MARINE BIOLOGICAL ASSOCIATION OF INDIA

MEMOIR I

THE RIBBON-FISHES OF THE FAMILY TRICHIURIDAE OF INDIA

BY

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Mandapam Camp

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FOREWORD

The Marine Biological Association of India founded in 1958 for the promotion of the cause of marine sciences in the Indian Region has been publishing regularly from 1959 its Journal which has already established itself as one of the leading scientific periodicals. In addition to the above, the Association has been holding symposia, the first one in January 1962 on Scombroid Fishes and the second in January 1965 on Crustacea. The Proceedings of these symposia issued already have become indispensable works of reference wherever researches on the concerned subjects are carried out.

One of the objectives of the Association has been to bring out monographs and other comprehensive accounts on the fauna and flora of the seas around India and the present Memoir entitled "The Ribbon-fishes of the family Trichiuridae of India" by Dr. P.S.B.R. James is the first of this series. It is based on his painstaking study for over three years on this economically important family of fishes about which the knowledge we had previously was only of a desultory nature. In addition to his own observations, all available information on the subject has been brought together to form a comprehensive account—the first of its kind in this country on any family of fishes.

Dr. James has endeavoured to make the account succinct and lucid. The biologists as well as the fishery scientists are expected to be benefited by this publication which is bound to serve as a valuable work of reference for a long time to come. Dr. James deserves to be congratulated for the preparation of the same and it is hoped that this pioneer attempt will be emulated by other fishery workers and research scholars and more accounts of this nature will be forthcoming in furtherance of our knowledge on our fish and fisheries.

The issue of this Memoir is certainly another milestone in the activities of the Marine Biological Association of India. The fact that the Association could do this in addition to the publication of the Journal and the Proceedings of the Symposia *without any aid from any organisation in this country* is a most unique achievement and shows the sustained patronage it is receiving from right thinking scientists all over the world. The Association is releasing the Memoir on the Ribbon-fishes with the earnest hope that it will be well received and found useful by all fishery biologists.

Marine Biological Association of India,
Mandapam Camp,
May 8, 1967.

S. JONES
President

PREFACE

Ribbon-fishes of the family Trichiuridae constitute one of the important commercial fisheries of India. There have been some earlier reports about their distribution, abundance and biological aspects but no attempt has been made towards a comprehensive study of this group of fishes. Four species of ribbon-fishes are now known to occur in the Indian Seas and while knowledge about their biology would be useful from the fishery point of view, it was also thought that a study of their systematic position and some aspects of anatomy would lead to a better understanding of the group as a whole. This account, which is mainly based on my thesis approved for the Doctor of Philosophy Degree in Zoology of the Banaras Hindu University, deals with the systematic position, some aspects of anatomy, biology and fishery of the ribbon-fishes from the Indian Seas. The analyses, interpretation of data and illustrations are my own.

I am deeply grateful to Dr. S. Jones under whose supervision and constant encouragement this work was carried out at the Central Marine Fisheries Research Institute, Mandapam Camp. I am also grateful to Dr. S. P. Ray-Chaudhuri for all the help received during the course of this work. For constructive criticism and valuable suggestions, I am thankful to Dr. Carl L. Hubbs. I am also thankful to Dr. C. V. Kulkarni for many valuable suggestions.

I wish to record my sincere thanks to Dr. R. Raghu Prasad, Dr. R. V. Nair, Mr. K. Virabhadra Rao, Mr. S. K. Banerji and Dr. E. G. Silas who have greatly helped me in various directions in this study. I am also thankful to my wife, Mrs. Indira V. James for all the assistance.

Some of the photographs presented in this work were kindly taken by Dr. R. P. Varma and Mr. K. G. Nambiar to whom my thanks are due. To the crew of M.L. 'Sagitta' and M.L. 'Mathi', I am thankful for the help during my collection trips.

For kindly making available some specimens of related fishes for my study, I am thankful to the authorities of the British Museum, U.S. National Museum and the Leiden Museum.

This work was done partly during the tenure of a Senior Research Training Scholarship of the Ministry of Scientific Research and Cultural Affairs, Government of India and partly under a Junior Fellowship of the Council of Scientific and Industrial Research, New Delhi. I am thankful to the authorities of these two organisations for the awards.

Thanks are due to Western Printers & Publishers, Bombay, for executing the printing of the memoir in such an excellent manner and in special to Mr. G. S. Pohekar, for all the interest taken in this connection.

Central Marine Fisheries Research Institute, Mandapam Camp, July 24, 1965.

P.S.B.R. JAMES

INTRODUCTION

Ribbon-fishes of the family Trichiuridae are widely distributed in the Indo-Pacific and the Atlantic and four of the species constitute an important commercial fishery at several places along the Indian coast. Various species of this family have been recorded by many earlier authors from different localities with brief remarks on their commercial importance but the present knowledge about their biology in general is very meagre. To mention some earlier works from India, on one or more of the species, Venkataraman (1944) dealt with the feeding habits and Chidambaram and Venkataraman (1946) their natural history. Devanesan and Chidambaram (1948) briefly reported on their fishery in Madras State. Jacob (1949) gave some details of their bionomics and Chacko (1950) reported the occurrence of eggs and larvae of *Trichiurus savala* (= *Lepturacanthus savala*) from waters around Krusadai Island, in the Gulf of Mannar. Mahadevan (1950) described the alimentary canal of *T. haumela* (= *T. lepturus*) and Prabhu (1950 and 1955) gave an account of its breeding habits and some aspects of the biology. Vijayaraghavan (1951) dealt with a qualitative and quantitative analysis of the stomach contents of *T. haumela* and *T. savala*.

From outside India there have been several reports on these or related species of ribbon-fishes but in this connection the works of Delsman (1927) on the eggs and larvae of *Trichiurus* spp., Tang and Wu (1936) on the spawning of *T. japonicus* (= *T. lepturus*), Lin (1936) on the hair-tails of China, Tham Ah Kow (1950) on the feeding habits of *T. haumela* from Singapore, Tucker (1956) on a systematic study of the family Trichiuridae, Rosa (1957) a synopsis of biological data on the species of Trichiuroidei and Misu (1958) on the age and growth and spawning of *T. lepturus* on the East China and Yellow Seas deserve special mention.

Since very little attention has been paid to a comprehensive study of the species occurring in Indian waters, the present work was initiated in December 1958 with the object of contributing additional information to the existing knowledge of the biology and fishery of this important group of commercial fishes.

This study is mainly based on samples of fish collected from the commercial catches at various fishing centres along Palk Bay and the Gulf of Mannar, in the vicinity of Mandapam. The main centres at which samples have been collected are Panaikulam, Athankarai and Thangachimadam on Palk Bay and Pudumadam on the Gulf of Mannar (Fig. 1) which are situated approximately 12 to 23 kilometers from the Institute.

The coast off Panaikulam and Athankarai is sandy and shallow and hence suitable for the operation of shore seines from Tuticorin type of boats usually at depths 4 to 6 metres and 1 to 1½ miles away from the shore. Off Thangachimadam, the coast is rocky with coral reefs extending to at least a mile into sea, as a result of which only bag nets are operated from catamarans at depths varying between 16 to 20 metres and about 10 miles off the shore. Off Pudumadam, the coast is partly sandy and partly rocky and shore seines are operated at suitable places at depths 4 to 6 metres and 1 to $1\frac{1}{2}$ miles away from the shore. Except at Thagachimadam, where fishing is carried out only at night, at all the other places mentioned above, fishing is done both during day and night.

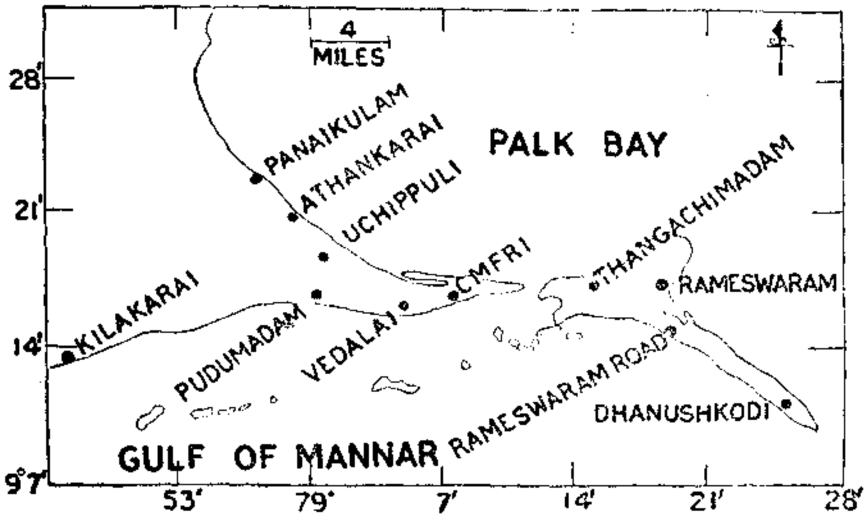

Fig. 1. Map showing important places of collection of material and the location of the Research Institute.

During the period March 1959 to February 1961 regular weekly samples of fish were collected from the above places. Except on a few occasions when fishes were scarce or fishing was suspended due to adverse conditions of weather, at least 50 fish were collected at random from the commercial catches. Since three of the species occur in this region, and only one of them (*E. intermedius*) throughout the year, the samples include at least 50 fish of this species and as many as available of the other species. As a result of this, the samples were utilised for detailed biological studies of *E. intermedius* and collection of data for other species for a comparison. Since the collection centres are away from the place of work and no quick transport facilities exist, it was necessary to preserve the fish in 5% formalin on the spot to avoid spoilage. Detailed observations were carried out at the laboratory during the following week in each case. Therefore, all observations included in this work except those on otoliths are made on preserved material uniformly throughout the course of study. For a study of age and growth, otoliths of fresh fish were utilised since otoliths of preserved fish were found unsuitable for study. Whenever it was considered necessary to examine the fish in fresh condition, this was done on the field itself or they were taken to the laboratory quickly for the purpose.

Each sample was washed and the necessary length measurements and weights were noted. The gonads and stomachs of as many fish as are required were then dissected out and preserved separately in 5% formalin for detailed examination at a later date.

For general observations and comparative studies, samples of the four species were collected by the author from important fish landing centres where ribbon-fishes are common, during March 1959 to February 1961. The centres visited were Waltair, Uppada, Pentakota, Kakinada, Madras, Adirampatam, Idinthakarai, Cape Comorin, Vizhingam, Vengurla, Malvan, Ratnagiri and Bombay along the Indian coast, and a few fishing centres around Colombo along the west coast of Ceylon. Samples of fishes were also obtained from the Hooghly and Matla estuaries, Puri, Gopalpur, Calicut, Mangalore, Karwar, Veraval, Kandla and Andaman Islands. The work deals in detail with the biology and fishery of *Eupleurogrammus intermedius* (Gray), the common species in Palk Bay and the Gulf of Mannar around Mandapam and comparative accounts of the other three species viz., *Eupleurogrammus muticus* (Gray), *Trichiurus lepturus* Linnaeus and *Lepturacanthus savala* (Cuvier). In addition to observations on the biology and fishery of these fishes it was considered useful to study the systematics as well as some aspects of the anatomy. Therefore, the present work is divided into four major parts namely, Systematics, Anatomy, Biology and Fishery.

Part I deals with the author's observations on the four species from India with details of generic diagnoses, synonymies and distribution. A key for the identification is included. Details of the range of variation of selected morphometric and meristic characters are given and a comparative account of the relative growth of certain body proportions discussed. Notes have been prepared on specimens of related trichiurids received from the British Museum (Natural History), United States National Museum and the Rijksmuseum Van Natuurlijke Historie, Leiden but only those on specimens from the British Museum have been given in this work.

In order to draw a clearer distinction between the different species and analyse the differences between them, their comparative osteology was studied indicating the degree of divergence or affinity between them. A detailed study of the hyperostosis in *T. lepturus* has been made. Results of these studies have already been published by the author in two separate papers but included in a revised form here to make this work self contained. Although some references have been made to the structure of the alimentary canal, teeth and gill rakers of ribbon-fishes by earlier authors, a need for a detailed study of these structures was felt to understand their significance from a taxonomic point of view and in their adaptation to feeding. Certain other aspects of the anatomy dealt with in Part II, in addition to the above, include an acocunt of the vascular system, the brain and important cranial nerves, the auditory organ, the air bladder, the renal organs and the gonads of *T. lepturus* and a comparison of other species. A brief account of the parasites of ribbon-fishes is also included in Part II.

All the biological information gathered during this period is incorporated in Part III, the salient features of which include observations on the food and feeding habits, length-weight relationship, relative condition factor, maturity and spawning, account of the young stages, age and growth and the racial investigations.

Part IV presents the observations made by the author on the distribution of the species during the period of investigation and their fishery along the Indian coast in general, the fishing methods, craft and tackle, fishing seasons along Palk Bay and the Gulf of Mannar, common methods of preservation and disposal of the catch. It also includes details of the ribbon-fish catches from 1950 to 1965 and their economic importance.

Wherever necessary, illustrations have been given and references pertaining to anatomy and biology have been listed at the end.

Part One

SYSTEMATICS

I

TAXONOMY OF THE INDIAN SPECIES OF TRICHIURIDAE

Until recently very little attention has been directed towards a systematic study of the ribbon-fishes of the family Trichiuridae. Day (1878) recorded three species under the genus *Trichiurus viz., Trichiurus haumela* (Forskal), *Trichiurus savala* Cuvier, *Trichiurus muticus* Gray from Indian waters and the later authors have referred only to these three species in their studies. James (1959) recorded for the first time, a fourth species of ribbon-fish, *Eupleurogrammus intermedius* (Gray) from Indian waters. The up-to-date nomenclature of the four species of ribbon-fishes from Indian waters along with the names given by Day is given below:

Day's species	Up-to-date nomenclature
1. *Trichiurus haumela* (Forskal)	*Trichiurus lepturus* Linnaeus
2. *Trichiurus savala* Cuvier	*Lepturacanthus savala* (Cuvier)
3. *Trichiurus muticus* Gray	*Eupleurogrammus muticus* (Gray)
	Eupleurogrammus intermedius (Gray)

It may be appropriate here to mention that de Beaufort (1951) recorded five species, *viz., Trichiurus glossodon, T. muticus, T. savala, T. haumela* and *T. auriga* from the Indo-Australian Archipelago of which the last species has been synonymised with *T. haumela* (= *T. lepturus*) by Tucker (1956).

According to Regan (1909) the Trichiuridae and Gempylidae constitute the first division, Trichiuriformes, of his suborder Scombroidei of the order Percomorphi. Trichiuriformes was defined as having "caudal fin-rays not deeply forked at the base, the hypural in great part exposed. Premaxillaries beak-like, free from the nasals; mouth toothed, with lateral cleft; strong anterior canines. Epiotics separated by supraoccipital. Gill membranes free from the isthmus. Pectoral fins placed low".

Family Trichiuridae was defined by Regan thus: "Body very elongate, strongly compressed; maxillary sheathed by the preorbital; spinous dorsal, if distinct, not longer than soft; anal with numerous short spines; pelvic fins reduced to a pair of scale-like appendages or absent; caudal small or absent. Dorsal and anal rays corresponding to the vertebrae, each interneural or interhaemal attached to a neural or haemal spine; pelvic bones, if present, united to form a slender spicular bone connected with the cleithra by a long ligament. Vertebrae numerous, 100 (43 + 57) to 159 (39 + 120) or more; ribs feeble, sessile".

In the above generalised diagnosis of the family, attention is drawn to several important osteological characters some of which require modifications as stated by Tucker (1956) in a recent preliminary revision of the family. Certain other modifications based on a comprehensive study of the osteology of three genera and four species of ribbon-fishes of this family from the Indian waters were also suggested by the author (James, 1961) which are included in section II.

According to the latest systematic position (Tucker. 1956), the family Trichiuridae is further divided into three subfamilies which may be distinguished thus:

I. Frontal ridges not elevated, no sagittal crest. Profile of head rising very gently from snout tip to dorsal .... Aphanopodinae

II. Posterior confluence of frontal ridges elevated, forming a prominent sagittal crest at the nape, which may or may not be continued forward as ridge-like elevation of the ethmofrontal region.

A. Ventral fins present. Lateral line descending gently from the shoulder and median or sub-median along the body. Lower hind margin of operculum convex .... Lepidopodinae

B. Ventral fins absent. Lateral line descending steeply from the shoulder and running near the ventral profile of the body. Lower hind margin of operculum more or less concave. Caudal always absent............... Trichiurinae

In Indian waters, the subfamily Lepidopodinae is represented by the genus *Eupleurogrammus* including two species, *E. intermedius* and *E. muticus* and the subfamily *Trichiurinae* by two genera *Trichiurus* and *Lepturacanthus* both of which are monotypic, represented by *Trichiurus lepturus* and *Lepturacanthus savala*. A preliminary Key to the field identification of the above four species has been given by the author (James, 1959), and a detailed Key to the identification of the species based on an examination of more material is given below.

1. Key to Species of Indian Ribbon-fishes

I. Pelvic fins present appearing as scale-like structures about midway between tip of lower jaw and vent (2.1 to 6.1 eye diameters behind the posterior end of the pectoral base); lateral line gently sloping from upper angle of operculum to tip of tail.

A. Origin of anal below D. 31-34; D. III, 123-129;
Vertebrae 31-32 + 126-131 = 158-163 * .... *E. intermedius*

B. Origin of anal below D. 38-42; D. III, 139-147;
Vertebrae 39-42 + 150-159 = 189-201 .... *E. muticus*

II. Pelvic fins absent; lateral line abruptly descending from upper angle of operculum to below P_1, from whence it runs straight to tip of tail.

A. Eye 5.0-7.0 in head; D. III, 131-136; Vertebrae 38-40 + 127-137 = 167-175; second anal spine rudimentary; distal half of dorsal and pectoral fins tinged grey .... *T. lepturus*

B. Eye 5.6-9.7 in head; D. IV, 108-123; Vertebrae 33-37 + 131-152 = 167-187; second anal spine prominent: margin of dorsal fin greyish .... *L. savala*

* Variation in total number but not aggregate, in all species.

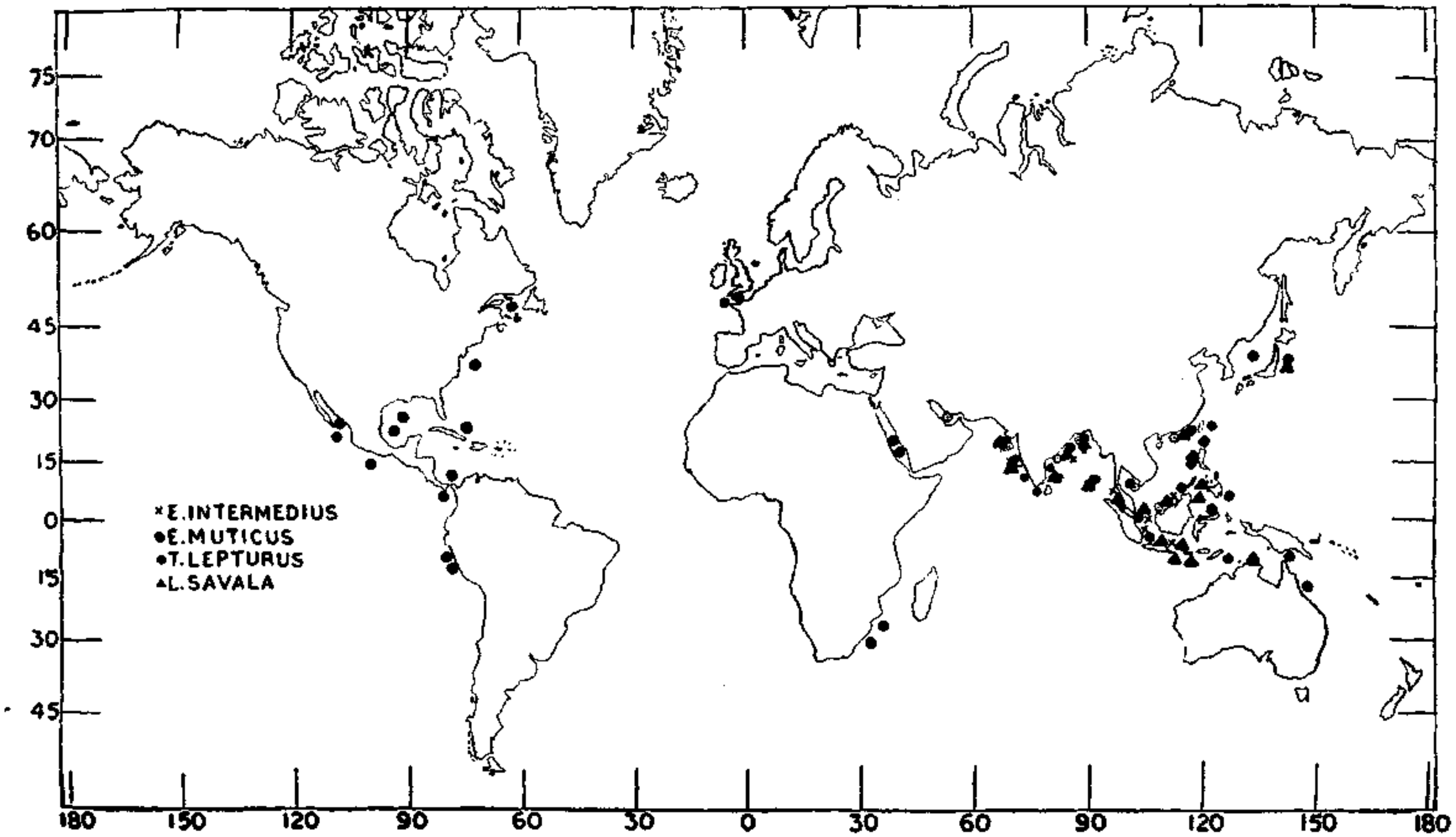

Fig. 2. World distribution of the four species of ribbon-fishes represented in Indian waters (the distribution of *T. lepturus* includes the distribution of all the species considered synonymous to it).

2. *Genus* EUPLEUROGRAMMUS *Gill*

Trichiurus (in part) Many authors from Linnaeus (1758).

Eupleurogrammus Gill, 1863, *Proc. Acad. nat. Sci. Philad.*, 1863: 226. Type species, *Trichiurus muticus* Gray.

Enchelyopus (in part) Bleeker, 1872, *Ned. Tijdschr. Dierk*, 4 (1872): 131.

Diagnosis : Body elongate, head 8.00-12.12 and depth (at vent) 10.83-23.15 in length (17.30-58.40 cm. standard length, 5.00-15.80 cm. snout-vent length), upper profile of head oblique, interorbital convex, eye diameter 5.10-7.68 in head; D. III, 123-129 or D. III, 139-147, aggregate 126-150; A. i + I, 113-121 or A. i + I + 113-122, aggregate 115-124, I, a small triangular scale-like structure behind vent, external fin suppressed, lower margin of operculum convex, operculum partly overlapping the pectoral base and fin; lacrymal covers two thirds length of maxilla and premaxilla; ventral fins scale-like, triangular or oval, 2.11-6.16 eye diameters behind the posterior end of pectoral base; caudal fin absent; vertebrae, 31-32 + 126-131 = 158-163 or 39-42 + 150-159 = 189-201; teeth, main series, upper jaw 7-12 or 12-25, lower jaw 7-12 or 16-23; gill rakers, main series, total 10-23; Pyloric caeca 7-12.

Two species

Distribution : Iranian Gulf, Coasts of India, Siam, China, Singapore, Sumatra, Java and Borneo.

Eupleurogrammus intermedius (Gray)
(Fig. 3,A)

Trichiurus intermedius Gray, 1831, *Zool. Misc. 1* : 10. Syn-types (3) B.M., (N.H.) No. 1869. 3. 19. 76. Type locality, Chusan.

Trichiurus medius Griffith, 1834, *Cuvier's Anim. Kingd. Pisces*, 349 (*nom. emend.* from Gray).

Trichiurus savala (*nec.* Cuvier, 1829) (part) Bleeker, 1852, *Verh. Bat. Gen.*, 24 Makr : 41 (Determination altered to *T. glossodon* by Bleeker).

Trichiurus glossodon Bleeker, 1860, *Acta Soc. Indo-Neerl., 8. Dertiende Bijdr. Vischf. Borneo* : 38. Type localities, Java, Sumatra, Singapore, Bintang, Borneo.
Delsman, 1927, *Treubia*, 9, Livr. 4 : 338.
de Beaufort, in de Beaufort and Chapman 1951, *Fish. Indo-Austr. Archip.*, 9 : 190.

Eupleurogrammus intermedius Tucker, 1956, *Bull. Brit. Mus. Nat. Hist. Zool.*, 4, (3) : 103.
James, 1959, *J. Mar. biol. Ass. India, 1* : 139-142.
Silas and James, 1960, *Ibid.*, *2* : 129-132.
James, 1960, *Ibid.*, *2* : 253-258.
James, 1961, *Ibid.*, *3* : 215-248.

D. III, 123-129; A. i + I + 113-121; Vertebrae, 31-32 + 126-131 = 158-163; teeth, main series, upper jaw 7-12, lower jaw 7-12; gill rakers, main series, total 10-23.

Distribution : Coasts of India, Singapore, Sumatra, Java, Borneo and Bintang (Fig. 2).

For a discussion of the species, see under *E. muticus.*

Eupleurogrammus muticus (Gray)

(Fig. 3,B)

Trichiurus lepturus (part) Linnaeus, 1758, *Syst. Nat.*, Ed. *10* : 246. Type locality, South Carolina.

Trichiurus muticus Gray, 1831, *Zool. Misc.*, *1* : 10, Holotype B.M. (N. H.) No. 1955. 5. 13.2. Type locality, India.
Gunther, 1860, *Cat. Fish. Brit. Mus.*, *2* : 348.
Day, 1876, *Fish India*, *2* : 200.
Klunzinger, 1884, *Fische, Rothen Meeres.*, 5 (1): 119-121-, pl. 12.
Fowler, 1936, *Hongkong Naturalist*, *7* : 77.
Lin, 1936, *Bull. Chekiang Prov. Fish. Exp. Station*, *2*:6.
Blegvad, 1944, *Danish Sci. Invest. Iran, Part 3*: 158.
de Beaufort, in de Beaufort and Chapman 1951, *Fish. Indo-Austr. Archip.*, 9 : 190.
Scott, 1959, *An introduction to the Sea fishes of Malaya*, 115.

Trichiurus muticus Vinciguerra 1926, *Ann. Mus. Civ. Genova*, *10* (3): 557.

Eupleurogrammus muticus Gill, 1863, *Proc. Acad. nat. Sci. Philad.*, 1863 : 226.
Tucker, 1956, *Bull. Brit. Mus. Nat. Hist. Zool.*, *4* (3): 105.
James, 1959, *J. Mar. biol. Ass. India*, *1*: 139-142.
Silas and James, 1960, *Ibid.*, *2*: 129-132.
James, 1960, *Ibid.*, *2*: 253-258.
James, 1961, *Ibid.*, *3*: 215-248.

Enchelyopus muticus Bleeker, 1872, *Ned. Tijdschr. Dierk.* *4* (1871): 131.

D. III, 139-147; A. i + I + 113-122; vertebrae 39-42 + 150-159 = 189-201; teeth, upper jaw 12-25, lower jaw 16-23; gill rakers, main series, total 13-22.

Distribution : Iranian Gulf, Coasts of India, Siam, China, Sumatra and Borneo (Fig. 2).

i. *Remarks* : Details given by Tucker (Table IV, p. 105) on the probable syntype of *T. glossodon* Bleeker shows lower values of body proportions and meristic counts from the syntypes of *Trichiurus intermedius* Gray. Bleeker (1860) himself suspected that *T. glossodon* may be identical with *T. intermedius* Gray which has hitherto been considered synonymous to *T. muticus.* Delsman (1927) and de Beaufort (1951) have indicated the distinction between *T. glossodon* and *T. muticus*. The present author's observations on several specimens of *E. intermedius* are comparable to those given by de Beaufort (1951) for *T. glossodon*, and of Tucker (1956) for *E. intermedius*. Although *T. glossodon* Bleeker is more widely recognised, *T. intermedius* Gray has priority and therefore, the former species is considered a synonym of the latter.

It is interesitng to note here that, although Gray (1831) has not given many details of body proportions or meristic data for what he calls *'Intermediate Trichiurus'* (*Trichiurus intermedius*, n.s.) and *'Armless Trichiurus'* (*Trichiurus muticus*, n.s.), his description of the former species as having among other characters, (1) 'front teeth very long, barbed, hinder ones moderate, rather distant', (2) 'tail rather short, thickish' and the latter species characterised by 'front teeth long, incurved, sample, hinder teeth small, close set', are good characters by which the above two species could be distinguished. However, it should be pointed out here, the broad spine mentioned by Gray in *T. intermedius* is more like a scaly structure, the front teeth in *T. muticus* are not simple but faintly barbed and his comment that there is no spine behind the vent in *T. muticus* is probably a mistake by oversight, for in this species, it is present but quite inconspicuous.

Trichiurus medius Griffith (1834) is considered a synonym of *T. intermedius* of Gray by Tucker (1956) as no new material is involved.

The two species of *Eupleurogrammus* were till recently placed under the genus *Trichiurus* with which they differ amongst other characters, in (i) the presence of ventral fins in the form of scale-like structures, (ii) the median lateral line, (iii) the rounded operculum, (iv) the uniseriate palatine teeth, (v) the hyaline nature of fins, (vi) the black lower margin of the lacrymal and (vii) a dark spot at the base of pectoral spine.

A closer examination of the two species reveals differences deeper than hitherto noticed. (i) The post anal portion of the body of *E. intermedius* ends abruptly while that of E. muticus gradually narrows down to end in a whip-like filament. (ii) point of greatest depth in *E. intermedius* is anterior to the anus, while it is at or behind anus in *E. muticus*. (iii) the snout is elongated and the dorsal profile gently slopes in *E. intermedius* while in *E. muticus* it is comparatively short and the dorsal profile sharply declevous, (iv) a parallel to long axis of body from snout passes through the lower margin of eye in *E. intermedius* but passes through the eye in *E. muticus*, (v) the ventrals are more conspicuous in *E. intermedius* than in *E. muticus*, (vi) the ventral profile of *E. intermedius* behind the vent is rough whereas it is smooth in *E. muticus*, indicating that the suppression of the anal is extreme in the latter, (vii) the canine-like teeth in *E. intermedius* are prominent and distinctly barbed with fewer other teeth which are widely spaced but in *E. muticus* the canine-like teeth are small, faintly barbed and other teeth small and close-set, (viii) the colour of *E. intermedius* in adult condition, is purely silvery whereas that of *E. muticus* is burnished silvery, (ix) *E. intermedius* as far as known, attains a maximum size of about 50 cm. standard length whereas *E. muticus* appears to grow beyond this length (58.4 cm. standard length recorded by the author).

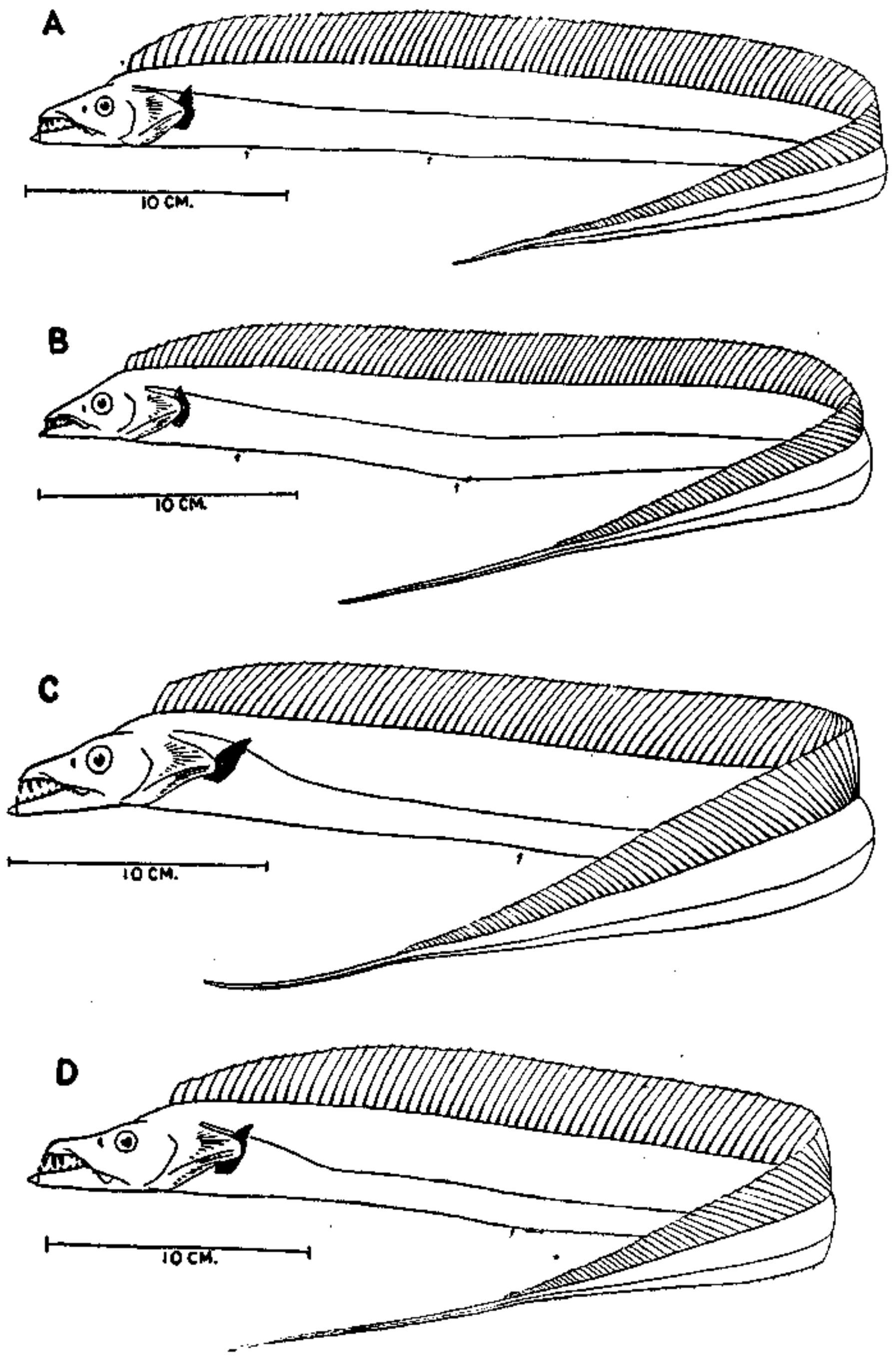

Fig. 3. A. *Eupleurogrammus intermedius* (Gray) B. *Eupleurogrammus muticus* (Gray) C. *Trichiurus lepturus* Linnaeus D. *Lepturacanthus savala* (Cuvier).

The anatomical characters in which the two species differ from one another are given elsewhere.

As rightly pointed out by Lin (1936), especially in a systematic study, it is advisable to compare the various body proportions with the snout-vent length rather than the standard length, since the tip of the tail of ribbon-fishes is liable to break frequently. In this study therefore, the ratios of body proportions have been calculated against the snout-vent length of the fish.

ii. *Morphometric characters* : Out of a number of morphometric characters studied, the following six characters were further analysed to find the degree of overlap between the two species : (1) Head length (snout to posterior end of operculum), (2) Height of head (vertical height at orbit), (3) Depth of body (vertical height at vent), (4) Eye diameter (maximum horizontal distance between the free margins), (5) Predorsal distance (snout to origin of dorsal fin) and (6) Height of longest dorsal fin ray (maximum vertical height). Details are presented in Table I and II. The size range for the two species is not strictly comparable but generally the proportions are indicative of the trend in each species.

TABLE I

Body proportions of E. intermedius and E. muticus as hundred times ratios to snout-vent length

Species	No. of specimens	Snout-vent length (range in cm.)	Range of ratio	Mean ratio	Standard deviation	Standard error
1. Head length						
E. intermedius	113	9.00–14.30	34.17–51.66	46.92	5.21	9.49
E. muticus	45	9.05–15.80	30.30–35.35	32.04	1.97	0.29
2. Height of head						
E. intermedius	113	9.00–14.30	13.29–17.17	14.86	1.56	0.14
E. muticus	45	9.05–15.80	13.25–15.32	14.46	1.42	0.21
3. Depth of body						
E. intermedius	114	9.00–14.30	20.10–25.20	22.88	2.35	0.22
E. muticus	45	9.05–15.80	17.36–25.00	22.18	2.52	0.37
4. Eye diameter						
E. intermedius	115	9.00–14.30	4.72—7.10	5.68	1.02	0.09
E. muticus	45	9.05–15.80	4.41—5.53	4.92	0.60	0.08
5. Perdorsal distance						
E. intermedius	115	9.00–14.30	22.58–28.10	24.46	2.10	0 19
E. muticus	43	9.05–15.80	19.85–24.73	22.20	1.10	0.16
6. Height of longest dorsal fin ray						
E. intermedius	115	9.00–14.30	11.20–16.48	13.64	1.41	0.13
E. muticus	45	9.05–15.80	10.72–12.87	11.68	1.55	0.23

TABLE II

Range of overlapping ratios of body proportions of E. intermedius and E. muticus

S. No.	Character	Range of overlapping ratio	*E. intermedius* No. of fish	*E. intermedius* Percentage	*E. muticus* No. of fish	*E. muticus* Percentage
1.	Head length	34.17 — 35.35	113	10.61	45	2.22
2.	Height of head	13.29 — 15.32	115	80.86	45	100.00
3.	Depth of body	20.10 — 25.00	114	96.40	45	86.66
4.	Eye diameter	4.72 — 5.53	115	37.39	45	71.11
5.	Predorsal distance	22.58 — 24.73	115	64 34	43	41.82
6.	Height of longest dorsal fin ray	11.20 — 12.87	115	14.78	45	75.55

From Tables I and II it may be seen that although the body proportions of the two species overlap in all the characters, the overlap is considerably less in the ratios of head length and the height of longest dorsal fin ray. The results are represented graphically (Fig. 4B) according to the improved graphical method of Hubbs and Hubbs (1953). A study of the divergence and intergradation between the two species (Table III) suggests that in addition to the above two characters, the predorsal distance may also be a useful character to compare them.

TABLE III

Percentage divergence and intergradation between E. intermedius and E. muticus

S. No.	Character	Divergence	Intergradation
1.	Head length	89.81	10.19
2.	Height of head	23.17	76.83
3.	Depth of body	13.55	86.45
4.	Eye diameter	60.37	39.63
5.	Predorsal distance	81.69	18.31
6.	Height of longest dorsal fin ray	79.60	20.40

iii. *Relative growth of body parts*: 225 specimens of E. intermedius (4.25-14.30 cm. snout-vent length) and 45 specimens of *E. muticus* (9.05-15.80 cm. snout-vent length) were examined for the relative growth of body parts and the six characters mentioned above were studied (Fig. 5).

It is noticed that the proportional *length of the head* decreases with age in both the species.

The *height of head* increases in proportion with age in both the species.

The *depth of body* increases more rapidly with increase in snout-vent length of the fish in both the species but at a decelerating rate.

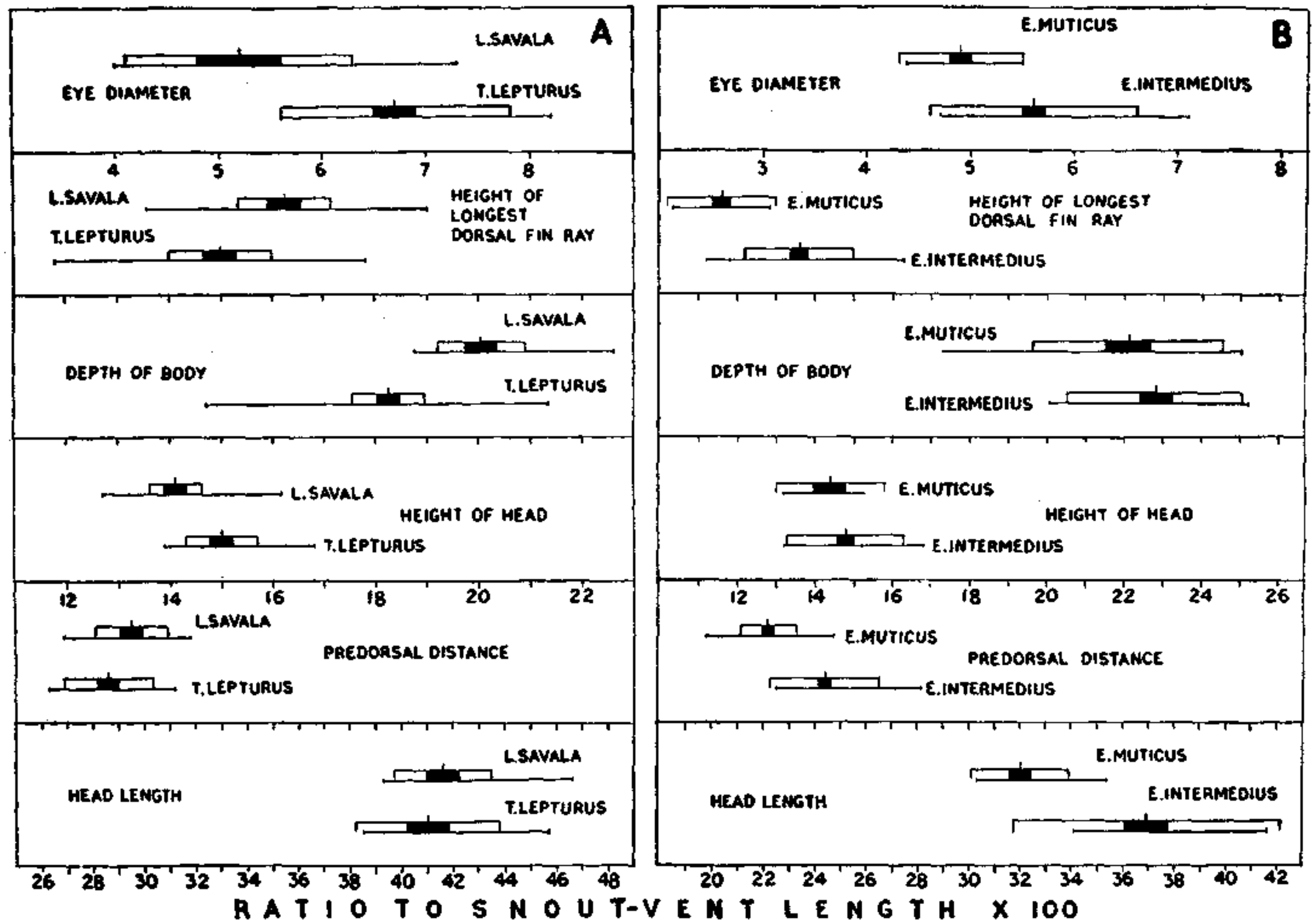

Fig. 4. A. Graphical representation of the variations in six morphometric characters of *T. lepturus* and *L. savala*
B. Graphical representation of the variations in six morphometric characters of *E. intermedius* and *E. muticus*.

The proportion of eye in young ones of both the species is greater than in the adults, and the *eye diameter* does not increase with increase in snout-vent length of the species.

The proportion of predorsal distance in case of *E. intermedius* decreases with increase in snout-vent length up to about 10 cm. and thereafter it seems to level off. In *E. muticus* also, a decrease in the rate of growth of this character may be seen but it does not appear to be so marked as in *E. intermedius*.

The *height of longest dorsal fin ray* is greater in proportion in the young ones of *E. intermedius* when compared to adults and its rate of growth decreases initially with increase in snout-vent length but ceases as the proportion levels off in larger fish. While the proportion of the height of the longest dorsal fin ray in the young ones of *E. muticus* is not known (for lack of data) the rate of growth of longest dorsal fin ray is equal to that of the snout-vent length in larger fish.

Therefore, it appears that the relative growth of head length, height of head, depth of body, eye diameter and predorsal distance follows more or less a similar pattern in the two species, whereas they seem to differ in the rate of growth of the height of longest dorsal fin ray with increase in snout-vent length of fish.

3. Genus TRICHIURUS Linnaeus

Lepturus Artedi, 1738, *Desc. Spec. Pisc.*, : 111, Type species, *Lepturus argenteus* Artedi.

Enchelyopus Klein, 1774, *Hist. Piscium*, : 51.

Gymnogaster Gronovius, 1754, *Mus. Ichth.*, *1* : 17, Type species, *Anguilla jamaicensis* Sloane.

Trichiurus Linnaeus, 1758, *Syst. Nat.*, *Ed. 10* : 246, Type species, *Trichiurus lepturus* Linn. ex Artedi.

Enchelyopus Bleeker, 1862, *Versl. Akad. Amsterdam*, *14* : 109, Type species, *Clupea haumela* Forskal.

Lepturus Gill, 1883, *Proc. Acad. nat. Sci. Philad.*, 1863 : 225 (*nec. Lepturus* Moehring, 1758; Brisson, 1760).

Diagnosis : Body elongate, head 6.48-8.04; depth 12.89-18.60 in length (29.50-77.20 cm. standard length, 9.45-30.20 cm. snout-vent length); eye 5.00-7.00 in head; D. III, 131-136; A. i + I + 103-109, I, a rudimentary spine behind the vent; external fin suppressed; lower margin of operculum concave, partly overlapping pectoral base and fin; lacrymal striated, fan-like, covers one third length of maxilla and premaxilla; ventrals absent; caudal absent; vertebrae 38-40 + 127-137 = 167-175; teeth, main series, upper jaw 9-14, lower jaw 9-14; gill rakers, main series total 10-21; pyloric caeca 23-41.

Probably a single variable species.

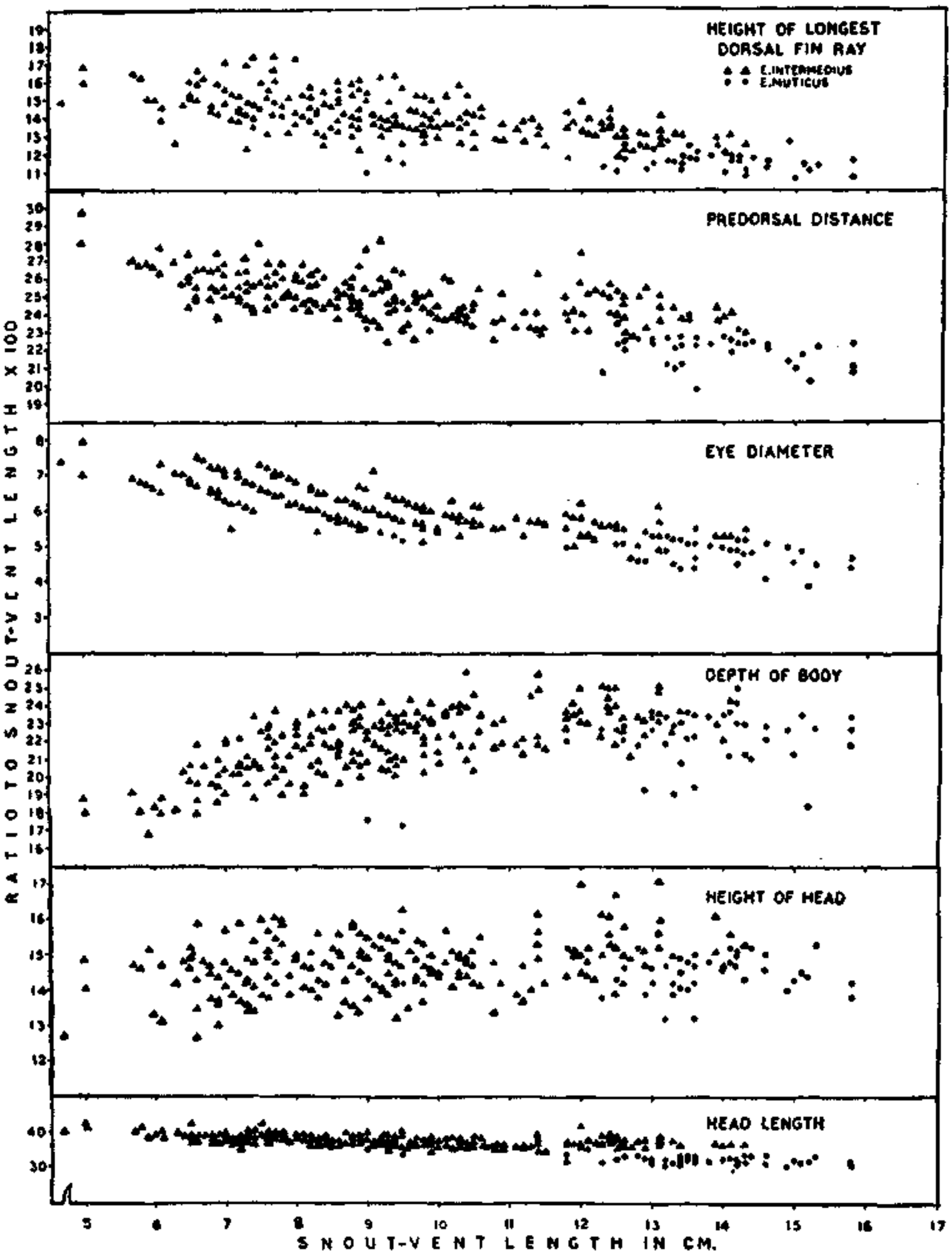

Fig. 5. Relative growth of body parts of *E. intermedius* and *E. muticus*.

Distribution : Tropical Atlantic coast of Brazil, Gulf of Maine, West Indies, Gulf of Mexico, North of Woods Hole, Massachusetts, Coast of Europe, Southern England, East Coast of Africa, Red Sea, Seas and estuaries of India, Andamans, Ceylon, Indo-Australian Archipelago, Sea of Japan, Sea of Mande, Coast of China, Philippine Islands, Australia, Pacific coast of tropical America including Gulf of California (Fig. 2).

*Trichiurus lepturus** Linnaeus

(Fig. 3,C)

Trichiurus lepturus (in part) Linnaeus (ex Artedi), 1758, *Syst. Nat. Ed. 10*: 246. Type in the Museum of the Royal University of Upsala. Type locality, South Carolina.
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Jordan & Evermann, 1896, *Bull. U.S. Fish. Comm.*, 1895.
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* See addendum

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Enchelyopus haumela Bleeker, 1862, *Versl. Akad. Amsterdam, 14* : 109.

Trichiurus malabaricus Day, 1865, *Proc. Zool. Soc. Lond.*, 1865 : 20, Holotype B.M. (N.H.) No. 1867, 5.30.2. Type locality, Cochin.

Trichiurus auriga Klunzinger, 1884, *Fische Rothen Meeres, 1* : 120, pl. 12, fig. 1. Type retained in Klunzinger's private collection, Stuttgart, Type locality, Kosseir, Red Sea coast of Egypt.

Weber, 1913, *Siboga Exp. Fische,* 406.
de Beaufort, in de Beaufort and Chapman, 1951, *Fish, Indo-Austr., Archip., 9* : 196.

Trichiurus coxii Ramsay and Ogilby, 1887, *Proc. Linn. Soc. N.S.W.*, 1887, 2 (2) : 562. Holotype Australian Museum, Sydney No. *I.* 1342. Type locality, Broken Bay, N.S.W.
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Trichiurus nitens Garman, 1899, *Mem. Mus. Comp. Zool. Harv., 26* : 69. Type locality, Coast of Peru.
Jordan, Evermann and Clark, 1930, *U.S. Commissioner of Fisheries Rep.*, 1928, pt. 2, 670 pp.
Breder, 1936, *Bull. Bingham Oceanogr. Coll. 2*, Art 3 : 12.
Hubbs and Hubbs, 1941, *Calif. Fish Game, 27* : 29.

Trichiurus savala Jordan and Seale, 1907, *Bull. U.S. Bur. Fish., 26* : 13.

Remarks : As noted above, several species have been recorded under the genus *Trichiurus* from various parts of the world. From the results of the present study on four species of trichiurids from Indian waters, it appears that the body proportions of all these species are subject to considerable variation. Tucker (1956) pointed out that the differences between *T. lepturus* of Atlantic and *T. haumela* of Indo-Pacific are not marked. The present author also had an opportunity to examine four specimens of *T. lepturus* from Atlantic ranging in size between 48.10-56.90 cm. standard length (17.40-22.30 cm. snout-vent length). The results of this examination are shown in Table IV with the average for five specimens of comparable length (17.70-22.50 cm. snout-vent length) from Indian waters.

TABLE IV

Body proportions of four specimens of T. lepturus as hundred times ratios to snout-vent length from Atlantic with average for five specimens from Indian waters

S. No.	Snont-vent length cm.	Head length	Height of head	Depth of body	Predorsal distance	Eye diameter	Height of longest dorsal fin ray
1. (Loc : Lagos)	22.30	40.80	14.79	18.16	29.47	6.50	14.12
2. (Loc : Lagos)	20.30	38.91	14.28	15.27	27.58	6.65	15.27
3. (Loc : Trinidad)	18.40	38.58	13.58	17.39	27.98	5.97	14.40
4. (Loc : Trinidad)	17.40	39.08	13.79	17.52	27.87	5.74	14.95
Average for five specimens from Indian Waters	17.70 22.50	41.11	15.25	19.60	29.23	6.42	15.04

Although the Indian specimens show slightly higher ratios for head length, height of head and depth of body, the ratios for the other three characters fall within the range for the Atlantic specimens. Generally, the specimens from the Atlantic and the Indian waters appear to be similar but for the brighter silvery colouration of the former.

Boeseman (1947) compared *T. lepturus* from Atlantic with *T. japonicus* Temmink and Schlegel from Pacific with the comment that the former showed a 'very distinct and constant difference'. The head in *T. lepturus* is larger (7.0-7.5 in length) while in *T. japonicus* it is smaller (8.1-8.6 in length). Basing on this difference he discriminated the two species. Lin (1936) described 12 specimens of *T. japonicus* and according to him, the head length varies from 7.0-9.4, which obviously covers the range of *T. lepturus* and *T. japonicus* described by Boeseman. A comparison of data for *T. japonicus* by Lin with the present author's data on the specimens from Indian waters reveals overlapping ratios of body proportions for the two species. The data of Lin on the depth in space between snout and anus varies between 5.1-6.0 (hundred times ratio to snout-vent length being 17.0-20.0) and the head length ranges between 2.5-2.7 (hundred times ratio to snout-vent length being 37.0-40.0). They show a close agreement with the present author's observations and it appears therefore, as Lin pointed out, that the series of intermediate forms makes it difficult to separate *T. japonicus* from *T. haumela* (=*T. lepturus*).

T. lajor Bleeker (1854) has been considered a synonym of *T. haumela* by Weber (1913) and de Beaufort (1951). The latter, on an examination of typical specimens of *T. lajor* commented that it is difficult to distinguish it from young of *T. haumela*.

T. malabaricus Day (1865) has been suppressed as a synonym of *T. haumela* by Day (1876) himself.

T. auriga Klunzinger (1884) was described originally by Klunzinger (1884, Red Sea) and later by Weber (1913, Timor Sea). de Beaufort (1951) redescribing Weber's specimen, commented that it is closely related to *T. haumela*, yet, distinguished it by the lesser height, larger eye, smaller pectorals and absence of barbs on the fangs. The two specimens described under this species are small (250 and 320 mm.) and hence the differences from *T. haumela* could be due to age.

T. coxii Ramsay and Ogilby (1887) has been reported so far only once and it does not appear to differ from *T. haumela* in the body proportions and the general description.

T. nitens Garman (1899) was originally described by its author as closely allied to *T. lepturus*, differing from the latter in length of snout, size of eyes and number of dorsal fin rays the details of which are as follows :

T. nitens	*T. lepturus*
D. 120-127, A. 94-103	D. 134-137, A. 101-106
Eye $5\frac{1}{3}$ in head, $1\frac{3}{5}$-$1\frac{3}{4}$ in snout.	Eye $\frac{1}{13}$ of head and 2 or more in snout
Snout to base of pectoral $7\frac{1}{8}$-$7\frac{1}{5}$ in total length	Snout to base of pectoral 8 in total length
Depth $17\frac{1}{2}$-19 in total length, $\frac{2}{5}$ length of head	Depth 16 in total length

Higgins (1921) reported two specimens from California but referred them to *T. lepturus*. Meek and Hildebrand (1923) examined eleven specimens of *T. lepturus* from Atlantic and four from the Pacific, although pointing out certain differences, they have not separated the fish from the two oceans into two distinct groups. Jordan, Evermann and Clark (1930) referred to *T. nitens* as a valid species, occurring in Galapagos Islands. Breder (1936) compared his data with that of Garman for *T. nitens* and of Meek and Hildebrand for the Pacific and Atlantic *T. lepturus*, giving an illustration of *T. nitens* Garman. As far as the number of dorsal rays and the proportion of maxillary are concerned, a close agreement could be noticed between the aforesaid authors (Breder, Table III, p. 13) and basing on this data, Breder constructed a key to separate *T. lepturus* from *T. nitens*. Hubbs and Hubbs (1941) mention three specimens from California as having 120-122 dorsal rays, eye 1.8-2.0 in snout, upper jaw 2.7 in head. According to them, four specimens from Atlantic have 134-141 dorsal rays, eye 2.3-2.4 in snout and upper jaw 2.4-2.6 in head. They also state that the sharpest distinction lies in the weaker dentition of the Pacific species, with its range of distribution from Southern California to Peru.

The body proportions furnished for the Pacific cutlass-fish (*T. nitens*), by various authors overlap with those for the specimens from Indian waters, as also noticed for the other species listed above. However, the mean dorsal fin ray count for thirteen specimens from Indian waters was noticed to be 132 (James, 1961) as against 132.9 for eleven specimens from Atlantic and 122.5 for four specimens of *T. lepturus* from the Pacific (Meek and Hildebrand), the Pacific fish having a much lower count than the Atlantic and Indian material. While this constitutes a good difference, more information about other meristic counts like the anal rays, vertebrae of the Pacific material seems necessary to substantiate the conclusions so far drawn, and hence, *T. nitens* is retained as a doubtful synonym of *T. lepturus*.

In conclusion, it may be remarked, although vast literature exists on the genus *Trichiurus*, no standard method had been employed so that the results of various authors from different parts of the world could be compared. On the other hand, especially in case of body proportions of the ecaudate species, it will be helpful if ratios of various morphometric characters are given uniformly as ratios to snout-vent length ,obviously to avoid the differences arising out of the frequent breaking of the tip of tail. As to the meristic data, they may be accurately enumerated by radiographs or by staining. The present author's experience has shown that there are a number of very minute dorsal and anal rays towards the termination of the fins of these fishes which may not be noticed with naked eye in fresh specimens.

4. Genus LEPTURACANTHUS Fowler

Trichiurus (in part) many authors.

Lepturacanthus (sub-genus of *Trichiurus* Linnaeus) Fowler, 1905, *Proc. Acad. nat. Sci. Philad.*, 1904 : 770. Type species *Trichiurus savala* Cuvier.

Diagnosis : Body elongate, head 7.10-10.00, depth 14.80-22.10 in length (14.60-56.40 cm. standard length, 3.95-19.70 cm. snout-vent length); eye 5.60-9.70 in head; D. IV, 108-123; A. i + 1 + 77-93, I, usually a prominent spine behind the vent, anal spinules clearly break through the ventral profile of body; lower margin of operculum concave, partly overlapping the pectoral base and fin; lacrymal striated, fan-like, covers one third length of maxilla, ventrals absent, caudal absent; vertebrae, 33-37 + 131-152 = 167-187; teeth, main series, upper jaw 7-15, lower jaw 7-15; gill rakers, main series total 3-13, pyloric caeca 15-16.

Monotypic.

Distribution : India including Andaman Islands, Singapore, Riouw, Bintang, Banka, Sumatra, Java, Bali, Sumbawa, Borneo, Reunion, Siam, Malaya, China, Japan, Philippines and North Australia (Fig. 2).

*Lepturacanthus savala** (Cuvier)

(Fig. 3,D)

Trichiurus savala Cuvier, 1829, *Regne Animal.*, 2 Ed. *2* : 219.

Syntypes in Paris Museum, Reg. No. a 5357-5358. Type locality, "Merdes Indes" (= Bombay and Malabar).

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Bleeker, 1852, *Verh. Bat. Gen., 24* : 41.

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Lin. 1936, *Bull. Chekiang Prov. Fish. Exp. Station,* 2 : 5.

Herre, 1933, *Jour. Pan Pacific Research Inst.*, 8 : 3.

* See addendum

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de Beaufort, in de Beaufort and Chapman, 1951, *Fish. Indo-Austr. Archip.*, 9 : 193-194.
Jones, 1951, *J. Zool. Soc. India, 3* : 131.
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i. *Remarks*: *Trichiurus armatus* Gray (1931) (*Armed Trichiurus*) considered a synonym of this species is characteristically described by its author as having 'fore head depressed, front teeth very large, barbed behind, intermaxillary bones very long, body compressed with a series of minute spines beneath'. It is noteworthy that there is no mention of the prominent dagger-like spine behind the vent for this species in the above description.

Trichiurus roelandti Bleeker (1860) was re-examined by de Beaufort (1951) and considered a synonym of *T. salava* (= *L. savala*). According to de Beaufort, the relatively shorter head, smaller eyes, longer tail, maxillary reaching to below hind border of eye mentioned by Bleeker are due to age.

A comparison of *Trichiurus* with *Lepturacanthus* reveals that they are closely related to each other and widely separated from other trichiurids. Although they share many characters, they still differ in several respects and this was expressed by Fowler (1905) in raising *Lepturacanthus* to a sub-generic status of *Trichiurus*. Tucker (1956) pointed out that the divergence between the two is comparable to that between *Aphanopus* and *Benthodesmus* and hence consistency requires elevation of *Lepturacanthus* to full generic status.

ii. *Morphometric characters* : The body proportions of *T. lepturus* and *L. savala* and the degree of overlap between them, measurements of the six morphometric characters defined earlier (in case of *Eupleurogrammus*) were further analysed and the details are presented in Tables V and VI. The stage of development (range in size of the fish) has not been kept uniform on which depend the mean, standard deviation and the standard error. However, they indicate the trend in each species but no strict comparison could be made.

TABLE V

Body proportions of T. lepturus and L. savala as hundred times ratios to snout-vent length

S. No.	Species	No. of speci-mens	Snout-vent length (Range in cm.)	Range of ratio	Mean ratio	Standard deviation	Standard error
1.	**Head length**						
	T. lepturus	43	9.45–30.20	38.59–45.67	41.06	2.88	0.43
	L. savala	32	9.30–19.70	39.38–46.66	41.61	1.93	0.34
2.	**Height of head**						
	T. lepturus	43	9.45–30.20	13.94–16.87	15.05	1.48	0.22
	L. savala	32	9.30–19.70	12.74–16.19	14.22	1.09	0.26
3.	**Depth of body**						
	T. lepturus	43	9.45–30.20	14.73–21.33	18.50	1.46	0.22
	L. savala	33	9.30–19.70	18.84–22.63	20.14	1.71	0.30
4.	**Eye diameter**						
	T. lepturus	43	9.45–30.20	5.62—8.23	6.76	1.11	0.16
	L. savala	32	9.30–19.70	4.06—7.36	6.28	1.13	0.20
5.	**Predorsal distance**						
	T. lepturus	43	9.45–30.20	26.31–31.27	28.63	1.78	0.27
	L. savala	32	9.30–19.70	26.90–31.82	29.50	1.48	0.26
6.	**Height of longest dorsal fin ray**						
	T. lepturus	43	9.45–30.20	11.83–17.88	15.06	2.06	0.31
	L. savala	31	9.30–19.70	13.65–19.04	16.55	1.82	0.32

TABLE VI

Range of overlapping ratios of body proportions of T. lepturus and L. savala

S. No.	Character	Range of overlapping ratio	*T. lepturus*		*L. savala*	
			No. of fish	Percentage	No. of fish	Percentage
1.	Head length	39.38 — 45.67	43	81.20	32	96.72
2.	Height of head	13.94 — 16.19	43	95.12	32	84.24
3.	Depth of body	18.84 — 21.33	43	41.76	32	87.36
4.	Eye diameter	5.62 — 7.36	43	81.20	32	31.20
5.	Predorsal distance	29.90 — 31.27	43	92.80	32	93.60
6.	Height of longest dorsal fin ray	13.65 — 17.88	43	81.20	31	81.12

As may be seen from Tables V and VI the body proportions of the two species overlap in all the six characters, but the degree of overlap is considerably less in case of depth of body and eye diameter (Fig. 4,A).

Studies on the divergence and intergradation between the two species (Table VII) indicate that the diameter of eye shows a good difference between the species.

TABLE VII

Percentage divergence and intergradation between T. lepturus and L. savala

S. No.	Character	Divergence	Intergradation
1.	Head length	15.40	84.60
2.	Height of head	37.93	62.07
3.	Depth of body	38.36	61.64
4.	Eye diameter	77.46	22.54
5.	Predorsal distance	25.79	74.21
6.	Height of longest dorsal fin ray	33.60	66.40

iii. *Relative growth of body parts* : Data for *T. lepturus* and *L. savala* are not adequate for a detailed discussion or comparison. Hence only a scatter diagram is presented (Fig. 6).

iv. *Colour of ribbon-fishes* : The characteristic silvery colouration of these fishes is due to the presence of lustrous particles present in the epidermis, which contain considerable amounts of ash, fat, uric acid, and lipids besides nitrogenous compounds and guanine which is the chief constituent (Fuyuo, 1954). It is also well known that the type of silver colouration depends on age, the amount of oil in the tissues and the nature of guanine particles.

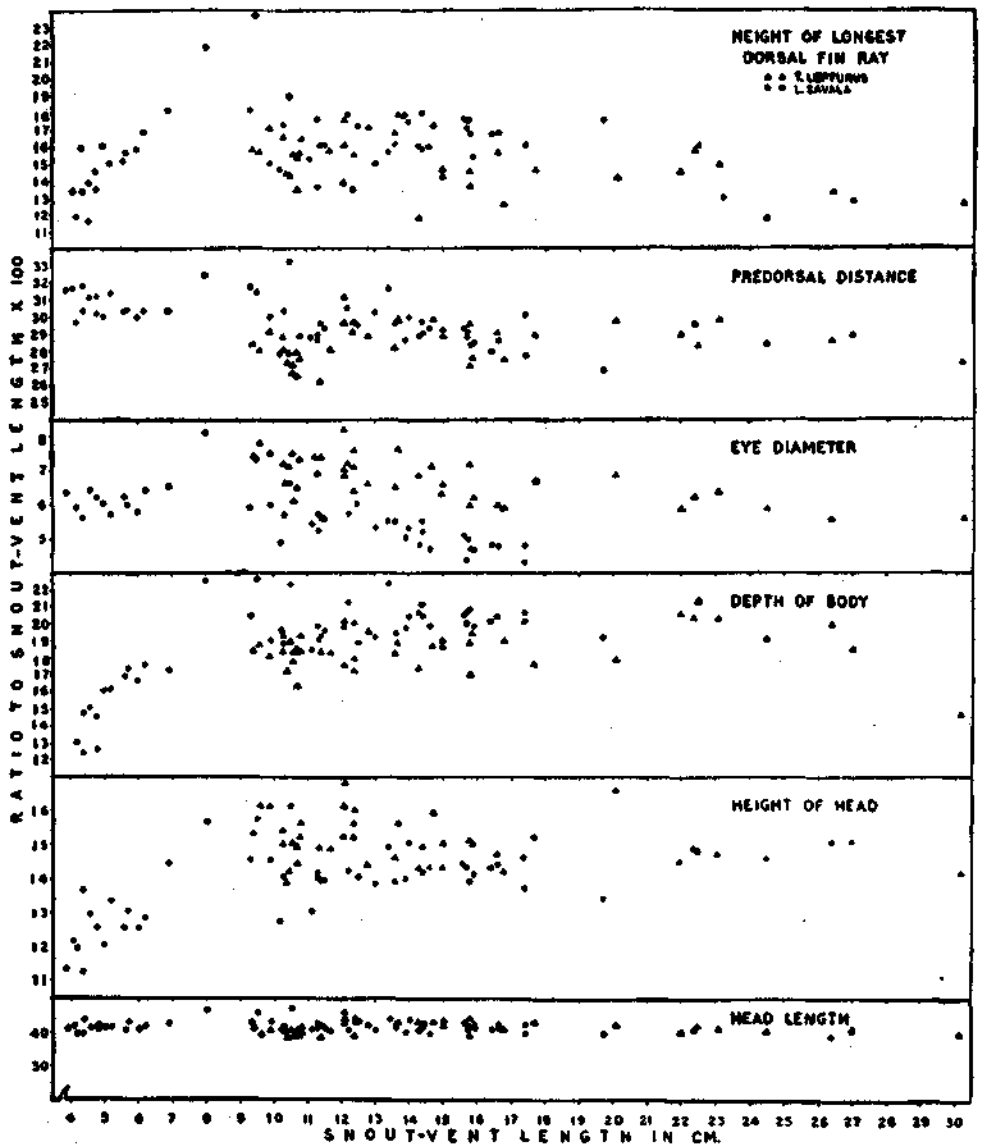

Fig. 6. Relative growth of body parts of *T. lepturus* and *L. savala*.

Some observations based on an examination of fresh and preserved material of the four species from Indian waters over a wide range of size are mentioned below. The colour of all species has been observed to change on preservation in 5% formalin. Fresh specimens of adults of *E. intermedius* appear bright silvery whereas those of *E. muticus* have a burnished silvery colouration. The fins of both species are hyaline except a dark spot at the base of pectoral spine. The lower margin of preorbital, the tip of snout and lower jaw and the tip of tail are black in both species. Adults of *T. lepturus* are grey along the back and silvery on the abdomen. The distal half of pectorals and dorsal are tinged grey. Tips of the jaws and tail are black. Adult specimens of *L. savala* are silvery, pectorals and dorsal hyaline except the margin of dorsal which is grey, the tip of snout and lower jaw are black. In some large specimens of both *T. lepturus* and *L. savala,* the pectorals and the dorsal fin attain a light yellow colour.

The young ones of all the four species are equally bright, being silvery in colour and differ from the adults in their pigmentation, which will be discussed in detail in a later section.

The lustrous particles in the epidermis of *T. haumela* (= *T. lepturus*) are utilized as a principal source of pearl essence in making imitation pearls (Fuyuo, 1954). Although this species appears darker than others, its comparatively larger size and greater abundance may be responsible for its being preferred for this purpose.

The results of the present study may be summarised as follows: (i) The body proportions of all the four species are subject to considerable variation. (ii) Between *E. intermedius* and *E. muticus* there is no overlap of the range of precaudal, caudal, total vertebrae, dorsal fin ray count and the number of vertebra up to which the dorsal and anal fin rays extend. (iii) Between *T. lepturus* and *L. savala* there is no overlap of the range of precaudal vertebrae, dorsal fin ray count, the anal fin ray count and the number vertebra up to which the dorsal and anal fin rays extend. (iv) For the character, height of longest dorsal a negative allometry is observed with increase in snout-vent length in case of *E. intermedius* whereas, the growth in height of longest dorsal fin ray is maintained equal to increase in snout-vent length in *E. muticus.* (v) Apart from meristic characters, it appears that the characters head length, predorsal distance and the height of longest dorsal fin ray are useful to compare *E. intermedius* with *E. muticus,* (vi) A study of the recorded distribution of the four species indicates that, except for *T. lepturus,* the other species are confined to the Indo-Pacific region.

Part Two

ANATOMY

II

COMPARATIVE OSTEOLOGY WITH REMARKS ON THE PHYLOGENY OF RIBBON-FISHES

Our present knowledge about the osteology of the ribbon-fishes is very meagre. Gunther (1860) has outlined some general osteological characters of *Trichiurus lepturus* and Starks (1911) and Gregory (1933) have made some remarks on the skull of the same species, while the osteological characters of the other two genera have not been examined so far. Regan (1909) made reference to some general osteological features of Trichiuriformes, including the Trichiuridae and Gempylidae.

Herein, an attempt is made to make a comprehensive and comparative study of the osteology of ribbon-fishes from Indian waters. From this study, it is also aimed to draw a clear distinction between the different species based on osteological characters, as many similarities and differences have been noticed amongst the species under investigation. A brief discussion of these characters and their systematic significance is given, together with an osteological key.

In comparing the osteology of the four species it was noticed that while they have many features in common, two of them viz. *T. lepturus* and *L. savala* share certain characters and stand apart from the two species of *Eupleurogrammus*. Hence a detailed description of the osteology of *T. lepturus* which appears to be the most widely distributed of all four species is given below, and the characters in which other species differ from it are mentioned. A comparison of these with other genera of the family is made, to infer their possible phylogenetic relationship. For this purpose, the works of Allis (1903), De Sylva (1955), Francisco (1956), Gregory (1933), Gunther (1860), Starks (1910, 1911) and Kishinouye (1923) have been a valuable aid.

The material for the study has been collected from different fish landing centres along the Indian coast and all the four species have been examined in different sizes. The majority of the fishes examined were obtained from local fish landing places on the Gulf of Mannar and Palk Bay.

Skeletons were prepared for study by cooking the fresh fish in water. It has been found easy first to boil the water and then keep the specimen in it just long enough (about 5 minutes) to loosen the muscles from the bones. The bones of the skull of all species were disarticulated and studied. Alizarin staining technique as employed by Hollister (1934) referred to by Clothier (1950) was used with slight modifications to study the skeleton *in situ*. The following procedure has been adopted for alizarin staining, which gave good results : For all preparations 4% KOH in distilled water was used. Staining solution was prepared by the following formula :—

Glacial Acetic acid	..	0.5 c.c.
Glycerine	..	3.0 c.c.
Chloral hydrate	..	10.0 c.c.
Alizarin stain	..	0.1 gm.

Specimens were first hardened and kept straight in 5% formalin for 10-15 days. They were washed thoroughly under running tap water and then placed in 4% KOH. They take 2 to 4 weeks to become transparent, and ready for staining. The staining solution is added drop by drop to fresh KOH containing the specimens till it showed a violet-pink colour. The specimens take stain in 2 to 7 days depending on the size as well as the species. After they are stained, the used up solution was pipetted out, fresh KOH and increasing quantities of glycerine were added at regular intervals and preserved finally in pure glycerine. At each stage they were kept at least for 48 hours. Young individuals take less time to clear and the bones are much clearer than in older groups. Radiographs of a dozen specimens of each species ranging in size between 25-65 cm. S.L. were also examined.

In naming the various bones of the skeleton Clothier (1950), Ford (1937), Gregory (1933), Gunther (1860), Harrington (1955), Kishinouye (1923), Ramaswami (1952) and Starks (1901, 1910, 1911) were followed.

1. General Features

The very elongate, narrow shape of the skull (Figs. 7 and 8) reflects the highly carnivorous nature of these fishes. The bones of the skull are thin, except those of the jaws. Gunther (1860), and Starks (1911) have remarked that the skull of *T. lepturus* is very similar to that of *Lepidopus* Gouan and *Aphanopus* Lowe belonging to the two other sub-families under Trichiuridae. Gregory (1933) has drawn attention to the close similarity of the skulls of *Trichiurus* Linnaeus and gempylids. Except for minor details the skulls in the other two genera viz. *Eupleurogrammus* and *Lepturacanthus* also resemble those of *Lepidopus* and *Aphanopus*.

The main features of the skeleton may be summarized as follows: Bones thin and light; neurocranium elongate and laterally compressed; supraoccipital crest low; posterior confluence of the frontals elevated to a median crest; dorsal surface of the skull with grooves and ridges posteriorly; dermethmoid cylindrical, forked posteriorly; vomer devoid of teeth, broad at the anterior end and tapering to a sharp point posteriorly; nasals long, and narrow; maxilla broadest at the posterior end and premaxilla at the anterior end; lower jaw tipped with a triangular piece of cartilage; premaxilla and dentary forming upper and lower margins of the mouth cleft; maximum of 3 canine-like barbed teeth anteriorly on each premaxilla and one on each dentary, the latter tooth remaining outside when the mouth is closed; these followed by variable number of smaller and simpler teeth on both jaws; palatine teeth in series or in villiform band; sub-orbital ring incomplete, lacrymal most prominent, membranaceous and sculptured; head of hyomandibular cruciform; margins of opercle and subopercle fringed; preopercle strong and bony with prominent ridges in the shape of 'Y'; pterotics produced posteriorly into spine-like processes; alisphenoids, simple, triangular; number of gill rakers variable and prominent on the outermost arch; vertebrae numerous, extending to tip of tail; ribs fragile; interneurals and interhaemals usually correspond to neural and haemal spines; pelvic girdle and fins absent or reduced; dorsal and anal fin rays numerous.

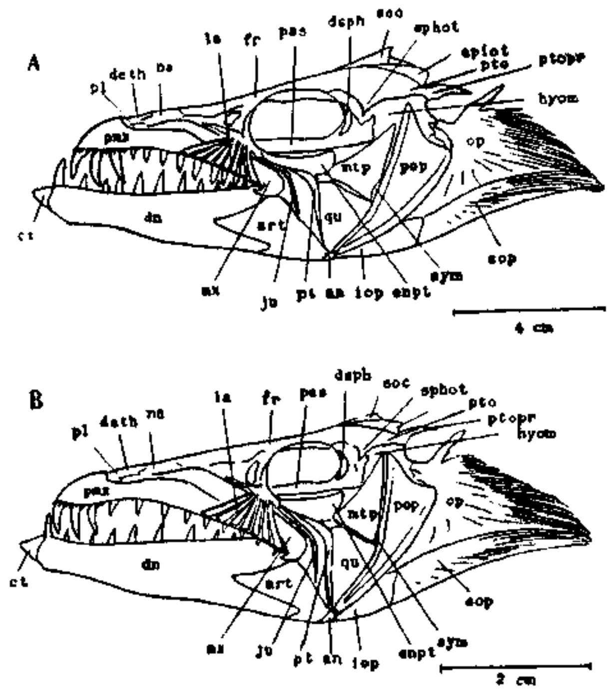

Fig. 7. Skull, lateral view. A. *Trichiurus lepturus.* B. *Lepturacanthus savala.*

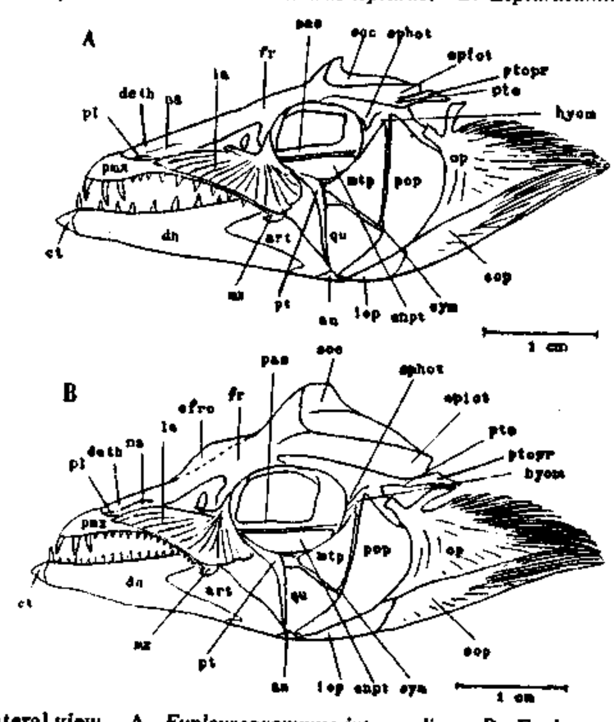

Fig. 8. Skull, lateral view. A. *Eupleurogrammus intermedius.* B. *Eupleurogrammus muticus.*

2. Neurocranium

The neurocranium (Figs. 9-13) in the three genera is long and narrow, broadest at the posterior end. The dorsal surface is more or less flat in *T. lepturus* and *L. savala* while it is convex in *Eupleurogrammus*. The dorsal profile in a complete specimen is sharply declevous to the snout from nape in *E. muticus*. Along the dorsal surface, the median ridge is not prominent except at tha supra-occipital region. On either side are three grooves, separated by 2 ridges of bone,

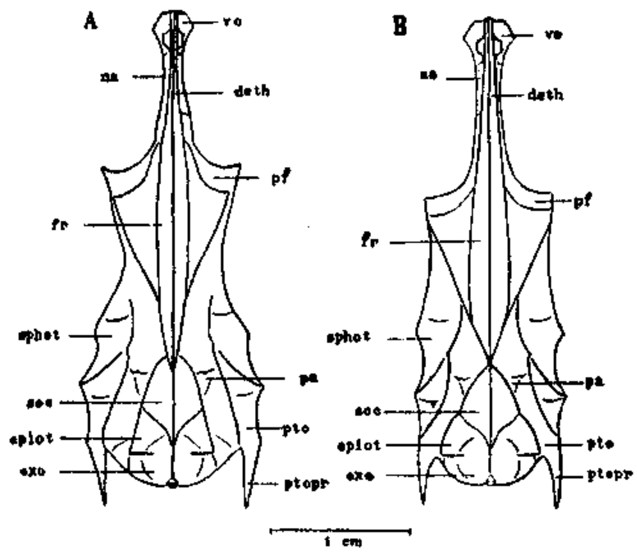

Fig. 9. Neurocranium, dorsal view. A. *T. lepturus* B. *L. savala.*

viz. the dilator, temporal and supratemporal grooves extending from the outer to the inner regions of the skull respectively. Unlike in *E. intermedius* the median ridge is carried forward by the frontals to the dermethmoid (ethmofrontal crest) in *E. muticus*, such a prominent crest being absent in the other two species resulting in lesser height of the neurocranium and consequently of the head. The supraoccipital crest is very feeble in all the species.

The grooves and ridges present a variable pattern over the dorsal surface of the skull. They are well defined only in *T. lepturus*. The temporal and pterotic ridges are quite distinct and run more or less parallel. The *temporal ridge* in *T. lepturus* stops short and fades into the general surface at about the posterior confluence of frontals. It presents posteriorly a flap-like projection whereas the outer terminates laterally and anterior to pterotic. In *L. savala* the ridge is much shorter and stops short anteriorly at the lateral mid-portion of supraoccipital presenting a flap-like projection posteriorly as in *T. lepturus*. In *E. intermedius* this ridge runs forward and terminates at the posterior end of the nasal, while in *E. muticus* it curves laterally merging with the general surface about the middle region of the orbit. The external or *pterotic ridge* in *T.*

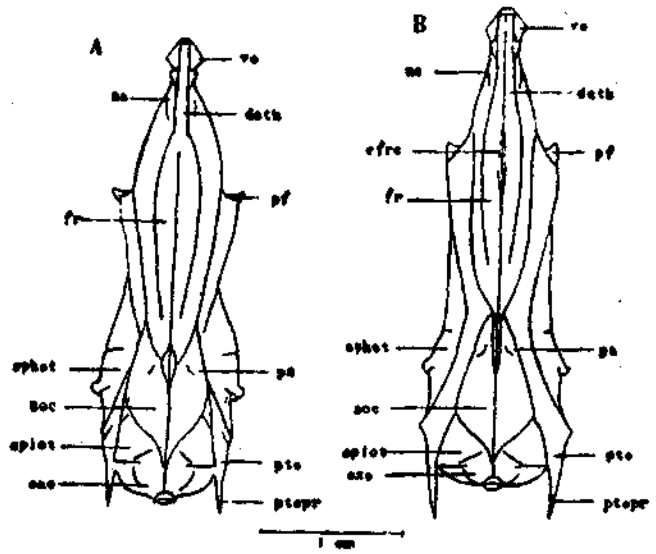

Fig. 10. Neurocranium, dorsal view. A. *E. intermedius*. B. *E. muticus*.

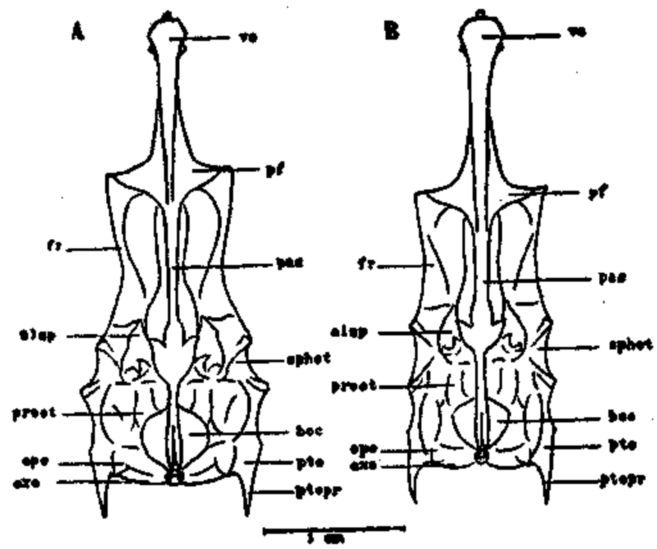

Fig. 11. Neurocranium, ventral view. A. *T. lepturus*. B. *L. savala*.

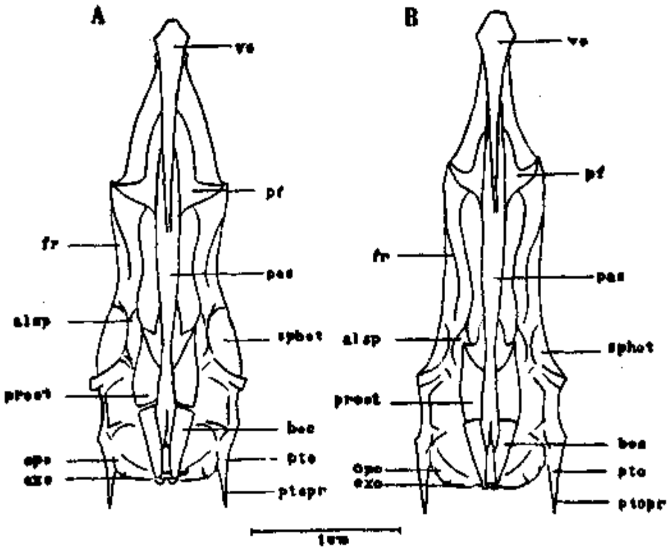

Fig. 12. Neurocranium, ventral view. A. *E. intermedius*. B. *E. muticus*.

lepturus extends forward to the mid-level of the orbit and fades into general surface. Posteriorly it merges with the lateral side of the pterotic bone. In its anterior course, it is deeply curved and runs parallel to the frontal ridge. In *L. savala* this ridge is very similar to that of *T. lepturus* but the anterior extremity is not parellel to the frontal ridge and being apparently approximated with the latter. The external ridge is very short in *E. intermedius* and it unites with the internal ridge at the level of supraoccipital to continue forward to the nasal. A similar condition is seen in *E. muticus* where it joins the internal ridge but terminates above the mid-level of the orbit. *The dilator groove* is much deeper and wider in *T. lepturus* and *L. savala* than in the species of *Eupleurogrammus*. The middle or *temporal groove* is broad in *T. lepturus* and very narrow and short in *L. savala* and *Eupleurogrammus*. It is relatively shorter in *E. intermedius* than in *E. muticus*. The groove is the biggest and broadest in *T. lepturus*, but shortest and narrowest in *L. savala* among the four species. The *supratemporal groove* is the widest of the grooves. It is comparatively shallower in *L. savala* than in the other forms.

The orbits are large in *T. lepturus* about $1/3$ length of neurocranium while they are small in *L. savala* measuring less than $1/8$ of the neurocranium. They are nearly equal in size in *Eupleurogrammus* species but less than $1/8$ the length of neurocranium.

3. Individual Bones of the Skull
(Figs. 14-17)

Olfactory Region : The dermethmoid (*deth*-17) is median and forked posteriorly. It is more or less cylindrical enclosing a cavity. Anteriorly it rests over three protuberances of the vomer, and posteriorly overlapped by the anterior ends of

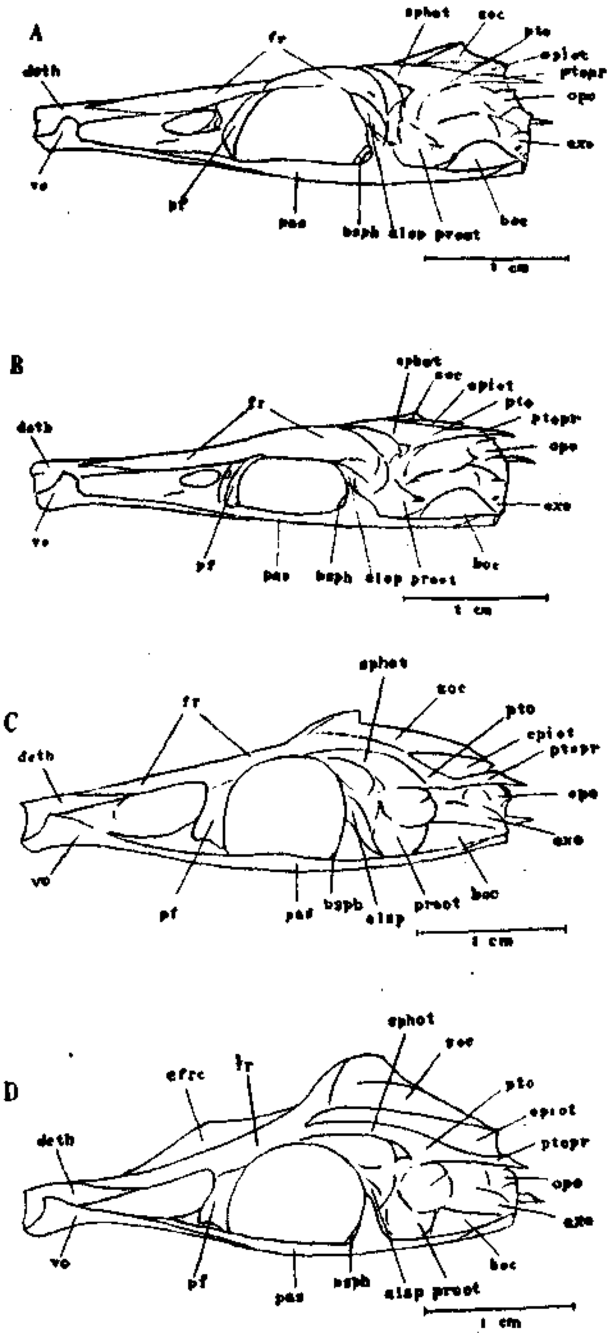

Fig. 13. Neurocranium, lateral view. A. *T. lepturus*. B. *L. savala*. C. *E. intermedius*. D. *E. muticus*.

frontals. Posterolaterally it is bounded by the prefrontals. At the anterolateral portion the dermethmoid supports the nasals. The anterior tip of the dermethmoid is blunt in *T. lepturus* and *L. savala* while it is sharp in *Eupleurogrammus.*

The *prefrontals* (*pf*-23) are two irregular bones, forming the anterior wall of the orbit and the posterior mesial walls of the nasal cavity. The bones meet along the median line and articulate above with the frontals, anteriorly with the lateral extensions of the dermethmoid and posteroventrally with the parasphenoid. The anteroventral extension of the bone found in *T. lepturus* and *L. savala* is absent in *Eupleurogrammus.* On the other hand there is a sharp anterodorsal process in *E. intermedius* and *E. muticus* which is absent in *T. lepturus* and *L. savala.*

The *nasals* (*na*-27) are elongate, flat bones, cemented along their entire length to the anterolateral sides of the dermethmoid. The nasals of *T. lepturus* and *L. savala* are alike and those of *E. intermedius* and *E. muticus* resemble each other. The nasals of the former two species differ from the latter two in that they are longer and slightly bent anteriorly.

The *vomer* (*vo*-16) is broad at the anterior end and narrows down to a long process posteriorly which ends in a sharp point. Anteriorly it articulates with the maxilla and posteriorly it lies in the groove on the external side of parasphenoid. It presents three protuberances at the anterior inner extremity, on which the dermethmoid rests. The vomer is devoid of teeth in all species. In *T. lepturus* and *L. savala* the anterior articulatory facet is short and straight while in *Eupleurogrammus* it is long and upturned.

Orbit Region: The paired *frontals* (*fr*-15) form the largest portion, approximately 2|3 of the dorsal roof of the skull. The bones are pointed anteriorly and cover the bifurcated posterior end of dermethmoid. Posteriorly they are broad. The frontals are closely approximated over their entire length, except at their anterior tips which diverge and partly cover the dermethmoid. The posterior confluence of the frontals is elevated in *T. lepturus* to a low crest which is least developed in *L. savala,* highest in *E. muticus.* The frontal crest in *E. intermedius* resembles that of *T. lepturus.*

Anteriorly the frontals lie over the posterior end of dermethmoid and the dorsal ends of the parethmoids. Laterally they contribute to the roof of the orbit and posteriorly they are connected with the supraoccipital, sphenotics, parietals, alisphenoids and pterotics.

The *alisphenoids* (*alsp*-24) are paired, small, triangular bones. They form the posterodorsal angle of the orbit wall and articulate with the sphenotics, prootics and basisphenoid. As in all scombroids, they do not articulate with parethmoids.

The *parasphenoid* (*pas*-13) is more or less similar in shape in all the genera and species. The part of the parasphenoid opposite the orbital cavity (when the neurocranium is viewed ventrally) is slightly broader in *Eupleurogrammus* than in the other two genera.

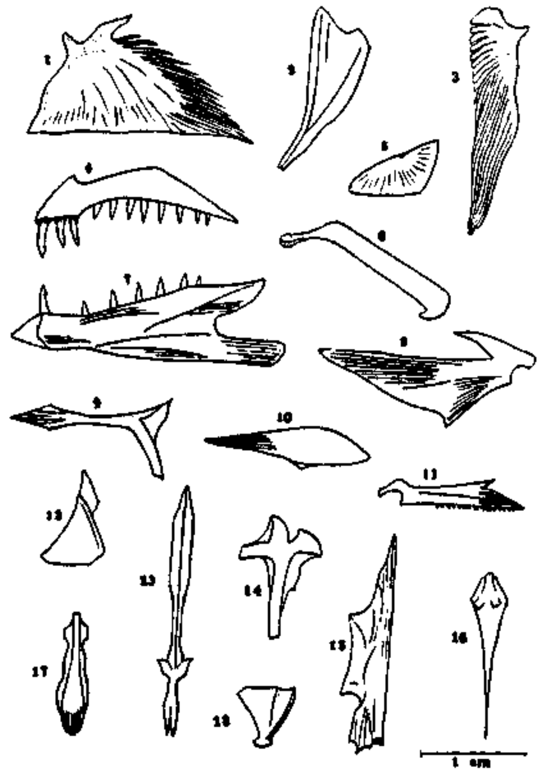

Fig. 14

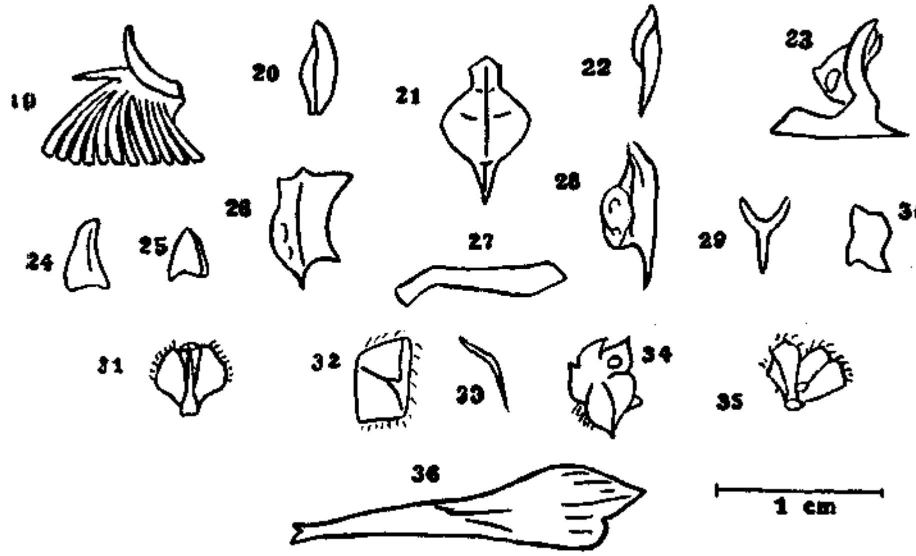

Fig. 15.

Figs. 14 and 15. Disarticulated bones, *T. lepturus*.

1. opercle, 2. preopercle, 3. subopercle, 4. premaxilla, 5. interopercle, 6. maxilla, 7. dentary, 8. articular, 9. ectopterygoid, 10. entopterygoid, 11. palatine, 12. metapterygoid, 13. parasphenoid, 14. hyomandibular, 15. frontal, 16. vomer, 17. dermethmoid, 18. quadrate, 19. lacrymal, 20. dermosphenotic, 21. supraoccipital, 22. symplectic, 23. prefrontal, 24. alisphenoid, 25. parietal, 26. sphenotic, 27. nasal, 28. pterotic, 29. basisphenoid, 30. opisthotic, 31. basioccipital, 32. epiotic, 33. jugal, 34. prootic, 35. exoccipital, 36. urohyal.

The *lacrymal* (*la*-19) is the largest bone of the suborbital ring and is characterized by the sculpture which decorates it. It consists of a dorsal bony rod and a membranous fringed flap. A curved dorsal process from the bony rod binds the anterior margin of the eye. The membranous part hides from view the major portion of the maxilla and the premaxilla on each side. The lacrymal differs strikingly in shape and relative size, in the two subfamilies. In *Trichiurus* and *Lepturacanthus* it is short, high and fan-like covering only about one-third of premaxilla and maxilla while in *Eupleurogrammus* it is comparatively large covering a greater portion (about two-thirds the length) of premaxilla and maxilla.

The second element of the suborbital ring is represented by a delicate bent bone, the *jugal* (*ju*-33) in *T. lepturus* and *L. savala* and unrepresented in *Eupleurogrammus*. It is situated immediately behind the lacrymal.

A third ossicle, the *dermosphenotic* (*dsph*-20) is crescent-shaped, freely suspended, small bone with an inward wing-like extension situated centrally at the posterior margin of the orbit, apparently forming the suborbital shelf. This bone is also not represented in *Eupleurogrammus*.

Otic Region: The *parietals* (*pa*-25) are paired small bones on the anterior sides of the supraoccipital and bear dorsally a small elevated ridge, which forms part of the temporal ridge. Anteriorly the parietals unite with the frontals and posteriorly with the epiotics. The parietals do not take part in the formation of the roof of the brain cavity, and are similar in all the genera.

The *supraoccipital* (*soc*-21) forms dorsally the median portion of the posterior end of the neurocranium. It is convex above, broadest in the middle and narrower at either ends. The posterior blunt end of it extends between the epiotics. The supraoccipital bears a ridge middorsally, its ridge separating the supratemporal grooves of the two sides. The supraoccipital is bounded anteriorly by the frontals, anterolaterally by the parietals and laterally by the epiotics. The posterior confluence of the frontals is elevated to a dorsomedian crest, more conspicuously in *Eupleurogrammus*. The posterior end of supraoccipital is somewhat blunt in *T. lepturus* and *L. savala* while it ends in a sharp point in *Eupleurogrammus*. In the latter, the ridge is confined to the anterior end of supraoccipital in continuation with the posterior confluence of frontals. It is low in *E. intermedius* but high in *E. muticus*, in which it is more strikingly seen in a lateral view of the skull.

The supraoccipital in several specimens of *T. lepturus* of various sizes from different localities was found to be subject to excessive thickening while the absence of this phenomenon in the other three species appears significant, as shown in a recent study (James, 1960) details of which are given in Chapter III.

The brain chamber opens between the alisphenoids. Its aperture is wider in *T. lepturus* than in *L. savala* and is much deeper in *E. muticus* than in *E. intermedius*.

The *pterotics* (*pto*-28) form the posterolateral corners of the skull and are produced into short spine-like processes on either side. They also contribute to the formation of the temporal and dilator grooves and to the main portion of the pterotic ridge. The pterotics bear anterior processes in *Eupleurogrammus* which are absent in the other two genera.

The *prootics* (*proot*-34) are irregular bones prominent on the ventral side of the neurocranium. The prootics in all the species are alike in shape and disposition and articulate with the parasphenoid, sphenotics, pterotics and basioccipital.

The *epiotics* (*epiot*-32) are two small bones, each with a dorso-lateral and a posterior surface intervened by a thin transparent area. Dorsally a process receives the upper branch of the post-temporal, thus forming a connection between the pectoral girdle and neurocranium. This process at the posterior end of the temporal ridge is equally prominent in all the species.

Anteriorly and along the median line the epiotics join the supraoccipital, posteriorly they unite with the exoccipitals and laterally with the pterotics.

The *sphenotics* (*sphot*-26) form the posterior part of the orbital roof and laterally a segment of the articular fossa for the head of the hyomandibular. The shallow open dilator grooves traverse the surface of the sphenotics. In *T. lepturus* and *L. savala* the sphenotic bears a prominent dorsal ridge which is lacking in *Eupleurogrammus* species. The lateral margin of sphenotic presents a concavity in the two former species while it is entire in the latter forms. In all cases there is an inward extension of this bone overlapped by the posterior end of the frontals. The sphenotics are flattened bones and bear a postero-lateral projection in all species.

The *opisthotics* (*opo*-30) are small scale-like bones interposed between the pterotics and the exoccipitals.

The *exoccipitals* (*exo*-35) are fan-shaped bones which enclose the foramen magnum and articulate with the basioccipital along the median line. Anteriorly they join the prootics, and laterally the pterotics. Their vertebral or paraoccipital condyles to the atlas are concave, and project beyond the basioccipital. The ventral surface is slightly concave and bears a prominent aperture or the foramen for the passage of the vagus nerve.

Basicranial Region: The *parasphenoid* (*pas*-13) is a long rod-like bone that forms the greater portion of the basicranial region of the neurocranium. It extends the entire length of the ventral median line between the olfactory region in front and otic region behind. The parasphenoid is long and bears posteriorly two small lateral ascending wings, one on either side to connect the prootics. Behind these wings the parasphenoid is constricted and gradually broadens with a gentle curvature upwards. At the sharp posterior bifurcated end the parasphenoid is embraced by the ventral sides of the basioccipital, and the median spine-like process of the latter fits into its forked end. The anterior end is simple and grooved externally for a distance, where it is overlapped ventrally by the posterior portion of the vomer. The portion between this point and the point of origin of lateral wings is the narrowest part of parasphenoid and forms the ventral margin of orbital cavity. The middle portion of the parasphenoid (ventral margin of orbital cavity) is narrow in *Trichiurus* and *Lepturacanthus* but broad in *Eupleurogrammus*. In *E. muticus* it is relatively broader than in *E. intermedius*.

The *basisphenoid* (*bsph*-29) is a small median Y-shaped bone, which unites the parasphenoid with the prootics and alisphenoids. The median vertical process is laterally compressed. The basisphenoid is very much alike in all the species, but greatly exposed in *T. lepturus* in a lateral view of neurocranium than in the other species.

The *basioccipital* (*boc*-31) is a short narrow bone with two wing-like extensions. It bears the concave rounded occipital condyle that articulates with the atlas. The median portion which is spine-like, fits into the forked posterior end of parasphenoid. The anterior end is broader than the solid posterior end.

The basioccipital supports dorsally the exoccipital of the corresponding side of the neurocranium and is bounded ventrally by the parasphenoid and in front by the prootics. The vertebral or paraoccipital condyles of the exoccipitals to the atlas rest on the hind end of basioccipital.

The shape and size of basioccipital varies in the different genera. In *Trichiurus* and *Lepturacanthus* it is short and broad especially at the anterior end. In *Eupleurogrammus* it is long and narrow, with the lateral wings less expanded at their anterior ends.

Except for the differences mentioned above, the basicranial bones are much similar in structure in all the three genera of ribbon-fishes.

4. Branchiocranium

Oromandibular Region: The *premaxilla* (*pmx*-4) is a long curved bone tapering anteriorly and posteriorly. The bone is thickest at the anterior end, with an ascending process. The ascending process is more pointed in *Eupleurogrammus* than in *Trichiurus* and *Lepturacanthus*. The nasal process of the premaxilla projects into the concavity in front of and over the dermethmoid.

The number of premaxillary teeth is variable in the species. Of the four species, *Eupleurogrammus muticus* bears the maximum number of teeth and *Lepturacanthus savala* the minimum. Observations on the oral armature in the Indian trichiurids in correlation with their feeding habits will be dealt with in a later section. However, brief details are given in Table VIII for comparison.

In the angle between the posterior margin of the ascending nasal process of the premaxilla and the dorsal edge of the shank of the bone there is a small backwardly directed process or projecting edge which has two depressions or articular facets, one on either side. The edge fits into the anterior forked cartilaginous part of the maxilla, while the two cartilaginous pieces of the latter lie firm in the two facets.

The *maxilla* (*mx*-6) is also a long, curved bone, the inferior surface of which lies over the superior surface of premaxilla behind the ascending process of the latter and extends beyond its posterior end. The head of the maxilla ends in a bifurcated cartilaginous piece, the two portions of which embrace the backwardly directed process of the premaxilla, while the cartilaginous pieces lie in depressions on either side. The maxilla is laterally compressed and is relatively broader at its posterior end.

The *dentary* (*dn*-7) is a large posteriorly forked bone, which forms the basis of the lower jaw, and like the premaxilla it is laterally flattened. It bears a single row of triangular, sharp teeth on the dorsal arm. The ventral arm is relatively narrower but longer than the dorsal one and both arms are covered by the anterior end of articular. The anterior end of dentary is joined with its fellow of opposite side by means of a symphsis. At the symphysial region, the lower jaw is tipped with a small conical piece of cartilage. The dentary is very much alike and the lower jaw is uniformly tipped with cartilage in all four species. The jaws are subequal, the lower being longer.

The *articular* (*art*-8) is more or less a spear-shaped bone, which is concave internally and convex externally, its concavity corresponding to the convexity of the dentary partly overlapped by the former. The posterior end of the articular bears 3 processes, the uppermost directed antero-dorsally, the lower directed antero-ventrally and the third directed posteriorly the last of which articulates with the head of quadrate. The articular is similar in general shape in all the species, except in *Eupleurogrammus* where it is broader with the dorsal process diverging less distinctly from it.

The *angular* (*an*) is a small bone attached to the posterior end of articular.

The *metapterygoid* (*mtp*-12) is a flat bone, triangular in shape. Its postero-dorsal margin presents a fringe or appendage of bone for the articulation of the stem of the hyomandibular, its anterior margin being entire. The ventral margin is also straight and borders the quadrate and symplectic. The dorsal narrow portion of the metapterygoid articulates firmly with the anterior lower angle of hyomandibular. The stem of the hyomandibular runs adjoined with the posterior margin of the metapterygoid. The metapterygoid is similar in all the species, but in *T. lepturus and L. savala* the posterior margin is more convex than in *Eupleurogrammus.*

The *ectopterygoid* (*pt*-9) is a T-shaped bone, the top of 'T' forming its posterior end. The ectopterygoid is joined with the entopterygoid dorsally, with the palatine laterally and anteriorly and with the quadrate and metapterygoid posteriorly. The shank of the 'T' is grooved anteriorly, with concavity situated dorsally and convexity ventrally opposing a concave narrow fringed anterior portion of the entopterygoid. The ventral convexity of the anterior end of ectopterygoid forms part of the roof of buccal cavity. The ectopterygoid is alike in all the species.

The *entopterygoid* (*enpt*-10) is a long typically thin papery bone which connects with the palatine, metapterygoid and ectopterygoid and lies on the para-

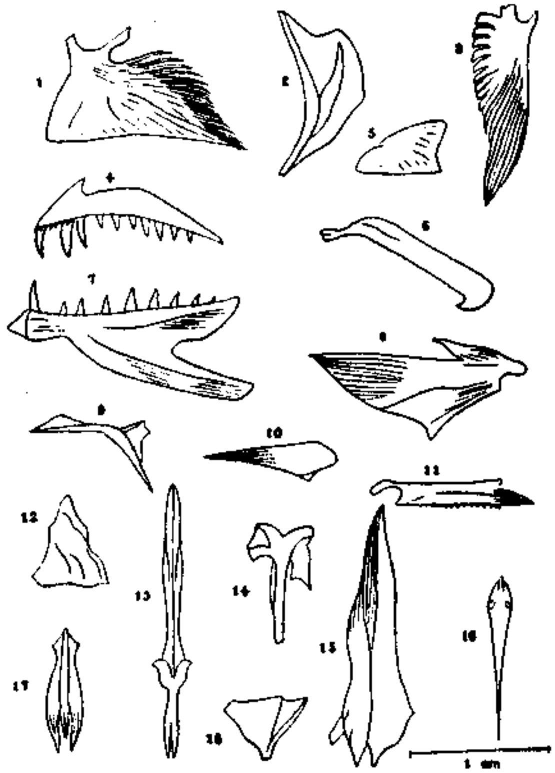

Fig. 16

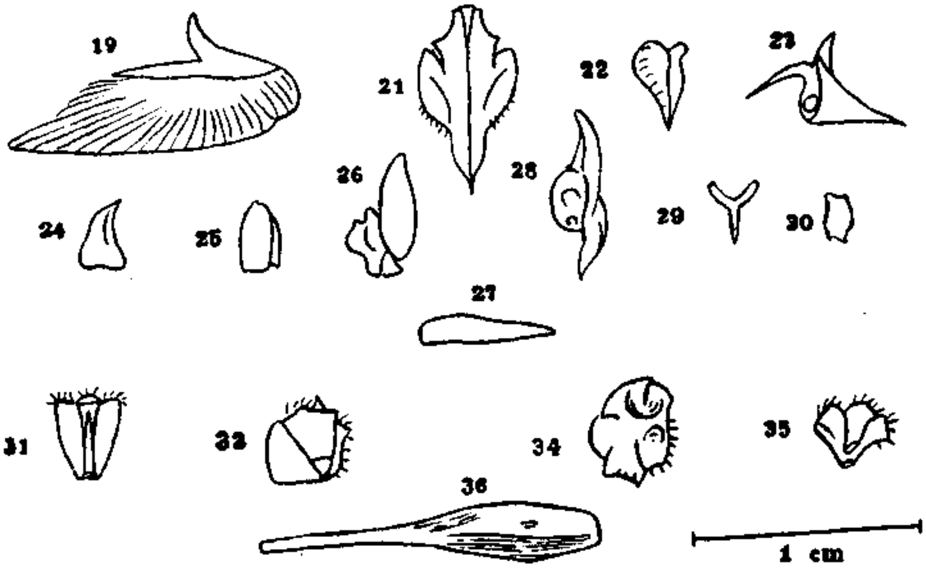

Fig. 17

Figs. 16 and 17. Disarticulated bones. *E. intermedius.* Order of numbers as in Figs. 14 and 15. Numbers 20 and 33 absent.

sphenoid with its mesial and posterior edges free. The dorsal surface is concave. The entopterygoid differs slightly in shape in the different species. In *Trichiurus* and *Lepturacanthus* the broadest portion of the entopterygoid lies about the mid-length of the bone whereas its anterior end is much sharper and posterior end broader in *Eupleurogrammus*. The ventral surface is smooth in all species.

The *palatine* (*pl*-11) runs forward on the external side of the vomer and hooks over the anterior end of the maxilla, immediately ventral to the nasal. Along the ventral edge, the palatine is armed with fine teeth. At the anterior end the palatine presents a hook-like process, strongly curved down in *T. lepturus* and *L. savala*, while it is just bent down in *Eupleurogrammus*. Posteriorly the palatine is broader and connects with the entopterygoid and ectopterygoid. The arrangement of the teeth on palatines varies with the genera. In *Trichiurus* and *Lepturacanthus* they are in the form of a villiform band, teeth being more prominent in *L. savala*, while in *Eupleurogrammus* they are arranged in irregular series.

The *quadrate* (*qu*-18) is a triangular bone with two prominent V-shaped ridges on the inner side. It is more or less a central bone, articulating dorsally (by its broadest side) with the metapterygoid and the stem of hyomandibular, posteriorly with the preopercle and ventrally with the articular and angular, the last two presenting a depression for the articular head of quadrate. Antero-dorsally, the quadrate is connected with ectopterygoid. Along the posterior margin, there is a thickened portion, grooved on its inner surface appearing as a strong spine-like process, directed upwards. This ridge or process provides articulation for the preopercle. The quadrate is broader than high in *Eupleurogrammus* and the reverse holds good, in *T. lepturus* and *L. savala*.

The groove on the inner surface of the quadrate lodges the *symplectic* (*sym*) a small, narrow bone which is scarcely visible externally and can be seen clearly when the quadrate is viewed from inside. The dorsal projecting portion of symplectic articulates with the lower end of hyomandibular.

Hyoid-Opercular Region: The *opercle* (*op*-1) is a thin bone, roughly triangular in shape. The anterior superior and middle portions are thicker than the rest of the opercle. Dorsally and anteriorly there are two processes, the shorter directed anteriorly to articulate with the opercular process of hyomandibular and the longer directed posteriorly. The superior and posterior free margins of opercle are finely fringed. Its anterior margin is plain, overlapped by the hind edge of preopercle and its ventral margin joins the dorsal border of subopercle.

The *subopercle* (*sop*-3) is a long, narrow, thin bone, broad anteriorly and narrow posteriorly. It is fringed along the posterior and inferior margins. Anteriorly it bears a small process, directed forward and upward to articulate with the preopercle. The bone is longer and narrower and inferior margin of the subopercle is concave in *Trichiurus* and *Lepturacanthus* while it is broader and the inferior margin convex in *Eupleurogrammus*.

The *interopercle* (*iop*-5) is triangular in shape and thin like the opercle and the subopercle, but very much smaller than the two. It forms the anterior and inferior free margin of the gill cover and along its inner surface it articulates with the ceratohyal. The dorsal margin of interopercle is overlapped by the ventral posterior margin of the preopercle and the posterior margin joins the subopercle and partly the opercle (at its posterior dorsal corner). The bone is essentially similar in all species except for the more convex dorsal margin in *Eupleurogrammus*.

The *preopercle* (*pop*-2) is a characteristic wing shaped bone, differing strikingly from all the other bones of the opercular complex. It is very bony and strongest of all the opercular bones, broad above and narrow ventrally. There are two strong bony ridges in the shape of 'Y' along anterior and posterior margins which are highly prominent on the inner surface. The posterior edge of preopercle overlaps the opercle and the subopercle, while its anterior margin with the ridge and a groove lies in juxtaposition with a similar ridge of the hyomandibular, articulating with the latter and also with the symplectic and the quadrate. The preopercle is similar in general shape in all the species, but is somewhat broader and shorter in *Eupleurogrammus* than in the other two genera.

The *hyomandibular* (*hyom*-14) is typically cruciform with three condyles, two of them for articulating with the neurocranium by means of two facets, one in the postero-inferior face of the sphenotic and the other on the ventral surface of the pterotic. The third condyle articulates with the opercle posteriorly. There is a fringe of bone in the angle of the posterior process and the stem of hyomandibular. The fringe is small in *T. lepturus* and *L. savala* while it is large and directed postero-ventrally ending in a sharp point in *Eupleurogrammus*.

Anteriorly, the ventral surface of the hyomandibular connects the metapterygoid, the symplectic and the interhyal, the last of which is orientated along the axis of the stem. The posterior portion of the stem presents a deep groove which articulates with the anterior surface of the vertical limb of the preopercle.

The stem of the hyomandibular is separated into anterior and posterior portions by a strong ridge which extends from the ventral end upward and forward in a slightly curved line. Between the ventral margin of the anteriormost condyle and the anterior margin of the stem of the hyomandibular below it, there is a narrow bony lamella.

The *hyoid arch* or *cornu* (Fig. 18, A-D) in all the four species contains in addition to the glossohyal, which is embedded in the tissues of the tongue, four separate bones, the basihyal, ceratohyal, epihyal, and interhyal. These pieces are connected by plain joints and fibrous connections. The interhyal articulates the complex posteriorly with the hyomandibular and symplectic, while the basihyal connects the anterior end to its fellow of the opposite side and to the anterior extremity of the first basibranchial of the branchial arch.

The *glossohyal* (*gloss*) is a flat bone, broad at the base and tapers anteriorly. The glossohyal in *T. lepturus* and *L. savala* is short and broad, while it is very long and gradually tapers in *E. intermedius* but is broader at the base and pointed at the tip, in *E. muticus*.

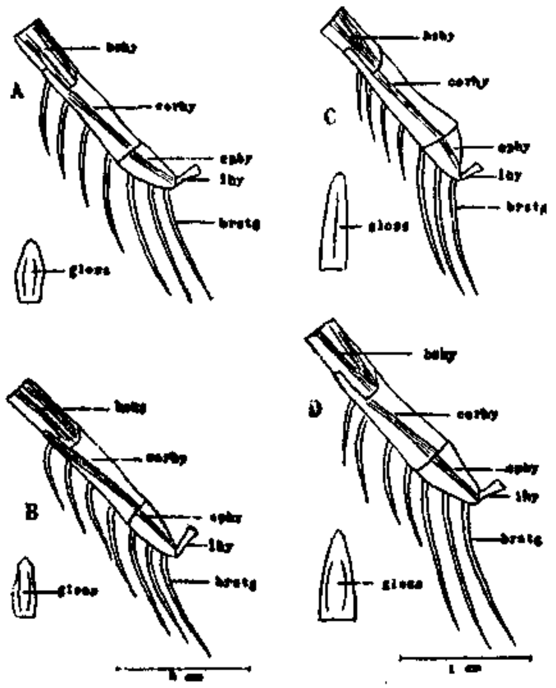

Fig. 18. Hyoid arch and glossohyal. A. *T. lepturus*. B. *L. savala*. C. *E. intermedius*. D. *E. muticus*.

The *basihyal* (*bshy*) is composed of two centres of ossifications firmly united in a straight line. The two halves are nearly of the same size. The ventral ossification at its posterior end rests over a narrow process of ceratohyal, while a dorsal smaller process of the latter binds the posterior corner of the dorsal half of basihyal.

The *ceratohyal* (*cerhy*) is the largest piece of the complex. It is broader at the posterior portion and slightly concave along its dorsal margin. Four of the *branchiostegal rays* (*brstg*) are attached to respective articular surfaces along its ventral margin. The anterior end of ceratohyal bears two processes, a longer ventral and a shorter dorsal, which articulate with the basihyal. The posterior end of ceratohyal is firmly articulated with the epihyal.

The *epihyal* (*ephy*) is triangular in shape, broad anteriorly and narrow posteriorly where it articulates with the interhyal. The three remaining branchiostegal rays take origin from the ventral margin of epihyal.

The *interhyal* (*ihy*) is a small, narrow bone, which articulates the hyoid complex with the hyomandibular and symplectic and is directed obliquely upward.

The three posterior branchiostegal rays are shorter in *T. lepturus* and *L. savala* while they are comparatively longer in *Eupleurogrammus*.

The *urohyal* (*urhy*) is enlongated and medially located between the basihyals. Its posterior end is laterally compressed, blade-like and embedded free in the muscular mass of the throat. In *Trichiurus* and *Lepturacanthus* the urohyal is much broadened specially the posterior portion, which ends in a sharp point while in *Eupleurogrammus* the urohyal is rod-like and the posterior end is broad but truncated.

Except for the relative length of the posterior branchiostegal rays and the shape of urohyal, the bones of the hyoid complex are very similar in the four species.

Branchial Region : The *branchial arches* (Fig. 19, A-D) are enclosed within the hyoid arch, with which they are connected at the base. They form the support for the gills and are composed of smaller bones. The branchial skeleton in the four species exhibits a similar general pattern as described below.

The three *basibranchials* (bb_1 bb_3) form a linear series along the median line, giving support and attachment to the four branchial arches. The first basibranchial fits into a depression on the posterior face of the glossohyal and laterally it is joined to the basihyals through intervening cartilage. The second and third basibranchials bear deep oblique grooves on each side to receive the first and second hypobranchials, respectively. All the basibranchials are narrowest in the middle region and broader at either end. The first basibranchial articulates with the second by a broad piece of cartilage and the second with the third by a narrow cartilage. The posterior half of the third basibranchial is much broader but narrows down into a process at the extremity. The third basibranchial is slightly larger than the other two.

The *first hypobranchial* (hb_1) arises from the posterior end of first basibranchial. The *second hypobranchial* (hb_2) is articulated at the posterior end of second basibranchial. Both first and second hypobranchials are narrow bones, the latter shorter than the former. The *third hypobranchial* (hb_3) is a short triangular bone and differs strikingly, being flat and not rod-like as the other two. They lie adjacent to the posterior end of third basibranchial.

The *ceratobranchials* (cb_1-cb_5) are very long, narrow, gently curved constituting the major support of the lower or ventral half of the branchial arches. The ceratobranchials decrease in length from the first to the last, but are similar in shape, except the fourth which is slightly twisted at its anterior end. The ventral surfaces of ceratobranchials are deeply grooved to their full length.

The *epibranchials* (eb_1-eb_4) form a series of four irregular curved pieces of bone, which are the main support to the upper or dorsal half of branchial arches. The fourth piece is the most internal, very narrow and bent while the other three are gently curved. All four elements are forked at their anterior ends.

The lower pharyngeals or modified *fifth ceratobranchials* (cb_5) bear villiform teem in a patch along the outer margin.

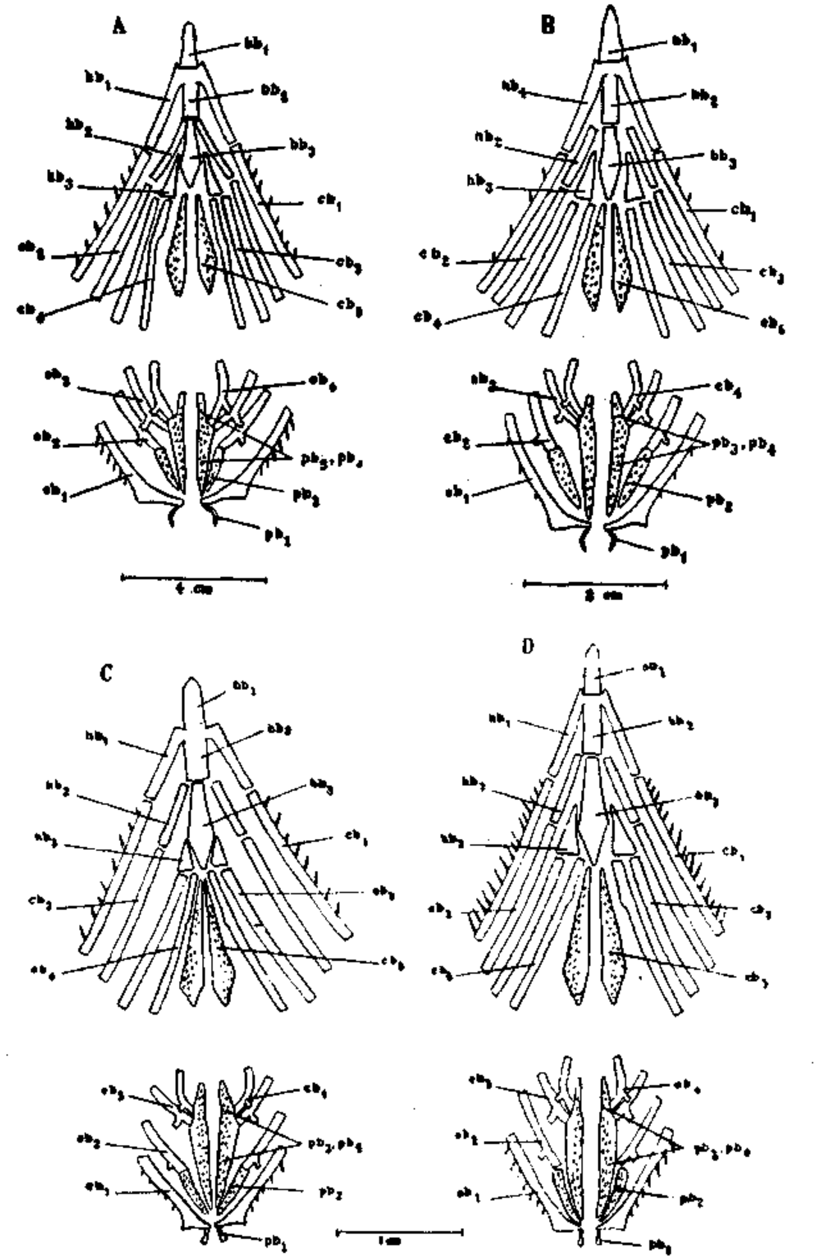

Fig. 19. Branchial arches, ventral half shown above, gill rakers indicated only on the outermost arch. A. *T. lepturus*. B. *L. savala*. C. *E. intermedius*. D. *E. muticus*.

The four upper pharyngeals or *pharyngobranchials* (pb_1-pb_4) are unequal in size and also bear fine teeth, except the first (suspensory pharyngeal) which is a tiny rod-like bone. This suspensory pharyngeal connects posteriorly the branchial arches to the neurocranium on its ventral side. The second upper pharyngeal is a flat wing-like bone articulating with the second epibranchial. The third and fourth upper pharyngeals are more or less united to form a single long piece on each side, and they articulate posteriorly with the last two of the epibranchials.

At their external margin the first epibranchial and all the ceratobranchials except the innermost bear a series of gill rakers, prominent and better developed only on the outermost arch. It may, however, be mentioned here that they are least developed in *L. savala* and best developed in *E. muticus*. The gill rakers are teeth-like, sharp and pointed, more or less straight sometimes with smaller, accessory spines. The number of gill rakers is quite variable among the species as shown in Table VIII. The surface of the extremities of the branchial arches is denticulated.

5. Pectoral Girdle and Fin

The *pectoral girdle* (Fig. 20, A-D) is situated close behind the neurocranium, and is connected with its upper part by the post-temporal.

The *post-temporal* (*ptm*) is a forked bone which affords the principal articulation of the pectoral girdle to the neurocranium. Its anterior end is divided into a long and sharp dorsal process and a short and blunt ventral process. The dorsal branch articulates with the epiotic, and the ventral lies over the pterotic. The posterior portion of the post-temporal is broader than either of its anterior processes. The post-temporal is alike in all the four species.

The *supracleithrum* (*supcl*) is a rod-like bone. broad and rounded at its anterior end, where it articulates with the posterior end of the post-temporal. Its posterior end rests on the dorsal part of the cleithrum. The supracleithrum is similar in *T. lepturus* and *L. savala*. In *E. intermedius*, it is straight and rod-like with a blunt posterior end, while in *E. muticus* it is slightly bent medially broader and sharper at the posterior end.

The *cleithrum* (*clt*) is a strong bent bone, being the largest of the bones of the pectoral girdle. Its ventral portion is broader and is folded back to present a concavity on the inner side. The cleithrum is similar in all the species, except that it is slightly broader at its upper portion, over the bent, in *E. muticus*.

The *scapula* (*scap*) is a small bone, articulating with the cleithrum on its inner side about the angle of the bent. It is pierced by a foramen, which is oblong in *T. lepturus* and *L. savala*, and roughly triangular in *Eupleurogrammus*.

The upper part of the scapula is thickened to receive the four *pterygials* (*ptryg*) which support the pectoral fin, the one at the base of the pectoral spine, being the largest.

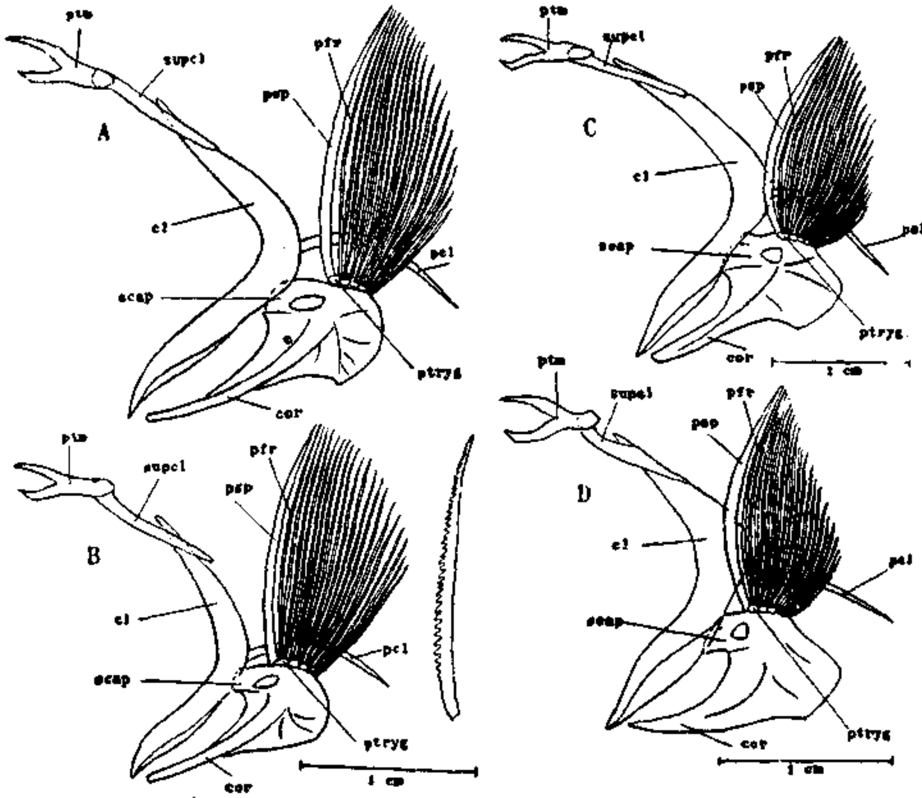

Fig. 20. Pectoral girdle and fin. A. *T. lepturus*. B. *L. savala*, serrated pectoral spine shown separate. C. *E. intermedius*. D. *E. muticus*.

The *coracoid* (*cor*) joins the scapula above, and ventrally articulates with the tip of the cleithrum. The dorsal portion is expanded and the ventral portion is rod-like. The shape of the coracoid is much alike in all except *E. muticus* in which it strikingly differs, the ventral portion being blade-like and flattened, instead of being rod-like.

The *postcleithrum* (*pcl*) is a fine rib-like process arising from the inner side of the cleithrum. It is directed posterior and downwards. It is more abruptly bent at its middle in *T. lepturus* and *L. savala* than in *Eupleurogrammus* species. Its posterior end surpasses vertical below 9th dorsal fin ray in *T. lepturus*, extends to or surpasses vertical below 8th dorsal fin ray in *L. savala*, extends to below 8th dorsal fin ray in *E. intermedius* and surpasses vertical below 8th dorsal fin ray in *E. muticus*.

Significantly enough the pectoral fin consists of one spine (*psp*) (not a true spine but a hardened soft-ray) and ten branched rays (*ptr*) in all the four species. The pectoral spine is often serrated (Fig. 20, B) along its outer margin, the serrations pointing downwards in some individuals of *L. savala*, a condition, not met with in innumerable specimens of *T. lepturus* and both species of *Eupleurogrammus* examined. It was also found that it has no relation with sex. The entire length of the spine except the base, bears the serrations which are more pronounced proximally than at the tip. The pectoral fins characteristically stand vertical and so close to the operculum that they are partly overlapped by it in all the species.

The pectoral fin differs in shape and height in the different species. The fin is relatively longer and reaches nearly the dorsal margin of the body in *T. lepturus* and *L. savala*, while it is much shorter in *Eupleurogrammus*. In the former two species the difference in height between the anteriormost and posteriormost rays (uppermost and lowermost rays) is not significant while in *Eupleurogrammus* species it is very striking, the rays falling rapidly in height. This difference in height of the rays gives the fin a characteristic shape in each of the groups (Fig. 20, A-D).

6. Pelvic Girdle and Fin

Pelvic girdle and fins are lacking in *T. lepturus* and *L. savala*. In *Eupleurogrammus* species the *pelvic girdle* (Fig. 21, A,B) is a much modified and rudimentary structure represented by a bony rod (*pelv*) equivalent to the pelvic bones and the fins by two reduced scale-like structures (*pvf*). The pelvic girdle is embedded free in the flesh of the abdominal wall and it consists of two halves. The anterior half is much shorter than the posterior. The basal portion of the anterior half is flattened out and the sides are folded back to enclose a groove and two lateral projections. The anterior end of the posterior half is broader

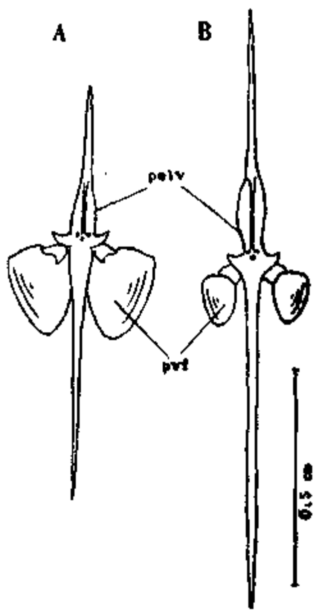

Fig. 21. Pelvic girdle and fins.
A. *E. intermedius*. **B.** *E. muticus*

and at this level are suspended the pelvic fins. Both extremities of the pelvic girdle end in fine points. The girdle appears longer in *E. muticus* than in *E. intermedius.*

The pelvic fins are two scale-like structures, directed posteriorly and situated about midway between tip of lower jaw and vent. They lie flush with the abdominal wall. The fins are comparatively bigger and triangular in *E. intermedius*, whereas they are oval and small in *E. muticus*. In general, the degree of reduction and rudimentary nature of the pelvic girdle and fins seems to be greater in the latter than in the former species.

7. Dorsal Fin

The *dorsal fin* (Pl. I, 1-4) is characteristically long in all the four species originating immediately behind the occipital crest and extending for a greater length along the dorsal margin of the body, towards the tip of the tail. It is low at the anterior and posterior ends, reaching its maximum height at a point opposite or slightly behind the anal region.

The fin consists of 3 anterior spines in *T. lepturus* and *Eupleurogrammus* while they are 4 in *L. savala* followed by simple rays. Table VIII gives the range in variation of the rays, in the species. The posteriormost few rays are usually very small and not easily detectable in fresh specimens. They are accurately enumerable only by help of radiographs or by alizarin staining.

Each radial of the dorsal fin consists of three pterygiophores, the proximal, middle and distal. The proximal or the first pterygiophore (interneural) is by far the largest and prominent of the series and forms the essential support of the fin ray. Each interneural is a long stiff spine, the distal portion of which along the dorsal margin of the body, is compressed from side to side with a short horizontal portion and provides articulation for the one preceding and succeeding it. Each interneural bears a transparent lamellar portion connecting the horizontal and vertical portions, on the anterior side. A large oval foramen perforates the lamellar portion, close to the angle of the horizontal and vertical limbs. The interneurals articulate below with the neural spines. Certain interneurals in some specimens of *T. lepturus* were occasionally thickened and give the appearance of ' stones '. Their occurrence, nature and significance have been discussed elsewhere (James 1960), which are also given in section III.

The middle pterygiophore is a small piece of bone, more or less triangular in shape and lies in line with the horizontal limb of the first. It fits in tightly over the posterior portion of the horizontal limb of the interneural with which it lies in a line and the anterior portion of the horizontal limb of the succeeding interneural.

The distal pterygiophore is equal in size with the middle and for the greater portion concealed by the two halves of the clasping base of the fin ray, except for its condylar basal (proximal) portion which abutts on the little concavity at the posterior end of the middle piece. This ball and socket-like articulation affords a free movement of the fin ray. The distal portion of this pterygiophore (which is clasped in between the two halves of the base of the fin ray) is flattened antero-posteriorly, and is distinctly seen in an anterior view of the fin ray. It still retains its supporting function and as stated above, provides for free motion of the fin ray, although it is known to have lost its function in most of the scombroids. The three pterygiophores articulate consecutively, though not in a vertical line.

There is usually a regular correspondence between the number of interneurals and the neural spines (hence indirectly with the number of vertebrae) excluding the first or atlas vertebra. Certain irregularities in this relation between the vertebrae and the neural spines and dorsal fin rays are mentioned elsewhere in the text.

Each fin ray consists of a base and a long flexible hair-like filament, with the two lateral halves of the latter firmly united. The base of each ray is compressed laterally and more or less spherical in shape. Between the two halves of the base of the fin ray lies the distal portion of the third pterygiophore with which the fin ray articulates.

The structure of the dorsal fin is essentially the same in all the four species of ribbon-fishes.

8. Anal Fin

The *anal fin* (Pl. I, 1-4) commences slightly behind the vent and runs midventrally towards the tip of the tail. The anal fin extends beyond the point of termination of the dorsal fin, in all the species.

The species differ in the structure of their anal fins. In all the species, the spinous anal is represented by two anterior spines (the 2nd spine variously modified) and the soft anal by a varying number of modified fin rays, in the form of spinules, which may or may not break through the mid ventral line of the body.

The first anal spine is very rudimentary in all the species, and appears only as an appendage of the second. The second anal spine in *T. lepturus* is less developed than in *L. savala* where it is usually a strong, dagger-shaped spine and more conspicuous in the juveniles. In *E. intermedius* and *E. muticus* the second anal spine is a dorso-ventrally compressed triangular scale (resembling their ventrals) rather than a typical spine of the type seen in the other two species.

The soft anal rays are represented by modified spinules which scarcely break through midventrally in *T. lepturus*, but distinctly break through as small curved sharp spines, directed posteriorly in *L. savala*. In *E. intermedius* and *E. muticus*, the external fin is entirely suppressed with the blunt protuberances of the basal elements slightly projecting out along the midventral line of the body in the former, while the ventral profile is very smooth in the latter.

Each radial is represented by the proximal piece or interhaemal spine, consisting of a long vertical proximal limb and a distal short horizontal limb. The horizontal limb articulates firmly with the one preceding and the other succeeding it, so that along the ventral margin of the body is formed a continuous rigid bony support or keel. The basal element is fused with the distal portion of the interhaemal at its middle point. The interhaemals articulate proximally with the corresponding haemal spines. The first interhaemal spine is usually thickened in all the species and is also the largest of the series, to the base of which are attached the two anal spines. There is a gap of one or sometimes none, in the series of interhaemal spines behind the first in *T. lepturus*, *E. intermedius* and *E. muticus* and invariably one or two similar gaps in *L. savala*.

Several interhaemal spines were found to show excessive thickening in individuals of *T. lepturus* collected from different parts of the Indian coast, as has been discussed elsewhere (James, 1960), details of which are given in section III.

The range in variation of the anal fin elements in the different species is summarised in Table VIII.

9. Vertebral Column

The *vertebral column* (Pls. I and II) of the ribbon-fishes exhibits a remarkable simplicity when compared to many scombroid fishes.

The vertebrae are more or less short in the anterior region and progressively long posteriorly to tip of the tail. This is specially so in *L. savala*, in which the tail is more filamentous and hair-like, when compared to the other three species. The vertebral column is very long and flexible in these fishes, in conformity with the ribbon-shaped body. But the length of the column is contributed more to by the increased number of vertebrae than by the length of each vertebra. The vertebral column is arched in the course of its length and the arched portion seems to be confined to pre-anal region in *T. lepturus* while it appears to be about midway between anus and tip of tail in the other three species. The bent however, appears more prominent in *E. intermedius*.

The neural and haemal spines are long, slender, terminating in sharp points. The spines are stiff and strong in the anterior vertebrae, while posteriorly they become very fine and fragile. The neural and haemal spines are grooved on their anterior and posterior faces. From the anterior end the neural spines gradually increase in height and they decrease in size towards the tip of tail behind the anal point. The anteriormost haemal spines are the longest, and they fall in height towards the tip of tail. The neural arch is shorter and smaller than the haemal, corresponding to the size of canals enclosed. The haemal canal is big in the anterior caudal vertebrae, decreasing in size towards the tail end.

Each vertebra has six longtitudinal grooves, ventral median, dorsal median and two pairs of laterals. This feature was also observed in many scombroid fishes (Kishinouye, 1923). The neural pre- and post-zygapophyses are well developed, especially the pre-zygapophyses with which successive vertebrae articulate. The haemal pre- and post-zygapophyses are well developed from the first cadual vertebra onwards. They are only minute processes in the precaudal region and towards the tail end they are reduced.

In all four species, the vertebral column presents a characteristic ridge on either side contributed to by small perpendicular lateral projections or apophyses on each individual vertebra. This lateral ridge appears from the vent or slightly in front of it. Each vertebra from this point bears a sharp, lateral conical projection at its anterior end on either side, with the anterior margin of the lateral process at right angles to the vertebra. The successive processes are clearly separated from one another but appear with wider interspaces at right angles in *Trichiurus* and *Lepturacanthus*, whereas they are closer and inclined anteriorly in *Eupleurogrammus*. At either end the processes are shorter,the highest being about the middle region of their course. About 71 such prominent processes may be counted in *T. lepturus*, 62 in *L. savala*, 82 in *E. intermedius* and 75 in *E. muticus*. The lateral ridges appear more highly developed in *E. intermedius* than in the other three species.

The vertebral number shows both interspecific and intraspecific variation in the species. It may, however, be stated here that due to the extremely fragile nature of the tip of the tail in all the species this region is continually susceptible to breaking and hence there is every possibility that the maximum number of vertebrae in each of the species may be slightly greater than what is stated in the present study. This may be more true in case of *L. savala*, in which, as already noted above, the tail is excessively fragile. To overcome this difficulty, the numbers of vertebrae corresponding to the termination of dorsal and anal fins are given for all species (Table VIII). In a true end of the tail the urostyle is just a rod-like bone, without the neural or haemal processes. The morphology of the most posterior vertebrae which show interesting differences in the species, is described in greater detail below.

The vertebral column may be divided conveniently into precaudal ,abdominal and caudal portions. The first caudal vertebra is the one with a long haemal spine that articulates with the first interhaemal spine. In all the four species it was found that the range in variation of the number of precaudal vertebrae is less than that in the caudal vertebrae. The details of the variation are presented in Table VIII. The vertebrae in each of the two regions are more or less uniform in structure, except for minor differences. The first or atlas vertebra is the smallest, ankylosed to the neurocranium and bears ribs. As in many scombroid fishes (Kishinouye, 1923) the neural spines of first few vertebrae are laterally compressed. Such spines are fewer in *Trichiurus* and *Lepturacanthus* than in *Eupleurogrammus*. The rest of the trunk vertebrae bear simple neural spines. The 2nd to the 11th vertebrae in *T. lepturus* bear each a median ridge ventrally, separating the median ventral groove into two lateral halves. A similar partition is seen in the case of *L. savala* from the 2nd to the 8th vertebrae but it divides the groove rather imperfectly. In both *E. intermedius* and *E. muticus* the 2nd to 8th vertebrae exhibit this character, and are similar to those in *L. savala* in the less pronounced nature of their ridges.

The parapophyses make their appearance on the 3rd vertebra, as two small projections on the two sides. They retain the same structure to a considerable length of the vertebral column and suddenly lengthen to form the first haemal arch. The posterior few precaudal vertebrae bear more pronounced parapophyses

TABLE VIII

Meristic counts of the four species of ribbon-fishes*

No.	Character	*T. lepturus*	*L. savala*	*E. intermedius*	*E. muticus*
1.	Total number of vertebrae ..	13 : 167–175 (170)	12 : 167–187 (177)	12 : 158–163 (160)	12 : 189–201 (192)
2.	Precaudal vertebrae ..	13 : 38–40 (39)	12 33–37 (35)	12 : 31–32 (31)	12 : 39–42 (40)
3.	Caudal vertebrae .	13 : 127–137 (131)	12 : 131–152 (141)	12 : 126–131 (129)	12 : 150–159 (152)
4.	First closed haemal arch at vertebra number ..	13 : 36–39 (38)	16 : 31–36 (33)	11 : 29–32 (30)	11 : 30–35 (33)
5.	Dorsal fin ray count ..	13 : III, 131–136 (132)	14 : IV, 108–123 (116)	12 : III, 123–129 (126)	12 : III, 139–147 (142)
6.	Dorsal extending up to vertebra number ..	13 : 135–140 (136)	14 : 113–128 (121)	12 : 127–132 (130)	12 : 143–151 (146)
7.	Anal fin ray count ..	13 : i+I, 103–199 (105)	14 : i+I, 77–93 (85)	12 : i+I, 113–121 (117)	12 : i+I, 113–122 (116)
8.	Anal extending up to vertebra number ..	13 : 143–148 (144)	14 : 116–130 (122)	12 : 146–153 (149)	11 : 154–163 (158)
9.	Teeth, upper jaw half, main series only ..	8 : 9–14 (11)	24 : 7–15 (10)	25 : 7–12 (10)	8 : 12–25 (19)
10.	Teeth, lower jaw half, main series only ..	8 : 9–14 (10)	24 : 7–15 (10)	25 : 7–12 (10)	8 : 16–23 (19)
11.	Gill rakers, upper limb, main series only ..	8 : 4–8 (6)	24 : 2–5 (4)	25 : 2–8 (5)	8 : 2–6 (4)
12.	Gill rakers, lower limb, main series only ..	8 : 6–13 (8)	24 : 1–8 (6)	25 ; 8–15 (11)	8 : 11–16 (14)
13.	Gill rakers, total, main series only ..	8 : 10–21 (14)	24 : 3–13 (10)	25 : 10–23 (17)	8 : 13–22 (19)

*For each character the number of specimens examined is followed by the count, and the mean for each indicated in parentheses. Teeth and gill rakers counted on the left side.

in *Eupleurogrammus* than in *T. lepturus* and *L. savala*. The relative position of the first closed haemal arch is given in Table VIII.

The *ribs* in all the four species are very fragile and thin, lining the abdominal cavity, but not forming a complete basket. The more anterior ribs are attached to the centra along their ventro-lateral sides while the posterior ones are articulated in the notch between the haemal pre-zygapophyses and parapophyses of each vertebra at its anterior end. All the ribs are loosely articulated to the vertebrae. The *epipleural ribs* are few, 4-6 in number, present on the first to sixth vartebrae in *T. lepturus* and the *pleural ribs* appear from 3rd vertebra onwards and extend up to 36-39th vertebra ; in *L. savala* epipleural ribs are 4-5, present on the first to fifth vertebrae, and the pleural ribs appear from the 4th vertebra and extend up to 31-35th vertebra ; in *E. intermedius* epipleural ribs are 3-5, present on the first to fifth vertebrae, and the pleural ribs appear from the 3rd vertebra and extend up to 29-32nd vertebra and in *E. muticus* epipleural ribs are 6, present on the first six vertebrae and the pleural ribs appear from the 1st vertebra extending up to 30-35th vertebra. All the epipleurals are directed dorsally and posteriorly in all the species. The epipleurals are short and stiff in all except in *E. muticus*, where the first two are short, and the last four are very long and stout and more stiff.

In *Trichiurus* and *Lepturacanthus* the ribs are more or less similar extending the full distance of the trunk, while in *Eupleurogrammus* the basket is confined to the anterior end of the trunk with the ribs in this region long and thin while the posterior ribs are strikingly short and blunt.

Morphology of the posteriormost vertebrae : In *T. lepturus* and *L. savala* the most posterior vertebrae have the neural spines and zygapophyses almost reduced (Plate II). This reduction is very great in *L. savala* when compared to *T. lepturus*. The vertebral column at this region is more in line with the dorsal profile in the former than in the latter. Each vertebra is a simple almost cylindrical rod with a very long, curved, fragile haemal spine, that lends supports to the ventral side of the tip of the tail in *L. savala*, while in *T. lepturus* the vertebra are long but dumbel-shaped and distinctly narrower at the mid portion than at either end, the haemal spine being cylindrical, broad at the base and sharp at the tip as in the former.

In *E. intermedius* and *E. muticus* the vertebrae are short, thick and bear distinct neural spines and zygapophyses till the last vertebrae (Pl. II). The vertebral column is above the mid-lateral line in both *E. intermedius* and *E. muticus*, with the short stumpy neural spines directed posteriorly. The haemal spines are very long and highly curved (more so in *E. intermedius*), with their distal halves laterally compressed (unlike the pointed ends as in *T. lepturus* and *L. savala*). Occasionally a double haemal spine may be present as in *E. muticus* (Pl. II).

The last vertebra in all the species very frequently assumes a bizarre appearance due to extra growths on all sides, much due to the continual loss and rounding off of the tip of the tail (Pl. II).

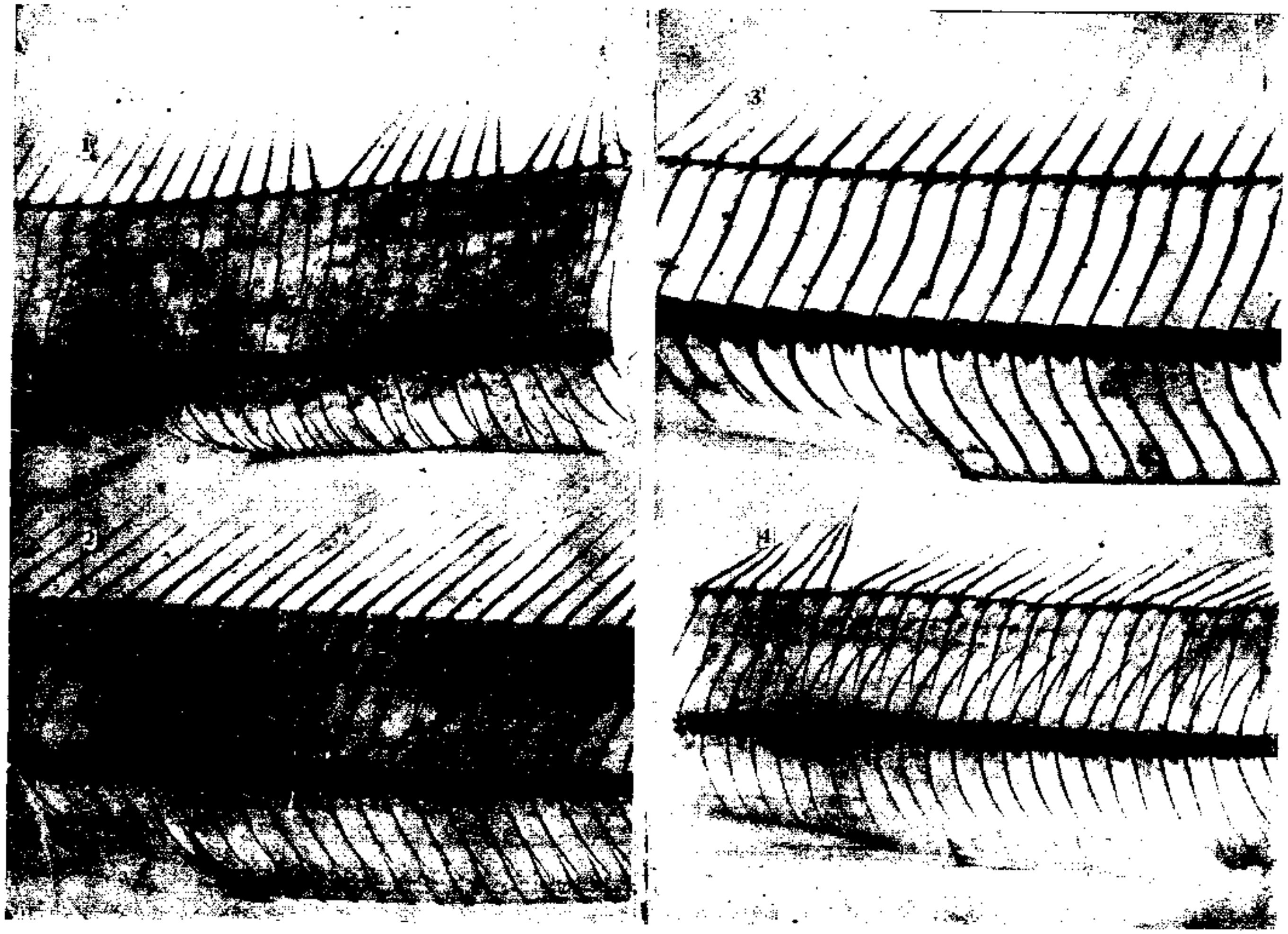

PLATE I

Comparative osteology of anal region, showing dorsal and anal fins and vertebral column (alizarin stained). 1. *T. lepturus* (S.L., 32.5; S.V., 10.8 cm.). 2. *L. savala* (S.L. 37.1; S.V., 11.8 cm.). 3. *E. intermedius* (S.L., 45.7; S.V., 14.0 cm.). 4. *E. muticus* (S.L., 42.9; S.V., 11.9 cm.).

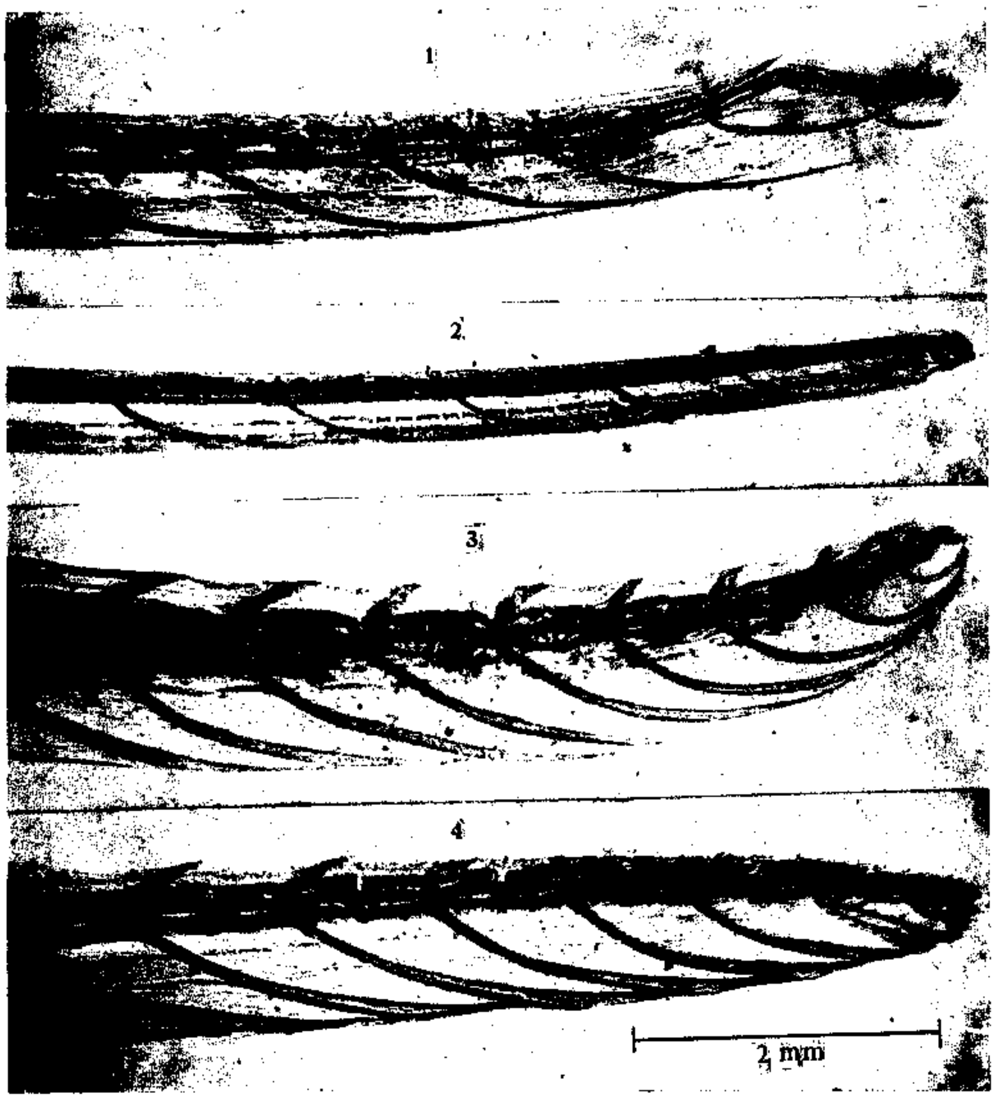

PLATE II
Photomicrographs of posterior vertebrae (alizarin stained). 1. *T. lepturus*. 2. *L. savala*. 3. *E. intermedius*. 4. *E. muticus*.

The dotted line below and parallel to vertebral column in the figures (Pl. II) indicates the course of the lateral line at this region of the body.

10. Relationship between the Subfamilies Trichiurinae and Lepidopodinae

As stated earlier, the four species dealt with in the present paper fall into two natural groups, *T. lepturus* and *L. savala* to the subfamily Trichiurinae, and *E. intermedius* and *E. muticus* to the subfamily Lepidopodinae, in which four other genera are also included. Of these, *Lepidopus* Gouan and *Assurger* Whitley are reported from the Indo-Pacific, while the genera *Evoxymetopon* (Poey) Gill and *Tentoriceps* Whitley are so far not reported from this region.

Tucker (1956) distinguishes these two subfamilies on the presence or absence of pelvic fins, the disposition of the lateral line and the shape of the hind margin of operculum. The present osteological study on three genera of these two subfamilies shows that the following additional characters also constitute a basis for their differentiation: (i) number of elements constituting the orbital ring, (ii) the relative extent of the lacrymal, (iii) relative length of the posterior three branchiostegal rays and (iv) the structure of the posterior caudal vertebrae. Besides these, it was found that the nature and arrangement of the palatine teeth is very distinct in the two subfamilies, as also the second anal spine.

While these characters constitute differences of some magnitude, the osteology of the other genera of the subfamily Lepidopodinae is expected to differ, especially as the genera show greater diversity. For instance, unlike *Eupleurogrammus*, the genera *Lepidopus, Assurger* and *Evoxymetopon* have a distinct caudal fin, which is also absent in *Tentoriceps.*

The osteological features of the members of the subfamily Aphanopodinae are not yet fully studied, as also of the other genera of the subfamily Lepidopodinae. In the light of this study, it is now possible to give a more comprehensive key based on the osteology of the genera and species studied here.

11. Osteological Key

I. Pelvic girdle and fins absent; orbital ring represented by three elements, the lacrymal, jugal and the dermosphenotic. Lacrymal bone small, covering hardly one-third the length of premaxilla and maxilla. Palatine teeth villiform in a broad band. Inferior margin of suboperculum concave. Second anal spine typically spine-like. Last three branchiostegal rays are slightly longer (about $\frac{1}{4}$ their own length) than the preceding. Posterior vertebrae with reduced or no neural spines (Subfamily Trichiurinae).

A. Orbital cavity large, about one-third the length of the neurocranium. Dorsal surface of neurocranium convex and occipital region elevated. Precaudal vertebrae 38-40 .... *T. lepturus.*

B. Orbital cavity small, less than one-third length neurocranium. Neurocranium dorsoventrally compressed. Precaudal vertebrae 33-37...... *L. savala.*

II. Pelvic girdle and fins present. Orbital ring, represented by one element only, the lacrymal. Lacrymal large, covering two-thirds of premaxilla and maxilla. Palatine teeth small, slightly recurved, arranged in irregular series. Inferior margin of sub-operculum convex. Second anal spine scale-like; last three branchiostegal rays about half their own length longer than the preceding. Posterior vertebrae with distinct neural spines. (Genus *Eupleurogrammus* of subfamily Lepidopodinae).

A. Precaudal vertebrae 31-32. Median crest on ethmofrontal region absent. Posterior end of maxilla extends to or surpasses vertical below front border of orbital cavity .... *E. intermedius.*

B. Precaudal vertebrae 39-42. Median crest on ethmofrontal region present. Posterior end of maxilla falls short of vertical below front border of orbital cavity .... *E. muticus.*

It has also been found that *T. lepturus* and *L. savala* attain bigger sizes than species of *Eupleurogrammus*, the former exceeding even one metre, while the latter has not been reported to exceed 625 mm. (de Beaufort and Chapman, 1951). The author's examination of a large series of samples of these species also indicates the same trend.

12. Relationships of the Genera of the Family Trichiuridae

Regan (1909) allied the Trichiuridae and the Gempylidae to form the first division, Trichiuriformes of his suborder Scombroidei, of the order Percomorphi. His suborder includes three other divisions namely, Scombriformes, Luvariformes and Xiphiformes. However, to have any understanding of the phylogenetic relationships of the genera studied here, a reference to osteological work on the various groups indicated above seems necessary. Important contributions to the osteology of the true scombroid fishes have been made by Allis (1903). De Sylva (1955), Gregory (1933), Gunther (1860), Kishinouye (1923), Leccia (1956), Starks (1910, 1911) and others.

Regan's definition of the division Trichiuriformes includes the following osteological features 'caudal fin rays not deeply forked at the base, the hypural in great part exposed. Premaxillaries beak-like, free from the nasals, Epiotics separated by supraoccipital. In his generalised definition of the family Trichiuridae, attention is drawn to several important osteological characters which the author is able to corraborate with slight modifications. These are as follows :—

(i) 'Maxillary sheathed by the preorbital.' The preorbital or lacrymal covers not only a part of maxillary (maxilla) but also the premaxilla in *T. lepturus*, *L. savala* and *Eupleurogrammus*.

(ii) 'Anal with numerous short spines.' The anal rays are represented by reduced spinules, more prominent in *L. savala* than in *T. lepturus*. In *E. intermedius* the basal elements can still be noticed as blunt protuberances along the mid-ventral line of the body, while the ventral profile is very smooth in *E. muticus*.

TABLE IX

Distinguishing osteological features between Trichiurus plus Lepturacanthus and Eupleurogrammus

S. No.	Character	*Trichiurus & Lepturacanthus*	*Eupleurogrammus*
1.	Pelvic fins	Absent	Present
2.	Number of ossicles in the orbital ring	Three	One
3.	Lacrymal	Covers only $\frac{1}{3}$ length of maxilla and premaxilla	Covers $\frac{2}{3}$ length of maxilla and premaxilla
4.	Palatine teeth	In villiform band	In irregular linear series
5.	Posterior three branchiostegal rays	Little longer than the preceding, about $\frac{1}{4}$ their own length	Strikingly longer than the preceding, about $\frac{1}{4}$ their own length
6.	Second anal spine	Spine-like	Scale-like
7.	Posterior caudal vertebrae	With reduced or no neural spines	With prominent neural spines

TABLE X

Distinguishing osteological features between Trichiurus and Lepturacanthus

S. No.	Character	*Trichiurus*	*Lepturacanthus*
1.	Occipital region of neurocranium	Convex	Flat, dorsoventrally compressed
2.	Orbital cavity	Huge, about $\frac{1}{3}$ length of neurocranium	Small, less than $\frac{1}{5}$ length of neurocranium
3.	Second anal spine	Rudimentary	Conspicuous and dagger-like

TABLE XI

Distinguishing osteological features between E. intermedius and E. muticus

S. No.	Character	*E. intermedius*	*E. muticus*
1.	Ethmofronal crest	Absent	Present
2.	Ventral portion of coracoid	Rod-like	Blade-like
3.	Orbital cavity	More dorsal	Central

(iii) 'Pelvic fins reduced to a pair of scale-like appendages or absent'. The pelvic fins consist each only of a scale-like spine in *Eupleurogrammus*.

(iv) 'Dorsal and anal rays corsesponding to the vertebrae, each interneural or interhaemal attached to a neural or haemal spine.' Usually the dorsal rays and their basals and interneurals always correspond to the trunk vertebrae. A similar condition is also seen for dorsal and anal rays in the caudal region but for occasional irregularities, such as three interhaemals with basal elements being related to a single vertebra; two interhaemals articulating with a single basal element; a haemal spine lacking an interhaemal, its basal element remaining free; and two interneurals and two interhaemals articulating with a single vertebra with double neural and haemal spines. These irregularities are seen in all the four species, and appear to be common on the haemal than neural side. Since their occurrence is sporadic, it is likely that they represent a teratological condition.

(v) 'Pelvic bones, if present, united to form a slender spicular bone connected with the cleithra by a ligament.' The pelvic bones form a fenestrated structure, elongated in *Eupleurogrammus*.

(vi) 'Vertebrae numerous 100 (43+57) to 159 (39+120) or more.' Vertebral counts are much higher than hitherto noticed, details of which are presented in Table VIII.

In addition to these, the osteological characters of the family Trichiuridae have been studied for the following forms, genus *Aphanopus* by Gunther (1860), genus *Lepidopus* by Gregory (1933) and Starks (1911). On the basis of this, as well as the present study, it is possible to say that the following characters are common to the five genera namely *Aphanopus, Lepidopus, Eupleurogrammus, Trichiurus* and *Lepturacanthus* thereby drawing attention to their close affinity: (i) elongated preorbital portion of skull, (ii) presence of longitudinal grooves and ridges on the skull, (iii) low occipital crest, (iv) fringed operculum and suboperculum, (v) absence of vomerine teeth, (vi) lacrymal covering the space between orbit and jaw bones (vii) numerous vertebrae and (viii) slightly barbed canine-like teeth.

The phylogenetic tree presented by Tucker (p. 126) represents the affinities well for the different genera including those studied here. While Table IX, X and XI distinguish *Trichiurus* and *Lepturacanthus* and the two species of *Eupleurogrammus*, the differences between *E. intermedius* and *E. muticus* appear deeper probably due to specialization (therefore divergence) of *E. muticus*. Among these specialised characters may be mentioned (i) the great development of ethmofrontal crest (ii) the low position of orbit attributable to the obviously specialized extreme elevation of the occipital region and the greater forward dislocation of the supraoccipital, and (iii) the blade-like rather than rod-like ventral part of the coracoid.

Explanation to Abbreviations in Figures

alsp., alisphenoid; an., angular; bb_1-bb_3., basibranchials 1-3; boc., basioccipital; brstg., branchiostegal ray; bshy., basihyal; bsph., basisphenoid; cb_1-cb_5., ceratobranchials 1-5; cerhy., ceratohyal; clt., cleithrum; cor., coracoid;* ct., cartilage; deth; dermethmoid, dn., dentary; dsph., dermosphenotic; eb_1-eb_4., epibranchials 1–4;* efrc., ethmofrontal crest; enpt., entopterygoid; ephy., epihyal; epiot., epiotic; exo., exoccipital; fr., frontal; gloss., glossohyal; hb_1-hb_3., hypobranchials 1-3; hyom., hyomandibular; ihy., interhyal; iop interopercle; ju., jugal; la., lacrymal; mtp., metapterygoid; mx., maxilla; na, nasal; op, opercle; opo., opisthotic; pa., parietal; pas., parasphenoid; pb_1-pb_4., pharyngobranchials 1–4; pcl., postcleithrum; pelv, pelvis; pf., prefrontal; pfr., pectoral fin ray; pl, palatine; pmx., premaxilla; pop, preopercle; proot., prootic; psp., pectoral spine; ptm., post-temporal; pto., pterotic; ptopr., pterotic process; pt., ectopterygoid; ptryg., pterygial; pvf., pelvic fin; qu., quadrate; scap., scapula; soc., supraoccipital; sop., subopercle; sphot., sphenotic; supcl., supracleithrum; sym., symplectic; urohy., urohyal; vo., vomer.

*New abbreviations.

III

HYPEROSTOSIS

The occurrence of swollen bones in the skull of *Trichiurus lepturus* has been mentioned by Cuvier (*vide* Gunther, 1860) and Starks (1911) reported on its thickened clavicle. Similar cases in respect of other bones have however, not been reported. The results of a detailed study of excess ossification or hyperostosis in *T. lepturus* from the Indian Seas are presented below.

Several samples of *T. lepturus* from various places, especially where it forms an important fishery, along the east and west coasts of India were collected during the period January 1959 to July 1960. 534 specimens of both sexes and of different sizes, varying betwen 43 to 978 mm. (S.L.) were examined for the extra ossified bones. Besides these, samples of three other species of ribbon-fishes occurring in Indian waters namely, *Lepturacanthus savala*, *Eupleurogrammus intermedius* and *Eupleurogrammus muticus* (James, 1959) were also examined, to ascertain any such instances of excessive thickening of bones. Alizarin stained specimens of the four species were studied to fix the identity of bones that become stone-like and to study the effect of such extra growths on the adjoining structures. Skeletons of fresh specimens were prepared by cooking in water and the disarticulated parts were scrutinized for additional ossifications. In addition to material from Indian coastal waters, four large specimens of *T. lepturus* from the Andaman Sea were also examined.

1. Observations

General considerations: Hyperostosis is confined to the supraoccipital bone and the interneural and interhaemal spines. Table XII shows a summary of the material examined and results obtained.

Of the four species of ribbon-fishes occurring in Indian waters, thickened bones appear to be present only in *T. lepturus* and its occurrence was found to be fairly common. Specimens examined for hyperostosis at random with respect to size show that of those affected, males with such bones are less numerous (36.5%) than the females (63.4%). Thickening of supraoccipital and the interhaemal spines is more common while that of interneurals appears to be comparatively rare. Occasionally, all the three types are found in the same individual or a combination of any two may be present. The thickened interneurals and interhaemals may be successive, alternating or even widely spearated by intervening normal spines. The successive bones may or may not unite but when they unite, they form a single massive 'stone'. The number of such modified bones forming a mass or 'stone' can be made out by counting the number of corresponding neural or haemal spines. The affected neural or haemal spines are slightly short and blunt at their extremities, whereas the normal ones are longer and pointed at their tips. As in the case of normal bones, the enlarged bones are covered by a layer of muscles and externally by the skin.

The bony enlargements are clearly perceptible externally in the bigger size groups but are not always symmetrical and often are seen prominently bulging on one side. In smaller individuals their presence can be detected by touch. The enlarged bones (Pl. III, Fig. 3) are of various shapes : oblong, oval, triangular, round or even irregular but are usually compressed laterally in conformity with the lateral flattening of body. Sometimes a single 'stone' presents a groove or depression to give it a bilobed appearance and when it is a compound structure involving more than one spine, intervening depressions indicate the number of such spines.

The swollen bones fully occupy the interspaces between the preceding and succeeding bones, often bringing pressure on normal bones to bend or curve round the enlargements (Pl. III, Figs. 3, 4). Longitudinal sections of the three types of enlarged bones (Pl. IV, Fig. 3) have been examined. The thickened supraoccipital presents a honeycomb-like pattern in a section. The bony substance is soft and alveolar. The thickened interneural or interhaemal is less alveolar and often presents a bigger central cavity, whose bony substance is harder than that of supraoccipital. In all cases, it appears, the bone deposition is more of a superficial, soft, cellular nature than a regular periosteal deposit. The more alveolar bones float, while their normal counterparts sink in water, showing that this modification tends to make the bones buoyant.

In the normal head of a specimen, the posterior confluence of the frontal ridges, and in continuation of it, the low supraoccipital crest are elevated to form a sagittal crest, which is confined to the nape (Pl. III, Fig. 1). When there is an enormous thickening of the supraoccipital bone, the whole occipital region of the skull is dorsally concealed by the bony mass, sometimes extending to the first one or two vertebrae and results in a further elevation and strong convex dorsal curvature at the nape region (Pl. III, Fig. 2). In such specimens, the pre-occipital profile of the head steeply dips down. The varying degree of enlargement of supraoccipital fully or partially overlaps the parietals and the temporal ridges on the sides. The supraoccipital enlargement is occasionally asymmetrical at the forked posterior end. It bears a median groove along the posterior half, which indicates the position of the origin of dorsal fin.

The interneural thickenings are much larger than the interhaemal. This is probably a direct result of the greater height of the interhaemals. The interhaemal thickenings appear never to exceed the height of the body between the lateral line (running along lower one-third of body) and the ventral margin of the body.

Analysis of frequency of occurrence.—From Table XII, and other data presented in the text, the following observations are made :—

The supraoccipital thickening (Pl. IV, Figs. 1 and 2) was found to be present in both sexes. Its occurrence was first noticed in a specimen measuring 422 mm. from Vizhingam (Trivandrum) on the west coast. The biggest specimen showing this enlargement was 707 mm. from Idinthakarai (Tinnevelly) on the Gulf of Mannar. However, a 978 mm (male) was found with a normal supraoccipital bone. The supraoccipital thickening occurs either exclusively or in combination with enlargements of interhaemal or interneural or both. Sex-wise it is distributed in the ratio of 13 males to 24 females (+ 4 of sex unknown).

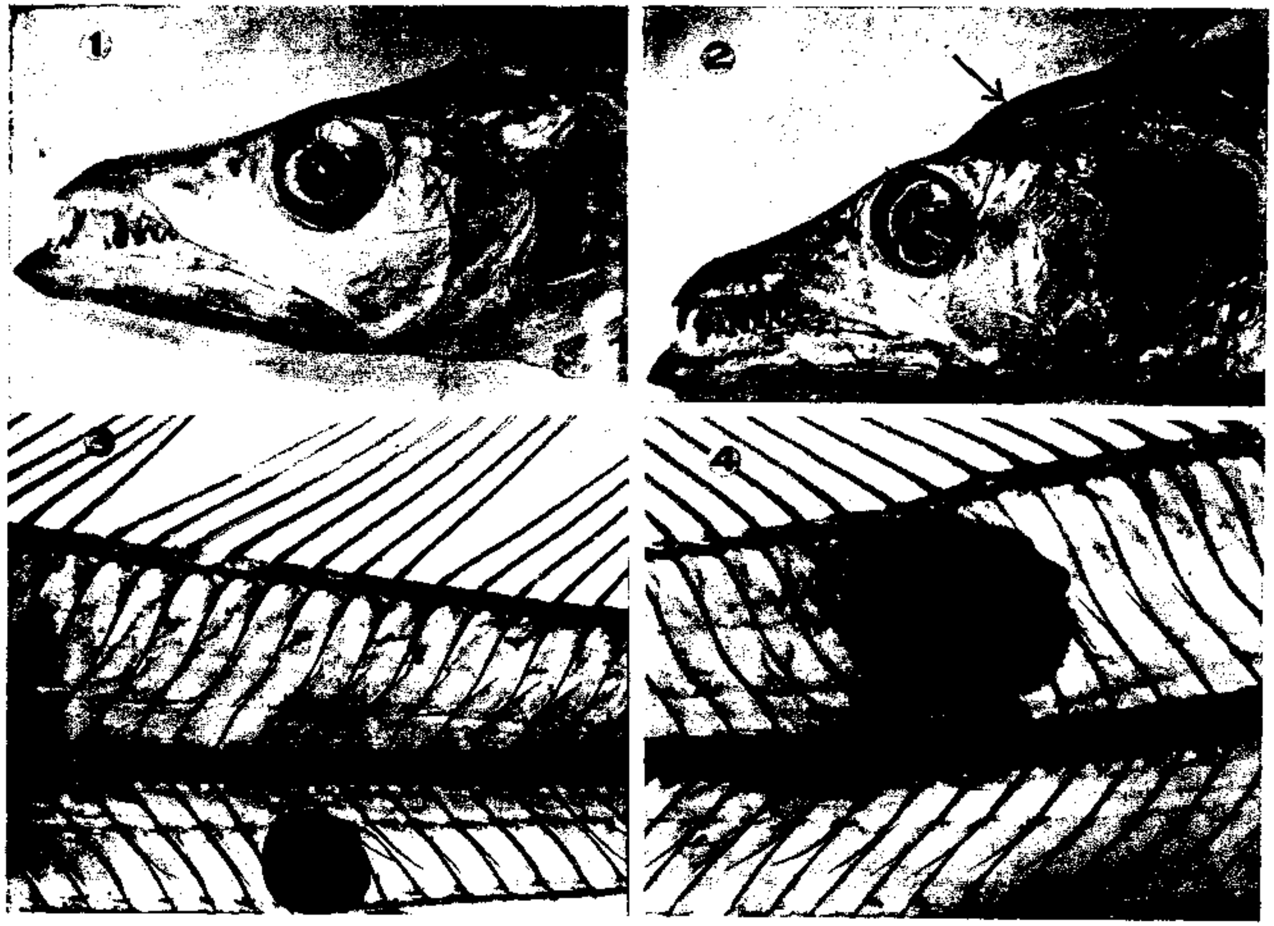

PLATE III

Trichiurus lepturus

Fig 1. Head (10 cm.) of specimen with snout-vent length 24.5 cm. Usual curvature at nape. 2. Head (9.5 cm.) of specimen with snout-vent length 22.5 cm. Arrow indicates unusual curvature at nape due to bone thickening. 3. Thickened interhaemal spine in specimen of 72.8 cm. S.L. 4. Thickened interneurals (fused condition) in specimen of 100 cm. S.L. Anterior end to the right side (figs. 3 and 4 photographs of alizarin stained material).

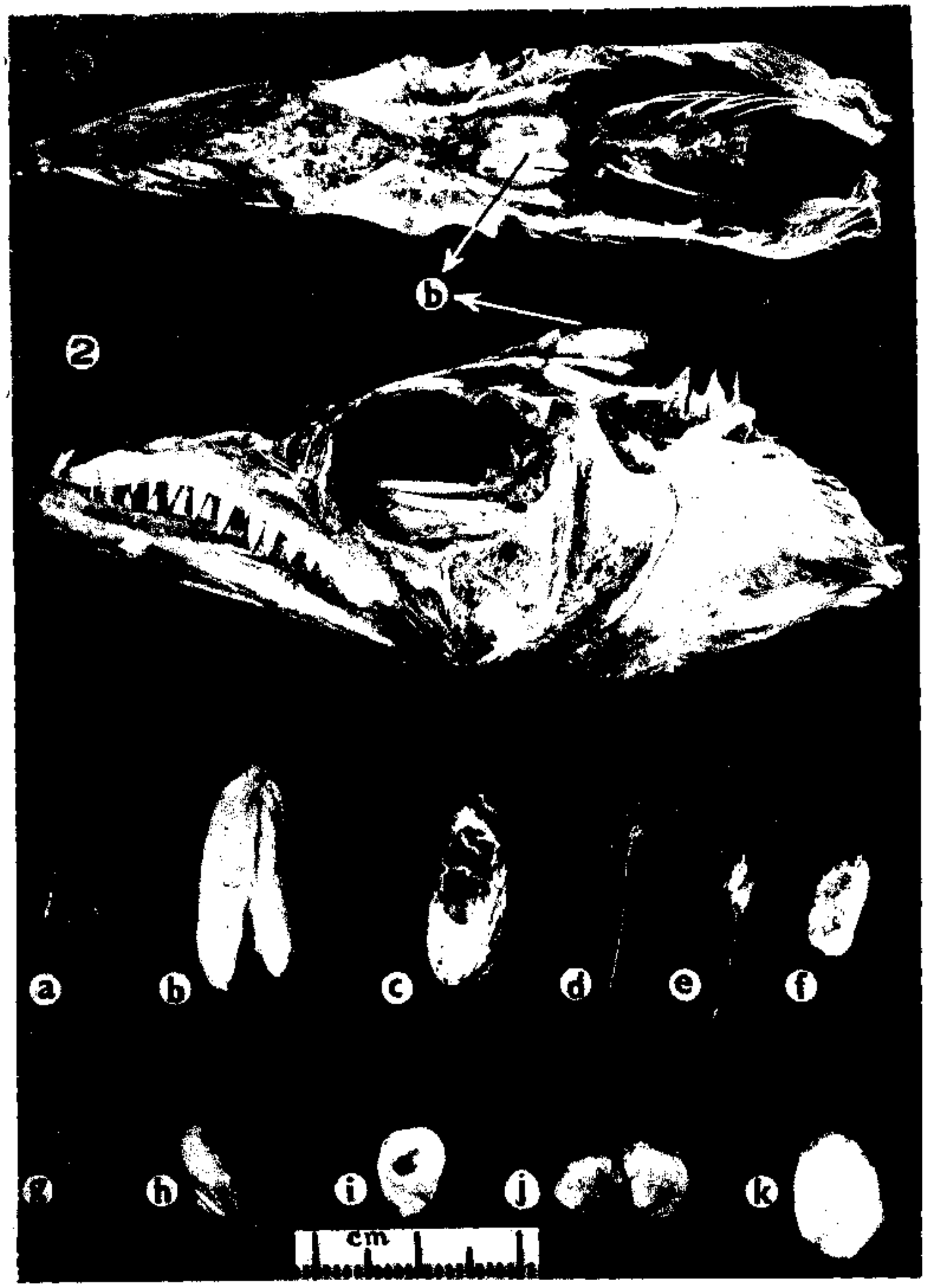

PLATE IV

Trichiurus lepturus

Fig. 1. Dorsal view of skull showing thickening of supraoccipital bone (*b*) in a specimen of 89.5 cm. SL., head length 13.35 cm. 2. Lateral view of the same. 3. Isolated bones. (*a*) Normal supraoccipital bone (57.4 cm. S.L.); (*b*) Ossified supraoccipital (68 cm. S.L.); (*c*) Longitudinal section of extraossified supraoccipital showing honey-comb pattern. (*d*) Normal interneural (57.4 cm. S.L.); (*e*) Ossified interneural (70.7 cm. S.L.); (*f*) Longitudinal section of ossified interneural (70.7 cm. S.L.); (*g*) Normal interhaemal (57.4 cm. S.L.); (*h*) Ossified interhaemal (70 cm. S.L.); (*i*) Longitudinal section of ossified interhaemal (58.5 cm. S.L.); (*j*) Two successive interhaemals ossified and on way to coalescence (63.7 cm. S.L.); (*k*) Ossified interhaemal, entire length (59.2 cm. S.L.).

TABLE XII

Summary of the data

(Expressed in percentages–third to tenth columns only)

Total number of specimens examined and sex	Total number showing bone enlargements	Occurrence of bone enlargements	Supraoccipital enlargement alone	Interhaemal enlargement alone	Interneural enlargement alone	Supraoccipital, Interhaemal together	Supraoccipital, Interneural together	Interhaemal, Interneural together	Supraoccipital, Interhaemal and Interneural
534	56*	10.4	26.9	28.5	1.6	44.6	12.5	10.7	7·1
Males	19	36.5	14.2	25.0	100	40.0	42.8	50.0	50.0
Females	33	63.4	85.8	75.0	Nil	60.0	57.2	50.0	50.0

* 4 Specimens, sex unknown, not included in calculation of percentage sex-wise.

Interhaemal enlargement (Pl. III, Fig. 3) was first noticed in a specimen of 422 mm. and the biggest specimen measures 728., both from Vizhingam (Trivandrum). The sex ratio for the occurrence of enlarged interhaemal is 15 males to 20 females (+4 of sex unknown).

The interneural enlargement (Pl. III, Fig. 4) was first noticed in a specimen of 523 mm. and the biggest specimen in which it occurs, measures 978 mm., both from Vizhingam (Trivandrum). Sex-wise, it is present in 5 males and 4 females (+1 of sex unknown).

It will be seen that interhaemal enlargements are more common than those of the interneurals. The location of the thickened bones is variable. The anteriormost interhaemal enlargement was found to be that against the 56th vertebra and the posteriormost against the 112th vertebra from anterior end, inclusive of atlas vertebra. In the case interneural thickenings, the anteriormost was found against vertebra 15 and the posteriormost against vertebra 88. This indicates that any interneural or interhaemal bone is equally susceptible to enlargement, although in the material examined, they fall within the limits mentioned above.

The fusion of the thickened bones is common on the haemal side, and except for one instance, it is absent on the neural side. The maximum number of 'stones' found in a single individual at a time is 5. The biggest 'stone', a compound interneural condition involving 3 spines, measures 23.5 mm. in height and 22.5 mm. in width.

2. Discussion and Conclusions

Excess ossification of bones is not uncommon in fishes, and many earlier workers have drawn attention to this phenomenon in the different groups. Barnard (1948) refers to such thickened bones in *Chrysoblephus gibbiceps* and *Caranx equula* and terms the condition as 'hyperostosis.' Chabanaud (1926, 1927) reported its occurrence in sciaenids. Ebina (1936) mentions extraordinary bone formation in the supraoccipital bone of *Evynnis cardinalis*. Gopinath (1951) described the secondary ossification of supraoccipital crest in certain carangids and suggested such bone formation helps the fishes to maintain equilibrium. Gregory (1933) mentioned the swelling of the supraoccipital in *Chaetodipterus faber* and Gunther (1960) mentioned the development of outgrowths from certain of the interneurals and neurals of *Lepidopus caudatus* which is known to be a teratological condition. Kesteven (1928) and Lutken (1880) as cited by Gopinath (1951) have described an occipital knob in the crest of *Pagrosomus auratus* and the large occipital crest which brings in a change in the head profile of *Coryphaena hippurus*, respectively.

All the above authors, except Gunther's reference to *Lepidopus*, have referred to excess ossification of the supraoccipital or its crest in a variety of fishes, while other bones appear evidently not to be involved. The present observations on *Trichiurus lepturus* draw attention to additional ossification not only of the supraoccipital bone but also the interneural and interhaemal spines and their combinations. Cuvier was the first to notice a thick mass of bone formed by the fusion of supraoccipital and parietals in the skull of *T. lepturus* and considers it as a peculiarity of the species. Gunther (1960) while describing the skull of the same species remarks that such a condition was not noticed by him. According to him, it could possibly be a disease of bones similar to that he noticed in *Lepidopus caudatus*.

Starks (1911) refers to thickening of bones in the skull and clavicle of two specimens of *T. lepturus* from the Atlantic. In addition, he found the lower part of the clavicle swollen, which evidently is a rare condition, in one specimen from China, labelled *Trichiurus japonicus* in the collection of Stanford University. He however, stated that there are no swollen interneurals, in his account of the general osteological characters of the genus *Trichiurus*.

The present observations show that enlargement of supraoccipital bone, and the interneural and interhaemal spines is quite common in *T. lepturus*, from different localities along the Indian coast. Individuals over 422 mm. only show the supraoccipital bone and interhaemal spine thickening, whereas the interneural thickening seems to be present only in specimens above 523 mm. Although the analysis of the sample shows a greater percentage of females with these enlarged bones, statistical analysis of data applying the test of significance at 5% level (chi-square) has shown that no reliable difference in respect to sex is indicated. It may, therefore, be concluded that the three types of thickened bones occur in individuals quite at random, and irrespective of age (above the size limits given), sex and locality.

While enlargement of these bones is common in *T. lepturus*, it is significant that not a single instance of this is revealed in an examination of several specimens of allied species of the family Trichiuridae from Indian waters, all of which have almost similar habits, external form and general osteological characters . Cuvier's description that this thickening and union of bones is a peculiarity of the species is not inconceivable from the present observations, while provision is also made to Gunther's contention that it could be a disease of bones. Bhatt and Murthi (1960) have referred to this condition as a case of osteoma— a neoplastic disease. It may safely be stated, whatever be the cause of excess ossification in this species, its occurrence is confined only to *T. lepturus* and not noticed in 600 specimens of *L. savala*, 3038 specimens of *E. intermedius* and 450 specimens of *E. muticus*, examined for this purpose.

It is interesting to note in this connection, bone thickening in *T. lepturus* has been reported from Atlantic and China (Starks, 1911) and attention is drawn to its occurrence in the same species now from Indian waters and Andaman sea, thus throwing more light on the homogeneity of the species *Trichiurus lepturus* both in the Atlantic and Indo-Pacific.

IV

ALIMENTARY CANAL

The simple, straight alimentary canal, the barbed nature of caniniform teeth and the elongation of the bones, specially of the preorbital region of the skull of ribbon-fishes truly illustrate their extremely predaceous nature. This is further borne out by a comparative study of their food and feeding habits which revealed the carnivorous and primarily piscivorous habit of these fishes to be described later.

Suyehiro (1942) and Mahadevan (1950) have described the alimentary canal of *Trichiurus haumela* (=*T. lepturus*) and Gunther (1860), Day (1876), Lin (1936), de Beaufort (1951), Okada (1955) and Tucker (1956) have briefly referred to the teeth and gill rakers of different species of ribbon-fishes but a comparative study of the alimentary canal and the teeth and gill rakers from a systematic point of view and in relation to their adaptation for feeding in the four species of ribbon-fishes has hitherto not been attempted. Some observations made by the author in this direction are given below. Teeth and gill rakers of the outer row on the outermost branchial arch are counted on the left side only.

1. Oral Armature

i. *Teeth* : Trichiurids are characterised by the possession of prominent teeth, especially those at the tips of both jaws, which are long, curved, barbed and caniniform. The jaws are well-developed and bear teeth along the edges lining the mouth (Fig. 22, D-G). The premaxilla and dentary of each side bear these teeth, while the vomer is devoid of them. The palatines bear small recurved teeth arranged either in villiform bands (*T. lepturus* and *L. savala*) or in a linear series (*E. intermedius* and *E. muticus*).

An examination of teeth in several specimens of the four species revealed that they are suited for seizing and biting the prey. They appear to be prehensile in nature and prevent the escape of prey from the mouth cavity. The caniniform teeth may be specially useful for this purpose. The stomach contents of the four species have shown that especially in case of *L. savala* various fishes which form its food are bitten into pieces if the size of the prey is big and then swallowed. The prehensile nature of the caniniform teeth of both jaws is further enhanced by the development of barbs on their inner sides.

In all the four species, a maximum of three fang-like teeth may be present at any time in each half of upper jaw. The number may be variable in the same species depending on replacement, damage and the time of collecting of the specimens. The caniniform teeth in the upper jaw are located in the front of premaxilla, usually arising from the thickest portion of the bone. The foremost of these although curved inwards like the others, is directed outwards, while the ones following it are directed downwards and backwards. While the rest of the teeth arise along the outer edge of the bone, the origin of caniniform teeth is always inner to the rest of the teeth. It has been observed, while some teeth are yet functional, new ones make their appearance in sockets which are apparently the positions occupied by teeth that were broken or shed. The cavities of such teeth are specially striking in some specimens of *L. savala* and *E. intermedius*. Teeth are solid, the dentine portion appearing as a core of elongated cells . Each tooth presents a cap with a distinct demarkation. The dentine extends into the cap region also. In the lower jaw, the caniniform teeth are situated at the tip of the dentary of each side and since the lower jaw is longer in all species of ribbon-fishes, these teeth remain outside when the mouth is closed. This may also be an adaptation to prevent the escape of prey. The fang-like teeth of lower jaw are only gently curved and they are not as prominently barbed as those on the upper jaw. Measurements of the lengths of the caniniform teeth of upper jaw and the lower jaw revealed that they do not bear any relation with the size of the fish (thereby, the age of fish) since these teeth are continuously replaced as and when they are worn out or broken. Consequently, a smaller fish may bear longer caniniform teeth and the converse may also be true.

In *E. intermedius*, some of the caniniform teeth may not be distinctly barbed. It is probable that these barbs develop with age. The caniniform teeth of *E. mutimus* are either not barbed or faintly barbed. Further, the fang-like teeth of the upper or lower jaw of the two sides may not be of the same length in the same fish.

In both the upper and lower jaws of all the four species, a number of smaller triangular teeth follow the caniniform teeth. These teeth, unlike the fang-like teeth, are situated along the median edge of premaxillaries and the dentaries and in the latter, it would appear as if they arise from a median groove since the bone is thicker than the premaxillary. In the upper jaw, this row of small teeth extends right from the anterior tip of premaxilla to its posterior end but in the lower jaw, the smaller conical teeth commence only behind the caniniform teeth. A few of these conical teeth at the anterior end may be directed forward whereas the following ones gradually have their tips directed backwards. The simple teeth are not located equidistantly along the jaw bone with the result that the interspaces are either bigger or smaller. On certain occasions, it was found, that two or three of these teeth may be situated so close to one another that hardly any space is left between them. It was also noticed that at the bases of functioned teeth, rudiments of replacement teeth could also be seen through the transparent edge of the jaw bone. The number of smaller teeth is also quite variable in any single species at a time as these are also constantly worn out and replaced. In both the upper and lower jaws, teeth at either end are smaller in size and those at the middle region are longer. At least in *L. savala*, teeth on the mandible are much smaller than those on premaxilla. In *E. intermedius* and *E. muticus* some of the ordinary teeth are straight and some are curved, although all of them are directed backwards. The smaller teeth external to the caniniform teeth in *E. intermedius* are linear, narrow, pointed and situated close together as if to bridge over the wide gaps between the larger fang-like teeth.

In certain cases, the worn out bases of older teeth may be seen along the edge of the bone. Very rarely, two new roots are seen in a gap between two functional teeth. However, a few of such were noticed in some specimens of *E. intermedius*. The roots take origin usually between two functional teeth and hence develop along side of a functional tooth. Some roots may arise directly below in the middle region of the bases of functional teeth and grow in an inward direction. This might eventually stimulate the shedding of the functional teeth which they apparently succeed. In the dentary, unlike in the premaxilla, a gap usually exists between the larger caniniform and the smaller conical teeth that follow on each side. As the secondary teeth make their appearance and grow, they seem to push the functional ones with the result that the adjoining side of the functional tooth gets worn out. Due to irregular replacement of worn out teeth at different stages, the teeth on the lower jaw do not show any regular pattern of arrangement. Consequently, teeth of various heights may be found along the edge of the bone. The bases of old, worn out teeth are often seen between bases of functional teeth in the premaxilla as well as the dentary.

A tendency for some of the ordinary teeth behind the fang-like teeth to develop barbs is seen only in the dentary of *L. savala*. This may be considered a secondary development since in this species, teeth on lower jaw are fewer and widely spaced when compared to other species. However, such a condition was not observed in its premaxilla or in the premaxilla and dentary of other species. A maximum of six of them may develop such barbs on their inner margins. Even the secondary teeth in this position, though small, develop faint barbs, probably indicating that teeth arising in this region are prone to develop this character. Some times as many as two teeth immediately behind the lower caniniform tooth of each side may not possess barbs but the following teeth up to a maximum of four or five may develop barbs in this species. In one specimen of *L. savala* a small canine-like tooth was present at the tip of premaxilla.

The smaller teeth in *E. muticus* are comparatively close-set in the premaxilla. A few anterior teeth in both the upper and lower jaws are straight and directed outwards. The anterior teeth are more closely set than the posterior ones in both the jaws. In this species, teeth that would be worn out in course of time have a characteristic appearance. These teeth develop constrictions at their bases, which, with time, may deepen and break the teeth but their bases alone may be seen for some time along the margin of the bone between functional teeth. Whether this is also the case in other species is doubtful, since such basally constricted teeth were not met with in them. On the other hand, as pointed out earlier, as the secondary teeth grow, they seem to bring pressure on that side of the functional teeth where they touch each other and eventually cause them to be replaced. The bases of older teeth are shorter and not deep in the bone while those of recent teeth are deep rooted. A continuous replacement of teeth is indicated by the presence of secondary teeth in various stages of development and in various sizes, the smallest being farther away from the margin of the jaw. The presence of bases of old and worn out teeth, functional teeth and the roots of replacement teeth at the same time in the premaxillary and the dentary bones of all the four species of ribbon-fishes indicates that teeth are not only worn out but are also continuously replaced by a reserve set of dentition.

Comparatively, the barbed caniniform teeth are pronounced in *L. savala* and least developed in *E. muticus*. It should also be pointed out that *L. savala* is unique in the respect that as many as six teeth following the caniniform tooth of each half of lower jaw may also be barbed. Teeth are widely set and fewer in this species whereas they are closely set and numerous in *E. muticus*. The other two species, *T. lepturus* and *E. intermedius* fall between these two extremes represented by *L. savala* and *E. muticus*. As far as other teeth and their arrangement are concerned, the four species do not appear to differ from one another.

ii. *Gill rakers* : Since the ribbon-fishes are carnivorous, the gill rakers on the branchial arches are least developed but among the species, they show variation in the relative degree of development which may be correlated with the differences in nature and arrangement of teeth and their diet (Fig. 22, H-N). The gill rakers are prominent only on the outermost arch (that nearest the operculum) and progressively reduced in number as well as size from outside inwards. Generally, there are about 16 gill rakers on the first, 7 on the second 5 on the third and none of the fourth branchial arch in *T. lepturus* ; 4 on the first, 2 on the second, none on the third and fourth arches in *L. savala;* 13 on the first, 9 on the second, 1 on the third and none on the fourth arch in *E. intermedius ;* 17 on the first, 10 on the second, 8 on the third and none on the fourth arch in *E. muticus*. All the gill rakers point inwards and forwards with smaller rudiments in the intermediate spaces which may replace the worn out ones in due course.

In all the species, it was observed, the gill rakers near and about the angle of the branchial arch are better developed and usually, the number of gill rakers is more on the ventral half of each arch than on the dorsal half. In some cases, a number of spines, as many as three of the same length arise from a single basal plate. When the floor of the pharyngeal cavity is raised, the gill rakers from the dorsal and ventral halves of each arch cross each other, specially at the angle.

Apart from these principal and prominent gill rakers counted on the outermost arch of left side, in all the specimens, there are a number of smaller ones interspersed between these. The extremes of the gill arches present roughened surfaces. As all the gill rakers are not of the same length, and their number variable in any one species, it follows that, like the teeth, these are also continuously replaced by a secondary set as and when the functional ones are worn out. This is further borne out by the fact that the length of the fish and the length of the biggest gill raker do not show any relation. It has also been observed that the length of the gill filaments increases with age, while that of the gill rakers may not be correlated with age.

Some observations were made on the gill rakers in young ones of these fishes to compare with those of adults. In case of *E. intermedius* the condition of gill rakers in young one of 12.7 cm. standard length (Fig. 22, I) seems to be truly reflected in the adult (Fig. 22, H). In *T. lepturus*, in a young one of 10.9 cm. standard length the gill rakers appear very long and bent, better

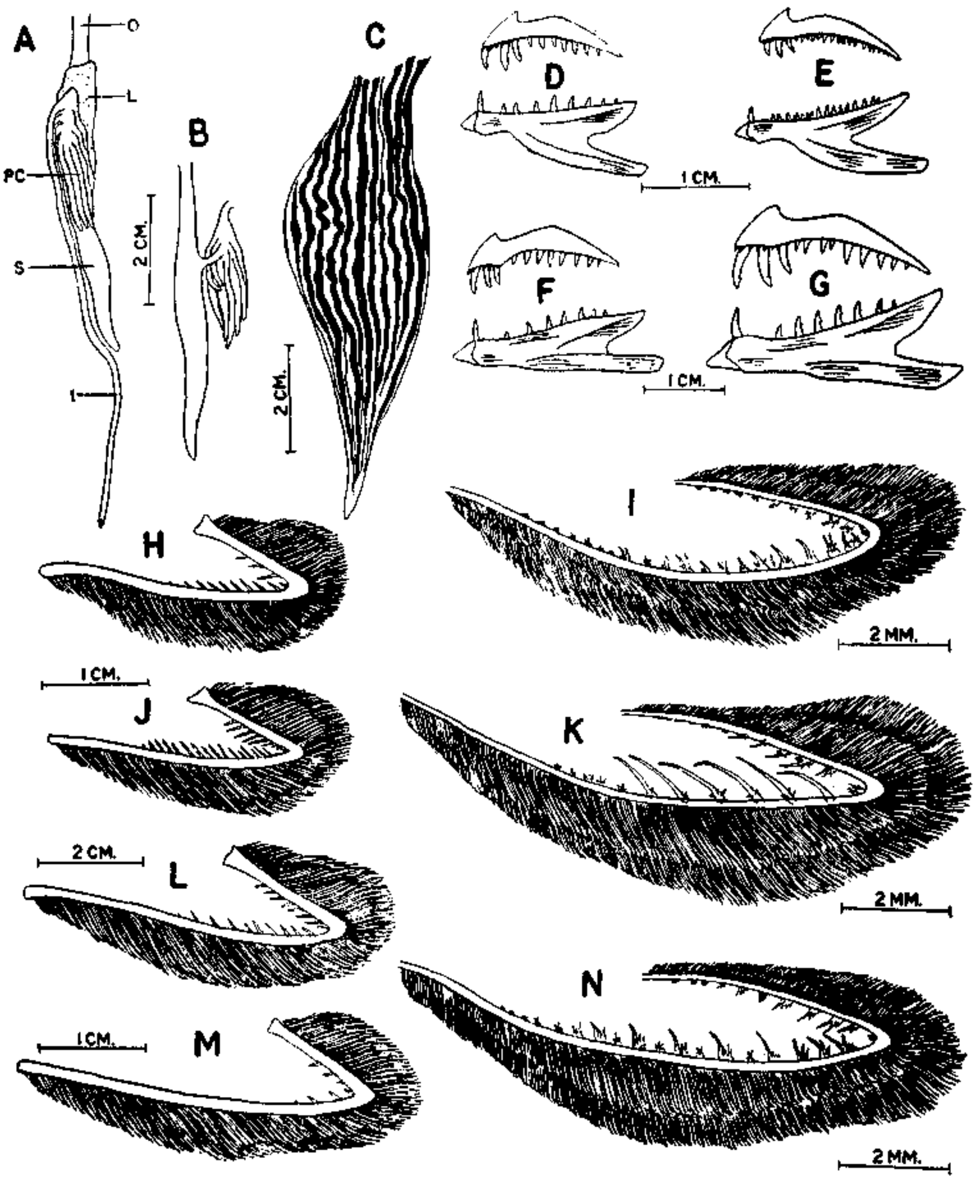

Fig. 22. A. Alimentary canal of *E. intermedius* I : intestine; L : Liver; O : Oesophagus; S: Stomach; PC: Pyloric caeca. B. The stomach of *E intermedius* with the pyloric caeca displaced to a side. C. Inner view of an empty stomach of *L. savala* showing the mucosal folds. D to G. Premaxillary and dentary of D. *E. intermedius*. E. *E. muticus*. F. *T. lepturus*. G. *L. savala*. H. to N. Left outermost gill of H. adult of *E. intermedius*. I. young one of *T. lepturus* L. adult of *T. lepturus*. M. adult of *L. savala* and N. young one of *L. savala* showing gill rakers.

developed on the ventral half than the dorsal half (Fig. 22, K). In the adult of this species they do not appear to be so striking (Fig. 22, L). In a young one of *L. savala* 14.5 cm. standard length the gill rakers are prominent (Fig. 22, N), but reduced in the adult (Fig. 22, M). Comparatively, the gill rakers are better developed in the young one of *T. lepturus* than in that of *L. savala*. It would appear therefore that the young one of *L. savala* may be as voracious as the adult (which was confirmed by the examination of stomach contents in which small fishes and other items such as *Lucifer* were present) whereas *T. lepturus* appears to become more voracious with increase in age. While the adults of both *E. intermedius* and *T. lepturus* resemble each other, their young ones differ strikingly for this character. The young ones of *E. intermedius* and *L. savala* have equally prominent gill rakers but their adults differ in that they are completely reduced and rudimentary in the latter species. As young ones of *E. muticus* were not available for study, a comparison of this species with others could not be made. However, it may be expected, as in *E. intermedius*, the condition in the young one is reflected in the adult of *E. muticus* (Fig. 22, J) where, it may be recalled, the gill rakers are well developed when compared to all the other species.

The gill rakers are reduced in the adult of *L. savala* whereas they are most developed in *E. muticus*, the other two species *T. lepturus* and *E. intermedius* occupying a place between the above two species with regard to the size and degree of development of gill rakers. The young one of *T. lepturus* differs strikingly from the adult in the nature of gill rakers, while in the other species, the condition seems to be the same in the case of young ones and adults. It may therefore be seen from the data presented above on the teeth and gill rakers of the four species of ribbon-fishes, the pronounced nature of teeth is associated with a lesser degree of development of gill rakers and *vice versa*.

2. Gross Anatomy

The alimentary canal of the four species of ribbon-fishes is similar in that it is short and straight (Fig. 22, A). The gape of the mouth is wide in all the species but comparatively, it is widest in *L. savala* and narrowest in *E. muticus*.

The buccal cavity is broad anteriorly but it progressively narrows down posteriorly towards the pharynx. The roof of the buccal cavity is lined by a thin flesh coloured or whitish membrane folded longitudinally and with a deep groove along the middle line. This membrane is continuous with that of the pharynx. Since the fishes are laterally compressed, the floor of the buccal cavity is less extensive than the roof. It is generally slippery due to a continuous secretion of mucus. The tongue is long and narrow in *Eupleurogrammus* species, short and broad in *T. lepturus* and *L. savala*. The membrane is studded with numerous melanophores. The surface of the tongue is flat in all the species and the edges curl downwards.

The pharyngeal region extends from the first gill arch to the last. The structure and number of gill rakers in the four species are variable as described above. All the gill arches bear a double row of gill filaments the inner row being longer than the outer. The ventral half of each arch is longer than the dorsal half and consequently the floor of the pharynx is much bigger than its roof. There is a gradual reduction of the size of ventral and dorsal portions of the gill arches from outside inwards. The central portion of the roof of the pharynx is formed by the ventral surfaces of the long palatines, which bear minute, inwardly pointed teeth.

The oesophagus is a short, cylindrical tube leading into the stomach. The oesophagus, like the stomach which will be described below, is capable of distention, since, its internal lining exhibits numerous longitudinal folds when the stomach is empty.

The liver consists of two lobes, the right lobe being smaller than the left which is elongate and surrounds the anterior portion of the stomach. The gall bladder is narrow and long. The structure of the liver and the gall bladder is similar in the four species.

The stomach is produced into a long tubular cardiac portion, on the right side of the anterior end of which is attached the pyloric part (Fig. 22,B). The wall of the cardiac stomach is thick, muscular and highly distensible, evidently to serve as a receptacle in these voracious fishes. The inner view of the caecal portion of the stomach, when empty, presents an interesting structure (Fig. 22,C). In the genus *Eupleurogrammus* 8-10, in *T. lepturus* about 16, and in *L. savala* about 10 mucosal folds have been observed. While some of the folds run for the entire length, others merge in the general surface. Interspersed between the major folds, may be found many smaller ones of various heights and each longitudinal fold is further folded cross-wise. This structure of the caecal portion of the stomach suggests its expanding capacity and the consequent increase in the absorptive surface.

The pyloric stomach is a narrow thick walled, short tube, taking origin very anteriorly on the ventral side directed towards the duodenum. The structure and point of origin are similar in *T. lepturus*, *L. savala* and *E. intermedius* but are somewhat different in *E. muticus*. In this species, it narrows down before giving origin to duodenum and its origin is about midway in the length of the cardiac stomach on the ventral side unlike its origin much anteriorly as in the other species.

The anterior portion of the intestine receives the pyloric caeca. The caeca are long, cylindrical and finger-shaped. They open by separate pores. The number of pyloric caeca shows interspecific as well as intraspecific variation in these fishes. Although variable, the number of these caeca in each species does not seem to overlap with those of others and the variation in their number is much greater in *T. lepturus* than in any other single species. The results of the examination of a number of specimens of the four species are presented in Table XIII.

It is likely, that an examination of a greater number of specimens of *T. lepturus* may bridge over the gaps in the variation between the two extremes

TABLE XIII

Variation in the number of pyloric caeca in the four species of ribbon-fishes

Species	No. of fish examined	Size range (Standard length cm)	Variation in number of pyloric caeca	Common number of pyloric caeca
T. lepturus	36	34.6-75.6	23-41	23
L. savala	73	16.0-53.1	14-19	15 & 16
E. intermedius	213	10.8-46.1	7-9	8
E. muticus	30	43.0-57.1	0-12	10 & 11

and thereby support the view that, like many body proportions, the number of pyloric caeca may also be highly variable in this species.

Rahimulla (1945) made detailed studies on the morphology, histology and probable functions of pyloric caeca in several Indian fishes. He classified them into 10 morphological groups, with Trichiuridae represented by *Trichiurus savala* (= *L. savala*) under group two (caeca arranged in a linear series and each caecum opening independently at the beginning of the duodenum). He however mentioned 32-34 caeca in *T. savala.*

The arrangement of the caeca in the various species is also found to be variable. In all the species, a varying number of them on the right side, from 1-5, are folded towards the left side, so that only their bases are seen, when viewed from ventral side. In certain cases, while the first few anterior caeca on right side are not folded, the following few may be folded and the rest remain normally spread out. In *T. lepturus*, when the caeca are numerous, they may be arranged in two layers one above the other, which feature was not met with in other species. This could be related to the greater number of caeca found in *T. lepturus*. While a maximum of 5 caeca are folded in this species, only 2 or 3 are folded in the other three species. Comparatively, the pyloric caeca are much narrower and longer in *E. muticus* than in the other species.

The intestine is a narrow straight tube, which is lodged for the greater part of its length in a narrow groove on the ventral surface of the gonads. It opens posteriorly at the anal opening.

3. Histology

The histology of the alimentary canal of *T. haumela* (= *T. lepturus*) has been described by Mahadevan (1950). Therefore the histology of the alimentary canal of *E. intermedius* alone is described below.

For histological studies the various regions of the alimentary canal of *E. intermedius* were fixed in aqueous Bouins and cross sections were cut uniformly at 6μ. The sections were stained in Dilafield's Haematoxylin and Eosin.

i. *Buccal cavity* : The lining of the buccal cavity consists of the mucosa and the submucosa. The mucosa is made up of stratified epithelium supported by a thick stratum compactum. The mucus epithelium lacks the longitudinal folds and taste buds. It contains numerous large mucus secreting cells with the nuclei situated at the bottom. Below the stratified epithelium is a thick basement membrane below which is situated the stratum compactum made up of bands of closely packed fibres occupying an area double that of mucosa. The submucosa is made up of areolar connective tissue.

The tongue is made up of the same layers except that the mucus epithelium consists of only two or three cell layers.

ii. *The Pharynx* : The histological structure is similar to that of buccal cavity.

iii. *Oesophagus* : The wall consists of mucosa, submucosa, muscularis and serosa (Fig. 23, A,B). The epithelial folds are formed by the mucosa and the submucosa. The epithelium is supported by a thin casement. The connective tissue fibres are situated below this, forming the tunica propria which is vascularised. The increase of surface by the mucosal folds and the vascularisation indicate the absorptive function of this region. The muscularis consists of a layer of striated circular muscles the fibres of which invade the tunica propria. The serosa is a thin layer.

iv. *Cardiac stomach* : The wall of the cardiac stomach is thick and extensile (Fig. 23, C,D). The epithelium is made up of columnar cells. The mucus cells present in the epithelium are broad towards lumen, narrower in the middle and vesicular towards the base. The glands are tubular separated from one another by connective tissue septa. Each gland is formed of 6 to 30 cells. The tunica propria is formed of loose areolar kind of connective tissue which sends strands in between the gastric glands. The muscularis is composed of a thin external unstriated longitudinal muscle layer and of a thicker internal unstriated circular muscle layer. The serosa is composed of a single layer of flat cells.

v. *Pyloric stomach* : The wall of the pyloric stomach is similar to that of the cardiac stomach except that the mucosal folds are conspicuous, the glands being completely absent and in that the muscular layers are very thick in the former (Fig. 23, E,F). The thickness of the circular layer of muscles which is about three times the longitudinal muscle layer is specially striking in the pyloric stomach.

Fig. 23. Histology of the alimentary canal of *E. intermedius* A. Transverse section of a segment of oesophagus B. A portion of the same magnified. C. Transverse section of a segment of the cardiac stomach D. A portion of the same magnified. E. Transverse section of a segment of the pyloric stomach F. A portion of the same magnified. G. Transverse section of a segment of the duodenum. H. A portion of the same magnified. Circ. mus. : Circular muscle; Col. epi. : Columnar epithelium; Gas. gl. : Gastric gland; Gob. cell : Goblet cell; Long. mus. : Longitudinal muscle; Muc. : Mucosa; Ser. : Serosa; Submuc. : Submucosa; Tun. pro. : Tunica propria.

(for illustration see page 75)

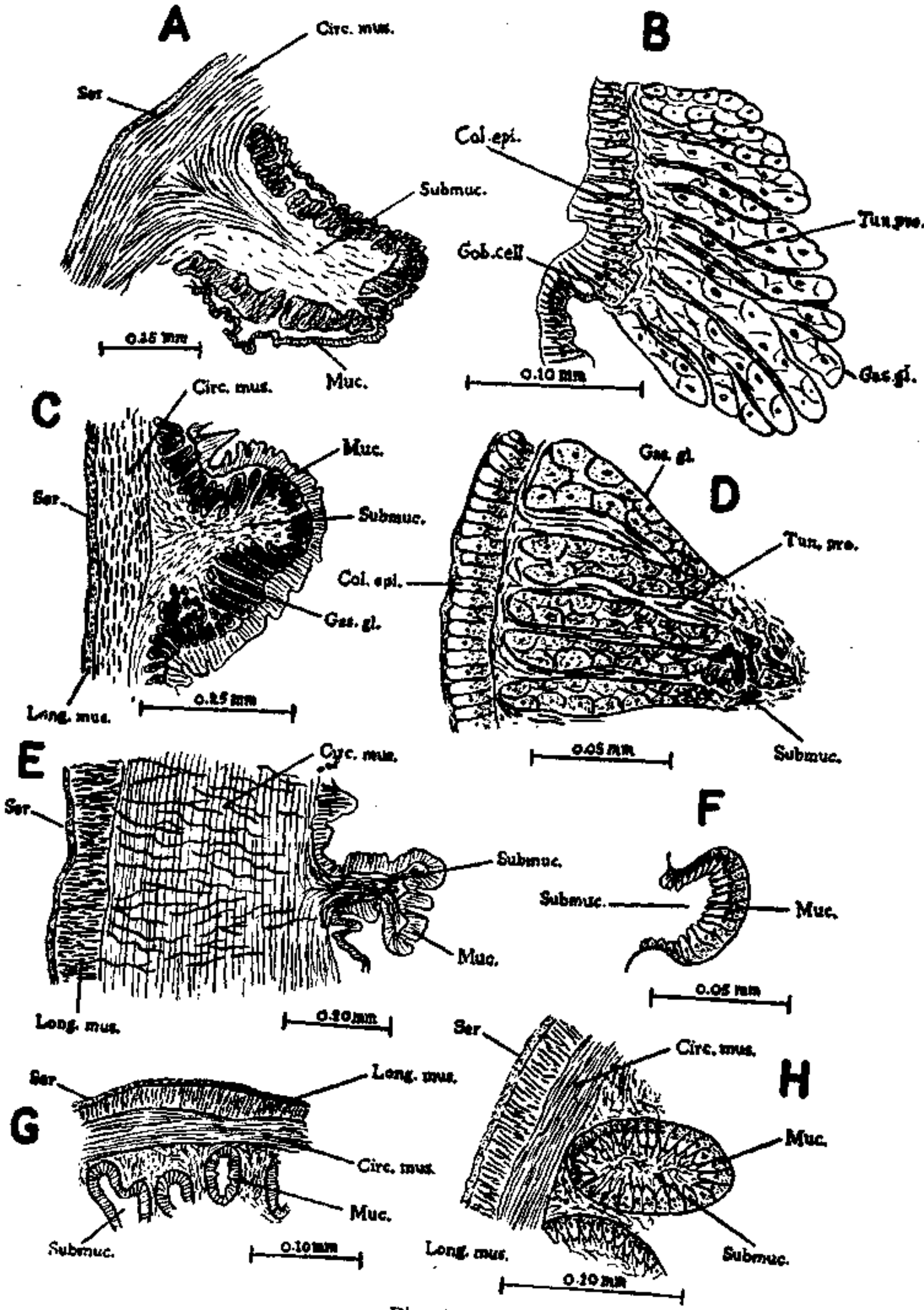
A
Circ. mus.
Ser
Submuc.
0.25 mm
Muc.
B
Col.epi.
Gob.cell
Tun.pro.
Gas.gl.
0.10 mm
C
Circ. mus.
Muc.
Ser.
Submuc.
Gas. gl.
Long. mus.
0.25 mm
D
Gas. gl.
Tun. pro.
Col. epi.
0.05 mm
Submuc.
E
Circ. mus.
Ser.
Submuc.
Muc.
Long. mus.
0.20 mm
F
Submuc.
Muc.
0.05 mm
G
Ser.
Long. mus.
Circ. mus.
Muc.
Submuc.
0.10 mm
H
Ser.
Circ. mus.
Muc.
Long. mus.
Submuc.
0.10 mm

Fig. 23.

vi. *Intestine* : The wall consists of the mucosa, tunica propria, muscularis and serosa (Fig. 23, G,H). Mucosal folds are mainly longitudinal but are also transverse at some places. They are long and profuse near the duodenal region. The folds are fewer in the posterior region of the intestine. The mucosal epithelium is composed of cylindrical and mucus secreting cells, the latter localized in the duodenal region. Goblet cells are found on the crests of the folds in the posterior region of the intestine. Wandering leucocytes and granular cells have also been noticed. Tunica propria supports the epithelium and is made up of loose fibres. The muscularis consists of the two layers, the circular layer being thicker than the longitudinal. The serosa forms a pavement epithelium.

vii. *Pyloric caecum* : The structure of the wall of pyloric caecum is similar to that of the wall of the intestine.

The structure of the alimentary canal of *E. intermedius* has been found to be essentially similar to that of *T. lepturus*, a fact that may be corroborated by the similar feeding habits of these fishes. Therefore it may also be expected that the structure of the alimentary canal in the other two species will be similar to that described above.

V

VASCULAR SYSTEM

The vascular system of the four species of ribbon-fishes has been found to be similar and therefore only that of *T. lepturus* is described below.

1. Heart

The heart is muscular, contained in the pericardial cavity, situated on the ventral side behind the branchial arches. It is composed of the three typical chambers, a sinus venosus which receives the venous blood from the body, an auricle and a ventricle. The sinus venosus and the auricle have thin walls when compared to those of the ventricle. The bulbus arteriosus is interposed between the ventricle and the root of the ventral aorta. The sinus venosus is posterior, the auricle dorsal and the ventricle ventral in position.

2. Arterial System

The *ventral aorta* is a large, median, thick-walled artery (*va*) situated beneath the floor of the pharynx and passes directly forwards from the ventricle. Four pairs of *afferent branchial arteries* (*Af.b.a.*) arise from the ventral aorta to supply the gills. The third and fourth pairs of the afferent branchial arteries (proximal to heart) arise close together while the second pair is situated much anterior to the third pair. The first pair of afferent branchial arteries are formed by the bifurcation of the ventral aorta at its anterior most end (Fig. 24).

The blood from the gills is returned to the dorsal aorta by four pairs of *efferent branchial arteries* (*Ef.b.a.*). The first two pairs are joined by a lateral vessel on each side which passes anteriorly and unites with its fellow of the opposite side, dorsal to the posterior region of the parasphenoid to form the *circulus cephalicus* (*c.c.*) Behind the second pair of efferent branchial arteries, the two lateral vessels join in the median line to form the anterior part of the *dorsal aorta.* As the dorsal aorta passes backwards, it receives a common vessel on each side formed by the union of the third and fourth efferent branchial arteries. Further behind, near the root of the coeliac artery arise the *subclavian arteries* (*sb.a*) supplying the pectoral fins. The *coeliac artery* (*cl.a*) divides into three main branches a little behind its origin. The first branch supplies the lobes of the liver (*Ha*) and the second the caecal part of the stomach (*Cs.a*). The third branch divides again into two branches the anterior one supplying the intestine (*Int.a*) and the posterior one the air-bladder and the gonad (*Ab.a; Ga*). After giving origin to the coeliac artery, the dorsal aorta (*Da*) continues as a mid-dorsal vessel giving off on either side *segmental arteries* (*Sa*) along neural and haemal spines. They also supply the kidneys. Posterior to the kidneys, the dorsal aorta is continued as the *caudal artery* (*Ca*).

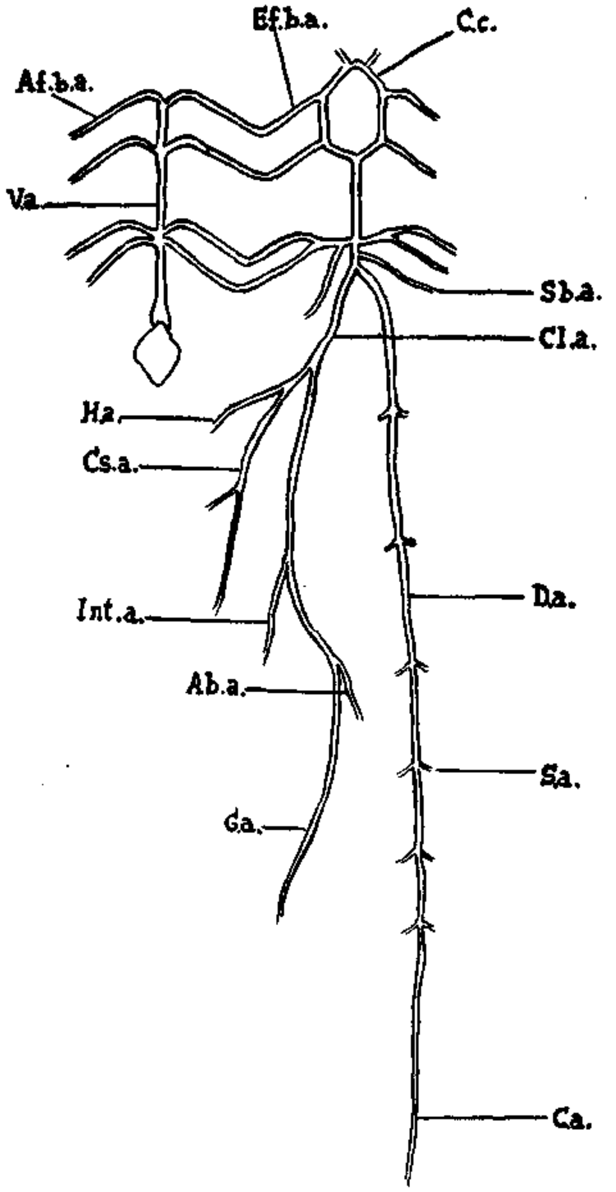

Fig. 24. The arterial system of *T. lepturus* (diagrammatic). Ab. a : Artery to air bladder; Af. b. a : Afferent branchial artery; C.a : Caudal artery; C.c. : Circulus cephalicus; Cl. a : Coeliac artery; Cs.a : Artery to cardiac stomach; D.a : Dorsal aorta; Ef. b.a : Efferent branchial artery; G.a : Artery to gonad; H.a : Hepatic artery; Int. a : Artery to intestine; S.a : Segmental artery; Sb.a : Subclavian artery; V.a : Ventral aorta.

3. Venous System

It consists of the inferior jugular veins, Cuvierian ducts, cardinal veins, segmental veins, hepatic veins, hepatic portal vein and the genital veins (Fig. 25).

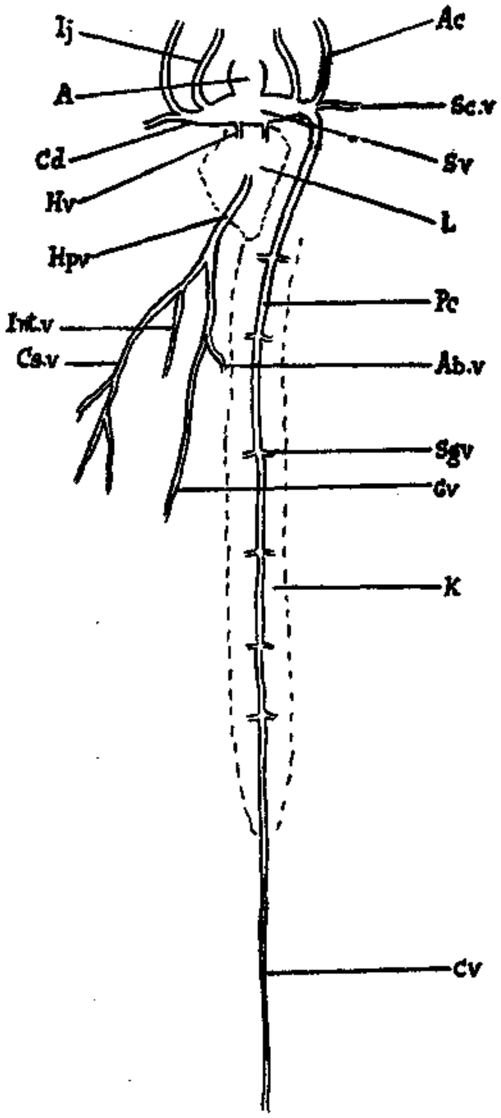

Fig. 25. The venous system of *T. lepturus* (diagrammatic). A : Auricle; Ab. v. Vein from air bladder; Ac : Anterior cardinal vein; Cd : Cuvierian duct; Cs. v : Vein from cardiac stomach; Cv : Caudal vein; Gv. Vein from gonad; Hpv. Hepatic portal vein; Hv. : Hepatic vein. Ij : Inferior jugular vein; Int. v. : Vein from intestine; K : Kidney; L. Liver; Pc. Posterior cardinal vein; Sc.v. Subclavian vein; Sgv : Segmental vein; Sv. Sinus venosus.

The *caudal vein* (*Cv*) from the posterior part of the body continues directly as the *posterior cardinal vein* (*Pc*) situated ventral to the dorsal aorta and without a renal portal system. As it passes anteriorly between the kidneys it receives minutes vessels from them (*Sg.v*) and opens into the *Cuvierian duct* (*Cd*) of the right side. The blood from the gonads is conveyed through a vessel (*Gv*) which passes mid-ventral to the gonads and during its course traverses the air bladder, receiving branches from it (*Abv*). This vessel joins a common vessel formed by the union of two smaller vessels returning blood from the intestine (*Int. v.*) and the caecal part of the stomach (*Cs. v.*). The combined large vessel, the *hepatic portal vein* (*Hpv*) enters and breaks up in the liver. Blood from the liver is emptied out into the *sinus venosus* (*Sv.*) by the *hepatic veins* (*Hv.*). Venous blood from the anterior region of the head is conveyed to the heart through a pair of *anterior cardinal veins* (*Ac*) and the *inferior jugular veins* (*Ij.*) which empty out into the Cuvierian ducts. The *subclavian veins* (*Sc. v*) from the pectoral fins convey blood to the corresponding Cuvierian ducts.

VI

NERVOUS SYSTEM

The structure of the brain and disposition of cranial nerves of *T. lepturus*, typical of the four species of ribbon-fishes is given below. Only minor variations in the size and shape of the different parts of the brain have been noticed in other species.

1. Brain

The brain cavity is small and the brain does not differ much from the typical structure of the brain of teleosts (Fig. 26). The striking features of the brain of *T. lepturus* are the enormous development of the optic lobes (*op.l*) and the cerebellum (*c*) and reduction in size of the cerebral hemispheres (*Ch*).

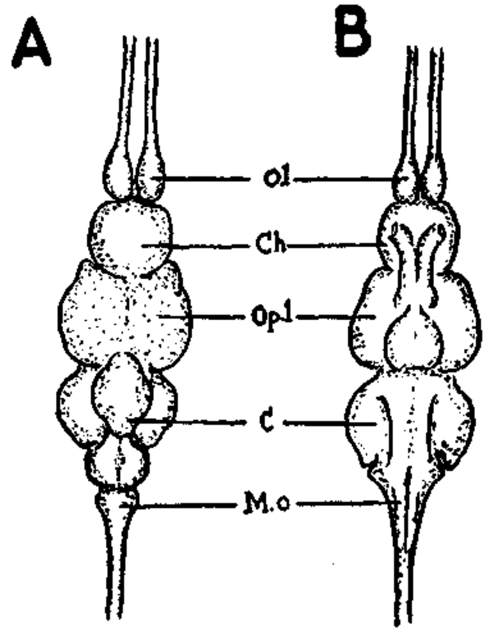

Fig. 26. The brain of *T. lepturus* (diagrammatic). A. Dorsal view. B. Ventral view. C : Cerebellum; Ch : Cerebral hemispheres; Ol : Olfactory lobe; Op.l : Optic lobe; M.o : Medulla oblongata.

2. Cranial Nerves

A description of the important cranial nerves is given below :—

i. *The trigeminal nerve* (V) (Fig. 27) : It is a stout nerve passing downwards along the hind margin of the eye, giving origin to three main branches. The first branch, *ophthalmicus superficialis* runs above the eye. The second slender branch, *maxillaris* (*Mx*) turns anteriorly and passes immediately below the lower margin of the eye to supply the upper jaw. The third stout branch,

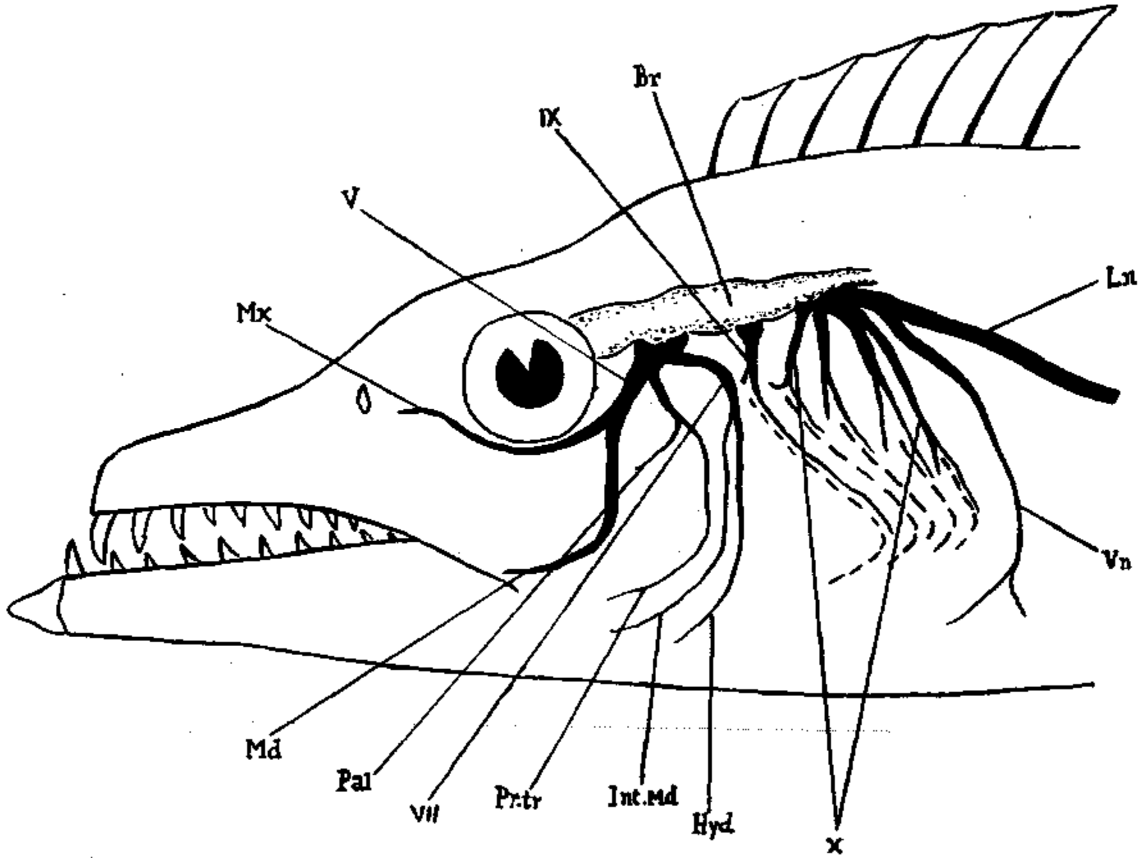

Fig. 27. The cranial nerves of *T. lepturus* (diagrammatic). Br. : Brain; Hyd : Hyoidean branch; Int. Md : Internal mandibularis; Ln : Lateralis; Mx : Maxillaris; Md : Mandibularis; Pal : Palatinus; Pr. tr. : Pre-trematic; Vn : Visceralis; V, VII, IX : Fifth, Seventh and Ninth nerves.

VII

OTHER INTERNAL ORGANS

1. Auditory Organ

The auditory organ of *T. lepturus* (Fig. 28) consists of the membranous labyrinth contained in the auditory region of the skull wall but the cavity in which it is placed is not shut off from the cranial cavity by bone or cartilage. The labyrinth consists of a central chamber or *vestibule* and three *semicircular canals* of which two are vertical (*Ac, Pc*) at right angles to each other and the third is horizontal (*Hc*). The vestibule is divided into an upper *utriculus* (*U*) into which the semicircular canals open and a lower *sacculus* (*S*) which possesses a small posteriorly directed process or *lagena* (*L*). No significant differences have been noticed in the auditory organ of the other three species.

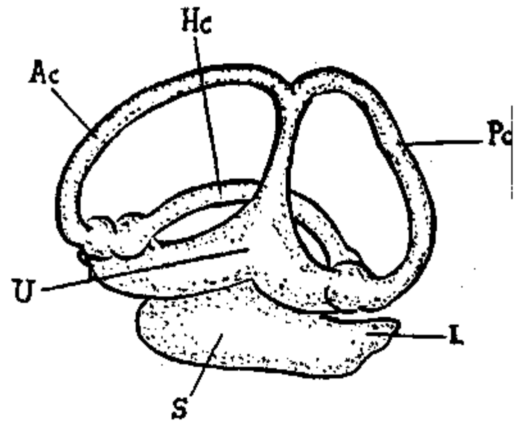

Fig. 28. Membranous labyrinth of *T. lepturus* (diagrammatic). Ac : Anterior canal; Hc : Horizontal canal; L : Lagena; Pc : Posterior canal; S : Sacculus; U : Utriculus.

2. Air-Bladder

The air-bladder of *T. lepturus* is long and tubular situated between the kidneys and the alimentary canal. Both the ends of the bladder are drawn into slender processes and terminate blindly. Anteriorly it extends up to the auditory region and posteriorly up to the level of first interhaemal spine. The external coat of the air bladder is thick and silvery whereas the inner lining is thin and transparent. The structure and disposition of the air bladder are similar in all the species.

3. Renal Organs

The kidneys are paired, thin, and ribbon-shaped structures lying closely adhered to the dorsal wall of the body cavity. They extend from about the level of the posterior end of the liver to a distance little short of the level of anus. The two ureters form a common duct to open at the urino-genital aperture. The urinary bladder is narrow and elongate, joining the common duct at its terminal portion. The structure of the renal organs is similar in all the species.

4. Gonads

The ovary is bilobed in structure, with the two lobes asymmetrical in length as well as in width. The right lobe is longer than the left. At the anterior end the right lobe contributes to part of the left, the two lobes being in the form of an inverted 'U'-shaped loop. The two lobes are fitted along the dorsal side with a groove of sepration visible ventrally. They are suspended from the dorsal wall of the abdominal cavity by a thin mesovarium. The ovary is of the pattern found in the ovaries of most teleostean fishes.

The structure of the testis is similar to that of the ovary but is more or less ribbon-shaped in all stages of maturity unlike the ovary which is cylindrical.

In both the ovary and the testis the posterior part of the wall of each lobe of the gonad is produced into a duct, both ducts opening together at the genital opening.

VIII

PARASITES

Of the four species of ribbon-fishes from Indian waters, *T. lepturus* and *L. savala* appear to harbour large number of parasites in the mouth, gut and the body cavity. Species of *Eupleurogrammus* seem to be less susceptible to parasitization.

During the present study, large number of cestode larvae (*Tetrarhynchus* sp.) were found in the body cavity of large specimens of *T. lepturus* and *L. savala* that have fed intensively. The pyloric caecal mass of these two species has been found infested occasionally with tetrarhynchid larvae. In such instances, the caeca have been found to be completely covered by an extra layer of tough tissue which, when teased out, yielded the parasites.

Gnanamuthu (1949) described the following three new copepod parasites of the ribbon-fish from south India. (1) A male and a female of *Caligus cunicephalus* have been found in the buccal cavity of a full grown *Trichiurus haumela* (= *T. lepturus*), during December-January. (2) A single female of *Caligus scablei* with spent egg strings was found firmly attached to the skin of *T. haumela* in October 1947 forming a thin, transparent scab. (3) Eleven adult females and one male of *Caligus longicervicis* have been recorded from inside the orobranchial cavity of nearly two dozen ribbon-fishes (*T. haumela*) caught at Madras in December and January. Several chalimi were found attached to a cymothoan (*Irona* sp.) parasitic in the mouth of one of the fish.

Prabhu (1955) observed larvae of cestodes, *Tetrarhynchus* sp. and *Gymnorhynchus* sp. in the gut of *T. haumela*. According to him, they were found in large numbers during times of intensive feeding in mature and spent fish but no larvae have been found in the guts of immature fish.

Part Three
BIOLOGY

IX

FOOD AND FEEDING HABITS

The distribution and fluctuation of the organisms that constitute the food of a species, like many other factors, may also affect the shoaling behaviour, migration, growth, condition and even the fishery. In view of this importance, considerable attention has been paid to the subject in recent years. Amongst the earlier works on this subject in India, mention may be made of those of Hornell and Nayudu (1924) on *Sardinella longiceps*, Devanesen ,1932) on *S. gibbosa*, Job (1940) on perches of Madras coast, Chidambaram and Venkataraman (1946) on the food fishes of the west coast of Madras Presidency, and Devanesan and Chidambaram (1948) on the common food fishes of Madras Presidency. Chacko (1949) in his studies on the food and feeding habits of fishes of the Gulf of Mannar, gave a resume of works till then, on the subject. These were followed by those of Bapat and Bal (1950, 1952), Bhimachar and George (1952), Prabhu (1950, 1955), Nair (1951, 1952), Bapat *et al* (1951), Vijayaraghavan (1951, 1953), Sarojini (1954), Kuthalingam (1955, 1956), Karekar and Bal (1958), Tampi (1958) and Venkataraman (1956, 1960) on the food and feeding habits of a wide variety of commercially important fishes. All the above authors discussed the food, its seasonal variations, feeding in relation to plankton, availability of food organisms in the environment, feeding habits in relation to sexual cycle, condition of feed, selectivity in feeding and other related aspects, and drew general conclusions that bear upon the biology of the species concerned. For instance, some fishes were classified as plankton feeders, others as carnivorous, omnivorous etc. While some of them were found to be surface feeders, others were classified as bottom feeders. In the plankton feeders, some show preference for phytoplankton, while others for zooplankton. Of the carnivores some may show a tendency towards a piscivorous nature, while others may be cosmopolitan in their tastes. It has been pointed out by some authors that there was a correlation between availability of the food of a particular species and the occurrence of fishery for the species. To quote a few instances, it was observed that the peak of fishery for the plankton feeders like mackerel and sardines along the Malabar coast is generally attained during September-December, when the inshore waters are rich in phyto-and zooplankton (George, 1953). A similar coincidence has been noticed between the fishery of Malabar sole, *Cynoglossus semifasciatus* and the availability of its favourite food item *Prionospio pinnata* (polychaete) between October and May (Seshappa and Bhimachar, 1955). A good fishery for the silver-bellies and white-baits during the monsoon months along the Malabar coast is said to be related with the abundance of their favourite food, *viz*., the copepods (Venkataraman, 1960). Thus the study of food of a fish round the year might throw some light on the biology and fishery of the species.

A few earlier investigators have studied the food and feeding habits of the ribbon-fishes belonging to the family Trichiuridae. The species involved were *Trichiurus haumela* (=*T. lepturus*) and *Trichiurus savala* (= *Lepturacanthus savala*). Venkataraman (1944) referred to the food of *Trichiurus* spp. in general. Devanesen and Chidambaram (1948), in an account of the common food fishes of the Madras Presidency mentioned the food of ribbon-fishes. In a qualitative estimation of the food components and feeding habits of some species occurring in the Gulf of Mannar, Chacko (1949) examined the gut contents of 24 specimens of *T. savala*. Jacob (1949) made reference to the diet of ribbon-fishes (*Trichiurus* spp.) in a study of their bionomics and fishery along the west coast of Madras Province. More recently the subject was investigated by Prabhu (1950, 1955) and Vijayaraghavan (1951), the former in the course of his study on some aspects of the biology of the ribbon-fish, *T. haumela* and the latter in a comparative study of the food and feeding habits of the two common species at Madras, *T. haumela* and *T. savala*. Most of the above mentioned authors made only a qualitative study of the food of ribbon-fishes, except Vijayaraghavan and Prabhu who have made a quantitative study as well, but confined to a limited period. Venkataraman (1960) mentioned briefly on the food of *T. haumela* from Malabar coast. From outside Indian waters, although many workers recorded ribbon-fishes at various localities there have not been any detailed accounts of their food except those of Suyehiro (1942) and Tham Ah Kow (1950). The former casually mentioned the food of *T. haumela* in a study of the digestive system of certain fishes from Japan and the latter reported on the diet of *T. savala* in an account of the food and feeding relationships of the fishes of Singapore Straits. It is significant that so far, the food of the other two species of ribbon-fishes, *Eupleurogrammus intermedius* and *E. muticus* occurring at various localities along the Indian coast was not investigated. The food and feeding habits of the four species of ribbon-fishes with special reference to that of *E. intermedius* are described below.

Various methods are in vogue in the study of food of fishes. To mention a few, Pearse (1915, 1916) used the volumetric method for the analysis of food of some shore fishes from Wisconsin. The same method was followed by Job (1940) in a study of the food of perches of the Madras coast and Sarojini (1954) for the analysis of food of grey mullets. Bapat and Bal (1950, 1952) estimated the percentage of various food items of some shore fishes of Bombay by eye estimation. Hynes (1950), while studying the food of freshwater sticklebacks estimated the food items by the points method and gave a review of the various methods for the analysis of food of fishes. The same method was used by Swynnerton and Worthington (1940) and in a modified form by Frost (1943) for the study of the food of minnow. In a study of the food of the mackerel, *Rastrelliger kanagurta*, Bhimachar and George (1952) followed both the points method and the number method. Seshappa and Bhimachar (1955) followed the occurrence method for the determination of relative importance of food items of the Malabar sole, *Cynoglossus semifasciatus*. Pillay (1952), in a critical review of the various methods used for analysis of food of fishes emphasised that the method used for any fish should suit its diet, and is of the opinion that the volumetric methods are the most accurate. However, this method is suitable for carnivorous fishes. Vijayaraghavan (1951) and Prabhu (1955) estimated the stomach contents of *T. savala* and *T. haumela* by the volumetric method.

Recently, Natarajan and Jhingran (1961) have stated that the occurrence method does not take into consideration the quantity of each item of food and similarly the quantitative methods do not emphasise the repeated occurrence of a food item. Thus, individually, either the occurrence method or a quantitative method is not suited for a proper analysis of food of fishes. In view of this, an index that takes into consideration both the occurrence as well as the quantity of food item which is termed the 'Index of Preponderance' appears more suitable as discussed by the above authors. For this purpose, they considered the volumetric (displacement) method as the most accurate of the quantitative methods to use in conjunction with the occurrence method.

The final analysis of food of *E. intermedius* was made by employing the "Index of Preponderance" as referred to by the above authors. The percentage occurrence of different items of food in different months from various localities was determined by summing the total number of occurrences of all items from which the percentage occurrence of each item was calculated. Since the ribbon-fishes were found to be highly carnivorous, the determination of the volume of each item of food was easily made by the displacement method. For this purpose, a narrow measuring cylinder was taken and filled up with water to a certain mark. The food item was then immersed in the water and the new level of water was noted. The difference in the two readings gave the volume of the particular food item. Then the percentage volume of each food item was determined from the total volume of all the stomach contents. The 'Index of Preponderence' is then given by the formula $\frac{V.O.}{\text{Sum } V.O.} \times 100$ where 'V' and 'O' represent the percentage volume and percentage occurrence of a particular item of food respectively.

To ascertain the condition of feed in various months, the degree of fullness of the stomach was noted in relation to length of fish before the stomach was actually opened. A stomach was designated 'full' when it was completely gorged with food, with its wall appearing very thin and in some extreme cases even transparent. It was considered "¾ full" when it was in a partly collapsed condition, in which case the wall was usually thick. Similarly, they were classified '½ full' and '¼ full' depending on the relative fullness and the space occupied by the stomach contents. The state of the stomach was termed 'little' when the contents occupied anything less than one-fourth the capacity of the full stomach. Those stomachs which were termed 'empty' contained practically nothing in them. In such cases the wall of the stomach having undergone shrinkage appeared thick with conspicuous inner folds. From the total number of fish examined in a month, the percentage occurrence of 'full', '¾ full', '½ full', '¼ full', 'little' and 'empty' stomachs was estimated.

The components of the stomach contents were usually indentified up to generic level and wherever possible, depending on the state of digestion, they were identified up to species. It should be pointed out here that due to different stages of digestion of the food items, it was not always possible to identify the individual items of the stomach contents termed 'fishes' in this study, which may include one or more of the fishes that are usually found in the stomach contents. Although it was convenient to group all these fishes under one head, it was thought advisable to treat them separately under each genus as far as they could be identified, since such a method would give a better qualitative picture of the diet. All the unidentifiable fishes are included in the category 'fishes'. The presence of sand grains is considered only accidental but although taken into consideration in the analysis it may actually be left out while grading the various food items.

1. Qualitative And Quantitative Analysis

The stomach contents of *E. intermedius* collected from fishing centres on Palk Bay and the Gulf of Mannar during the period March 1959 to February 1961 were analysed by the occurrence and volumetric methods as indicated above and graded by the Index of Preponderence. Details are presented in Table XIV.

During the year 1959 "fishes" were prominent in May, August, September, November and December.

Stolephorus was present in the stomach contents in March to August, with peak occurrence in March, April, June and July. Other than *Stolephorus*, fishes that occasionally occurred in the diet in various months were *Kowala coval, Sardinella, Atherina forskali, E. intermedius, Leiognathus* and *Dussumieria.*

Thrissocles occurred in March, August to December. It was maximum in November. Young ones of *Sphyraena* were recorded in March and July and those of *Hemirhamphus* were present in March, May, October and November. Juveniles of *Tetrodon* were met with in the food during September and November.

Fish larvae were present in the food in April, September and November, while juvenile fishes occurred during October to December with peak occurrence in October.

Acetes was present in minor quantities in March and April and again from October to December with peak occurrences in November and December.

Squilla was recorded in minor quantities almost throughout the year except for June and December, where the number of fish examined was less and their size range small.

Like *Squilla, Lucifer* was also recorded in all the months except March. It reached the maximum in October.

Cephalopods, represented by young ones of *Octopus* and *Sepia* were occasionally present in the diet. *Octopus* was recorded in March and September. *Sepia* occurred in the diet during November.

Zoaea and megalopa larvae were present in the stomach contents in March, April, July and September to November, contributing to a minor percentage only.

Mysids were recorded in March and May to December.

Copepod species, *Calanopia elliptica* was recorded only once in November which was considered an accidental inclusion.

During the year March 1960 to February 1961 fish collected from Panaikulam, Alagankulum, and Athankarai on the Palk Bay and Pudumadam on Gulf of Mannar were examined. The details are presented in Table XV.

TABLE XIV

Relative importance of food items in the stomach contents of E. intermedius from Panaikulam*
(March 1959 to February 1960)

S. No.	Item of food	Mar. (103)	Apr. (165)	May (61)	Jun. (38)	Jul. (6)	Aug. (66)	Sept. (3)	Oct. (74)	Nov. (69)	Dec. (57)	Jan. (61)	Feb. (33)
1.	*Stolephorus*	91.68	98.34	14.15	99.21	71.29	2.04	0.20	—	—	—	—	—
2.	*Acetes*	6.70	0.44	—	—	—	—	—	0.23	13.23	13.27	11.07	11.66
3.	*Squilla*	0.67	0.21	0.09	—	0.12	4.63	28.11	1.59	2.40	—	0.05	9.71
4.	*Thrissocles*	0.27	—	—	—	—	0.31	0.68	0.26	4.57	—	—	—
5.	*Sphyraena*	0.12	—	—	—	0.20	—	—	—	—	—	—	—
6.	*Hemirhamphus*	0.01	—	0.03	—	—	—	—	0.16	1.09	—	—	—
7.	Fish scales	0.02	0.07	0.06	0.06	0.77	0.41	0.34	0.16	0.43	—	0.03	—
8.	*Octopus*	0.01	—	—	—	—	—	0.20	—	—	—	—	—
9.	Mysids	0.47	0.04	0.06	0.08	0.03	0.04	0.07	0.45	0.21	0.07	—	—
10.	Crab larvae	0.02	0.01	—	—	0.03	—	0.47	0.10	0.54	—	—	0.15
11.	Isopods	0.01	0.04	—	—	0.06	0.04	—	0.03	0.05	0.07	0.03	—
12.	Sand grains	0.02	0.16	0.19	—	0.50	—	0.20.	0.39	0.86	—	0.32	0.82
13.	"Fishes"	—	0.64	81.00	0.03	18.87	83.20	50.69	31.01	56.29	56.04	84.38	74.82
14.	Fish eggs	—	0.03	—	—	18.87	83.20	—	—	0.11	—	—	—
15.	Fish larvae	—	0.01	—	—	—	—	1.89	—	0.05	—	0.21	—
16.	*Lucifer*	—	0.01	4.42	0.62	6.86	2.98	15.12	19.93	11.34	0.66	0.95	2.69
17.	*Kowala coval*	—	—	—	—	1.24	—	—	—	—	—	—	—
18.	Copepods	—	—	—	—	0.03	—	—	—	0.11	—	—	—
19.	*Sardinella*	—	—	—	—	—	0.25	—	—	—	—	—	—
20.	*Atherina*	—	—	—	—	—	5.60	0.61	—	—	—	—	—
21.	*Eupleurogrammus intermedius*	—	—	—	—	—	0.49	—	—	—	—	—	—
22.	*Tetrodon*	—	—	—	—	—	—	1.41	45.68	1.63	—	—	—
23.	Juvenile fishes	—	—	—	—	—	—	—	—	5.65	29.87	2.92	—
24.	*Leiognathus*	—	—	—	—	—	—	—	—	1.09	—	—	—
25.	*Sepia*	—	—	—	—	—	—	—	—	0.22	—	—	—
26.	*Dussumieria*	—	—	—	—	—	—	—	—	0.11	—	—	—
27.	Zoaea larvae	—	—	—	—	—	—	—	—	—	—	0.02	—
28.	Prawns	—	—	—	—	—	—	—	—	—	—	—	0.15

* Number of fish examined each month given in parentheses. Other figures indicate percentage.

TABLE XV

Relative importance of food items in the stomach contents of E. intermedius from Panaikulam*
(March 1960 to February 1961)

S. No.	Item of food	Mar. (74)	Apr. (44)	May (30)	Jun. (54)	Jul. (34)	Aug.	Sept.	Oct. (33)	Nov. (58)	Dec. (39)	Jan. (38)	Feb. (36)
1.	*Stolephorus*	—	—	0.12	—	—	Sample not available	Sample not available	—	0.21	—	—	—
2.	*Acetes*	53.87	0.79	0.06	0.12	—			2.28	23.34	25.80	10.12	6.41
3.	*Squilla*	9.75	10.34	—	0.70	0.30			—	0.04	0.53	0.36	0.26
4.	*Thrissocles*	0.19	—	0.49	1.05	—			—	4.13	—	—	—
5.	*Sphyraena*	—	—	—	—	—			—	—	—	—	—
6.	*Hemirhamphus*	—	—	—	—	—			—	—	—	—	—
7.	Fish scales	0.04	0.26	0.42	0.58	0.91			0.18	0.12	—	—	0.13
8.	*Octopus*	—	0.07	—	—	—			—	—	0.79	0.09	—
9.	Mysids	—	0.04	0.24	—	—			—	—	—	—	—
10.	Crab larvae	—	—	—	—	—			—	—	—	—	—
11.	Isopods	—	0.04	—	—	—			—	—	—	—	—
12.	Sand grains	0.21	0.60	0.30	0.70	1.22			0.18	0.53	0.39	0.18	0.13
13.	"Fishes"	10.44	70.44	97.70	41.24	36.27			88.78	67.07	28.70	75.67	27.77
14.	Fish eggs	—	—	—	—	—			—	—	—	—	—
15.	Fish larvae	—	—	—	0.23	—			—	—	—	—	—
16.	*Lucifer*	2.48	0.11	0.36	35.00	21.34			6.39	3.44	13.38	2.17	2.33
17.	*Kowala coval*	—	—	0.30	20.38	39.80			—	0.61	—	—	—
18.	Copepods	—	—	—	—	—			—	—	—	—	—
19.	*Sardinella*	—	—	—	—	—			—	—	—	—	—
20.	*Atherina*	—	—	—	—	—			—	0.28	—	—	—
21.	*Eupleurogrammus intermedius*	—	—	—	—	—			—	—	—	—	—
22.	*Tetrodon*	—	—	—	—	—			—	0.08	—	—	—
23.	Juvenile fishes	22.91	17.16	—	—	—			2.19	0.24	29.12	11.40	62.98
24.	*Leiognathus*	—	—	—	—	—			—	—	—	—	—
25.	*Sepia*	—	0.15	—	—	—			—	—	0.13	—	—
26.	*Dussumieria*	—	—	—	—	—			—	—	—	—	—
27.	Zoaea larvae	0.11	—	—	—	0.15			—	—	0.39	—	—
28.	Prawns	—	—	—	—	—			—	—	—	—	—

* Numbers of fish examined each month given in parentheses. Other figures indicate percentage.

During the year 1960 "fishes" occupied an important place throughout the year. Their peak occurrence was observed in the month of May and fairly high from January to April and August to November.

Stolephorus was recorded in the stomach contents in May and November.

Thrissocles was recorded in May, June, August, September and November. It was maximum in November.

Young ones of other fishes were occasionally recorded in the diet. *Sphyraena* was noticed in March, *Kowala coval* in May to July and November; *Dussumieria* in September; *Atherina forksali* in September and November; *E. intermedius* in August and September and *Tetrodon* in November.

Next in importance to "fishes" was *Acetes* which occurred from January to June, October and persisted till December. The occurrence of *Acetes* in the stomach contents was maximum in March and fairly high in January, February and November and December.

Lucifer was found in the stomach contents throughout the year, with peak occurrence from June to September.

Young ones of *Squilla* were recorded during January to April, June to September, November and December. This item of food was present only in minor quantities throughout.

Juvenile fishes were present in January, March, April, August to December. They were maximum in March, August and December.

Fish larvae were recorded in minor quantities in January and August.

Zoaea and Megalopa larvae were present from January to March and December.

Penaeid prawns were recorded only once in February.

Cephalopods were represented in the stomach contents by young ones of *Sepia* and *Octopus* in April and December.

Isopods were met with in the diet in minor quantities in January and April while mysids were recorded in April and May.

In the year 1961, the stomach contents of specimens collected from Panaikulam were examined in January and February. The food items were dominated by "fishes" in January and juvenile fishes in February. The second and third places of importance in the diet were occupied by juvenile fishes and *Acetes* in January, "fishes" and *Acetes* in February respectively. Other items present in both the months were *Lucifer* and *Squilla*. Young ones of *Octopus* were recorded in January only.

2. Variations in the Food

i. *Variation during years*: A comparison of the analyses of stomach of *E. intermedius* during 1959, 1960 and 1961 revealed that the diet was essentially similar during these periods.

"Fishes" were prevalent in the diet almost round the year with peak occurrence in April 1959 and May 1960; they have shown a decrease in 1960 from 1959.

The presence of *Thrissocles* in the diet was found to be slightly different in 1959 and 1960. It was available for the fish for a longer duration in 1959 than in 1960 but its maximum availability was in November of both years.

Young ones of *Sphyraena* were recorded in the food in March and July 1959 and March 1960 while those of *Hemirhamphus* were noticed only in 1959. From this it appears that these items of food were not available in plenty but when available were no doubt, utilised. A similar trend was noticed with respect to the young ones of fishes like *Kowala coval, Atherina forskali, Dussumieria, Sardinella, Leiognathus, Tetrodon* and *E. intermedius* as judged from their sporadic appearance.

Juvenile fishes contributed to the diet for a greater part of the year in 1960 than in the previous. They were maximum in October 1959 and March 1960. Juvenile fishes formed the chief diet of fishes in February 1961, while they occupied a second place in January 1961.

Fish larvae formed part of the food in April, September and November in 1959, while they were recorded in January, June and August in the following year. They were represented only by minor quantities in both the years.

Acetes was recorded in March, April and October to December 1959, January to April and August to November in 1960 and January and February 1961. This would show that *Acetes* formed an important food item occurring at the same time during the three different periods. Its occurrence in the stomach contents was maximum in November 1959 while the maximum in 1960 was recorded during March.

Squilla was present in the stomach contents throughout the year except for June and December in 1959 and May and October in 1960. It was also recorded in January and February 1961. It appears from the data presented above that this item although represented in very minor quantities was one that was preferred by the fish almost throughout the year. Only young ones of *Squilla* were present in the stomach contents.

Lucifer, like *Squilla*, was represented throughout the year but only in minor quantities. It was maximum in October 1959 and June 1960. This is also probably another item preferred by the fish whenever available.

Isopods and mysids were in minor quantities in the food but better represented in 1959 than in 1960. The occurrence of decapod larvae in the stomach contents was similar to that of isopods and mysids and constituted only a minor percentage of the food.

Cephalopods represented by *Octopus* and *Sepia* were recorded in both the years but are of minor importance in the diet.

The occurrence of fish scales was obviously associated with the occurrence of various kinds of fishes.

The food as analysed by the 'Index of Preponderance' has shown interesting correlations in the corresponding months of two different years. For this purpose, all fishes are grouped as a single item.

In March 1959, the first three ranks were occupied by fishes, *Acetes* and *Squilla* respectively, while *Acetes*, juvenile fishes and fishes occupy the corresponding places in March 1960. 'Fishes', *Acetes* and *Squilla* continue to be important in April 1959, while 'fishes', juvenile fishes and *Squilla* were important in April 1960. In May 1959, 'fishes, *Lucifer* and *Squilla* were maximum in the stomach contents and the same trend was observed in May 1960 with mysids taking the place of *Squilla*. The composition of the diet was observed to be similar in May 1959 and June 1960 and the diet in June 1959 was the same as in May 1960. It would therefore appear that the same items of food were available for the fish in both these months during two successive years. Similarly 'fishes', *Lucifer* and *Squilla* were the three important items in July of both the years. Although specimens were not available for analysis from the same place in August and September in two successive years, it was found that 'fishes', *Squilla* and *Lucifer* were prominent in August 1959 (Panaikulam) and the same three items were present in the food in August 1960 (Athankarai), with *Lucifer*, occupying the second place instead of *Squilla*.

The trend seen in the diet of fish in August 1959 from Panaikulam continued to be the same in September 1959 also but in those from Athankarai in September 1960, the third place was occupied by juvenile fishes instead of *Squilla* as observed in the previous month. In October 1959, juvenile fishes rank first in the food elements followed by 'fishes' and *Lucifer*. But in October 1960, 'fishes' continued to contribute to maximum of the diet followed by *Lucifer* and *Acetes*. In November 1959 and 1960, 'fishes', *Acetes* and *Lucifer* were the three important items in the diet. 'Fishes', juvenile fishes and *Acetes* in December 1959 and juvenile fishes, 'fishes' and *Acetes* in December 1960 were recorded in the order of importance in the stomach contents. In January 1960, 'fishes', *Acetes* and juvenile fishes ranked high in the diet while the corresponding places were taken by 'fishes', juvenile fishes and *Acetes* in January 1961. 'Fishes', *Acetes* and *Squilla* were recorded as the three prominent items in the diet in February 1960, whereas juvenile fishes, 'fishes' and *Acetes* were important in February 1961.

Thus, from the data presented above, the major items in the diet of *E. intermedius* from one particular place did not differ significantly from year to year although the relative importance of a particular item was somewhat different between years, the gross picture, however, remaining the same.

ii. *Variation between places*: Data for comparison between different localities at the same time is available only for a few months, the details of which are given in Table XVI.

In June 1959, fish collected at Panaikulam and Uchippuli (both on Palk

TABLE XVI

Relative importance of food items in the stomach contents of E. intermedius from localities other than Panaikulam*

S. No.	Item of food	1959				1960				
		Jun.	Sep.	Nov.	Dec.	Mar.		Aug.		Sep.
		Uchippuli (13)	Thangachimadam (13)	Pudumadam (21)	Pudumadam (21)	Pudumadam (9)	Athankarai (4)	Alagankulam (32)	Athankarai (40)	Athankarai (41)
1.	*Stolephorus*	93.75	5.88	—	—	—	—	—	—	—
2.	*Lucifer*	5.96	2.94	—	1.13	—	9.52	38.01	16.39	15.83
3.	Fish scales	0.28	—	—	—	—	—	—	0.04	—
4.	"Fishes"	—	82.35	63.20	0.19	35.82	57.15	22.17	77.17	65.83
5.	Crab larvae	—	2.94	0.35	—	—	—	—	—	—
6.	Mysids	—	2.94	0.35	—	—	—		—	—
7.	Sand grains	—	2.94	2.80	1.13	—	—	0.20	—	0.13
8.	*Acetes*	—	—	18.93	77.43	0.34	28.57	—	—	—
9.	*Squilla*	—	—	1.40	0.57	—	4.76	0.10	3.03	0.26
10.	Juvenile fishes	—	—	12.62	14.22	59.75	—	39.51	2.70	0.27
11.	Isopods	—	—	0.35	—	—	—	—	—	—
12.	*Thrissocles*	—	—	—	5.31	—	—	—	0.52	0.40
13.	*Sphyraena*	—	—	—	—	4.09	—	—	—	—
14.	Fish larvae	—	—	—	—	—	—	—	0.04	—
15.	*Eupleurogrammus intermedius*	—	—	—	—	—	—	—	0.11	9.86
16.	*Dussumieria*	—	—	—	—	—	—	—	—	5.30
17.	*Atherina*	—	—	—	—	—	—	—	—	2.12

* Number of fish examined each month given in parentheses. Other figures indicate percentage.

Bay) were examined. It was observed that at both the places the diet was dominated by *Stolephorus* and *Lucifer*.

During September 1959 stomach contents of fish from Panaikulam and Thagachimadam were examined. In both the places fishes were prominent in the diet.

In November 1959 specimens were collected from Panaikulam (Palk Bay) and Pudumadam (Gulf of Mannar). The items of food were dominated by 'fishes' in both the localities but amongst 'fishes' a greater variety of them was represented at Panaikulam than at Pudumadam. The second place was occupied by *Acetes* at both the localities but this was followed by *Lucifer* in case of the diet of fish from Panaikulam and juvenile fishes in case of the food of fish from Pudumadam. The qualitative analysis has shown that the number of different food items was greater in the stomachs of fish from Panaikulam than in those from Pudumadam.

In the diet of fish from Panaikulam in December 1959, 'fishes' ranked high whereas its place was taken by *Acetes* in the stomach contents of fish from Pudumadam in the same month. Juvenile fishes were second in importance at both places but the third place was taken by *Acetes* in case of fish from Panaikulam and *Squilla* in case of those from Pudumadam. The number of items was same in both the cases.

In the food of fish from Panaikulam, *Acetes*, juvenile fishes and 'fishes' were important; from Athankarai. 'fishes', *Acetes* and *Lucifer* were dominant and from Pudumadam juvenile fishes, 'fishes' and *Acetes* were the major items in the diet during March 1960.

During August 1960, fish were collected from Athankarai and Alagankulam (Palk Bay). The stomach contents of these revealed 'fishes' as the dominant item of food of fish from Athankarai followed by *Lucifer* and *Squilla*. The important items in the stomach contents of fish from Alagankulam were juvenile fishes followed by *Lucifer* and 'fishes'.

The particulars given above on the diet of *E. intermedius* from different localities at the same time indicate that essentially the food constituents were same during a particular time at nearby places as well as places distant to each other. The relative importance of each item was slightly different between places, which, probably was dependent on the abundance of that item in the environment.

3. Food in Relation to Age

Details of the percentage occurrence of various food organisms in the stomach contents of *E. intermedius* in the different size groups during March 1959 to February 1960 and March 1960 to February 1961 are presented in Table XVII and XVIII respectively (Fig. 29, A,B).

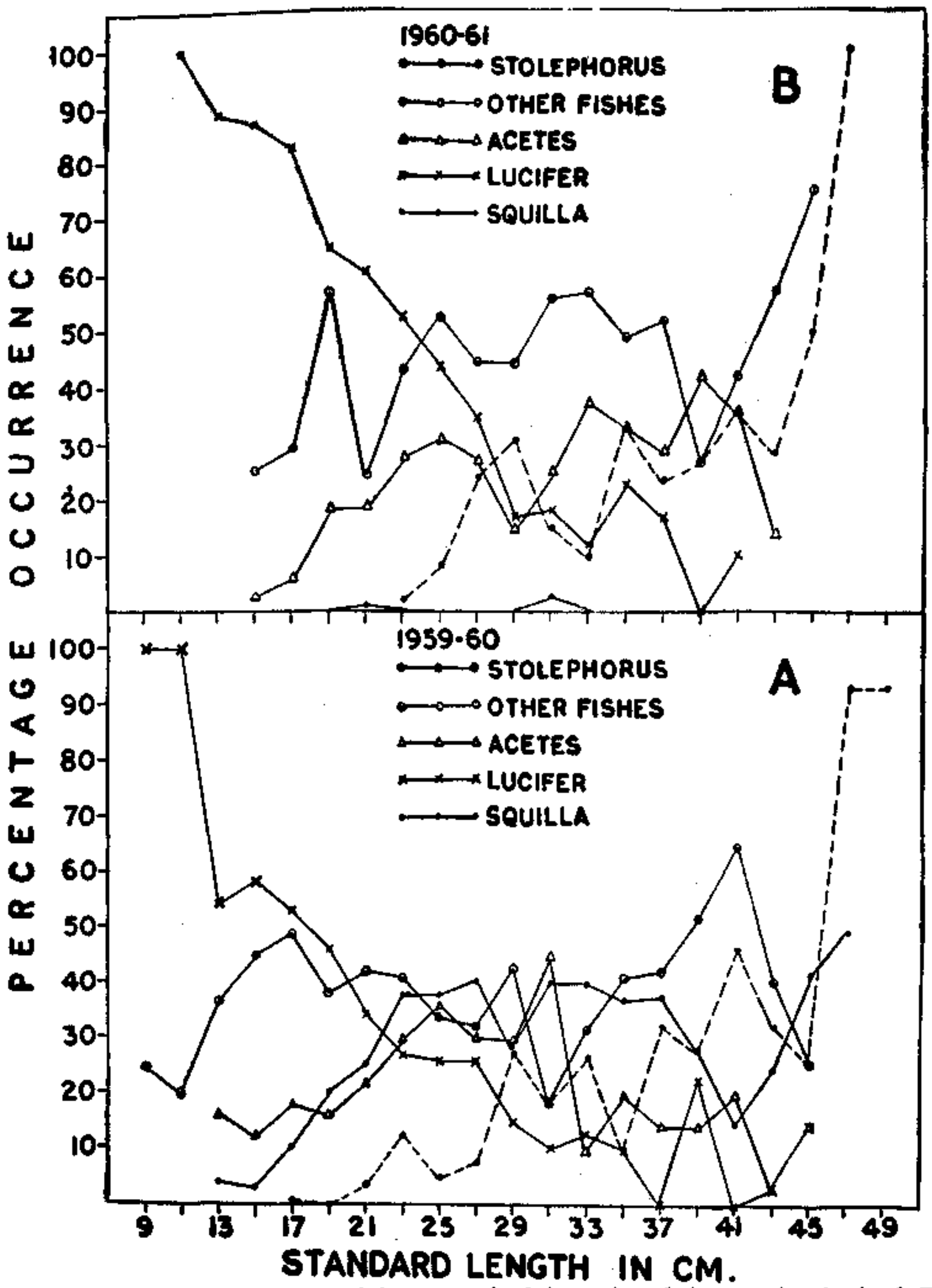

Fig. 29. Percentage occurrence of important food items in relation to size (age) of *E. intermedius* during A) 1959-'60 and B) 1960-'61 (only mid-points of 2 cm. size groups indicated along X-axis).

TABLE XVII

Percentage occurrence of food items in the stomach contents of E. intermedius in various size group (March 1959 to February 1960)

Size group (cm.)	No. of fish examined	*Lucifer*	"Fishes"	*Stolephorus*	Mysids	*Acetes*	*Squilla*	*Dussumieria*
8-10	4	100.00	25.00	—	—	—	—	—
10-12	5	100.00	20.00	—	20.00	—	—	—
12-14	24	54.16	37.49	4.16	—	16.66	—	—
14-16	55	58.17	45.45	3.63	3.63	12.72	—	—
16-18	77	53.24	49.35	7.79	3.89	18.18	1.29	—
18-20	67	46.26	38.80	20.89	5.97	16.41	—	—
20-22	90	34.44	42.22	25.55.	7.77	22.22	4.44	—
22-24	73	27.39	41.09	38.35	5.47	30.13	13.69	1.36

Size group (cm.)	No. of fish examined	*Hemirhamphus*	Juvenile fishes	Sea grass	Crustacean remains	Fish eggs	*Sepia*	Copepods
8-10	4	—	—	—	—	—	—	—
10-12	5	—	—	—	—	—	—	—
12-14	24	—	8.33	—	—	—	—	—
14-16	55	—	18.18	—	3.63	—	—	—
16-18	77	—	15.58	—	2.59	—	—	1.29
18-20	67	—	16.41	—	4.47	—	—	1.49
20-22	90	—	8.88	1.11	3.33	1.11	1.11	—
22-24	73	2.73	4.10	1.36	2.73	—	—	1.36

Size group (cm.)	No. of fish examined	Megalopa larvae	Fish larvae	Zoaea larvae	Isopods	Sand grains
8-10	4	—	—	—	—	100.00
10-12	5	—	—	—	—	40.00
12-24	24	—	—	—	—	16.66
14-16	55	—	1.81	—	—	7.27
16-18	77	—	—	1.29	—	14.28
18-20	67	—	1.49	—	1.49	7.46
20-22	90	3.33	—	2.22	—	14.44
22-24	73	1.36	1.36	—	1.36	15.06

Size group (cm.)	No. of fish examined	*Lucifer*	"Fishes"	*Stolephorus*	Mysids	*Acetes*	*Squilla*	*Kowala coval*
24-26	76	26.31	34.20	38.15	7.89	36.83	5.26	—
26-28	49	26.53	32.65	40.81	4.08	30.61	8.16	—
28-30	53	15.09	43.39	32.07	1.88	30.18	28.30	—
30-32	37	10.81	18.99	40.54	—	45.94	18.91	2.70
32-34	37	16.21	32.43	40.54	2.70	10.81	27.02	—
34-36	29	10.34	41.37	37.93	3.44	20.68	10.34	3.44
36-38	21	—	42.85	38.09	4.76	14.28	33.33	—
38-40	21	23.80	52.38	28.57	—	14.28	28.57	—
40-42	20	—	65.00	15.00	5.00	20.00	50.00	—

TABLE XVII (Contd.)

Size group (cm.)	No. of fish examined	*Sphyraena*	*Hemirhamphus*	Juvenile fishes	Sea grass	Crustacean remains	Fish eggs	*Sepia*	Megalopa larvae
24-26	76	2.63	—	11 84	1.31	1.31	—	—	—
26-28	49	2.04	—	4.08	2.04	6.12	—	—	6.12
28-30	53	—	—	7.54	—	3.77	1.88	1.88	—
30-32	37	2.70	—	5.40	—	2.70	—	—	—
32-34	37	—	2.70	2.70	—	8.10	—	—	—
34-36	29	—	—	—	—	10.34	6.89	—	6.89
36-38	21	4.76	—	—	—	—	4.76	—	—
38-40	21	—	—	—	—	—	14.28	—	19.04
40-42	20	—	—	—	—	—	—	—	10.00

Size group (cm.)	No. of fish examined	Fish larvae	Zoaea larvae	Isopods	Sand grains	*Octopus*	*Thrissocles*	Prawns
24-26	76	1.31	1.31	2.63	17.10	—	—	—
26-28	49	4.08	2.04	4.08	18.36	—	—	2.04
28-30	53	1.88	—	—	18.86	1.88	1.88	1.88
30-32	37	—	2.70	—	16.21	2.70	2.70	—
32-34	37	2.70	10.81	5.40	16.21	—	2.70	—
34-36	29	6.89	3.44	3.44	31.03	—	6.89	—
36-38	21	—	9.52	4.76	4.76	—	4.76	—
38-40	21	—	—	4.76	28.57	—	4.76	—
40-42	20	—	5.00	5.00	5.00	5.00	—	—

Size group (cm.)	No. of fish examined	*Lucifer*	"Fishes"	*Stolephorus*	Mysids	*Acetes*	*Squilla*	*Hemirhamphus*	Crustacean remains
42-44	27	3.70	40.74	25.92	3.70	3.70	33.33	3.70	3.70
44-46	19	15.78	26.31	42.10	10.52	15.78	26.31	—	5.26
46-48	2	—	—	50.00	—	—	100.00	—	—
48-50	2	—	—	—	—	—	100.00	—	—

Size group (cm.)	No. of fish examined	Fish eggs	Megalopa larvae	Zoaea larvae	Isopods	Sand grains	*Thrissocles*	*Leiognathus*	*Tetrodon*	*Atherina*	*E. intermedius*
42-44	27	7.40	3.70	3.70	14.81	18.51	3.70	3.70	3.70	7.40	—
44-46	19	5.26	5.26	10.52	5.26	15.78	5.26	5.26	5.26	10.52	5.26
46-48	2	—	50.00	—	—	—	50.00	—	—	—	—
48-50	2	—	—	—	—	—	—	—	—	—	—

TABLE XVIII

Percentage occurrence of food items in stomach contents of E. intermedius in various size groups
(March 1960 to February 1961)

Size group (cm.)	No. of fish examined	*Lucifer*	'Fishes'	*Acetes*	*Squilla*	Juvenile fishes	Mysids	Zoaea larvae	Sand grains	Iso-pods
10-12	4	100.00	—	—	—	—	—	—	25.00	—
12-14	9	88.88	—	—	—	11.11	—	—	22.22	—
14-16	31	87.09	25.80	3.22	—	3.22	—	—	—	—
16-18	31	83.87	29.03	6.45	—	12.90	—	—	16.12	—
18-20	66	65.14	57.57	19.69	—	10.60	—	—	19.69	—
20-22	52	61.53	24.99	19.23	1.92	28.84	—	—	13.46	—
22-24	39	53.84	43.58	28.20	2.56	28.20	—	2.56	7.69	—
24-26	45	44.44	53.33	31.11	8.88	13.33	2.22	2.22	13.33	2.22
26-28	40	35.00	45.00	27.50	10.00	25.00	5.00	—	12.50	—

Size group (cm.)	No. of fish examined	*Sepia*	*Octopus*	Megalopa larvae	Fish larvae	*Tetrodon*	*Stolephorus*	Crustacean remains	*Kowala coval*
10-12	4	—	—	—	—	—	—	—	—
12-14	9	—	—	—	11.11	—	—	—	—
14-16	31	—	—	3.22	3.22	—	—	—	—
16-18	31	—	—	—	—	—	—	—	—
18-20	66	—	1.51	—	—	—	—	3.03	1.51
20-22	52	—	—	—	—	—	1.92	—	—
22-24	39	—	—	—	—	—	—	2.56	—
24-26	45	—	—	—	2.22	2.22	—	—	6.66
26-28	40	2.50	—	—	—	—	—	—	5.00

TABLE XVIII (Contd.)

Size group (cm.)	No. of fish examined	*Lucifer*	'Fishes'	*Acetes*	*Squilla*	Juvenile fishes	*Dussumieria*	Mysids	Zoaea larvae	Sand grains	Isopods	*Atherina*
28-30	45	17.77	44.44	15.15	24.44	28.88	—	2.22	4.44	17.77	—	2.22
30-32	32	18.75	56.25	25.00	31.25	6.25	—	3.12	6.25	18.75	—	—
32-34	40	12.50	57.50	37.50	15.00	17.50	—	—	7.50	10.00	—	—
34-36	30	23.33	49.99	33.33	33.33	16.66	—	3.33	3.33	6.66	—	—
36-38	17	17.64	52.94	29.41	23.52	17.64	—	—	11.76	17.64	—	—
38-40	19	—	26.31	42.10	26.31	26.31	—	—	—	31.57	—	—
40-42	19	10.52	42.10	36.84	36.84	15.78	—	—	—	15.78	—	—
42-44	14	—	57.14	14.28	28.57	7.14	7.14	—	—	7.14	—	—
44-46	4	—	75.00	—	50.00	25.00	—	—	—	—	—	—
46-48	1	—	—	—	100.00	—	—	—	—	—	—	—

Size-group (cm.)	No. of fish examined	*E. intermedius*	*Sepia*	*Octopus*	*Stolephorus*	Crustacean remains	*Kowala coval*	*Thrissocles*
28-30	45	—	—	4.44	—	2.22	8.88	—
30-32	32	—	—	—	3.12	3.12	6.25	—
32-34	40	—	—	—	—	—	2.50	—
34-36	30	3.33	—	—	—	—	—	—
36-38	17	—	—	—	—	—	—	—
38-40	19	—	—	—	—	—	5.26	—
40-42	19	5.26	—	—	—	—	—	5.26
42-44	14	7.14	7.14	—	—	—	—	7.14
44-46	4	—	—	—	—	—	—	—
46-48	1	—	—	—	—	—	100.00	—

It may be observed from Tables XVII and XVIII that "fishes" which were the most important item of the diet of *E. intermedius* were preferred by all sizes of fish from 8.00 to 46.0 cm.

Fishes like *Dussumieria, Sphyraena, Tetrodon, E. intermedius, Atherina forskali, Hemirhamphus, Leiognathus, Sardinella* and *Kowala coval* were occasionally found in fish of bigger size groups over 18.0 cm. *Thrissocles* was recorded in fish of the size range between 28.0 to 48.0 cm.

Juvenile fishes were found in the stomach contents of fish from 12.0 to 46.0 cm. but they were found in increasing percentage in fish between 20.0 to 46.0 cm.

Fish larvae were seen in the stomachs of fish of a restricted size range between 14.0 to 36.0 cm. Very small fish and very big fish do not seem to prefer this item.

Another item of food that formed part of the diet of all the size groups was *Lucifer* found in the specimens ranging in size between 8.00 to 46.0 cm. But unlike the "fishes", it was dominant only in the 12.0 to 28.0 cm. size range.

Acetes occurred in fish between 12.0 to 46.0 cm. with frequent occurrence in the size groups between 16.0 to 32.0 cm.

Very small fish do not appear to be feeding on *Squilla* but those between 16.0 to 50.00 cm. had *Squilla* in their stomach contents. The percentage occurrence of this item was high in 26.0 to 44.0 cm. size groups.

Zoaea larvae were met with in the stomachs of fish measuring 16.0 to 46.0 cm. and megalopa larvae from 20.0 to 48.0 cm.

Mysids formed the food of fish from 10.0 cm onwards upto 46.0 cm while isopods were recorded in fish of the size range 8.0 to 46.0 cm.

Octopus and *Sepia* were recorded in the stomach contents of fish of the size range 18.0 to 44.0 cm.

In the data for the two years presented in the Tables XVII and XVIII, the same general trend as to the preference of various food items by fish of different age groups was noticed. The percentage occurrence of a few important food items in various size groups shows that while the occurrence of "fishes" *Stolephorus* and *Acetes* follow the same pattern, the percentage occurrence of *Lucifer* was high in smaller groups and gradually falls in bigger groups. But in case of *Squilla*, the percentage frequency rises from smaller size groups to bigger size groups. A similar pattern was observed in both the years as regards the occurrence of these items is concerned.

A few items like "fishes" and *Lucifer* were consumed by fish of all sizes while certain items like *Acetes*, *Squilla*, zoaea and megalopa larvae, juvenile fishes were found in only higher size groups. Occasionally, juveniles of fishes like *Dussumieria*, *Atherina*, *Tetrodon*, *Sardinella*, *Sphyraena*, *E. intermedius*, *Leiognathus*, *Kowala*, *Thrissocles* were found in the stomachs of fish over 22.0 cm.

Thus, there appears to be no striking change in the diet of *E. intermedius* from the young to adult stage. The diet was more or less uniform and dependant more on the availability of particular organisms than on any other factor. The only change that may be seen as the fish grows is, the increasing number of items added to the diet and the addition of a wide variety of fishes mentioned above to the food of bigger size groups. The diet tends to be more piscivorous with the increase in age of the fish.

4. Selectivity of Feeding

To ascertain whether *E. intermedius* exhibits any selectivity in feeding, a regular record of fishes and other organisms occurring along with it in the nets was maintained throughout the period of collection of material for the study of food and feeding habits. Special emphasis was laid on various types of fishes that constituted the catches since diet of *E. intermedius* was found to be predominantly piscivorous. Their occurrence in different months at Panaikulam (unless otherwise mentioned) is shown in Tables XIX and XX.

TABLE XIX

Fishes and other organisms occurring along with E. intermedius in the shore seines during the period March 1959 to February 1960 *(Data refer to Panaikulam unless otherwise mentioned)*

S.No.	Fishes and other organisms	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept. PK	Sept. TM	Oct.	Nov. PK	Nov. PM	Dec. PK	Dec. PM	Jan.	Feb.
	FISHES															
1.	*Himantura* spp.	+	+	+	..	+	+	—	—	+	—	+	—	+	—	+
2.	*Elops machnata*	—	—	—	..	—	—	—	—	—	—	—	—	—	+	—
3.	*Megalops cyprinoides*	—	—	—	..	—	—	—	—	—	—	—	—	—	—	—
4.	*Dussumieria* spp.	—	—	—	..	—	+	+	+	+	+	+	+	+	+	—
5.	*Hilsa kanagurta*	—	—	—	..	—	—	+	—	—	—	—	—	—	—	—
6.	*Ilisha* spp.	—	—	—	..	—	+	—	—	—	+	—	+	+	+	+
7.	*Kowala coval*	—	—	—	..	—	+	—	—	—	+	—	+	—	+	+
8.	*Opisthopterus tardoore*	—	—	—	..	—	—	—	+	—	—	—	—	—	—	+
9.	*Sardinella* spp.	+	+	+	..	+	+	+	+	+	+	+	+	+	+	+
10.	*Nematalosa nasus*	+	—	—	..	—	+	—	—	—	+	-	—	—	+	—
11.	*Stolephorus* spp.	+	+	+	..	+	+	+	—	+	+	+	+	+	+	+
12.	*Thrissocles* spp.	—	—	+	..	+	+	—	—	—	+	—	+	—	+	+
13.	*Chirocentrus dorab*	+	+	+	..	—	+	—	—	+	+	+	—	+	+	+
14.	*Chanos chanos*	—	—	—	..	+	—	—	—	—	—	—	—	—	—	—
15.	*Tachysurus* spp.	—	—	—	..	—	—	—	—	—	—	—	—	+	—	—
16.	*Pseudarius* spp.	—	—	—	..	+	+	—	—	+	+	—	+	—	+	+
17.	*Plotosus* spp.	—	—	+	..	+	—	—	—	—	—	+	—	+	—	—
18.	*Tylosurus* spp.	—	—	—	..	—	+	—	—	—	+	+	—	+	—	—
19.	*Hemirhamphus* spp.	+	+	+	..	+	+	+	—	—	+	+	—	+	—	—
20.	*Trachyrhamphus serratus*	—	—	—	..	—	—	—	—	—	—	—	—	+	—	—
21.	*Sphyraena* spp.	—	+	—	..	+	—	—	—	—	+	—	—	—	—	—
22.	*Mugil* spp.	—	—	—	..	+	+	—	—	—	—	—	+	—	—	—
23.	*Atherina* spp.	—	—	—	..	—	+	—	—	—	—	—	—	—	—	—
24.	*Polynemus* spp.	—	—	—	..	—	+	—	—	+	—	—	+	—	+	—
25.	*Therapon* spp.	—	—	+	..	—	—	+	—	—	+	—	—	+	—	—
26.	*Apogon* spp.	—	—	—	..	—	—	+	—	—	—	—	—	—	—	—
27.	*Sillago sihama*	—	+	+	..	+	+	+	+	—	—	—	—	+	—	+
28.	*Lactarius lactarius*	—	—	+	..	+	+	—	+	+	—	—	—	—	—	—
29.	*Caranx* spp.	+	+	—	..	+	+	+	—	+	+	+	+	+	+	+

TABLE XIX (Contd.)

S.No.	Fishes or other organisms	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.		Oct.	Nov.		Dec.		Jan.	Feb.
								PK	TM		PK	PM	PK	PM		
30.	*Chorinemus* spp.	—	—	—	..	+	—	+	—	—	—	—	—	—	—	—
31.	*Lutianus* spp.	—	—	—	..	—	—	—	—	—	—	—	—	—	+	—
32.	*Nemipterus japonicus*	—	—	—	..	—	—	—	—	—	—	—	—	+	—	—
33.	*Gerres* spp.	—	+	+	..	+	+	—	+	+	—	—	—	+	+	+
34.	*Leiognathus* spp.	+	+	+	..	+	+	—	+	+	+	+	—	+	—	+
35.	*Pomadasys* spp.	—	—	+	..	—	—	—	—	+	+	—	—	—	+	+
36.	*Johnius* spp.	+	—	+	..	+	+	+	—	+	+	+	+	+	+	+
37.	*Otolithus* spp.	—	—	—	..	—	—	—	—	—	+	—	+	—	—	—
38.	*Sciaena* spp.	—	—	—	..	—	—	—	—	—	—	—	—	—	—	—
39.	*Lethrinus* spp.	—	—	—	..	—	—	—	—	—	—	—	—	+	—	—
40.	*Upeneus* spp.	—	—	—	..	—	—	+	—	—	—	—	—	+	—	—
41.	*Ephippus orbis*	—	—	—	..	—	—	—	—	—	—	—	—	+	—	—
42.	*Drepane punctata*	—	—	—	..	—	+	—	—	+	+	—	—	—	—	—
43.	*Siganus* spp.	—	—	—	..	—	—	—	—	—	—	—	—	—	—	—
44.	*Lepturacanthus savala*	+	+	+	..	+	+	—	—	—	+	+	+	+	+	+
45.	*Trichiurus lepturus*	—	+	+	..	+	+	—	—	+	+	+	+	+	+	+
46.	*Rastrelliger kanagurta*	—	—	—	..	+	—	—	—	—	—	+	—	+	—	—
47.	*Scomberomorus* spp.	—	—	+	..	+	+	+	—	—	—	+	+	+	—	—
48.	*Stromateus* spp.	—	+	—	..	+	—	—	—	+	+	—	—	—	+	+
49.	*Platycephalus* sp.	—	—	+	..	—	—	—	—	—	—	—	—	—	—	—
50.	*Cynoglossus* spp.	—	—	+	..	+	—	+	—	+	—	—	—	—	—	—
51.	*Tetrodon* spp.	—	—	—	..	—	—	—	—	—	—	—	—	—	—	—
52.	*Pegasus* sp.	—	—	—	..	—	—	—	—	—	—	—		!	—	—
	CRUSTACEA															
53.	*Penaeus* spp.	—	—	—	..	—	—	—	—	—	+	—	+	+	+	—
54.	*Metapenaeus* spp.	—	+	—	..	—	—	—	—	—	—	—	—	—	—	—
55.	*Acetes* spp.	—	—	—	..	—	—	—	—	—	+	—	+	—	+	—
56.	*Portunus pelagicus*	+	+	—	..	—	—	—	—	—	—	—	—	—	—	—
	MOLLUSCA															
57.	*Sepia* spp.	—	—	—	..	—	+	—	—	—	—	—	—	—	—	—
	COELENTERATA															
58.	Small madusae	—	—	—	..	+	+	—	—	—	—	—	—	—	—	—

+ = Presence; – = Absence; .. = No data; PK = Panaikulam; TM = Thangachimadam; PM = Pudumadam

TABLE XX

Fishes and other organisms occurring along with E. intermedius in the shore seines during the period March 1960 to February 1961 *(Data refer to Panaikulam unless otherwise mentioned)*

S.No.	Fishes or other organisms	Mar. PK	Mar. PM	Apr.	May	Jun.	Jul.	Aug. AK	Sept. AK	Oct.	Nov.	Dec.	Jan.	Feb.
	FISHES													
1.	*Himantura* spp.	—	—	—	—	—	—	+	—	—	+	—	—	—
2.	*Elops machnata*	—	—	—	—	—	—	—	—	—	—	—	—	—
3.	*Megalops cyprinoides*	—	—	—	—	—	—	—	—	+	—	—	—	—
4.	*Dussumieria* spp.	+	+	+	+	—	—	+	+	+	+	—	—	+
5.	*Hilsa kanagurta*	—	—	+	—	+	+	+	+	+	—	—	—	—
6.	*Ilisha* spp.	—	—	+	+	+	—	+	—	—	+	—	+	+
7.	*Kowala coval*	—	—	+	—	+	+	+	+	+	+	—	—	—
8.	*Opisthopterus tardoore*	—	—	—	—	—	—	—	—	—	—	—	—	—
9.	*Sardinella* spp.	+	+	+	+	+	+	+	+	+	+	+	—	—
10.	*Nematalosa nasus*	—	—	—	—	—	—	—	+	—	—	—	—	—
11.	*Stolephorus spp.*	+	—	+	+	+	+	+	+	+	+	+	+	+
12.	*Thrissocles* spp.	+	—	+	+	+	—	+	+	+	+	+	+	+
13.	*Chirocentrus dorab*	+	+	+	+	+	—	+	+	+	+	+	+	+
14.	*Chanos chanos*	—	—	—	—	—	—	—	—	—	—	—	—	—
15.	*Arius* spp.	—	—	—	—	—	—	—	—	—	—	—	—	—
16.	*Pseudarius* spp.	—	—	—	—	+	+	+	+	+	—	—	+	—
17.	*Plotosus* spp.	—	—	—	—	—	—	—	+	—	—	—	—	—
18.	*Tylosurus* spp.	—	—	+	—	+	—	+	—	+	+	—	—	—
19.	*Hemirhamphus* spp.	+	—	+	+	+	+	+	+	+	+	+	+	+
20.	*Trachyrhamphus serratus*	—	—	—	—	—	—	—	—	—	—	—	—	—
21.	*Sphyraena* spp.	+	—	+	—	+	—	+	—	—	—	—	—	—
22.	*Mugil* spp.	—	—	—	—	+	+	+	+	+	+	—	—	—
23.	*Atherina* spp.	—	—	—	—	—	—	—	—	—	—	—	—	—
24.	*Polynemus* spp.	—	—	—	—	—	—	—	—	—	+	—	—	—
25.	*Therapon* spp.	—	+	—	—	—	—	—	—	+	—	—	—	—
26.	*Apogon* spp.	—	—	—	—	—	—	—	—	—	—	—	—	—
27.	*Sillago sihama*	—	—	+	—	+	+	+	+	+	+	+	+	—
28.	*Lactarius lactarius*	+	—	—	+	—	—	—	—	—	—	—	—	—
29.	*Caranx* spp.	+	+	+	—	+	+	+	+	+	+	+	+	+

TABLE XX (Contd.)

S.No.	Fishes or other organisms	Mar. AK	Mar. PM	Apr.	May	Jun.	Jul.	Aug. AK	Sept. AK	Oct.	Nov.	Dec.	Jan.	Feb.
30.	*Chorinemus* spp.	—	+	+	—	+	—	—	—	—	—	—	—	—
31.	*Lutianus* spp.	—	—	—	—	—	—	—	—	—	—	—	—	—
32.	*Nemipterus japonicus*	—	—	—	—	—	—	—	—	—	—	—	—	—
33.	*Gerres* spp.	+	+	+	—	+	+	+	+	+	+	—	—	—
34.	*Leiognathus* spp.	+	+	+	+	+	+	+	+	+	+	+	+	—
35.	*Pomadasys* spp.	—	—	+	—	—	—	—	—	+	+	—	+	—
36.	*Johnius* spp.	+	—	—	—	—	—	—	—	—	—	—	—	—
37.	*Otolithus* spp.	+	+	+	—	—	—	—	—	—	—	—	—	—
38.	*Sciaena* spp	+	+	+	—	+	+	+	—	+	+	—	+	+
39.	*Lethrinus* spp.	—	—	—	—	—	—	—	—	—	—	—	—	—
40.	*Upeneus* spp.	—	+	—	—	—	—	—	—	—	—	—	—	—
41.	*Ephippus orbis*	—	—	+	+	—	—	—	—	—	—	—	—	—
42.	*Drepane punctata*	—	—	—	—	—	—	—	—	—	—	—	—	—
43.	*Siganus* spp.	—	+	—	—	—	—	—	—	—	—	—	—	—
44.	*Lepturacanthus savala*	+	+	+	—	+	—	—	—	+	+	—	—	—
45.	*Trichiurus lepturus*	+	+	+	—	—	+	—	+	+	+	—	+	—
46.	*Rastrelliger kanagurta*	—	+	—	+	—	—	—	—	—	—	—	—	—
47.	*Scomberomorus* spp.	—	—	+	+	+	+	+	+	+	+	+	—	—
48.	*Stromateus* spp.	+	—	+	—	—	—	—	+	—	—	—	+	+
49.	*Platycephalus* sp.	—	—	—	—	—	—	—	—	—	—	—	—	—
50.	*Cynoglossus spp.*	—	—	—	—	—	—	—	—	—	—	—	—	—
51.	*Tetrodon* spp.	—	—	+	—	—	—	—	—	—	—	—	—	—
52.	*Pegasus* sp.	—	—	—	—	—	—	—	—	—	—	—	—	—
	CRUSTACEA													
53.	*Penaeus* spp.	—	!	—	—	—	—	+	—	—	—	—	—	—
54.	*Metapenaeus* spp.	—	—	—	—	—	—	—	—	—	—	—	—	—
55.	*Acetes* spp.	—	—	—	—	—	—	+	—	—	—	—	+	+
56.	*Portunus pelagicus*	—	—	+	—	—	—	+	—	—	—	—	—	—
	MOLLUSCA													
57.	*Sepia* spp.	—	—	—	+	—	—	—	—	—	—	—	—	—
	COELENTERATA													
58.	Small medusae	—	—	—	—	—	—	—	—	—	—	—	—	—

+ = Presence; — = Absence; PK = Panaikulam; PM = Pudumadam; AK = Athankarai.

As may be seen from these data, the diet of *E. intermedius* appears to be dependent on the availability of the food organisms and at the same time the species seems to prefer only certain kinds out of many available in the environment. The food generally consisted of a predominance of fishes but here again, the size of the organisms was a limiting factor. Although a wide variety of fishes occurred in different months, all of them did not form the food. It was only the small fishes like *Stolephorus, Leiognathus, Thrissocle, Kowala coval* and *Atherina forskali* that were of most usual occurrence in the stomach contents. However, the juveniles of bigger fishes were also preyed upon whenever available, most common of which are those of *Hemirhamphus, Sphyraena, Tetrodon, Sardinella* and *Dussumieria*. It may therefore be inferred from these observations that *E. intermedius* is not an indiscriminate feeder but that a certain amount of selectivity in diet was exercised depending, of course, on the availability of particular organisms in the environment.

Although it was not possible to maintain a regular collection and qualitative analysis of plankton from the area of collection of the fish samples for analysis of stomach contents, a few samples were, however, collected and analysed. For understanding the general pattern of distribution of planktonic organisms and its relation to the food of fish, the works of Prasad (1954, 1956, 1958) and Bapat (1955) which were spread over a number of years and refer to Palk Bay and Gulf of Mannar were also consulted.

In August 1959 the analysis of samples revealed an abundance of phytoplankton, few fish eggs and larvae. In May, 1960, during the first half, phytoplankton was abundant and fish eggs and larvae were rare but during the second half, there was a predominance of zooplankton especially consisting of zoaea larave, *Lucifer*, mysids, young ones of *Squilla*, young ones of polychaetes, pteropod shell, abundance of hydro-medusae, copepods, few fish eggs and larvae. Phytoplankton was comparatively less. During June 1960, *Lucifer*, fish eggs and larvae, juvenile fish, zoaea larvae, young ones of *Squilla*, pteropod shells and medusae were recorded. In July, 1960, zoaea larvae, *Lucifer* and phytoplankton were prominent. During September 1960, *Lucifer*, zoaea larvae, few fish larvae and phytoplankton were noticed in the plankton collections.

Although a strict comparison round the year cannot be made, the gross picture is presumed to be the same at other nearby localities on Palk Bay and Gulf of Mannar. A comparison of the stomach contents and occurrence of various planktonic organisms have shown some degree of correlation with an evident preference for certain particular varieties. This is further supported by the fact that some of the common zooplanktonic forms like copepods, chaetognaths, pteropods, polychaetes, and *Noctiluca* were not met with in the stomach contents whereas megalopa larvae, young ones of *Squilla* and *Lucifer* were repeatedly present. Of the planktonic forms, *Lucifer* appeared to be the most preferred item of food.

5. Condition of Feed

The stomachs of all the specimens collected for the study of food and feeding habits were classified depending on their relative fullness, into 'full', '¾ full', '½ full', '¼ full', 'little' and 'empty' as explained earlier. Fish stomachs classified as 'full', '¾ full', and '½ full' were considered to have actively fed, whereas those with '¼ full' and 'little' as poorly fed. The percentage occurrence of the categories are presented in Tables XXI and XXII.

In March 1959, majority of the fish fed actively and in April, the reverse was true. In May the percentage of fish that fed actively showed a steep rise, which was continued in June and July. A fall was noticed in August. In September, majority of fish were again in the category of poor feeding whereas in October they fed actively. This was continued in November and December. During January 1960, over 50% of the fish had stomach contents less than '¼ full' and the condition continued in February also. In March, unlike in the previous year, fish fed poorly as also in April. As in the previous year, in May, majority of the fish fed actively. From June onwards till December feeding was poor during the year in contrast to that of the previous year. During January 1961 and February the condition that was observed in the previous year was repeated.

The variations in feeding intensity were further studied based on the size of fish and actual volume of stomach contents measured by the displacement method. Fish caught at a uniform time of the day, throughout the period of investigation, were examined. Since nearly 50% of the fish mature at 35 cm. S.L., they were grouped into the immature (below 35 cm.) and the mature (above 35 cm.) fish. The average volume of the stomach contents in each month for the two groups was then calculated from the total volume of stomach contents and the number of fish that contributed to this volume (Tables XXIII and XXIV).

During the year March 1959 to February 1960, for immature fish, the average volume of stomach contents was higher than the average for the whole year in March, June, July, September and January; for mature fish, it was higher in March, August and November. During the following year, March 1960 to February 1961, the average volume of stomach contents for immature fish was higher than the average for the year in March to May, August October and February; for mature fish, it was higher in May, August, September ana November (Fig. 30, A,B).

It would appear from the above data that the intensity of feeding in botn immature and mature fish is high in certain months and low in other months showing that the variations in feeding activity are not related to spawning. Although in general, both mature and immature fish may feed voraciously when the favourite food item i.e., *Stolephorus* and other fishes, is available in plenty, the abundance of this food item is not always associated with intense feeding. For instance, in March, 1959, out of a total volume of 18.8 ml. of food of mature fish, "fishes" contributed to 15.9 ml. and the average volume was found to be 0.85 ml. which was higher than the grand average (0.65) as shown in

TABLE XXI

Percentage occurrence of the stomachs of E. intermedius in various degrees of fullness

(March 1959 to February 1960)

Condition of feed	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
No. of fish	103	65	61	38	67	66	43	74	69	57	61	33
Full	7.76	6.15	13.11	26.31	8.95	9.09	4.65	8.10	13.04	—	3.27	—
¾ full	29.13	12.30	34.44	42.13	31.37	27.29	20.93	52.73	30.46	29.84	26.24	—
½ full	17.49	20.00	31.16	15.78	20.89	21.21	13.95	10.81	8.69	22.80	13.11	36.36
¼ full	12.61	32.33	16.39	2.63	16.41	13.63	23.25	16.21	14.49	28.07	32.80	51.52
Little	29.13	26.15	3.27	5.26	19.40	21.21	30.25	8.10	23.18	14.03	19.67	12.12
Empty	3.88	3.07	1.63	7.89	2.98	7.57	6.97	4.05	10.14	5.26	4.91	—

TABLE XXII

Percentage occurrence of the stomachs of E. intermedius in various degrees of fullness

(March 1960 to February 1961)

Condition of feed	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
No. of fish	74	44	30	54	34	40	41	33	58	39	38	36
Full	5.40	—	3.32	—	—	2.50	2.43	12.12	5.17	2.56	—	5.55
¾ full	6.75	15.90	26.67	20.37	8.82	7.50	2.43	9.00	12.06	17.96	15.78	13.88
½ full	16.23	20.45	26.67	5.55	17.65	17.50	7.31	21.21	8.62	5.12	10.52	19.44
¼ full	37.85	40.93	26.67	25.92	26.47	35.00	12.19	15.15	31.03	20.51	52.66	33.36
Little	31.07	18.18	10.00	35.20	38.24	30.00	58.55	36.37	43.12	43.60	15.78	16.66
Empty	2.70	4.54	6.67	12.96	8.82	7.50	17.09	6.06	—	10.25	5.26	11.11

TABLE XXIII

Average volume of stomach contents of E. intermedius
(March 1959 to February 1960)

Month	Immature fish			Mature fish		
	Total No. of fish	Total vol. of stomach contents ml.	Average volume ml.	Total No. of fish	Total vol. of stomach contents ml.	Average volume ml.
Mar.	81	20.20	0.24	22	18.80	0.85
Apr.	47	9.00	0.19	18	8.00	0.44
May	60	9.90	0.16	1	0.40	0.40
Jun.	37	10.40	0.28	1	0.20	0.20
Jul.	59	12.50	0.21	8	3.30	0.41
Aug.	34	5.90	0.17	32	26.60	0.83
Sept.	30	7.30	0.24	13	7.40	0.56
Oct.	73	13.30	0.18	1	0.10	0.10
Nov.	57	8.90	0.15	12	9.80	0.81
Dec.	56	7.40	0.13	1	0.10	0.10
Jan.	56	14.80	0.26	5	2.00	0.40
Feb.	28	5.00	0.17	5	1.80	0.36
Grand total and average	618	124.60	0.20	119	78.50	0.65

TABLE XXIV

Average volume of stomach contents of E. intermedius
(March 1960 to February 1961)

Month	Immature			Mature		
	Total No. of fish	Total volume of stomach contents. ml.	Average volume. ml.	Total No. of fish	Total volume of stomach contents ml.	Average volume ml.
Mar.	47	11.40	0.24	27	10.80	0.40
Apr.	30	9.30	0.31	14	6.00	0.42
May	28	7.30	0.26	2	1.00	0.50
Jun.	50	6.80	0.13	4	1.10	0.27
Jul.	32	5.50	0.17	2	0.20	0.10
Aug.	31	9.80	0.31	9	5.90	0.65
Sept.	31	1.90	0.06	10	12.10	1.21
Oct.	30	7.10	0.23	3	0.70	0.23
Nov.	50	9.10	0.18	8	9.10	1.13
Dec.	35	7.20	0.20	4	0.90	0.2[illegible]
Jan.	35	6.80	0.19	3	0.10	0.03
Feb.	31	9.40	0.30	5	1.80	0.36
Grand total and average	430	91.60	0.21	91	49.70	0.54

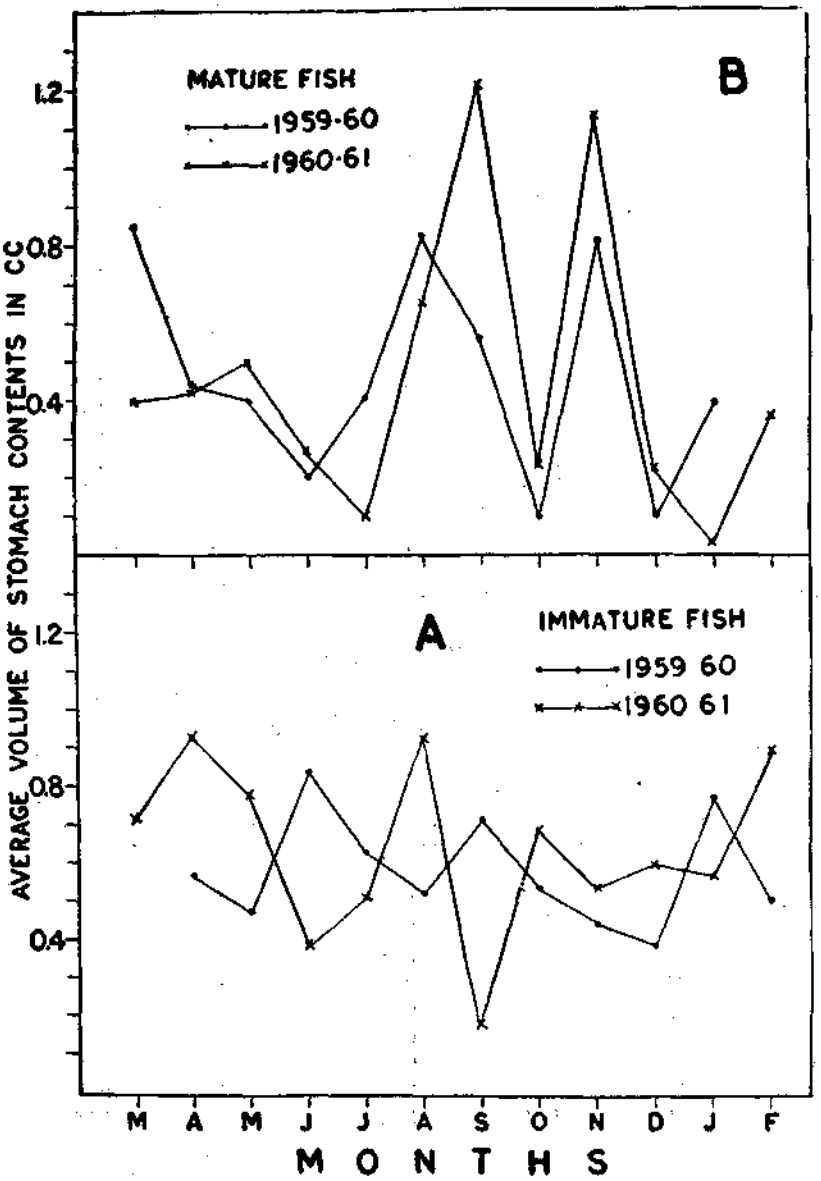

Fig. 30. Average volume of stomach contents of *E. intermedius* in various months for A) immature and B) mature fish.

Table XXIII. The same month, "fishes" contributed to 17.2 ml. out of a total volume of 20.2 ml. of food of immature fish. While this may be an instance of the correlation between abundance of favourite food and intense feeding, the same was not true in August 1959 where it may be seen the mature fish fed actively (out of a total of 26.6 ml. 23.5 ml. of food was contributed by "fishes") indicating that non-availability of favourite food was not the main reason for slack feeding at times. Thus, the observations on feeding intensity show that the fish feeds heavily at irregular intervals.

6. Feeding Habits

During the course of examination of stomach contents and study of food of *E. intermedius*, certain interesting observations were made on the feeding habits.

The fish was sometimes observed to have preyed upon some whole organisms. This was obviously governed by the size of the prey. The common items that were found whole in the stomachs were *Lucifer*, *Squilla*, *Acetes*, larvae and juveniles of fishes like *Stolephorus*, *Thrissocles* and *Sphyraena*. Not only that whole items of food were at times present but that the stomach sometimes contained exclusively certain items like *Stolephorus*, *Acetes*, *Squilla*, *Lucifer*, juvenile fishes, *Thrissocles*, *Kowala coval*, *Dussumieria*, *Sardinella* and *Atherina* indicating the abundant availability and the preference shown for them. Zoaea and megalopa larvae were also noticed as undigested chitinous remains whereas in the other instances cited above the entire stomach was literally full with a particular item alone. The percentage occurrence of different items that were present exclusively in the food in various months is given in Tables XXV and XXVI.

Large individuals of *Atherina*, *Leiognathus*, *Sardinella*, *Dussumieria* and *E. intermedius* were invariably bitten and swallowed, parts of which were occasionally found missing.

From the nature of stomach contents it may be inferred that the fish feeds mainly on the surface. Almost all the fishes which form its diet are pelagic, *E. intermedius* itself being pelagic. The other items of diet other than fishes also indicate that it mainly feeds on the surface.

To verify whether *E. intermedius* is a diurnal feeder or has restricted feeding habits, some fish collected at night from Vedalai, Pudumadam (Gulf of Mannar) and Thangachimadam (Palk Bay) were examined. The stomachs were found to be in varying degrees of fullness indicating that the fish feeds both during day as well as night.

Whenever fishes and any other small item like *Lucifer* were found together in the stomach contents, fishes were always found at the bottom of the stomach and *Lucifer* at the top indicating that it would have fed first on fishes and later on a smaller item which would occupy relatively less space and at the same time supplement the fish diet.

TABLE XXV

Percentage occurrence of food items exclusively present in the stomach contents of E. intermedius
(March 1959 to February 1960)

S. No.	Item of food / No. of fish examined	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
		103	65	61	38	67	66	43	74	69	57	61	33
1.	*Stolephorus*	26.19	33.84	9.83	57.89	23.88	—	2.32	—	—	—	—	—
2.	"Fishes"	—	6.15	24.58	—	7.46	28.78	6.97	13.51	7.24	14.03	21.31	18.18
3.	*Lucifer*	—	—	4.91	2.63	19.40	15.15	16.27	17.56	4.34	8.77	4.91	—
4.	*Thrissocles*	—	—	—	—	—	—	—	—	1.44	—	—	—
5.	*Acetes*	8.73	—	—	—	—	—	—	—	8.69	8.77	1.63	6.06
6.	*Sphyraena*	0.97	—	—	—	—	—	—	—	—	—	—	—
7.	*Squilla*	1.94	1.54	—	—	—	3.03	—	—	1.44	—	—	—
8.	*E. intermedius*	—	—	—	—	—	1.51	—	—	—	—	—	—
9.	*Sardinella*	—	—	—	—	—	1.51	—	—	—	—	—	—
10.	*Atherina*	—	—	—	—	—	—	2.32	—	—	—	—	—
11.	Juvenile fishes	—	—	—	—	—	—	—	5.40	—	19.29	8.19	—
12.	*Leiognathus*	—	—	—	—	—	—	—	—	1.44	—	—	—
13.	Fish larvae	—	—	—	—	—	—	—	—	—	—	1.63	—

TABLE XXVI

Percentage occurrence of food items exclusively present in the stomach contents of E. intermedius
(March 1960 to February 1961)

S. No.	Item of food / No. of fish examined	Mar. 74	Apr. 44	May 30	Jun. 54	Jul. 34	Aug. 40	Sept. 41	Oct. 33	Nov. 58	Dec. 39	Jan. 38	Feb. 36
.	*Stolephorus*	—	—	—	—	—	—	—	—	1.72	—	—	—
2.	"Fishes"	6.75	34.99	50.00	11.11	8.82	20.00	21.95	30.30	20.68	2.56	26.31	11.11
3.	*Lucifer*	1.35	—	3.33	33.33	26.47	15.00	36.58	21.21	18.96	10.25	2.63	5.55
4.	*Thrissocles*	—	—	6.67	—	—	2.50	—	—	1.72	—	—	—
5.	*Acetes*	17.56	—	—	—	—	—	—	—	15.51	—	7.89	5.55
6.	*Squilla*	1.35	—	—	—	—	5.00	2.43	—	—	2.56	—	—
7.	Juvenile fish	9.45	18.18	—	—	—	—	—	6.06	1.72	—	10.52	27.77
8.	Fish larvae	—	—	—	1.85	—	—	—	—	—	—	—	—
9.	*Kowala coval*	—	—	—	3.70	14.70	—	—	—	—	—	—	—
13.	*Dussumieria*	—	—	—	—	—	—	2.43	—	—	—	—	—
11.	*Atheirna*	—	—	—	—	—	—	2.43	—	—	—	—	—
12.	Megalopa larvae	—	—	—	—	—	—	—	—	—	2.56	—	—
	Zoaea larvae	2.70	—	—	—	—	—	—	—	—	2.56	—	—

Cannibalism: It would be of interest to note here that *E. intermedius* exhibits cannibalistic tendency as was observed for other species of ribbon-fishes by Day (1876), Tham Ah Kow (1950) and Prabhu (1955). During the course of the present investigation, in at least four instances its own species (*E. intermedius*) was found in the stomach contents of some specimens. In one instance a '½ full' stomach of a specimen of 44.2 cm S.L. collected from Panaikulam on 20-8-1959 contained semidigested pieces of *E. intermedius* measuring 2.5 cc in volume and the fish was in a partially spawned state. A second instance was noted from the stomach of a fish of 35.3 cm. S.L. collected from Athankarai (Palk Bay) on 23-8-1960 in a spent condition, with '½ full' stomach contents measuring 0.6 cc. including *E. intermedius* (0.3 cc), fish larvae and juveniles and *Squilla*. *E. intermedius* was bitten into two pieces but its head was not present. The third and fourth instances were from fish of 40.2 and 43.4 cm. S.L. both mature, collected from Athankarai on 6-9-1960. In the fish of 40.2 cm. S.L. the stomach was '½ full' with the contents measuring 2.0 ml. including *E. intermedius* (1 ml.) and some other fishes. The former was bitten into three pieces and found in a semi-digested condition. In the fish of 43.4 cm. S.L., the stomach was '¾ full', the contents measured 3.0 ml. including *E. intermedius* (2.7 ml.) which was bitten into three pieces, *Thrissocles* also being present.

In all the instances cited above, only mature fish exhibited a tendency towards cannibalism, all the fish fed actively and the percentage volume occupied by *E. intermedius* in the total volume of stomach contents was always greater than 50%. In one instance it was found to be the exclusive item of food. However, from these observations it is difficult to conclude whether the devouring of its own species is intentional or accidental.

7. Food of Species

To make a comparison with the diet of *E. intermedius*, the food of the other three species of the ribbon-fishes from Indian waters was also examined. Since a quantitative analysis was not possible round the year, only a qualitative analysis of food was attempted.

i. *Eupleurogrammus muticus*: A total of 47 specimens of *E. muticus* collected from Bombay during December 1959 and February 1960 and from Puri (Orissa coast) in February 1960 in the size range 35.6 - 56.7 cm. S.L. were examined. The most common items of food were *Lucifer*, *Squilla*, "fishes" and zoaea larvae.

ii. *Trichiurus lepturus*: The food and feeding habits of this species of ribbon-fish were studied from 59 specimens in the size range 16.5 to 62.3 cm. S.L. from Palk Bay and the Gulf of Mannar and 38 specimens in the size range 18.6 to 97.8 cm. S.L. from other parts along the Indian coast (Kerala, Andhra and Bombay coasts and Andaman Islands) and the west coast of Ceylon. A qualitative analysis of the stomach contents has shown that the fish feeds on *Stolephorus*, *Acetes*, "fishes", *Lucifer*, mysids, *Sardinella*, *Kowala coval*, *Thrissocles*, polynemids, juvenile fishes, *Metapenaeus*, young ones of *Sepia* and megalopa larvae.

Since material of this species was not available locally throughout the year, adequate number of specimens could not be examined for a detailed study. However, from the above observations, it may be said that this species is also highly carnivorous showing a tendency for a predominantly piscivorous diet.

Specimens collected at night have shown that there was no diurnal variation in its feeding activity and when the size of the prey was big, the same was bitten into pieces and swallowed, as was observed in the case of the other species.

iii. *Lepturacanthus savala* : Of this species, 184 specimens during the year 1959, 190 specimens in 1960 and 57 specimens in 1961 were collected from Kilakarai, Pudumadam, Vedalai and Rameswaram Road fishing centres of the Gulf of Mannar and Adirampatnam, Panaikulam and Thangachimadam fish landing places on Palk Bay.

Regular analysis of food of fish collected from Panaikulam was made. The qualitative analysis of the food items in different months is presented in Tables XXVII and XXVIII.

A comparison of the food of *L. savala* from other localities also indicates that "fishes" form its major diet followed by *Acetes*, and prawn (*Penaeus* and *Metapenaeus*). *Squilla, Lucifer, Octopus, Sepia*, zoaea larvae were preyed upon whenever available. Of the fishes special mention may be made of *Stolephorus, Sardinella, Dussmieria* and *Caranx*.

A comparison of the stomach contents of *L. savala* with fishes and other organisms landed in the nets along with it reveals that this species also exercises a certain amount of selectivity for certain varieties of fishes like *Stolephorus, Sardinella, Dussumieria*, prawns of the genera, *Penaeus* and *Metapenaeus*, shrimps represented by *Acetes*. However, the size of fishes devoured was big and they were also bitten on some occasions. To ascertain whether *L. savala* feeds at night some fish were also collected at night. The examination of their stomachs revealed that they were in varying degrees of fullness indicating that the species feeds at night also. Three ripe fish collected in May 1959 had their stomachs empty indicating a probable cessation of feeding during spawning season. In the ripe fish the gonads occupy almost the entire body cavity and it was observed that the empty stomach was even displaced to a side. Because of the enlarged gonads and lack of space in the body cavity, fish probably abstain from feeding at this time. In these specimens the abdomen was quite distended even with an empty stomach. Further distension by having stomach contents may not be possible. Consequently, the fish might feed voraciously after spawning, a fact, which could not be verified in the present study for lack of enough material. Such a condition was however, not observed in *E. intermedius* probably because of the difference in breeding habits.

It was observed that this species also exhibits a tendency for cannibalism although it was not found to devour its own species but a related one (*E intermedius*). A specimen of *L. savala* 46.0 cm. S.L., mature, collected on 14-3-1960 from Panaikulam with a 'full' stomach of 4.0 ml. in volme contained exclusively three broken bits of *E. intermedius*.

TABLE XXVII

Qualitative analysis of the stomach contents of L. savala

(March 1959 to February 1960)

Month	No. of fish examined	Size range (S.L. cm.)	Items of food	Condition of feed
Mar	26	20.6-46.1	*Stolephorus, Acetes, Squilla*	Poor
Apr.	19	30.1-55.9	*Stolephorus, Acetes, Sardinella,* polychaete remains	Poor
May	8	17.1-28.5	"Fishes", *Lucifer*	Poor
Jun.	2	13-6-23.6	"Fishes", *Lucifer Acetes*	Poor
Jul.	3	16.6-25.7	"Fishes", *Lucifer*	Poor
Aug.	1	29.4	"Fishes"	Poor
Sept.	No. data	—	—	—
Oct.	1	37.5	—	Empty
Nov.	9	20.0-44.8	"Fishes", mysids, *Acetes*	Active
Dec.	4	19.4-27.4	*Acetes*	Active
Jan.	55	15.4-56.4	*Acetes,* "fishes" *Penaeus,* mysids.	Poor
Feb.	40	19.0-52.8	*Acetes, Octopus Squilla,* prawns.	Poor

TABLE XXVIII

Qualitative analysis of the stomach contents of L. savala

(March 1960 to February 1961)

Month	No. of fish examined	Size range (S.L. cm.)	Items of food	Condition of feed
Mar.	29	21.1-40.8	"Fishes" *Acetes, Penaeus,* juvenile fishes, *E. intermedius*	Poor
Apr.	8	21.4.-36.4	"Fishes"	Poor
May	1	19.7	"Fishes"	Poor
Jun. to Sept.	No data	—	—	—
Oct.	10	13.9-24.8	*Acetes,* "fishes"	Poor
Nov.	4	26.2-46.2	"Fishes", *Acetes, Sepia*	Poor
Dec.	15	16.9-41.7	*Acetes,* "fishes" prawns juvenile fishes	Poor
Jan.	34	19.1-45.7	"Fishes", *Metapenaeus, Acetes*	Poor
Feb.	23	17.6-44.4	"Fishes", *Acetes,* juvenile fishes.	Poor

8. Discussion

Suyehiro (1942) in his brief remarks on the food of *T. haumela* (= *T. lepturus* from Japan, stated that the stomachs of this fish contained cuttle-fish besides pieces of its own species, which are generally used for baiting and that those found in the stomachs were possibly the same used as baits. Venkataraman (1944) in an account of food of *Trichiurus* spp. from West coast observed that all the species are carnivorous with an insatiable appetite, feeding indiscriminately, prawns and white-baits forming however, the favourite food. Other items recorded by him were *Sardinella fimbriata, Leiognathus splendens, L. bindus, Cynoglossus semifasciatus, Lactarius lactarius, Dussumieria hasseltii, Engraulis mystax, E. dussumieri, Ambassis dayi, Pristipoma* spp., *Caranx* spp., *Kowala thoracata, Sciaena* spp., fish eggs and larvae. Devanesan and Chidambaram (1948) have recorded some of the above items in the food of ribbon-fishes from Madras coast. Jacob (1949) also mentioned the same items in the diet of ribbon-fishes from the west coast of Madras. Tham Ah Kow (1950) has reported on *T. savala* (= *L. savala*) from Singapore that its main food is *Stolephorus* of various sizes and occasionally large amounts of mysids, *Acetes*, small trichiurids and *Dussumieria*. Vijayaraghavan (1951) from Madras in the food of *T. haumela* recorded teleosteans, *Acetes, Lucifer*, mysids, amphipods, copepods, ostracods, sergestids, zoaea of brachyura, megalopa of crabs, polychaetes, leptocephalus along with algae, green matter, prawns, cumacea, hermit crabs, *Squilla*, copepod nauplii, *Sepia*, larval gastropods, and bivalve larvae. In the food of *T. savala* he listed teleosteans, *Acetes, Lucifer*, copepods and their nauplii, prawns, Cirripedia, bivalve larvae, polychaetes, algae and green matter, *Squilla* and their larvae, Anomura, palaemonids, mysids, *Leander*, cumaceans, ostracods, megalopa of brachyuran crabs, zoaea of crabs, pycnogonids, porcellanids, pteropods and *Sepia*. He analysed the stomach contents of the two species in 10″ and 20″ size groups separately and concluded that variations and rate of feeding are probably correlated with physiological requirements of the fish while variations in volume of chief food items consumed may be related to their dearth in environment. Observations of Chacko (1949) show *Sardinella gibbosa, Dussumieria hasseltii, Leiognathus bindus* and *Lactarius lactarius* from the stomachs of *T. salava* from the Gulf of Mannar.

The items of food of *T. haumela* recorded by Prabhu (1950, 1955) were *Hemirhamphus* spp, *Therapon* spp., *Dussumieria* spp., *Kowala coval, Mugil* spp, *Caranx* spp., *Sardinella* spp., *Leiognathus* spp., *Sciaena* spp., *Trichiurus* spp., *Stolephorus* spp., *Penaeus* spp., *Metapenaeus dobsoni, Acetes* spp., *Sepia* and silicoflagellates. His observations have shown that the immature, mature and spent fishes differ in the degree of feeding as well as the nature of diet. The immature ones have been found to feed on young prawns and clupeids without any seasonal variations. The mature and spent specimens have been found to be voracious feeders even resorting to cannibalism. He found slackness in feeding just prior to spawning and active feeding after spawning.

The observations of the present author on the food of the four species of ribbon-fishes agree with those of all previous workers but with certain differences as to the wide range of food organisms recorded from place to place, which could be attributed to the environmental differences determining the relative abundance of certain food items in different localities wherefrom the samples were procured for study. It may be stated that the ribbon-fishes are mainly piscivorous supplementing their diet by a wide variety of other items. From the accounts of all the earlier authors and including the present observations it is also evident that these fishes although feed on a great variety of organisms they do restrict themselves only to some particular varieties. Venkataraman (*op. cit.*) remarked that coupled with the voracity of feeding these carnivorous fishes exhibit a total lack of choice in their food. That this is not so has been explained by Prabhu (1955) who opines that though *T. haumela* is a complete carnivore, it seems to be a selective feeder to some extent. The present observations also show that not only *T. lepturus* (= *T. haumela*) but also the other species dealt with here exhibit selectivity in diet. This is borne out by the fact that the same items were repeated in their diet irrespective of the locality and from such widely separated areas along the Indian coast, west coast of Ceylon and Singapore. Further, as Prabhu has pointed out in case of *T. haumela,* it was observed in case of *E. intermedius* and *L. savala* also that the young fishes feed on small fishes and shrimps whereas the adults prey upon big organisms. The feeding habits of young ones of *E. muticus* are not known since a wide range in size of specimens of this species could not be examined but from the trend observed, it may be like the other three species in this respect.

It is very interesting to note here that even when the diet of all the four species is more or less common, competition between species for the different kinds of food is usually not keen. When a particular sort of food is abundant, a number of different fishes may feed upon it but if it becomes scarce the fishes do not all turn to the same diet for a second choice. As many as three species of ribbon-fishes were collected at times from the same net and the stomach contents examined. In many occasions although all of them contained some common organisms like fishes, *Acetes* and *Lucifer* it was observed that the size of the prey differed in each species. This specificity in selection of food probably enables different species to live together in the same habitats. In case of *L. savala,* it was found from stomach contents that it always chased big sized prey. Regarding the size of prey, *T. lepturus* stands next to *L. savala,* followed by *E. intermedius* and presumably *E. muticus* occupies the last place. This, as was pointed out by Forbes (1888) and quoted by Pearse (1916) was found to be dependant on their structural equipment. Of the four species, *L. savala* has definitely the most powerful caniniform teeth and lengthy jaws to seize and accommodate the big sized prey effectively in the mouth cavity before swallowing it. The small number of teeth, and their arrangement with bigger interspaces and the rudimentary nature of gill rakers point out the high degree of carnivorous nature of this species as compared with others. The greater number, closer arrangement, less powerful teeth, the relatively shorter jaws coupled with slightly better development of the gill rakers in *T. lepturus* and *E. intermedius* are suitable for feeding on small sized prey. In *E. muticus* all these adaptive features are yet more pronounced to facilitate feeding on smaller organisms to a larger extent. The details of the structural adaptations with reference to feeding habits in these species have already been discussed in an earlier section and it would suffice here to state that although all species of ribbon-fishes are carnivorous, the degree of carnivorous nature varies amongst them, *L. savala* being the most voracious and *E. muticus* the least with *T. lepturus* and *E. intermedius* between them.

That the ribbon-fishes are cannibalistic was reported by Day (1876) and Prabhu (1955) in *T. haumela* and Tham Ah Kow (1950) in *T. savala*. According to Prabhu, during times of intensive feeding, mature and spent individuals of *T. haumela* were found with young and mutilated individuals of the same species in their stomachs. He pointed out that this was not due to lack of other favourite food which was abundant simultaneously but probably due to overcrowding of the shoals. The present observations record a few instances of canniblism in *E. intermedius* and one instance where the stomach contents of one specimen of *L. savala* contained pieces of the former species. Further, in the instances cited above, *E. intermedius* devoured its own kind when other food items were available and in one or two cases, along with other items. But it should be remarked here that in all the cases recorded, always the mature fish were prone to this habit and concurrent with the observations on *T. haumela*, cannibalistic tendency in *E. intermedius* was observed only at times of intensive feeding. However, there is no evidence to show that overcrowding of shoals leads to cannibalism in ribbon-fishes.

Venkataraman (1944) stated that he found during September 1943 guts of ribbon-fishes being literally clogged with macerated fish eggs and that this feature might greatly hit other fisheries. Prabhu (1955) remarks that he did not come across fish eggs in the stomach contents of *T. haumela*, but in the present study few fish eggs were occasionally met with in the stomach contents of the *E. intermedius* which could belong to some of the fishes engulfed by it, or it may be an accidental inclusion. However, they were not met with in such enormous number as described by Venkataraman. Devanesan and Chidambaram (1948) stated that the diet of ribbon-fishes is remarkable because it consists mostly of economically important food fishes, though this wide range in fish diet does not include oil sardine or mackerel. Jacob (1949) while remarking on the fluctuations in ribbon-fish fishery stated that ribbon-fishes being predatory on other economically important fishes, their overfishing can hardly do harm to the fisheries as a whole. While this could be one form of check over them, according to him, ribbon-fishes also form a prey for still more voracious fishes like *Chirocentrus dorab*. He states that *Polynemus tetradactylus* and *Lactarius lactarius* are known to feed on young ribbon-fishes. In this connection, it may be worthwhile to point out here that on 23rd February 1960 an yellow eel *Muraenesox telabonoides* measuring 164 cm T.L. landed by the New India Fisheries trawlers at Sassoon Docks (Bombay) had in its stomach, one complete individual of *T. lepturus* measuring 60 cm. S.L. The trawlers operate mostly off Saurashtra coast and off Cambay at depths of 15 to 25 fathoms.

Occasionally, during the course of the analysis of stomach contents, a varying number of empty stomachs were met with in all the species. Empty stomachs and stomachs with contents were recorded from fishes collected both during day as well as night at different localities which indicates that in these fishes there is no diurnal variation in the feeding habits. It was also pointed out, that except probably in case of *L. savala* complete cessation of feeding associated with sexual cycle was not noticed. Prabhu (1955) reported slackness in feeding of *T. haumela* prior to spawning. As far as *E. intermedius* is concerned such a phenomenon was not noticed. Suyehiro (1942) gave the explanation that owing to its low swimming velocity in comparison with other fishes, *T. haumela* experiences difficulty in obtaining food and hence the occurrence of empty stomachs but the number of fish he examined was too small to draw any conclusions.

The frequent occurrence of empty stomachs or stomachs with little contents in case of *L. savala* at times other than the spawning season and also in case of the other species may probably be dependent on the ratio between the size of the fish and the size of the prey as found by Allen (1935) for the perch, *Perca fluviatilis*. When the fishes feed on smaller organisms, they require a number of them and hence the necessity to feed constantly. Consequently, their stomachs will be rarely empty. When the prey is larger the fishes obtain enough food quickly and there may be some interval between two consecutive feeds during which time large proportion of stomachs with little or no contents will be met with in the samples obtained for study. This may be specially applicable in case of *L. savala* where the size of the prey is big as compared with the prey of other species.

X

LENGTH-WEIGHT RELATIONSHIP

The length-weight relationship of fishes, according to Le Cren (1951), is calculated primarily with a two fold aim. First to determine the mathematical relationship between the two variables, length and weight, so that if one is known the other could be computed. Second, to measure the variations from the expected weight for length of individual fish or groups of fish as indications of fatness, general well being or gonad development. In view of this practical utility, an attempt was made to determine the length-weight relationship of *Eupleurogrammus intermedius*, the details of which are presented below.

It is known that with increase in length of fish, the weight also increases but in a more rapid way, thereby showing that the weight of fish is a function of length. Since length is a linear measure and the weight a measure of volume, it was generally found that, for fishes, the relation between length and weight could be expressed by the hypothetical cube law, $W = c\ L_3$, where 'W' represents the weight of fish, 'L' its length and 'c' a constant. If the form and specific gravity remains constant, the formula could be used to calculate the weight of fish of known length or *vice versa*. But Le Cren (*op. cit.*) pointed out that it is better to fit a general parabolic equation of the form $W = a\ L$ which expresses the relation between the two factors better than the cubic formula where 'W' and 'L' represent weight and length of fish respectively, 'a' a constant equivalent to 'c' and 'n' a constant to be determined empirically i.e., from the data.

The applicability of the simple cubic relationship of weight and length of fishes has been much discusssed. If, as a fish grows, it does not change form or density, the weight will be proportional to the cube of any linear dimension. Changes in morphology with increasing age, however, often cause the coefficient of regression of logarithm of weight on logarithm of length to depart substantially from 3.0. The value of the exponent 'n' in the parabolic equation usually lies between 2.5 and 4.0 (Hile, 1936; Martin 1949) and for ideal fish which maintains constant shape, $n = 3$ (Allen, 1938). Beverton and Holt (1957) stated that important departures from isometric growth ($n = 3.0$) are rare. However, as shown by Blackburn (1960) in the case of Australian barracouta, *Thyrsites atun* (Euphrasen) the value of 'n' was considerably below 3.0. Therefore, in case of *E. intermedius* it was thought better to fit the general equation.

Standard length was measured from snout to tip of tail in centimeters and weight was taken in grams for each specimen. Specimens where the tail was suspected to be broken have been rejected. The method was adopted uniformly throughout the study. A total of 660 fish—517 females ranging in length from 14.4 to 49.4 cm. and 143 males ranging in length from 12.4 to 40.5 cm. during March 1959 to February 1960 and a total of 378 fish—284 females ranging in size between 11.2 to 46.1 cm. and 94 males ranging in size between 13.3 to 38.2 cm. during March 1960 to February 1961 from Panaikulam were utilised for this purpose.

The general equation $W = a\ L^n$ can be written as $\log W = \log a + n \log L$., i.e., $Y = A + BX$ where $A = \log a$; $B = n$; $Y = \log W$ and $X = \log$

TABLE XXIX

Sum of squares and products of length-weight data of males and females of E.intermedius

Period	No. of fish	Sex	SX	SY	SX^2	SY^2	SXY
1959-60	517	Females	733.3686	490.9405	1048.7174	570.9120	725.3789
1959-60	143	Males	193.8586	105.0892	264.0990	93.8618	146.9859
1960-61	284	Females	405.6220	286.0875	583.6178	339.1574	423.2855
1960-61	94	Males	127.9179	73.1635	175.3018	71.9798	103.8376

SX, SY = Sum of X and Y; SX^2, SY^2, SXY = Sum of squares and products.

TABLE XXX

Corrected sum of squares and products of length-weight data, regression coefficient and deviation from the regression

Period	Sex	D.F.	Sum of squares and products			B	Errors of Estimate	
			X^2	XY	Y^2		D.F.	S.S.
1959-60	Females	516	8.4243	28.9753	104.7185	3.4394	515	5.0583
1959-60	Males	142	1.2900	4.5192	16.6317	3.5032	141	0.7999
1960-61	Females	283	4.2897	14.6828	50.9681	3.4228	282	0.7118
1960-61	Males	93	1.2218	4.2778	15.0396	3.5012	92	0.0621

D.F. = Degrees of freedom; XY, X^2, Y^2 = Corrected sum of products and squares; B = Regression coefficient, S.S. = Sum of squares.

L, which is a linear relation between Y and X. This linear equation was fitted separately for the two sexes, to the data collected during the two years mentioned above. The estimates of the parameters 'A' and 'B' for each case were obtained by the method of least squares. Table XXIX gives the sum of squares and products of X and Y and Table XXX gives the corrected sum of squares and products as well as the estimate of the regression coefficient, 'B' for each case. This table also presents in the last column, the deviation from the regression.

Table XXXI presents the analysis of covariance to test if the regressions of Y and X are significantly different for the two sexes for each year. As may be seen from the table no significant differences were found in the regression coefficient of the sexes in each year. Hence the data for both sexes were pooled for each year and a common length-weight relationship was fitted for each year separately.

TABLE XXXI

Analysis of Covariance

Source of variation	Degrees of freedom	Sum of squares	Mean square	Observed F.	5% F.
Deviation from individual regressions within sexes during 1959-60	656	5.8582	0.0089	2.0697*	253 — 254
Differences between regressions	1	0.0043	0.0043		
Deviation from average regression	657	5.8625			
Deviation from individual regressions within sexes during 1960-61	374	0.7739	0.0020	2.9000*	3.92-3.84
Differences between regressions	1	0.0058	0.0058		
Deviation from average regression	375	0.7797			

* Non-significant.

The equations for the two years were found to be :

$$W=0.0001151\ L^{3.4466} \quad \text{and}$$
$$W=0.0001268\ L^{3.4342}$$

The corresponding logarithmic equations may be represented as

$$\log W= -3.9390 + 3.4466 \log L \text{ and}$$
$$\log W= -3.8969 + 3.4342 \log L.$$

Analysis of covariance was employed again to test whether the estimate of 'B' differed significantly between years, for the pooled data. The details are presented in Tables XXXII to XXXIV and the results have shown that there was no significant difference in the regression of Y on X between years.

TABLE XXXII

Sum of squares and products of pooled length-weight data of E. intermedius for the years 1959-60 and 1960-61

Period	No. of fish	SX	SY	SX^2	SY^2	SXY
1959-60	660	927.2272	596.0297	1312.8164	664.7738	872.3648
1960-61	378	533.5399	359.2510	758.9196	411.1372	527.1231

SX, SY = Sum of X and Y; SX^2, SY^2, SXY = Sum of squares and products.

TABLE XXXIII

Corrected sum of squares and products of pooled length-weight data, regression coefficient and deviation from the regression

Period	D.F.	Sum of squares and products			B	Errors of Estimate	
		X^2	XY	Y^2		D.F.	S.S.
1959-60	659	10.1566	35.0059	126.5136	3.4466	658	5.8618
1960-61	377	5.8378	20.0484	69.7072	3.4342	376	0.8563

D.F. = Degrees of freedom; XY, X^2, Y^2 = Corrected sum of products and squares; B = Regression coefficient. S.S. = Sum of squares.

TABLE XXXIV

Analysis of Covariance

Source of variation	Degrees of freedom	Sum of squares	Mean Square	Observed F	5% F
Deviation from individual regression within years	1034	6.7181	0.0064		
Differences between regressions	1	0.0004	0.0004	16.0000*	253—254
Deviation from average regression.	1035	6.7185			

* Non-significant.

As there was no variation between years (Table XXXIV) the entire data for the two sexes and for the two years was therefore pooled and a general relation between Y (log W) and X (log L) was calculated. It was found to be $W = 0.0001184\ L^{3.4445}$. The corresponding logarithmic equation may be represented as $\text{Log } W = -3.9268 + 3.4445 \log L$.

The observed values of length and weight of *E. intermedius* (collected during 1960-61) were plotted (Fig. 31,A) and the calculated length-weight curve fitted to the data. The two sets of data show a close relationship as may be seen from the figure. Similarly the logarithmic values of observed lengths and corresponding weights were plotted (Fig. 31,B) and the regression line fitted to the data indicates a straightline relationship between the two variables.

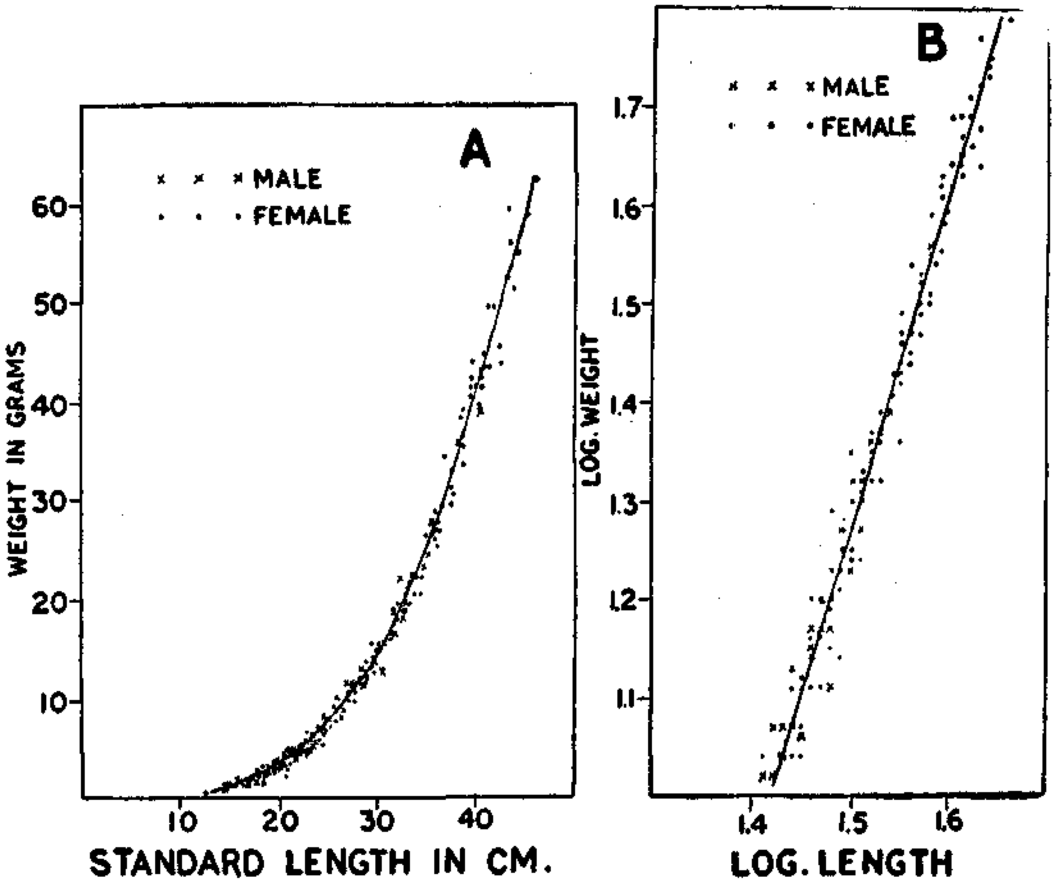

Fig. 31. Parabolic (A) and logarithmic (B) relationship between length and weight of *E. intermedius.*

While the above formula holds good for the length-weight relationship of *E. intermedius*, the significance of the variation in the estimate of 'B' for this species from the expected value for ideal fish (3.0) was tested by the 't' test as given by the formula $t = \frac{b - B}{Sb} = \frac{3.4445 - 3.0000}{0.0203} = 21.8965$ which was found to be significant at 5% level. Hence, the cubic formula $W = a\,L^3$ will not be a proper representation of the length-weight relationship of *E. intermedius*. The exponent is clearly greater than 3 and the best estimate of 'n' in the case of this fish based on two year's data is 3.4445.

Using the formula $W = A\,L^B$ where W = Weight, L = Length, A = a constant and B an exponent to be determined, Prabhu (1955) found that the length-weight relationship for *T. haumela* (= *T. lepturus*) may be expressed as $W = 0.0004935\ L^{3.0819}$ which indicates that the two species differ in their length-weight relationship.

XI

RELATIVE CONDITION FACTOR

The analysis of length-weight relationship with the object of finding the variation from the expected weight for length of individual fish or groups of individuals as indicative of fatness, general well being or gonad development may be termed as condition (Le Cren, 1951). Tester (1940) has shown that variations in the specific gravity of flesh of fish occur, and Kestevan (1947) discussed their importance in studies on condition. Usually, the density of the fish is maintained as the same as that of surrounding water, and hence, changes in weight for length are due to changes in form or volume and not specific gravity. Such changes are analysed by the condition factor or coefficient of condition or ponderal index (Hile, 1936; Thompson, 1943) which is given by the formula $K = \frac{100W}{L^3}$ where 'K' represents the condition factor, 'W' the weight and 'L' the length of the fish respectively. This formula is based on comparison with ideal fish, where the cubic relationship holds good.

Further modifications of the above general relationship have been proposed. The value of 'K' will be affected if the fish does not obey the cube law in its length-weight relationship. Factors like age, sex, maturity, racial differences, food supply, degree of parasitization, environment and selection in sampling may also affect 'K' indirectly through the value of the exponent. Instead, by using an empirical, calculated length-weight relationship, $W = a L^n$, the factors affecting 'K' could be eliminated (Le Cren, *op. cit.*). The condition factor so calculated is called the relative condition factor (K_n), and is given by the formula $K_n = W/a L^n$. This may otherwise be denoted as $K_n = W/\overline{W}$, where 'W represents the observed weight and $\overline{W}$ the calculated weight of fish obtained by using the logarithmic formula. The difference therefore, between K (condition factor) and K_n (relative condition factor) is that, the former measures the deviation of an individual from the average weight for length, while the latter measures the deviation from a hypothetical ideal fish.

The relative condition factor K_n for *E. intermedius* was calculated by employing the formula $K_n = W/\overline{W}$ as explained above. The length and weight data for 801 females from Panaikulam and 60 females from Athankarai (both on Palk Bay) were utilised in this study. Since the number of males studied was small (237) compared to females and their size range also limited, the condition of females alone was studied.

Regression of weight on length was calculated separately for 801 females from Panaikulam and 60 females from Athankarai. The equations for the regressions were found to be $W = 0.0001408\ L^{3.3909}$ and $W = 0.0001413\ L^{3.3880}$ respectively. Based on these formulae, the calculated weights of all the specimens were determined. The relative condition factor, K_n, was obtained for each fish by subtracting the logarithmic equivalent of calculated weight from the logarithmic equivalent of observed weight and the geometric mean of K_n was calculated for each month by taking the average of the above values. Since the object of the study is to trace the condition cycle of the fish through the year and in two successive years and its relation to maturity and feeding habits, they were classified into two groups, the immature (below 35 cm. S.L.) and the mature (above 35 cm. S.L.) fish since nearly 50% of the fish were found to be mature at 35 cm. S.L. The geometric means of the condition factor, K_n for monthly samples of *E. intermedius* for the above two groups were calculated separately and presented in Tables XXXV and XXXVI along with the number of observations contributing to each mean, and the weighted average for each year (Fig. 32, A,B).

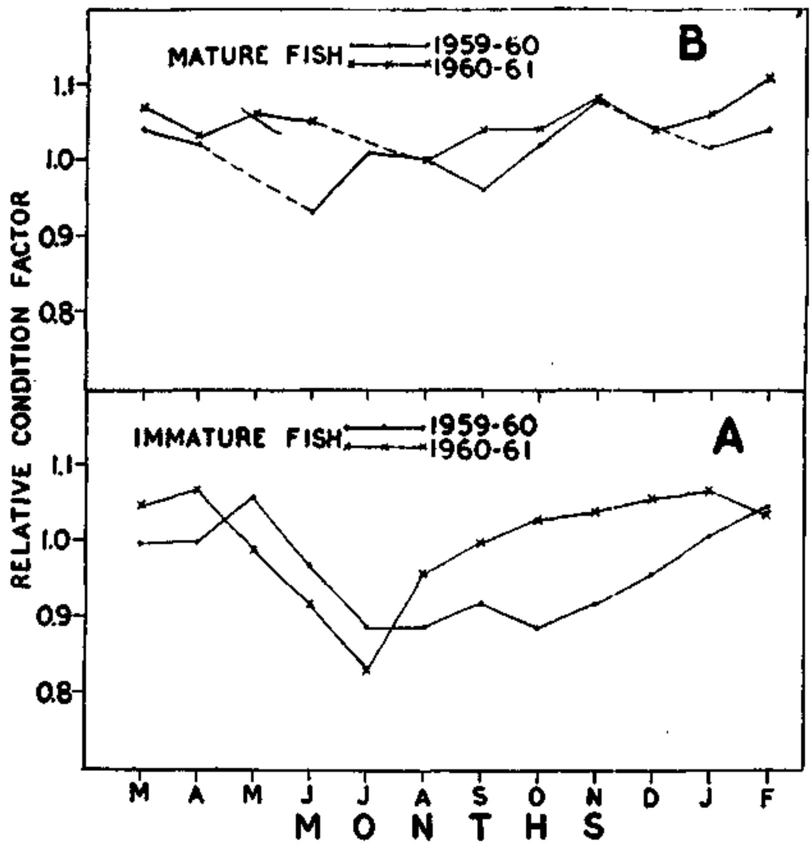

Fig. 32. Variations in the relative condition factor of *E. intermedius*. A. Immature fish. B. Mature fish.

It may be seen from these tables that the condition of immature fish during the year March 1959 to February 1960 was lower than the weighted average for the whole year in July, August and October. For the mature fish, the same year, condition was lower than the weighted average from June to September. The observations during March 1960 to February 1961 show that the condition of immature fish was lower than the weighted average for the whole year from May to September and that of the mature fish in April, June, August to October and December. It should be pointed here that the number of mature fish contributing to each mean is small in many of the months in spite of best attempts to collect them and hence great reliance may not be placed on such values.

TABLE XXXV

Geometric means of condition factor (March 1959 to February 1960)

Month	Immature fish		Mature fish	
	No. of fish	K_n	No. of fish	K_n
Mar.	49	1.002	19	1.042
Apr.	33	1.002	15	1.026
May	43	1.067	—	—
Jun.	42	0.972	1	0.931
Jul.	27	0.897	8	1.017
Aug.	26	0.893	32	1.005
Sept.	23	0.923	9	0.964
Oct.	73	0.893	1	1.023
Nov.	48	0.924	11	1.089
Dec.	8	0.067	—	—
Jan.	26	1.018	2	1.025
Feb.	17	1.057	3	1.049
Weighted average for the year	415	0.911	101	1.023

TABLE XXXVI

Geometric means of condition factor (March 1960 to February 1961)

Month	Immature fish		Mature fish	
	No. of fish	K_n	No. of fish	K_n
Mar.	24	1.056	24	1.077
Apr.	19	1.074	8	1.034
May	18	0.094	2	1.062
Jun.	28	0.924	3	1.054
Jul.	9	0.839	—	—
Aug.	22	0.969	9	1.007
Sept.	20	1.007	9	1.040
Oct.	18	1.036	3	1.041
Nov.	33	1.043	6	1.086
Dec.	26	1.063	3	1.046
Jan.	26	8.071	4	1.068
Feb.	25	1.044	3	1.114
Weighted average for the year	268	1.019	74	1.057

Variations in condition of different fishes have been attributed to different factors by earlier authors. Thompson (1943) pointed out that the high and low condition in the plaice *Pleuronectes platessa* are found before and after spawning. Hickling (1945), in case of the Cornish pilchard, *Sardina pilchardus* found the condition low before spawning and high after it, which was explained by him as due to sexual cycle and the availability of food respectively. Qasim (1957) offered the explanation that the increase and decrease of condition in the shanny, *Blennius pholis* are probably due to general building up and loss of reserves respectively. Blackburn (1960) in his studies on the Australian barracouta, *Thyrsites atun* remarked that it was not possible to interpret the changes of condition in this fish basing on sexual cycle or the intake of food, and that it may depend on several other factors.

In the case of *E. intermedius*, although the condition of immature fish differs from that of mature fish, in various months, it may be seen that in some months at least, the condition of both immature and mature fish are either high or low, indicating that probably factors other than sexual cycle may be responsible for variations in the condition. Further, it was also noticed that the variations in the condition factor have not shown any relation to differences in the intensity of feeding of immature and mature fish. According to Brown (1957) the balance between maintenance and growth may vary with physico-chemical factors of the environment (e.g. temperature) and with size, age and physiological state of the fishes. Therefore, the available data suggest that the changes in condition of *E. intermedius* are probably related to factors other than the reproductive cycle and the feeding habits.

XII

REPRODUCTION

An average of 150 specimens of *E. intermedius* landed in shore seines at Panaikulam (Palk Bay) were examined every month. Data presented here refer to fish collected at Panaikulam but general observations on maturity and spawning of this species collected from Pudumadam, Kilakarai and Dhanushkodi (Gulf of Mannar) and Thangachimadam (Palk Bay) were also made.

The length, weight, sex and state of maturity of the fish in each sample were noted. All specimens where the tail was suspected to be broken were rejected. The ovaries were then removed and hardened in 5% formalin. Examination of preserved ovaries revealed on comparison with fresh material that there was no appreciable shrinkage or swelling of the ova due to preservation.

1. Maturity

i. *Distribution of ova in the ovary*: In order to test the distribution of ova in the ovary of *E. intermedius* mature ovary of Stage IV from a specimen measuring 41.5 cm. S.L. was selected. Three portions of the left ovary from anterior, middle and posterior regions were cut out and teased on microslides. The ova diameter measurements of ova in each part were noted separately and the frequencies were plotted (Fig. 33,A). The frequency curves show a similar pattern of distribution of the immature, maturing and mature ova. Similarly, the distribution of ova in the right ovary was also found to be uniform. The frequencies from all the three regions from one ovary were then pooled and plotted (Fig. 33,B) which shows the same type of distribution of ova. However, to eliminate any differences between the regions of the ovary or between the two ovaries, in all further studies, ova diameter studies were made from a sample taken from the middle region of both ovaries.

Ovaries in all stages of maturity contain immature ova measuring up to 0.11 mm. throughout the year and in stages other than the immature (Stage I) and maturing stage (Stage II), only ova above 0.11 mm. were measured. Several other earlier workers (Clark, 1934; de Jong, 1940) have followed the same method and found that it gave satisfactory results.

ii. *Classification of maturity stages*: In order to study the maturity and ascertain the spawning season, 3057 females and 1329 males of this species were examined and dependending on the macroscopic appearance and the microscopic structure of the ova in the females, the following stages of maturity were recognised for the species. The maturity stages for the males were classified dependant only on the macroscopic structure. The description given below applies to maturity of females (unless otherwise mentioned) since males of advanced stages of gonad development were not available for study.

Stage I — Immature: In this stage, the ovaries appear very small and transparent. They occupy less than one third of the body cavity. Ova are not visible to the naked eye, irregular and transparent. Yolk formation has not commenced. Majority of the ova in this stage range in size between 0.01 to 0.09 mm and with the maximum size of the ova up to 0.19 mm.

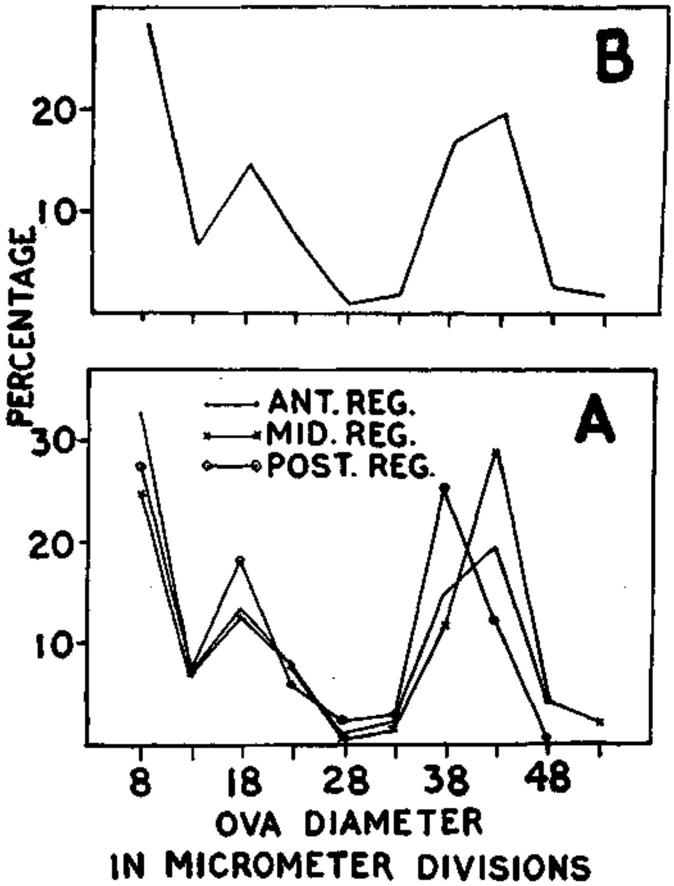

Fig. 33. A. Ova diameter frequency polygons of the anterior, middle and posterior regions of a mature ovary of *E. intermedius*. B. Combined ova diameter frequency polygon of the above.

Testes are very slender and thin, occupying about the same space as the ovaries.

Stage II — Maturing : Ovaries in this stage are slightly larger, occupying more than one-third of body cavity. The first batch of eggs gets separated from the immature egg stock. The immature eggs are transparent and irregular in shape whereas the group that is separated from them (maturing ova) are partly opaque due to commencement of yolk deposition and they assume a rotund appearance. The mode of the maturing group of eggs falls at 0.34 mm, the maximum size of eggs being 0.47 mm.

Comparatively, testes in this stage occupy lesser space than ovaries. They are narrow and ribbon-like.

Stage III A — Early mature : Ovaries occupy about half of the body cavity and appear distinctly yellow in colour. The ovarian wall is thick. Ova are spherical, opaque and with a full deposition of yolk. The mode of the largest group of ova falls at 0.62 mm, the maximum size of the ova being 0.76 mm.

Testes in this stage appear creamy white, long and ribbon-shaped. They extend up to half the length of body cavity.

Stage III B — Late mature : Ovaries in this stage occupy about three fourths of the body cavity and retain the distinctly yellowish colour of the previous stage. The ovarian wall becomes thin. The mode of the largest group of ova in this stage falls at 0.81 mm, the maximum size of the ova being 1.14 mm.

Stage IV A — Early ripe : Ovaries are enlarged and occupy almost the entire body cavity. They lose the yellow colour of Stage III, the ovarian wall becomes almost transparent and the intra-ovarian eggs appear light yellow in colour. Ovaries are fully packed with large eggs and the largest common egg diameter falls at 1.38 mm., the maximum size of the eggs being 1.61 mm.

Stage IV B — Late ripe : Ovaries occupy the entire body cavity and displace the viscera to a side. They are very turgid, transparent white in colour and the ovarian wall becomes very thin, delicate and easily rupturable. Eggs turn semi-transparent and the oil-globule is fully formed measuring 0.53 mm. The largest common egg diameter in this stage falls at 1.57 mm., the maximum size of the ova being 1.71 mm.

Stage V — Spawning : Not available. The mode of the largest eggs is expected to be above 1.57 mm., and the maximum size of the eggs above 1.71 mm.

Stage VI A — Partially spent : In this stage the ovaries occupy nearly half of the body cavity. They appear yellowish, partly empty and may be found often in distorted shapes. The stage resembles Stage III but differs from it in the relatively smaller size and the loosely packed nature of the ovaries. Further, such ovaries are often found with a few transparent areas scattered all over, which are occupied by the residual eggs. In fresh condition some blood patches may also be seen. The common egg diameter falls at 0.62 mm., and the maximum size being 0.85 mm.

Stage VI B — Fully spent : In this stage, ovaries appear quite shrunken and flaccid, not fully packed with ova and with a few blood patches in fresh condition. Majority of the ova are small, transparent, invisible to the naked eye and belong to the immature stock. Scattered amongst them a few large whitish granular ova visible to naked eye may be present. The mode of the largest group of eggs falls at 0.34 mm., with the maximum size up to 0.47 mm. It resembles Stage II but differs from it in the partly empty, compressed and shrunken appearance of the ovaries.

Testes appear shrunken, semi-transparent and partly empty.

The classification of maturity stages in *E. intermedius* is summarised in Table XXXVII with a comparison of the maturity stages defined by the International Council for the Exploration of the Sea (Wood, 1930) as reproduced by Lovern and Wood (1937).

TABLE XXXVII

Classification of maturity stages in E. intermedius

Stage of maturity in *E. intermedius*	Description of the intra-ovarian eggs		Mode of largest group of eggs (mm)	Maximum size of intra-ovarian eggs (mm)	Stages followed by the ICES
I		Immature	0.01–0.09*	0.19	I
II		Maturing	0.34	0.47	II
III A	Mature	Early mature	0.62	0.76	III
III B		Late mature	0.81	1.14	IV
IV A	Ripe	Early ripe	1.38	1.61	V
IV B		Late ripe	1.57	1.71	
V		Spawning	Above 1.57	Above 1.71	VI
VI A	Spent	Partially spent	0.62	0.85	VII
VI B		Fully spent	0.34	0.47	

* Range of size of majority of ova.

iii. *Development of ova to maturity*: Ova diameter measurements of 750 ova from a mature ovary were taken at random and they were grouped into four occular micrometer division groups with each division giving a magnification of 0.019 mm. The ova diameter frequency polygon of a mature ovary (Fig. 33,B) shows the presence of three distinct groups of ova. The first group, which may be termed the immature stock, ranges in size up to a maximum of 0.28 mm. The second group, which may be called the maturing ova range in size between 0.28 to 0.57 mm. The third group, which are considered to be mature, measure more than 0.57 mm.

Ova diameter measurements of as many as 118 ovaries in the different stages of maturity have shown these three groups of ova depending on their stage of maturity. Based on characteristic macroscopic appearance, correlated with microscopic study of the ova, six stages of maturity have been defined as given above.

Ovaries typical of the six stages described above have been selected and the ova diameter frequency polygons of these ovaries were drawn (Fig. 34, A-H). In stage I, majority of the ova are in the size range 0.01 to 0.09 mm. and a few of them measure up to 0.19 mm. In Stage II, the first batch of developing ova are withdrawn from the general egg stock with a mode at 0.34 mm and a maximum size of 0.47 mm. As the ovary passes on from Stage II to Stage III A, a second group of ova gets separated from the original immature stock. The first group progresses further and shows a mode at 0.62 mm. and the second

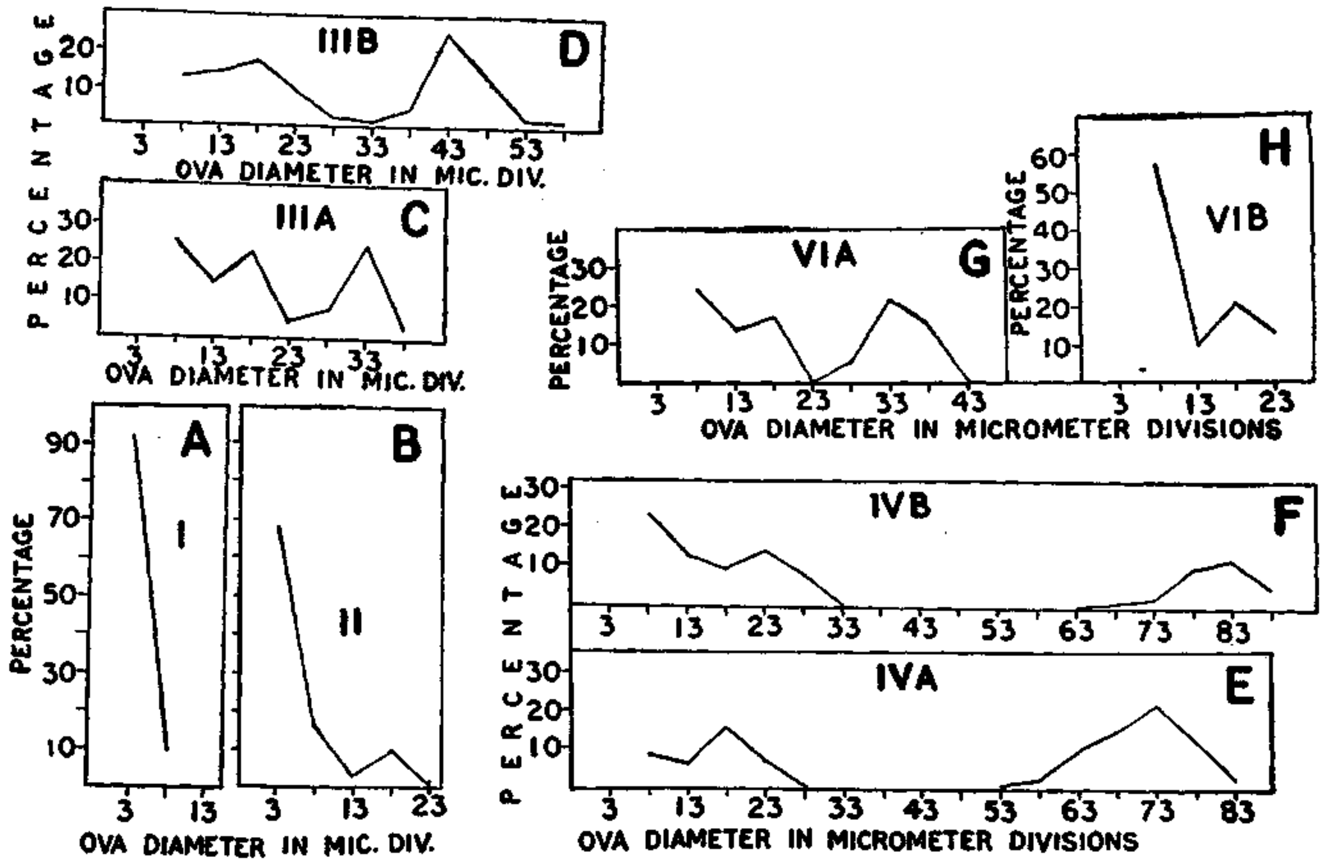

Fig. 34. A to H. Ova diameter frequency polygons of the ovaries of *E. intermedius* in various stages of maturity.

group has the mode at 0.34 mm. In the next stage of development (Stage III B), in addition to the immature stock of eggs, the two advanced groups noted in the previous stage are present. The mode at 0.34 mm remained stationary indicating that there was no growth in this group whereas the mode 0.62 mm has progressed further to show a peak at 0.81 mm. This mode, evidently constituting the mature group of eggs which will be spawned in the ensuing spawning season is distinctly separated from the immature and maturing groups of eggs as may be seen in the frequency curve of this stage. Up to this stage the first group of eggs appears to grow at a slightly faster rate than the second group. From Stage III A to Stage III B, for the maturing group of eggs, there is practically no difference, whereas the mature group progresses in size. This trend is reflected more clearly in Stage IV A, wherein the maturing group of eggs stands stationary with a mode at 0.34 mm, but the mature group shifts from a mode at 0.81 mm to a mode at 1.38 mm. The ovary in Stage IV B shows the ova diameter frequencies with the mode of largest group of eggs at 1.57 mm. The second batch of eggs which remained stationary from Stage III A with a mode at 0.34 mm shows little advance in this stage to a mode at 0.43 mm. However, from Stage III A onwards the first batch of eggs appears to grow at a much faster rate than before, with the result that the first group of eggs is distinctly separated from the second group which ultimately follows it. Stage V which would indicate the spawning condition was, however, not available for study. The ovary after extrusion of the first group of eggs shows a condition (Stage VI A) which depicts the partially spent ovary. The ova diameter frequency polygon of this stage (Fig. 34, G) resembles Stage III A, where, in addition to the three groups of ova typically found in a mature ovary, a few residual eggs are also present. While the absence of residual eggs in the ovaries may not be accepted as proof that the fish has never spawned, their presence constitutes good evidence that spawning has occurred. The mode of the largest group of eggs falls at 0.62 mm. In addition to the stages described above, some ovaries (Fig. 34, H) with the ova diameter frequencies resembling those of Stage II were also met with during the course of this study, in which, two groups of ova are present (Stage VI B). The first group measures a maximum of 0.28 mm and the second group varies in size between 0.28-0.47 mm. with a mode at 0.34 mm. Such a condition of ovary has been noticed only in mature fish above 30 cm. (size at first maturity) and resembles Stage II but for the compressed and partly empty nature. This condition of ovary is expected to result when all the batches of mature ova have been extruded. The ovaries probably remain for some time in this state, before maturation of a new group of eggs commences.

2. Spawning

Teleostean fishes have been found to exhibit different types of spawning habits according to Hickling and Rutenberg (1936), de Jong (1940), and many other recent workers. Based on these observations at least four major groups of fishes could be made, depending upon their spawning habits.

Group I : Includes fishes that have a short spawning, once a season. The mature ovaries of such fishes show two distinct groups of eggs, the immature and the mature, distinctly separated from each other.

Group II : In this category of fishes, spawning takes place only once but over a long period. Here, the range in size of mature eggs will be approximately half the total range in size of eggs.

Group III : This group includes fishes that are expected to spawn twice in a season whose mature ovaries contain, in addition to the mature group of eggs another group immediately following it, and which has undergone about half the maturation process.

Group IV : Fishes that spawn intermittently over a long period. In the ovaries of such fishes the successive batches of eggs are not sharply differentiated indicating that the maturation process is a continuous one.

An examination of the ova diameter frequencies of mature ovaries of *E. intermedius*, indicates that they contain, in the early stages of maturation at least (Fig. 34,C) three groups of ova which are not sharply differentiated. As the fish approach the spawning season, the mature group of eggs appear to grow at a faster rate and gets distinctly separated from the maturing group of eggs (Fig. 34,F). Soon after the elimination of this group of eggs, another mature group of eggs takes its place (as shown in a partially spent ovary). Hence, regarding its spawning habits, this species may be said to approach Group III fishes described above.

If there is a periodicity in spawning, all the fish collected at any particular time are expected to belong to the same stage of maturity (Clark, 1934). In the present case a single sample collected on a particular day contained fish in at least three different stages of maturity, if not more and in many months, advanced stages of maturity coupled with partially spent and spent were recorded which indicates the absence of any periodicity.

A total of 2238 fish during March 1959 to February 1960 and 2286 fish during March 1960 to February 1961 were examined to study the percentage occurrence of gonads in different stages of maturity. The details are presented in Tables XXXVIII and XXXIX.

In March 1959 (Fig. 35,A) Stages I to IV were present Stage II being the most predominant. In April, almost the same picture was seen except that the percentage of Stage II was slightly less and an increase in Stage I and Stage III was noticed. During May, only Stages I to III were represented, I and II being dominant. Once again in June, Stage II was dominant but stage III was not represented. In July, Stage I was prominent and Stage II which was not represented in the previous month, was noticed in a small percentage. In August, fish of all stages from I to IV, VI A and B were also simultaneously recorded. During September, except Stage IV which was recorded in the previous month, all the other stages were present in the commercial catches. In October, only Stages I and II were recorded whereas in November all the stages were again represented. In December, Stages I to III and VI B were noticed. The occurrence of fish in different stages of maturity in January 1960 was almost the same as in December 1959, except that Stages III and VI B were represented in lesser percentages. During February, only Stages I to III were recorded.

TABLE XXXVIII

Percentage occurrence of gonads of E. intermedius in different stages of maturity
(March 1959 to February 1960)

Month	No. of fish	Sex	Stages of maturity					
			I	II	III	IV	VIA	VIB
Mar.	94	F	1.06	62.76	27.66	8.51	—	—
	29	M	6.90	93.10	—	—	—	—
Apr.	58	F	27.58	36.21	29.31	6.90	—	—
	9	M	33.33	55.55	11.11	—	—	—
May	57	F	49.12	47.37	3.51	—	—	—
	13	M	69.23	30.77	—	—	—	—
Jun.	182	F	37.91	62.08	—	—	—	—
	57	M	61.40	38.59	—	—	—	—
Jul.	207	F	56.01	41.05	2.90	—	—	—
	75	M	81.33	18.67	—	—	—	—
Aug.	162	F	32.09	44.44	9.87	1.23	9.87	2.47
	40	M	77.50	22.50	—	—	—	—
Sept.	93	F	20.43	41.93	6.45	—	7.53	23.65
	42	M	16.67	54.74	—	—	—	28.57
Oct.	123	F	60.16	39.84	—	—	—	—
	56	M	66.07	33.93	—	—	—	—
Nov.	167	F	32.93	54.49	7.78	1.80	1.80	1.20
	37	M	40.54	59.46	—	—	—	—
Dec.	88	F	50.00	46.59	2.27	—	—	1.10
	66	M	62.12	37.88	—	—	—	—
Jan.	288	F	76.73	22.22	0.69	—	—	0.34
	179	M	79.88	20.11	—	—	—	—
Feb.	89	F	21.35	70.78	7.86	—	—	—
	27	M	25.92	74.07	—	—	—	—

F = Female; M = Male.

TABLE XXXIX

Percentage occurrence of gonads of E. intermedius in different stages of maturity
(March 1960 to February 1961)

Month	No. of fish	Sex	Stages of maturity					
			I	II	III	IV	VIA	VIB
Mar.	162	F	2.47	53.08	9.26	3.09	25.30	6.79
	61	M	9.83	81.96	—	—	3.28	4.92
Apr.	72	F	4.16	52.77	12.50	1.39	9.72	19.44
	12	M	16.66	75.00	—	—	—	8.33
May	58	F	1.72	79.31	5.17	—	1.72	12.07
	8	M	—	100.00	—	—	—	—
Jun.	225	F	76.44	20.89	—	—	—	2.67
	178	M	93.24	6.74	—	—	—	—
Jul.	46	F	39.13	56.52	4.35	—	—	—
	44	M	22.73	77.27	—	—	—	—
Aug.	150	F	57.99	33.33	4.67	—	1.33	2.67
	54	M	77.77	22.22	—	—	—	—
Sept.	132	F	24.24	58.33	7.57	—	5.30	4.54
	50	M	40.00	60.00	—	—	—	—
Oct.	129	F	58.13	33.33	2.32	—	1.55	4.65
	58	M	82.75	17.24	—	—	—	—
Nov.	183	F	39.89	53.55	1.63	—	1.09	3.82
	52	M	61.54	38.46	—	—	—	—
Dec.	80	F	23.75	70.00	2.50	1.25	2.50	—
	29	M	37.93	62.07	—	—	—	—
Jan.	241	F	33.19	56.01	0.83	—	1.24	8.71
	88	M	52.27	46.59	—	—	—	1.14
Feb.	131	F	25.95	67.93	—	0.76	2.29	3.05
	43	M	44.18	55.81	—	—	—	—

F = Female; M = Male.

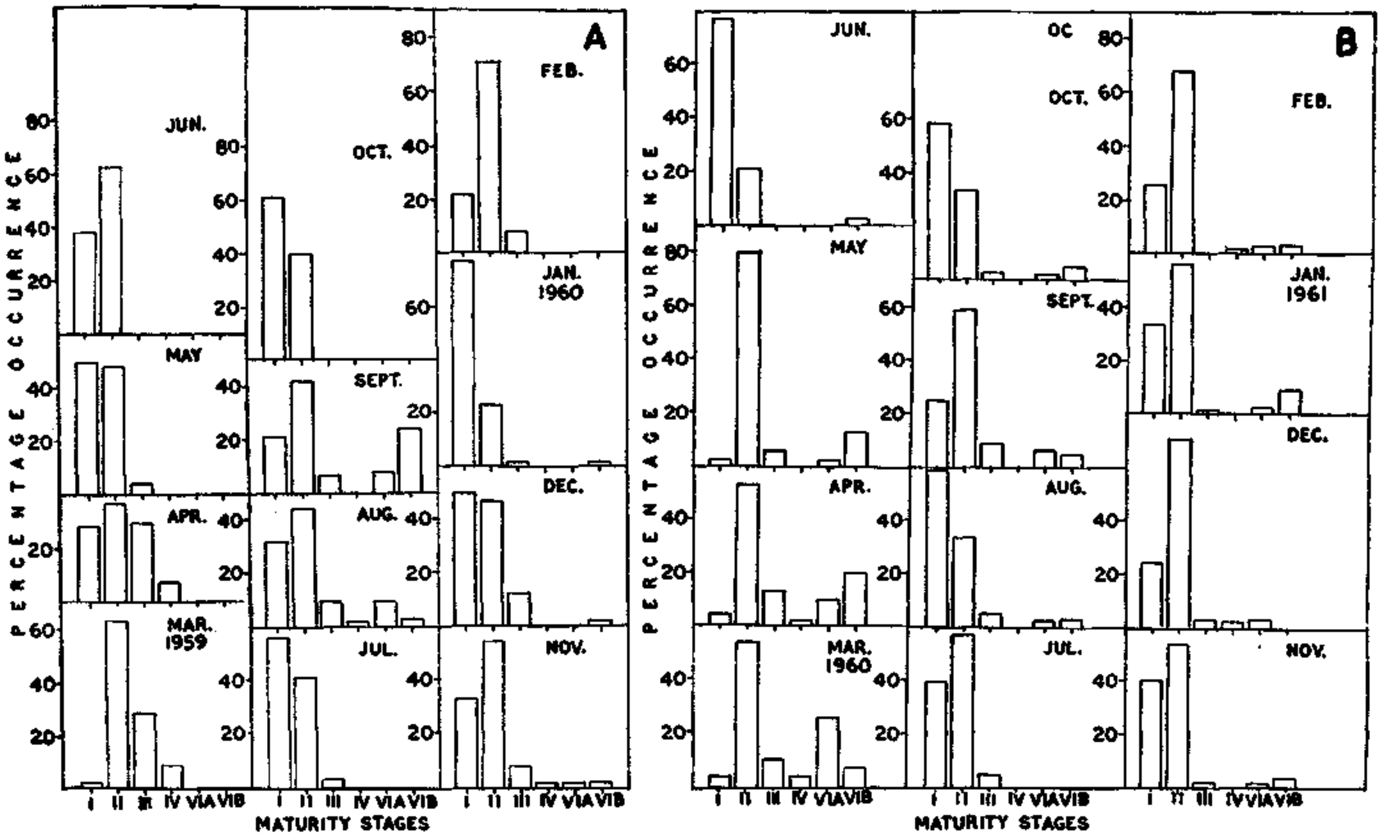

Fig. 35. Percentage occurrence of ovaries of *E. intermedius* in different stages of maturity (A) 1959-60 and (B) 1960-61.

During the following year March 1960 to February 1961 (Fig. 35,B) the following observations were made as to the occurrence of maturity stages. In March, fish of all Stages from I to IV and VI A and VI B were recorded. The same condition was noticed in April. In both the months, Stage II was dominant. In May, except Stage IV, all the other stages present in the previous months were again recorded. During June, only Stages I, II and VI A were recorded and in July, Stages I to III were only noticed. In August, Stage I to III, VI A and VI B were recorded. A similar condition was seen in September to November. In December, Stages I to IV and VI A were recorded. In January 1961, Stages I to III, VI A and VI B were noticed. In February, Stages I, II, IV, VI A and VI B were present in the commercial catches.

A comparison of the above data on the maturity of *E. intermedius* over two successive years indicates that fish of various maturity stages may be present in any month of the year. For instance, fish of maturity Stages I to III were present throughout the year except in June. Similarly fish with ovaries in an advanced stages of development (Stage IV) may be seen in February, March, April, August, November and December. Partially spent individuals (VI A) were recorded in January to May, August to December. Fully spent fish (VI B) were recorded from January to June and August to December. The occurrence of fish in Stage III almost throughout the year and Stage IV in a number of months with simultaneous occurrence of partially spent or spent individuals indicates that there is a continuous addition of mature fish every month.

Males of Stage I and II only were recorded throughout the year, the details of which are shown in Tables XXXVIII and XXXIX. The reasons for the absence of advanced stages of both sexes are not clear but it may indicate that the fish are not spawning in inshore waters.

The percentage occurrence of mature fish (Stages VI A and VI B) are shown in Tables XL and XLI.

TABLE XL

Percentage occurrence of mature and spent fish
(March 1959 to February 1960)

Month	Total no. of fish of all stages	Mature fish	Spent fish	
		Stages III & IV	Partially spent fish fish VI A	Fully spent fish VI B
Mar.	94	27.66	—	—
Apr.	58	27.58	—	—
May	57	3.51	—	—
Jun.	182	—	—	—
Jul.	207	2.41	—	—
Aug.	162	11.11	10.05	1.34
Sept.	93	5.38	7.53	3.2
Oct.	123	—	—	—
Nov.	167	8.38	1.80	0.60
Dec.	88	2.27	—	—
Jan.	288	0.69	—	—
Feb.	89	6.74	—	—

TABLE XLI

Percentage occurrence of mature and spent fish
(March 1960 to February 1961)

Month	Total no. of fish of all stage.	Mature fish	Spent fish	
			Partially spent fish	Fully spent fish
		Stages III & IV	Stage VI A	Stage VI B
Mar.	162	5.55	16.75	0.67
Apr.	72	9.72	1.30	—
May	58	—	—	—
Jun.	225	—	—	0.44
Jul.	46	4.35	—	—
Aug.	150	4.67	13.33	—
Sept.	132	7.57	5.30	—
Oct.	129	2.32	—	—
Nov.	183	1.64	1.09	—
Dec.	80	3.75	1.20	—
Jan.	241	0.82	0.40	1.20
Feb.	131	0.76	1.50	—

As may be seen from these tables, mature fish occur almost throughout the year with peaks in March, April, August and November during 1959 and February, April, September and December during the year 1960. This, however, does not prove that spawning occurs round the year because the duration of time the fish remain in these stages before spawning is difficult to ascertain. In this respect the occurrence of partially spent individuals some of them with residual eggs of previous spawning might provide a clue as to the time of spawning. Fish in partially spent condition and spent condition (Stages VI A and VI B) show a similar distribution pattern (Fig. 36) as the mature fish (Stages III and IV). Therefore, the occurrence of partially spent individuals with residual eggs of previous spawning over a number of months indicates that individuals of this species may spawn in any of these months. This is further supported by the occurrence of young fish of about 10 cm. S.L. in a number of months as indicated by the length frequency studies.

i. *Description of residual eggs* : A record of these eggs in various stages of resorption in the ovaries of *E. intermedius* was considered important especially because individuals of this species were found to spawn in a number of months. Only on one occasion on 20-9-1960 at Athankarai (Palk Bay) the author came across two fish (45.2 and 46.4 cm. S.L.) both mature, which had a few residual eggs in the ovaries. These were evidently destined to degenerate and be resorbed. The residual eggs oozed out on application of pressure on the abdomen. The eggs were transparent in fresh condition and on preservation in 5% formalin, they collapsed and hardened into plate-like structures. A more careful microscopic examination of these ovaries later, revealed that the rest of the ova were in the immature and maturing condition. No mature ova were present, indicating that the fish have spawned only recently. The condition of the ovary with the removal of the few transparent eggs returned to the partially spent condition especially as regards its flaccid nature and the ova diameter frequency. That the residual eggs which were spherical and transparent in fresh condition collapse

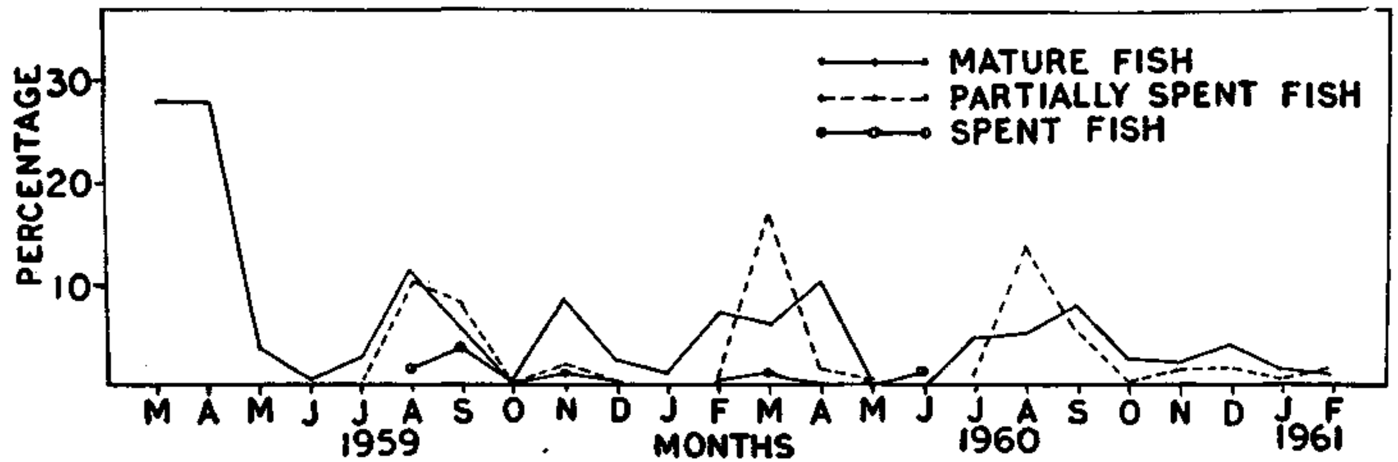

Fig. 36. Percentage occurrence of mature, partially spent and spent fish (*E. intermedius*) during the period March 1959 to February 1961.

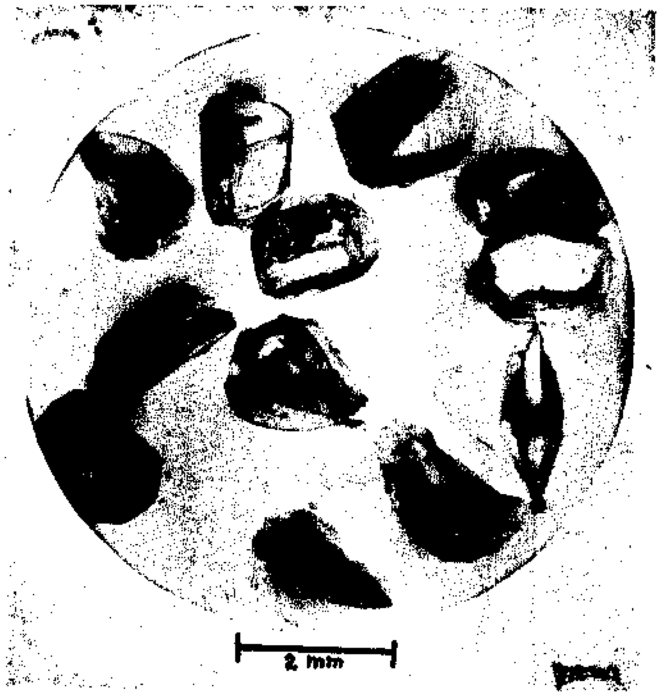

PLATE V
Residual eggs from the ovaries of *E. intermedius*.

and became plate-like structures on preservation in formalin in course of time was actually found in the case of the two fish cited above.

While the above instance stands in support of a very recent spawning (probably the same month) after which resorption of the residual eggs would commence, several other instances were recorded by the author during the present investigation from which it may be concluded that those fish have spawned only recently. Some specimens ranging in length from 37.7 to 45.5 cm. S.L. have been observed in January, March, April, August, September, October and December to have ovaries in the partially spent condition with some superficial transparent areas on their surface, irregularly scattered. When teased out on a microslide, these transparent areas of a ovary which has been preserved in 5% formalin were found to be occupied by one or two transparent plate-like structures, evidently the remains of residual eggs of recent spawning (Pl. V). Due, partly to shrinking of yolk mass and the resulting collapse of the chorion and partly due to the compression from all sides of other developing ova for the next spawning, these residual eggs are folded and crumpled to assume distorted shapes. The oil-sac was found to be ruptured and the released oil appears as droplets round the sac. The eggs remain free, translucent and pale orange coloured. They have been measured to range from 1.33 to 2.40 mm. in size. This wide range in size of these remains of residual eggs does not, however, represent the original size of the eggs as they loose shape with time due to degeneration and compression.

The particulars of record of residual eggs in the ovaries of this species are given in Table XLII.

TABLE XLII

Occurrence of residual eggs in the ovaries of E. intermedius.

Date	Standard length (cm.)	Size of residual eggs (mm.)	Date	Standard length (cm.)	Size of residual eggs (mm.)
6-8-59	41.1	—	14-4-60	40.8	1.60 to 1.97
31-10-59	40.0	1-17		41.5	—
3-11-59	42.8	—	9-8-60	43.6 42.7	— —
9-12-59	43.1	2-40			
13-1-60	43.0	—	23-8-60	37.7 42.9 45.5	— 1 84 1.74
14-3-60	41.0	—			
31-3-60	41.1	—	6-9-60	42.4	1.33
			20-9-60	46.4 45.2	Transparent eggs
			24-9-60	45.3	1.82 to 2.19

It may be worthwhile to mention here that such residual eggs in the ovaries of yellowfin tuna have been noted by Yuen and June (1957). In this case, the authors have described a few stages in their resorption. According to them, immediately after spawning the residual eggs almost resemble ripe eggs except that they are shrivelled up owing to shrinkage of yolk mass and resulting collapse of the chorian. The oil-sac is usually ruptured and the released oil appears as bright yellow droplets. The eggs at this stage are stilll translucent and free. Later, these eggs collect in masses of semi-opaque tubules, which are surrounded by connective tissue. With the passage of time, these masses appear to shrink and eventually become non-descript particles to be finally lost in the ovary.

A great similarity with the above description of the residual eggs of yellowfin tuna was observed for the residual eggs of *E. intermedius*. Although the final stages of resorption were ot observed in this species, the first stage was definitely noted in many fish. Yuen and June (1957) attribute the free, shrivelled up, translucent eggs to a time immediately after spawning in yellowfin and as explained above, the same may hold good in case of *E. intermedius*. Therefore, all the fish with such ovaries containing the shrivelled up eggs should be classed as those that have spawned recently.

ii. *Frequency of Spawning* : The multiplicity of modes in the mature ovary of a fish indicates that it spawns more than once in a season (Clark, 1934; Hickling and Rutenberg, 1936; de Jong 1940). In the case of *E. intermedius*, the same condition was observed. It is understood that as the mature group of eggs is eliminated, its place is soon taken up by the maturing group of eggs which has already undergone half the maturation process. Since, according to de Jong (1940), the second group which has undergone half the maturation takes about half the time taken by an immature group to attain maturity, subsequent spawning should take place soon after. But it will have to be proved that this group does not degenerate and be resorbed. In case of *E. intermedius* two types of spent ovaries were recorded, as already explained. In the first type (partially spent), at least one batch of eggs was eliminated recently which may be evidenced by the remains of residual eggs in such ovaries. In this ovary, the second batch of mature eggs which will be spawned in due course has already made its appearance with a mode at 0.62 mm. In the second type (fully spent), all the mature eggs were presumably spawned out and the ovary contains only two groups of eggs, the largest group with a mode at 0.34 mm only. Fish with the first type of ovaries return to spawning state soon after as they contain mature group of eggs whereas the second type evidently takes a longer time to return to spawning activity. The presence of these two types of ovaries leads to an inference that an individual fish spawns more than once in a year.

In an early stage of maturation (Stage III A) the ova diameter frequency shows that there is no distinct separation between the first batch and second batch of eggs. But in a more advanced stage (Stage IV A) the mature group of ova appears sharply separated from the maturing group. This clear separation of mature group of ova from the maturing group tends to show that spawning at a time may be of short duration. As explained earlier, till the mature group of eggs was eliminated, there was practically no progress in the maturing group. Once the mature group of eggs was eliminated its place is taken up by the second group as shown by the polygon of the partially spent fish.

3. Comparision Of The Spawning Habits Of The Four Species Of Ribbon-Fishes From Indian Waters

In addition to the common species, *E. intermedius* from Palk Bay and the Gulf of Mannar, material of the other three species, *Eupleurogrammus muticus, Trichiurus lepturus* and *Lepturacanthus savala* was also examined for a study of the maturity and spawning. Round the year observations on these species from the nearby localities were not possible as material was scanty and also because only three of the species (including *E. intermedius*) occur in this region. However, data on the second common species *L. savala* which is of seasonal occurrence in the area were collected as and when it was available. The mature gonads of *E. muticus*, specimens of which were collected from other localities were utilised for a study of the nature of spawning of this species. Some general observations have also been made by the author on the maturity and spawning of *T. lepturus*.

During January 1959 specimens of *L. savala*, both males and females were observed to be in Stage II. In February, Stage III and IV were recorded. In March and April, Stages II and III were common. Again in May, Stage IV was frequently noticed. Thereafter, from June to October, specimens of this species were not available for examination. In November and December Stages I, II and III were recorded. A similar occurrence of the maturity stages of this species was noticed in the following year also although specimens in advanced stages of maturity were not recorded as in the previous year. Since the nature of the mature ovary might throw some light on the type of spawning of the fish, the ova diameter frequency of mature ovary of *L. savala*, 52.7 cm. S.L. collected on 20-2-1959 from Rameswaram Road (Gulf of Mannar) was studied. A total of 750 ova were measured at random from the anterior, middle and posterior regions of the ovary (Fig. 37). It was found that the distribution of ova in these three regions of the ovary was uniform. Ova measuring less than 0.11 mm. representing immature stock were numerous in all the ovaries and hence they were not measured in this study. Three distinct groups could therefore be made out in the frequency curve of a mature ovary. The first, immature, transparent, invisible to naked eye, measuring less than 0.11 mm which are not shown in the curve. The next group, maturing, visible to naked eye, yellowish with deposition of yolk, range in size between 0.20 to 0.47 mm. with a mode at 0.34 mm. The third group, mature, range in size between 0.87 to 1.42 mm. with a mode at 1.10 mm. This last group of eggs are large and opaque which are destined to transform into ripe eggs and be shed in the ensuing spawning season.

The occurrence of two modes of ova other than the immature group in the ova diameter frequency curve of a mature ovary and also the occurrence of ripe individuals twice a year (once in February and in May) indicate that individuals of *L. savala* spawn more than once. Whether these are two distinct spawnings with a gap of about 2 months in between (March and April) or it is a prolonged spawning is difficult to judge from the data available for this species from this area. Since the maturing group of eggs and the mature group are distinctly separated from one another it may be likely that spawning at a time is of short duration. Jacob (1949) referred to the occurrence of ripe *T. savala* (= *L. savala*) along the west coast of Madras in the months of April, May and October. However, in the present study mature individuals were recorded only in February and May and young ones measuring 6.1 cm. S.L., in June in Palk Bay and the Gulf of Mannar.

The ova diameter frequency polygon of a mature ovary of *L. savala* shows certain amount of similarity with that of a mature ovary of *E. intermedius* described earlier and the young ones of these two species were also collected simultaneously (in June 1960) from Thangachimadam (Palk Bay). While this fact suggests that spawning in these two species takes place at about the same time, the duration and the frequency of spawning may be variable in the species.

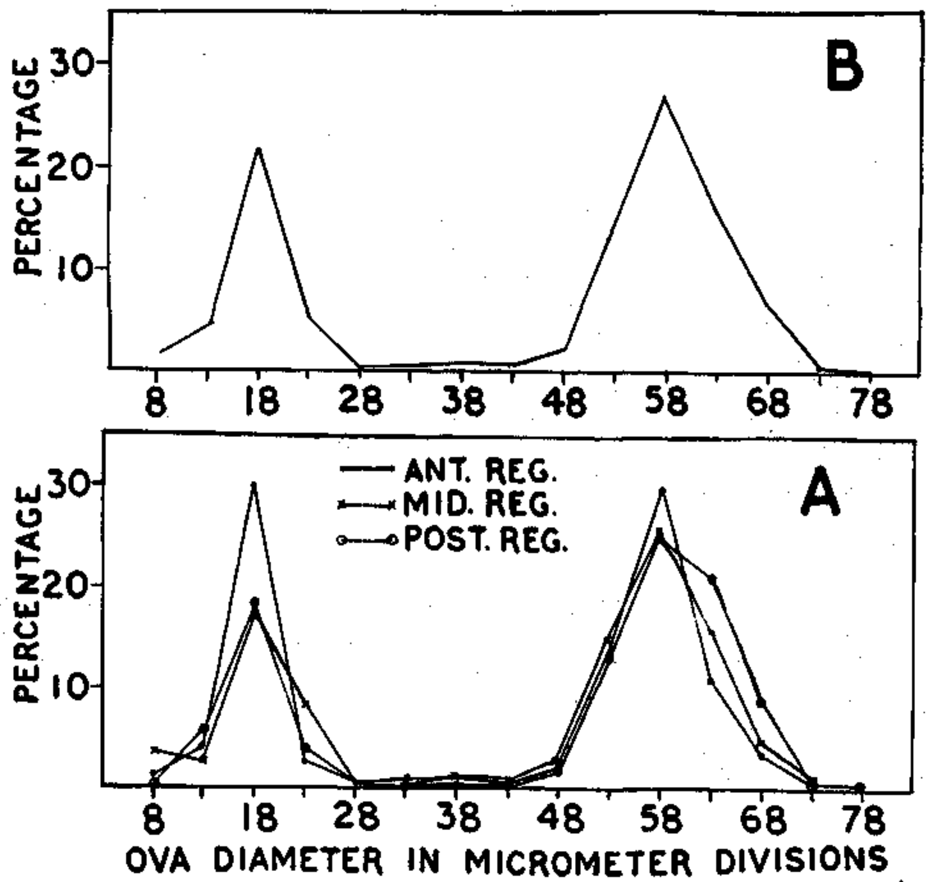

Fig. 37. A Ova diameter frequency polygons of the anterior, middle and posterior regions of a mature ovary of *L. savala*. B Combined ova diameter frequency polygon of the above.

In case of *T. haumela* (= *T. lepturus*), a third species of ribbon-fish from Indian waters, Prabhu (1955) found that in a mature ovary, the mature stock of ova is sharply differentiated from the immature stock indicating that spawning is of short duration, once a year. The occurrence of gravid specimens in April and May and their reappearance in large number in spent condition in July coupled with observation of young ones measuring 7.0 to 9.0 cm. only once a year towards the end of July, according to him, indicated that the species spawns towards the end of June and that the spawning is probably restricted to a definite short period.

While there was no possibility to collect enough material of this species from this area for a study of maturity and spawning, some general observations made by the author on the species are mentioned here. In January, a few individuals examined were in Stage II of manurity. In February and March some specimens were found to be in Stage III. During April, Stage III females were noticed but they were not available for examination in May. However, the male specimens examined in May were in Stage III. After May this species was quite scarce in the commercial catches in this area. In July, one female, measuring 57.5 cm. S.L. was found to be in the spent condition.

Specimens of this species were also collected from other places along the Indian coast. An examination of these in June 1959 at Waltair, Kakinada (Bay of Bengal) did not reveal gravid females. A large number of specimens were collected and examined from fishing centres at Idinthakarai (Gulf of Mannar) Cape Comorin, and Vizhingam (Arabian Sea) in September, 1959. Majority of the specimens were over 45 cm. S.L. and were in the spent and spent recovering condition. A field examination of *T. lepturus* along the Bombay coast—Versova and Sassoon Docks (Arabian Sea) in February 1960 revealed the occurrence of individuals in Stages I and III only.

This species was observed to move in great shoals in the inshore waters after June, at many places along the Indian coast. Since majority of the individuals in such shoals were above 45 cm. (47 to 48 cm. being the size at first maturity for the species), and all of them in spent and spent recovering stage, it may be possible that it returns to inshore waters in enormous numbers after spawning and that shoaling is associated with spawning.

An young one of this species, measuring 4.33 cm. S.L. collected at Idinthakarai (Gulf of Mannar) on 28-8-1959 was available for study. From the size of this specimen and the date of collection, it may be inferred that spawning would have taken place recently. Prabhu (1955) pointed out that it is probable that the postlarvae of this species grow to a size of 7 to 9 cm. in length in a period of a month and a half,* which according to him, agrees with the observations of Tang and Wu (1936). It may therefore be possible that the young one mentioned above might belong to an individual that spawned late in the season and the above general observations on the maturity and spawning of *T. lepturus* appear

* however, the rate of growth of 18 cm. in first year for this species stated by him, does not agree with this.

to support the conclusions of Prabhu although some slight differences as to the exact time and duration of spawning are indicated. This may be a result of the difference in localities of collection of material.

The distribution of ova in the anterior, middle and posterior regions of a mature ovary of E. muticus (61.4 cm. S.L.) collected from Kakinada was found to be uniform (Fig. 38). A total of 750 ova were measured at random from the three regions. The frequency curve indicates two distinct groups of ova excluding the immature group below 0.11 mm. which were not measured. The immature group of ova are numerous, transparent and invisible to naked eye. The second group, maturing ova, are opaque and yellow in colour with full yolk deposition. They range in size between 0.39 to 0.85 mm. with a mode at 0.53 mm. The last group, mature ova, are large, opaque yellowish in colour and range in size from 0.96 to 1.52 mm. with a mode at 1.19 mm. The

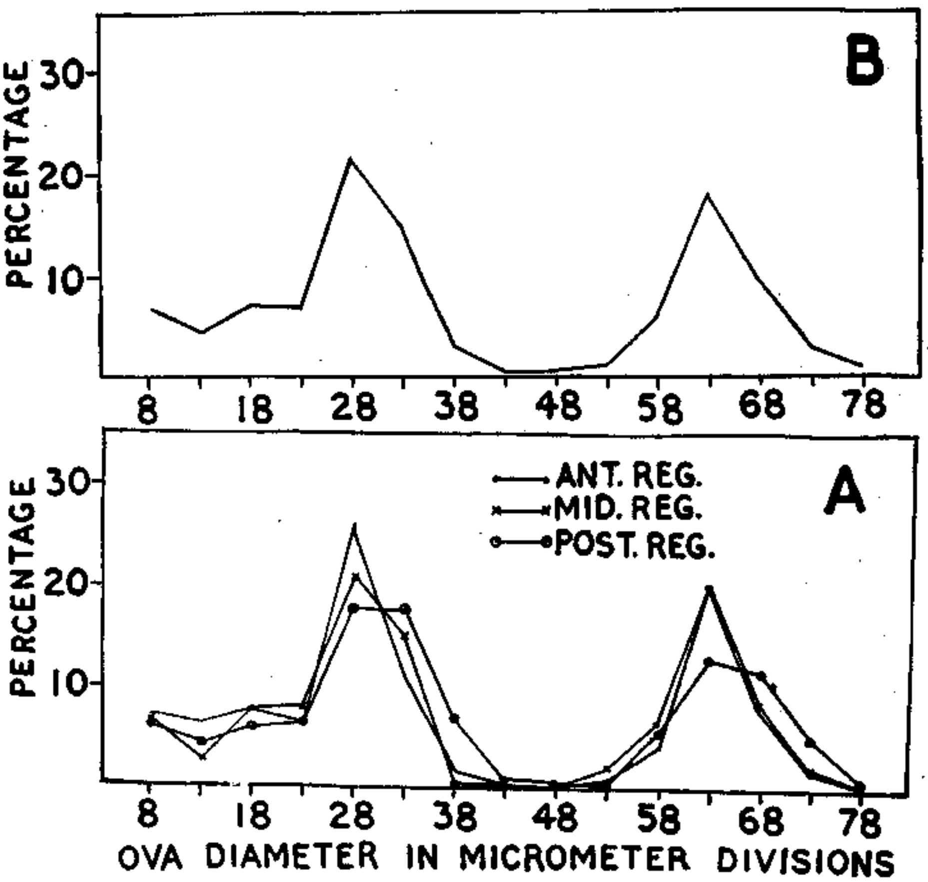

Fig. 38. A Ova diameter frequency polygons of the anterior, middle and posterior regions of a mature ovary of *E. muticus*. B Combined ova diameter frequency polygon of the above.

presence of the second mode in the ova diameter frequency curve of a mature ovary of *E. muticus* which has nearly undergone half the maturation indicates that individuals of this species may spawn more than once in a season. Since the time required for the second group of ova (maturing) to transform into the mature group will be about half the time taken by immature group to reach maturity, it is evident that the ova represented by an intermediate group will be shed soon after the mature group is spawned. The maturing group and the mature group are distinctly separated from each other which tends to show that spawning at a time may be of short duration. Whether spawning is short or prolonged, which is difficult to conclude from the available data, it may at least be said that this species spawns more than once in a year.

A comparison of the spawning habits of the four species of ribbon-fishes from Indian waters appears interesting in view of the fact that they show similarity in several other respects. From the account given above, one species, *T. lepturus* appears to spawn once a year and for a short duration. The other three species *E. intermedius, E. muticus* and *L. savala* seem to spawn more than once in a year based on a study of the ova diameter measurements. Three groups of ova, the immature (not represented in the curves) maturing and mature are apparent in the ovaries. In an advanced stage of development of the ovary, the maturing and mature stocks of ova are sharply differentiated indicating that spawning at a time in all the three species is of short duration. The presence of a second batch of eggs (maturing group) in the ovaries of the three species suggests that individual fish spawns more than once. However, in the absence of regular data on the occurrence of mature individuals over a single continuous period, it has not been possible to draw any positive conclusions on the periodicity of spawning in *L. savala* and *E. muticus*.

4. Relation between the Size of the Gonads and the Size of the Fish

If the size of the gonads shows a constant relation with the size of the fish, it may be useful as an index of maturity of the species. It was generally observed that the size of the gonad increased with the length of the fish in both males and females of *E. intermedius*. In order to find the relation between the size of the gonads and the length of the fish, a total of 287 fish (204 females ranging in size between 14.3-49.4 cm. S.L. and 83 males between 14.5-40.5 cm. S.L. collected from Panaikulam (Palk Bay) were examined. As pointed out earlier, the gonads in the partially spent and spent fish are much shrunken, and distorted in appearance showing discrepancies in the usual relation with the length of the fish. Hence they were excluded from this study.

The standard length of the fish and the length of the gonad were noted for each specimen along with the stage of maturity. All specimens where the tip of the tail was suspected to be broken have not been included. Males and females were treated separately. Standard length was plotted against the length of the ovaries in a scatter diagram (Fig. 39A). Similarly, the standard length was plotted against the length of testes separately. (Fig. 39B). While a curvilinear relationship was indicated in case of the ovary, the relationship of the testis with the length of the fish is not clear, since males above 40 cm. were not available. However, it appears that it may also be of the same type as for the ovaries.

When the length of the ovary was plotted against the square of the length of fish (Fig. 40) it still showed the curvilinear relationship. To test further, the relation between the length of fish and length of the ovary, the observed values of the latter were plotted against the cube of the length of fish (Fig. 41) which was found to be linear. Therefore, the linear equation was fitted to the data by the method of least squares and the estimates of 'A' and 'B' were obtained using the formula $Y = A + BX$, where 'A' and 'B' are two constants and Y represents the length of the ovary and X the cube of length of fish in thousands. The equation was found to be $Y = 1.6 + 0.0507 X$. The significance of the relationship between the length of the ovary and the cube of length of fish was tested by analysis of variance (Table XLIII).

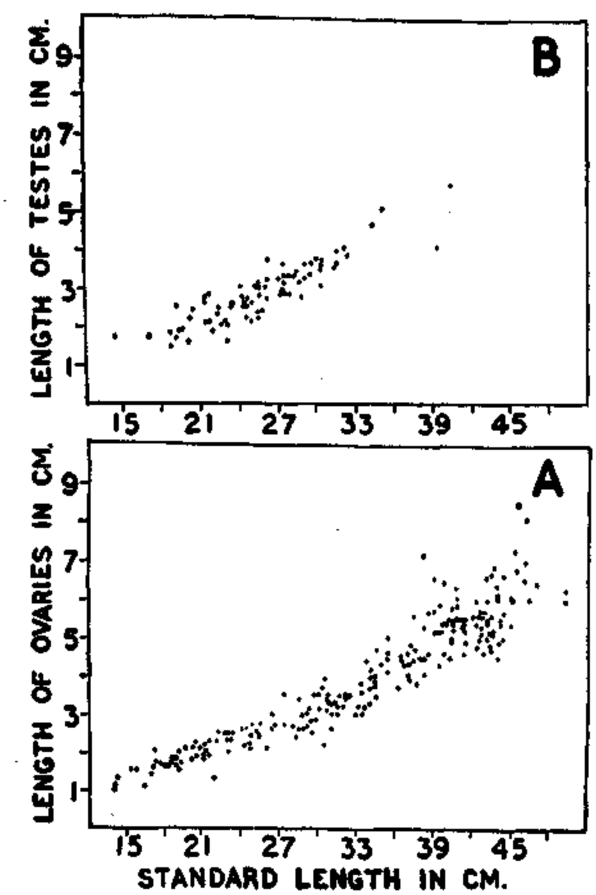

Fig. 39. Relation between (A) length of fish and length of ovaries and (B) length of fish and length of testes in *E. intermedius*.

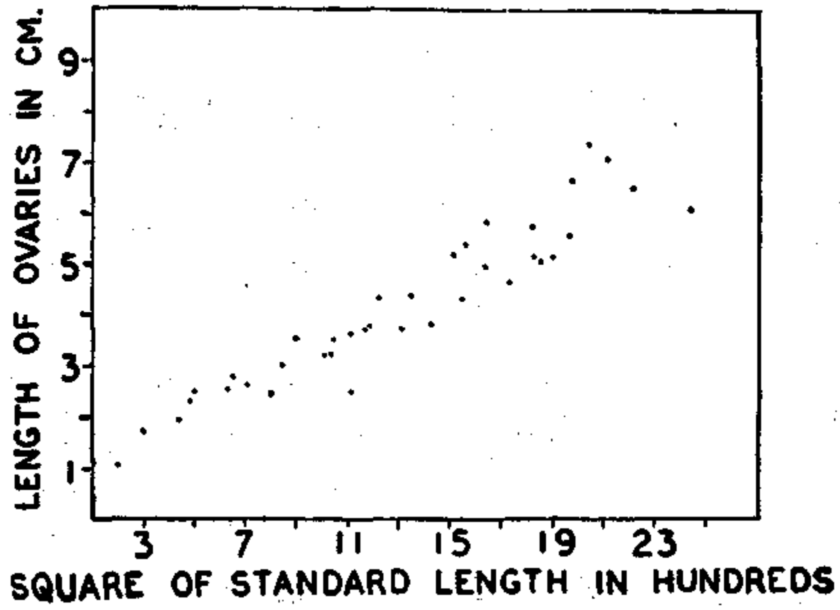

Fig. 40. Relation between square of length of fish and length of ovaries in *E. intermedius*

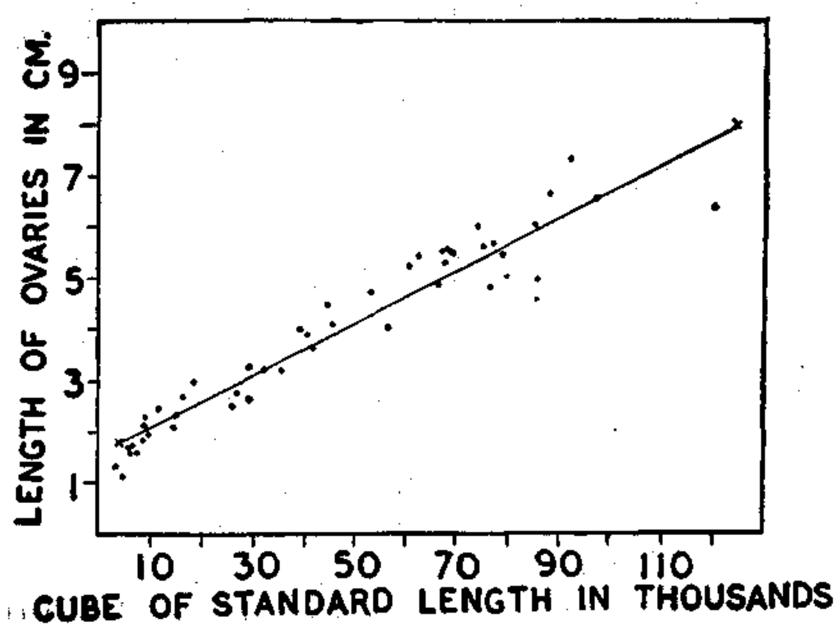

Fig. 41. Relation between cube of length of fish and length of ovaries in *E. intermedius*.

TABLE XLIII

Analysis of variance

Source of variation	Degrees of freedom	Sum of squares	Mean square	Observed F.	5% F.
Deviation due to regression	1	125.05	125.05	378.93	7.31-7.08
Deviation from regression	47	15.55	0.33		
Total	48	140.60			

From Table XLIII it may be seen that the linear relation between the length of the ovary and cube of length of fish explains about 90% of the variation in the length of the ovary, which bears a highly significant relation with the cube of length than mere length or the square of length of fish. However, the growth rate of ovary appears gradual up to about 30 cm. S.L. and thereafter increase in size of fish is accompanied by a rapid increase in size of ovary.

Comparison with other species : During the course of this investigation, 65 females ranging in size between 21.0-56.4 cm. S.L. (5.6-19.7 cm. snout-vent length) and 33 males ranging in size between 37.1-46.6 cm. S.L. (8.0-17.8 cm. snout-vent length) of *L. savala* collected from Panaikulam (Palk Bay) were also examined. In order to compare the rate of growth of gonads in this species with that in *E. intermedius*, the length of ovaries and testes were plotted against snout-vent length since the tip of tail was suspected to be broken in many of the specimens, in the form of a scatter diagram (Fig. 42). It may be seen that the length of the gonad and the snout-vent length of the fish show a curvilinear relationship as in the case of *E. intermedius* indicating that the increase in size of the gonad in both males and females, at least after about 15 cm. snout-vent length.

Prabhu (1955) made some observations on the growth rate of gonads in *T. haumela* (= *T. lepturus*) and found that the relation between size of gonad and size of fish in males and females of this species is simple and direct. He noticed that the testis increases in size at a slightly higher rate than the ovary. Therefore, the above observations show that the growth rate of gonads in *E. intermedius* and *L. savala* appears to be different from the growth rate of gonads in *T. haumela*.

5. Gonado-somatic Index

The state of maturity of a fish may be determined from the largest common egg diameter of the ovary as well as the size of the ovaries. But in the case of *E. intermedius* the weights of ovaries belonging to the various stages of maturity have been found to overlap. Recently June (1953) and Yuen (1955) have found that the relative ovary weight (ovary weight x 10^3/ fish weight) is more suitable to explain the state of maturity of the Hawaiian yellowfin and

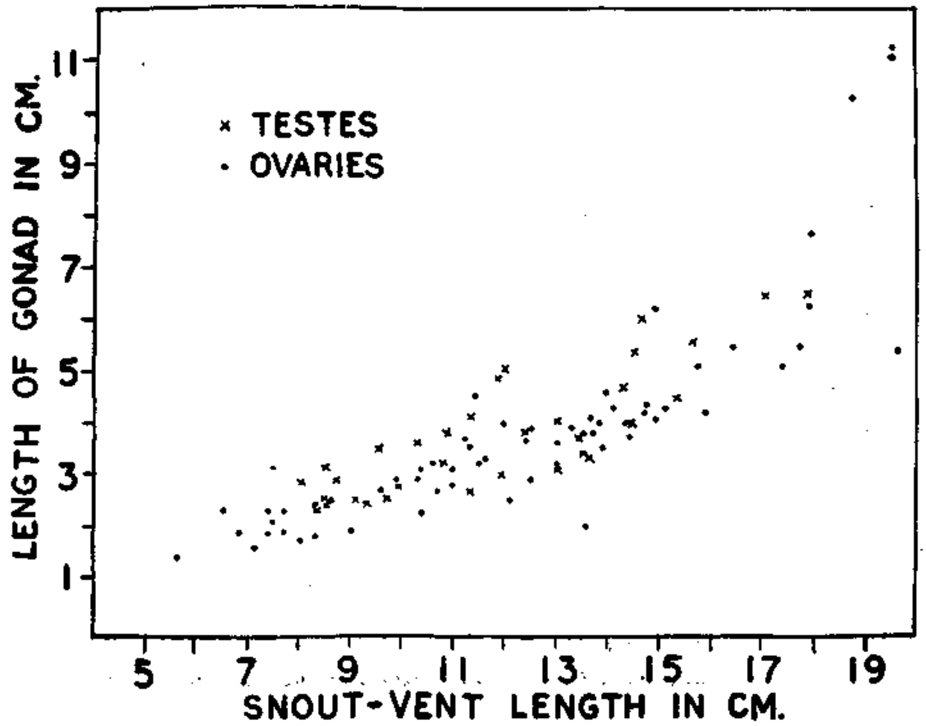

Fig. 42. Relation between the snout-vent length of fish and length of gonads in *L. savala.*

Central Pacific big-eye tuna respectively. Since this ratio may be useful to indicate the maturity and intensity of spawning in *E. intermedius,* fish collected from Panaikulam (Palk Bay) during March 1959 to February 1960 were examined. This study is confined only to females as mature males were not available. The weights of individual fish were first noted. The ovaries were then carefully removed from each of these fish and they were weighed to the nearest milligram.

The relative ovary weight which may also be termed the gonado-somatic index was calculated for individual fish in different months using the formula given above. The relative ovary weight of each individual fish is plotted against the largest common egg diameter (Fig. 43). The immature ovaries have relative ovary weight up to 2.5, and the maturing ovaries show a relative ovary weight between 2.5 and 12.5. The mature ovaries have shown a relative ovary weight above 12.5 and it progressively increased with maturity. The data, therefore, suggest that the increase in ovary weight is associated with progress of maturity in this species.

The variation in relative ovary weights of mature fish above 35 cm. were further analysed to find its relation to spawning. Data for mature fish were available only for a few months and hence only variations between these months were tested. (Tables XLIV and XLV).

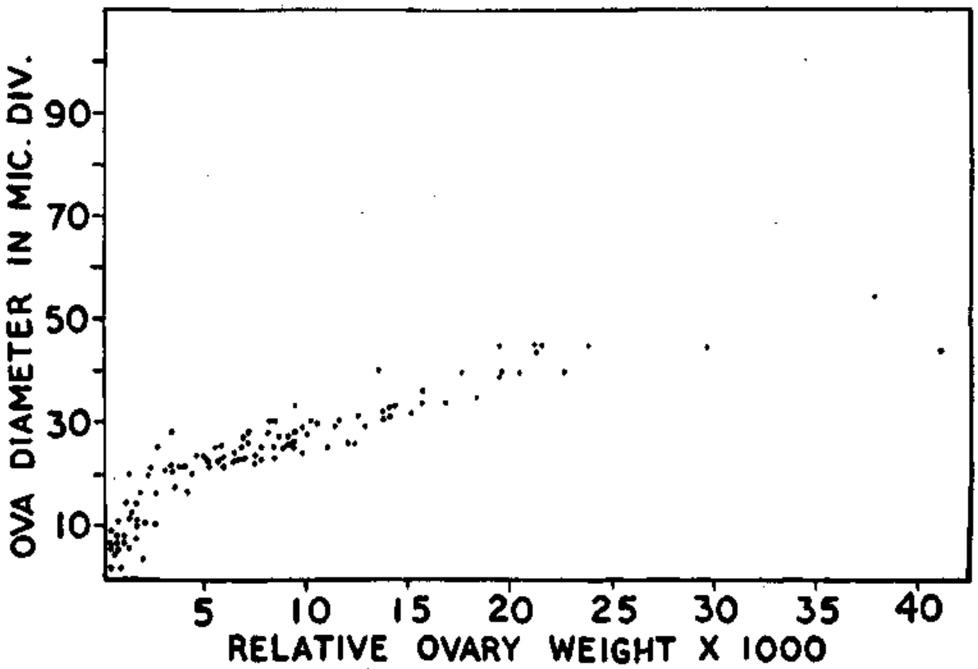

Fig. 43. Relation between the relative ovary weight and the ova diameter in *E. intermedius*.

TABLE XLIV

Relative ovary weights of mature fish

(Above 35 cm. S.L.)

Month	No. of fish	r	r^2	$\bar{r}$
1959				
Mar.	18	257.04	4943.8704	14.28
Apr.	5	60.25	829.7101	12.05
Jul.	30	259.09	2924.5165	8.63
Aug.	13	163.79	3098.9453	12.59
Sept.	4	36.18	537.3188	9.04
Nov.	12	305.07	22495.2313	25.42
1960				
Feb.	2	19.38	191.7122	9.69

r = Relative ovary weight; r^2 = Square of relative ovary weight; $\bar{r}$ = Mean of relative ovary weight.

TABLE XLV

Analysis of Covariance

Variation	Degrees of freedom	Sum of squares	Mean square	Observed F.	5% F.
Between months	6	2542.69	423.78	1.80	2.25 to 2.18
Within months	77	18052.89	234.45		

From the Table XLIV and XLV it may be seen that although there was some variation in the relative ovary weights between months, they do not seem to differ significantly from one another. This may be due to spawning period spread over a number of months which may not substantially change the gonado-somatic index but otherwise expected to vary significantly in case of fish with a short spawning period.

6. Size at First Maturity

To determine the minimum size of *E. intermedius*, 1495 females and 622 males during the period March 1959 to February 1960 and 1562 females and 707 males during the period March 1960 to February 1961 were examined. Males of advanced stages of maturity were generally rare although a few spent individuals were recorded occasionally. Females of all stages of maturity were available except those in the spawning condition.

i. *Relation between size of fish and maturity*: Fish were grouped sex-wise into two centimeter size groups and the percentage occurrence of fish of various maturity stages in the size groups was calculated. Care was taken to exclude fish where the tail was suspected to be broken. For the purpose of calculating the size at first maturity, fish belonging to stages III, IV and VIA have been grouped under mature fish. The details are presented in Table XLVI and XLVII.

TABLE XLVI

Percentage occurrence of females of E. intermedius in different stages of maturity in various size groups (March 1959 to February 1960)

Size group (S. L. cm.)	No. of fish	Stages of maturity					
		I	II	III	IV	VIA	VIB
8—10	1	100.00	—	—	—	—	—
10—12	13	100.00	—	—	—	—	—
12—14	67	100.00	—	—	—	—	—
14—16	124	100.00	—	—	—	—	—
16—18	149	100.00	—	—	—	—	—
18—20	204	100.00	—	—	—	—	—
20—22	232	25.86	74.13	—	—	—	—
22—24	164	—	100.00	—	—	—	—
24—26	119	—	100.00	—	—	—	—

TABLE XLVI (Contd.)

26—28	71	—	100.00	—	—	—	—
28—30	87	—	100.00	—	—	—	—
30—32	56	—	100.00	—	—	—	—
32—34	45	—	77.72	8.88	—	—	13.30
34—36	29	—	65.51	24.13	—	—	10.34
36—38	28	—	42.85	42.85	—	3.57	10.71
38—40	29	—	10.34	58.62	6.89	20.68	3.44
40—42	26	—	—	61.53	3.84	19.23	15.38
42—44	30	—	—	59.99	9.99	19.99	9.99
44—46	16	—	—	62.50	37.50	—	—
46—48	3	—	—	66.66	33.33	—	—
48—50	2	—	—	50.00	50.00	—	—

TABLE XLVII

Percentage occurrence of females of E. intermedius in different stages of maturity in various size groups (March 1960 to February 1961)

Size group (S. L. cm.)	No. of fish	Stages of maturity I	II	III	IV	VIA	VIB
8—10	—	—	—	—	—	—	—
10—12	6	100.00	—	—	—	—	—
12—14	28	100.00	—	—	—	—	—
14—16	82	100.00	—	—	—	—	—
16-18	154	100.00	—	—	—	—	—
18—20	204	100.00	—	—	—	—	—
20—22	235	43.40	56.59	—	—	—	—
22—24	171	—	100.00	—	—	—	—
24—26	139	—	100.00	—	—	—	—
26—28	99	—	100.00	—	—	—	—
28—30	94	—	100.00	—	—	—	—
30—32	88	—	82.94	1.13	—	—	15.91
32—34	84	—	59.52	2.38	—	4.76	33.33
34—36	62	—	40.32	17.74	—	8.06	33.87
36—38	37	—	21.62	10.81	—	29.73	37.84
38—40	29	—	—	31.03	6.89	44.83	17.24
40—42	21	—	—	42.86	—	52.38	4.76
42—44	20	—	—	65.00	10.00	25.00	—
44—46	6	—	—	49.99	—	49.99	—
46—48	3	—	—	33.33	33.33	33.33	—
48—50	—	—	—	—	—	—	—

TABLE XLVIII

Percentage occurrence of males of E. intermedius in different stages of maturity in various size groups (March 1959 to February 1961)

Size group (S. L. cm.)	1959—1960							1960—1961						
	No. of fish	Stages of maturity						No. of fish	Stages of maturity					
		I	II	III	IV	VIA	VIB		I	II	III	IV	VIA	VIB
8-10	1	100.00	—	—	—	—	—	1	100.00	—	—	—	—	—
10-12	13	100.00	—	—	—	—	—	1	100.00	—	—	—	—	—
12-14	97	100.00	—	—	—	—	—	17	100.00	—	—	—	—	—
14-16	83	100.00	—	—	—	—	—	81	100.00	—	—	—	—	—
16-18	113	100.00	—	—	—	—	—	119	100.00	—	—	—	—	—
18-20	57	100.00	—	—	—	—	—	141	100.00	—	—	—	—	—
20-22	68	41.18	58.82	—	—	—	—	120	45.85	54.16	—	—	—	—
22-24	73	—	100.00	—	—	—	—	81	—	100.00	—	—	—	—
24-26	46	—	100.00	—	—	—	—	37	—	100.00	—	—	—	—
26-28	24	—	100.00	—	—	—	—	32	—	100.00	—	—	—	—
28-30	19	—	94.74	—	—	—	5.26	30	—	96.66	—	—	—	3.33
30-32	10	—	60.00	—	—	—	40.00	23	—	78.26	—	—	—	21.74
32-34	8	—	75.00	—	—	—	25.00	15	—	86.66	—	—	6.66	6.66
34-36	6	—	83.30	16.70	—	—	—	8	—	87.50	—	—	12.50	—
36-38	2	—	50.00	—	—	—	50.00	—	—	—	—	—	—	—
38-40	1	—	—	—	—	—	100.00	1	—	—	—	—	—	100.00
40-42	1	—	100.00	—	—	—	—	—	—	—	—	—	—	—

From Table XLVI it could be seen during March 1959 to February 1960 up to 20 cm., all the female fish were in the immature stage. From 21 cm. onwards they pass into the maturing stage and a few of them (8.88%) were found to be mature in the 32-34 cm. size group. Spent fish were recorded for the first time in this group. In the 34-36 cm. size group, while a greater percentage of the fish (65.51%) are still in the maturing stage, 24.13% have attained maturity and in the next size group 36-38 cm. as many as 46.42% of the fish were found mature. In the 38-40 cm. size group only a few fish (10.34%) were found to be in the maturing stage whereas 86.19% of them were mature at this size. From this size onwards, the percentage of mature fish gradually increased and all of them were practically mature at 45 cm. (Fig. 44,A). Spent individuals were first noticed in the 32,34 cm. size group and in all the size groups above it.

Since the mature and ripe males were scarce, the data available on the percentage occurrence of spent individuals was considered to indicate the size at first maturity. As may be seen from Table XLVIII all the males were immature up to 20 cm. In the 20-22 cm. size group, more than 50% of them were in the maturing stage and in 22-24 cm. size group all the males were in the maturing stage. Spent individuals were recorded for the first time in the 28-30 cm. size group.

Data collected on the condition of gonads of both sexes during the period March 1960 to February 1961 gave similar results as above. Females (Table XLVII) were found to be in the immature stage up to 20 cm. and maturing stage up to 30 cm. S.L. Only 1.13% of them were mature in the 30-32 cm. size group when spent individuals were recorded for the first time. The percentage of mature individuals gradually increased thereafter and at 38 cm. more than 50% of the females were found to be mature and practically all of them at 45 cm. (Fig. 44,B).

Males measuring up to 20 cm. were immature. In the size group 20-22 cm. more than 50% were in the maturing stage and the percentage of these increased in the following size groups. Spent individuals were first recorded in the size group 28-30 cm. (Table XLVIII).

Pooled data for the percentage occurrence of stages III, IV and VI A for each year and the average for two years have been calculated (Table XLIX). It may be seen from the table that in the 30-32 cm. size group 0.55% and in the 32-34 cm. size group 8.01% of the fish were mature. In the following size group 34-36 cm., 20.93% were mature and in the next size group, 36-38 cm. as many as 43.48% of the females were mature. In the 38-40 cm. size group there was a sudden rise of mature individuals to 84.47%. The percentage of mature fish increased steadily in the higher size groups and practically all fish were mature at 45 cm. The results of the study show a great similarity in the maturity of both males and females in two successive years of study and hence the average results may be indicative of the general trend (Fig. 44,C). In the first year, the spent individuals (females) were first recorded in the 32-34 cm. size group and in the following year they were noticed in 30-32 cm. size group. In both the years over 40% of the females were found mature in the 36-38 cm.

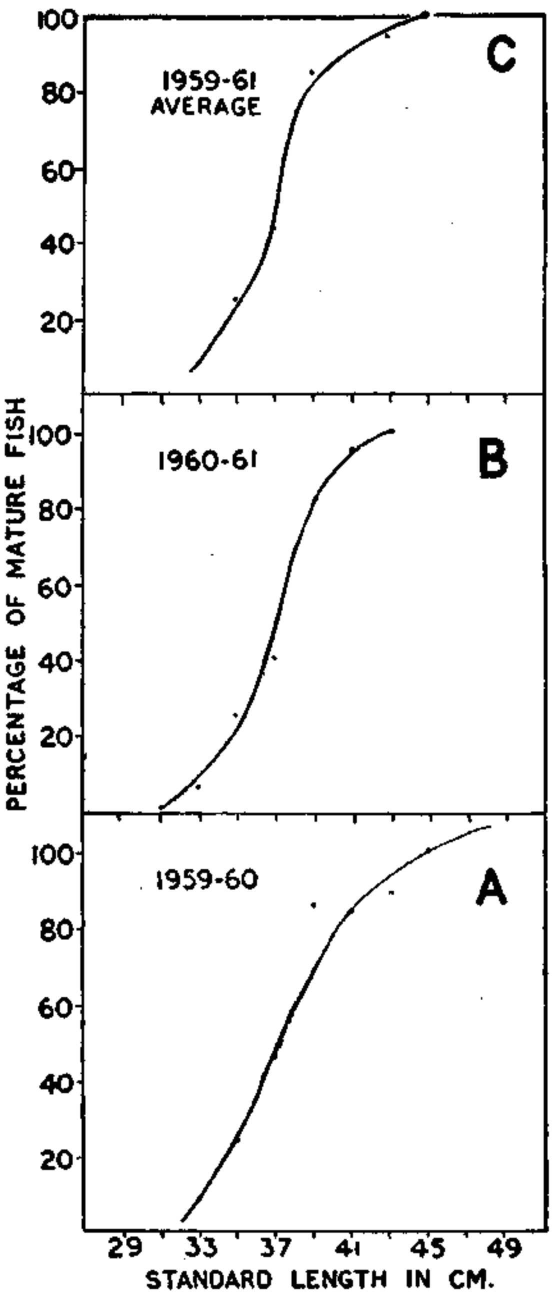

Fig. 44. Size at first maturity in females of *E. intermedius* based on data for the period (A) 1959-'60. (B) 1960-'61 and (C) pooled data for the period 1959-'61 (only midpoints of 2 cm. size groups indicated along X-axis).

size group and in the following size group, the percentage was found to increase very rapidly up to 86% which indicates that over 50% of the females are mature at about 38 cm. S.L. Although from the above data it is clear that a few fish were found to be mature at 30-32 cm., majority of the fish attain maturity at about 38 cm.

TABLE XLIX

Percentage occurrence of mature females of E. intermedius in various size groups

Size group (S. L. cm.)	1959-60	1960-61	Average
30–32	—	1.13	0.55
32–34	8.88	7.14	18.01
34–36	24.13	17.74	20.93
36–38	46.42	40.54	43.48
38–40	86.19	82.75	84.47
40–42	84.60	95.24	89.92
42–44	89.97	100.00	94.98
44–46	100.00	100.00	100.00

As regards the males, during the first year, spent specimens of the smallest size were first recorded in the 28-30 cm. and a similar observation was made in the following year. This indicates that the minimum size at maturity for males may be about 28-30 cm. but the data available do not permit an inference as to the size at which majority of the individuals may be mature. A comparison of the minimum size of maturity of males and females reveals that both the sexes reach maturity almost about the same size, males probably slightly earlier than females.

Since some fish were found to mature at 30-32 cm. size, while the majority mature about 38 cm. it will be of interest to compare the percentage occurrence of mature fish (Stages III and IV) above 38 cm. (Tables XXXIX and XLI) and below this size (Table L) in order to ascertain the nature of spawning in these two groups.

TABLE L

*Percentage occurrence of mature fish**

(Below 38 cm. S. L.)

Month	1959-60		1960-61	
	Total No. of fish‡	Percentage*	Total No. of fish‡	Percentage†
March	94	8.50	162	6.79
April	58	8.60	72	4.17
May	57	—	58	5.17
June	182	—	225	—
July	207	0.48	46	—
August	162	—	150	—
September	63	1.07	132	—
October	123	—	129	—
November	167	1.20	183	—
December	88	—	80	—
January	288	—	241	—
February	89	1.12	131	—

* Includes Stages III and IV
‡ of all stages
† of mature fish

It may be seen from these tables, although the representation of mature fish in various months was scanty, the maximum percentage of mature fish below 38 cm. was generally low when compared to fish above 38 cm. indicating that great majority of the fish reach sexual maturity at about 38 cm.

Incidentally it may be mentioned here that the minimum size at maturity for *T. haumela* (= *T. lepturus*) has been determined to be 47-48 cm. (Prabhu, 1955).

ii. *Size at first maturity as determined from ova diameter studies* : The size at first maturity and intensity of spawning in *E. intermedius* was also determined from data collected on the largest common egg diameter during spawning times. Since fish of advanced stages of maturity were found to be prevalent in the months of March, April, August, September, November and December, only data pertaining to these months were used. Fish above 29 cm. were examined for this purpose (as some fish were found to be mature at about 30 cm. from other evidence). The common egg diameter was plotted against the size of the fish during these months in the form of scatter diagrams (Fig. 45, A,B).

Three different groups of ova could be noticed in both the sets of data presented, although a great overlap may be seen in their size range in all the months. The first group, the immature, range in size up to 0.28 mm. The second group, maturing, range in size between 0.28 to 0.57 mm. The third group, mature, are above 0.57 mm. A few fish from about 30 cm. were found to contain the second group of ova but the mature ova were found only in fish above 38 cm. This may indicate that some fish may be found mature from 30 cm. onwards but majority of them mature at about 38 cm. A similar result was obtained in the second year of observation also. Some fish were found to contain mature eggs from about 31 cm. while a majority of them contained these eggs from about 38 cm. Therefore, basing on these observations also, it may be said that in this species, a small percentage of fish may be found mature at 30 cm. but majority of them attain maturity at about 38 cm.

The above observations also help to find the intensity of spawning in different months. It is clear that spawning may be occurring in all the months mentioned above but the intensity appears greater in March and April of both the years when compared to other months.

VII. Fecundity

Fecundity of fishes is usually determined from the number of ova of the mature group in the ovary, a demarkation of which varies in different species depending on the spawning habits. Hickling and Rutenberg (1936) stated that in the herring a clear separation of the ripe eggs that will be spawned and the yolkless eggs may be noticed. Farran (1938) pointed out that in the herring the ripe eggs that will be spawned are approximately of the same size and that this batch may be fixed up with the commencement of yolk deposition. Therefore, a count of these eggs gives the fecundity of the fish.

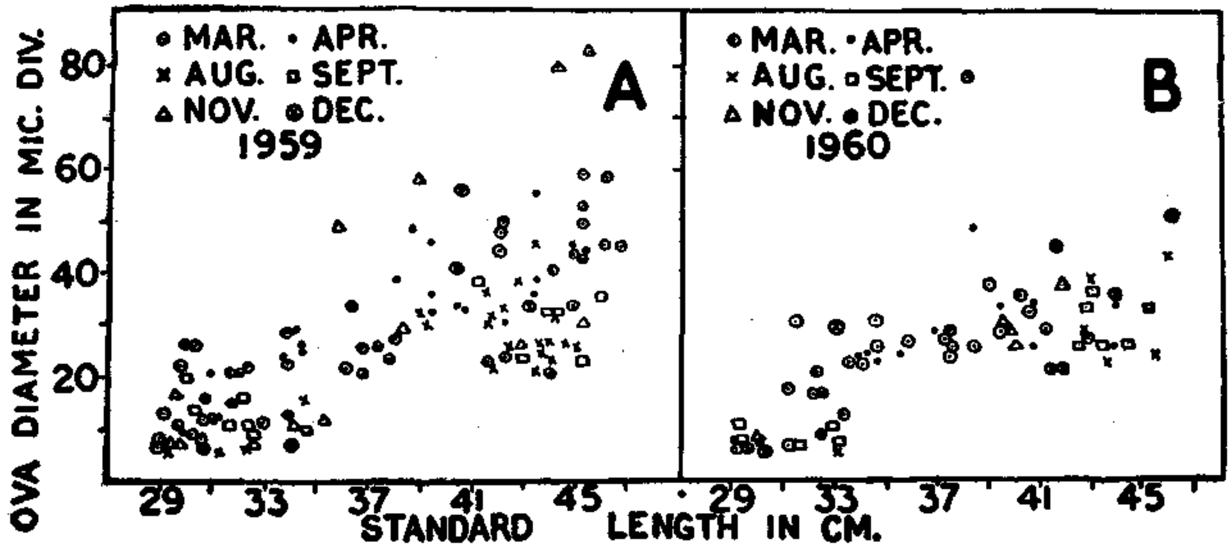

Fig. 45. Size at first maturity in females of *E. intermedius* as determined by the ova diameter studies during (A) 1959-'60 and (B) 1960-'61.

An examination of the mature ovaries of *E. intermedius* has shown that there are usually three groups of ova in such ovaries and the number of mature intraovarian eggs was taken to be the fecundity of each individual. A total of 20 mature individuals were examined. The standard length and weight of fish were noted. The ovaries were taken out and excess moisture removed with the help of filter papers and were weighed to the nearest milligram. From the central portion of the ovaries, a piece was cut out and its weight was determined separately. The ova in each of such pieces were teased out by two needles into a watch-glass. By this method it was possible to dislodge almost all the ova except the very minute ones some of which remained in groups and others attached to bigger ova. Since the aim was to count only the mature group of ova, this method was found simple and easy to apply for this species. All the mature ova in each of the sample pieces were counted. From the number of ova contained in each bit of the ovary, its weight and the total weight of the ovaries, the total number of mature ova for each individual female fish was estimated. (Table LI).

TABLE LI

Number of mature ova in individuals of E. intermedius

S. No.	Length of fish (S. L. cm.)	Weight of fish (gm.)	Length of ovaries (gm.)	Weight of ovaries (gm.)	Total number of mature ova	Stage of maturity
1.	42.0	65.0	5.3	0.87	8707	IV A
2.	41.8	55.0	6.3	1.32	3960	IV A
3.	46.1	59.0	7.0	1.40	5304	IV A
4.	46.8	66.0	6.0	1.40	4324	IV A
5.	45.2	54.0	6.0	1.50	6352	III B
6.	45.2	57.0	7.3	2.16	4226	IV A
7.	37.4	32.0	4.8	0.30	3982	III B
8.	49.4	69.0	6.3	0.83	6166	IV A
9.	45.0	62.0	6.1	1.95	9950	IV A
10.	42.1	51.0	6.0	1.85	5905	IV A
11.	49.4	75.0	6.0	1.46	7264	III B
12.	39.6	40.0	6.5	1.20	2268	III B
13.	44 2	58.0	8.6	5.75	3963	IV A
14.	45.3	72.0	8.5	7.59	4429	IV B
15.	38.9	39.0	6.6	1.87	2880	IV A
16.	39 3	45.0	5.9	1.00	2402	III B
17.	40.9	41.0	5.9	0.95	2249	III B
18.	43.4	58.0	7.0	2.37	6469	IV A
19.	38.2	36.3	7.2	2.72	2236	IV B
20.	46.0	60.7	6.7	1.65	3122	III B

Since the number of batches spawned by an individual and the interval of time between successive spawnings is not known, the actual number of eggs produced by an individual cannot be estimated correctly. Instead, the above table indicates the potential stock of eggs present in various individuals irrespective of the number of batches each of them would have already spawned.

i. *Relation between fecundity and length of fish* : The relation between fecundity and length of fish was found to vary in different fishes. Clark (1934) using the method of least squares found that in the California sardine, *Sardina caerulea* the number of ova produced by individual sardines increased as the square of length. Farran (1938) found that it increased at a rate higher than the fourth power of its length and Hickling (1940) found that the fecundity of the herring increased at a rate greater than the third power of its length. Simpson (1951) in a study of the fecundity of plaice, *Pleuronectes platessa* found that fecundity is related to the cube of length using the formula $F = KL$ where $F =$ number of ova, $K =$ a constant and $L^3 =$ the cube of length of fish. Lehman (1953) found a correlation between length of fish and fecundity in the shad, *Alosa sapidissima* by the method of least squares. Mac Gregor (1957) discussed the relationship between fecundity and the length of the Pacific sardine, *Sardinops caerulea* using different formulae and concluded that there were no significant differences in the regressions on length, square of length or cube of length.

The fecundity observations on 20 individuals of *E. intermedius* are plotted against the length (Fig. 46, A). As true for many fishes, in a general way, the number of eggs increased with the size of the fish. However, it has also been observed that the fecundity of individual fish of the same length may vary considerably. Therefore, it was not possible to fit any of the relationships discussed above for data on the fecundity of *E. intermedius* as far as the relation with the length of the fish is concerned.

ii. *Relation between fecundity and weight of the ovary* : In order to find whether any relation exists between the weight of the ovary and the number of eggs produced, the observed values were plotted in a scatter diagram (Fig. 46, B). It may be seen that the two sets of data do not show any relationship.

iii. *Relation between fecundity and weight of fish* : The relation between fecundity and weight of fish was tested by plotting the observed values in a scatter diagram (Fig. 46, C). It was found that fecundity of *E. intermedius* is not related to the weight of the fish.

iv. *Comparison of the fecundity of the four species of ribbon-fishes* : The potential stock of eggs in the mature ovaries of a few specimens of the two other species of ribbon-fishes, *L. savala* and *E. muticus* was estimated by the same method as described for *E. intermedius*. It was found, in 6 specimens of *L. savala* ranging in size between 37.0-54.0 cm. S.L. (17.9-19.5 cm. snout-vent length) the fecundity ranged between 9178 to 17347 eggs. In two specimens of *E. muticus* (49.5 and 55.1 cm. S.L.), a total of 1327 and 2087 mature ova were counted. In 18 specimens of *T. haumela* (= *T. lepturus*) ranging in size between 42.0-60.0 cm. Prabhu (1955) found 4000 to 16000 ova. He has shown that fecundity was closely related to the mean weight of the ovary and increased at a rate greater than the fourth power of its length. A comparison of the fecundity of the four species of ribbon-fishes from Indian waters indicates (although great reliance cannot be made on the fewer observations for *L. savala* and *E. muticus*) that fecundity in *T. lepturus* and *L. savala* appears to be higher than in *E. intermedius* and *E. muticus*. Whether it is in any way related to the spawning habits of these species is difficult to judge from the nature of the data at present available.

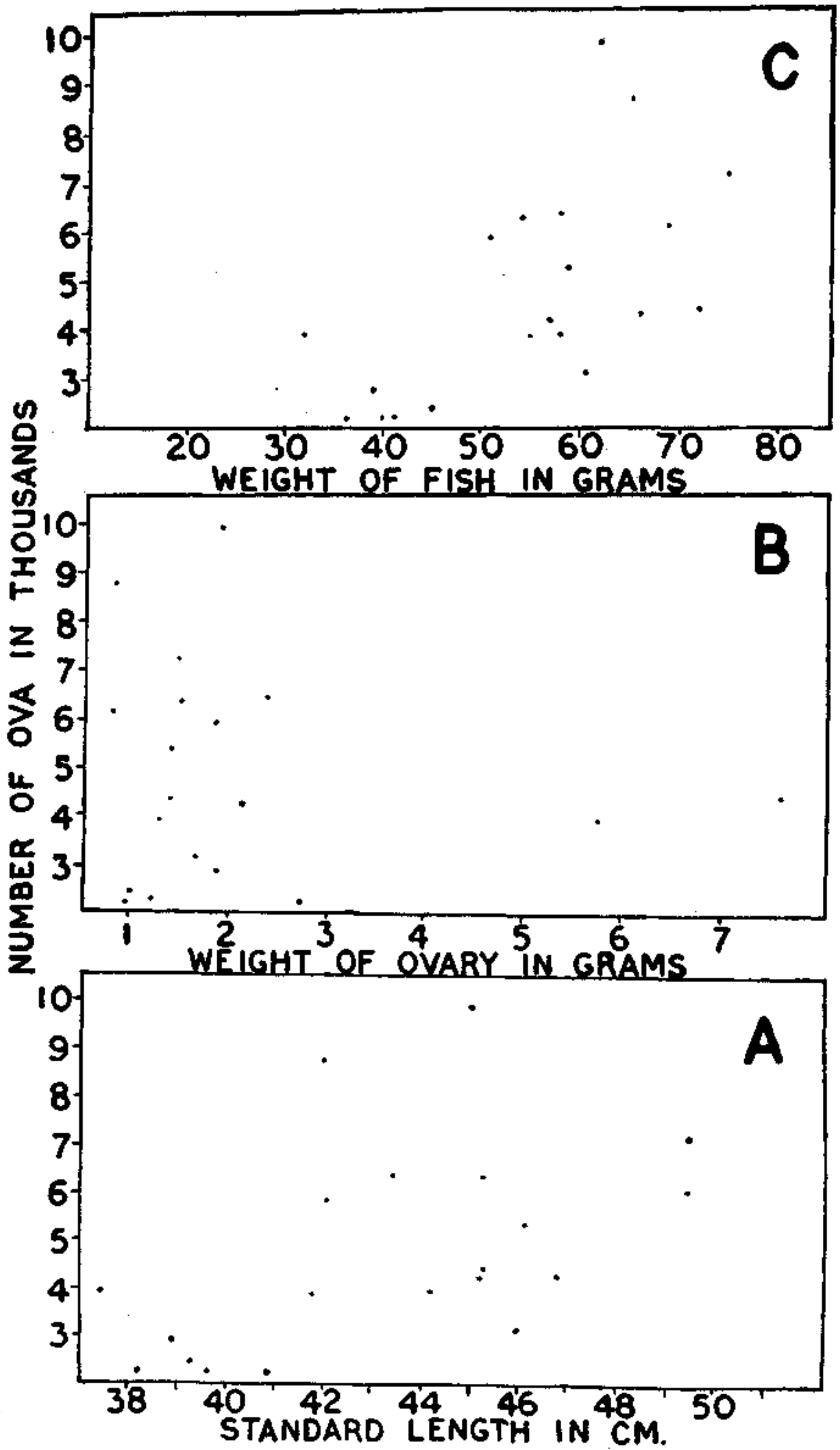

Fig. 46. Relation between fecundity and (A) length of fish, (B) weight of ovary and (C) weight of fish in *E. intermedius*.

7. Sex Ratio

During the course of this study about 5000 specimens of *E. intermedius* were examined in a wide range of size but it was not possible to detect any external characters such as the body proportions, meristic characters or colour which could be useful for sex determination. As fish were brought to the laboratory for study, along with other measurements, their sex was also noted. In fish over 12 cm. S.L. it was easy to determine th esex microscopically. But below this size both for males and females, microscopic examination was necessary.

Sexes were found to be disproportionate in the commercial catches, the females outnumbering the males. Further, males of advanced stages of maturity as well as the spent individuals were seldom noticed in the samples. Females of all stages of maturity and spent individuals were commonly recorded. The percentage occurrence of sexes in different months is given in Table LII.

TABLE LII

Sex ratio of E. intermedius in the commerical catches
(March 1959 to February 1961)

Month	1959–60			1960–61		
	Total No. of fish	Percentage of females	Percentage of males	Total No. of fish	Percentage of females	Percentage of males
March	123	76.42	23.57	223	72.64	27.35
April	67	86.56	13.43	84	85.71	14.28
May	70	81.42	18.57	66	87.88	12.12
June	239	76.15	23.85	403	55.83	44.17
July	282	73.40	26.59	90	51.11	48.89
August	202	80.19	19.80	204	73.53	26.47
September	135	68.88	31.11	182	72.53	27.47
October	179	68.71	31.28	187	68.98	31.01
November	204	81.86	18.14	235	77.87	22.13
December	154	57.14	42.86	109	73.39	26.60
January	467	61.67	38.33	329	73.25	26.75
February	116	76.72	23.27	174	75.29	24.71

It may be seen from the above table, the percentage of males was low throughout the year as well as in two successive years. The percentage of males during April, May, August and November 1959 was considerably low when compared to other months during the year. Similarly, a very low percentage occurrence of males was recorded in April, May, August and November 1960. The higher percentage occurrence of males during the two years, however, did not show any regular pattern. The absence of males of advanced stages of maturity may be due to a differential behaviour of the sexes (at least mature fish), the males probably moving in separate shoals from females. Generally, mature males do not seem to remain in the inshore waters. The sex ratio figures also show that the segregation of sexes could result in differential fishing, the females being fished more than the males throughout the year. Since mature males were not observed it is difficult to conclude how far the variations in the sex ratio are associated with spawning.

In case of the second common species from this area, *L. savala* also it was not possible to differentiate sex based on external characters. In fish measuring above 15 cm. S.L. it was possible to distinguish the sex easily by macroscopic examination of the gonads and below this size it was found necessary to examine the gonads microscopically. The number of fish available for examination each month was too small and hence the data was pooled for each year separately and the sex ratio calculated. The ratio of males to females was found to be 1 : 1.7 in the first year and 1 : 1.2 in the second year of observation. From the above data it appears that in this species also, females outnumber the males in the commercial catches. While males of advanced stages of maturity were rare, some females in advanced stages of maturity were collected during the course of this study. It may possibly indicate that as in *E. intermedius*, in this species also, there may be a differential behaviour of sexes which results in differential fishing, the females being fished more than the males. However, the sex ratio of this species in the commercial catches does not appear to be as disproportionate as in *E. intermedius*.

XIII

LIFE-HISTORY

Along the Indian coast ribbon-fishes are commonly caught in the inshore waters between July to March with peak occurrences in different months at different places. One or more species may be caught at any particular place. In spite of the older age-groups occurring regularly in the fishery whereby the species may be expected to breed in the Indian coastal waters, it is significant to remark that the planktonic eggs, larvae and young stages are extremely rare. While the sampling may not be adequate, from the available data it appears that these fishes do not seem to breed in the inshore areas.

1. Eggs and Larvae

The only account of the eggs and early larval stages of trichiurids from Indian waters is that of Chacko (1950) who mentioned the eggs and larvae of *Trichiurus savala* (= *Lepturacanthus savala*) with the spawning season extending from September to October and the diameter of the eggs being 2.15-2.40 mm. According to him, the oil-globule measures 0.7 mm. and yellowish in colour. The larva is characterised by paired black pigment spots near the ear vesicles and 34 preanal and 126 postanal myotomes.

Delsman (1927) described six different kinds of eggs belonging to the genus *Trichiurus* from the Java Sea which he ascribed to at least four different species. He states that the eggs are characterised by their large size and a large oil-globule. According to him, the embryos are transparent with a few black pigment spots only. The newly hatched larvae are easily recognised by the enormous number of myotomes, especially in the tail, the poor pigmentation restricted to a few scattered black pigment cells on the head, on the oil-globule and on the tail. He held the view that though the genus could be easily identified, the determination of the species was difficult. Judging from the number of myotomes in the larvae and vertebrae in the adults, he concluded that the eggs might belong to four species, *Trichiurus haumela* (= *T. lepturus*), *T. savala* (= *L. savala*) *T. glossodon* (*Eupleurogrammus intermedius*) and *T. muticus* (= *E. muticus*).

Tang and Wu (1936) in a preliminary note on the spawning ground of *Trichiurus japonicus* (= *T. lepturus*) referred to its eggs and early stages but no other details are given except a statement that the fry grow to 54-95 mm in about a month.

Okada (1955) described that the pelagic eggs of *T. lepturus* measure 1.35 to 1.80 mm. in diameter, with a light copper-red globule and germinal disc. The post larva, smaller than 10 mm. has a deep body and large head, not showing the ribbon-like form of the adult. A strong spine is present in front of the dorsal fin in the young of 7 to 8 mm., which becomes gradually obscure. The anal fin is also well developed with a strong spine and rays which degenerate at a later stage.

During the course of the present study, attempts made for the collection of eggs, larvae and the young stages were met with partial success only in that the young ones of three of the species have been collected which are described in the following pages. As pointed out earlier, the breeding habits of the four species of ribbon-fishes from Indian waters seem to differ and in the case of the species without any periodicity of spawning, the number of eggs released in a batch appears small. It has also been pointed out that fish in the spawning state were not met with, from which it appears that they may not be spawning in inshore waters. In the absence of data on the eggs and early developmental stages of these fishes from Indian waters, the observations of Delsman (1927) on this subject are summarised in Table LIII before a detailed description of the young stages collected by the present author is given which may help to connect the stages as far as known.

Further development of the larvae into adult fish has not been described by Delsman, but he indicated that the transformation may be quite gradual and resembles that described for *Lepidopus* by Strubberg (1918).

TABLE LIII

Particulars of the eggs and larvae of ribbon-fishes described by Delsman from the Java Sea

	Particulars	*T. haumela*	*T. savala*	*T. glossodon*	*T. muticus*
1.	Date of collection of eggs	November 10, 15, 1923	November 13, 1923	November 13, 1923	June 21, 1923
2.	Diameter of eggs	2.40–2.45 mm.	1.96–2.04 mm.	1.75–1.88 mm.	1.70–1.81 mm.
3.	Diameter of oil-globule	0.65 mm	0.40–0.45 mm.	0.40 mm.	0.42 mm.
4.	Colour of oil-globule	Slightly yellowish	Yellowish	Colourless	Yellowish
5.	Hatching period	2 x 24 hours	2 x 24 hours or slightly less	2 x 24 hours or slightly less	2 x 24 hours or more
6.	Spawning time	Night, not limited to one definite time	Night	Night	11 A. M.
7.	Colour of embryo	Paired pigment spots near olfactory organ, eye and ear visicle and behind the latter. A pair on the tail, branched spots on oil-globule.	Colourless. Black spots on head, tail and branched cells on surface of oil globule	As in *T. savala*	Black pigment spot on the tail.
8.	Newly hatched larva	6.6 mm.	5.2 mm.	5.6 mm.	4.4 mm.

2. Description of the Young Stages

Our existing knowledge of the early stages of *Trichiurus* species refers to a 54 mm. stage by Tang and Wu (1936) of *T. japonicus* (= *T. lepturus*) and a 67 mm. specimen of *T. haumela* (= *T. lepturus*) by Nair (1952). The present author was able to collect two small specimens of two species of ribbon-fishes and one small specimen of a third species was made available to him for study (Pl. VI). Since these specimens happen to be the first record of smallest stages known from Indian waters, a detailed description of these three specimens is given below..

i. *Particulars of collection* : A specimen measuring 43.3 mm. S.L. of *T. lepturus* was collected on 28-8-1959 at about 11 A.M. at Idinthakarai (Gulf of Mannar). The specimen was collected from a bag net, locally called 'Madi valai' along with other bigger fishes including *T. lepturus*. The net is usually operated at a distance of 5 to 10 miles from the shore and at a depth of 20 to 30 metres.

An young one of *L. savala* measuring 61.0 mm. S.L. was collected on 3-6-1960 at Thangachimadam (Palk Bay). A few other specimens collected during the month from the same place were in the size range 66-154 mm. S.L.

An young one of *E. intermedius* measuring 59.5 mm. S.L.,* was collected on 7-6-1960 at Thangachimadam (Palk Bay). A few other specimens collected during the month from the same place were in the size range 66-144 mm. S.L.

The specimens of *L. savala* and *E. intermedius* were picked up from bag net catches which included primarily large quantities of *Leiognathus* spp. The young ones of ribbon-fishes were apparently entangled in the mucus of the silver-bellies. Off Thangachimadam, bag nets are operated at a distance of 10 miles from the shore and at depths varying between 16 to 20 metres.

ii. *Pigmentation* : The young one of *E. intermedius* is bright silvery in colour which is easily lost on touch. Fine black-pigment spots are present on the tip of maxilla, mandible and front margin of eye which are similar to those of adult. The lower margin of preorbital in the specimen is grey even at this stage which is characteristic of the adult. As in the adult, the fins are hyaline. However, the black spot at the base of pectoral spine, characteristic of the adult is not noticeable at this stage. In fact it has not been noticed in specimens up to 104 mm. standard length. A few black patches are present on the tip of the tail which are also noticed in the adult.

The colour of the young one of *T. lepturus* is silvery which was partly lost on handling the specimen. Black pigment spots are seen on the tip of the snout and lower jaw in addition to a series of large stellate or irregular

* Another specimen of this species measuring 50 mm, S.L. was collected subsequently by Mr. V. Sriramachandramurty on 26-8-67 from an other trawl net landed at Mandapam (Palk Bay). The specimen is interesting in that it shows a radimentary caudal fin and prominent anal spinules which evidently get reduced with growth

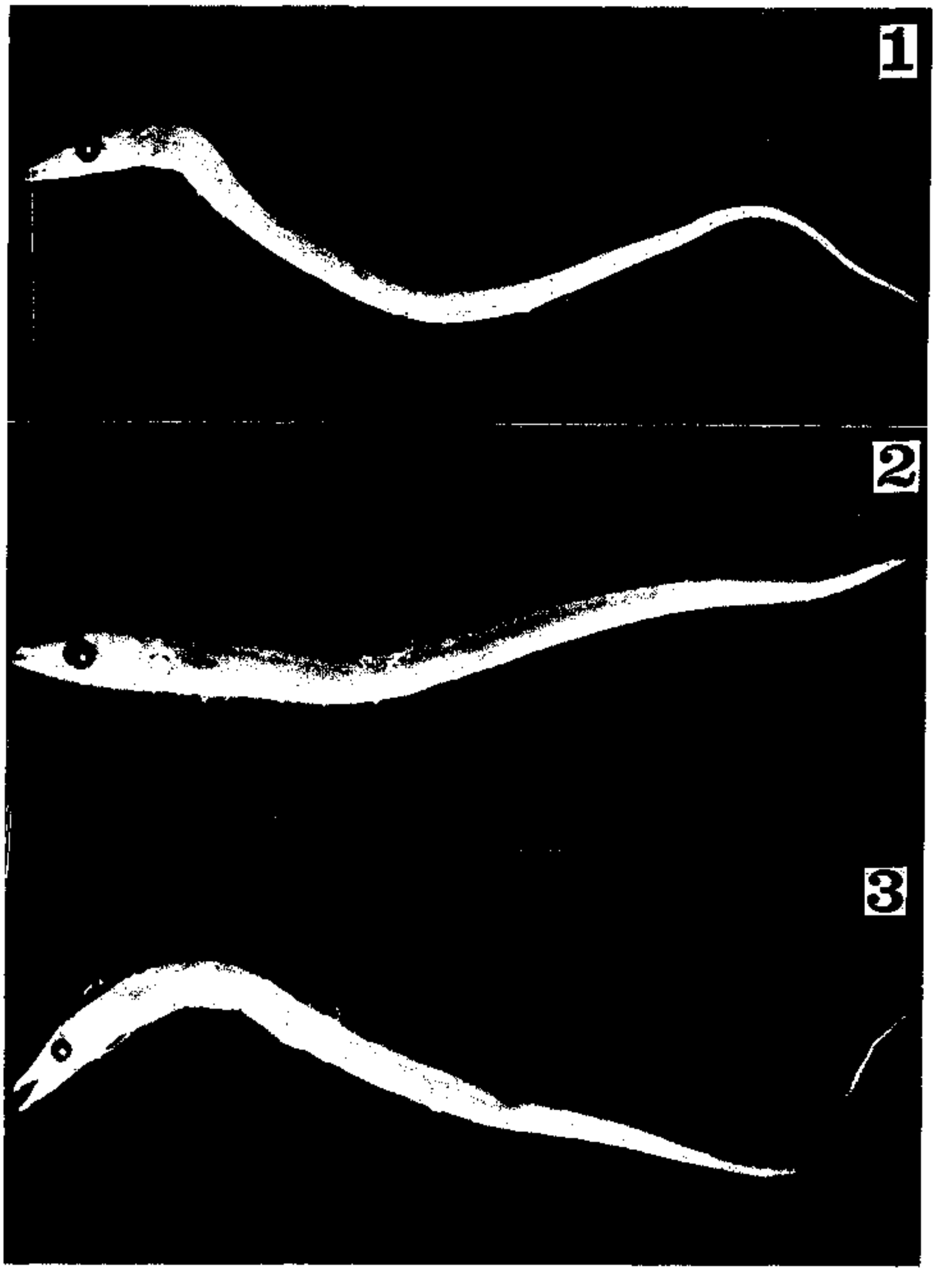

PLATE VI

Young ones of (1) *E. intermedius* (59.5 mm. S. L., head length 9.0 mm) (2) *T. lepturus* (43.3 mm. S L., head length 7.6 mm.) and (3) *L. savala* (61.0 mm. S. L., head length 8.0 mm.)

black blotches regularly alternating with the dorsal fin rays up to D. 69. Posteriorly, the distribution is irregular to tip of tail. A bigger black blotch is present on the tip of tail which is more or less retained in an extended and intense form in the adult. The silver-grey colour of the body and black pigment on the distal half of dorsal and pectoral fins of the adult are, however, not noticed in the specimen. The pigmentation on the snout and lower jaw in the young one resembles that of the adult.

As in *E. intermedius* and *T. lepturus*, the young one of *L. savala* is also characterised by the silver colouration and the black pigment spots on the snout and mandible. It bears about 41 black spots along the base of dorsal fin extending to a short distance behind the vent. They are not noticed in the posterior one-third length of the body. However, a few black spots are present on the tip of the tail which is transparent and the rod-like vertebrae at this region characteristic of this species could be seen through a microscope.

Since there are numerous dorsal and anal rays in all the species, and the posterior ones being very small and hidden which could be accurately enumerated only by alizarin staining (in which case the specimens cannot be preserved permanently) and because the specimens are considered valuable, detailed meristic counts were not attempted. But it may be mentioned here, that characters diagnostic of the species could be made out even at this stage.

iii. *The dorsal fin* : A very striking feature of the dorsal fin of the young ones of the three species is the distinctness of the three dorsal spines from the following rays. Each of them bears minute teeth-like processes or serrations which appear to be more prominent in *T. lepturus* than in the other two species. The rays are simple and fall in height towards the tip of tail.

In the adults of all the three species, the dorsal spines do not exhibit any such teeth-like processes and they are not easily distinguishable from the rays. It may not be out of place to point out here, that such teeth-like processes or serrations were, however, noticed by the author on the distal half of anterior margin of the pectoral spine of some individuals of *L. savala*.* This condition was not noticed in *T. lepturus*, *E. intermedius* and *E. muticus*.

iv. *The anal fin* : In the young one of *E. intermedius* the first anal spine is rudimentary and the second anal spine is dagger-like, with teeth-like processes on the outer surface, which are irregularly directed. The anal spinules are sharp and distinctly break through the ventral margin of the body. In the young one of *T. lepturus*, the first anal spine is concealed, the second anal spine is distinct, elongate and grooved along its inner surface. The latter is also armed with many denticulations irregularly directed. The spinules following the second anal spine are armed with minute teeth-like processes and distinctly break through the ventral profile of body. In the young one of *L. savala* the first anal spine is concealed and the second anal spine is prominent, dagger-shaped, and devoid of any processes. The spinules following the latter are

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* See addendum

conspicuous, devoid of teeth-like processes and break through the ventral profile of body.

A comparison of the structure of the anal fin in the young ones and adults of the three species is interesting, especially in case of *E. intermedius* and *T. lepturus*. In the anal fin of adult specimens of *E. intermedius* the second anal spine is more like a scale than a spine but in the young of this species it is a distinct spine bearing many denticulations. The anal spinules in the adult appear as blunt prominences along the ventral profile of the body whereas in the young one, they distinctly break through the ventral margin of the body. In the adult of *T. lepturus* the anal fin is rudimentary, the second anal spine very small and not denticulated. The spinules which break through the ventral margin of the body in the young one are not visible in the adult. In case of *L. savala* apparently there is no difference in structure of the anal fin of the young one and the adult.

v. *Body proportions* : Some morphometric measurements and their proportions as hundred times ratios to snout-vent length of the young ones of the three species described are given in Table LIV. The body proportions of adults of these three species of ribbon-fishes are given earlier (Tables I and V).

TABLE LIV

Measurements and body proportions as hundred times ratios to snout-vent length of the young ones of three species of ribbon-fishes*

S. No.	Character	*E. intermedius*	*T. lepturus*	*L. savala*
1.	Standard length	59.5	43.3	61.0
2.	Snout-vent length	19.0	19.4	20.0
3.	Head length	9.0 (47.36)	7.6 (39.17)	8.0 (40.00)
4.	Height of head	2.5 (13.15)	2.4 (12.37)	2.5 (12.50)
5.	Eye diameter	1.0 (5.26)	1.3 (6.70)	1.0 (5.00)
6.	Snout	3.0 (15.78)	2.5 (12.88)	3.0 (15.00)
7.	Predorsal distance	7.0 (36.84)	6.4 (32.98)	5.0 (25.00)
8.	Depth of body (at vent)	2.0 (10.52)	2.1 (10.82)	2.0 (10.00)
9.	Depth of body (maximum)	2.5 (13.15)	2.5 (12.88)	3.0 (15.00)
10.	Height of longest dorsal fin ray	3.0 (15.78)	2.3 (11.85)	2.5 (12.50)
11.	Length of second anal spine	—	0.6 (3.09)	1.0 (5.00)
12.	Snout to origin of ventrals	11.0 (59.89)	—	—

* Measurements in mm; parentheses indicate ratios.

A comparison of the body proportions of the young ones and adults of the three species indicates that the proportion of the *length of head* is greater in young one of *E. intermedius* than in the adults, whereas it bears the same relation in young and adult specimens of *T. lepturus* and *L. savala.*

The proportion of the *height of the head* appears to be similar in young and adults of *E. intermedius* whereas in *T. lepturus* and *L. savala* it is smaller in young ones than in adults.

The *depth of body* in young stages of all the three species is smaller in proportion when compared to the adults.

The *diameter of the eye* in the young ones of all the three species bears the same proportion as in the adult specimens.

The proportion of *predorsal distance* is greater in the young ones of *E. intermedius* and *T. lepturus* whereas it is smaller in the young one of *L. savala* than in the adult.

The proportion of the *longest dorsal fin ray* bears a similar ratio in young ones and adults of *E. intermedius* and *T. lepturus* whereas it is smaller in the young one of *L. savala* than in the adult.

The only complete description of the metamorphosis of a trichiurid is that of *Lepidopus* described by Strubberg (1918). Although descriptions of comparable stages of the species from Indian waters with those of *Lepidopus* are lacking, the above observations on the smallest specimens recorded from Indian waters indicate that there is some similarity in the structure and transformation of the young ones of all the species especially in the precocious development of the anterior portion of dorsal fin and the distribution of melanophores on the body. The diagnostic characters of the species, like the decurved or median lateral line, the presence or absence of ventral fins, the caniniform teeth and the prominent or rudimentary nature of anal spines are distinct even at this stage.

XIV
AGE AND GROWTH

Determination of the age and growth of fish of commercial importance is significant in that it contributes to an understanding of the age-class structure of the stock and the role played by various year-classes in the fluctuations of the fishery. A knowledge of the age and growth of fish is also essential to determine the mortality and survival rate of various year classes and the success of the yearly brood, all of which contribute towards a rational exploitation the stocks.

Methods of determining the age of fish may be broadly classified into two categories (i) analysis of length frequency data by Petersen's method, which enables in determining modal or average size of the fish at different ages and (ii) counting the number of periodic rings or zones on certain skeletal structures, the chief of which are scales, otoliths, opercular bones, vertebrae and fin rays. If these marks are periodic in nature, the method enables in determining the age of individual fish under study.

1. Length Frequency Analysis

As this method involves only the length measurements of fish, it is a relatively quick method. The principle on which this method is based may be stated as follows :

Lengths of individuals of the same age group in a population of fish are approximately normally distributed. If there is one or two specific spawning periods in a year, the length frequency distribution generally presents a multimodal curve which can be decomposed into its several normal components. Depending on whether the spawning is annual or biannual, the modes will represent the successive year or half-year classes respectively. This method is useful to find the average size of the few earlier year-classes and with advance in age, the growth slows down, resulting in overlapping of the modes, thereby making it difficult to separate them. In case of fishes without a short and restricted spawning, extreme care is necessary to apply this method and interpret the results therefrom, because of frequent overlapping of various groups entering the fishery. Under such circumstances, the only possible way is to trace a size group as far as possible after it enters the commercial fishery and find the average monthly growth rate in different stages from which the approximate values of average size at different ages may be calculated. The progression of modes in the length frequency data for the species under study was traced on these lines and anything more than this will not be warranted in such cases.

Random samples of *E. intermedius* were collected every week from commercial catches landed at Panaikulam (Palk Bay) during the period March 1959 to February 1961. The fish were caught in shore seines operated at depths varying between 4 to 8 metres and at a distance of 1 to 1½ miles from the shore. The catches therefore belong to the inshore fishing grounds only.

Fish were preserved in 5% formalin on the field, and the procedure was adopted uniformly throughout this study as it was found convenient. Standard length (from tip of snout to tip of tail) of the fish was utilised for length frequency analysis. Care was taken not to include any specimen where the tip of tail was suspected to be broken. The length measurements were grouped at 2 cm. interval, with the midpoint representing the particular size group. In a size group for instance, 8.0-10.0, all individuals measuring between 8.1 and 10.0 cm. were included. An individual measuring 10.1 cm. was, therefore, placed in the next higher group, although this group is denoted as 10.0-12.0 cm. and so on.

To avoid taking cognizance of false modes arising out of sampling defects, it is usual to collect samples, pool them for each month and trace the progression of a mode through months. Since the number of fish in the monthly samples was not always adequate, (due to nonavailability of the fish as well as irregular times of fishing) the samples for two months were pooled for length frequency distribution studies. For the same reason, sexes were not treated separately in this method of analysis. However, a few relevant points pertaining to the two sexes as noticed in the length frequency distribution are mentioned later. It may however be mentioned here that females were dominant in the commercial catches.

The data: The total number of fish in each size group are shown in Table LV and the corresponding percentage frequency in Table LVI. The results are plotted in the form of length frequency curves for bimonthly periods (Fig. 47).

TABLE LV

Length frequency data for E. intermedius
(March 1959 to February 1961)

Size group (S.L. cm.)	1959—60						1960—61					
	Mar-Apr.	May-Jun.	Jul.-Aug.	Sept-Oct.	Nov-Dec.	Jan-Feb.	Mar-Apr.	May-Jun.	Jul.-Aug.	Sept-Oct.	Nov-Dec.	Jan-Feb.
8-10	—	—	—	—	9	1	—	—	—	1	—	—
10-12	3	—	10	—	18	12	—	3	—	3	3	—
12-14	10	7	39	2	19	187	—	15	—	21	14	5
14-16	5	19	50	23	22	102	—	80	13	31	18	16
16-18	4	36	83	40	43	41	1	120	25	51	27	52
18-20	6	54	87	50	42	37	9	101	86	58	43	101
20-22	9	84	73	51	57	46	19	41	68	50	65	43
22-24	19	61	39	42	64	51	25	17	36	42	55	88
24-26	26	25	41	29	32	34	20	23	20	25	31	60
26-28	15	12	23	4	23	24	33	20	14	15	25	26
28-30	12	5	33	9	22	23	40	13	10	15	26	20
30-32	14	1	23	3	15	11	45	13	7	22	7	19
32-34	8	3	11	6	14	13	36	11	2	12	12	26
34-36	10	1	5	3	8	9	28	5	2	6	6	24
36-38	10	1	11	1	4	4	16	3	2	5	—	11
38-40	4	—	8	1	12	2	23	1	—	—	3	3
40-42	2	—	13	4	4	3	13	—	1	3	2	2
42-44	8	—	16	5	.1	1	4	—	4	5	1	5
44-46	9	—	6	1	1	1	1	—	1	3	—	2
46-48	3	—	—	—	—	—	—	—	1	1	1	—
48-50	1	—	—	—	—	—	—	—	—	—	—	—
Total	178	309	571	274	410	602	313	466	292	360	339	503

TABLE LVI

Percentage frequency of E. intermedius in the various size groups
(March 1959 to February 1961)

Size group (S.L. cm.)	1959 - 60						1960—61					
	Mar-Apr.	May-Jun.	Jul-Aug.	Sept-Oct.	Nov-Dec.	Jan-Feb.	Mar-Apr.	May-Jun.	Jul-Aug.	Sept-Oct.	Nov-Dec.	Jan-Feb.
8-10	—	—	—	—	1.19	0.17	—	—	—	0.28	—	—
10-12	1.68	—	1.75	—	4.39	1.99	—	0.64	—	0.83	0.88	—
12-14	5.61	2.26	6.83	0.73	4.63	31.06	—	3.22	—	3.33	4.13	0.99
14-16	2.81	6.15	8.75	8.39	5.36	16.94	—	17.16	4.45	8.61	5.31	3.18
16-18	2.25	11.65	14.53	14.60	10.49	6.81	0.32	25.74	8.56	14.16	7.96	10.34
18-20	3.37	17.47	15.23	18.25	10.24	6.14	2.87	21.66	29.45	16.11	12.68	20.08
20-22	5.05	27.18	12.78	18.61	13.90	7.64	6.07	8.79	23.28	13.88	19.17	8.55
22-24	10.67	19.74	6.83	15.32	15.61	8.47	7.98	3.65	12.33	11.66	16.22	17.49
24-26	14.60	8.09	7.18	10.58	7.80	5.65	6.39	4.39	6.85	6.94	9.14	11.93
26-28	8.42	3.88	4.03	1.46	5.61	3.99	10.54	4.29	4.79	4.16	7.37	5.17
28-30	6.74	1.62	5.78	3.28	5.36	3.82	12.78	2.79	3.42	4.16	7.66	3.98
30-32	7.86	0.32	4.02	1.09	3.66	1.83	14.37	2.79	2.40	6.11	2.06	3.78
32-34	4.49	0.97	1.93	2.19	3.14	2.16	11.50	2.36	0.68	3.33	3.54	5.17
34-36	5.61	0.32	0.87	1.09	1.95	1.49	8.94	1.07	0.68	1.67	1.77	4.77
36-38	5.61	0.32	1.93	0.36	0.97	0.66	5.11	0.64	0.68	1.39	—	2.19
38-40	2.25	—	1.40	0.36	2.93	0.33	7.35	0.21	—	—	0.88	0.60
40-42	1.13	—	2.28	1.46	0.97	0.50	4.15	—	0.34	0.83	0.59	0.40
42-44	4.49	—	2.80	1.82	0.24	0.17	1.27	—	1.37	1.39	0.29	0.99
44-46	5.05	—	1.05	0.36	0.24	0.17	0.32	—	0.34	0.83	—	0.40
46-48	1.68	—	—	—	—	—	—	—	0.34	0.28	0.29	—
48-50	0.56	—	—	—	—	—	—	—	—	—	—	—

An examination of the data reveals certain conspicuous modes together with a few smaller modes. While the identity of some of the smaller modes is doubtful, yet, in the description given below they are mentioned as such and growth rate calculated only by tracing a few conspicuous modes in the length frequency curves.

In the March-April 1959 sample, five modes may be seen at 13, 25, 31, 36 and 45 cm., whereas in the next 2 month period only two modes may be recognised at 21 and 33 cm. While the appearance of the 21 cm. group of this period could not be traced back, that of the 33 cm. would have resulted from the 31 cm. mode of March-April, indicating a growth of 2 cm. In the next period, July-August five modes may be seen at 19, 25, 29, 37 and 43 cm. The mode at 19 cm. would have resulted from the 13 cm. group of March-April, showing progress of 6 cm., the 29 cm. group from the 25 cm. group of the March-April period indicating a growth of 4 cm. The other modes seen during this period may not appear to be directly related to any of the previous modes. In the September-October period, the modes are seen at 21, 29, 33 and 43 cm. Here again, it may be possible to explain that only one of the above modes, (the one at 21 cm.) would have resulted due to a growth increment of 2 cm. of the 19 cm. size group of the previous period. During the November-December period, a fresh mode makes its appearance at 17 cm., which could be considered as an addition of new individuals to the fishery. The other modes are at 23 cm. and 39 cm. The former group of individuals may be traced back to those with a mode at 21 cm. in the September-October period showing a growth of 2 cm. The latter group which was evidently not represented in the immediately preceding two periods (July-August and September-October) might have resulted from the 23 cm. size group of May-June showing a progress of 6 cm. during the interval. In the January-February 1960 period, a still smaller new group of individuals with a mode at 13 cm. enters the fishery. Three other modes during this period may be seen at 23, 33, and 41 cm. The mode at 23 cm. of the previous period does not seem to have shifted (which may be seen at 23 cm.) and this may be due to an addition of smaller individuals both during this period and the previous period as indicated above (mode at 17 cm. in November-December and at 12 cm. in January-February, 1960). The mode at 33 cm. may be traced back to the 29 cm. mode of September-October and similarly, the mode at 41 cm. may correspond to the 39 cm. size group of the previous period. Thus the two modes show a shift of 4 cm. and and 2 cm. respectively.

Following the progress of modes during the course of another year, in March-April 1960, the modes are at 23, 31 and 39 cm; of these three groups, only the one at 39 cm. may be traced back to the 33 cm. size group of September-October with a progress of 6 cm. during the period, the other two groups might have resulted due to overlap in size groups and addition of individuals to the fishery in the preceding two periods. In May-June, two modes were seen at 17 and 25 cm. both of which may be traced back to the 13 cm. size group of January-February period, and the 23 cm. size group of the March-April period respectively. During July-August, two groups are seen at 19 and 43 cm. While the first mode may be a result of 2 cm. growth of the mode

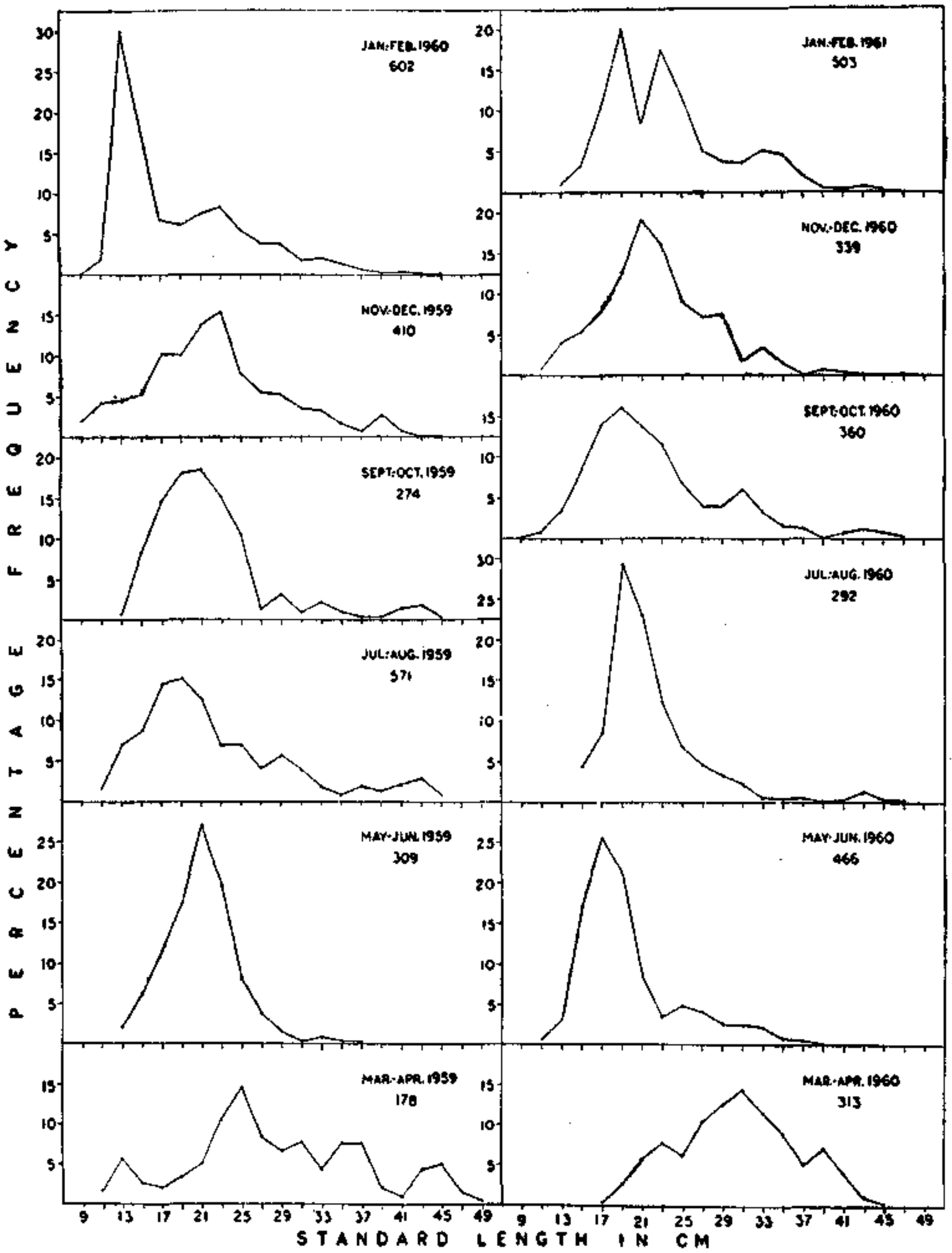

Fig. 47. Length frequency curves of *E. intermedius* for 1959-'60 and 1960-'61 (only mid-points of 2 cm. size groups indicated along X-axis).

at 17 cm. in the previous period, the one at 43 cm. seems to have resulted due to the progress of the mode at 39 cm. in March-April. In the September-October period, three modes at 19, 31 and 43 cm. may be seen, which are difficult to trace back but in the following period (November-December) a progress of 2 cm. of the first two groups of this period may be seen to result in modes at 21 and 33 cm. respectively. During January-February 1961, four modes are seen at 19, 23, 33 and 43 cm. The mode at 19 cm. evidently represents a new generation entering the fishery, whereas the 23 cm. mode of this period would have resulted from the 21 cm. group of the previous period with a growth increment of 2 cm. The other two groups could have resulted from an overlap of the size of individuals of higher groups.

2. Growth Rate

As explained earlier, only some of the modes in the length frequency curves could be followed for a certain period, after which the identity of those modes becomes doubtful. With this caution, some of the modes in the length frequency curves are traced as follows, to indicate the probable growth trend for this species.

The first mode seen in March-April 1959 was at 13 cm. It was not seen in May-June period. However, it appears to have progressed to 19 cm. in July-August. Thus in four months, the mode has progressed by 6 cm. i.e., a monthly growth of 1.5 cm., after it entered the fishery at 13 cm. It is well known that the same growth rate is not maintained as the fish grows further and it is possible that growth rate in the earlier stages before it entered the fishery must have been higher than 1.5 cm. per month. Hence at the completion of one year, the fish is likely to attain a size somewhere between $12 \times 1.5 = 18$ cm. and $12 \times 2 = 24$ cm. Assuming an average growth rate of 1.75 cm. per month during the course of first year, the most likely length at the completion of one year may be 21 cm. Tracing the growth of the group which was at 13 cm. in March-April 1959, it may be seen that this group completes first year in September-October 1959, when it is 21 cm. The mode shifts to 23 cm. in November-December indicating a growth of 2 cm. in 2 months. Following this group through subsequent months, it appears that a size of 31 cm. was attained in September-October 1960 i.e., at the completion of two years. Taking a maximum growth rate of 1 cm. per month after completion of first year the fish is expected to be $21 + 12 = 33$ cm. when it is two years old.

After completion of two years, it grows 2 cm. in two months. Thereafter no data is available to trace its growth and to determine its size at the completion of three years.

A second group with the mode at 25 cm., seen in March-April 1959, was not seen in May-June but appears at 29 cm. in July-August and 33 cm. in September-October, when it must be two years old. Following the same group further, it may be seen that it progresses to 39 cm. in March-April 1960 and probably 43 cm. in July-August by which time it should be three years old indicating a growth of 10 cm. in the third year.

A similar progress may be noticed in some of the other groups as described above and on the whole it may reasonably be stated that in the first year of its life, the monthly growth rate for this species is about 1.75 cm., in the second year the average monthly growth rate is about 1 cm. and and less than an average of 1 cm. per month in the third year.

In addition to the presence of three year old fish in the commercial catches, the length frequency data also suggest that some fish of the fourth year-class may also be met with (above 43 cm.) but they are few and do not form a group as such. Therefore, it was not possible to state the approximate size of fish at the completion of four years although there are indications that the life span of the species may be at least four years.

The length frequency data indicate that (1) the size groups above 42 cm. are represented only by females during the entire period of study, (2) during different months also, females constitute the highest sizes represented (3) the size range of the first year class is greater than the higher year classes, (4) there is an overlap in size between different age groups (5) the larger size groups (over 40 cm). are better represented in March-April, and August-September of each year.

3. Use of Skeletal Structures

The general validity of determining age from the periodic markings on certain skeletal structures of fish like the scales, otoliths is well established and the method has become an accepted routine in many fishery investigations. Van Oosten (1929) gave a very elaborate review of the scale method. Chugunnov (1926), as referred to by Menon (1950) gave a detailed analysis of the literature (mainly by Russian workers) of age determination by bones and Graham (1929) gave a most valuable survey of several papers on age determination of fishes by the use of scales, otoliths, and other bones. Menon (*op. cit.*) reviewed literature on the use of bones other than otoliths, in determining the age and growth-rate of fishes. Amongst other references on the subject mention may be made of the works of Hickling (1933), Le Cren (1947) Jones and Hynes (1950), Bagenal (1954), Bowers (1954), Qasim (1957), Kelley and Wolf (1959).

Growth checks similar to those found in the temperate fishes have been noticed in the skeletal parts of tropical and subtropical fishes amongst many others by Mohr (1921), Hornell and Naidu (1924) Devanesan (1943), Nair (1949), Seshappa and Bhimachar (1951, 1955 1955), Pillai (1954), Radhakrishnan (1954, 1957), Jhingran (1957), Sarojini (1957), Misu (1958), Seshappa (1958), Balan (1959), Venkatasubba Rao (1961) and Kutty (1961). However, the validity and the interpretation of these growth checks or age indices, present certain difficulties when applied to different fishes especially the tropical inhabitants. Delsman (1929) and Hardenberg (1938) held that, due to absence of any periodicity in seasons, methods used elsewhere may not be applicable to tropical fishes.

In order to find whether any of the bones in *E. intermedius* will be useful as indicators of its age, the vertebrae, operculum and otoliths were examined.

i. *Vertebrae* : Fresh fish were cooked in boiling water to remove the flesh. After the muscles were sufficiently soft, they were removed with the help of a scalpel and the vertebrae from different regions of the column were removed, washed and dried in air. Each vertebra was sectioned longitudinally into two halves and the inner surface was examined under a binocular microscope. Faint concentric markings were seen on the surface but they were not clear and easy to interpret in fish of different sizes. Attempts to make the markings clearer in different liquid media like water, spirit, glycerine, xylol, creosote oil and cedarwood oil were not fruitful.

ii. *Operculum* : The operculum is the largest bone of the opercular complex and it was examined for seasonal marks. The opercular bones of several fresh fish of various sizes were removed by the same method as described for the vertebrae. This bone also showed some indistinct markings along the edge (over the bony unfringed area) but attempts to make them more clear were not fruitful.

iii. *Otoliths* : As in many fishes, the otoliths of *E. intermedius* have shown certain makings or 'rings' which are clearer than those on the vertebrae or the operculum. Hence, a detailed study of these bones was made.

iv. *Description of the otoliths* : The otoliths are two small, elongated bones, broader at the anterior end and narrow posteriorly. Each otolith is convex towards the external side and concave along the inner surface. In the fresh fish they are translucent while in the preserved fish (in 5% formalin) they become opaque. Examination of otoliths from fresh fish under low power of binocular microscope by reflected light revealed an opaque centre and one or more alternating transparent rings (narrow) and opaque areas (wide) the number of rings depending upon the size of the specimen. These areas are better seen in otoliths of fresh fish than in those of preserved fish and clarity is increased when viewed under a microscope with reflected light. Both the otoliths from the same fish are alike but sometimes one of them was difficult to read. However, to make it uniform, otolith of the left side was made use of in the present study.

v. *Method of preparation of the otoliths for study* : Fresh fish were utilised for this study. The standard length and sex of the specimens were first noted. The head of each specimen was split open into two equal halves by passing a sharp scalpel through the head in a median dorso-ventral direction which exposed the otoliths. Sagitta, which is the largest and widely used in the determination of age of fishes (Jones and Hynes, 1959) was picked out by a fine forceps, cleaned in water, dried and stored in envelopes for detailed examination later.

Cleaned otolith did not show the transparent and opaque zones straight away and it was also difficult to locate the nucleus. Hence it was found necessary to grind the convex surface of the otolith gently over a carborundum (Menon, 1950) taking care that the edge was not damaged. The ground otolith was placed in different liquid media mentioned above, to ascertain which of them was most suitable to make it clear and readable. Cedarwood oil gave the best results and so dry otoliths were examined in cedarwood oil uniformly throughout this investigation.

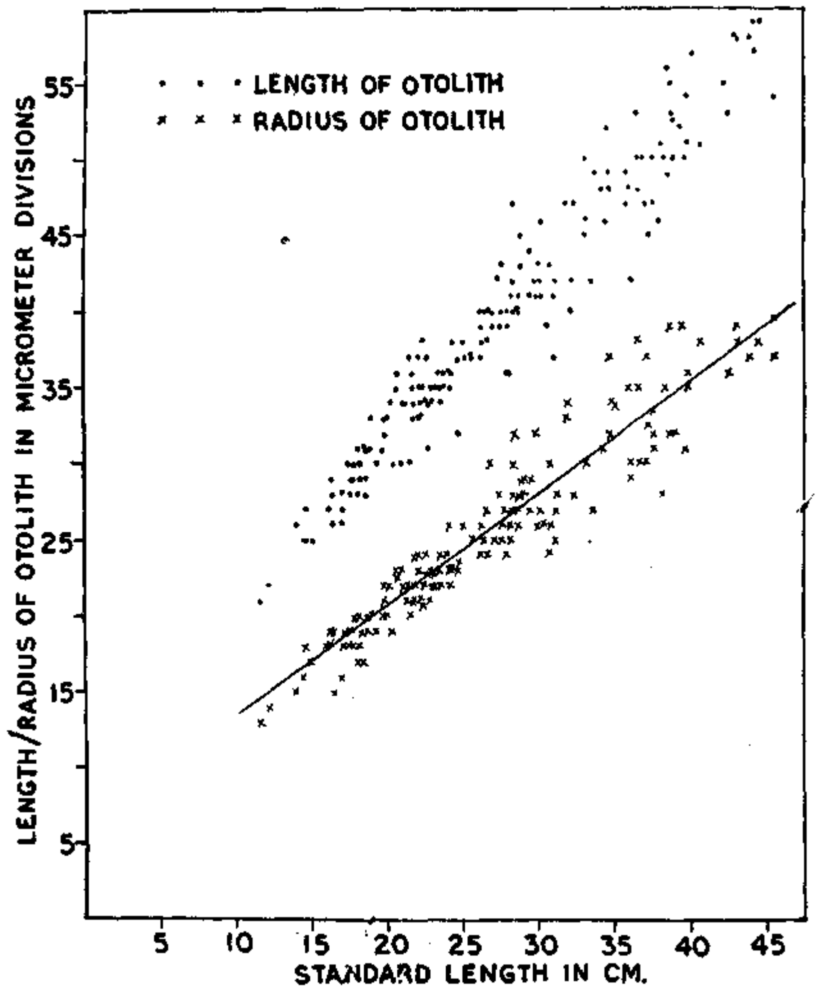

Fig. 48. Relation between standard length of fish and length/radius of otolith in *E. intermedius*.

vi. *Determination of age* : The maximum length of otoliths of 163 specimens of *E. intermedius* was measured and plotted against the standard length (Fig. 48). It may be seen that a linear relationship exists between the length of fish and the length of otolith using the formula, $0 = A + BL$, where '0' represents the length of the otolith and 'L' the length of fish, 'A' and 'B' two constants and the relationship may be expressed as $0 = 6.3189 + 0.7283\,L$. Based on this relationship and on the assumption that each of the transparent rings are formed annually, the average size of fish when each of the transparent rings formed has been calculated. A similar relationship may be noticed between the length of the fish and the radius of the otolith (Fig. 48). Before counting the number of rings, the condition at the periphery was carefully examined. The margin of the otolith at the periphery was often difficult to determine as was also noticed earlier for other species (Jones and Hynes, 1960 ; Bowers, 1954 ; Qasim, 1957). In the first place, each transparent zone is narrow and therefore does not become well defined until the succeeding opaque zone is laid down. Secondly, the growing edge of the otolith is always thin and therefore somewhat transparent. Thirdly, the rings do not appear all round the margin at the same time but appear earlier in some places than in others or distinct only at certain points. Lastly, the otoliths of older age groups are some times not clear to read beyond the second year of growth. Jones and Hynes (1950) remarked, when there is a false zone it is devoid of a sharply defined inner boundary and accordingly, the first two difficulties mentioned above were overcome by examining carefully the nature of the transparency. The third and fourth difficulties were overcome by following up the ring as far as possible and ascertaining that it alternates with the opaque zone on either side. Cases of false or multiple zones in the otoliths were extremely rare and unreadable or doubtful cases were discarded. Walford and Mosher (1943) used the following criteria for the identification of the annulus in the otolith of the sardine, "An annulus is more or less translucent band concentric with the margin of the otolith, the intervening spaces being opaque. It can usually be traced entirely around the otolith, although it is easily observed at the blunt anterior end than at the sides or posterior end. Annuli tend to be zones rather than lines". It was found that these criteria were also useful in the case of *E. intermedius* but the annuli are more like rings than broad zones.

As emphasized by Graham (1929) and Van Oosten (1929) before attempting to interpret the zones on the otoliths as evidence of age of the fish, it is necessary to provide corroborative evidence that the zones are annual. In the present study this is accomplished by the length frequency distribution as described earlier and the seasonal formation of zones on the otoliths which has shown that the narrow transparent rings are mainly formed from November to April. Russell (1942), in his lectures on the overfishing problems states "Growth is seasonal and periodic, slowing down or ceasing in the winter months in most cases. This rhythm of growth is mirrored on the structure of certain parts such as the scales, the otoliths, the vertebrae and the opercular bones which show in diverse ways, alternating bands or rings indicating summer and winter growth. It is possible for example by counting the dark winter rings in the otolith of a plaice to ascertain the age in years".

On the assumption that of each of these rings in the otolith of *E. intermedius* is formed annually, the translucent bands were counted and the number of these bands was taken to be the age of fish in years. This assumption is reasonable since fish of equal length were nearly always found to be of equal age and the age structure of the samples was found nearly to agree with that obtained by the length frequency study.

Altogether, otoliths from 200 fish of both sexes were examined. On examination it was found (as was also the case in length frequency study) the majority of the fish showed one ring or two rings while those with three or more rings were quite scarce, at least in the commercial catches. Otoliths were examined in such a way that all the available size groups were covered without much repetition. Doubtful cases, where the growth marks were not clear, have been excluded from consideration.

Direct reading of the otoliths for each sex was done separately and the number and length of fish in each age group along with the mean length are shown in Table LVII. The mean length of each age group was calculated from the number of fish and their actual lengths. The data was then pooled and the mean length at each year was calculated (Table LVIII).

TABLE LVII

Number and length of fish in each age group (sex-wise) of E. intermedius

Size group (S.L. cm.)	Number and size of fish in each age group								
	Male				Female				
	No. of fish	O	I	II	No. of fish	O	I	II	III
8-10	—	—	—	—	—	—	—	—	—
10-12	3	2	1	—	4	4	—	—	—
12-14	2	2	—	—	3	2	1	—	—
14-16	2	—	2	—	4	—	4	—	—
16-18	9	—	9	—	10	—	10	—	—
18-20	7	—	7	—	8	—	8	—	—
20-22	6	—	6	—	11	—	11	—	—
22-24	7	—	7	—	13	—	13	—	—
24-26	3	—	3	—	7	—	6	1	—
26-28	2	—	2	—	13	—	9	4	—
28-30	4	—	3	1	9	—	1	8	—
30-32	2	—	—	2	3	—	1	2	—
32-34	—	—	—	—	3	—	—	3	—
34-36	1	—	—	1	7	—	—	7	—
36-38	—	—	—	—	9	—	—	9	—
38-40	—	—	—	—	12	—	—	10	2
40-42	—	—	—	—	1	—	—	1	—
42-44	—	—	—	—	4	—	—	—	4
44-46	—	—	—	—	4	—	—	—	4
Total No. of fish	48	4	40	4	125	6	64	45	10
Mean length (S.L. cm.)	—	—	20.7	31.6	—	—	21.6	34.1	42.9

TABLE LVIII

Number and size of fish in each age group (Pooled data) of E. intermedius

Size group cm.	No. of fish in each are group				
	O	I	II	III	Total
8-10	—	—	—	—	—
10-12	6	2	—	—	8
12-14	4	1	—	—	5
14-16	—	6	—	—	6
16-18	—	20	—	—	20
18-20	—	15	—	—	15
20-22	—	17	—	—	17
22-24	—	20	—	—	20
24-26	—	9	1	—	10
26-28	—	11	4	—	15
28-30	—	4	9	—	13
30-32	—	1	4	—	5
32-34	—	—	3	—	3
34-36	—	—	8	—	8
36-38	—	—	9	—	9
38-40	—	—	10	2	12
40-42	—	—	1	—	1
42-44	—	—	—	4	4
44-46	—	—	—	4	4
Total no. of fish	10	106	49	10	175
Mean length (S.L. cm.)	—	21.1	33.9	42.9	—

From Table LVII it may be seen that for each age group, in both sexes, there is a wide range in size and a certain degree of overlap in size between different age groups. This may be explained by the fact that the total range in size of each year-class includes not only their size at the close of that particular year but also the length increments between that year and the next. For instance, a fish measuring 13 cm. with one ring will be taken as one year old and a fish measuring 25 cm. with only one ring (but with further growth towards a second ring) is also considered as one year old. The extremes of the length range in a particular age group, therefore, denote the maximum growth during that period and the average corresponds to the size at approximately the middle of each year's growth.

The data also indicate certain sexual growth rate differences. The mean lengths attained by the males during their first and second year of life (20.7 and 31.6 cm.) appear to be lower than those of the females (21.5 and 34.1 cm.). Since males of third year-class were not met with in the commercial catches, a comparison of the third year class, sex wise, could not be made. It may also be incidentally remarked here that, as far as seen, the maximum size attained by the males appears to be smaller than that of the females. These differential growth trends between sexes appear to be in line with the findings of earlier workers (Pincher, 1947; Orcutt, 1950; Arora, 1951; Morrow, 1951; Seshappa and Bhimachar, 1954 Bowers, 1954). The pooled data from otolith studies (Table LVIII) indicate that the fish attain a mean length of 21.1 cm. at the end of first year, 33.9 cm. at the end of second year and 42.9 cm. at the end of third year. These values are more or less in agreement with those obtained by the length frequency study.

4. Summary of all Evidence

The length frequency study indicates in addition to fish of the third year class, a few fish belonging to the fourth year-class. As mentioned earlier, since all big fish that were met with in the commercial catches were females, it is possible that the females have a longer life span than males, probably up to four years. Males appear to grow at a slower rate than females, as shown from otolith studies. Taking into consideration the average lengths of the fish computed from length frequency studies and supported by evidence from otolith studies as indicative of growth in *E. intermedius*, a growth of nearly 21 cm. is shown during the first year and about 12 cm. in the second year and nearly 10 cm. in the third year. It is therefore evident, that the growth rate in this species is fairly high during the first year and decreases from the second year onwards, which is in line with the findings of Ford (1933) and others, that fishes in general, have an accelerated growth during the first year and a slower rate of growth subsequently with increase in age.

Intense spawning for the species appears to take place between March-April and August-September and November-December and the resultant young ones were observed to enter the fishery in November-December and January-February periods. As there is no short and definite spawning period, the identity of individual modes in the length frequency curves is masked to a certain extent but the dominant size groups in the fishery are usually between 15-35 cm. which comprises the first, second and partly of the third year-class fish. The size at first maturity was determined to be 30 cm. which corresponds to the size attained by the fish when it is about to complete its second year of life, indicating that the fish spawns first when it is about two years old. The relatively small percentage occurrence of fish above 35 cm. in the commercial catches in most of the months and their occasional appearance in limited numbers in some months probably indicates that these fish move away from inshore waters for spawning. Similarly, the absence of juveniles and young fish in the fishery may be due to the same reason.

Comparison of Species

Since enough material of other three species of ribbon-fishes was not available regularly, a study of their age and growth was not attempted as in the case of *E. intermedius*. The age and growth of *T. haumela* (= *T. lepturus*) from Indian waters was studied by Prabhu (1955), relevant points from which are discussed below. This species, according to him, attains a length of 18 cm. in the first year, 30 cm. in the second, 46 cm. in the third and 54 cm. in the fourth year of its life. A comparison of this with *E. intermedius* shows that the latter grows faster in the first year but in the second year growth in both the species shows almost the same trend while in the third year of their life they differ strikingly. Prabhu explained that the very high rate of growth of *T.*

haumela during its third year of life may be due to some bias in the samples due to inshore migration of different size groups. However, the growth of the two species in their fourth year of life could not be compared for lack of data. The disappearance of mature individuals during certain months probably for spawning is noted in both the cases. It may therefore, be said that the two species differ in their growth rate at least in their first year of life and the difference in the maximum size attained by the two species may be a reflection of the difference in their life span. It is interesting to note here that Prabhu's data for *T. haumela* does not include the size groups above 56 cm. In the present study the author has come across several specimens above that size and some of them nearly double. Evidently, the life span of this species appears to be much more than 4 years but unfortunately enough data are not available at present to substantiate it. If this is proved to be so, the rate of growth in different years of life is also likely to be different. It may therefore be possible to conclude that the upper age limit of *E. intermedius* may be lower 'than that of *T. haumela*.

From the maximum size recorded by the author for the other two species *E. muticus* (58.4 cm. S.L.; 15.8 S-V. cm.) and *L. savala* (56.4 cm. S.L.; 19.7 S-V. cm.) from Indian waters and presuming the same nature of growth as for the other two species mentioned above, it may be remarked that these two species also indicate a probable life span of at least four years, if not more. The assumption may be reasonable, since, two of the species studied so far show somewhat identical growth trends and since all the four species were found to have similar habits of life, like the food and feeding habits which influence, among other things, the growth of these fishes, although actual evidence to justify the conclusion is needed.

In this context, it may be worthwhile to refer to the work of Misu (1958) on the age and growth of *T. lepturus* from the East China and Yellow Seas. His study includes fish below 600 mm. (60 cm.) with a life span of six years, according to him. The average calculated lengths (from otolith studies) from first to sixth year of its life for this species are 18.3, 27.7, 33.1, 37.0, 40.1 and 42.1 cm. respectively. It is evident from this, although the species attains almost the same size at the end of first year as its counter part from Indian waters (as also *E. intermedius*) the rate of growth of *T. lepturus* in the East China and Yellow Seas appears much slower in the subsequent years in that locality and also in comparison with the rate of growth of the same species in Indian waters. It may probably be the result of local conditions prevailing in the two regions.

6. Growth of Young Fish

Although the occurrence of young ones of ribbon-fishes in Indian waters is not so common, some in formation is available as to the time of occurrence and length of these stages of at least three species. From this and other data so far known about the age and growth of these particular species, it may be possible to get a general idea of the rate of growth of young fish. Their absence in the commercial catches may be due to the small size and consequent selection by the gear or due to their occurrence in deeper waters since spawning was so far not found to take place in inshore areas. Young ones of *E. intermedius* have been collected by the author from Thangachimadam (Palk Bay) in June 1960. The smallest specimen recorded was 59.5 mm. S.L. From the same locality and at the same time, young ones of *L. savala* were also collected, smallest specimen being 61.0 mm. S.L. One much smaller specimen of *T. lepturus* was available for study from Idinthakarai (Gulf of Mannar) measuring 43.3 mm. S.L. collected on 28-8-1959. Perhaps, these are the smallest specimens so far recorded for these three species from Indian waters. Unfortunately, young ones of the fourth species, *E. muticus* were not available for study.

Other information available about young ones of trichiurids from Indian waters is that of Nair (1944) who recorded two small specimens of *T. haumela* (= *T. lepturus*) from Madras coast on 22-9-1944 and 9-12-1944. The smallest specimen was 6.7 cm. Prabhu (1955) reported juveniles of the above species along the Madras coast and further south during the month of July measuring 7-9 cm. From the above information and the probable times of spawning in various species, the following general conclusions may be drawn. Since intense spawning was found to take place in March-April amongst other periods for *E. intermedius*, the occurrence of fish of 59.5 mm. S.L. in June indicates that this length was attained in about two months time. This appears to be in agreement with the conclusions drawn from length frequency study. As young ones of *L. savala* were also collected during the same time and if spawning occurs during March-April, growth rate of about 61.0 mm. may be presumed in about two months time for this species also. Prabhu (1955) remarked that the spawning of *T. haumela* takes place in June and the occurrence of juveniles between 7-9 cm. towards the end of July indicates the growth rate of about this size in one and half months duration. This however, does not seem to be in agreement with his statement that this species attains a length of 18 cm. in the first year. Possibility of the wrong identification of juveniles is also not ruled out. He has compared this with the statement of Tang and Wu (1936), that *Trichiurus japonicus* (= *T. lepturus*) attains a size of 5.4-9.5 cm. length within a period of a month and a half from the time of spawning. If the spawning of *T. haumela* in Indian waters takes place in June, the occurrence of a young one of 43.3 mm. in August indicates that it may be about two months old.

Delsman (1927) gave an account of the early development of the eggs belonging to genus *Trichiurus* from the Java Sea in which he described the developmental stages of six types of eggs, the identity of which, according to him, is doubtful. However, the biggest newly hatched larva measures about 6.6 mm. and the two day old larva reaches about 8.0 mm. length (as judged from his figures). This would indicate that the larva is fairly big even at hatching and hence, it is reasonable to think that at least some species of ribbon-fishes attaining a length of about 60 mm. are at least two months old.

Thus, from all the evidence, it is possible to say that in ribbon-fishes, growth from the time of hatching and throughout the first year is rather rapid and decreases thereafter and that the species appear to show more or less similar growth trends in the early stages. Judging from the maximum size attained by the different species, it may be possible that they differ in their longevity.

XV

RACIAL INVESTIGATIONS

Racial studies of fishes are carried out with the objective to determine whether a species consists of independent groups or is homogeneous throughout its range of distribution. This study is considered important because, continuous fishing on a particular population, if homogeneous, has a direct and important effect on the population of the same species in every other locality. Conversely, where a species is composed of two or more groups, fishing at any one locality, whatever be its magnitude, has no effect on the other unfished populations of the same species. There may also be cases where intermediate relations prevail with varying degrees of intermingling.

There has been considerable variation in the terminology used by earlier workers to denote the smaller groups of a species (e.g., 'populations', 'subpopulations', 'stocks', 'groups', 'races') Marr (1957), while defining each of these terms, pointed out that it is desirable that each author defines the term used.

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

Tester (1937) indicated the existence of local populations in the herring, *Clupea pallasii* in the coastal waters of British Columbia, from an analysis of meristic counts and morphometric characters. The vertebral counts have been specially useful in this study. Hubbs and Perlmutter (1942) used the graphical method of analysis in their studies on *Anchoviella mitchilli* as described by Dice and Leraas (1936). Hubbs and Perlmutter (*op. cit.*) and Clark (1947) used vertebral counts as the basis for distinguishing the populations of *A. mitchilli* and the Pacific sardine along the North American coast respectively. Roedel (1952) and Schaefer (1952) used both meristic and morphometric characters for a racial study of Pacific mackerel, *Pneumatophorus diego* in California waters and for a comparison of yellowfin tuna of Hawaiian waters and of the American west coast respectively. Godsil (1948) in a preliminary population study of the yellowfin and albacore (*Thunnus germo*) from Japan and Hawaiian islands used only body proportions since meristic counts were found unsatisfactory.

Ahlstrom (1957) reviewed the results of the studies on the subpopulations of Pacific fishes. According to him, subpopulations may be detected by two methods, *viz.*, the indirect method which employs the average differences of morphometric and meristic characters between groups of fishes to indicate homogeneity or otherwise and the direct method in which fishes are tagged, the recovery results indicating the identity of stocks. Obviously, the first method is less expensive and widely employed by workers all over the world. To quote Ahlstrom (1957), "Under conditions of partial or complete isolation of groups of fish, slight differences in body proportions or meristic characters will be preserved in each group. The small differences will not necessarily be apparent in individual specimens but often only in an average of a large number of specimens. The significance of the differences is appraised by means of statistical procedures based on the theory of probability. The differences might be due to either environment or hereditary factors. It is usually extremely difficult to determine whether differences are phenotypic or genotypic; yet knowledge of the causes of the difference is essential to an understanding of their significance".

As to the cause of the morphological differences which characterise races, Hjort (1930) reported that "some regard the formation of races as the result of a fortuitous hereditary combination of characteristics and others as due to an interplay of the power of adaptation shown by the animals concerned and the physico-chemical conditions predominating in particular areas of the sea".

One of the reasons for the belief that environmental conditions can alter the characters by which races are distinguished is that such characters are not fixed but may vary from year to year in one localised population. Schmidt (1930), who made elaborate investigations on races of fishes remarks that some external factors are capable of altering the average characters by which races in fishes are determined but it may be wrong to ignore the fact that the differences in the average characters by which the races are determined may also be of a hereditary genotypic nature.

Farris (1957) reviewed literature on the use of chromatography as a tool for the study of speciation but before the method could be profitably utilised, the limits of individual variations have to be determined.

Aznar (1958) used morphometric and meristic characters for a study of population of *Cetengraulis mysticetus* from different parts of eastern tropical Pacific Ocean, while Broadhead (1959) utilised only morphometric characters in a study of the yellowfin *Neothunnus macropterus* from the eastern tropical Pacific Ocean. Pillay (1951, 1957) used morphometric characters in a study of the species of *Barbus* and both morphometric and meristic characters in a study of the hilsa, *Hilsa ilisha*.

The relative growth of body parts of a fish vary at different stages of its life-history and this was exemplified by Godsil (1948), Schaefer (1948), Schaefer and Walford (1950) and Marr (1955). It is therefore imperative that the ratios between the body parts of fishes from different localities cannot be used for distinguishing populations unless the stage of development (size range of fish) is kept uniform. In order to overcome this difficulty the comparison of the different samples is based on the comparison of the regression of one dimension on that of another, taken as a measurement of overall size. This method is widely used by almost all the workers who have attempted a study of the populations of various fishes.

The relative growth of body parts of *Eupleurogrammus intermedius* has been discussed earlier in the systematic study.

In the present investigation of a morphometric comparison of samples of *E. intermedius* the term 'population' is used to denote a particular group of individuals which inhabit a particular area of the sea, in a given time, showing certain distinct morphometric characters.

1. Relation between the Standard Length and Snout-Vent Length

In ribbon-fishes in general, the tip of the tail is very fragile and liable to break easily. Hence it was thought the snout-vent length will be a more reliable character than the standard length especially in racial studies. Before the analysis of various morphometric characters was made, it is necessary to find the relation between the standard length and the snout-vent length. A total of 213 fish ranging in size between 14.4-46.4 cm. S.L. were taken and the standard length (from the tip of the snout to tip of tail) and the snout-vent length (from tip of snout to anterior margin of vent) were noted. The observed values of snout-vent length were plotted against those of standard length (Fig. 49).

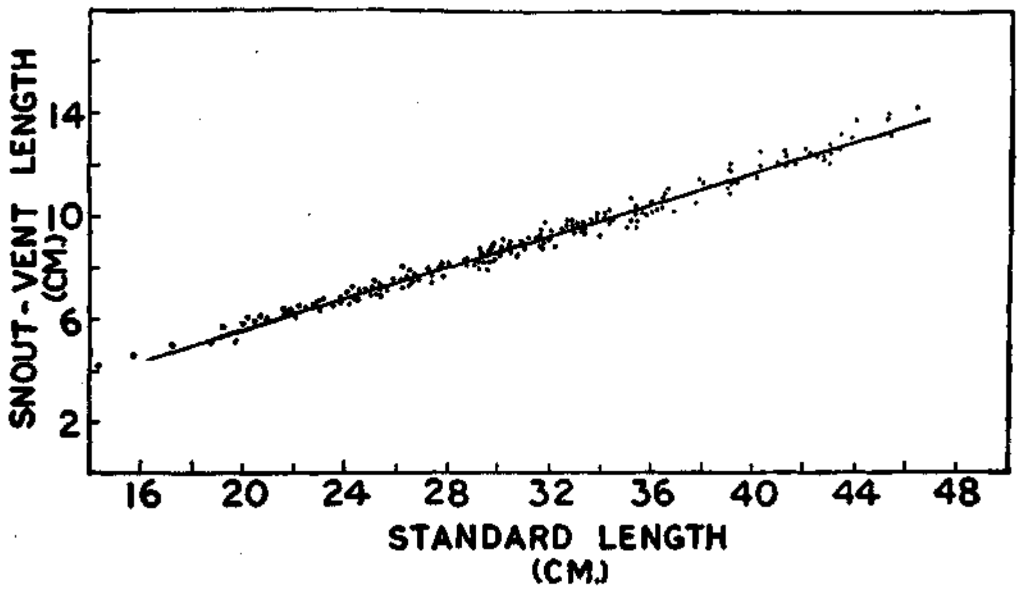

Fig. 49. Relation between standard length and snout-vent length of *E. intermedius*.

The regression equation was calculated by the method of least squares using the formula, $Y = a + b X$, where 'X' and 'Y' denote standard length and snout-vent length of the fish respectively, and 'a' and 'b' are two constants. The regression line was then fitted to the data and the relationship between the two lengths was found to be linear. The relevant particulars are given in Table LIX.

TABLE LIX

Sum of squares and products, and regression coefficient for the relation between standard length and snout-vent length of E. intermedius

N	SX	SY	SXY	SX^2	SY^2
213	6508.15	1901.00	60824.69	207840.57	17815.57

continued..

x^2	y^2	xy	b	$\bar{X}$	$\bar{Y}$
8986 04	849.37	2740.22	0.3049	30.5547	8.9249

N = Number of fish, SX, SY = Sum of X and Y, SXY, SX^2, SY^2 = Sum of products and squares, xY, X^2, Y^2 = Corrected sum of products and squares, b = Regression coefficient $\bar{X}$ $\bar{Y}$ = Mean of X and Y

The regression equation from Table LIX was found to be Y = –0.3912 + X 0.3049. It may be seen that all the observed values lie very close to the regression line (Fig. 49) indicating a high degree of correlation between the snout-vent length and standard length in *E. intermedius*. In further analysis the snout to vent length was taken as the independent character and other body dimensions and dependant characters.

In this study, the significance of each morphometric character was considered at 5% probability level. In the last column (5% F) of tables, the value of the nearest or the next numbers as given in F tables were noted. Individual points were not plotted but the regression lines drawn in each case were fitted to the original data.

Out of as many as 12 morphometric characters studied, only 6 of them which could be accurately measured were selected for further analysis. Since *E. intermedius* has as many as 123-129 dorsal rays, 113-121 anal rays and 158-163 vertebrae of which accurate counts could be made only by X-rays or alizarin staining the former being expensive and the latter a relatively slow method for analysis in a number of specimens in series of samples, the analysis of meristic counts was not attempted.

2. Morphometric Characters

Marr and Schaefer (1949) while describing the tunas have selected certain specific characters and each character was defined by them. In their study they have emphasised that characters selected may be preferably those, most

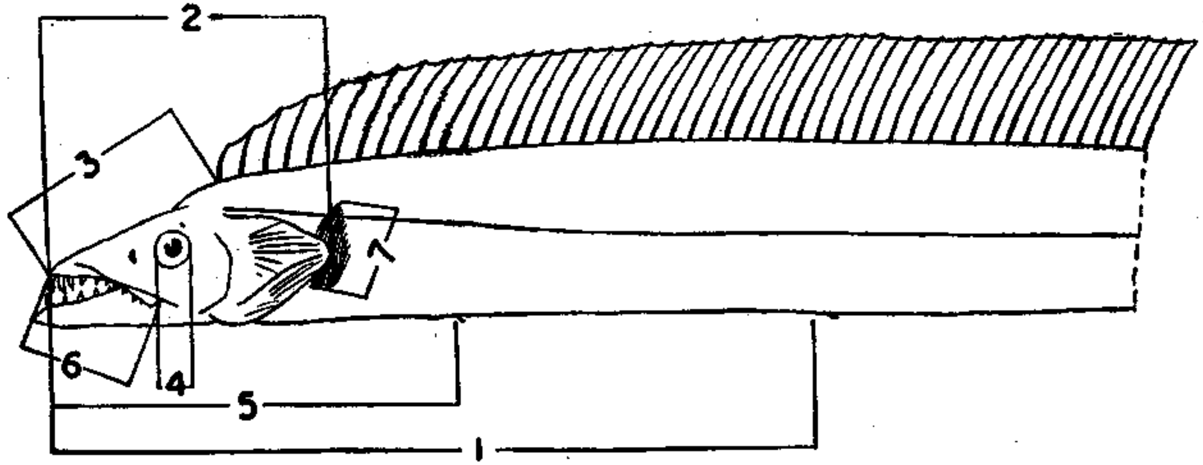

Fig. 50. Diagram of *E. intermedius* showing the morphometric measurements taken: (1) Snout-vent length (2) Head length; (3) Predorsal distance (4) Eye diameter (5) Snout to origin of ventrals (6) Snout to tip of maxilla and (7) Height of pectoral.

commonly used by workers from other parts and that they should be easy to measure accurately. Accordingly, in the present study, six morphometric characters (Fig. 50) which could be accurately measured were selected and defined below.

(i) *Head length* : Distance from tip of snout to posteriormost point of operculum.

(ii) *Predorsal distance* : Distance from snout to origin of dorsal fin.

(iii) *Eye diameter* : Maximum horizontal distance between the free orbital margins.

(iv) *Snout to orgin of ventrals* : Distance from tip of snout to origin of ventrals.

(v) *Height of pectoral* : Maximum height of the fin from base of pectoral spine.

(vi) *Snout to tip of maxilla* : Distance between tip of snout and posterior end of maxilla.

3. Comparison of Sexes

To determine the differences, if any, between the males and females for the characters selected, measurements of the above characters of 27 males and 32 females taken at random were made. Scatter diagrams for all these characters (Fig. 51, scatter data omitted for clarity of figures) revealed that a linear relationship (though not a strict linearity) exists between the snout-vent length and the six characters. The regression equations, therefore, were calculated as before. Throughout this study, the snout-vent length is designated as 'X', and the different morphometric characters as 'Y', in each case. The method of analysis of covariance was employed for all the characters.

The statistical analysis of the six characters, sex-wise, are given in Tables LX and LXI and the results are summarised in Table LXII.

It may be seen from Table LXII that all the morphometric characters studied were non-significant at 5% probability level, between sexes. Therefore, in further analysis of these characters, the samples were treated without differentiation of sex.

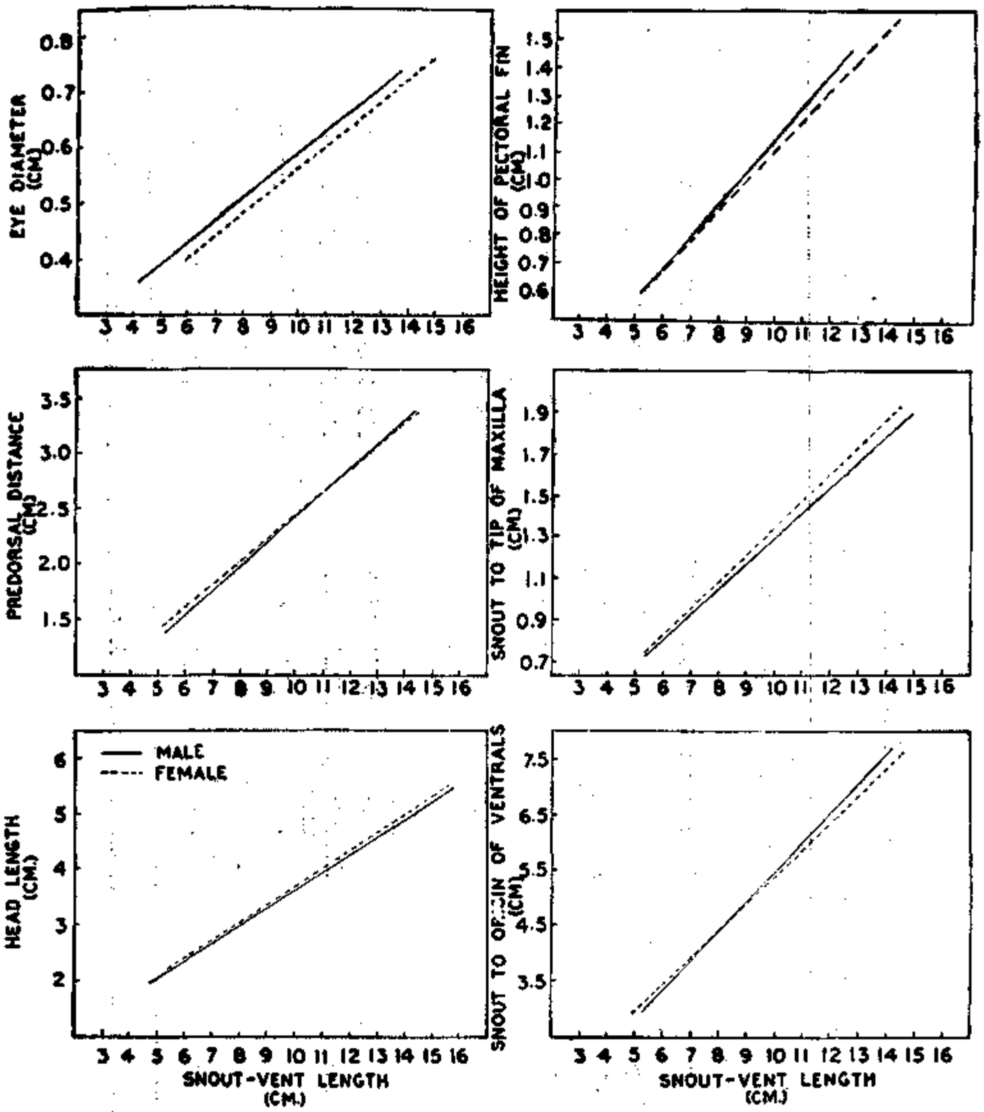

Fig. 51. Comparison of sexes for six morphometric characters of *E. intermedius*.

TABLE LX

Sum of squares and products of morphometric data of males and females of E. intermedius

Sex	N	Independent variable X	Dependent variable Y	SX	SY	SX^2	SY^2	SXY
F	32	-do-	Head length	232.20	86.20	2032.5650	278.9600	752.5975
M	27	Snout-vent length	-do-	299.05	110.30	2851.9975	388.2750	1049.2350
F	32	-do-	Predorsal distance	232.20	56.80	2032.5650	121.4200	1496.3075
M	27	-do-	-do-	299.05	73.35	2851.9975	170.6475	697.3300
F	32	-do-	Eyediameter	232.20	14.50	2032.5650	7.8700	126.1300
M	27	-do-	-do-	299.05	17.05	2851.9975	9.1875	161.4875
F	32	-do-	Snout to origin of ventrals	232.20	127.50	2032.5650	612.6950	1115.3925
M	27	-do-	-do-	299.05	161.70	2851.9975	831.5150	1539.3750
F	32	-do-	Snout to tip of maxilla	232.20	31.10	2032.5650	36.4850	272.1600
M	27	-do-	-do-	299.05	40.55	2851.9975	52.4175	386.5075
F	32	-do-	Height of pectoral	232.20	26.95	2032.5650	27.4825	236.0800
M	27	-do-	-do-	299.05	33.25	2851.9975	35.2975	316.9775

M : Male; F : Female; N : Number of fish; SX, SY : Sum of X and Y; SX^2, SY^2, SXY : Sum of squares and products.

TABLE LXI

Corrected sum of squares and products of morphometric data, regression coefficient and deviation from average regression for males and females of E. intermedius

Sex	Independent variable X	Dependent variable Y	D.F.	Sum of squares and products X^2	Y^2	XY	b	Errors of Estimate S.S.	D.F.
M	Snout-vent length	Head length	26	35.6450	3.7586	11.2775	0.3163	0.1800	25
F	-do-	-do-	31	57.2818	8.0850	18.4480	0.3220	0.1424	30
M	-do-	Predorsal distance	26	35.6450	1.9297	7.8275	0.2195	0.1920	25
F	-do-	-do-	31	57.2818	2.5156	11.8514	0.2068	0.0417	30
M	-do-	Eye diameter	26	35.6450	0.0830	1.4300	0.0401	0.0256	25
F	-do-	-do-	31	57.2818	0.1031	2.1499	0.0375	0.0224	30
M	-do-	Snout to origin of ventrals	26	35.6450	10.6117	18.8925	0.5300	0.5983	25
F	-do-	-do-	31	57.2818	14.4247	28.2380	0.4925	0.5043	30
M	-do-	Snout to tip of maxilla	26	35.6450	0.6624	4.7000	0.1318	0.0427	25
F	-do-	-do-	31	57.2818	1.0331	7.5551	0.1318	0.0366	30
M	-do-	Height of pectoral	26	35.6450	0.5825	4.3100	0.1209	0.0614	25
F	-do-	-do-	31	57.2818	0.7487	6.2459	0.1090	0.0677	30

M: Males; F: Females; D.F. : Degrees of freedom; X^2, Y^2, XY: Corrected sum of squares and products; b: Regression Coefficient; S.S. : Sum of squares.

TABLE LXII

Analysis of Covariance

S. No.	Source of variation	Degrees of freedom	Sum of squares	Mean square	Observed F	5% F
1.	HEAD LENGTH					
	Deviation from individual regressions within sexes	55	2.3343	0.042441	60.63000*	251-252
	Differences between regressions	1	0.0007	0.000700		
	Deviation from total regression	56	2.3350			
2.	PREDORSAL DISTANCE					
	Deviation from individual regressions within sexes	55	0.2745	0 004990	1.4257*	251-252
	Differences between regressions	1	0.0035	0.003500		
	Deviation from total regression	56	0.2372			
3.	EYE DIAMETER					
	Deviation from individual regressions within sexes	55	0.0480	0.038087	95.2175*	251-252
	Differences between regressions	1	0.0004	0.000400		
	Deviation from total regression	56	0.0484			
4.	SNOUT TO ORIGIN OF VENTRALS					
	Deviation from individual regressions within sexes	55	1.1026	0.020047	1.5064*	4.08-4.00
	Differences between regressions	1	0.0302	0.030200		
	Deviation from total regressions	56	1.1328			
5.	SNOUT TO TIP OF MAXILLA					
	Deviation from individual regressions within sexes	55	0.0793	0.001441	14.4100*	251-252
	Differences between regressions	1	0.0001	0.000100		
	Deviation from total regressions	56	0.0794			
6.	HEIGHT OF PECTORAL					
	Deviation from individual regressions within sexes	55	9.1291	0.002347	1.2782*	4.08-4.00
	Differences between regressions	1	0.0030	0.003000		
	Deviation from total regressions	56	0.1321			

* Non-significant

4. Comparison of Samples

For a detailed morphometric comparison, a total of five samples of fish were collected, three of which were from Pudumadam (Gulf of Mannar), Panaikulam (Palk Bay) and Kakinada (Bay of Bengal) in the year 1959 and two from Panaikulam and Athankarai (Palk Bay) in 1960. The samples collected from different places in the same year and from the same place in different years were pooled together and analysed. The relevant details are presented in Tables LXIII to LXVI and the results are summarised in Table LXVII and LXVIII. Regression lines were fitted to the data, separately for each character (Fig. 52).

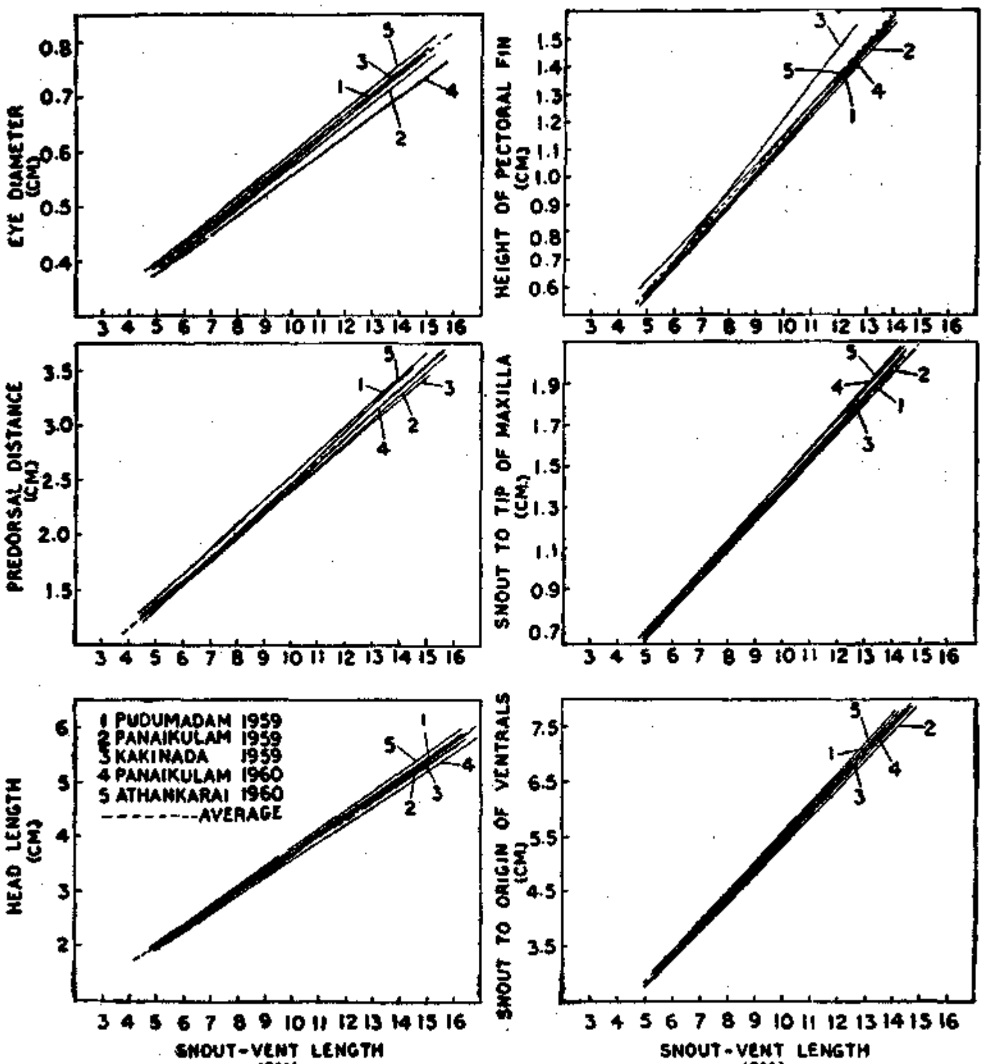

Fig. 52. Comparison of five different samples of *E. intermedius* for the six morphometric characters.

TABLE LXIII

Sum of squares and products of morphometric data for E. intermedius from Pudumadam, Panaikulam and Kakinada during the year 1959

S. No.	Locality	N	SX	SY	SX^2	SY^2	SXY
1.	HEAD LENGTH						
	Pudumadam	42	365.85	137.60	3324.6375	468.4950	1247.4650
	Panaikulam	32	320.85	119.53	3383.6175	466.4909	1255.3715
	Kakinada	30	249.55	93.45	2108.7675	295.0525	788.4050
2.	PREDORSAL DISTANCE						
	Pudumadam	42	365.85	91.65	3324.6375	207.7375	830.5125
	Panaikulam	32	320.85	79.05	3383.6176	203.5075	828.9325
	Kakinada	30	249.55	62.40	2108.7675	131.3200	525.9150
3.	EYE DIAMETER						
	Pudumadam	42	365.85	22.35	3324.6375	12.1525	200.2975
	Panaikulam	32	320.85	18.60	3383.6175	11.0850	192.9925
	Kakinada	30	249.55	15.95	2108.7675	8.5675	133.9850
4.	SNOUT TO ORIGIN OF VENTRALS						
	Pudumadam	42	365.85	204.10	3324.6375	1031.3700	1850.7875
	Panaikulam	32	320.85	175.45	3383.6175	1006.0275	1843.9250
	Kakinada	30	249.55	134.95	2108.7675	617.5475	1140.1025
5.	SNOUT TO TIP OF MAXILLA						
	Pudumadam	42	365.85	50.35	3324.6375	63.4175	458.6675
	Panaikulam	32	320.85	44.50	3383.6175	65.4000	470.0825
	Kakinada	30	249.55	34.80	2108.7675	41.1700	294.3500
6.	HEIGHT OF PECTORAL						
	Pudumadam	42	365.85	42.90	3324.6375	45.5500	388.4775
	Panaikulam	32	320.85	35.90	3383.6175	42.3250	378.1300
	Kakinada	30	249.55	29.85	2108.7675	31.2425	252.5775

N: Number of fish; SX, SY: Sum of X and Y; SX^2, SY^2 SXY : Sum of squares and products.

TABLE LXIV

Sum of squares and products of morphometric data for E. intermedius from Panaikulam and Athankarai during the year 1960

S. No.	Locality	N	SX	SY	SX^2	SY^2	SXY
1.	HEAD LENGTH						
	Panaikulam	59	531.25	196.50	4884.5625	665.2350	1801.8325
	Athankarai	60	555.50	212.15	5552.8600	801.1625	2107.6050
2.	PREDORSAL DISTANCE						
	Panaikulam	59	531.25	130.15	4884.5625	292.0675	1193.6375
	Athankarai	60	555.50	142.15	5552.8600	357.7325	1407.8250
3.	EYE DIAMETER						
	Panaikulam	59	531.25	31.55	4884.5625	17.0575	287.6175
	Athankarai	60	555.50	34.35	5552.8600	20.3775	334.4250
4.	SNOUT TO ORIGIN OF VENTRALS						
	Panaikulam	59	531.25	289.20	4884.5625	1444.2100	2654.7675
	Athankarai	60	555.50	306.75	5552.8600	1694.5825	3066.3700
5.	SNOUT TO TIP OF MAXILLA						
	Panaikulam	59	531.25	71.65	4884.5625	88.9025	658.6675
	Athankarai	60	555.50	79.20	5552.8600	113.7200	793.4425
6.	HEIGHT OF PECTORAL						
	Panaikulam	59	531.25	60.20	4884.5625	62.7800	553.0575
	Athankarai	60	555.50	62.80	5552.8600	71.1350	627.5675

N: Number of fish; SX, SY: Sum of X and Y; SX SY SXY: Sum of squares and products.

TABLE LXV

Corrected sum of squares and products of morphometric data, regression coefficient and deviation from average regression for E. intermedius from Pudumadam, Panaikulam and Kakinada during 1959

S.No.	Locality	D.F.	Sum of squares and products			b	Errors of Estimate	
			X^2	Y^2	XY		S.S.	D.F.
1.	HEAD LENGTH							
	Pudumadam	41	137.8227	17.6912	48.8708	0.3546	0.3621	40
	Panaikulam	31	166.5950	20.0090	56.8965	0.3415	0.5774	30
	Kakinada	29	32.9775	3.9558	11.0568	0.3358	0.2431	28
2.	PREDORSAL DISTANCE							
	Pudumadam	41	137.8227	7.7442	32.1756	0.2334	0.2326	40
	Panaikulam	31	166.5950	8.2293	36.3328	0.2181	0.3055	30
	Kakinada	29	32.9275	1.5280	6.8510	0.2081	0.1026	28
3.	EYE DIAMETER							
	Pudumadam	41	137.8227	0.2592	5.6131	0.0407	0.0306	40
	Panaikulam	31	166.5950	0.2738	6.4985	0.0390	0.0204	30
	Kakinada	29	32.9275	0.0875	1.3076	0.0397	0.0356	28
4.	SNOUT TO ORIGIN OF VENTRALS							
	Pudumadam	41	137.8227	39.5412	72.9308	0.5292	0.9489	40
	Panaikulam	31	166.5950	44.0681	84.7650	0.5088	0.9390	30
	Kakinada	29	32.9275	10.4975	17.5435	0.5328	1.1505	28
5.	SNOUT TO TIP OF MAXILLA							
	Pudumadam	41	137.8227	3.0575	20.0831	0.1457	0.1311	40
	Panaikulam	31	166.5950	3.5172	23.9005	0.1435	0.0884	30
	Kakinada	29	32.9275	0.8020	4.8720	0.1480	0.0812	28
6.	HEIGHT OF PECTORAL							
	Pudumadam	41	137.8227	1.7308	14.7879	0.1073	0.1442	40
	Panaikulam	31	166.5950	2.0497	18.1765	0.1091	0.0666	30
	Kakinada	29	32.9275	1.5418	4.2753	0.1298	0.9867	28

D.F. : Degrees of freedom; X^2, Y^2, XY : Corrected sum of squares and products; b : Regression coefficient; S.S. : Sum of squares.

TABLE LXVI

Corrected sum of squares and products of morphometric data, regression coefficient and deviation from average regression for E. intermedius from Panaikulam and Athankarai during 1960

S.No.	Locality	D.F.	Sum of squares and products			b	Errors of Estimate	
			X^2	Y^2	XY		S.S.	D.F.
1.	HEAD LENGTH							
	Panaikulam	58	101.0615	10.7901	32.4999	0.3216	0.3387	57
	Athankarai	59	409.8559	51.0355	143.4496	0.3500	0.8282	58
2.	PREDORSAL DISTANCE							
	Panaikulam	58	101.0615	4.9655	21.7361	0.2151	0.2906	57
	Athankarai	59	409.8559	20.9555	91.7530	0.2239	0.4151	58
3.	EYE DIAMETER							
	Panaikulam	58	101.0615	0.1863	3.5339	0.0350	0.0628	57
	Athankarai	59	409.8559	0.7122	16.4013	0.0400	0.0559	58
4.	SNOUT TO ORIGIN OF VENTRALS							
	Panaikulam	58	101.0615	26.6399	50.7421	0.5021	1.1628	57
	Athankarai	59	409.8559	126.3232	226.3763	0.5523	1.2885	58
5.	SNOUT TO TIP OF MAXILLA							
	Panaikulam	58	101.0615	1.8903	13.5139	0.1337	0.0833	57
	Athankarai	59	409.8559	9.1760	60.1825	0.1468	0.3390	58
6.	HEIGHT OF PECTORAL							
	Panaikulam	58	101.0615	1.3556	11.0025	0.1089	0.1578	57
	Athankarai	59	409.8559	5.4044	46.1442	0.1126	0.2092	58

D.F. : Degrees of freedom; X^2, Y^2, XY : Corrected sum of squares and products
b : Regression coefficient; S.S. : Sum of squares.

TABLE LXVII

Comparison of morphometric measurements of E. intermedius from Pudumadam, Panaikulam and Kakinada during 1959 and Panaikulam and Athankarai during 1960 by analysis of covariance

S. No.	Source of variation	Degrees of freedom	Sum of squares	Mean square	Observed F	5% F.
1.	HEAD LENGTH					
	Deviation from individual regressions between places	213	2.3495	0.011030		
	Differences between regressions	4	0.0828	0.020700	1.8766*	2.37
	Deviation from average regression	217	2.4323			
2.	PREDORSAL DISTANCE					
	Deviation from individual regression between places	213	1.3464	0.006321		
	Differences between regressions	4	0.0329	0.008225	1.3012*	2.37
	Deviation from average regression	217	1.3793			
3.	EYE DIAMETER					
	Deviation from individual regressions between places	213	0.2053	0.000963		
	Differences between regressions	4	0.0022	0.000550	1.7509*	5.63
	Deviation from average regression	217	0.2075			
4.	SNOUT TO ORIGIN OF VENTRALS					
	Deviation from individual regressions between places	213	5.4897	0.025773		
	Differences between regressions	4	0.3495	0.087375	3.3901**	2.37
	Deviation from average regression	217	5.8392			

* Non-significant; ** Significant.

TABLE LXVII (Continued)

S. No.	Source of variation	Degrees of freedom	Sum of squares	Mean square	Observed F	5% F.
5.	SNOUT TO TIP OF MAXILLA					
	Deviation from individual regressions between places	213	0.7230	0.003394		
					1.0680*	2.37
	Differences between regressions	4	0.0145	0.003625		
	Deviation from the average regression	217	0.7375			
6.	HEIGHT OF PECTORAL					
	Deviation from individual regressions between places	213	1.5645	0.007345		
					1.8945*	5.63
	Differences between regressions	4	0.0155	0.003875		
	Deviation from average regression	217	1.5800			

* Non-significant.

From the analysis of covariance of the above mentioned six morphometric characters of the species from the five localities during 1959 and 1960 pooled together, it may be seen that five of the characters, viz., head length, predorsal distance, eye diameter, snout to tip of maxilla and height of pectoral did not show significant differences between places while the character snout to origin of ventrals was found to be significant at 5% level and also at 1% level. Hence this character was further analysed by the same method, in combination of two's, in view of the statistical difference. Details of this analysis are presented in Table LXVIII.

TABLE LXVIII

Analysis of covariance of the character snout to origin of ventrals between places during 1959 and 1960

Source of variation	Degrees of freedom	Sum of squares	Mean square	Observed F.	5% F.
Deviation from individual regressions between places (Pudumadam '59 & Panaikulam '59)	70	1.8879	0.026970	1.1568*	4.00-3.92
Differences between regressions	1	0.0312	0.031200		
Deviation from average regression	71	1.9191			
Deviation from individual regressions between places (Pudumadam '59 & Kakinada '59)	68	2.0994	0.030873	102.9100*	252-253
Differences between regressions	1	0.0003	0.000300		
Deviation from average regression	69	2.0997			
Deviation from individual regressions between places (Pudumadam '59 & Panaikulam '60)	97	2.1117	0.021770	1.9614*	4.00-3.92
Differences between regressions	1	0.0427	0.042700		
Deviation from average regression	98	2.1544			
Deviation from individual regressions between places (Pudumadam '59 & Athankarai '60)	98	2.2374	0.022830	2.4222*	4.00-3.92
Differences between regressions	1	0.0553	0.055300		
Deviation from average regression	99	2.2927			
Deviation from individual regressions between places (Panaikulam '59 & Kakinada '59)	58	2.0895	0.036025	2.2800*	251-252
Difference between regressions	1	0.0158	0.015800		
Deviation from average regression	59	2.1053			

TABLE LXVIII (Continued)

Source of variation	Degrees of freedom	Sum of squares	Mean square	Observed F.	5% F.
Deviation from individual regressions between places (Panaikulam '59 & Panaikulam '60)	87	2.1018	0.024158		
				8.9474*	252-253
Differences between regressions	1	0.0027	0.002700		
Deviation from average regression	88	2.1045			
Deviation from individual regressions between places (Panaikulam '59 & Athankarai '60)	88	2.2275	0.025312		
				8.8614**	4.00-3.92
Differences between regressions	1	0.2243	0.224300		
Deviation from average regression	89	2.4518			
Deviation from individual regressions between places (Kakinada '59 & Panaikulam '60)	85	2.3133	0.027215		
				1.1630*	252-253
Difference between regressions	1	0.0234	0.023400		
Deviation from average regression	86	2.3367			
Deviation from individual regression between places (Kakinada '59 & Athankarai '60)	86	2.4390	0.028360	2.4448*	252-253
Differences between regressions	1	0.0116	0.011600		
Deviation from average regression	87	2.4506			
Deviation from individual regressions between places (Panaikulam '60 & Athankarai '60)	115	2.4513	0.021315	9.5988**	4.00-3.92
Differences between regressions	1	0.2046	0.204600		
Deviation from average regression	116	2.6559			

* Non-significant

** Significant.

The results indicate that for the character snout to origin of ventrals, fish from Panaikulam (Palk Bay) collected in 1959 and 1960 differed from those collected from Athankarai in 1960 while fish from Pudumadam (Gulf of Mannar) in 1959 and Kakinada (Bay of Bengal) during 1959 did not show significant differences between the samples or with those of Panaikulam and Athankarai, for this character.

The results of the morphometric study of *E. intermedius* may be summarised as follows :

Head length : The character did not show significant differences in fish drawn from different localities.

Predorsal distance : A comparison of regressions between the samples revealed that the differences between them for this character were non-significant.

Eye diameter : The analysis of samples showed no significant differences for this character.

Snout to origin of ventrals : Regressions of this character showed no significant differences between fish of Pudumadam 1959 and Panaikulam 1959 ; Pudumadam 1959 and Kakinada 1959 ; Pudumadam 1959 and Panaikulam 1960 ; Pudumadam 1959 and Athankarai 1960 ; Panaikulam 1959 and Kakinada 1959 ; Panaikulam 1959 and Panaikulam, 1960 ; Kakinada 1959 and Panaikulam 1960 ; Kakinada 1959 and Athankarai, 1960. The character has shown significant difference between fish of Panaikulam 1959 and Athankarai 1960 and also between those of Panaikulam 1960 and Athankarai 1960.

Snout to tip of maxilla : Comparison of samples revealed that differences between them for this character were non-significant.

Height of pectoral : The differences between the samples for this character were found to be non-significant.

This study, based on an analysis of samples drawn from five different localities during a two year period revealed that, of the six characters analysed, only one of them viz., the origin of ventrals showed a significant difference in fish drawn from two of the places. (Panaikulam and Athankarai — Palk Bay). Fish collected from Panaikulam during these two successive years, however, did not show any difference for this character but these when compared with fish from Athankarai during 1960, have shown a significant difference. Individuals of this species seem to spawn at different times and the temperature and salinity conditions of the waters round Mandapam are also known to vary considerably (Prasad, 1957 ; 1958). Hence the difference noted above could be of phenotypic nature. In view of this it is rather difficult to draw any conclusions on the basis of available data and this study only shows that fish from the different localities are almost indistinguishable by the characters analysed here.

Part Four

FISHERY

XVI

DISTRIBUTION AND FISHERY OF THE FOUR SPECIES OF RIBBON-FISHES ALONG THE INDIAN COAST

Day (1876) recorded the occurrence of *T. haumela* and *L. savala* from the seas and estuaries of India and *T. muticus* from the sea only. Hamilton (1822) described *T. lepturus* (wrong identification for *L. savala*) from the river Ganges. In the estuaries of India (e.g. Hoogly and Matlah) the present observations show that *T. lepturus* and *L. savala* are common but species of *Eupleurogrammus* are also occasionally met with. It will be of interest to note here that several other workers from outside India have also recorded the occurrence of *T. lepturus* and *L. savala* in the estuarine waters (de Beaufort, 1951; Okada, 1955; Smith, 1963). While all the four species are pelagic and move in shoals in shallow waters, *T. lepturus* is known to occur in depths upto 345 fathoms (Goode and Bean, 1859) wherefrom it is sometimes taken on lines. A general survey of the fishery at some important places along the Indian coast was made by the author and some first hand observations made at some of these places where the ribbon-fish fishery is of considerable magnitude are mentioned below.

1. Distribution of Species along Indian Coast

From reports available so far, the various species of ribbon-fishes constitute a substantial fishery at different places in the States of Orissa, Andhra Pradesh, Madras, Kerala and to some extent in Maharashtra. At each of the places one or more species may occur at a time and contribute to the fishery. In the other States along the Indian coast, ribbon-fishes were also reported to occur stray but they do not seem to constitute a fishery. The distribution of ribbon-fishes along the coast is more or less continuous with *T. lepturus* occurring almost throughout, while that of the other three species appears patchy (Fig. 53). The season for the fishery in different States may vary considerably but generally extends from July to March with peak occurrence in different months at different localities. The most common types of gear operated for these fishes are shore seines and bag nets of different shapes along the Indian coast. In West Bengal, with special reference to fisheries of Hooghly and Matla estuaries, all the four species of ribbon-fishes were observed to occur, *L. savala* and *T. lepturus* being the dominant species. The catches of these species are confined to the lower zones of the Hooghly and Matla estuaries and other areas of lower Sunderbans, from November to February. The fish occurring in these areas were generally found to be immature or mature specimens of the above two common species. Ribbon-fishes in this area are caught mostly in the fixed or stationary nets which may be rectangular or conical in shape.

Along the Orissa coast, three species of ribbon-fishes, *T. lepturus*, *L. savala* and *E. muticus* were recorded. These fishes are caught in shore seines called 'Berjal'. One end of the net is kept on shore, the rest carried by a boat and payed out in a semicircular way. The other end is brought to another point on the shore and then the two ends are slowly dragged by two parties of men.

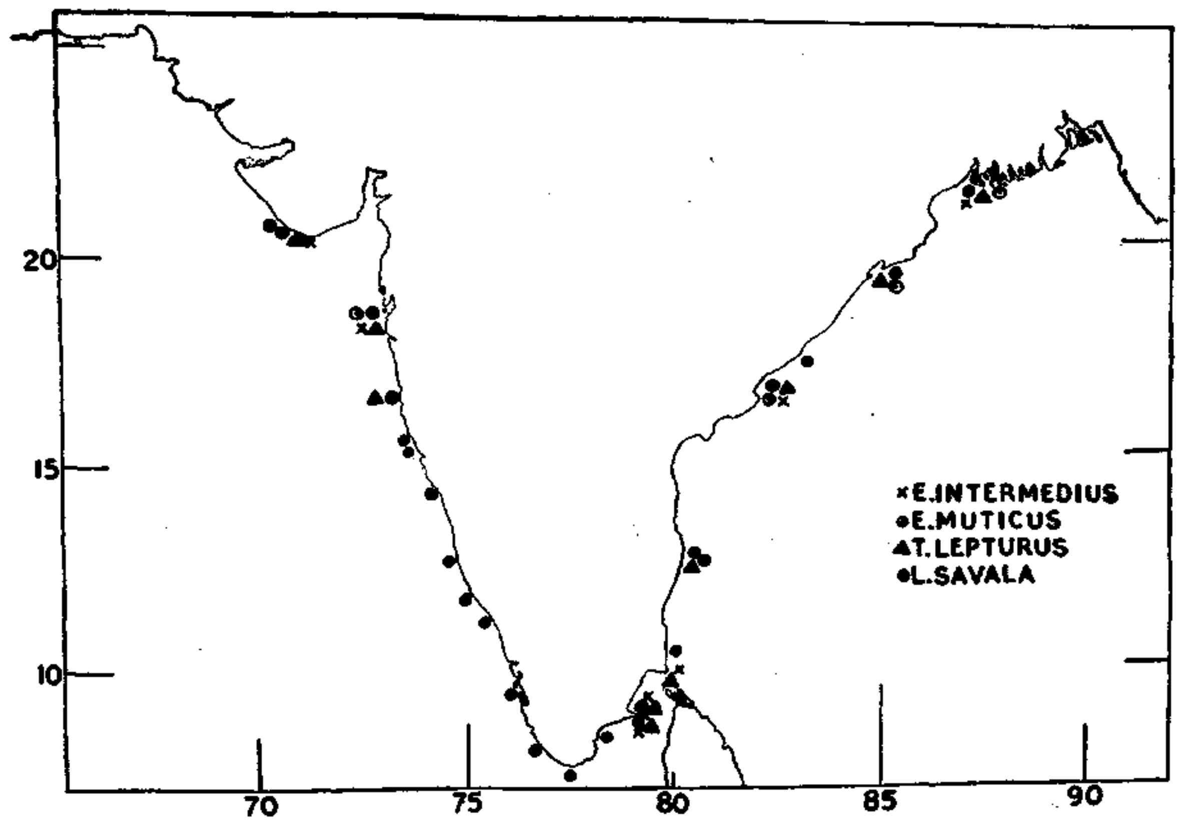

Fig. 53. Distribution of the four species of ribbon-fishes along the Indian coast.

It appears *E. muticus* predominates in the fishery along this part of the coast, the season extending from July to about November.

Ribbon-fishes called 'savallu' in Telugu language, afford an important seasonal fishery along the Andhra Pradesh coast. In north Andhra (Visakhapatnam) they are caught abundantly during July and December. All the four species were recorded in this area but *T. lepturus* seems to contribute to a greater portion of the catches. Individuals of this species measuring up to three-fourths of a metre are quite common. In central Andhra (Kakinada) all the four species are recorded of which *L. savala* seems to be the dominant. Along the south Andhra coast (south of Masulipatam) T. lepturus appears to be the common species. Along the Andhra Pradesh coast these fishes are usually caught in shore seines called 'Pedda vala' or 'Alivi vala' and bagnets or boat seines called 'Iraga vala' or 'Thuri vala'. The general structure and principle of operation of shore seines is the same as mentioned above. The bag nets are conical in shape with or without wings, operated from two catamarans or boats. The mesh of the bag is small and it increases towards the mouth and flanks. Ribbon-fishes are reported to be common after August up to about December in this region.

In Madras State, *T. lepturus, L. savala* and *E. muticus* (which may include both species of the genus) were reported to occur. At Madras proper *T. lepturus* appears to be the common species followed by *L. savala* and *E. muticus*. These three species are locally called 'Olai valai' Karthigai valai' and 'Savalai' respectively. Elsewhere in the State, all the species may be termed 'Savalai'. In the northern part of Madras State the fishery extends from July to about December. *T. lepturus* appears to be the most common species up to south as far as Point Calimere. Further south, in the Palk Bay and Gulf of Mannar, *T. lepturus, L. savala,* and *E. intermedius* occur together of which *E. intermedius* is predominant round the year, in the vicinity of Mandapam. The occurrence of *L. savala* is only seasonal and *T. lepturus* was recorded as stray individuals or as occasional shoals. Along the extreme south-east coast of Madras, only *T. lepturus* and *L. savala* were recorded of which *T. lepturus* appears to be the common species. Large shoals of this species appear in the inshore waters after August in this part of the coast and the fishery extends from September to November with peak occurrence in November. The gear operated for these fishes in this State are shore seines ('karai valai') and boat seines (madi valai')

Along the south-west coast (Kerala), ribbon-fishes are called 'Vala'. Two of the species, *T. lepturus* and *L. savala* were reported to occur and the former seems to be most common. They are caught in bag nets called 'Thattu madi' and Thalayan vala' (which is used exclusively for catching ribbon-fishes). Large shoals of *T. lepturus* are common after August along this region.,

Along the Mysore coast, the two species mentioned above were reported to occur, *T. lepturus* being common. They are locally called 'Pambole' in Canarese language and are mostly caught in shore seines called 'rampan' nets. This is a wall net of enormous length with wooden floats and stone sinkers attached to the head and foot ropes of the net respectively to keep the net in position. The mode of operation is same as for shore seines of other localities, mentioned above.

Further north at Vengurla, Malvan and Ratnagiri, *T. lepturus* and *L. savala* were reported to occur, the former being the common species. They are abundant only during September to December but occasional occurrence of huge shoals was also reported. At Bombay all the four species of ribbon-fishes occur, *E. muticus* being the most common. They are called 'Pitiurkti', 'Pitiwagti' and 'Bala'. Ribbon-fishes are commonly caught in bag nets called 'Dol nets' fixed in the sea by stakes or bouys with the mouth of the net opposite the current, in a horizontal position. Usually two hauls are made at night. They are reported to be common along this part of the coast from November to about March.

Along the north-west coast at Veraval and Kandla, all the four species have been recorded although they do not constitute a substantial fishery in this region. They are caught in 'Dol nets', as described above.

The following interesting features about the distribution of ribbon-fishes along the Indian coast are noteworthy :

(i) *T. lepturus* which has a wide distribution in the Indo-Pacific and the Atlantic, occurs almost all along the Indian coast and appears to be the dominant species in Indian waters.

(ii) All the four species of ribbon-fishes may be found along the coasts of West Bengal, Andhra Pradesh and Maharashtra.

(iii) Along the east coast, *E. muticus* was recorded from West Bengal to Madras and along the west coast, the southern limit appears to be Bombay. When compared to the distribution of other species, the distribution of *E. muticus* appears patchy.

(iv) During the period of the present author's observations, *Eupleurogrammus* species have not been recorded from the south-west coast of India, south of Bombay.

2. Fishing Methods and Seasons along Palk Bay and Gulf of Mannar

Three species of ribbon-fishes occur in Palk Bay and the Gulf of Mannar in the vicinity of Mandapam, of which *E. intermedius* is the most common species occurring throughout the year in Palk Bay. *L. savala* is only seasonal and *T. lepturus* occurs sporadically. However, occasional shoals of the latter species are also reported from this region.

A general survey of the fishing centres along the Palk Bay and the Gulf of Mannar was made with a view to gather information about the fishing methods with special reference to the ribbon-fish fishery in the area.

A description of the fishing methods, fishing seasons, general trend of the fishery and the disposal of the catch is given below.

i. *Fishing methods* : At many places along Palk Bay and Gulf of Mannar, ribbon-fishes are caught in shore seines operated in the inshore waters at depths varying from 4-6 metres and at a distance of 1-1½ miles from the shore. They are also caught in bag nets operated from catamarans at depths varying between 16-20 metres at a distance of about 8 to 10 miles.

ii. *Shore seine operation* : The net is operated from a *Tuticorin type of boat* which is a large boat made of teak measuring about 13 metres in length with a maximum width of 1½ metres and a depth of 78 cm. with nearly vertical stems and sterns. The shearline is straight and both ends of the boat are sharp. The upper-most plank which is very broad is framed wth a separate short piece not fastened to the main frame. The boat is generally rowed by 8 to 10 persons while paying out the net. Mast and sail are used when moving from one fishing centre to another. The cost of the boat varies from Rs. 1500 and above.

The net which is called 'karai valai' (karai = shore; valai = net) consists of a bag and side wings (Fig. 54, A). The bag which measures nearly 10 metres is divided into belly and cod end. The cod end has the smallest mesh of 1.5 cm. The belly is preceded by the cotton wings, each measuring about 39 metres. The cotton wings are in turn followed by the hemp wings. At the juction of these two parts the mesh size is about 23 cm. and as the hemp wing joins the warps the size of the mesh increases progressively. The hemp wing on either side measures about 480 metres and is bounded by a head rope and a foot rope to which are attached floats and sinkers respectively—the floats at 2.8 metres apart and the sinkers at 9.1 metres. At the centre of the mouth of the bag the head rope is provided with a master float and two smaller floats on either side. There are 12 to 15 warps each measuring about 60 metres attached to each hemp wing. Sometimes the number of warps is reduced to only 4 or 5.

The entire net is loaded in the Tuticorin type of boat described above and the boat is launched into the sea with one end of the warp on the shore held by a person. For paying out the net, the boat is manned by 8 to 10 men, six of whom will be rowing it in the direction required, one person at the rudder and another to sight shoals of fishes by standing at the bow of the boat. As soon as a shoal is sighted, the whole net is quickly payed out around the shoal and the other end is brought to the shore. On each side 10 to 20 men drag the net. As the net is pulled, the two parties progressively come closer till the net has come close to the shore. As the net is hauled up, the wings are carefully guarded to remain as walls to prevent escape of fish and the mouth of the net is closed till it is completely pulled on to the shore.

iii. *Bag net operation* : The catamaran of this area is made up of three logs of wood tied in such a way that the middle one is at a lower level than the other two at the sides (Pl. VII, fig. I).

The catamarans work in pairs. One in each pair is slightly longer and wider than the other. The bigger one is about 7 metres long and 0.9 metres wide while the smaller one is about 6.5 metre long and 0.8 metre wide. A light bamboo of about 10 metres length which serves as a mast carries a triangular sail of cotton cloth. The two crafts are tied together at the anterior ends in a converging manner to minimise friction in sailing. The mast and sail are common to each pair of catamarans. Two men form the crew of each catamaran.

The net called 'madi valai' (madi = bag; valai = net) consists of a bag-like portion with side wings (Fig. 54, B). The bag is about 9 metres long and 1.8 metres wide at the mouth. The cod end measures about 60 cm. and has a mesh of 0.5 cm. The bag is preceded by the hemp wings which measure 46 metres on either side and are in turn followed by the warps of the same length. At the junction of the hemp wing and the warp a single float is attached to the head rope and a sinker to the foot rope.

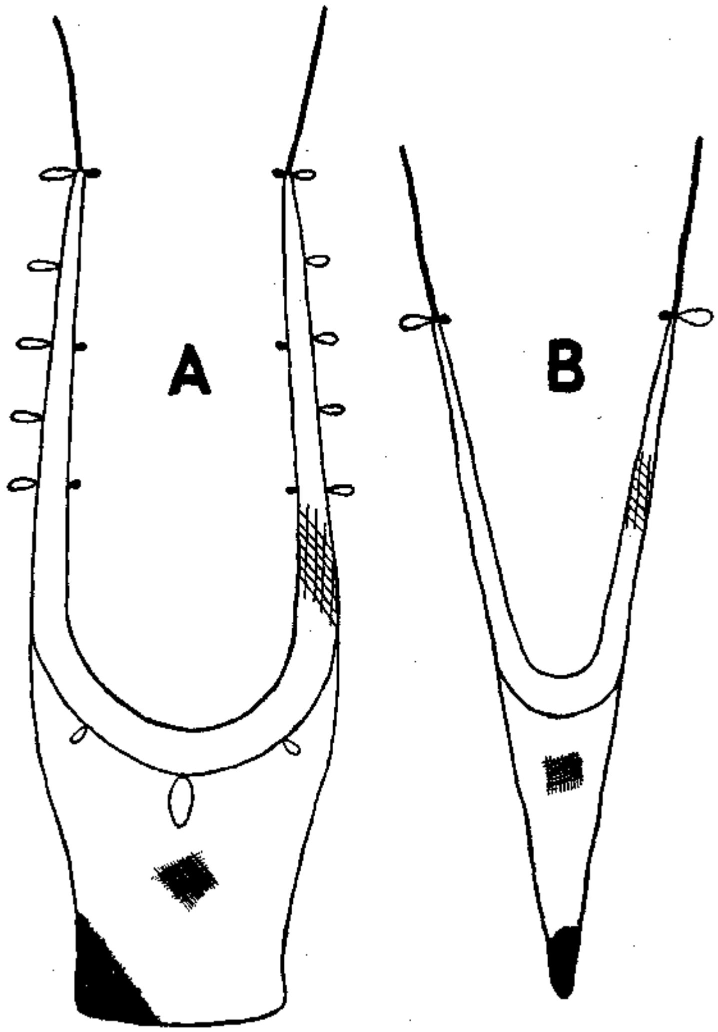

Fig. 54. Diagrammatic representation of (A) shore-seine and (B) boat-seine or bag net.

The net is shot from two catamarans which simultaneously move apart and proceed in the direction of the wind. After 15 to 30 minutes the two catamarans come close together and at the same time pulling the warps of the net. When the two catamarans lie side by side the bag portion of the net comes to the surface. The almost total absence of free board in catamarans enables this net to be hauled with ease. The fishes are transferred from the cod end of the net to palmyra leaf baskets. The operations are repeated till the baskets are full or it is time for their return to the shore.

iv. *Fishing season in Palk Bay and the Gulf of Mannar* : The north-east monsoon commences in October-November and lasts up to March-April. During this period Palk Bay becomes rough and hence it becomes difficult to operate the nets at most of the places along this coast. However, at some places fishing is continued in this season also except for a few days when the sea becomes very rough. But during this period fishing is carried out in the Gulf of Mannar where the sea is relatively calm. The south-west monsoon commences in March-April and lasts till October-November during which time the Gulf of Mannar becomes rough and all fishing operations remain suspended. During this period intense fishing is done on Palk Bay side.

vi. *Trend of the fishery* : Of the three species of ribbon-fishes mentioned above *E. intermedius* is fairly abundant round the year on Palk Bay side (specially at Panaikulam and Athankarai) and for a restricted period on the Gulf of Mannar side (Pudumadam). Very young and immature fish are landed along with other fishes in bag nets at Thangachimadam. At other localities, this species occurs only as stray individuals. The second common species, *L. savala*, is usually fished during the north-east monsoon time at fishing centres on Palk Bay. After about February catches for this species are poor. The third species, *T. lepturus* makes its appearance only sporadically in this area. Individuals measuring even up to three fourths of a metre are occasionally met with at several places. This species is sometimes landed in appreciable quantities on the Rameswaram Island, in shore seines and drift nets (Vali valai). On such occasions, it probably moves in shoals in the inshore waters. There were recent reports of such instances (September-October 1962) when they were caught in enormous numbers on this island. The commercial catches of ribbon-fishes in this area are constituted by *E. intermedius* in the size range of 14-35 cm.; *L. savala* between 12-35 cm. and *T. lepturus* between 50-75 cm. Generally, the season for the fishery extends from August to about March with peak occurrence from November to February.

vi. *Disposal of catch* : When the catch of ribbon-fishes is only limited, the large fish are consumed locally in fresh condition and the small fishes are usually sun dried on the beach. When heavy catches are obtained, they are pit-cured with salt and sent by rail to interior places for marketing.

3. Particulars of Catch

Particulars of total marine fish production, annual ribbon-fish catch and their percentage composition in India during the period 1950 to 1965 are presented in Table LXIX.

TABLE LXIX

*Total marine fish production, ribbon-fish catch and its percentage in total catch in India during the years 1950 to 1965.**
(Catch in metric tons)

Year	1950	1951	1952	1953	1954	1955
Total marine fish production	579994	533890	528322	581434	588229	595696
Total ribbon-fish catch	18107	16945	35666	56296	29554	32669
Percentage	3.12	3.17	6.75	9.68	5.02	5.48

Year	1956	1957	1958	1959	1960	1961
Total marine fish production	718702	875420	755774	584193	878242	683569
Total ribbon-fish catch	24481	38427	41918	31830	17467	19515
Percentage	3.40	4.38	5.54	5.44	1.98	2.85

Year	1962	1963	1964	1965
Total marine fish production	644244	655484	859582	815120
Total ribbon-fish catch	20586	16452	25891	41298
Percentage	3.19	2.50	3.01	5.06

* Particulars taken from the Annual Reports of the Central Marine Fisheries Research Institute, Mandapam Camp.

It may be seen from the above table that the ribbon-fish landings were maximum in the year 1953 (9.68%) and minimum in the year 1960 (1.98). It was estimated, on the average for 10 years (1951 to 1960), ribbon-fish landings amount to 32526 metric tons constituting 4.9% of the total marine fish landings and occupying seventh place in the commercially important fishes of India.

4. Economic Importance

As judged by the magnitude of the fishery they support, ribbon-fishes occupy an important place among marine fishes of India. Although not considered a quality fish, they are consumed by all people and being abundant and cheap, they are especially preferred by the common man. Large fish are generally preferred for fresh consumption, while the smaller ones are sun dried. Being thin and ribbon-like they are best suited for this method of preservation which is more economical. During seasons of abundance,

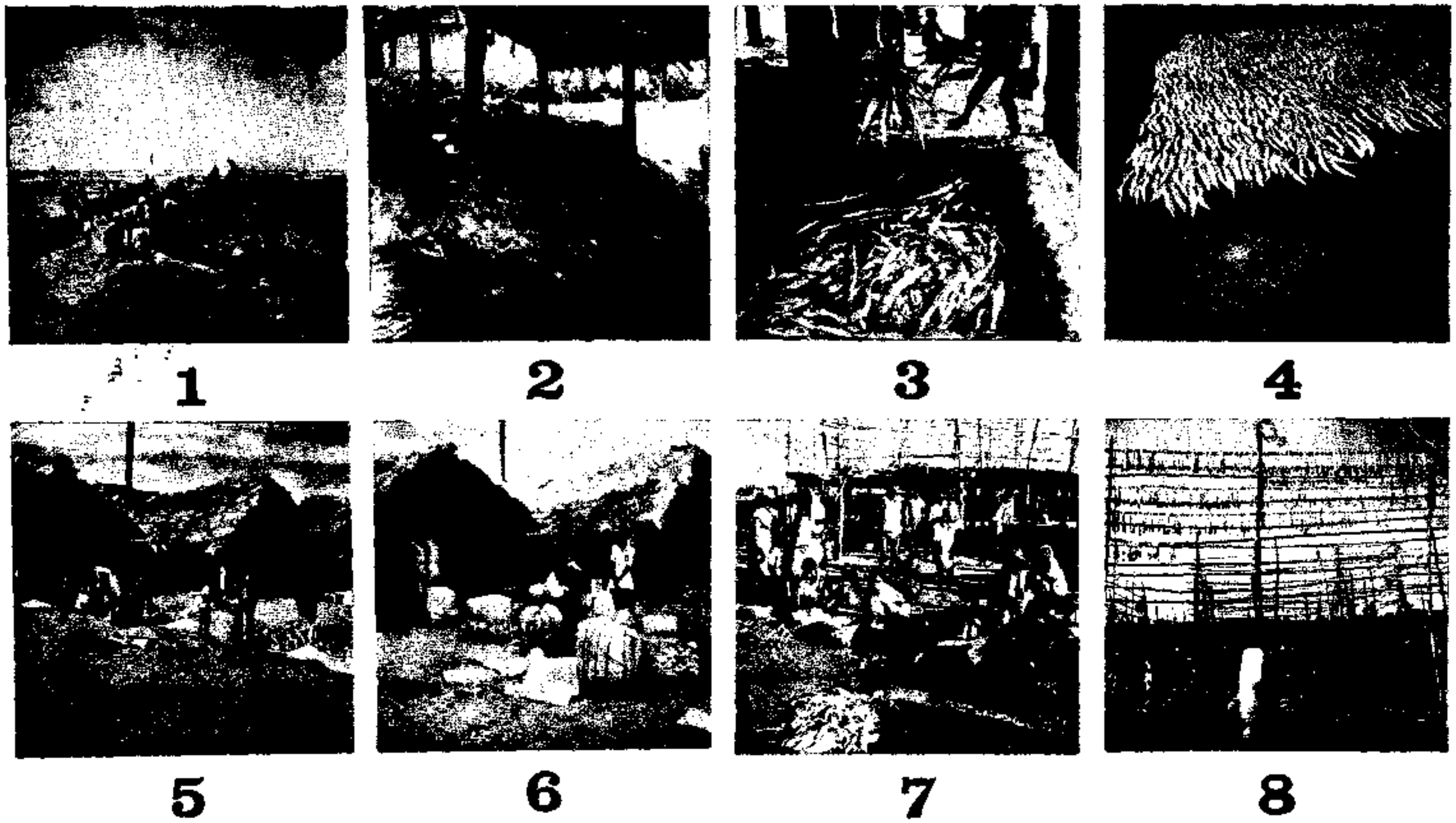

PLATE VII

1. One of a pair of catamarans from which bag net is operated. 2 A heap of ribbon-fishes with intermediate layers of salt during the process of salt curing 3 and 4. Washing and sun drying the salted ribbon-fishes. 5 and 6. Packing the cured ribbon-fishes. 7 and 8. Sorting of ribbon-fishes and their sun drying on specially erected wooden frames along the Bombay coast.

these fishes are cured by various methods, the most popular being the salt curing method. The simplest way is to keep the fish for a day in salt solution and then dry them in the sun on the beach. At some places, salt amounting to even 25% of the weight of fish is used for curing. In such cases, salt is sprayed over layers of fish heaped on palmyra leaf mats (Pl. VII, fig. 2). The heaps are left in that condition for at least four or five hours. Then the heaps are turned, more salt is added and the fish muscle is slit laterally in several longitudinal lines for better penetration of salt and easy preservation. Next day, the fishes are washed thoroughly in water kept in cement tanks and then dried in sun (Pl. VII, figs. 3,4). Another method is to keep the salted fish with intermediate layers of salt in rectangular cement tanks and press them down with feet. The third day the cured fishes are taken out, washed and carefully packed in palmyra leaf baskets with alternating layers of salt (Pl. VII, figs. 5,6). This method is employed when there is a special market for this product. The salt cured fish is costlier than the sun dried, the former costing Rs. 1.20 per Kg. while the latter costs only Rs. 0.70 per Kg. along the southeast coast of Madras.

Along Bombay coast, trichiurids are usually sun-dried. The fish are tied in bundles at the tail portion and these bundles are hung on wooden stands erected along the shore for drying a variety of fishes including the ribbon-fish (Pl. VII, figs. 7,8). The fish are left in this condition for a varying number of days till they are perfectly dried.

At various places along the east and west coasts of India ribbon-fishes are also used as an effective bait for bigger fishes, specially those caught on the hook and line. This was specially observed in Andhra Pradesh, Madras and Maharashtra States. The head and tail portions are removed, the middle portion cut into pieces and used as bait. Seer, tuna, carangids, eels, catfishes and sciaenids are some of the fishes commonly caught with this bait. Apart from local consumption both in the fresh and cured states, great quantities of the cured products are exported to countries like Ceylon and Malaysia. It is said the products have good market in those places.

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* Not referred to in original.

ADDENDUM

ON TWO RECENT REPORTS OF FOUR NEW SPECIES OF RIBBON-FISHES (FAMILY TRICHIURIDAE) FROM INDIA

After the present work has gone to Press in August 1966, two short accounts of four new species of ribbon-fishes (Family Trichiuridae) from India have been published, which call for comments here.

Gupta (*Proc. Zool. Soc. Calcutta*, 19(2): 169-171, October 1966, issued on 25-2-67) described briefly two new species of ribbon-fishes of the genus *Trichiurus* Linnaeus, *viz.*, *T. gangeticus* and *T. pantului* from the Hooghly estuarine system, surprisingly without citing any earlier literature. According to him, both species are closely related to *T. haumela* (= *T. lepturus*). Examination of holotypes, paratypes and other specimens referable to these species in possession of the present author indicate that, while the characters given for *T. gangeticus* are noticeable and distinctive, those of *T. pantului* (especially, the second anal spine being more than diameter of pupil and some of the anal spinules with serrations) are not seen even in the holotype and paratypes and therefore invalid. The other characters of *T. pantului* are inadequate to make distinction from *T. lepturus* and hence the former is considered synonym of the latter.

Subsequently, Dutt and Thankam (*J. Bombay nat. Hist. Soc.*, 63(3): 755-758, December 1966, issued on 20-7-67) described two more new species of trichiurid fish from Waltair, namely *Trichiurus russelli* and *Lepturacanthus serratus* refering to pertinent earlier literature including the present author's observations (*J. Mar. biol. Ass. India*, 3 : 234, fig. 14, 1961). Examination of published details of *T. russelli* and *L. serratus* show that they agree with *T. pantului* and *T. gangeticus* of Gupta (op. cit.) except that 1) their affinity is aptly indicated by Dutt and Thankam (*op. cit.*) by placing them in two different genera with which the present author is in agreement, instead of both being placed under the genus *Trichiurus* as done by Gupta (*op. cit.*), 2) the dorsal rays and anal spinules of *T. russelli* are shown in the figure as extending almost to tip of tail (rather unusual in ribbon-fishes) and 3 serrations reported on some anal spinules of *T. pantului* are not mentioned for *T. russelli*.

Since the above mentioned two pairs of new species represent, if at all, but two new species, the correct nomenclature should only be *Trichiurus pantului* Gupta for the first species(which is a synonym of *T. lepturus*, therefore *nomen-nudum*) and *Lepturacanthus gangeticus* (Gupta) for the second species, synonymising *T. russelli* Dutt and Thankam with the former and *L. serratus* Dutt and Thankam with the latter. Therefore, the second report of two new species has, in substance, suggested only a nomenclatorial change.

Preliminary observations indicate, however, that the new species are not adequately described. Based on an examination of material and published details, it appears that, if at all there is any case for distinction, it may be for *L. gangeticus* (especially based on its meristic counts and serrations in the pectoral spine) and not for *T. pantului* which is considered a synonym of *T. lepturus*.

While only brief comments on the new species are given here, full details are being published in Volume 9 of the Journal of the Marine Biological Association of India.