+	+	+	+	+	+	+	+	+			
17. Snout to pelvic	..	+	+	+	+	0	+	+	+	+	+	+	+	+	+	+	+		
18. Length of pelvic	..	+	+	+	+	0	+	+	+	+	+	+	+	+	+	+	+	+	
19. Girth	..	+	+	+	+	0	+	+	+	+	+	+	+	+	+	+	+	+	+

(Ranges of Correlation coefficients : 0=0.200-0.300 : 'a' = 0.800-0.899 : '+' = 0.900-0.999) that the yellowfin tuna caught by pole-and-line fishery around Sri Lanka ranged from 20 to 145 cm (?) and from the Maldive area 20.5 to 56.5 cm. Joseph (1985) reported on the yellowfin tuna taken by the drift gillnet fishery around Sri Lanka in the size range 28-94 cm.

In the longline catches from the oceanic waters around India, the size of yellowfin tuna was observed to range from 50-170 cm (Fig. 1) indicating that the longline caught tunas are larger when compared to those taken by surface gears. Two distinct modes are discernible at 80 cm and at 120 cm fork length respectively.

The length-weight relationship collected from 210 specimens of yellowfin tuna taken by longline gear from the oceanic waters around India during the period 1982-1984 indicates that the relationship can be expressed by the regression :

$$W = 0.0001036\, L^{2.66410684}$$

However, in the live-bait pole-and-line fishery at Minicoy, Madan Mohan and Kunhikoya (MS) observed the length-weight relationship of yellowfin tuna (young ones) as follows :

Males	: Log W = —10.751095 + 2.961902 LogL
Females	: Log W = —11.137845 + 3.010763 LogL
Pooled	: Log W = —11.036032 + 3.001012 LogL

Food of yellowfin tuna

Observations on the food of yellowfin tuna (males and females) taken by the longline fishery from the oceanic waters in November 1984 indicate that the pelagic crab (*Charybdis edwardsii*) was met with frequently in the food items of this species. The percentage composition of different food items (by volume) of the yellowfin tuna observed was as follows :

Items		Percentage composition
Teleosts		
Barracuda	..	2.60
Decapterus spp.	..	2.30
Priacanthus spp.	..	1.30
Puffer fish	..	0.40
Small tunas	..	14.10
Teleosts parts	..	18.70
Others	..	0.04
Crustaceans		
Crabs (*Charybdis edwardsii*)		58.50
Cephalopods		
Squids	..	2.10

Details regarding the size, stage of maturity, condition of the stomach and the food items of yellowfin tunas examined, and the number and volume of the food items are presented in Table 5.

The UNDP/FAO Pelagic Fishery Project (IND/593) reporting on their survey results for 1972/73 (*Progress Report No 6:* Survey results 1972/73, IND 69/593, 141 pp. 1974) indicate the abundant occurrence of *Spratelloides japonicus* (*Anchoviella japonicus*) on the Angria Bank at 16° 30′ - 16° 40′ N "in August when they occurred in spawn ng aggrega ions ". The size range was 25 to 80 mm and all fisa are said to have "fully developed gonads and appeared to be spawning in this area at this time". Besides this species, the project survey found another excellent tuna bait fish, *Caesio* sp. on the San Pedro Bank further south. This is also indicative of the greater abundance of tunas along this belt. The recent results of the Fishery Survey of India (FSI) and the Central Institute of Fisheries Nautical and Engineering Training (CIFNET) longliner's catch of yellowfin tuna in good quantities along the Angria Bank and San Pedro Bank are highly significant. Heavy concentration of puffer fishes, another forage species for the yellowfin tuna has also been noticed during the October, Jan February period in this area. In Fig. 2 the distribution and abundance of yellowfin tuna seen from longline catches of the FSI and CIFNET Fishery Vessels is indicated to show the areas of very high hook rates around the San Pedro Bank.

No attempt has hitherto been made to investigate the age and growth parameters of yellowfin tuna taken by the longline fishery from the oceanic waters of India. However, based on the data collected from the *live-bait pole-and-line fishery* at Minicoy and Sri Lanka the following estimates are available :

Source		L∞	Z	M	E
Present study	..	145	3.168	0.49	0.85
Sivasubramaniam (1985)	..	174	2.680	0.70	0.74

As opined by Silas and Pillai (1982), the development of surface fishery in the Indian Ocean may potentially increase the total production of yellowfin tuna from this area although it may reduce the abundance of this species in the longline catches. This trend needs close monitoring.

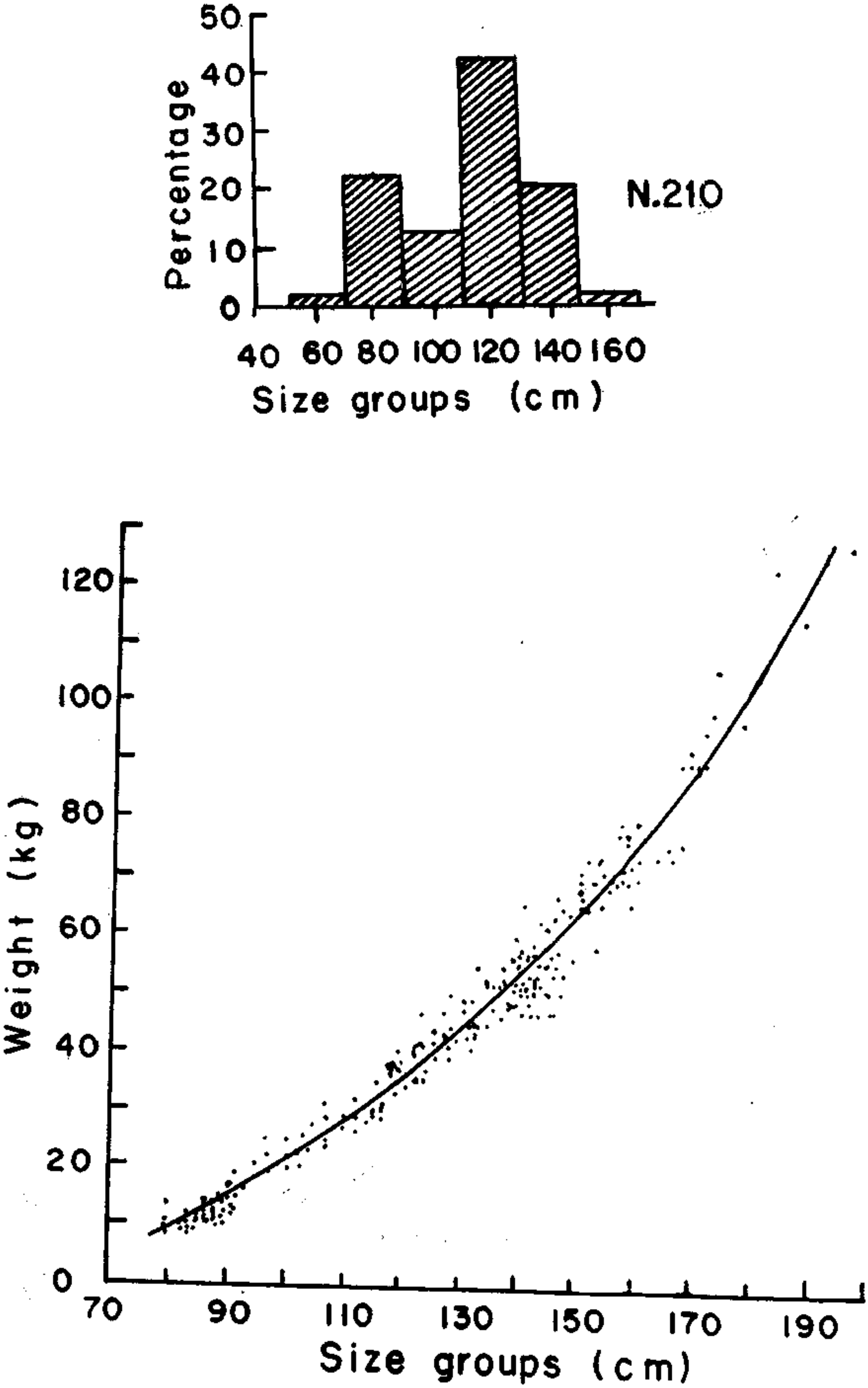

Fig. 1. Length frequency distribution (percentage) (upper) and length-weight relationship of *T. albacares* (lower) taken by longline fishery from the oceanic waters of the Indian Seas.

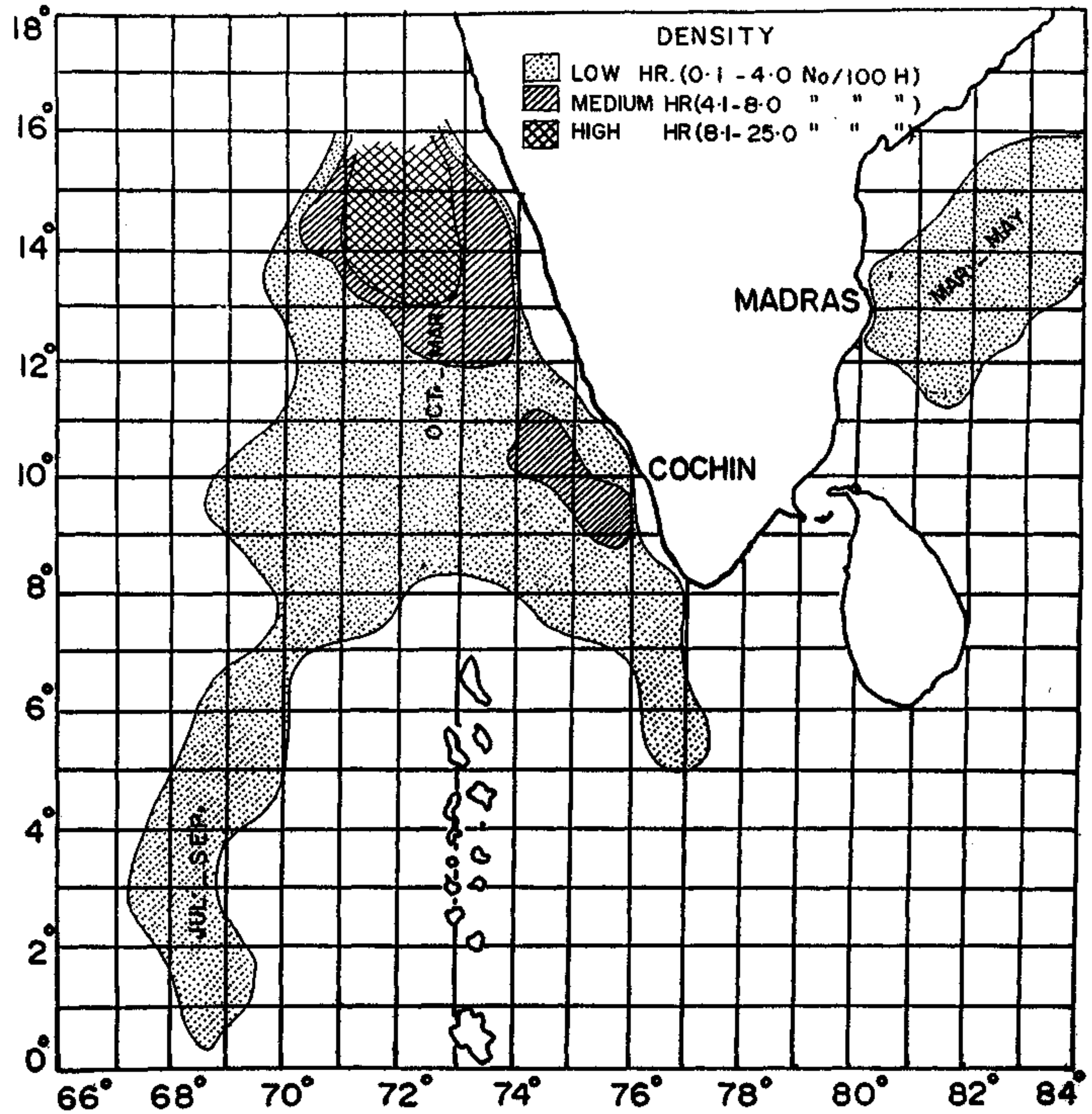

Fig. 2. Distribution and abundance of yellowfin tuna (*Thunnus albacares*) taken by longline fishery by CIFNET and FSI during the period 1981-85 (Courtesy : K. V. N. Rao and P. P. Pillai).

TABLE 5. *Food items of* T. albacares *in the tuna longline fishery* (November 1984)

Fork length (cm) (1)	Sex and stages of maturity (2)	Fullness of stomach (3)	Food items (4)	No. (5)	Volume (ml) (6)
			MALES		
78	M III	1/8	Teleost remains	..	50.00
78	M II	TR	Squids	3	8.00
82	M II	TR	Squids	1	3.00
82	M III	EM	..	..	..
86	M III	EM	..	..	..
78	M IV	EM	..	..	..
79	M IV	TR	Teleost parts	..	2.00
82	M IV	EM	..	..	..
83	M IV	1/8	Crabs	3	45.00
83	M IV	EM	..	..	..
84	M IV	TR	*Decapterus* sp. (digested)	1	30.00
86	M IV	EM	..	..	..
86	M IV	TR	Teleost parts	..	3.00
88	M IV	TR	Semidigested crabs and squids (parts)	..	5.00
89	M IV	TR	Teleost parts	..	15.00
89	M IV	TR	Teleost parts	..	12.00
89	M IV	TR	Squids	3	10.00
91	M IV	1/8	Semidigested teleosts	..	55.00
91	M IV	TR	Teleost parts and squids	..	4.00
94	M IV	EM	..	..	..
115	M IV	1/4	Crabs	11	200.00
115	M IV	TR	Crabs and teleost parts	..	..
117	M IV	EM	..	..	..
91	M V	EM	..	..	..
93	M V	1/4	Semidigested tuna	1	100.00
133	M V	1/2	Semidigested tuna	1	500.00
136	M V	TR	Crab	1	25.00
137	M V	EM	..	..	17.00
139	M V	EM	..	..	..
140	M V	1/4	Barracuda (Semidigested)	2	200.00
140	M V	1/8	Semidigested fish	..	15.000
140	M V	1/8	Crabs	5	80.00
141	M V	1/4	Crabs	21	300.00
141	M V	3/4	Crabs	46	750.00
141	M V	3/4	Crabs	41	600.00
			Squids and teleost parts	..	11.00
141	M Spent	1/2	Crabs	22	400.00
142	M V	1/8	Crabs	5	180.00
147	M V	1/2	Crabs	16	320.00
			Squids and teleost parts	..	12.00
149	M Spent	1/8	Crabs	7	100.00

(1)	(2)	(3)	(4)	(5)	(6)
			FEMALES		
68	F III	1/4	Squids	3	50.00
79	F III	EM	..	..	..
82	F IV	EM	..	..	..
84	F IV	1/8	Pufferfish	1	28.00
84	F IV	TR	Squids	4	18.00
85	F IV	EM	..	..	..
85	F III	EM	..	..	..
86	F IV	TR	Squids and teleost parts	..	4.00
86	F IV	EM	..	..	..
86	F IV	TR	Squids and teleost parts	..	4.00
86	F IV	TR	Teleost parts	..	3.00
87	F III	TR	Small squids	3	10.00
87	F IV	EM	..	..	..
87	F IV	TR	Semidigested crabs	..	10.00
87	F IV	EM	..	..	..
88	F IV	TR	Teleost parts	..	20.00
88	F III	TR	Teleost parts	..	3.00
89	F IV	TR	Teleost parts	..	25.00
89	F IV	TR	Teleost parts	..	2.00
89	F IV	TR	Semidigested squids	..	5.00
89	F IV	EM	..	..	..
90	F IV	EM	..	..	..
91	F IV	1/8	*Decapterus* sp. (semidigested)	1	95.00
107	F Spent	EM	..	..	..
112	F Spent	1/2	Semidigested teleosts	3	400.00
117	F Spent	1/2	Semidigested small tuna	1	300.00
118	F Spent	1/2	Crabs	11	
			Squids and small tunas		408.00
123	F IV	Crabs		4+2	70.00
		1/8	Squids and teleost parts		10.00
128	F IV	1/2	Semidigested teleost	1	350.00
132	F IV	Full	Squids	2	900.00
			Priacanthus sp.	1	100.00

(EM—empty., TR—trace)

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OBSERVATIONS ON TUNA FISHERY AT RATNAGIRI-MALWAN AREA, NORTH-WEST COAST OF INDIA

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Ratnagiri and Malwan, on the coast of Maharashtra State, support a good tuna fishery which is of considerable importance to the local fishermen. Except for the preliminary note by Ranade (1961), no scientific information is available on the tuna fishery of this coast. With a view to enhance our knowledge on the fishery and biology of tunas from this area, a survey was conducted by the Central Marine Fishereis Research Institute during September to December, 1979. The present account deals with the relevant information collected during the period of survey and thereafter.

FISHERY

The tuna landings of this area for the years 1979-1982 are shown in Fig. 1. During 1979, peak catch was recorded in August, in 1980 it was in October. In 1981 distinct peak in landings was noted during November and in 1982 it was in October. It is evident from the trend of landings that in this area tuna fishery commences from August and peak landings are recorded during the September-November period.

The main gear employed in this area is the drift gill net ('Kedar Jal'). Nets of different mesh sizes are employed in the tuna fishery such as 'Parse' (13 cm mesh size), 'Kandali Jal' (11.5 cm mesh size) and 'Vagri Jal' (9 cm mesh size). The size of the net varies from 120-180 m and depth from 2.5 to 3.0 m. During operation, different units are plied together and proper floats and sinkers are attached. Out-trigger canoes of 4.8 m and mechanised boats of 7.8 to 8.5 m are employed in the drift gillnet fishery in this area.

In the Ratnagiri area, the major drift gillnet landing centres are Vijayadurgh, Golap, Mirkirwada, Rajwada and Kurla towards the south of Ratnagiri and Kalbadevi, Jaigod, Kudli Budhul, Asgoli and Dhabol towards the north. In the Malwan area, the major landing centres for the drift gillnet fishery are Dendi, Tarkali, Ijmailkudin Kochra, Navabhag, Mooth and Kervada in the southern part and Hirle, Appey, Mithnumbri and Devagad in the northern part. It was observed that most of the fishes landed are marketed fresh and a part is sundried and transported to internal markets.

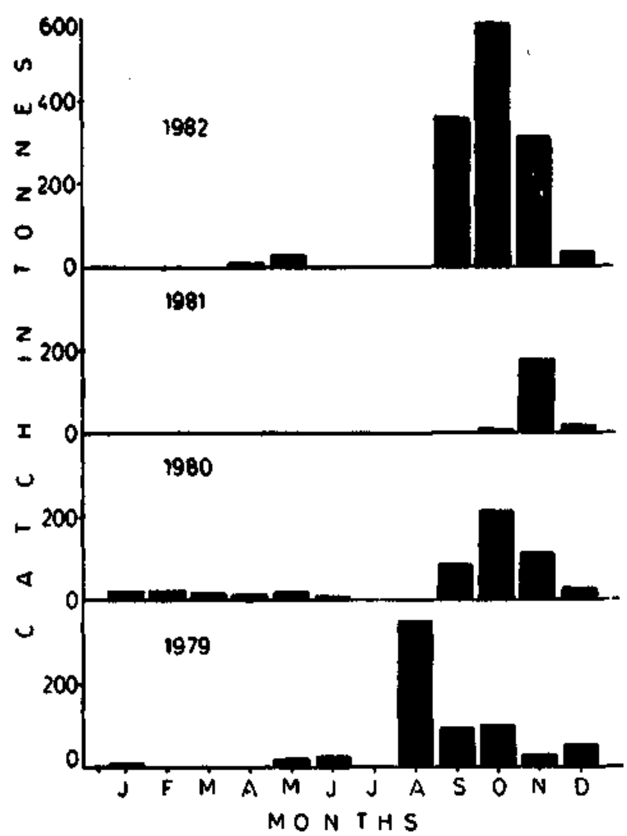

Fig. 1. Tuna landings in the Ratnagiri-Malwan Area, 1979-'82.

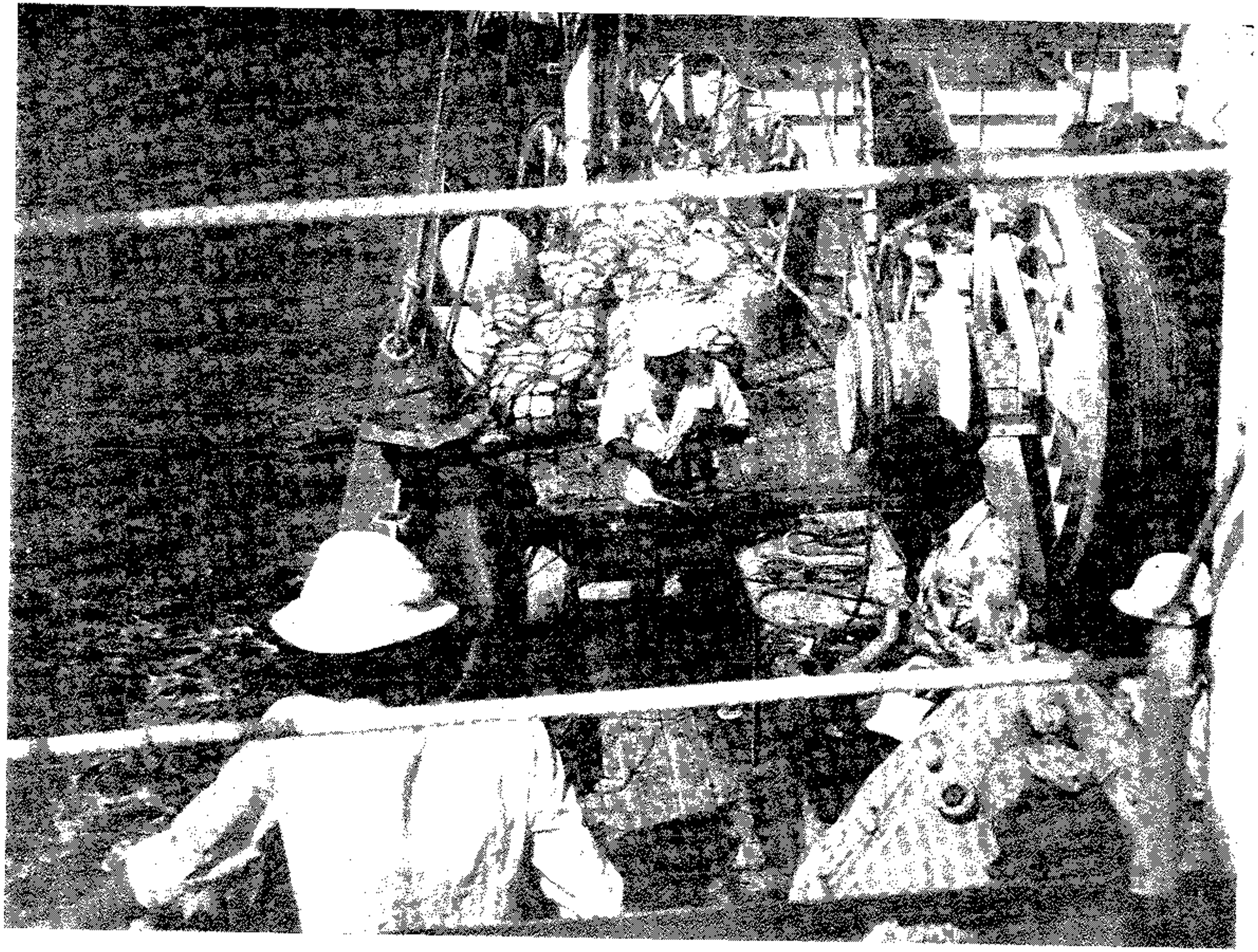

PLATE 1. Tuna longline being hauled in on board M.V *Prashikshani*, the longline vessel of CIFNET, Cochin.

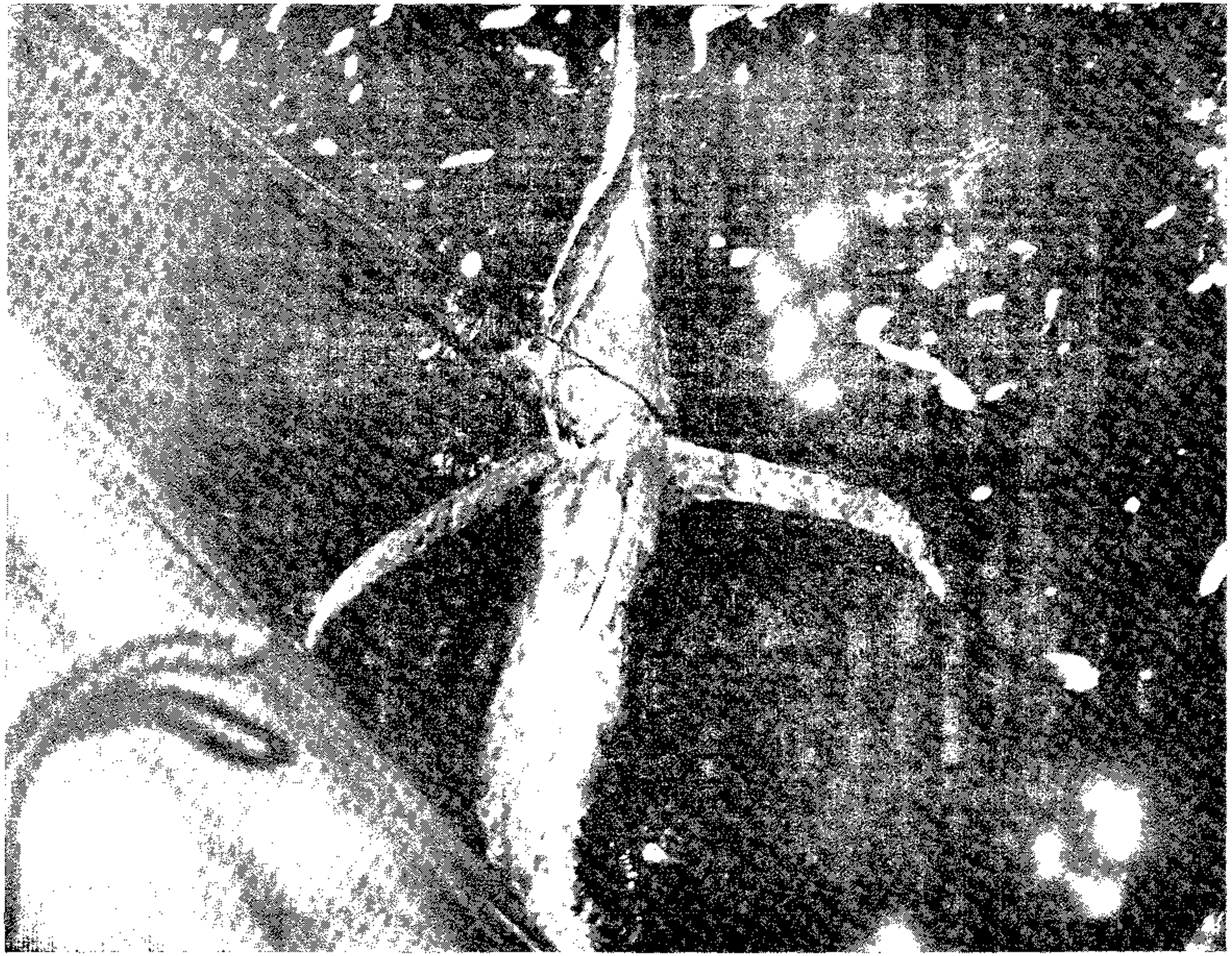

PLATE II. Longline caught marlin being harpooned prior to taking on board M·V *Prashikshani*.

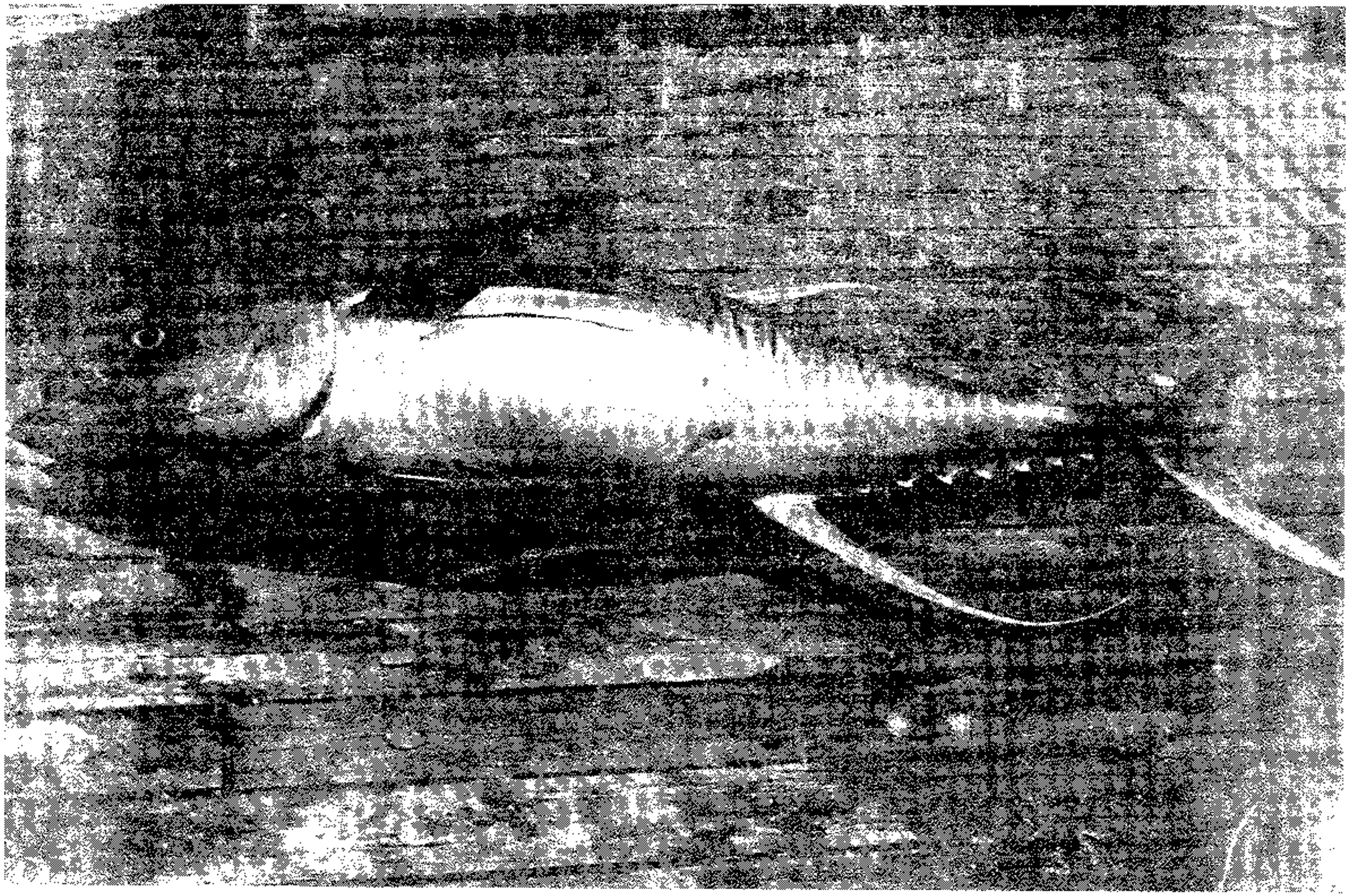

PLATE III. Yellowfin tuna, *Thunnus albacares* taken by longline.

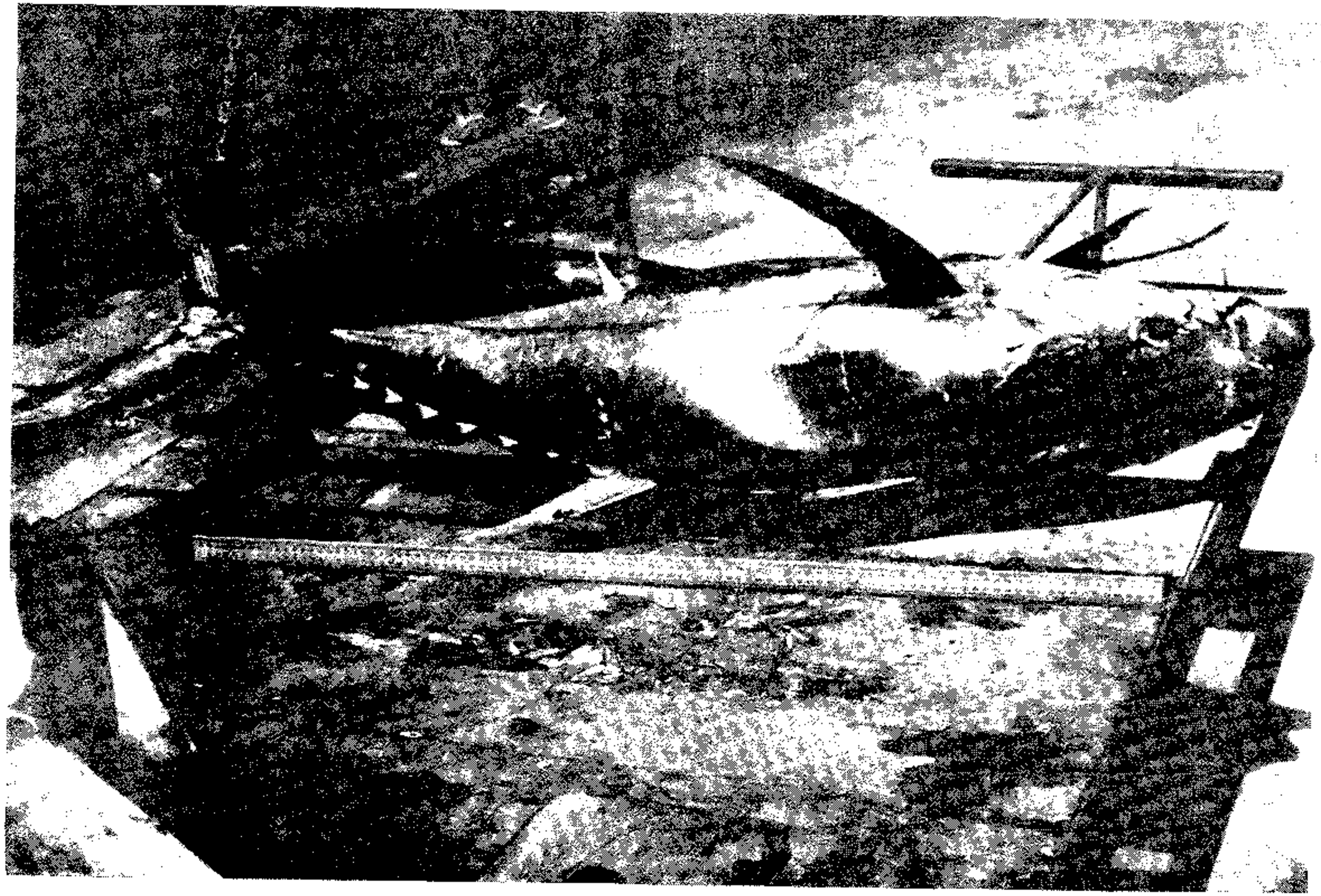

PLATE IV. Yellowfin tuna, *Thunnus albacares* taken by longline, another view.

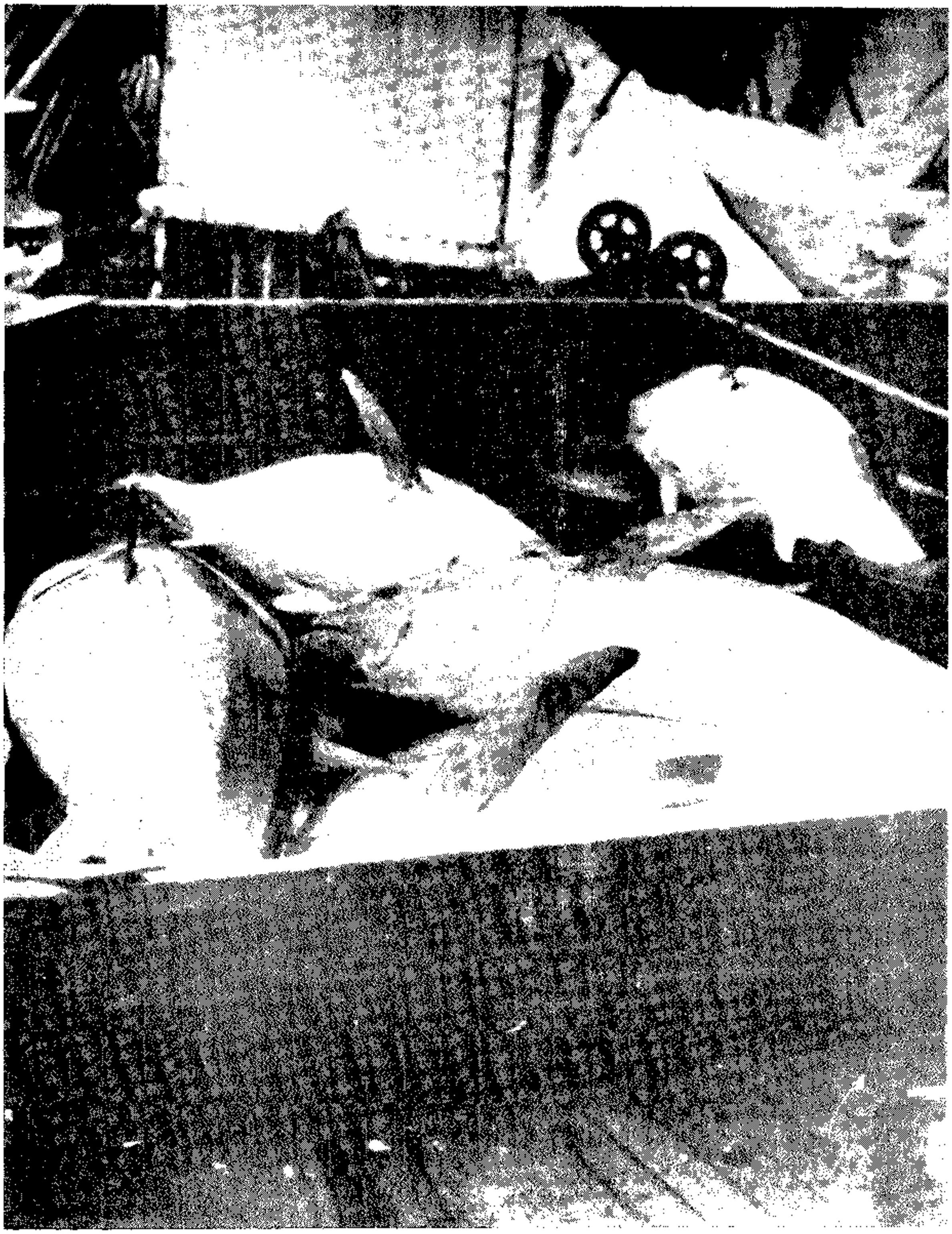

PLATE V. Yellowfin tuna catch on board M/V *Prashikshani*.

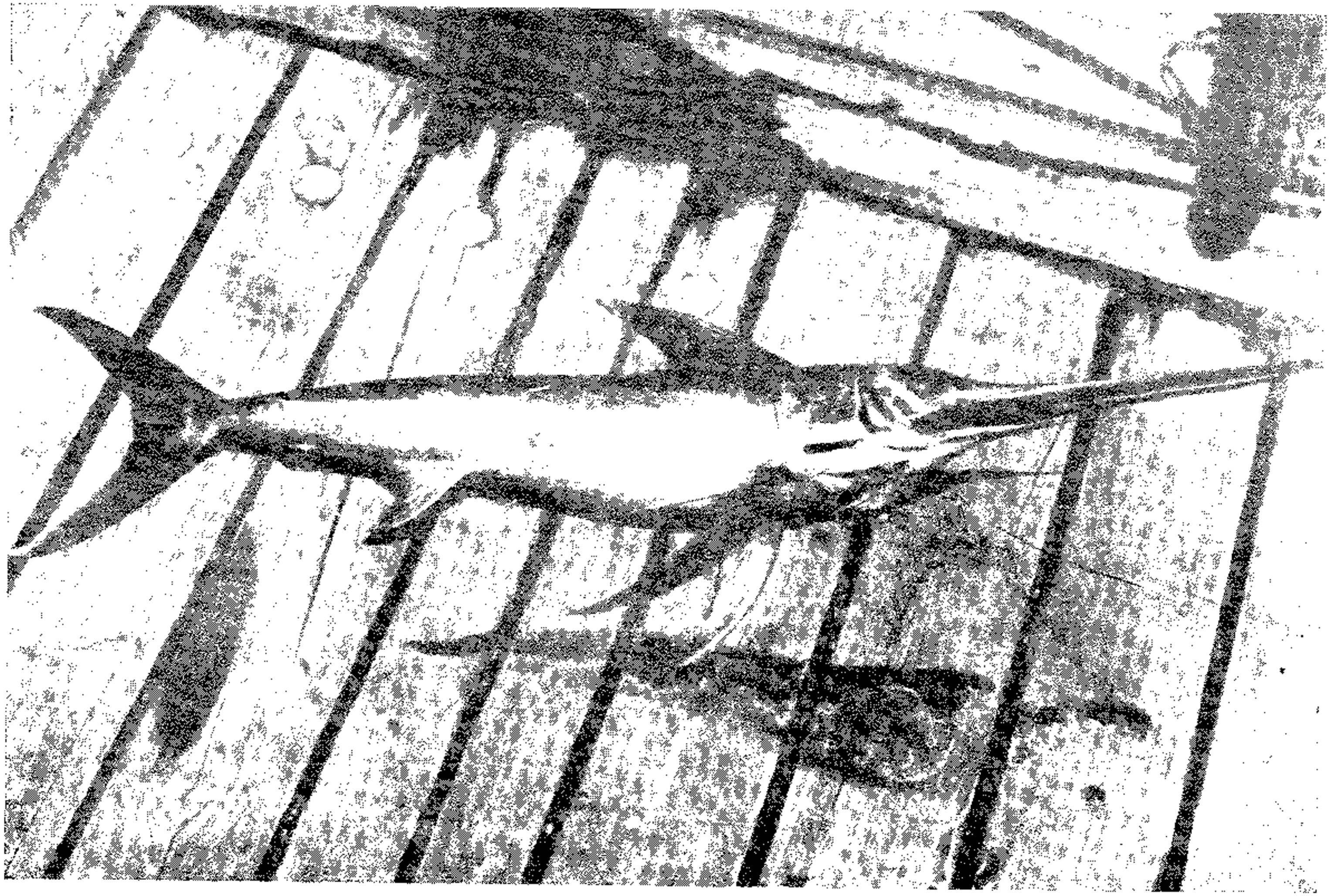

PLATE VI. Young swordfish, *Xiphias gladius* taken by longline.

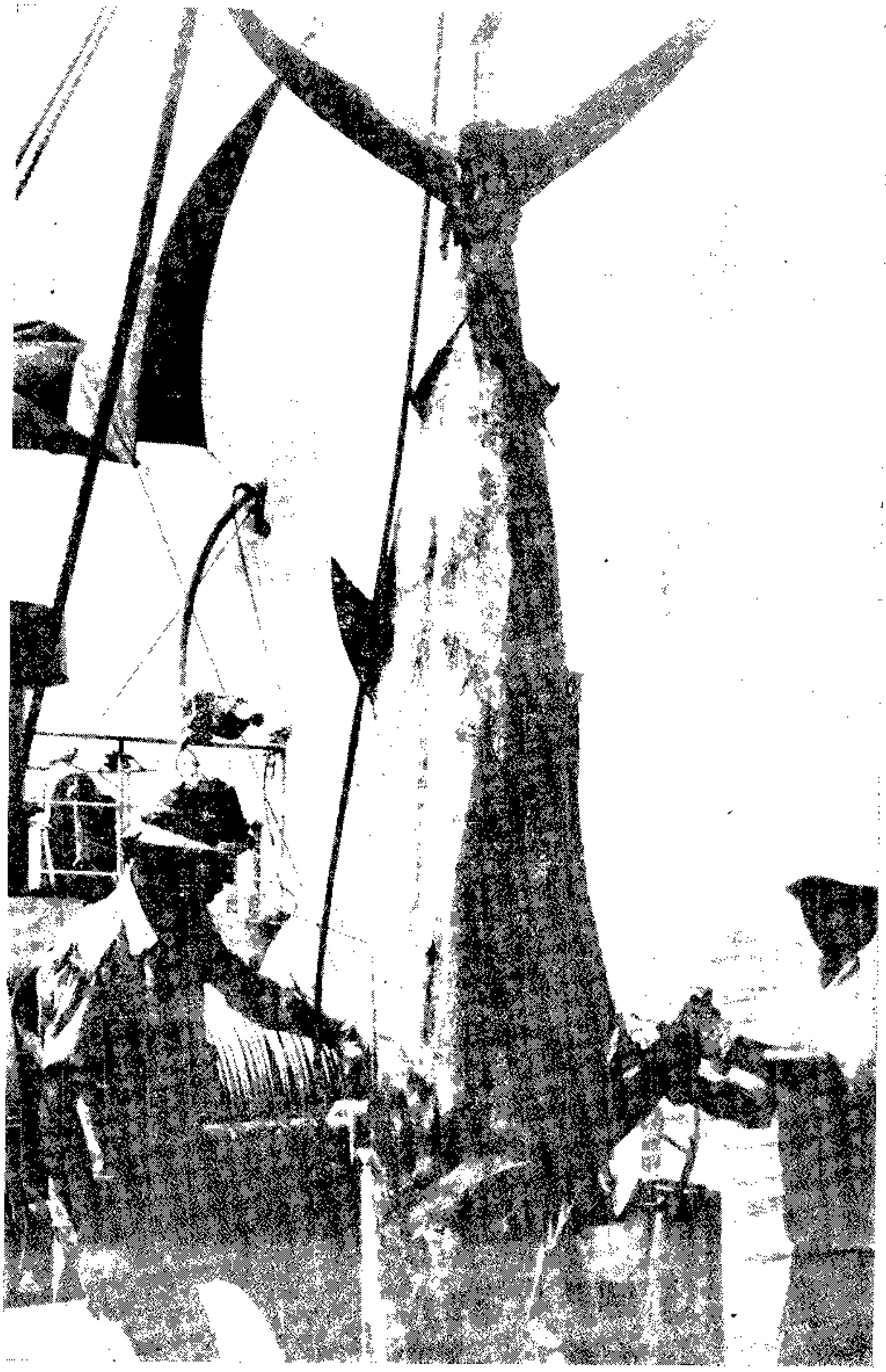

PLATE VII. Striped marlin, *Tetrapturus audax* on board M/V *Prashikshani*.

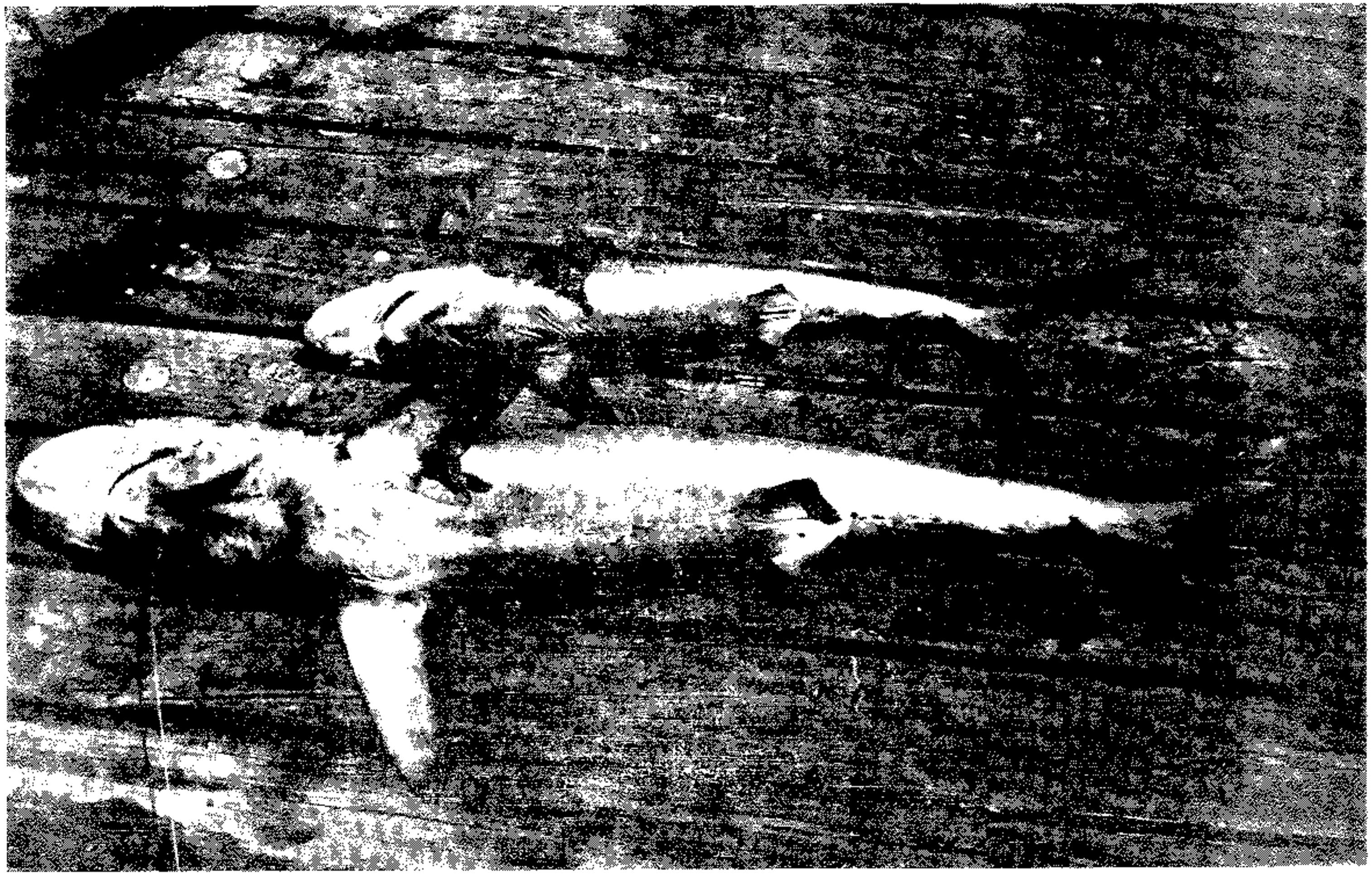

PLATE VIII. Black tip shark, *Carcharinus melanoptera* on board M/V *Prashikshani*.

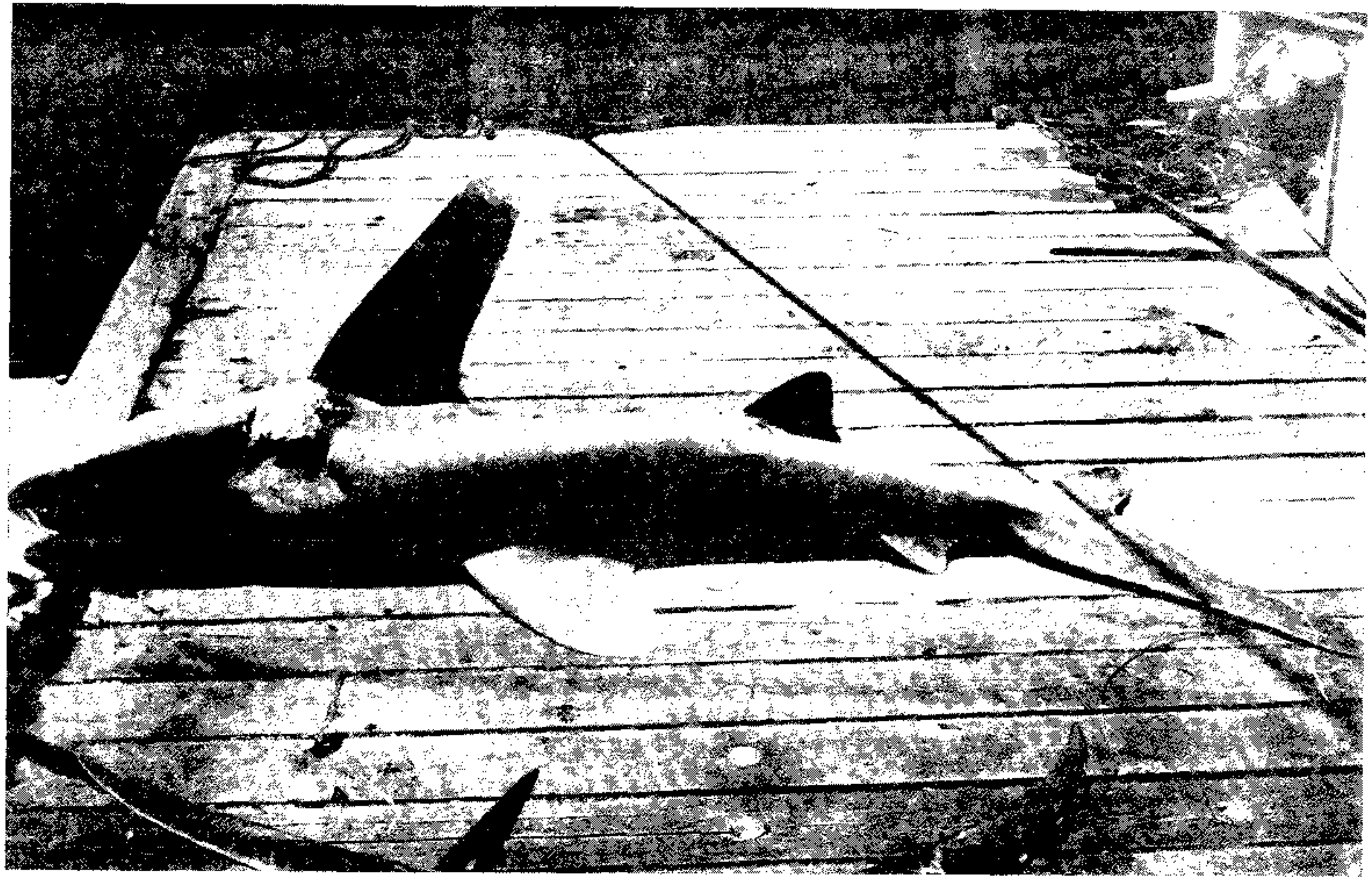

PLATE IX. White tip shark, *Carcharinus longimanus* on board M·V *Prashikshani*.

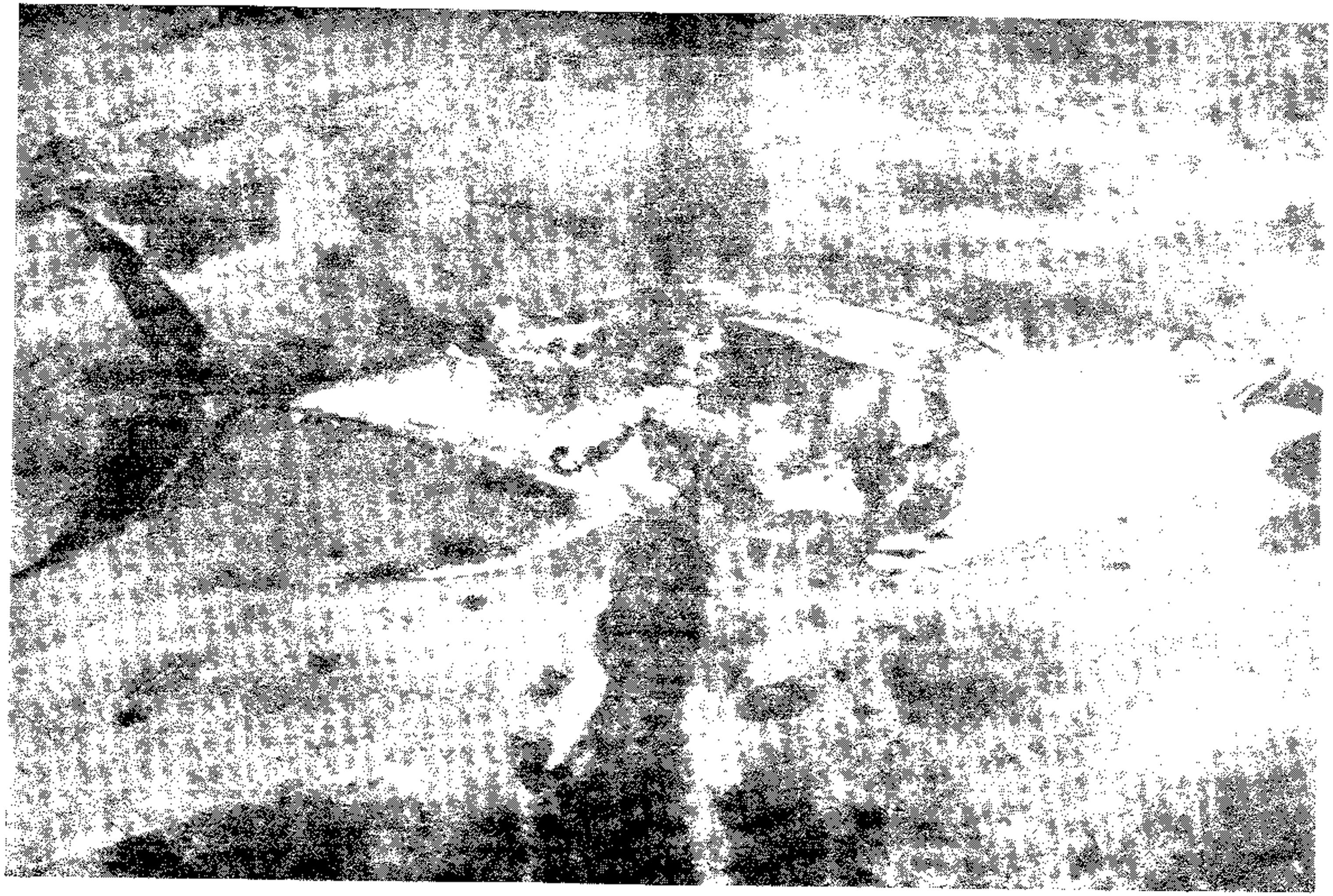

Plate X. Shark-eaten yellowfin tuna, *Thunnus albacares* on board M.V *Prashikshani*.

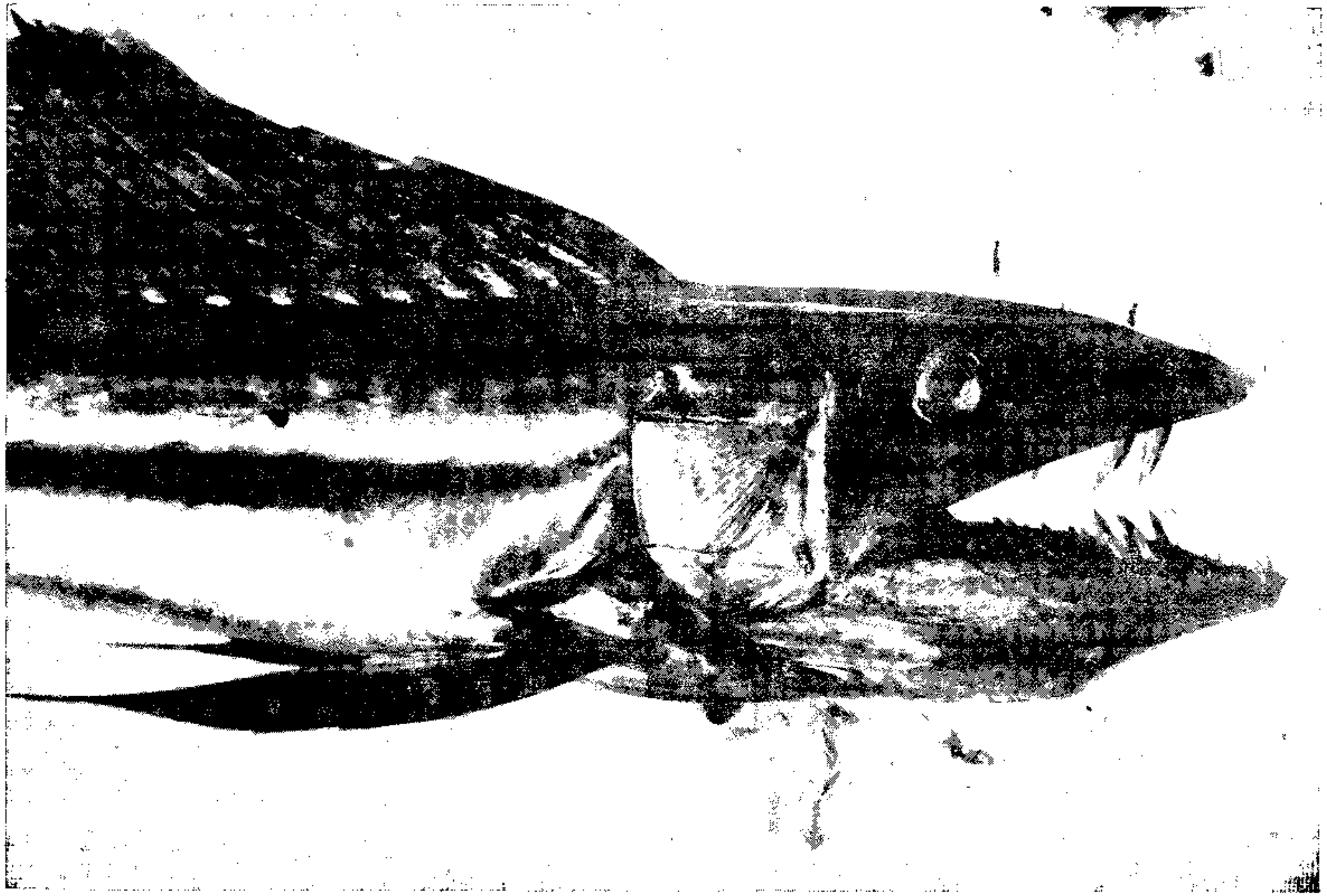

PLATE XI. Head of lancet fish, *Alepisaurus ferox* taken by longline. (*Photos* by *P. P. Pillai*).

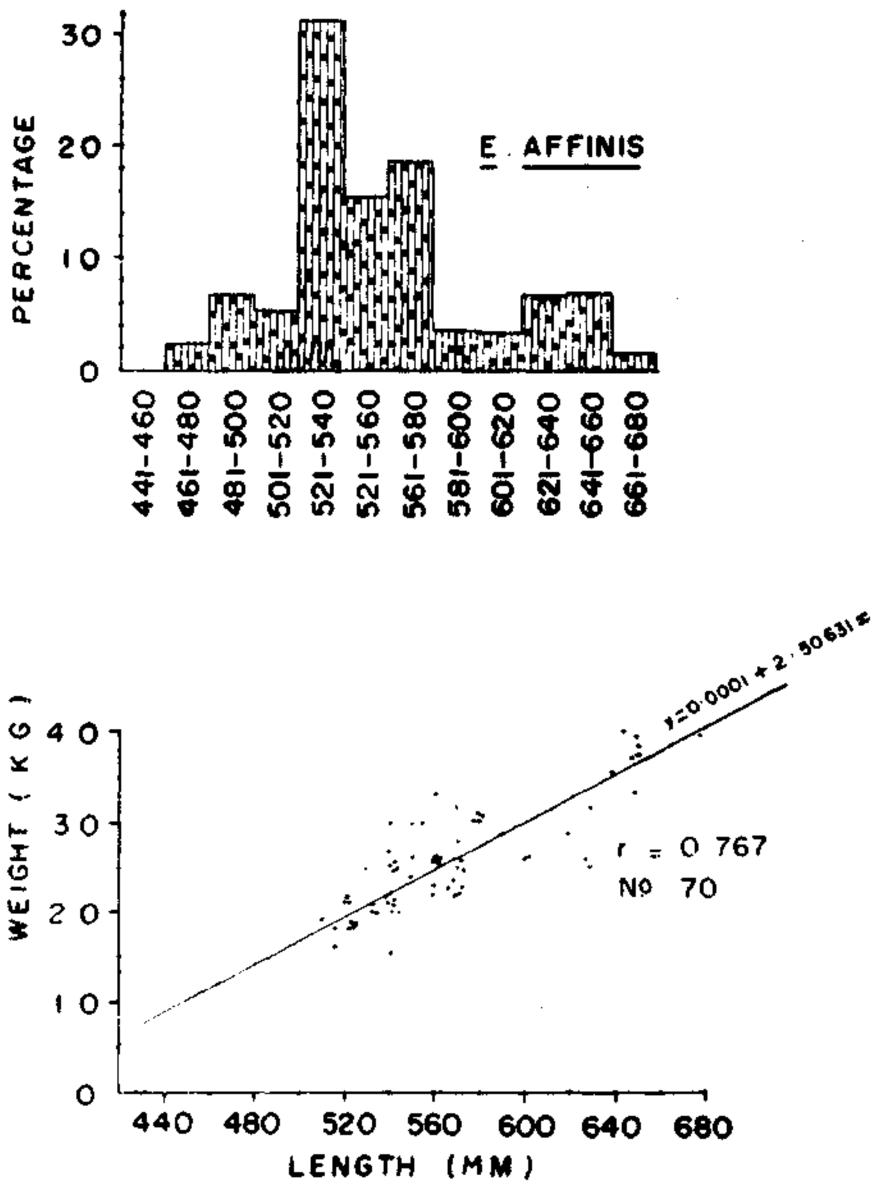

Fig. 2. Length frequency distribution (percentage) and length-weight relationship of *E. affinis* at Ratnagiri-Malwan Area.

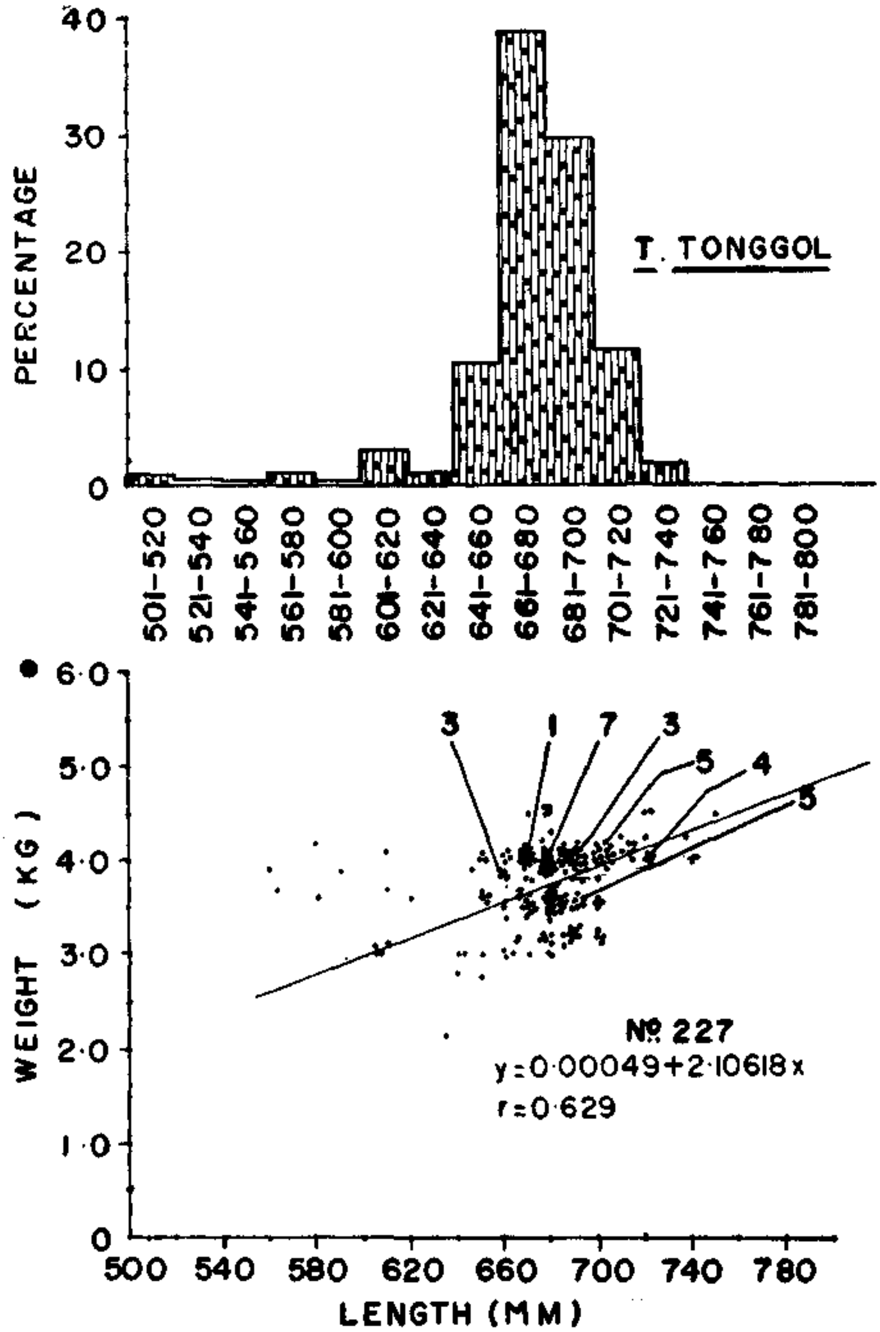

Fig. 3. Length frequency distribution (percentage) and length-weight relationship of *T. tonggol* at Ratnagiri-Malwan Area.

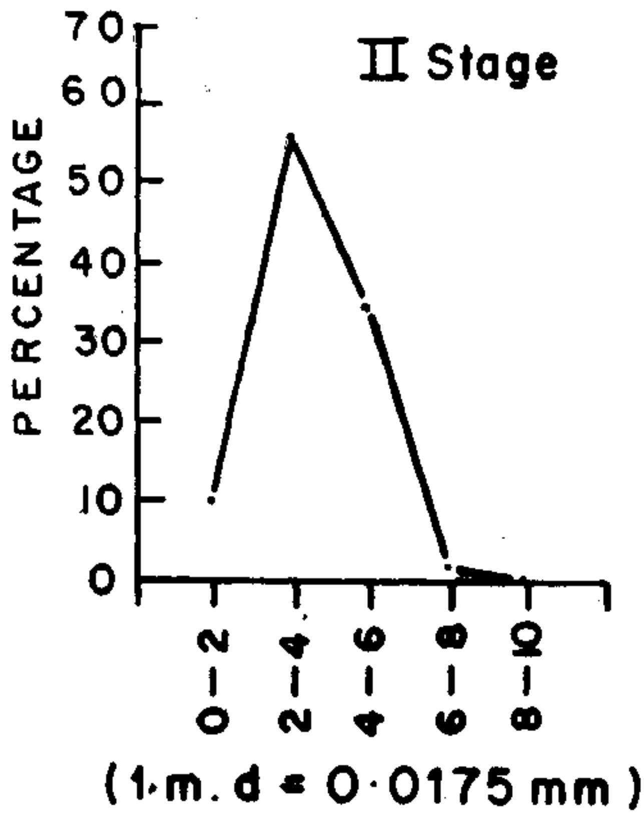

Fig. 4. Ova diameter frequency polygon of *T. tonggol* at Ratnagiri.

According to Ranade (1961) *Euthynnus affinis* and *Thunnus tonggol* form more than nine-tenth of the total catch of tunas landed at Ratnagiri. A study of the composition of species landed in this area indicates that the longtail tuna (*Thunnus tonggol* ; 'Khavalya Gadar') constitute more than 60 per cent of the total tuna landings followed by the little tuna (*Euthynnus affinis* ; 'Bibya Gadar') and frigate tuna (*Auxis thazard* ; 'Gedari'). Occasionally young yellowfin tuna (*Thunnus albacares* ; 'Peemp') are also taken by the drift gillnets.

BIOLOGY

During the period of observation, the main species landed were *T. tonggol* and *E. affinis*. The length distribution and length-weight relationship of 70 specimens of *E. affinis* and 227 specimens of *T. tonggol* were studied. Gill rakers of 33 specimens of *T. tonggol* collected from Ratnagiri have been examined for gill raker counts and ovaries from 36 females collected and ova diameter measured for estimating maturity stages.

E. affinis occurred in the size range 46-68 cm with a major mode at 54 cm. Another mode was also discernible at 57 cm (Fig. 2). The length-weight relationship of 70 specimens observed was (Fig. 2):

$y = 0.001 + 2.50631\,x$, and the 'r' value was 0.767.

Thunnus tonggol occurred in the size range 51-74 cm and a single mode was observed at 68 cm size (Fig. 3). The length-weight relationship of 227 specimens (Fig. 3) observed was:

$y = 0.00049 + 2.10618\,x$, and the 'r' value was 0.669.

The gillraker counts (33 samples) indicate that it was 7 or 8 in the upper limb and 17 or 18 in the lower limb. Silas (1967) has statistically examined the differences of the gill raker counts of *T. tonggol* from the Australian Coast and Gulf of Mannar and stated the possibility of the existence of distinct races of *T. tonggol* in this area. A comparison of gill raker counts presented by Serventy (1956) from Australian coasts, Silas (1967) and Ranade (1961) with the present observation indicate that there is distinct variation between the populations of *T. tonggol* from the Australian and Indian coasts (Table 1).

TABLE 1. *Comparison of gill-raker counts between samples of* T. tonggol *from the Australian coasts, Gulf of Mannar and Ratnagiri coast*

Author	Locality	Range and mean in gill raker counts (Upper)	(Lower)
Serventy (1956)	Northern Australia	5-8 (6.1)	13-18 (15.74)
Serventy (1956)	Western Australia	5-8 (6.39)	14-18 (16.04)
Silas (1967)	Gulf of Mannar	6-7 (7.03)	16-19 (17.95)
Ranade (1961)	Ratnagiri coast	8	18
Present study	Ratnagiri coast	7-8 (7.21)	17-18 (17.44)

This is indicative of genetic difference and the possible existance of subpopulations of *T. tonggol* This aspect needs further elucidation.

36 ovaries collected from the females of the length range 63-74 cm size were examined for ova diameter measurements. The major peak in size of the ova was at 0.035-0.070 mm indicating that all the specimens were in the stage II of maturity according to the definition of the stages of maturity by the ICES scale (Fig. 4).

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OBSERVATION ON THE TUNA SHOALS ASSOCIATED WITH FLOTSAM IN THE OFFSHORE WATERS OF MINICOY ISLAND DURING 1982-83 SEASON

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The association of fishes with floating objects has been exploited by a number of fisheries. Tunas have long been known to aggregate around floating objects such as logs, masses of drifting seaweed, debris and other flotsam. Japanese pole-and-line fisheries and American purse seine and live-bait fisheries take advantage of the association of yellowfin tuna (*Thunnus albacares*) and oceanic skipjack (*Katsuwonus pelamis*) with logs and other flotsam (Uda 1983 ; Mc Neely 1961 ; Kimura 1954 and Inoue *et al.* 1963, 1968). The catch per set of yellowfin and other tunas in association with flotsam by purse seiners has increased in recent years.

This paper provides preliminary information on the catch pattern, ecology and behaviour of tuna species associated with floating objects in the waters around Minicoy during 1982-83 tuna fishing season.

These studies are based on data collected during 1982-83 tuna fishing season only for those fishing boats who fished on tuna shoals associated with flotsam. Distance and direction from Minicoy of flotsams and species and quantity of bait fishes used were recorded by enquiry with fishermen engaged in tuna fishing. Flotsam objects were physically examined by the author. Fork length of skipjack and yellowfin, their stomach condition, sex and maturity stages were recorded whenever it was possible.

CHARACTERISTICS AND DISTRIBUTION OF FLOTSAM OBJECTS

On most of the occasions, flotsam objects were wooden material drifting with sea currents towards Minicoy. Other objects which were associated along with tuna shoals were nylon nets, rubber pieces, nylon ropes and plastic pieces. Maximum flotsam were observed from October to December 1982 and April-May 1982. During February and March flotsam could not be observed around Minicoy waters. Distance of sightings from Minicoy varied from 2 km to 7 km and flotsam were observed in almost all the direction from the Island.

Most of the flotsam had some attached algal material and very rarely a few ascidians. Fishermen informed the author that very few small fishes were found around flotsam. When tuna fishing commenced around flotsam, these small fishes disappeared from sight. This may be the reason that tuna responded to bait fishes whenever it was thrown from the fishing boat.

BAIT FISHES USED

Chromis spp. were the main species followed by *Spratelloides delicatulus* used to attract tuna from floating objects to tuna fishing boats. Out of 75 fishing boats observed during these studies the amount of bait could be recorded only for 28 boats which used 57.5 kg of bait fishes.

Monthwise amount of bait fishes used, catches from around flotsam and catch per unit of bait are given in Table 1. The maximum CPUB was recorded during October and lowest in December.

Always more than one fishing boat approached a floating object. The first boat used bait to chum tuna and on most of the occasions it was not necessary for other boats to throw bait since tuna shoals were already feeding on bait thrown by the first boat.

TUNA CATCHES

Totally 26 nos. of flotsam were observed from November 1982 to May 1983. 75 tuna fishing boats approached

TABLE 1. *Amount of bait used and fish catch from flotsam objects*

Month		No. of Units operated	Bait used In kg.	Fish catch In kg.	Catch per unit of bait In kg.
September	..	3	14	2201.5	157.25
October	..	8	14	5706.1	407.57
November	..	11	11.5	4264.5	370.83
December	..	2	9	932.5	103.61
May	..	4	9	2776	308.44
Total for the season		28	57.5	15880.6	276.18

these shoals and caught 40,886.1 kg of fishes around them. The maximum catch was recorded from six flotsam during October when 14 fishing boats could catch 13,371.6 kg of fishes. This was followed in April when 17 boats fished 7,960.5 kg of fishes from around five flotsam and in November when 19 boats caught 7,121.5 kg of fishes from around 8 flotsams.

Specieswise, yellowfin (*Thunnus albacares*) dominated the catches and accounted for 18,875.5 kg (46.17%) of the total catches. It was followed by skipjack (*Katsuwonus pelamis*) 11,106.3 kg (27.16%), sharks 7,558 kg (18.48%), *Elagatis bipinnulatus* 2,677.8 kg (6.56%), *Coryphaena* 376.5 kg (0.93%), *Acanthocybium* 210 kg (0.52%), *Sphyraena* 10 kg (0.02%), *Euthynnus affinis* 15 kg (0.03%), *Auxis* 9 kg (0.02%), *Caranx* spp. 7.5 kg. (0.02%) and miscellaneous fishes 40.5 kg (0.09%) (Table 2).

On one occasion fishermen located a flotsam which was surrounded by sharks. When fishermen tried to catch them, they d spersed from the flotsam and did not return. Once a tuna shoal was located little away from the floating object. On some occasions biting by the tuna species was very poor and even with the help of bait fish they could not be chummed.

SEASONAL VARIATION IN OCCURRENCE OF DIFFERENT SPECIES

During the course of these investigations both the species of tunas i.e. *Katsuwonus pelamis* and *Thunnus albacares*, Sharks (*Carcharias* spp.) and *Elagatis bipinnulatus* were available from September to May. Other species such as *Caranx* spp., *Coryphaena* spp., *Auxis*, *Euthynnus affinis* and *Acanthocybium* were caught occasionally. The percentage occurrence of different species is given in Table 2 from which it can be seen that yellowfin dominated in flotsam catches during September to November and April, while skipjack dominated during December, January and May. Sharks supported the catches substantially during November, December and April. Catches of *Elagatis bipinnulates* were good during September, October and December.

Catch per unit effort ; Average catch per unit of effort for the season as a whole from flotsam associated catches was 908.58 kg. The maximum cpue as can be seen from Table-3 was recorded during October being 1593.05 kg which was followed during December 1,150.5 kg, September 1,040.33 kg, April 780.44 kg, May 722.83 kg, November 624.70 kg and lowest during January 507.67 kg.

It is interesting to note here that the average cpue from flotsam catches was about three times higher than the average cpue for pole-and-line catches during 1982-83 tuna fishing season. The main reason for the higher cpue for flotsam associated catches is, the availability of fishes in good numbers around these floating objects

TABLE 2. *Percentage contribution of different species of fish from flotsam associated catches*

Month		*Katsuwonus pelamis*	*Thunnus albacares*	Shark	*Elagates bipinnulatus*	*Acanthocybium* sp.	*Sphyraena* sp.	*Coryphaena* sp.	*Auxis* sp.	*Caranx* sp.	*Euthynnus affinis*	Misc.	Total in kg.
September	..	21.87	61.73	6.45	9.45							0.50	3,121
October		11.46	59.81	16.65	11.33	0.45		0.14				0.16	13,371.6
November	..	30.33	37.84	24.40	5.40	0.08	0.14	1.49	0.11		0.21		7,121.5
December	..	35.94	19.62	22.72	10.60	3.82		7.30					3,451.5
January	..	78.04	6.70	14.18	0.10	0.78			0.10			0.10	1,532
February	..	..	..	..	..	..	..	..	..	..	..	..	..
March	..	..	..	..	..	..	..	..	..	..	..	..	..
April	..	24.90	49.44	24.62	0.94					0.10			7,960.5
May	..	43.49	35.55	10.01	0.95								4,337
Total	..	11,106.3	18,875.5	7,558	2,677.8	210	10	376.5	9	7.5	15	40.5	40,886.1
Percentage	..	27.16	46.17	18.48	6.56	0.52	0.02	0.93	0.02	0.02	0.03	0.09	

TABLE 3. *Monthwise total effort, nos of flotsams, total fish catch and catch per unit of effort for flotsam associated fish landings during 1982-83 tuna fishing season*

Months	Effort	Flotsam nos.	Total fish catch In kg.	Catch per unit of effort in kg.
September ..	3	1	3121	1040.33
October ..	8.4	6	13371.6	1593.05
November ..	11.4	8	7121.5	624.70
December ..	3	1	3451.5	1150.5
January ..	3	2	1523	507.67
April ..	10.2	5	7960.5	780.44
May ..	6	3	4337	722.83

Catch per flotsam object ; As can be seen from Fig. 1 the maximum catch per flotsam was recorded during December being 3,451.5 kg which was followed in September 3 121 kg, October 2,228.6 kg, April 1.592.10 kg, May 1445.67 kg, November 890.91 kg and January 761.50 kg. The average catch per flotsam object for the season as a whole was 1,572.54 kg.

Length frequency distribution of tunas ; The fork length of two main species of tunas namely skipjack (*Katsuwonus pelamis*) and yellowfin (*Thunnus albacares*) were recorded and analysed.

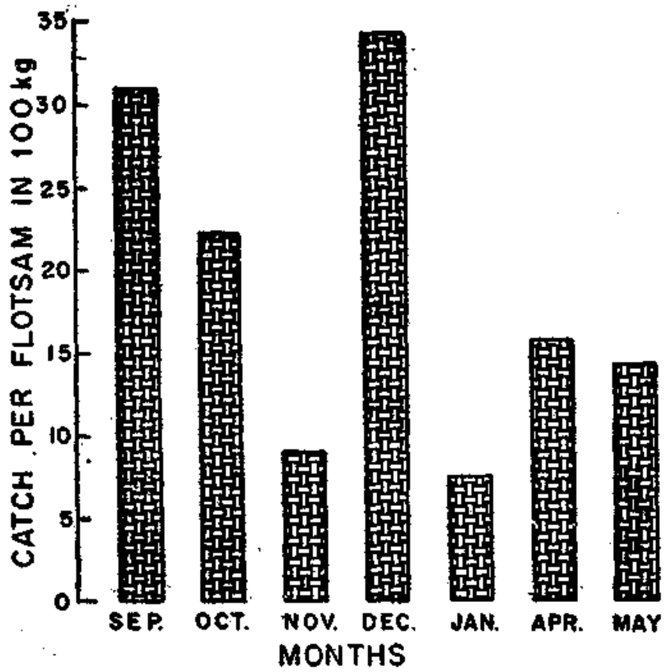

Fig. 1. Total catch of tunas from around flotsam at Minicoy, 1982-'83.

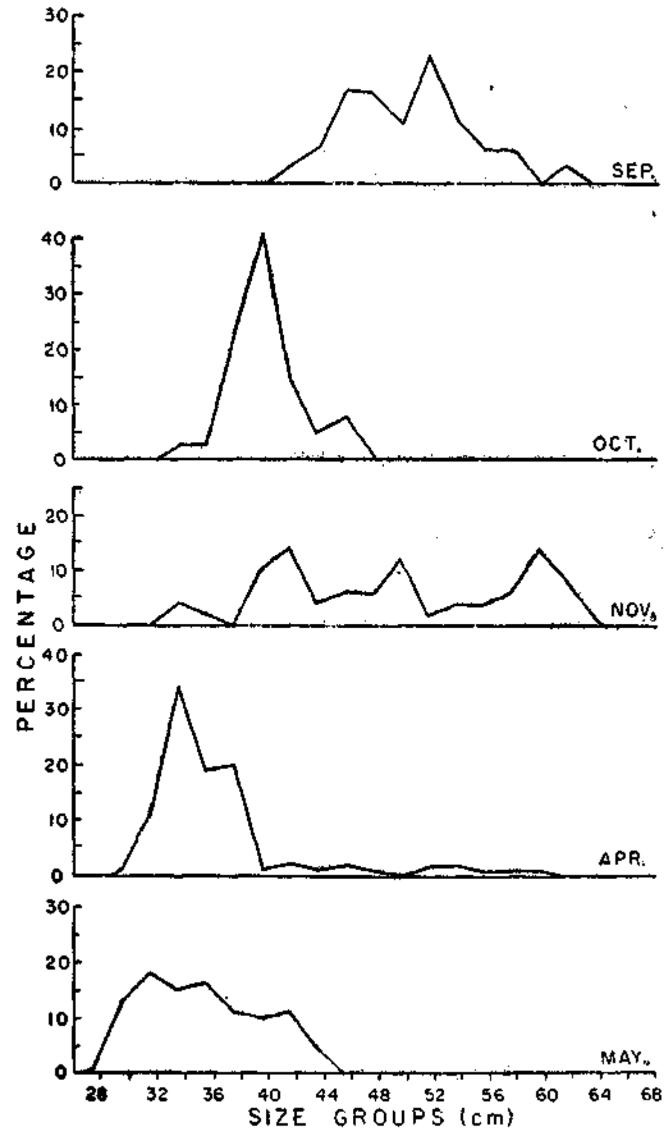

Fig. 2. Length frequency distribution of *K. pelamis* taken from around flotsam at Minicoy, 1982-'83 (Sept.-Nov. 1982 and April-May 1983)

Katsuwonus pelamis ; As can be seen from Fig. 2, during September the length of the fish ranged from 400 mm to 620 mm and size group 440-540 mm dominated. The next month, the length ranged between 340 to 560 mm. During November it ranged from 320 to 640 mm with 3 size groups 380-420 mm, 480-500 mm and 580-600 mm dominating. During April it ranged from 280 to 600 mm when the size range 300 to 380 mm was dominant. Next month the range was 260 to 440 mm with size group 280-420 mm showing dominance.

Thunnus albacares ; As can be seen from the Fig. 3, during September the length of yellowfin ranged from 420 to 640 mm and size group 520 to 560 mm

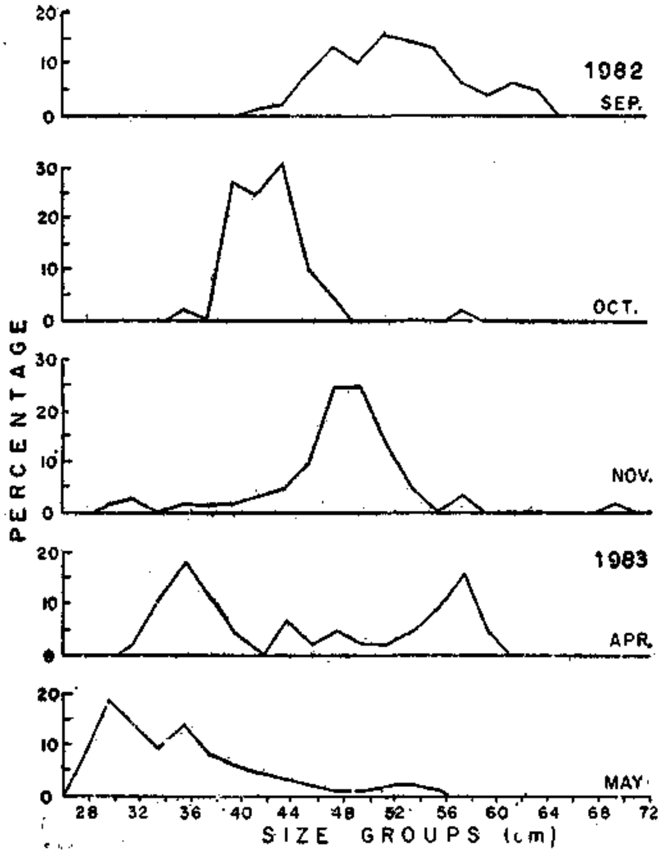

Fig. 3. Length frequency distribution of *T. albacares* taken from around flotsam at Minicoy, 1982-'83.

dominated. But next month catches were dominated by young fish with modal size range from 400-440 mm. In November length ranged from 300-700 mm and size group 480-500 mm dominated. During April length of fish ranged from 320 to 600 mm, but two modal sizes 340-380 mm and 560 to 580 mm were dominant. During May, yellowfin catches from flotsam were dominated by small fishes, *i.e.*, from 300 to 360 mm while the total range was 280 to 560 mm.

From July to November, wind and upwelling cause both clockwise and anticlockwise surface sea currents in Lakshadweep and Maldives region (Silas and Pillai, 1982). Every year it is seen during August to October period that large number of Coelenterates specially pelagic Siphonophores (*Porpita* spp., and *Physalia physalis*) are washed ashore along the western shore of Minicoy. During September 1982, an unusual invasion of Minicoy lagoon by *Ctenochaetus strigosus* in large profusion was observed for the first time in the history of Minicoy Island. Schools of this species almost covered the Minicoy lagoon, stock of which certainly originated elsewhere but reached Minicoy alongwith strong sea water currents. This clearly indicates a strong sea surface current towards Minicoy bringing alongwith it flotsam objects. Strong wind also plays an important role in the floating and drifting of wooden objects. So the occurrence of flotsam objects around Minicoy from September to December and again during April and May may be because of mixed processes of strong sea surface current and strong winds towards Minicoy.

The occurrence of very young skipjack ranging from 30 to 40 cm associated with flotsam objects during October and again during April-May is significant. Shoals of such small skipjack may be available far away from Minicoy, but they are reaching Minicoy only when they are associated with flotaing objects. Generally length of the skipjack at recruitment to the commercial catches at Minicoy is more than 40 cm.

But in the case of yellowfin, young fishes between 30 to 50 cm were found associated mostly with flotsam. Even in commercial catches at Minicoy, yellowfin available is more than 50 cm in length. Big yellowfin of more than 70 cm long are caught only by the troll line gear during the monsoon season. So it can be said that in one way floating objects help in the recruitment of young tunas to commercial pole-and-line tuna fishing.

Hypothesis

Several hypothesis have been proposed to explain the association of fishes with floating objects, but the reasons for the attraction of fishes to floating objects have not been fully substantiated. Some of them are :

1. Fish are attracted to the object to feed on associated forage organisms, algae or decaying matter.
2. Fish seek shade under the object.
3. The object provides shelter from predators.
4. The object is used as a substrate on which the fish lay their eggs.
5. The object functions as a cleaning station where pelagic fishes congregate to have their parasites removed by other fishes.

Gooding and Magnuson (1967) and Hunter and Mitchell (1967) have examined these hypothesis. While the former authors concluded that shelter from predators was probably the most significant drawing force in attracting fish to a floating object, Hunter and Mitchell, on the other hand, found no evidence in support of the hypothesis. They concluded :

1. Fishes associate with floating objects because the object serve as a schooling companion and,

2. In the case of non-pelagic species and others undergoing a change from pelagic to other modes of existance and object may function as a substitute for a reef or some other type of substrate.

As far as hypothesis with regard to feeding is concerned the floating objects examined during these studies, did not contain much food except some algal encrustation. On one occasion one small plastic piece served as floating object and nothing was attached to it. More over, for juvenile and non-piscivorous adult fishes this hypothesis would not apply. Food content analysis of tunas revealed that mostly bait fish used for chumming tuna were present. The only possibility of food may be the visible macro-plankton under the shadow of the object. But it is not clear how a small floating object can provide plankton aggregation for large shoals of fish.

As for the hypothesis regarding laying of eggs, most of the species caught from flotsam such as skipjack, yellowfin, *Elagatis bipinnulatus* and *Coryphaena* spp. are pelagic in nature and they shed their eggs in open sea.

During these studies floating objects such as nylon rope or nylon nets were also encountered which cannot give shelter to even very small school of fishes.

Most of the species caught from the floating objects generally school at the surface and some of them occur together. At Minicoy skipjack and yellowfin are found schooling together. On most of the occasions *Elagates bipinnulatus* and dolphin fish are also caught along with tunas. Tuna schools are found sometimes with shoals of sharks and dolphins.

After examining all the above hypothesis it appears that association of tunas with floating objects is nothing but merely a coincidence. Since almost all the species are found at one time or other schooling together their occurrence with floating objects does not show any change in their schooling pattern. Whenever a tuna shoal with other species of fish move with the sea water currents incidentally they observe a floating object as reference point and aggregate around it. In short, floating objects appear to serve only as companions drifting in the same direction with tuna shoals. It helps tuna fishermen in locating tuna shoals and makes their task easier for scouting of tuna schools.

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INDIAN TUNA FISHERY DEVELOPMENT—PERSPECTIVES AND A MANAGEMENT PLAN

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Speaking at an International Conference ' Fisheries development in 2000 A.D. ' (New Delhi, 1985) Dr. W. Philip Appleyard in a global context opined that the marine demersal catches could be increased from 22 million to 37 million tonnes ; the marine pelagic catches from 24 million to 50 million tonnes ; tuna catches from around 3 million to at least 8 million tonnes and cephalopods from around 1 million to 10 million tonnes. A potential saving of post-harvest losses of 11 million tonnes may also be added to these to exceed 110 million tonnes of fishes needed by 2000 A.D.

The production of tunas has shown spurts of increase from time to time, mainly due to the new areas of operation of purse seiners combined with market demand. Estimates of larger stocks of skipjack tuna have been made from different oceanic areas. The South Pacific Commission (SPC) have estimated about 8 million tonnes of skipjack resources from the South Pacific Area. Apparently, these optimistic estimates have resulted in projecting a trend to yield about 8 million tonnes of tunas from the world oceans by 2000 A. D. With the most sophisticated development in tuna fishing, particularly with the use of the modern purse seiners—taking into consideration the development during the past 2 decades, and international marketing constraints, it would appear to us a herculian task to double today's world production of tunas within the next fifteen years.

A review of the production trend of tunas in recent years for the Indian Ocean and for India has been presented earlier. The prime requirement in the planning of tuna fishery development is the need to maintain and improve production targets with good management measures. We propose that by 2000 A.D. the tempo of tuna fishery development programme by India should achieve a commercial production target in terms of quantity (tonnes) as follows :

Areas	Present catch (t)	By 1990 (t) (Silas & Pillai 1982)	By 2000 A.D. (t)
Coastal species (Drift gillnetting, pole and line (live-bait) fishing and other methods of coastal fishing ..	@19,000	45,000	75,000
Skipjack and young yellowfin tunas (Purse seining) ..	..	50,000	1,50,000
Large oceanic tunas (Longlining) ..	@ 100	20,000	60,000-75,000
	19,100	1,15,000	2,85,000-3,00,000

In order to achieve the above objectives, the major input-output items in the tuna fishery development programme and the sectors through which they could be effectively implemented are :

(i) Augmenting production through improvement in the traditional small scale fishery sector (Drift gillnetting, coastal purse seining, surface trolling, FAD's)

(ii) Development and improvements of medium commercial sector fishery (Pole and line (bait-boat fishing) fishing and FAD's)

(iii) Development of large scale commercial fishery sector (Large scale high seas purse seining and long-lining).

Tuna Fishery in the Small Scale Sector

Currently, tuna fishery is limited exclusively to the small scale fishery sector and immediate attention should be paid for an expansion and diversification within this sector. Bulk of the catches from the shelf waters is taken by drift gillnets, shore seines, surface troll lines and hooks and lines, using non-mechanised boats such as canoes and catamarans and ' pablo type ' mechanised boats. It is estimated that about 2600 gillnetters and 133,000 non-mechanised boats are in operation in 1980 (CMFRI 1982) along the coasts of India (Figures from Maharashtra, Lakshadweep and Andaman and Nicobar Islands not included).

Augmenting production of coastal species of tunas through diversification in the small scale fishing with greater use of drift gillnets and other suitable gears and crafts needs priorty attention. A recent trend in the motorisation in the small scale sector is the rapidly increasing number of canoes fitted with outboard engines, which have increased the operational range of these boats further offshore. Silas and Pillai (1982) reported about the non-mechanised canoes which are towed by mechanised boats for gillnetting in the deeper waters along the Calicut coast. Under a planned programme, adoption of this method in other areas where gillnetting is not practised at present would help in augmenting the production of larger pelagics such as tunas and seerfishes.

The major strategies for further development in the drift gillnet fishery have been discussed earlier (Silas *et al.* 1984). At present, storage facilities in the boats are lacking and when there is good catch of larger pelagics, about 10-15% of the catch is landed in deteriorated condition due to the dumping of the catch on the deck space. Proper icing and storing facility on board the boat which may merit structural modifications of the boat to store the catch are the problems which need serious consideration. Further by employment of energy saving devices, such as the use of sails, the area of operation of the mechanised gillnetters could be increased. Hauling of the net is normally done manually and it is time consuming. Installation of suitable mechanical net hauler would help in increasing the soaking time by reducing the hauling time. Another area which needs attention is the development of the bottom-set gillnetting (sub-surface fishery) practised by fishermen during certain seasons to catch quality fishes such as seerfishes and in which tunas are caught in good numbers.

Increasing drift gillnet operations in the areas such as Ratnagiri southwards to Calicut, in the Gulf of Mannar and along the coasts of Orissa and West Bengal would enhance the production of tunas to a considerable extent. The results of a case study on the drift gillnet fishery during 1981-'82 at Cochin (Silas *et al.* 1984) is indicative that it would not be difficult to increase the production from the present level from the inshore waters. A more intensive tuna fishery programme will be necessary in the shelf waters along the south-east and south-west coasts of India and the Wedge Bank Area with a concurrent product development programme and an internal marketing strategy.

Diversification in the fishery is often spoken of in order to reduce effort on shrimp trawling. The seasonal conversion of mechanised boats involved with shrimp trawling as efficient gillnetters with mechanised hauling system needs consideration. Since these boats range in size between 9.6-13.0 m OAL, the operational range, better storage facility and longer period of stay away from the port should be considered even if it involves modifications in the design.

Drift gillnetting for tunas also results in the landings of quality by-catch of other pelagics such as seerfishes, sharks, carangids, pomfrets and catfishes which fetch good prices at the landing centre (Silas *et al.* 1984). Assuming that each boat could harvest annually or seasonally 25-30 tonnes of larger pelagics of which about 20 per cent will be tunas, the average catch of tunas per boat per annum will be to the tune of about 6 tonnes.

Small purse seiners (OAL 11.5-13.5 m) also land good quantities of tuna from the shelf waters and regulated purse seine fishery for tunas along the south-west coast of India should yield good results. The annual catch of one such purse seiner may be from 400-500 tonnes of pelagic fishes such as mackerel, sardine, horse mackerels, pomfrets and tunas, among which tunas constitute about 20 per cent of the total annual catch. There are about 350 such purse seiners operating in the shelf waters of Maharashtra (Ratnagiri, 25) Goa (50), Karnataka (200) and Kerala (Cochin, 60). The sharing of resource between this and the drift gillnet fishery sectors need careful study and appraisal.

The major effort expended in the skipjack tuna fishery is in the surface fishery using pole-and-line and live-bait. Presently, about 120 mechanised boats are engaged in the pole-and-line fishery in the Lakshadweep Islands. Some of the major constraints in the fishery is the availability of live-bait, desirable bait species, scouting time for tuna shoals, behaviour of tuna shoals and fuel energy cost in running the boats (Silas and Pillai 1982). There is strong evidence that tampering of the Island lagoon ecosystem by dredging adversly affects the natural habitat of baitfishes. Minicoy lagoon is a good example where siltation is taking place in part of the lagoon and reef area. Regulatory measures to protect the lagoon ecosystem for stabilising natural resources of baitfishes is a pre-requisite for the successful surface tuna fishing in these Islands. Further, culture production of baitfishes for better development of pole-and-line fishery in the small scale fishery sector will be an effective step for augmenting tuna production. At present, pole-and-line live-bait fishery for tunas in the Lakshadweep Island involves only daily fishing. It was suggested by Silas and Pillai (1982) that the introduction of larger boats for bait-boat fishery involving voyages of a few days and improvements in operational techniques may pave the way for augmenting tuna production in these Islands. In this connection, the major aspects which need attention are the designing of the boats with bait tanks, chilling tank and fishhold; availability of required quantity of baitfish; fueling and servicing base facilities; frozen on shore storage facility; tuna cannery; trained manpower and other infrastructure including fresh water.

Larger boats of 15-20 m OAL with greater operational range could be used to fish around these islands for 4-5 days carrying enough live-bait and chilling and storing facilities for the catch. Each boat may require about 2.5 to 3 tonnes of live-bait per annum for operation, It is estimated that the operation of one such boat could produce 200 tonnes of skipjack and young yellowfin tuna per annum and to start with an introduction of 100 boats of this type in the Lakshadweep and Andaman and Nicobar Islands should enhance the yield of skipjack and yellowfin tunas to about 20,000 tonnes annually.

However, recent trends indicate that development priorities in the Lakshadweep Islands may take a different turn. A programme of sand mining from the lagoons for cement production and other industrial developments are being planned which we feel will undoubtedly adversely affect the island lagoon ecosystem on the reefs to even create major ecological imbalances. For one thing, siltation resulting in denudation of the reefs and other changes will naturally adversely affect natural baitfish occurrence and abundance in the lagoons which may negate any planned tuna development programme in the islands involving the pole and line-bait system. Even now, serious consideration should be given to see whether species of anchovies and sardines from along the mainland coast could be used as substitute bait.

Recent development in the tuna fishery by the employment of different types of anchored fish aggregating devices have been discussed by Silas and Pillai (1982). The use of FAD's to attract and hold schools of surface and pelagic fish species including tunas is one of the significant recent developments in the tuna fishery. The attraction of pelagic fishes including tunas to floating objects has been investigated by several authors (Hunter and Mitchell 1967, 1968; Inoue *et al.* 1968; Prindle and Walden 1976; Prindle 1981; Preston 1982). Murdy (1980) and Matsumoto *et al.* (1981) reported on the different types of FAD's employed in tuna fishing off Mindoro, Negros and Mindanao islands in the Phillippines and in the Hawaiian waters. Christy *et al.* (1981) mentioned of trials to be undertaken in the Republic of Maldives. Recently a comprehensive report on the FAD's mooring systems in general use in the Pacific Island countries has been published (Boy and Smith 1984).

The major impact of FAD's will be in the artisanal sector as fishing around these structures results in increased catches, reduction in the scouting and voyage times form the shore which conserve fuel energy and also it is a satfey factor for the operation of small boats. The traditional fishing methods employed for catching tunas were by hooks and lines, but recently commercial purse seining has been introduced in several localities.

As one of the steps towards augmenting the production of tunas in the artisanal sector it is desirable to use the fish aggregating devices as the 'Payayos' in the Philippines and Indonesia and the FAD's in the Pacific Island countries. Preferred areas are to be demarcated for setting up these devices and employment of efficient fishing methods suitable for the same all along the east coast of India particularly outside the shelf waters of the Tamilnadu and Andhra Predesh and around Lakshadweep and Andaman and Nicobar Islands. However, the problem of maintaining the fish aggregators is not a new or simple task as it involves anchoring at depths of 1000 m or more and a knowledge of the ocean currents in such areas. Fish aggregation around the FAD's is due to the concentration of small fishes in the area and hence large concentration of young tunas could be anticipated in these areas. Thus it is to be noted that these devices may lead to growth overfishing in view of the nature of aggregation of tunas. The report of landings of large quantities of early juveniles and young skipjack (weighing 70-100 gms each, 12-14 cm in length) to the tune of 100 tonnes per day during the 1981 season at General Santos City, Philippines, by the commercial ring net and purse seine fishery (Floyd and Pauly 1981) is one such instance. According to them, it is possible that *payaos* have apparently contributed to growth overfishing in Philippines because they render small tunas accessible to the fisheries. Installation of FAD's and strict monitoring of the catch for size and species, if not adhered to from the beginning, will lead to negative results as reported above.

A gap analysis would indicate that the difference between today's and projected production from the small scale sector by 2000 A.D. is about 60,000 tonnes of tunas. The known distribution of tunas and the information on the fishery which are indicative enable us to suggest that we may be able to enhance the production of tunas by planned development of the small scale fishery sector. The areas which require immediate attention and encouragement is the intermediate level of operation in the artisanal sector in our country. Of the total targeted production, about 25,000 tonnes of tunas could be taken by development and diversification in the fishery involving operation of catamarans, canoes with outboard engines and mechanised boats (32' size) for gillnetting; about 30,000 tonnes by medium sized purse seiners and about 5,000 tonnes by employing bait boats using pole-and-line gear.

Purse seine fishery

Under the large scale commercial tuna fishery from the surface waters of the high seas, a concerted effort should be made for the proper development and management of purse seine fishery. Under the plan for the management of tuna fishery in the Indian Ocean, Silas and Pillai (1982) discussed different aspects of the surface fishery for tunas in the Indian Ocean *in vitro*. Successful surface fishery for tunas can be established by large scale purse seine operations through joint venture/ownership arrangements. Immediate effort should be made to develop the operational facility for tuna purse seining in areas such as Andaman Sea which has a high potential for surface species. In this context training programme for personnel on the operational side for operation of large purse seiners will be necessary. Further, for the proper development and management of the purse seine fishery, environmental parameters such as the thermocline structure and current pattern are prerequisites. Information presented earlier by Silas and Pillai (1982) are indicative of the prevailing conditions in the Indian Ocean. Satellite imagery of sea surface characteristics will form an important tool to pinpoint areas of concentration of surface shoaling tunas such as skipjack young yellowfin and albacore. The development of surface fishery will result in harvesting of young yellowfin tuna which if not regulated will have an adverse effect on the fishery for adults which are taken by the regular longline gear.

In the present context, the production target by 2000 A.D. through the operation of larger purse seiners from the surface waters of the high seas is about 150,000 tonnes. A total of about 110,000 tonnes of tunas per annum from the EEZ and contiguous high seas could be produced by employing two categories of large purse seiners such as 10-12 purse seiners each of annual production capacity of 6000 tonnes and 20 purse seiners each of 4000 tonnes production capacity.

Longline fishery

Silas and Pillai (1982) dealt with in detail different aspects of longline fishery including the operational methods, constraints and management problems from within the EEZ of India and the high seas. In order to increase production of oceanic tunas, and to achieve production targets, it is imperative that we should enter into tuna longline fishery, especially deep longlining for deep swimming tunas such as bigeye tunas, initially through joint venture. It is estimated that about 150 longliners each with capacity to produce around 450 tonnes of tunas annually are required to achieve the production target of 60,000-75,000 tonnes by 2000 A.D. In this connection, better utilisation of by-catch such as pelagic sharks economically is another area needing attention.

Infrastructure priorties

Embarking in tuna fishery in a large way is highly capital intensive and it will not be economical to fish the tuna resources of the EEZ of India and contiguous high seas with only an internal market in view. While some amount of coastal species such as tuna-like fishes will find an internal market, the major option should be augmentation of exports of tunas and tuna products as part of an overall strategy of diversification of exports of marine products. In connection with the large scale production of tunas by large purse seiners and longliners, foreign market demand for selling the products should be taken into consideration. It is estimated that a demand for about 150,000 tonnes of tunas (whole weight) or about 125,000 tonnes of frozen and canned tuna products could be expected for the external market. Initially joint ventures with buy back arrangements should accellerate development.

Building up of infrastructure for export of tunas and tuna products is an essential pre-requisite and this would involve :

— Harbour and facilities for landing, handling and transporting ;
— Frozen storage
— Product development
— Export oriented canneries (with production capacity of 6000-10,000 tonnes) provided with required water and electricity supply and pollution preventive measures ;
— Quality control and streamlining for inspection for export.

The current trend of events indicate that even for the present production of tunas, a proper internal marketing system has not been developed nor have we done any major improvements in post-harvest technology. In India, average landing of tunas from the coastal waters during 1982-'83 was about 19,000 tonnes. Silas and Pillai (1982) pointed out the imperative necessity for the development of post-harvest technology for the better utilisation of tunas harvested from the coastal waters. There is considerable scope for the exploitation of the 'red meat' tunas *E. affinis*, *A. thazard* and *A. rochei* and it will be necessary to develop internal market for these species in fresh, frozen and processed form through improved post-harvest technology. The following basic infrastructures should be considered while charting out options for the development of internal market for tunas and tuna products :

— Landing facilities ;
— Cold storage facilities ;
— Transportation of iced and frozen tuna meat ;
— Larger product on of "masmin" a smoked dried product and products such as fish paste;
— Tuna canneries to produce canned packs of tunas for internal consumption ;
— Processing of tuna wastes for animal feeds.

In the tuna fishery development and management programme by India, a favourable point is the availability of abundant skilled and semi-skilled labour. We feel that in the field of small scale boat-building and replacement of boats, the existing facilities can be utilised with regard to manpower. For the production of fibre glass and intermediate type of boats (60') existing facilities are to be modernised and new facilities added to them. For the manpower requirement to construct larger purse seiners and longliners, joint venture programmes, purchase agreements as well as indigenous construction through the development of yards or commissioning of new yards are required. Financial assistance in the form of subsidies for constructing suitable fishing vessels is one of the options available for tuna fishery development in India. In the programme of augmentation of tuna production through the channels discussed earlier, available manpower could also be effectively utilised in the fishing operations on board the vessels, shore based establishments, handling of fish at harbour, transportation, internal marketing and in the processing of tunas into products for export and internal markets.

Under the 'Options open for tuna fishery development in the EEZ of India and the contiguous high seas' Silas and Pillai (1982) suggested the following :

—Augmentation of the production of coastal species of tunas through diversification in the small scale fishery with greater use of drift gillnets and other suitable gears ; introduction and development of surface fishery for skipjack and other tunas ; introduction of larger boats for live-bait pole-and-line fishery in the Lakshadweep for undertaking prolonged fishing trips and improvements in operational techniques ; baitfish culture and production for better development of pole-and-line fishery ; entry into longline fishery and large scale purse seine fishery initially through chartering or joint venture programmes ; identification of productive areas for tuna fishery, their spawning and feeding grounds and other environmental features including satellite technology for locating tuna aggregating areas ; financial assistance for building up infrastructure and acquiring or constructing suitable fishing vessels ; development of alternate source of energy in tuna fishery for making operations more viable and economical and viable in small scale sector ; augmentation of production in the island areas and along the coasts by use of FAD's ; and improvements in the post-harvest technology, product development and marketing combined with infrastructure for demand for tuna within the country and in the export market'.

With a view to benefit the tuna fishing industry, in a series of charts (Figs. 1-5) showing the linkages and the infrastructure facilities involved in the operation of tuna longline fishery, tuna purse seining, pole-and-line (live-bait) fishery and drift gillnetting for tunas and the infrastructure facilities required for the general use of the FAD's are presented. The proformae (I-V) given at the end are for data acquisition for stock assessment.

PROJECTIONS

The present level of cost of tunas is indicative of the fact that based on the production targets for 2000 A.D. mentioned earlier, the total revenue from the surface and sub-surface fisheries for tunas in the shelf waters and from the EEZ and contiguous high seas of India could be as follows:

(i) *Yellowfin and bigeye tuna*

Graded as category 'A'; for about 75,000 tonnes at the rate of Rs. 15,000 per tonne—Rs. 112,5000,000.

(ii) *Skipjack tuna*

Graded as category 'B'; for about 150,000 tonnes at the rate of Rs. 5,000 per tonne—Rs. 75,0000,000.

(iii) *Coastal tunas*

Graded as 'C'; for about 75,000 tonnes at the rate of Rs. 3000 per tonne—Rs. 22,5000,000.

Total revenue is thus estimated as Rupees 210 crores for an estimated production of about 300,000 tonnes of tunas by 2000 A.D. To achieve this, the most important single factor today is a Policy decision on—whether India should seriously enter tuna fisheries in a large way or not.

Fig. 1

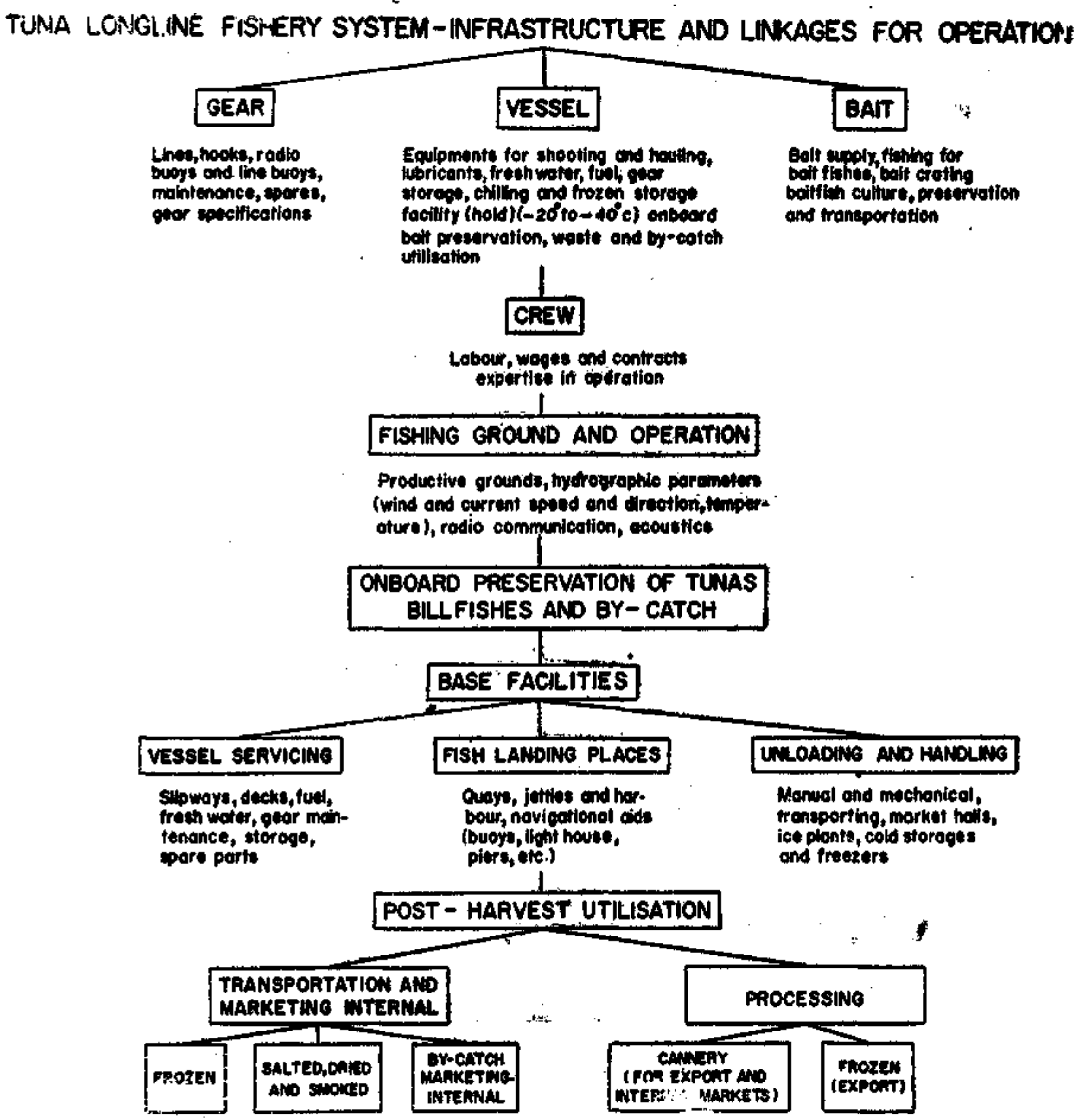

TUNA LONGLINE FISHERY SYSTEM-INFRASTRUCTURE AND LINKAGES FOR OPERATION
GEAR
Lines, hooks, radio buoys and line buoys, maintenance, spares, gear specifications
VESSEL
Equipments for shooting and hauling, lubricants, fresh water, fuel, gear storage, chilling and frozen storage facility (hold) (-20° to -40°c) onboard bait preservation, waste and by-catch utilisation
BAIT
Bait supply, fishing for bait fishes, bait crating baitfish culture, preservation and transportation
CREW
Labour, wages and contracts expertise in operation
FISHING GROUND AND OPERATION
Productive grounds, hydrographic parameters (wind and current speed and direction, temperature), radio communication, acoustics
ONBOARD PRESERVATION OF TUNAS BILLFISHES AND BY-CATCH
BASE FACILITIES
VESSEL SERVICING
Slipways, decks, fuel, fresh water, gear maintenance, storage, spare parts
FISH LANDING PLACES
Quays, jetties and harbour, navigational aids (buoys, light house, piers, etc.)
UNLOADING AND HANDLING
Manual and mechanical, transporting, market halls, ice plants, cold storages and freezers
POST-HARVEST UTILISATION
TRANSPORTATION AND MARKETING INTERNAL
PROCESSING
FROZEN
SALTED, DRIED AND SMOKED
BY-CATCH MARKETING-INTERNAL
CANNERY (FOR EXPORT AND INTERNAL MARKETS)
FROZEN (EXPORT)

Fig. 2

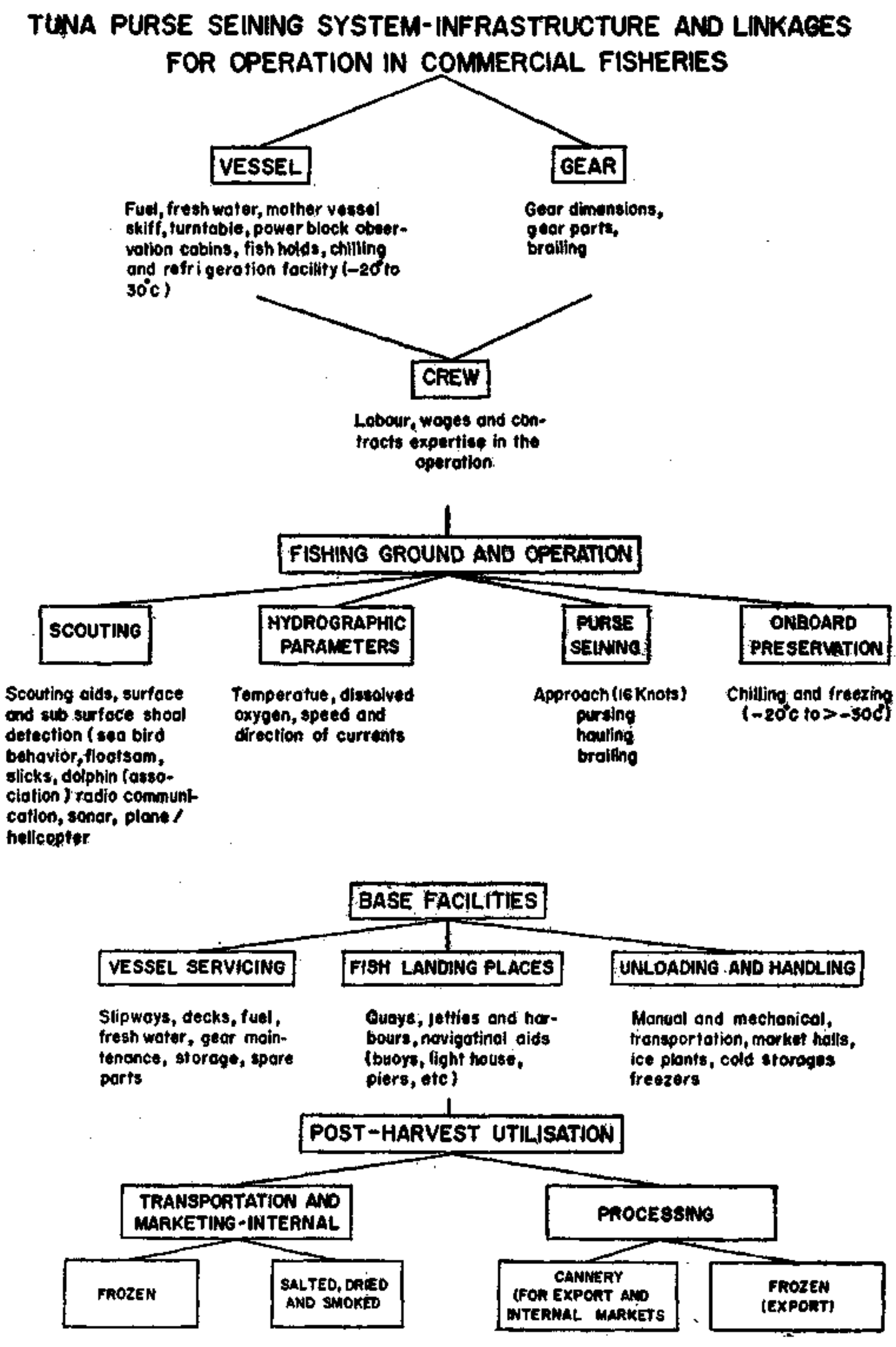

TUNA PURSE SEINING SYSTEM-INFRASTRUCTURE AND LINKAGES FOR OPERATION IN COMMERCIAL FISHERIES
VESSEL
GEAR
Fuel, fresh water, mother vessel skiff, turntable, power block observation cabins, fish holds, chilling and refrigeration facility (–20°to 30°c)
Gear dimensions, gear parts, brailing
CREW
Labour, wages and contracts expertise in the operation
FISHING GROUND AND OPERATION
SCOUTING
HYDROGRAPHIC PARAMETERS
PURSE SEINING
ONBOARD PRESERVATION
Scouting aids, surface and sub surface shoal detection (sea bird behavior, floatsam, slicks, dolphin (association) radio communication, sonar, plane / helicopter
Temperatue, dissolved oxygen, speed and direction of currents
Approach (16 Knots) pursing hauling brailing
Chilling and freezing (–20°c to >–30°c)
BASE FACILITIES
VESSEL SERVICING
FISH LANDING PLACES
UNLOADING AND HANDLING
Slipways, decks, fuel, fresh water, gear maintenance, storage, spare parts
Quays, jetties and harbours, navigatinal aids (buoys, light house, piers, etc)
Manual and mechanical, transportation, market halls, ice plants, cold storages freezers
POST-HARVEST UTILISATION
TRANSPORTATION AND MARKETING-INTERNAL
PROCESSING
FROZEN
SALTED, DRIED AND SMOKED
CANNERY (FOR EXPORT AND INTERNAL MARKETS
FROZEN (EXPORT)

Fig. 3

POLE AND LINE (LIVE-BAIT) TUNA FISHING SYSTEM-INFRASTRUCTURE AND LINKAGES FOR OPERATION IN COMMERCIAL FISHERIES (MEDIUM SIZE)

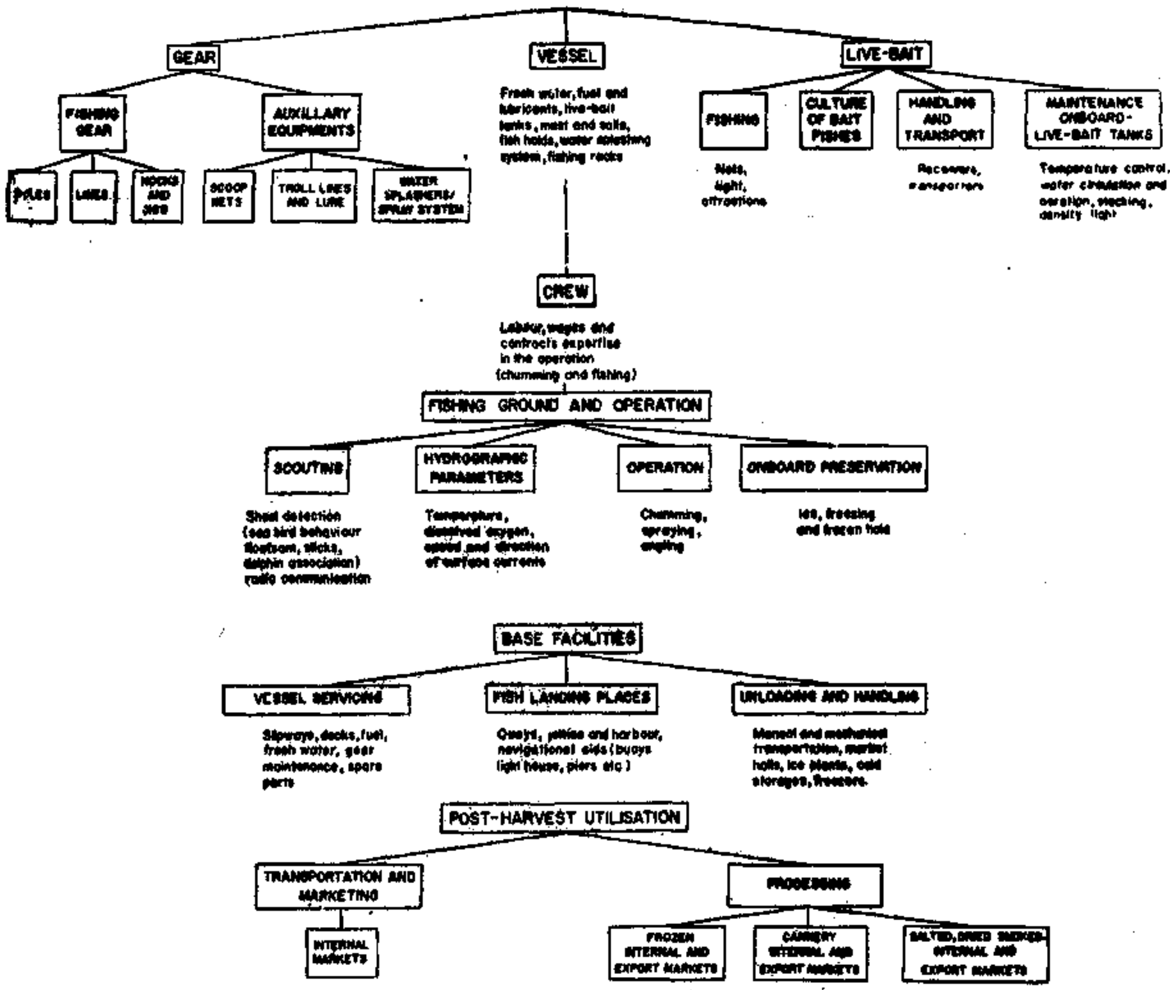


Fig. 4

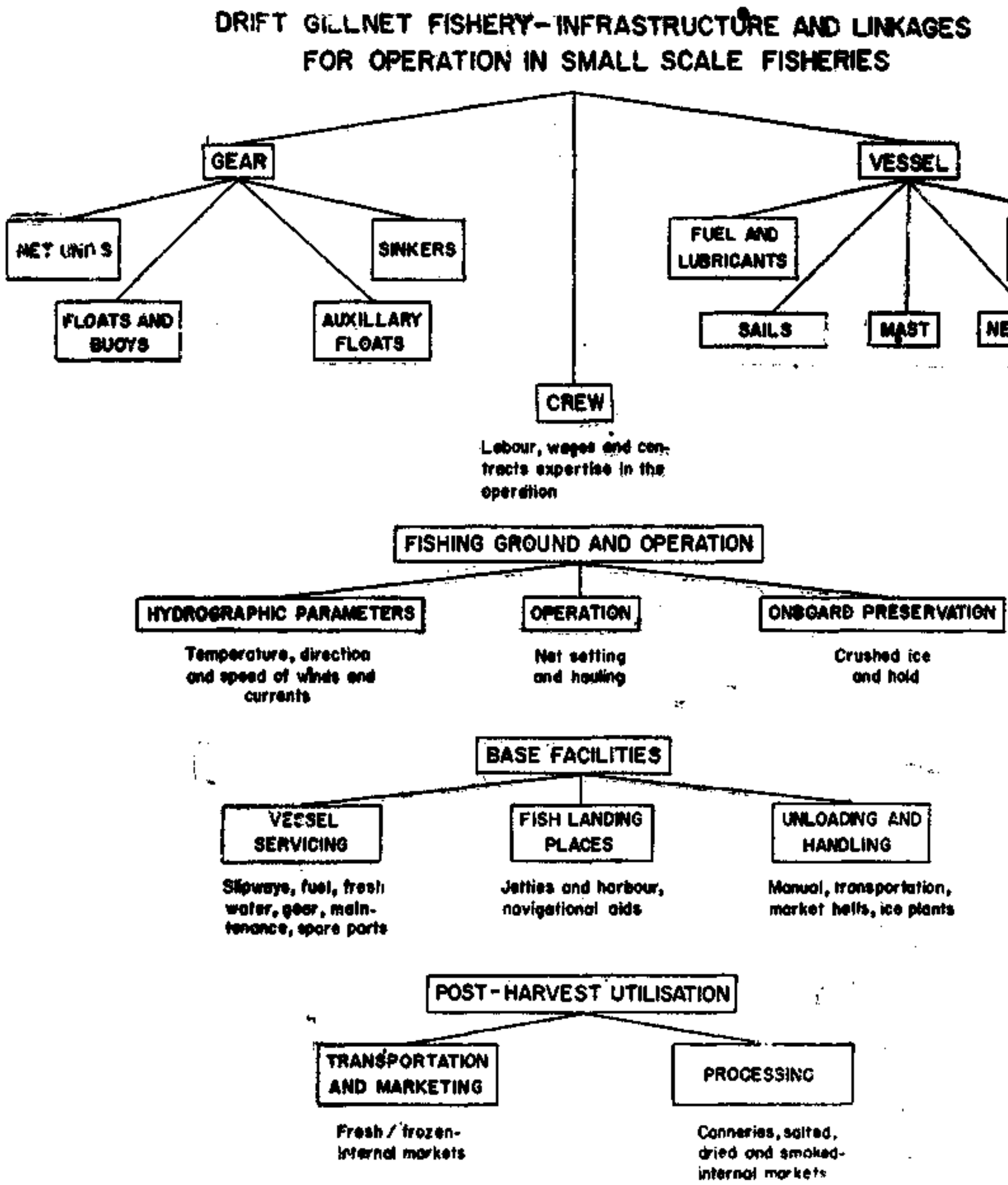
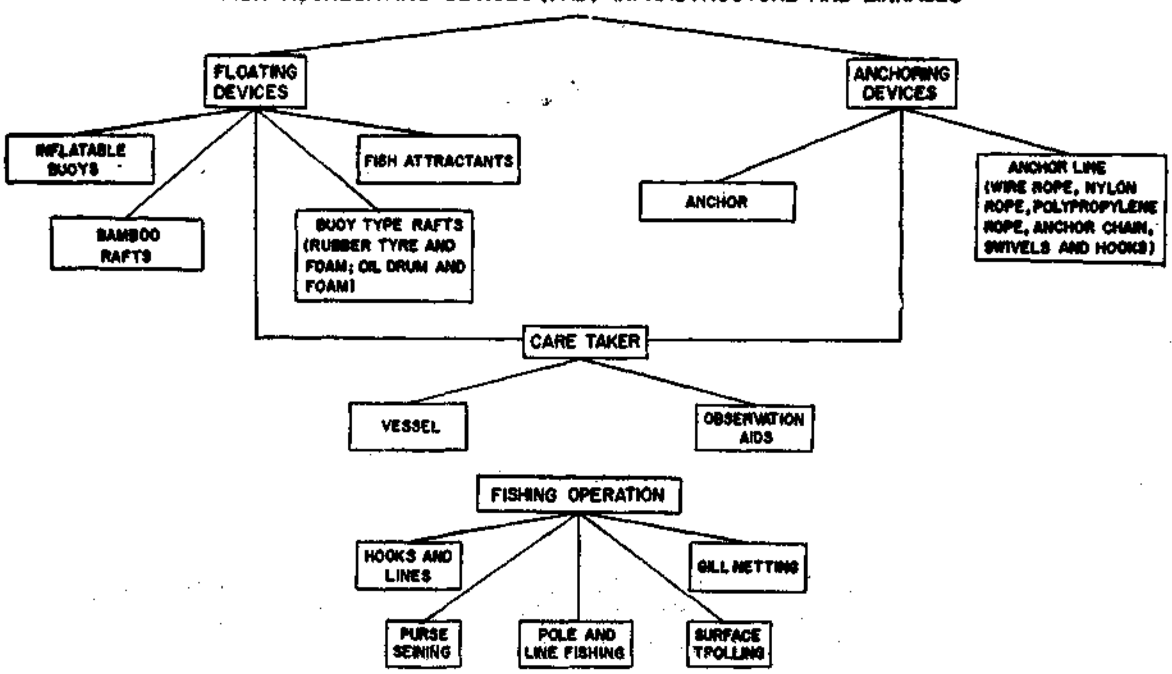

DRIFT GILLNET FISHERY–INFRASTRUCTURE AND LINKAGES
FOR OPERATION IN SMALL SCALE FISHERIES
GEAR
NET UNITS
SINKERS
FLOATS AND BUOYS
AUXILLARY FLOATS
VESSEL
FUEL AND LUBRICANTS
FISH HOLD AND CRUSHED ICE
SAILS
MAST
NET HAULER
CREW
Labour, wages and contracts expertise in the operation
FISHING GROUND AND OPERATION
HYDROGRAPHIC PARAMETERS
Temperature, direction and speed of winds and currents
OPERATION
Net setting and hauling
ONBOARD PRESERVATION
Crushed ice and hold
BASE FACILITIES
VESSEL SERVICING
Slipways, fuel, fresh water, gear, maintenance, spare parts
FISH LANDING PLACES
Jetties and harbour, navigational aids
UNLOADING AND HANDLING
Manual, transportation, market halls, ice plants
POST-HARVEST UTILISATION
TRANSPORTATION AND MARKETING
Fresh / frozen-internal markets
PROCESSING
Canneries, salted, dried and smoked-internal markets

Fig. 5

FISH AGGREGATING DEVICES (FAD) - INFRASTRUCTURE AND LINKAGES



PROFORMA

ESTIMATED FISHING EFFORT AND CATCH

Year :

Centre :

Resource :

Month	Name of the fishing gear/craft									Total		
	E	C	C/E	E	C	C/E	E	C	C/E	SE	C	C/SE
Jan.												
Feb.												
Mar.												
Apr.												
May												
Jun.												
Jul.												
Aug.												
Sept.												
Oct.												
Nov.												
Dec.												
Total :												

E—Number of units/Trawling hours : *C*—Catch (kg) : *C/B*—Catch per boat/Trawling hour* : *SE*—Standardised effort (specify) and *C/SE*—Catch per standardised effort.

(* Indicate trawling speed and width (m) of Bottom trawl)

PROFORMA 11

ESTIMATE SPECIES COMPOSITION OF CATCH

(By Wt.)

Year : Centre :

Fishing gear : Resource :

Month	Catch composition of species (Specify)	Monthly Total (kg)
Jan.		
Feb.		
Mar.		
Apr.		
May		
Jun.		
Jul.		
Aug.		
Sep.		
Oct.		
Nov.		
Dec.		
Annual Total (Wt)		
%		

PROFORMA III

MONTH-WISE ESTIMATED SIZE-DISTRIBUTION OF DOMINANT SPECIES (NO. OF FISH PER UNIT EFFORT) IN THE CATCH

Year : Centre :

Gear : Species :

Length groups mm/cm*	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
0—													
5—													
10—													
15—													
20—													
25—													
30—													
35—													
40—													
,,													
,,													
,,													
,,													
100—													
105—													
110—													
115—													
120—													
125—etc.													
Sample Size (No. measured)													

* UNIT of measure in (mm) for smaller species and (cm) for larger species.
Groups : O = (0 - 4), 5 = (5-9) and 10 = (10-14) units of measure.

PROFORMA IV

GONADAL CONDITION OF ADULTS*

Year :

Centre :

Species :

Sex-ratio/ Maturity etc. :	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total No.	Total %
Male														
Female														
Resting (II)														
Developing (II-IV)														
Gravid (V-VI)														
Spent (VII)														
Sample size (in number)														

* All fish above the size at first maturity *only need* be included.

PROFORMA V

FEEDING CONDITION

Year :

Centre :

Species :

Month	Day (0600-1800 hrs)				Night (1800-0600 hrs)				Sample size	Name dominant food items
	0	0.5	1	1+	0	0.5 (Nos.)	1	1+		
Jan.										
Feb.										
Mar.										
Apr.										
May										
Jun.										
Jul.										
Aug.										
Sep.										
Oct.										
Nov.										
Dec.										
Total No.										
Per cent										

Scale : 0 = Empty, 0.5 = Half full, 1 = Full and 1 + = Gorged.

ANNEXURE—I

Glossary of statistical terms used

L_t — Length of fish having age ' t '

L_∞ — Asymptotic length

K — Brody's growth coefficient

t_0 — Age of fish at length zero

W_∞ — Asymptotic weight

N_t — Number of fish at time ' t '

L_1 — Lower limit of a length class

L_2 — Upper limit of a length class

N_1 — Number of fish in the population having length L_1

N_2 — Number of fish in the population having length L_2

t_1 — Age corresponding to L_1

t_2 — Age corresponding to L_2

Δ_t — The difference in time to grow from L_1 to L_2

$C_{1,2}$ — Number of fish caught with lengths between L_1 and L_2

Z — The instantaneous total mortality rate

F — The instantaneous fishing mortality rate

M — The instantaneous natural mortality rate

E — Rate of exploitation

l_c — Length at first capture

l_r — Length at recruitment

R — Number of recruits

Y — Yield

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Boat used for Drift gillnet fishery and also for surface trolling at Tuticorin.

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