THE SYSTEMATICS OF INDO-PACIFIC *SAURIDA* AND *TRACHINOCEPHALUS* (PISCES: SYNODONTIDAE) AND THE BIOLOGY OF FOUR LOCAL SPECIES.

by

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MARCH, 1984

Thesis submitted for the degree of
Doctor of Philosophy
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ABSTRACT

Lizardfish species of the genera *Saurida* Cuvier and Valenciennes and *Trachinocephalus* Gill 1862 in the Indo-Pacific are morphologically cryptic and widely distributed. Their habitats range from shallow water to deeper waters, sand/muddy bottoms or reefs.

Many morphological features of lizardfish are variable and often of limited value in establishing taxonomic relationships. Synonymies and especially misidentifications are prevalent. An exploratory electrophoretic analysis confirmed intra-specific variation but also revealed specific differences which reflected species affinities. Accordingly the diagnosis of Indo-Pacific Saurida is revised and eleven species - *S. argentea, S. australis, S. elongata, S. filamentosa, S. flamma, S. gracilis, S. isarankurai, S. longimanus, S. nebulosa, S. tumbil* and *S. undosquamis* - are described. *S. australis* is removed from the synonymy of *S. undosquamis* and inter-relationships between members of the genus are described. *S. wanieso* and *S. micropectoralis* both described by Shindo and Yamada (1972) are synonymized under *S. filamentosa* and *S. argentea* respectively. *S. wanieso* is considered as a geographical race of *S. filamentosa* whereas *S. micropectoralis* is, by priority, a junior synonym of *S. argentea*.

The biology of lizardfish were studied from collections taken within and without Moreton Bay between August 1979 and December 1981. The analysis of stomach items and morphological adaptations revealed that the food and feeding strategies of lizardfish consist of adaptability to a wide range of food items, food sizes and environmental conditions instead of specialization to few food items. The most important component of stomach items (by frequency of occurrence) were fish in over 85% of stomachs analysed (i.e. those with food). The other two major components were Crustacea and Cephalopods in about 5-16% and about 7% respectively.

Stomach content analysis indicated that lizardfish fed during both day and night. Mouth and body structures are well suited to their hunting techniques and carnivorous mode of feeding.

Lizardfish reproduction within and without Moreton Bay is described with emphasis on the development of the gonads. Four types of eggs based on size and yolk content are described. Eight and six stages of identifiable gonads based on a) types and quantities of ova present and b) texture and macroscopic appearance are described for the ovaries and testes respectively.

The species exhibit size polymorphism - the females predominate in sizes greater than male $S.L_{50}$ whereas the males predominate in sizes about the male $S.L._{50}$ and below. The reproductive strategy involves an extended spawning season, early maturation, high fecundity coupled with serial spawning.

The ages of *S.tumbil*, *S. undosquamis* and *T. myops* on the one hand and *S. filamentosa* on the other were determined by the scale and vertebrae methods respectively and were supplemented by the length frequency method. The observed maximum ages in the species were 5, 4, 12 and 3 for *S. undosquamis*, *S. tumbil*, *S filamentosa* and *T. myops* respectively. Lizardfish growth is asymptotic and allometric and was described in terms of Von Bertalanffy and other growth parameters. The overall growth strategy apparently involves a number of features - very rapid linear growth, early maturation, annual and allometric growth.

The four lizardfish species were parasitized by cestodes, hemiurid trematodes, nematodes, isopods and acanthocephalans. Negative binomial distribution (truncated and non-truncated) analyses in comparison with actual frequency distribution of the most common parasite in Moreton Bay, *Callitetrarhynchus gracilis* (Rudolphi) 1819, suggested that 'heavily' infected fish were missing from the samples.

STATEMENT OF RESPONSIBILITY

This thesis is an original work and has not been previously submitted to another university. Assistance received and any information not derived from the study are specifically acknowledged.

EBENEZER LARYEA ADJEI

ACKNOWLEDGEMENT

I am grateful to Professor J.M. Thomson for his supervision, for translating some articles in Russian and critical reading of the manuscript.

Many people have been very helpful during the course of this study and to all I extend my sincere gratitude. In particular I would like to thank - Dr. R.J. McKay and Mr J. Johnson of the Queensland Museum, Brisbane; Dr. J.R. Paxton of the Australian Museum, Sydney (AMS) and Dr. B.C. Russell formerly of AMS but now at the Smithsonian Institute, Washington - for loan of material, for providing some important literature references and laboratory space during the study.

I am especially grateful to Mr. Les Wale, skipper of the University research vessel, 'Sea Wanderer', for his pleasant company and considerable efforts he put in in obtaining specimens from Moreton Bay and also for setting up contacts with some professional fishermen who assisted me in many ways, in particular Mr. Bob Sanderson, then skipper of the 'Rex Andria' who provided the deep sea specimens.

Messrs S. Cook, D. Webb and Dr. N. Bruce often provided assistance in the field. Messrs S. Cook, C. Keenan, A.P. Bradshaw and W. Thomas of Zoology Department very often collected specimens for me during their field work on Moreton Bay. On the other hand, Messrs Greg Campbell, Queensland Fisheries, Bundaberg; B. Wallis, skipper of 'Curlew' Innisfail; Dr. H. Sweatman, Centre for Environmental and Urban Studies, Macquarie University; the crews of FV Courageous and FRV Soela and Dr. K. Sainsbury all of CSIRO, Cronulla provided specimens from the Great Barrier Reef and the North West Shelf.

In addition I would like to thank the following persons or curators of fish for loans of personal or museum collections - Dr. P.J. Whitehead, British Museum of Natural History,

London (BMNH); Dr. V.G. Springer, National Museum of Natural History - Smithsonian Institution, Washington; Dr. J.E. Randall, Bernice P. Bishop Museum, Honolulu; Mr. John Paska, Kanudi Fisheries Research Museum, Konedobu, Papua New Guinea; Dr. Y. Tominaga, University of Tokyo Zoology Museum; L.E. Timms, Department of Primary Production of the Northern Territory of Australia, Fisheries Division; Mrs. P.J. Kailola, Fish Taxonomy consultant, Adelaide and Mr. T. Gloerfelt-Tarp of Bali, Indonesia.

Summaries of occurrences of lizardfish from North West Cape to Darwin, and off New South Wales were supplied by Dr. Grant West, CSIRO, Cronulla and Mr. R.J. William, New South Wales State Fisheries, Sydney respectively.

Dr. J.B. Shaklee, CSIRO, Cleveland and Mr. C. Keenan provided equipment for electrophoretic runs.

I would also like to thank Dr. R. Lester, Parasitology Department, University of Queensland for the identification of cestode and nematode parasites and discussions on data of cestode larvae; Dr. D.I. Gibson, BMNH, for the identification of stomach trematodes of *S. undosquamis* and Dr. N. Bruce, formerly of Zoology Department, University of Queensland, now with Smithsonian Institution, Washington for the identification of crustacean parasites.

My gratitude to the technicians of Zoology Department for their help with equipment on many occasions - in particular, to Mr. T. Dyer, the Chief Technician, and to Mr. T. Gorringe for his invaluable help and patience in photographing the dental configuration of lizardfish.

The staff of the Biological Sciences Library were very helpful in obtaining literature references, especially inter-library loans. Miss Margaret Russet formerly of University of Queensland, and now at Batemans Bay kindly translated several articles in French.

Mr. W. Hutchinson, the Administrative Officer of Zoology Department, was very helpful on administrative matters.

My sincere thanks to my friend Miss Lidia C. Meszaros for her support and encouragement, and also for typing the manuscript.

The research was funded by University of Queensland Research Grants. The Ghana Government (University of Ghana) provided only for living expenses between July 1979 and March 1983.

Finally, I would like to thank my step-father, Mr. F.P.K. Amo-Tenkorang, and especially my mother who had to take out a mortgage to see me through the initial years of secondary school when my father refused to help. And also my brother Mr. W. Adjetey Adjei and sisters Helena and Sabina Adjeley Adjei who have supported me whenever possible in my academic career so far.

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1. GENERAL INTRODUCTION

The family Synodontidae is a group of fish characterized by lizard-like head, spineless fins and a small adipose fin and are almost circumtropical in distribution.

The family, represented on a conservative estimate by 40 species belonging to three genera have some of the most abundant species in the Indo-Pacific region. These species, especially *S. undosquamis*, *S. tumbil* and *S. elongata* form the basis of important commercial fisheries for food or poultry feed in Israel (Ben-Tuvia, 1953; Latif and Shenouda, 1973; Ben-Yami and Glaser, 1974), India (Rao, 1974), Gulf of Thailand (Ruamragsa and Isarankura, 1965; Vadhanakul, Eiamsa-ard and Kuantanom, 1975; Sinoda and Intong, 1978; Sinoda, Lim and Tan, 1978), Sunda Strait, northern and north-western shelves of Australia (Liu, Lai and Yeh, 1978; Liu and Lai, 1980) and the seas of China and Japan (Liu and Tung, 1956; Liu and Chen, 1959; Tatara, 1965). In Japan they are the raw material for meat paste known as 'Kamaboko' or 'Himodori' (Makinodan and Ikeda, 1971; Akashi and Oono, 1972; Suzuki, Kanna, Okazaki and Morita, 1978; Kurokawa, 1979; Yamazawa, Murase and Shiga, 1980). Although about 25 lizardfish species occur in Australian waters (See Castelnau, 1878-79; Macleay, 1882; Ogilby. 1897, 1910a,b; Waite, 1905 - 08; McCulloch, 1920-22, 1927, 1929 - 30, 1934; Norman, 1935; Whitley, 1943, 1948; Marshall, 1964; Grant, 1965, 1972, 1975, 1978; Shindo and Yamada, 1972; Allen, Hoese, Paxton, Randall, Russell, Starck, Talbot and Whitley, 1976; Russel and Cressey (1979); Cressey, 1981) they are unacceptable to the Australian market because of their rather insipid nature. Notwithstanding they are a potential resource for export-oriented fisheries in Australia.

In the development of reliable management strategies, correct identification of the species is paramount. Incorrect or inconsistent identification of fish species form a fundamental block to the scientific management of fisheries by preventing both biological studies and the collection of reliable fisheries statistics.

In 1981, Roger Cressey of the Smithsonian Institute, Washington, published a comprehensive review of the species of the genus *Synodus* of the Indo-West Pacific region. However the current taxonomic literature on Indo-Pacific *Saurida* is unsatisfactory and is plagued by synonymies, incorrect and inconsistent identifications. With regards to the biology of lizardfish, too often in the past, many authors have been content to accumulate sometimes unrelated facts, mainly anecdotes. The two most studied species are *S. undosquamis* and *S. tumbil*, many of these studies over short periods and even some tainted with incorrect identification (i.e. polyspecific samples e.g. Okada and Kyushin, 1955; Liu and Tung, 1959; Rao, 1974) and have thus depreciated the fishery management value of the studies.

The present study is divided into two sections, the first dealing with the taxonomy and distribution of Indo-Pacific *Saurida* and *Trachinocephalus* as a whole, and the second with the biology of four abundant local species. Under the first section the taxonomy has been revised. The revision provides identification keys as well as descriptions, figures, synonymies and distributions for all species. The problem of inter- and intra-specific variation which has plagued their classical or conventional systematics, as with many other cryptic species, was investigated by exploratory electrophoretic analysis of general and specific (enzyme) proteins. This aspect of the study is reported on under - "Morphological and biochemical systematics of Indo-Pacific lizardfish". The biology involved the collection and analyses of baseline data on adaptive strategies for or to

1) food and feeding
2) age and growth
3) reproduction
and 4) parasites.

The principles and common methods in use for the study of the four topics just mentioned are described and/or discussed in the various introductory sections. The synthesis of the results on the various topics was undertaken in a general discussion with the view of elucidating the obvious success of the family in the Indo-Pacific region.

1.1 MATERIALS AND METHODS

1.1.1 Systematics

Where possible materials held by museums were obtained and examined, especially from the Queensland Museum, Brisbane (QM), Australian Museum Sydney (AMS) and B.P. Bishop Musuem Honolulu, Hawaii (BPBM). Trips were also made to QM and AMS to examine collections which could not be borrowed for various reasons. Data and *fresh specimens of Synodontidae of the North and North-Western shelves of Australia were obtained by crews of FV Courageous and FRV Soela, both of the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Cronulla, New South Wales. Also many **people provided many other specimens from various parts of the Indo-Pacific region. Personal collections were also made within and off Moreton Bay.

* Used for electrophoresis.
** Details provided in appropriate sections.

1.1.2 BIOLOGY

1.1.2.1 Collection of Samples

Samples of the four abundant local species - *Saurida tumbil* (Bloch) 1795, *S. undosquamis* (Richardson) 1848, *S. filamentosa* Ogilby 1910 and *Trachinocephalus myops* (Bloch and Schneider) 1801 - were collected by bottom trawls. *S. undosquamis* and *S. tumbil* and a handful of *T. myops* were obtained by *forty-minute otter trawls using the University's trawler 'Sea Wanderer' in Moreton Bay from depths between about 10 to about 40 metres between August 1979 and December 1981. Large specimens (2) of *S. undosquamis*, the bulk of *T. myops* and all of *S. filamentosa* were obtained outside Moreton Bay, between 32-64 kilometres north of Cape Moreton from depths of about 80-200m mainly between May 1980 and February 1982. Any significant observations on condition of fresh fish with regards to reproduction (e.g. running eggs or milt and spent individuals), and parasites (ecto- and sometimes endo-parasites) were noted in the field and those individuals marked. The nature of the bottom of the section of bay trawled (gauged by sediments brought up with catches) was noted.

1.2 MORETON BAY (Fig. 1.1)

Figure 1.1 shows the trawled areas or stations in Moreton Bay.

Moreton Bay is a subtropical water mass. It is bordered by the Moreton and North Stradbroke Islands but linked to the Pacific Ocean by a number of channels.

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* Unless otherwise stated.

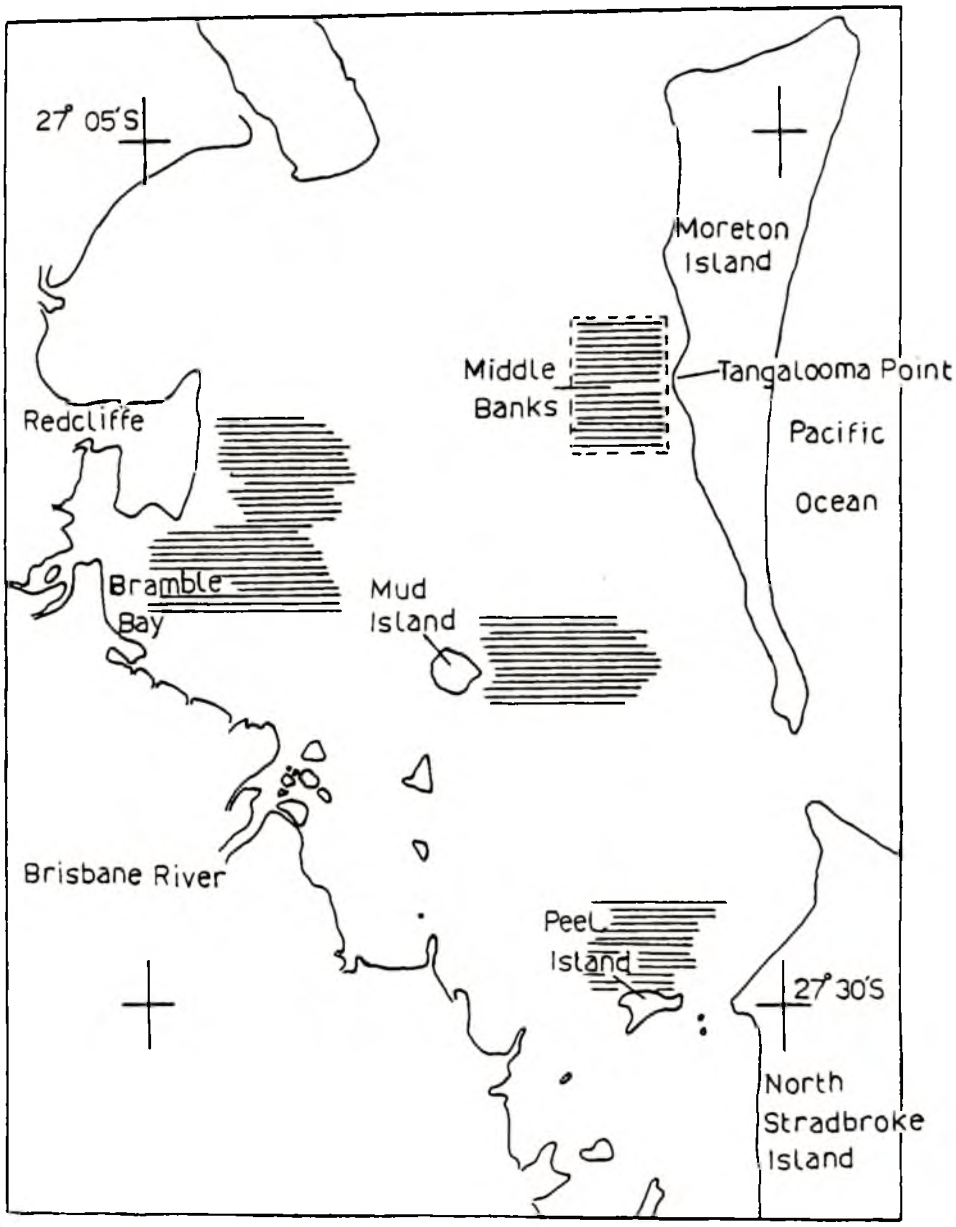

Fig.1.1 : Map of Moreton Bay showing areas trawled.

Moreton Bay is also partly a complex estuarine system into which drain a number of rivers - Brisbane, Logan-Albert, Pine, and Caboolture. There are a number of islands in the bay, especially in the Southern Section. Apart from those islands close to estuaries (i.e. Fisherman, Mud and Macleay), all are surrounded by ill-defined fringing reefs extending to depths of 2-4 metres and dominated by *Favia speciosa* (Dans). (See Stephenson, Williams and Lance, 1970; Stephenson, Williams and Cook, 1974; Stephenson, Cook and Newlands, 1978; Stephenson and Williams, 1981).

Fish samples were regularly taken from the following areas: Bramble Bay, off Redcliffe, east of Mud Island, north of Peel Island and from Middle Banks (especially from Tangalooma Point). For safety reasons and also possible damage to gear, trawling was restricted to the above areas since many of the other areas were too shallow, had wrecks or were too confined for safe trawling.

1.3 TREATMENT OF SAMPLES

All samples for biological *study were preserved in 5-10% formalin and returned to the laboratory. After three weeks of formalin preservation, formalin was washed off fish four times with fresh tap water and then soaked out in tap water for two days, presumably to remove more formalin trapped in the body cavity.

Each fish was given a reference number and the following biological observations were noted after excess water had been drained off and also removed with paper towel:-

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* Some were also used in conventional systematic studies.

Standard *length	-	the perpendicular distance between the snout tip and the crease of the caudal fin (was measured to the nearest 1mm on a measuring board i.e. the posterior margin of the hypural bones).
Whole body *weight	-	measured to the nearest 0.1 g.
Food and Feeding	-	types of items in stomach, length and weight of some well preserved prey specimens, diurnal feeding activity (gauged by fish numbers and stomach fullness with time), and morphological adaptations associated with food and feeding.
Age	-	determined from scales or vertebrae and length frequency analysis.
Growth	-	as indicated by changes in weight and length of fish.
Sex	-	determined by examining gonads under a dissecting microscope.
Reproduction	-	as indicated by changes in weight and texture of gonads.
Parasitology	-	types of ecto- and endo-parasites and also the analysis of numbers of the common parasite and its effect on the species.

* All references to length and weight unless otherwise stated refer to standard length and whole body weight respectively.

1.4 CHANGES IN WEIGHT AND LENGTH OF FISH AFTER FIXATION IN FORMALIN FOLLOWED BY SOAKING IN WATER

The changes (loss or gain in weight or length varied with the individual fish, most probably its physiological state. The results for 38 *S. undosquamis* and 20 *S. tumbil* are summarized in Table 1.

Table 1 : Effect of formalin on Length and Weight

Species		Percentage changes (±) in					
		Weight			Length		
		*Duration		After Soaking out in water	*Duration		After Soaking out in water
		24hrs	3 weeks		24hrs	3 weeks	
S. undosquamis ** (121-182mm)	range	0.3-6.4	0.7-7.1	0.6-3.4	0.0-4.8	0.0-3.0	0.0-1.4
	Average	2.5	3.5	2.2	1.0	0.8	0.4
S. tumbil ** (124-267mm)	range	0.0-7.4	0.4-2.5	0.3-1.9	1.0-4.8	1.8-4.6	1.0-2.8
	Average	2.0	1.1	1.6	2.4	3.3	1.9

* of treatment in formalin

** size range.

In a study of Pond and Amur wild carps, Amosov (1960) found changes in weight and length to be between 0.1 - 7.3 and 0.20 and 0.93 respectively.

1.5 DATA ANALYSES

Statistical methods followed Sokal and Rohlf (1969) and to a limited extent "Statistical Package for the Social Sciences" (SPSS) documented in

Nie, Hull, Jenkins, Steinbrenner, Bent (1975),
Statistical Package for the Social Sciences
Second Edition
McGraw-Hill Book Company.

Other statistical texts were also consulted and are mentioned in the appropriate sections.

Methods - hypotheses or models - employed in the analyses of age and growth were mainly taken from Ricker (1975) and Bagenal (1978). The analysis of parasite data (i.e. distribution of cestode larvae) followed Crofton (1971).

2. MORPHOLOGICAL AND BIOCHEMICAL SYSTEMATICS

2.1 INTRODUCTION

All species are the product of an historic process; speciation: first and foremost the establishment of reproductive isolation and a subsequent divergence of the population. The concomittant adaptations with speciation enable the species to meet their environmental conditions. The survival in, and the effective utilization of an heterongeneous environment by a species might entail the possession or the acquisition of a variety of adaptive responses (i.e. intra-specific variation in responses/ morphology) by members of the population. This variation in species can either be genetically or environmentally induced, or can be the product of a combination of the two. With time groups corresponding to varieties of adaptive responses become new species if reproductively isolated.

Proper identification of species is a pre-requisite for most ecological studies, and this identification is dependent upon an adequate classification being available. Unfortunately, more often than not, it is very difficult to distinguish between inter- and intra-specific variation using techniques of classical or conventional taxonomy. However, each change in an organism can ultimately be traced to alterations occurring at the molecular level, at least in theory and with the application of protein analysis, especially the electrophoretic studies of genetic variation, inter- and intra-specific variation of species and also the reproductive strategy practised by species are rather easily circumscribed.

In the past thirty years, electrophoretic analysis of proteins have been used to elucidate the evolutionary process and also to disentangle many inter- and intra-specific variations:

a) in populations - e.g. Imhof, Leary and Booke (1980) demonstrated the existence of at least four populations of lake whitefish *Coregonus clupaeformis* (Salmonidae) in northern Lake Michigan.

b) in species and/or genera of e.g. Albulidae (Shaklee, Tamaru and Waples, 1982), Mugilidae (Anderson, 1982), Percichthyidae (MacDonald, 1978), Salmonidae (Ferguson, 1974; Ferguson, Himberg and SVardson, 1978), Scorpaenidae (Tsuyuki, Roberts, Lowes Hadaway, and Westrheim, 1968), Synodontidae (Shaklee et al, 1982; Taniguchi, 1969). Shaklee et al (1982) found strong agreement between the estimate of relationships based on genetic distance values and that based on morphological similarity in *Synodus ulae, S. variegatus, S. englemani, S. binotatus and Saurida gracilis.*

Despite these findings some school of taxonomists have been very wary of these "biochemical species". This state of affairs is adequately summed up by Moss (1979) - "Advances in data and technique can provide additional dimensions of knowledge, but they also pose a continual challenge: How does one integrate and reconcile them with existing classifications? Some taxonomists are inclined to believe that only new data sources and new techniques yield crucial insight; others are more inclined to stretch the existing classifications rather than to demolish them".

2.1 Historical review of the classification of Lizardfish

Lizardfish belong to a group of fish usually referred to as 'iniomous' fish. *Regan (1911) considered these iniomous fish as 'marine malacopterous physostomes with the pelvic fins abdominal or thoracic in position, and the pelvic bones free from the cleithra; an adipose dorsal fin

* Quoted in Harry, 1952.

is typically present, the premaxillaries exclude the maxillaries from the gape, the gill openings are wide, the pectoral arch is attached to the skull by a forked post-temporal, there is no mesocorocoid, the lateral centra are co-ossified with the arches, the air bladder is small or absent, and the ovaries are provided with oviducts.' *Prior to Regan's definition, the ordinal level of these fish was variously and correctly or incorrectly referred to as Cyprini (Bonaparte 1832-41, 1846), Physostomi (Müller, 1944; Gunther, 1864, 1880, 1887), Isospondyli (Gill, 1872; Jordan, 1905), Malacopterygii (Gill, 1893, Goode and Bean, 1895a, b), Teleostei (Boulenger, 1904) and Haplomi *sensu* Gill (Gregory, 1907). The name 'Iniomi' ('Iniomes') was first proposed by Gill in 1884 to describe Sternoptychidae and its near relations. *However between 1896 and 1940 'Iniomi' was commonly used to describe the ordinal level (Jordan and Evermann, 1896; Regan, 1909, 1911, Jordan, 1923; Parr, 1928, 1929) and Berg (1940) referred to the Iniomi as Scopeliformes.

Most of the above works placed emphasis on osteological characters and sometimes with very little research (Harry, 1952). Harry *(op cit)* grouped iniomous fish into three orders based on his research on anatomy and classification:

1. Iniomi (with suborders Myctophoidea (Aulopodoidea) and Alepisauridea (Paralepidoidea).
2. Cetunculi.
3. Ateleopodes

In recent times iniomous fish (Iniomi) have been referred to as Myctophiformes (Gibbs, 1959; Golvan, 1962; Mead, 1966; Okiyama, 1974; Masuda, Araga and Yoshino, 1975; Sulak, 1977) though in a general classification of teleostean fish using modern concepts of phyletic classification, Greenwood, Rosen Weitzman and Myers (1966) assigned iniomous fish to Salmoniformes *sensu lato*. The order Myctophiformes is frequently

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* See Harry 1952.

divided into two suborders, Myctophoidea/Myctophoidei and Alepisauroidea (Mead, 1966; Okiyama, 1974). Markle, Scott and Kohler (1980) however put the family Synodontidae under order Aulopiformes.

The familial classification of lizardfish has not been without a diversity of names either. The *family name of this group of fish has been variously given as or placed under Scopelidae (Bonaparte 1832-41, 1846; Gunther 1864, 1880, 1887; Macleay, 1882; Day, 1878-88; Boulenger, 1904; Gregory, 1907; Goodrich, 1909), Scopelini (Müller, 1844), Aulopidae (Cope, 1871), Synodontidae **(Gill, 1862, 1872, 1893; Goode and Bean, 1895a, b; Jordan and Evermann, 1896; Ogilby, 1897; Jordan, 1905, 1923; Regan, 1909, 1911, 1929; Parr, 1929; McCulloch, 1920-22, 1927, 1929-30, 1934; Romer, 1945; Munro, 1961; Greenwood et al, 1966; Nielson, 1973; Linberg, 1974; Masuda, Araga and Yoshino, 1975; Sulak, 1977; Coleman, 1980), Alepidosauridae (Goodrich, 1909), Myctophidae (Parr, 1928), ***Synodidae (Ogilby, 1910a; Berg, 1940; Golvan, 1962; Dutt, 1973; Rao, unpublished), ***Sauridae (Rao, unpublished).

2.1 The Family Synodontidae

According to the +Zoological Code, 'Synodontidae', first proposed by **Gill (1862), is the correct etymological name of the family of lizardfish. Though the type genus of the lizardfish family is *Synodus* (Gronow) Scopoli, 1763, its family name (Synodontidae) is based on Synodontis Cuvier, 1817, the type genus of the family of African freshwater catfish (now Mochochidae). The discrepancy is due to a once held

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* See Harry (1952).

** Established as Synodontoidae in 1861 and amended to Synodontidae in 1872.

*** Also see Linberg (1974) p. 279.

\+ Article 28, p. 81 of the Bulletin of Zoological Nomenclature Vol. 31, 1974.

belief that the two groups of fish were closely related as reported by Gunther in 1864 - 'These *fishes show a great resemblance in the family characters to the Siluroids; they might be called the marine Siluroids.' Thus some taxonomists (e.g. Dutt, 1973) have persisted with Synodidae to indicate the difference in stem of the family name: *Synodus* and Synodidae as against *Synodus* and Synodontidae.

The family Synodontidae appears to have evolved from the Aulopidae (Harry, 1952; Sulak, 1977). Synodontidae, a family of small or moderate size fish with elongate and almost cylindrical bodies with an adipose fin are found in tropical and warm temperate seas in all oceans, some at great depths. The head is lizard-like and the mouth is large and terminal. Teeth numerous, long, sharp, usually recurved and in rows, visible even when mouth is closed.

At present there are about forty recognized species in the family Synodontidae. The number of genera however depends upon individual opinion as to the relationship between the genera and the many myctophiform families. Norman (1935) and Sulak (1977) recognize five genera: *Harpadon* Lesueur, 1825a; *Saurida* Cuvier and Valenciennes, 1849; *Bathysaurus* Gunther, 1878; ***Synodus* Gronow, 1763 and *Trachinocephalus* Gill, 1861, whereas Harry (1952) and Marshall (1964) exclude *Harpadon* and *Bathysaurus* from the family. *Synodus* and *Trachinocephalus* are closely allied and rather advanced with respect to the more primitive *Saurida, Harpadon* or *Bathysaurus* (See Sulak 1977 pp. 53-60). Sulak (1977) revised Synodontidae as follows:

Family Synodontidae Gill, 1862

Subfamily Harpadontidae Jordan, 1923
Genus Harpadon Lesueur, 1825 (Incl.
Peltharpadon Fowler, 1934)

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* i.e. Iniomous fish *sensu lato*

** Cressey (1981) included *Xystodus* Ogilby 1910 in *Synodus*

Genus *Saurida* Valenciennes, 1849

Subfamily Bathysauridae

Genus *Bathysaurus* Gunther, 1878
(Incl. Macristium Regan, 1911)

Subfamily Synodontinae Gill, 1862

Genus *Synodus* Gronow, 1763
(Incl. *Xystodus* Ogilby, 1910)

Genus *Trachinocephalus* Gill, 1862.

Whitley (1937) proposed six new subgenera for the genus *Synodus: Negotirus, Newtonscottia, Austrotirus, Allouarnia, Exotirichthys* and *Esosynodus,* on the basis that 'the key characters given by Norman being sufficiently diagnostic for their definition'.

In 1935, Norman undertook a major review of the genera *Synodus, Trachinocephalus* and *Saurida* and reported 16, 1 and 9 species respectively from the warmer parts of the Atlantic and Indo-Pacific Oceans. Since the publication of Norman's (1935) monograph, several new species have been described from the Indo-Pacific region and in one instance Waples (1982) removed *Saurida nebulosa* from the synonymy of *S. gracilis*. Several reviews have also been attempted usually on regional basis and very often with only the literature as the source of data (e.g. Matsubara and Iwai, 1951; Gibbs, 1959; Anderson, Gehringer and Berry, 1966; Shindo, 1968; Shindo and Yamada, 1972; Yeh and Liu, 1973; Rao, 1977; Yamada and Ikemoto, 1979). Because of the widespread range of lizardfish and their similarities, there have been several instances of misidentifications, synonymies and also nomenclatural errors (e.g. Matsubara and Iwai, 1951; Okada and Kyushin, 1955; Liu and Tung, 1959; Shindo and Yamada, 1972; Rao, 1977). These errors and synonymies have arisen through lack of awareness of previously published names (e.g. *S. argentea* Macleay, 1882 vrs *S. micropectoralis* Shindo and Yamada, 1972), or through non-appreciation of the amount of variation existing within lizardfish (e.g. *S. filamentosa* Ogilby, 1910 vrs *S. wanieso* Shindo and Yamada, 1972) or sometimes as a result of lack of sufficient specimens.

Trachinocephalus has been recognized as a monotypic species (Norman, 1935; Harry, 1952; Sulak, 1977; Cressey, 1981). On the contrary, *Saurida* consists of several morphologically cryptic species. The classification of *Saurida* has proved difficult using conventional morphological and anatomical characters - so many of these characters have limited value in establishing taxonomic relationships because of their overlapping ranges among the species. The difficulty is compounded by considerable intra-specific variability; the most similar and misidentified pairs and the triad being -

1. *S. undosquamis* - *S. australis*
2. *S. tumbil* - *S. argentea*
3. *S. filamentosa* - *S. wanieso*
4. *S. flamma* - *S. gracilis* - *S. nebulosa*

In a biochemical and morphological review of Hawaiian *Saurida*, Waples (1982) reported the co-existence of three species where only one species, *S. gracilis* (Quoy and Gaimard) 1824, was hitherto recognized. The following are currently the recognized Indo-Pacific species of *Saurida* and *Trachinocephalus*:

1. *Saurida tumbil* (Bloch), 1975
2. *S. gracilis* (Quoy and Gaimard), 1824
3. *S. elongata* (Temminck and Schlegel), 1846
4. *S. undosquamis* (Richardson), 1848
5. *S. nebulosa* Valenciennes, 1849
6. *S. filamentosa* Ogilby, 1910
7. *S. longimanus* Norman, 1939
8. *S. isarankurai* Shindo and Yamada, 1972

9. *S.* *micropectoralis* Shindo and Yamada, 1972
10. *S.* *wanieso* Shindo and Yamada, 1972
11. *S.* *flamma* Waples, 1982 and
12. *Trachinocephalus myops* (Bloch and Schneider), 1801.

In this study, a review of the genera *Saurida* and *Trachinocephalus* is attempted using conventional morphological/ anatomical techniques and exploratory electrophoretic analysis of general and selected proteins.

2.2 MATERIALS AND METHODS

2.2.1 Electrophoretic Studies

2.2.1.1 Species Samples

Fish samples were obtained from the following areas (number of specimens and length (mm) range in brackets):

	Remarks
a) Moreton Bay (S.E. Queensland) *S. tumbil* (20,180-250) *S. undosquamis* (20,150-220) *T. myops* (4,130-150)	Trawled from 10-40m on muddy/sandy flats.
b) Off Moreton Bay (S.E. Queensland) *S. filamentosa* (15,250-400) *T. myops* (15,80-190)	Trawled from 80-200m by Bob Sanderson, Skipper of the 'Rex Andria'.
c) Hervey Bay (Queensland) *S. argentea* (2,169-214)	Taken on a hook by Clive Keenan from estuarine shallow water in a sand bank.
S. australis (30,230-300)	Trawled by Greg Campbell between Lady Elliot and Fairfax Islands, east of Bundaberg
d) North-West Shelf of Australia *S. argentea* (30,200-300) *S. filamentosa* (12,200-300) *S. longimanus* (2,108-125) *T. myops* (8,80-160)	Obtained by the Crew of FRV 'Soela' trawling on coral, muddy and/or sandy bottoms; 50-120m.

e) Lizard Island (Great Barrier Reef) *S. nebulosa*	Obtained on coral reef by Dr. Hugh Sweatman.

All fish samples were put on ice or were stored in a freezer prior to transportation to the laboratory. In the laboratory, the fish were weighed, measured for length, sealed in polythene bags and then frozen at -20 to -30°C until required.

2.2.1.2 Preparation of tissue extracts

Tissue extracts were prepared from the eye, liver and white muscle - the muscle was excised from between the dorso-medial line and above the lateral line but just anterior to the vertical plane of the origin of the dorsal fin. Between 1-3g of tissue in an approximately equal volume of grinding *buffer was ground with an Ultra-Turrax tissue grinder. The homogenized tissue was centrifuged at about 5°C at 14250-14500 rpm (i.e. about 25300g**) for 20 minutes in Sorvall Centrifuge. The supernatant was decanted into 10 ml glass tubes and centrifuged for a further 60 minutes. The supernatant was again decanted into smaller glass or plastic tubes and stored in a freezer at -20 to -30°C (at the Zoology Department, University of Queensland) or at -70°C (when working at CSIRO (Cleveland Laboratories)). The enzymes, at these freezing temperature, retained their resolution for at least six months. However samples could not be frozen and thawed more than three times without considerable loss of resolution.

* Grinding buffer - 1.21g Tris:0.37g EDTA (Na_2):0.00153g NADP per 1 H_2O, ph adjusted to 6.8 with HCl.

** Acceleration due to gravity.

The method involving an horizontal electrophoresis on pore gradient polyacrylamide gels and staining with o.2% Coamasie Blue R as described by Gahne, Jenuja and Crolmus (1977) was employed in the analysis of general proteins. Specific enzyme analysis followed Redfield and Salini (1980) and a CSIRO (Cleveland) Electrophoresis Manual (unpublished). A variety of buffers were tried in the preliminary analysis to find the best buffer-enzyme systems with regard to enzyme resolution but concurrently with the analysis of inter-generic differences and similarities using samples of *S. tumbil*, *S. undosquamis* and *T. myops*. In the main analysis, extracts of all the species were examined. However all extracted samples, including the only samples of *S. longimanus* and *S. nebulosa* were lost due to prolonged thawing and a resultant loss of resolution by the enzymes because of power failure over a weekend. Work continued on only readily available species and the following 24 enzymes were surveyed:

1.	Aspartate aminotransferase	(AAT)
2.	Alcohol dehydrogenase	(ADH)
3.	Aconitate hydratase	(AH)
4.	Adenylate kinase	(AK)
5.	Creatine kinase	(CK)
6.	Esterase	(EST)
7.	Fructose biphosphate aldolase	(ALD)
8.	Gylceraldehyde-phosphate-dehydrongenase	(GDH)
9.	Glutamate dehydrongenase	(GDH)
10.	Glycerol-3-phosphate dehydrongenase	(G-3-PDH)
11.	Glucose-6-phosphate dehydrogenase	(G-6-PDH)
12.	Glucose phosphate isomerase	(GPI)
13.	Isocitrate dehydrogenase	(IDH)
14.	Lactate dehydrogenase	(LDH)
15.	Malate dehydrogenase	(MDH)
16.	Malate dehydrogenase (NADP)/Malic enzyme	(ME)
17.	Mannose phosphate isomerase	(MPI)
18.	Phosphogluconate dehydrogenase	(PGDH

19.	Phosphoglucomutase	(PGM)
20.	Pyruvate kinase	(PK)
21.	Sorbitol dehydrogenase	(SDH)
22.	Superoxide dismutase	(SOD)
23.	Umbelliferyl esterase	(UMB)
24.	Xanthine dehydrogenase	(XDH)

The following *buffers were employed in gel preparations and electrode set-ups:

Buffer		Chemical Composition
		Continuous buffer
CAAPM	-	Citric acid H_2O : Aminopropylmorpholine
CAEA	-	Citric acid H_2O : N - (3 aminopropyl) - diethanolamine
EBT	-	Tris : Boric Acid : EDTA (Tetrasodium salt)
PC-1	-	Citric acid (monohydrate) : K_2HPO_4
TC-1	-	Tris : Citric acid H_2O
TC-2	-	Tris : Citric acid H_2O
TC-4	-	Tris : Citric acid H_2O
TECB	-	Tris : EDTA : Citric acid : Boric acid
		Discontinuous buffer
POULIK	-	gel; Tris : Citric acid H_2O electrode; Boric acid : NaOH.

The approximate voltages and running times of the buffer systems were as follows:

Buffer	Starting Voltage (V)	Starting Current (mA)	Running Time (hrs)
CAAPM	200	45	4
CAEA	200	27	4
EBT	300	51	4

---

* See Redfield and Salini (1980) (and CSIRO (Cleveland laboratories Electrophoresis Manual (unpublished)) for details.

PC-1	100	65	5½
POULIK	140-250	** 40	5
TC-1	175	55	4
TC-2	100	58	6
TC-4	150	55	4
TECB	200	60	7

All species were examined in side-by-side comparisons on the gels so as to eliminate variations due to treatment. A number of photographs were taken of each gel as the bands developed. Illustrations of patterns were also drawn and distances travelled by the various bands from the origin noted in many cases. Other data obtained included relative enzyme activity (presence or absence) and comparison between the tissue types.

2.2.2 Morphological/Anatomical Studies

2.2.2.1 Species Samples

This study was based on ***specimens collected from various localities or examined on loan from institutions and museums and on the literature. Several specimens, and where possible holotypes or paratypes, of each species were examined. Various characters were studied and where necessary or possible photographs were taken or illustrations drawn. All measurements are straight-line distances made either with wooden or plastic rulers and recorded to the nearest millimeter, or with dial calipers with an accuracy of ±0.05mm. Excessively distorted specimens were measured when they were the only specimens available.

** Constant Current.

*** Details provided under the appropriate species

2.2.2.2 Measurements, Counts and definitions (See Fig 2.1)

Measurements are given as proportions of a) standard (S.L.) and/or b) head (H.L.) length unless otherwise stated. Standard length, as described previously in the main introduction, was measured by placing the fish on a measuring board with the tip of the snout touching the head block and measuring the perpendicular distance between the snout tip and the crease of the caudal fin (i.e. the posterior margin of the hypural bones). The crease was located by flexing the caudal fin at right angles to the body's axis. Head length is the distance between the tip of the snout and the posterior extension of the fleshy margin of the opercle at the level of the upper edge of the pectoral fin base. Snout length stands for the distance between the tip of the snout and the anterior margin of the orbit, whereas eye diameter is the horizontal distance between the anterior and posterior borders of the orbit.

The length of a *fin or ray was measured as the distance between the tip and the origin or base. Prepelvic, predorsal, preanal, prepectoral and preadipose lengths denote distances between the tip of the snout and the origin of the designated characters or features. **Scales on the dorso-medial line were counted as follows:

predorsal - the number of scales between occiput and origin of dorsal fin (including the anterior-most rounded scale which is almost covered with skin as well as scales in front of dorsal origin.

* Dorsal fin measured when laid back.

** Scales bisected by the dorso-medial (straight) line running from occiput to caudal fin.

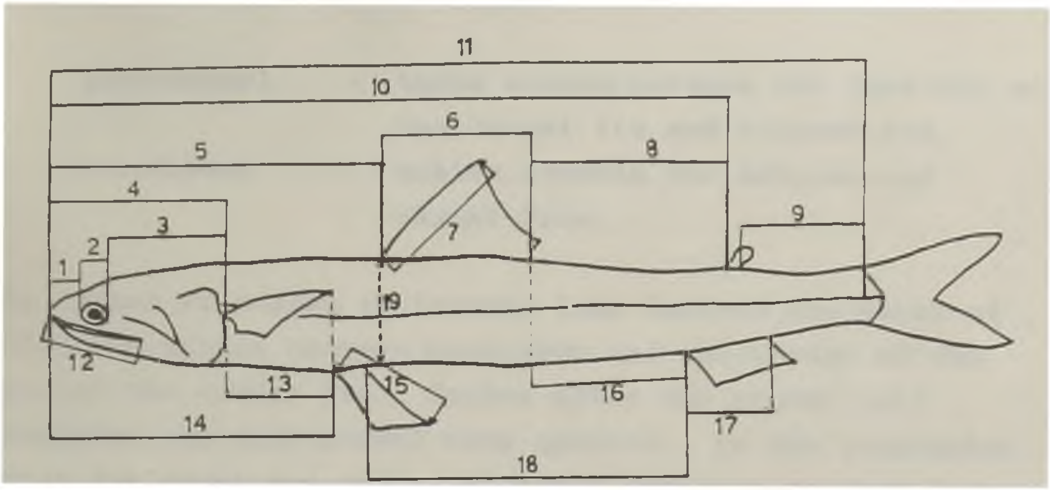


Fig.2.1 : Length measurements.

1. Preorbital/snout
2. Eye diameter
3. Postorbital
4. Head
5. Predorsal
6. Dorsal fin base
7. Dorsal fin
8. Interdorsal
9. Peduncle/postadipose
10. Preadipose
11. Standard
12. Premaxillary
13. Pectoral fin
14. Prepelvic
15. Pelvic
16. Dorsal fin to anal fin.
17. Anal fin base
18. Interventral
19. Depth of body

interdorsal	-	those scales between the last ray of the dorsal fin and adipose fin.
preadipose	-	scales between the adipose and caudal fins.

The number of scales in lateral line denotes the count of all pored scales between operculum and the crease at the base of the caudal fin. Scales after the crease (all elongated and some pored) were ignored. In the transverse scale row count the number of upper rows was counted from the origin of the dorsal fin down to the lateral line; the number of lower rows was counted from the origin of the anal fin, upward to the lateral line. In either transverse row counts, the lateral line scale itself and the modified scales at the base of the dorsal or anal fin were not counted. Scale-pockets/traces when visible were counted where scales were lost. With the fin ray counts, the last ray of the dorsal or anal fin which is divided to its base was counted as one element. Fin rays were counted more easily under a magnifying glass (or a microscope as with very small specimens.)

The premaxilla length was taken as the straight line from the symphysis to the tip of the snout. All other measurements or counts are as denoted by the names or terms as illustrated in Fig. 2.1. In addition to the number of rows in the palatine teeth, the shape of the teeth bands and the configuration of the teeth in the bands and on vomer were studied in detail - many specimens were decapitated and also cut at only one articulation of the premaxillary to angular. These were dried out gradually in the laboratory to reduce shrinkage and later dried out in the sun after an exploratory confirmation of the configuration of the teeth with 'wet' specimens. The configurations before and after drying were compared and specimens with least shrinkage were photographed.

Coloration was recorded from both fresh and preserved specimens in a range of sizes or as reported in the literature. Unless otherwise noted for the species, the ecological information presented is based on personal observation in the field and field notes of the collectors and museums or institutions. Vernacular names were taken from Grant (1972, 1978), Marshall (1964), Munro (1961), Coleman (1980) and Waples (1982). *Synonymies are, with few exceptions, those mentioned by McCulloch (1929-30), Norman (1935) and Anderson, Gehringer and Berry (1966).

2.2.2.3 Abbreviations of Museums/Institutions

AMS - Australian Museum, Sydney
BMNH - British Museum (Natural History), London
BPBM - Bernice P. Bishop Museum, Honolulu
DPPFD - Fisheries Division (Department of Primary Production), Darwin, Northern Territory.
KFR - Kanudi Fisheries Research Museum, Konedobu, Papua New Guinea
QM - Queensland Museum, Brisbane
SI - Smithsonian Institution, Washington, D.C.
SOSC - Smithsonian Oceanographic Sorting Centre
USNM - United States National Museum
ZUMT - University of Tokyo, Zoology Department, Tokyo

* Only the original papers or those containing valuable information are quoted when synonymies are extensive.

2.3 RESULTS

2.3.1 Electrophoresis (Biochemical Systematics).

2.3.1.1 General Proteins (Plates 1,2A, B)

General protein patterns were examined in eight species: *S. filamentosa, S. australis, S. undosquamis, S. tumbil, S. argentea, S. longimanus, S. nebulosa* and *Trachinocephalus myops* by separation of muscle and liver extracts on polyacrylamide gels. The examination revealed similar but distinct electrophoregrams which are consistent with patterns of morphological similarities and differences between the species. Individual electrophoregrams also exhibited intra-specific variations.

2.3.1.2 Specific Proteins

Starch gel electrophoresis was employed for study of muscle, liver and eye enzymes. Data were obtained for relative enzyme activity (i.e. rate of staining and/or intensity of stain, presence or absence in some cases), inter- and intra-species comparisons. The following observations were made: Whereas some tissue specificity of enzymes was noted, the eye extracts showed consistently low activity levels for many of the enzymes examined, probably due to low concentrations. Poor resolution was noted in some enzymes and only extracts giving best resolutions are discussed here - enzymes with poor resolution are given cursory treatment. In some instances achromatic bands occurred with the desired patterns. The achromatic bands were due to dehydrogenase(s), probably ADH or SOD reacting with 'sufficient alcohol present as a contaminant of the chemical used' - Ferguson (1980).

TABLE 2.0: Legend for plates and figures.

a - *Saurida australis*
f - *S. filamentosa*
l - *S. longimanus*
m - *Trachinocephalus myops*
n - *Saurida nebulosa*
r - *S. argentea*
t - *S. tumbil*
u - *S. undosquamis*

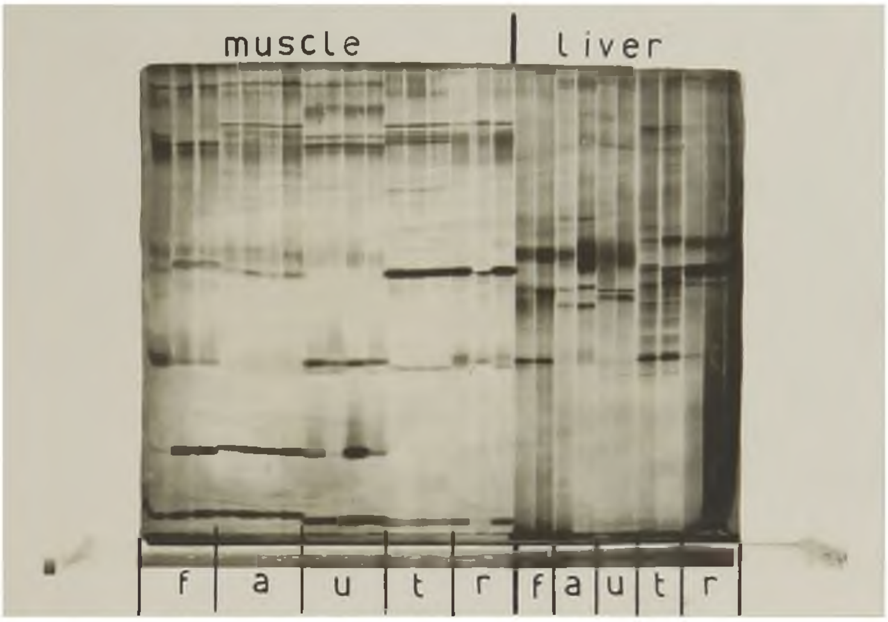


Plate 1

Comparison of general protein patterns of *Saurida* (group B). Legend follows Table 2.0 (p.25a).

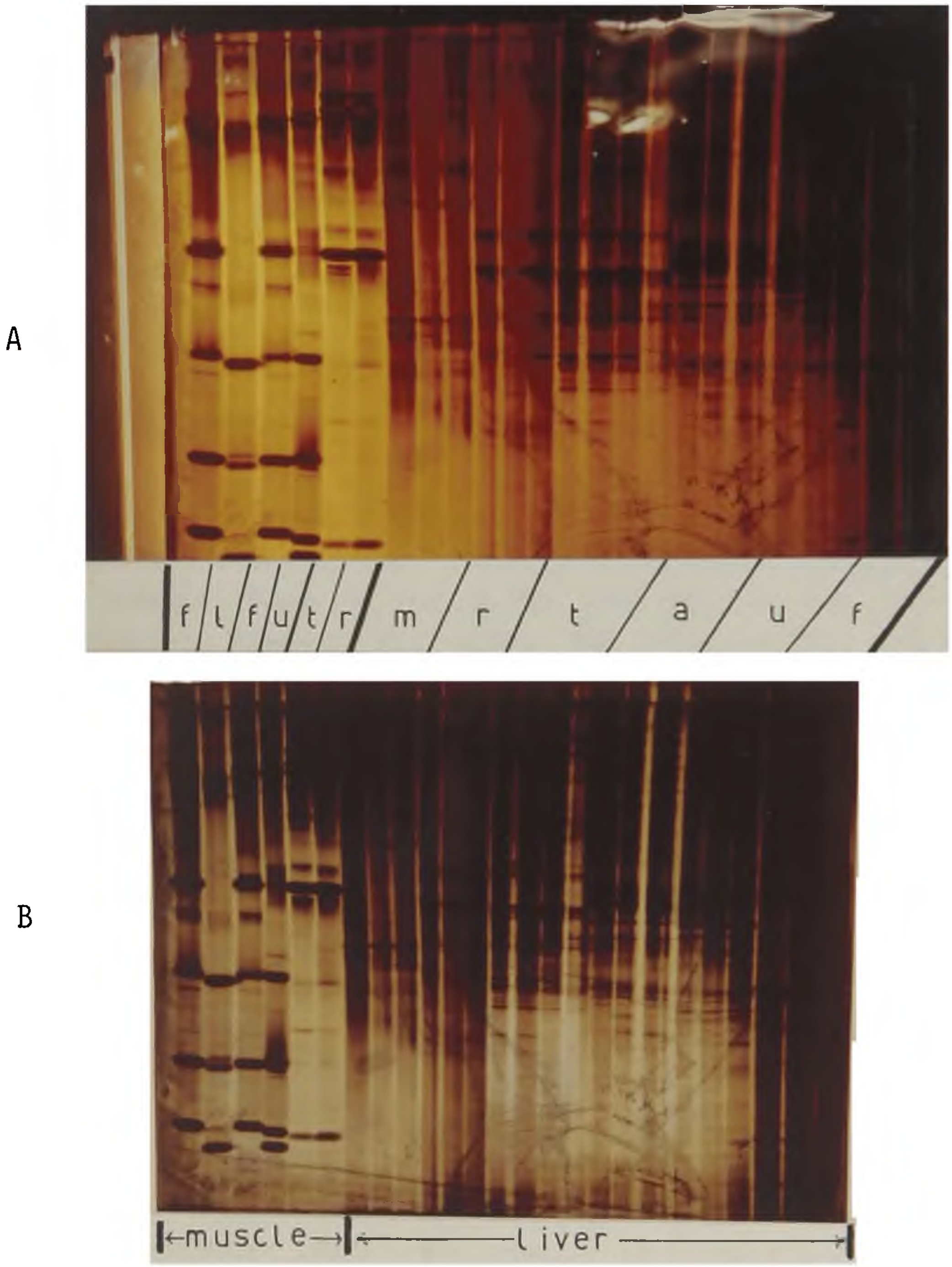


Plate 2*

Comparison of general protein patterns of *Saurida* (group A) and *Trachinocephalus*. Legend follows Table 2.0 (p.25a).

*Two different exposures of film same gel.

2.3.1.3 Generic differences and similarities

Twenty *enzyme-buffer systems were surveyed for genetic differences and similarities in mobilities of specimens of ***Saurida* and ****Trachinocephalus*. Specific mobility differences, presumably reflecting generic differences, were found in AK (CAEA-m; Plate 3, Fig. 2.2A), IDH (CAAPH-1; Fig. 2.2B), MPI (PC-1-1,e; Fig. 2.2.C), GPI (TC-2-t), MDH (CAEA-t; Plate 4) and ME (CAEA-t).

Similarities in band mobilities in *Saurida* and *Trachinocephalus* were found in the following enzyme-buffer systems: AAT (CAEA-t; Fig. 2.2D), ADH (TC-2-m,l; Fig. 2.3A), GAPDH (CAEA-t; Plate 5, Fig. 2.3B), GDH (TC-2-m; Fig. 2.3C), PGDH (CAEA-t; Plate 6, Fig. 2.3D), SDH (PC-1-m; Fig. 2.4A), SOD (POULIK-1, e; Fig. 2.4B), UMB (EBT-t; Fig. 2.4C), XDH (EBT-m,l; Fig. 2.4D), EST (POULIK-t; Plate 7), G-3-PDH (TC-1-t), LDH (CAAPM-t; Plate 8), PGM (TC-1-t) and PK (TECB-t).

2.3.1.4 Inter- and intra-specific variation

The electrophoresis runs involved two periods of analyses (January - March 1982, July - September 1982) with regards to the availability of the species. To avoid the repetition of names, the species analysed during the two periods are referred to as groups: Group A (January - March 1982) - *S. tumbil*, *S. australis*, *S. undosquamis*, *S. filamentosa*, *S. argentea*, *S. nebulosa*, *S. longimanus* and *T. myops*. +Group B (July - September 1982) - all species in Group A except *S. nebulosa*, *S. longimanus* and *T. myops*.

* Tissues: m - muscle, l - liver, e - eye, t - all three tissues.

** 3 each of *S. tumbil* and *S. undosquamis*

*** 2 specimens of *T. myops*

\+ Species available after power failure caused loss of stored extracts.

Plate 3: AK (CAEA), muscle

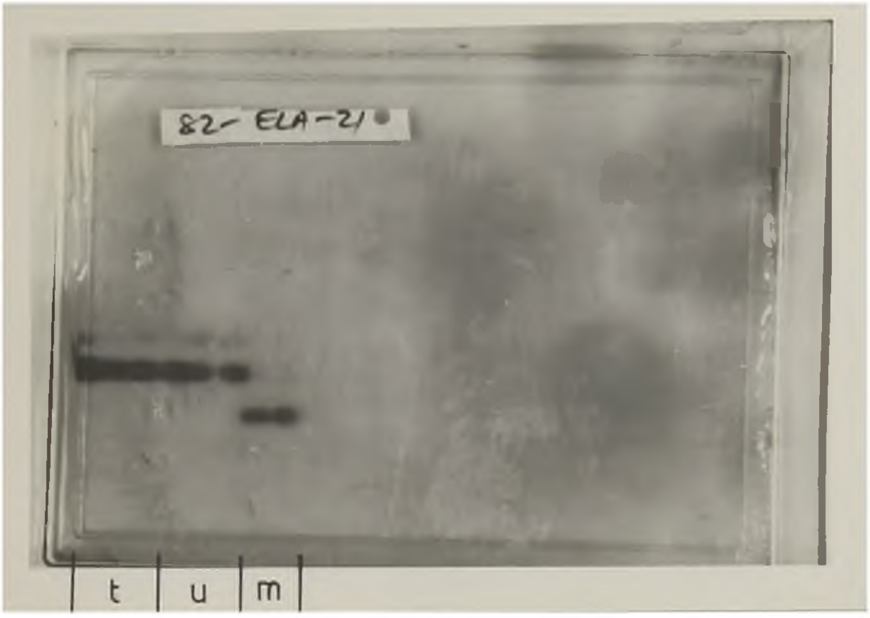
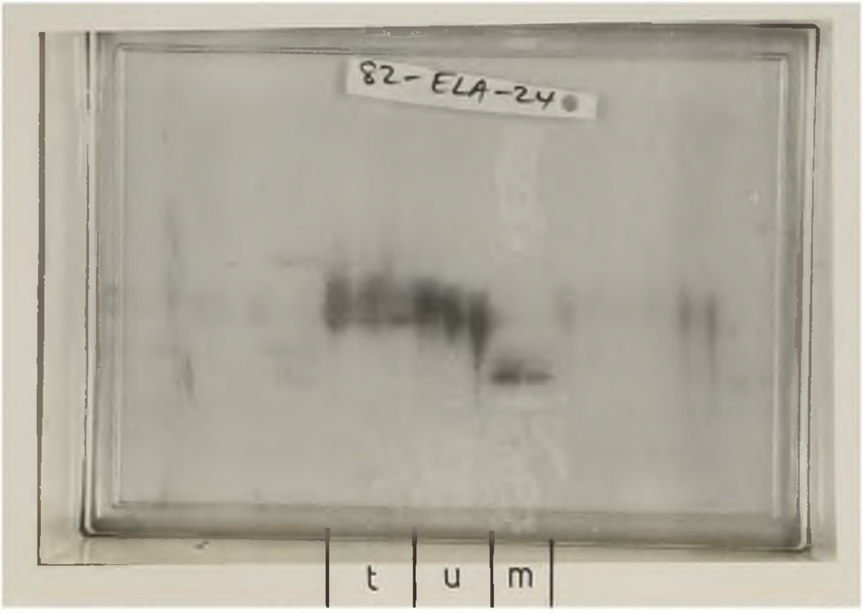


PLATE 4: MDH (CAEA), Liver



Plates 3 and 4: Inter-generic comparison of zymogram patterns of AK and MDH of *Saurida* and *Trachinocephalus*.

Legend follows Table 2.0 (p.25a).

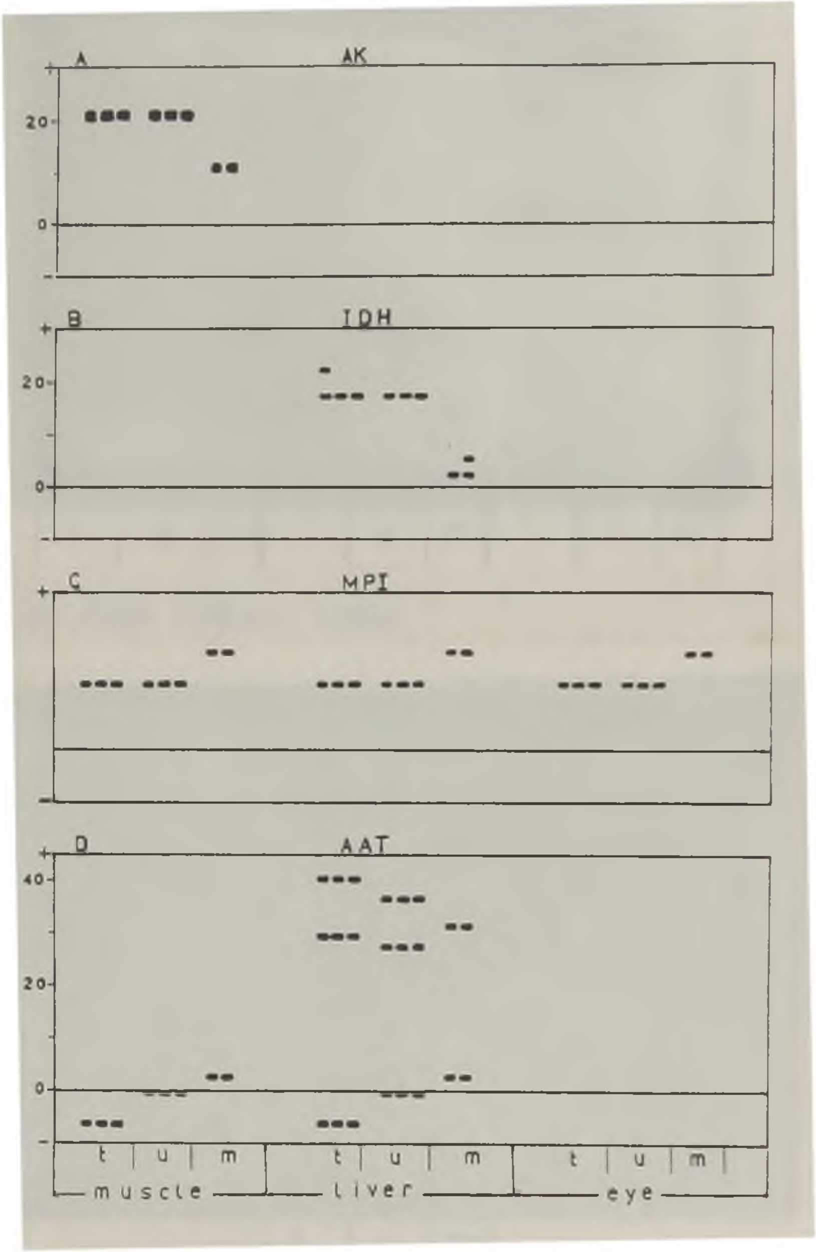


Fig.2.2 : Diagrams of the zymogram patterns of some enzymes of *Saurida* and *Trachinocephalus*. Legend follows Table 2.0 (p.25a)

Plate 5: GAPDH (CAEA)

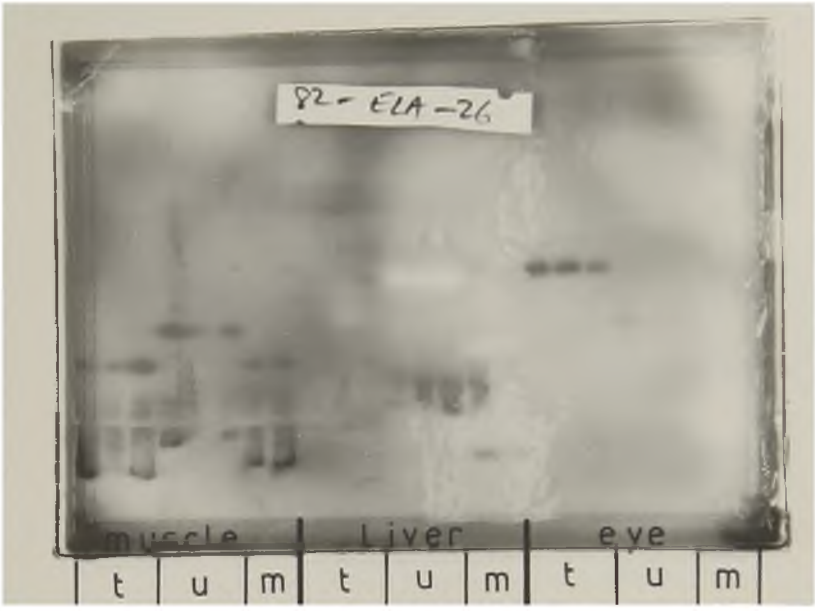
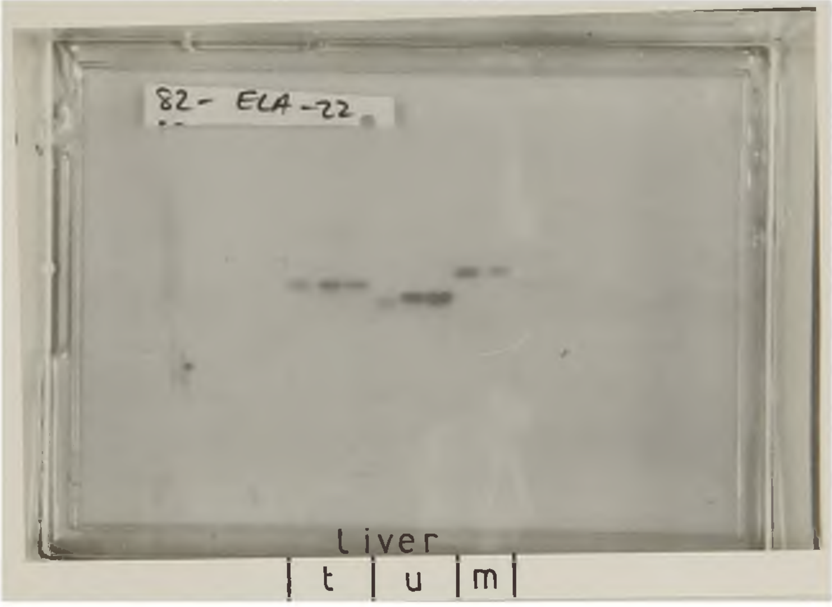


Plate 6: PGDH (CAEA), liver



Plates 5 and 6: Inter-generic comparison of zymomgram patterns of GAPDH and PGDH of *Saurida* and *Trachinocephalus*. Legend follows Table 2.0 (p.25a).

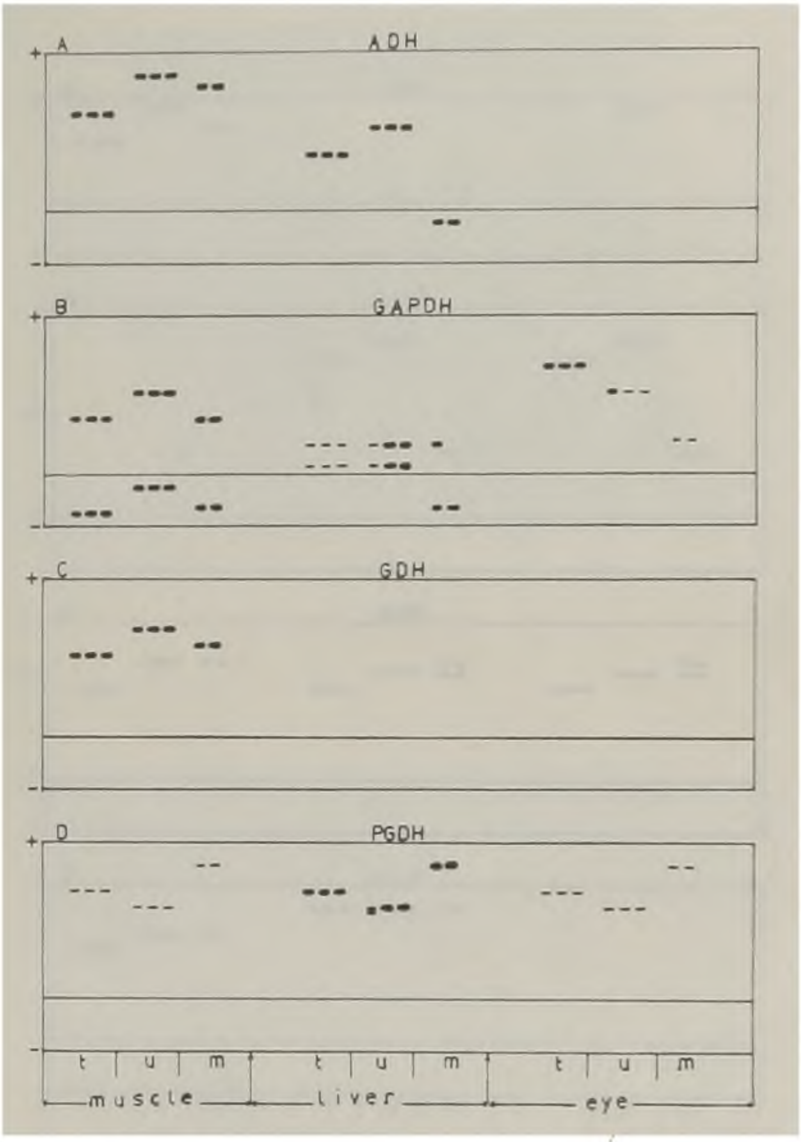


Fig. 2.3 : Diagrams of the zymogram patterns of some enzymes of *Saurida* and *Trachinocephalus*. Legend follows Table 2.0 (p.25a.)

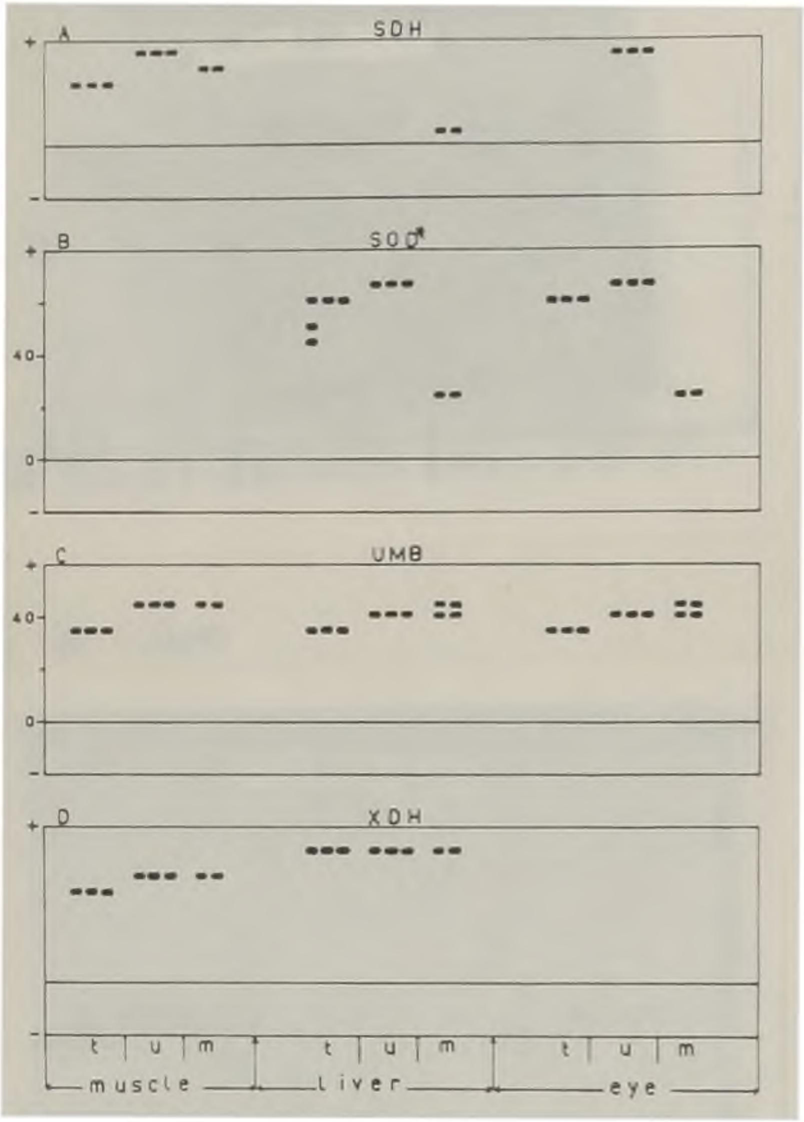


Fig. 2.4: Diagrams of the zymogram patterns of some enzymes of *Saurida* and *Trachinocephalus*. Legend follows Table 2.0 (p.25a)

* Achromatic bands

Plate 7: EST (POULIK)

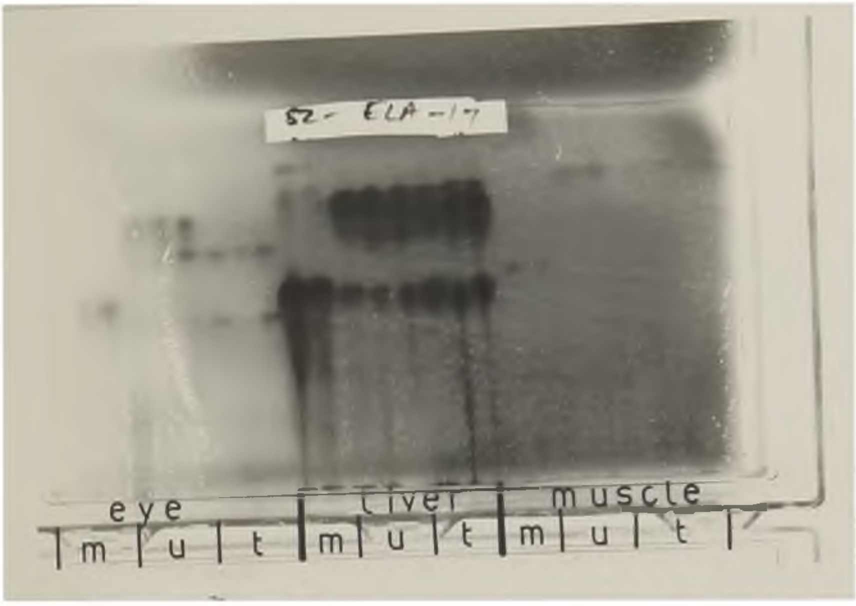
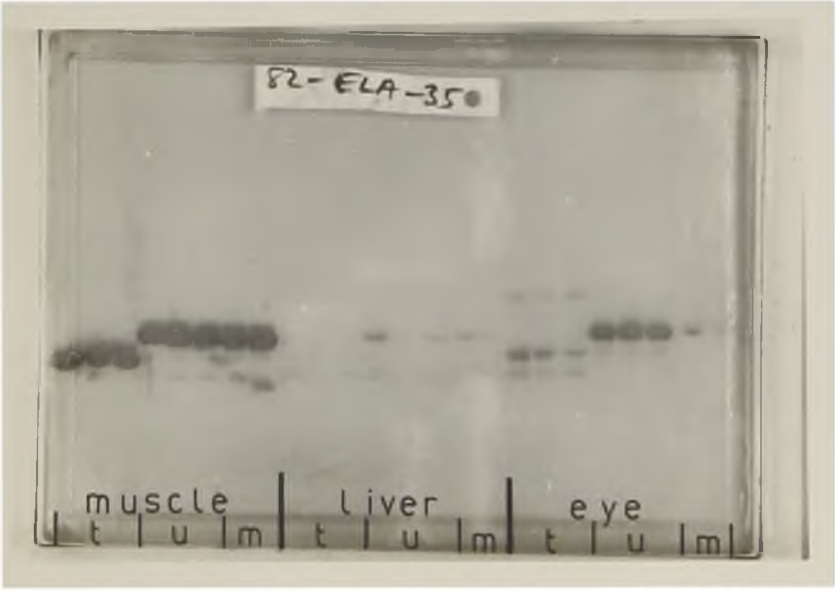


Plate 8: LDH (CAAPM)



Plates 7 and 8: Intergeneric comparison of zymogram patterns of EST and LDH of *Saurida* and *Trachinocephalus*. Legend follows Table 2.0 (p.25a).

2.3.1.4.1 Observations in Group A

ALD (EBT)

Though the ALD zymogram indicated good separation of species, its resolution was very poor and cannot be discussed any further.

CK (EBT). Fig. 2.5A

CK stained well in muscle and eye. Each species, except *S. tumbil* and *S. argentea* had distinct eye ($CK-B_2$) - muscle ($CK-A_2$) array of bands.

EST (POULIK). Fig. 2.5B

Liver: Two forms (fast and slow) were detected in the species. *S. australis* and *S. filamentosa* were single banded and most anodal, whereas *S. nebulosa* had the lease anodal form. *S. argentea, S. undosquamis* and *S. longimanus* shared identical double banded patterns.

EST was not detected in muscle and was poorly resolved in eye.

GAPDH (CAEA). Fig. 2.6A

Muscle: anodal and cathodal forms were detected in the specimens. Each species appears to exhibit a distinctive array of bands. The most anodal form was detected in *S. argentea* and the most cathodal in *S. tumbil* and *S. australis*. No activity was apparent in *S. longimanus*.

There was poor resolution in both liver and eye extracts.

G-3-PDH (TC-1). Plate 9, Fig. 2.6B

Muscle: each species exhibited a distinctive array of bands. *S. longimanus, S. nebulosa* and *S. undosquamis* had a common (most) anodal band. The least anodal forms were found in *S. filamentosa, S. undosquamis, S. australis* and *T. myops*.

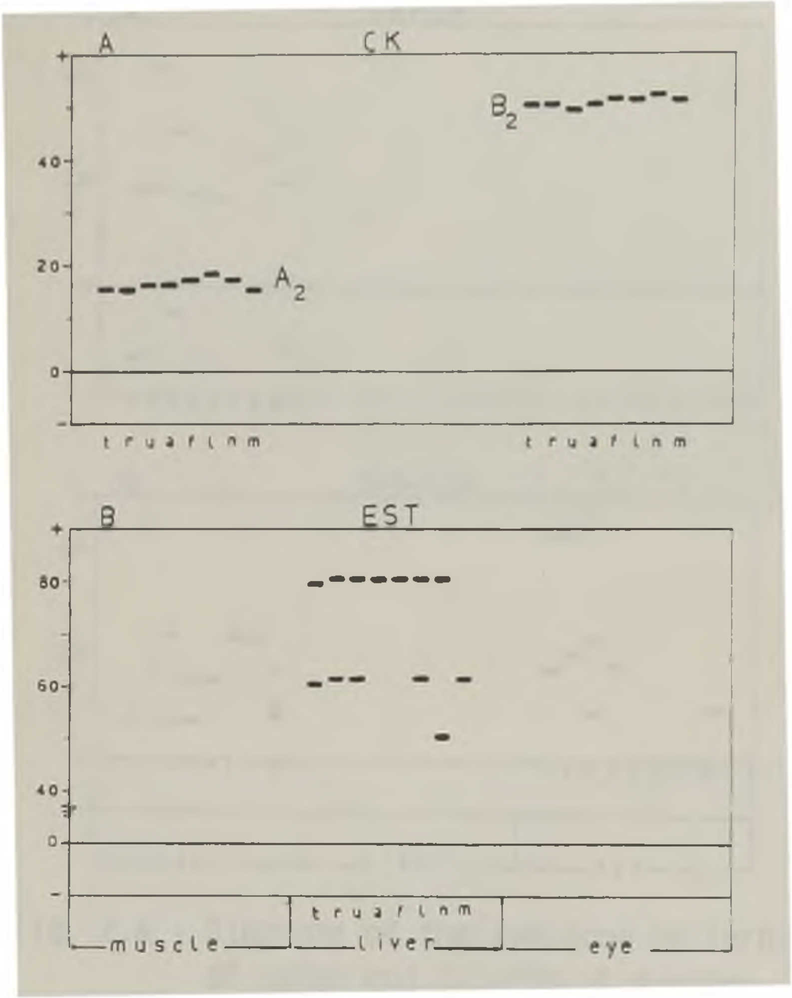


Fig. 2.5: Diagrams of the zymogram patterns of CK and EST of species of *Saurida* and *Trachinocephalus*. Legend follows Table 2.0 (p.25a)

Plate 9: G-3-PDH) (TC-1)

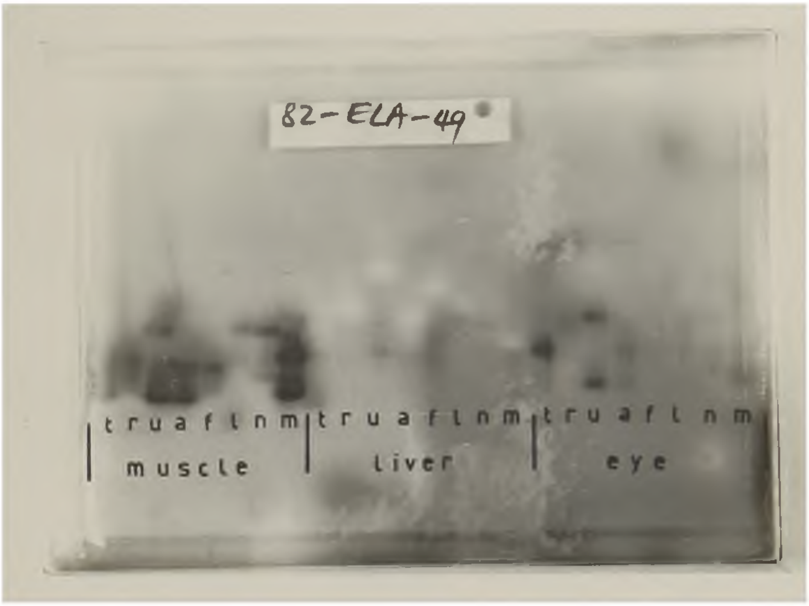


Plate 10: LDH (TC-1)

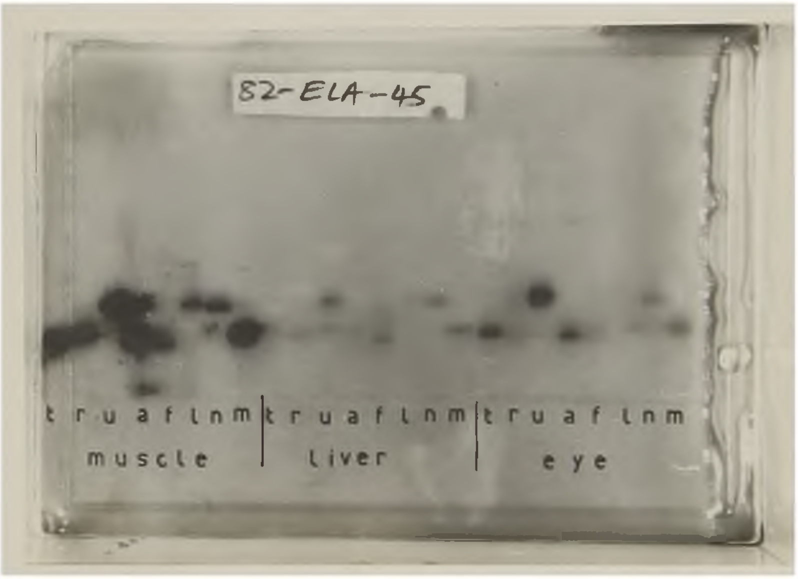


Plate 9 and 10: Comparison of zymogram patterns of G-3-PDH and LDH of species of *Saurida* and *Trachinocephalus*. Legend follows Table 2.0 (p.25a).

Similar patterns were discernible in eye and liver extracts though poorly resolved.

LDH (TC-1). Plate 10

LDH was detected in all tissues examined. The mobilities of the species reflected species differences and similarities.

MDH (TC-1). Plate 11

MDH was detected in all tissues, each of the eight species exhibiting distinctive phenotypes for the various isozymes.

SOD (POULIK). Plate 12 and Fig. 2.7

S. tumbil was found to be polymorphic for liver SOD, an achromatic band pattern characteristic of control by two co-dominant alleles. No polymorphism was detected in the eye isozyme of *S. tumbil* and neither was any difference found between the mobilities of the two isozymes. SOD was not detected in muscle.

As illustrated in Fig. 2.7, the fastest band of *S. tumbil* is homologous with bands in *S. argentea* and *S. longimanus*.

2.3.1.4.2 Observations in Group B

The species were examined by side-by-side comparisons with *S. filamentosa* interspersed between species as control for enzyme activity - four specimens were scored for each species per gel.

Plate 11: MDH (TC-1)

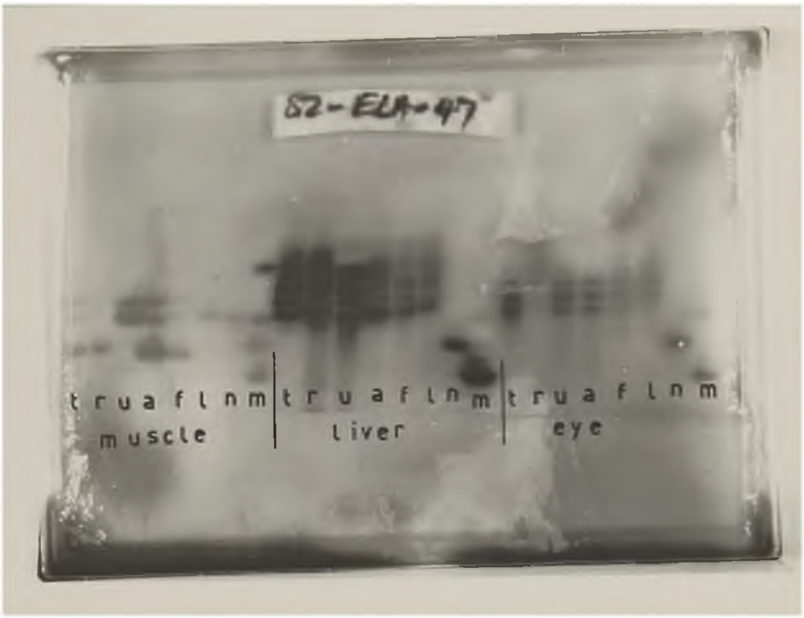


Plate 12: SOD (POULIK)

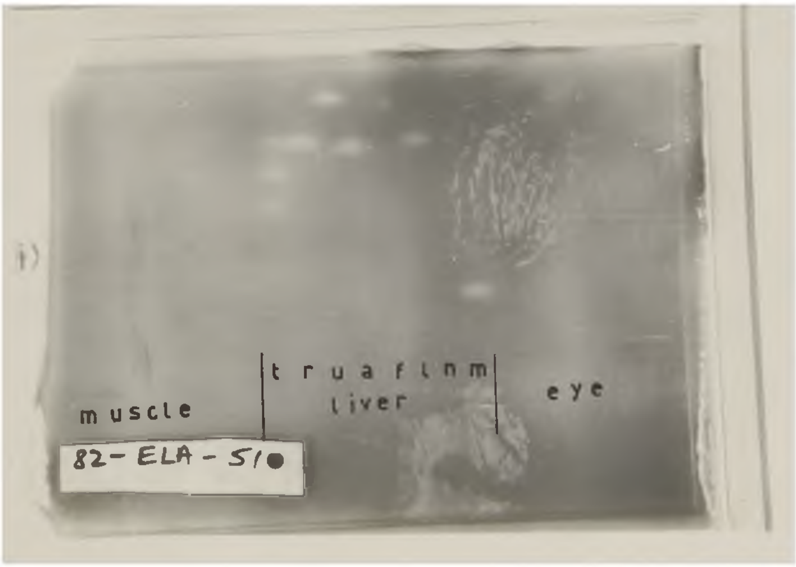


Plate 11 and 12: Comparison of zymogram patterns of MDH and SOD of *Saurida* and *Trachinocephalus*. Legend follows Table 2.0 (p.25a).

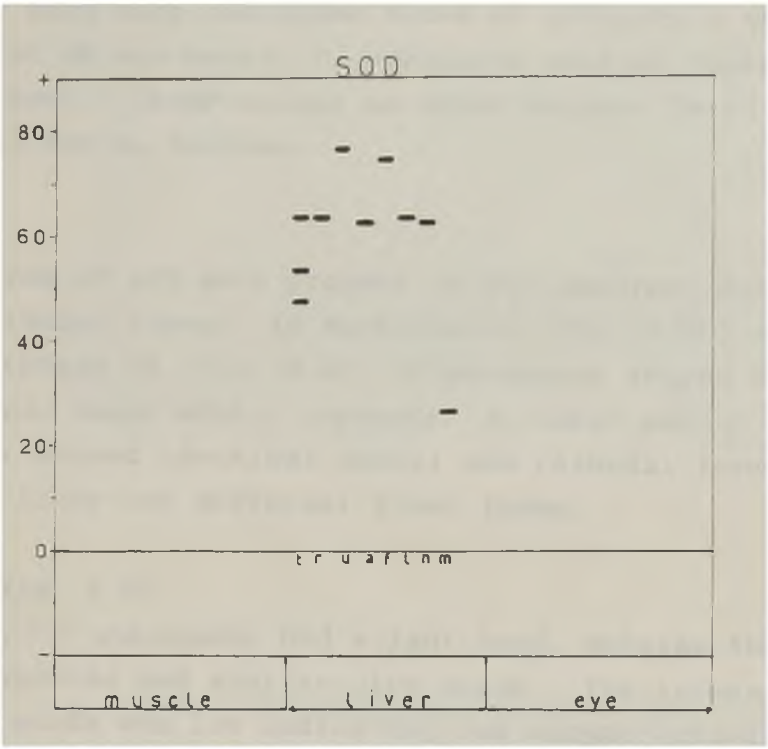


Fig. 2.7 : A diagram of the zymogram patterns of SOD of species of *Saurida* and *Trachinocephalus*. Legend follows Table 2.0 (p.25a)

The species exhibited similar patterns in AK (muscle; Plate 13, Fig. 2.8A) as well as in MDH (muscle; Plate 14, Fig. 2.8B) They each had three zones of activity - the first zone of AK was broad; *S. undosquamis* stained faster than the others. Observations on other enzymes (with buffer in brackets) are as follows:-

AAT (CAEA)

Two forms of AAT were present in the species: anodal and cathodal forms. In both muscle (Fig. 2.8D) and liver (Plate 15, Fig. 2.8C) *S. undosquamis* shared same identical bands with *S. australis*. *S. tumbil* and *S. argentea* shared identical anodal and cathodal forms in the liver but different liver forms.

ADH (EBT) Fig. 2.9A

Muscle: *S. undosquamis* had a fast band, whereas the other species had similar slow bands. The intensity of the stain was low indicating low enzyme activity.

AH (TECB)

Muscle (Fig. 2.9B): There were two types of mobilities - fast in *S. filamentosa*, *S. australis* and *S. undosquamis*, and slow in *S. tumbil* and *S. argentea*.

Liver AH showed up only in *S. tumbil* (Fig. 2.9C).

EST (EBT)

Liver (Plate 16): *S. australis*, *S. filamentosa* and *S. undosquamis* shared distinctly different patterns from *S. tumbil* and *S. argentea* though resolution was poor.

GDH (CAAPM)

Muscle (Plate 17): All the five species except *S. undosquamis* had an identical band mobility.

Plate 13.

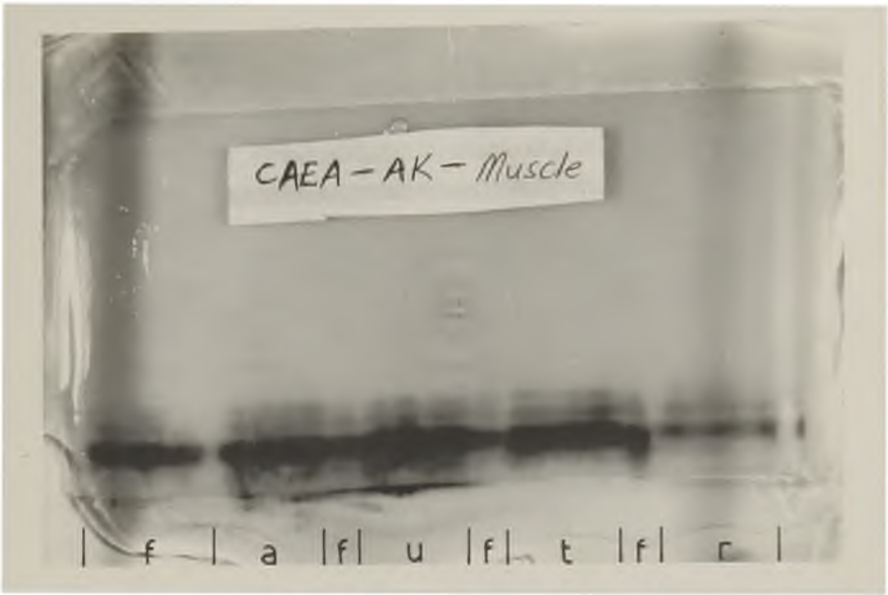
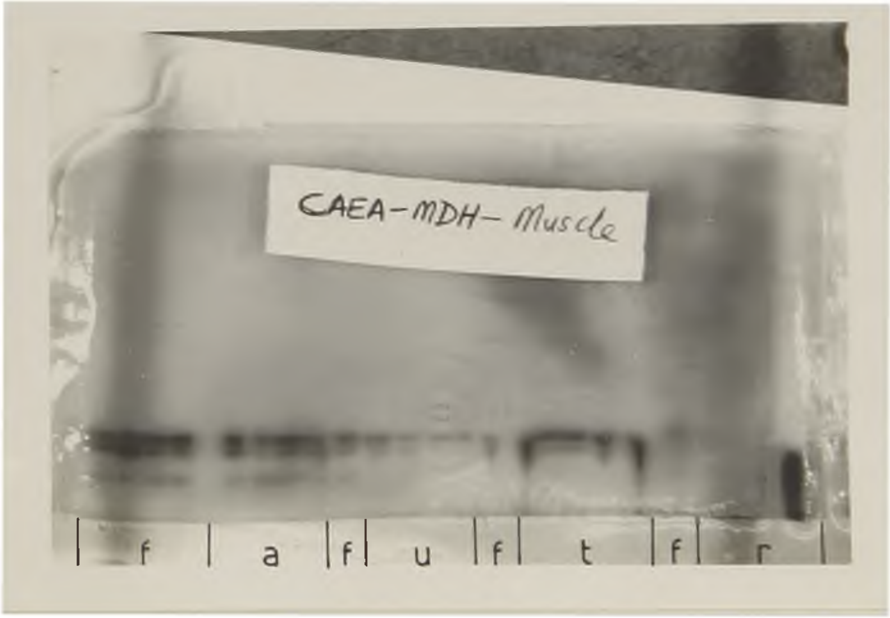


Plate 14.



Plates 13 and 14: Comparison of zymogram patterns of AK and MDH of 5 species of *Saurida*. Legend follows Table 2.0 (p.25a).

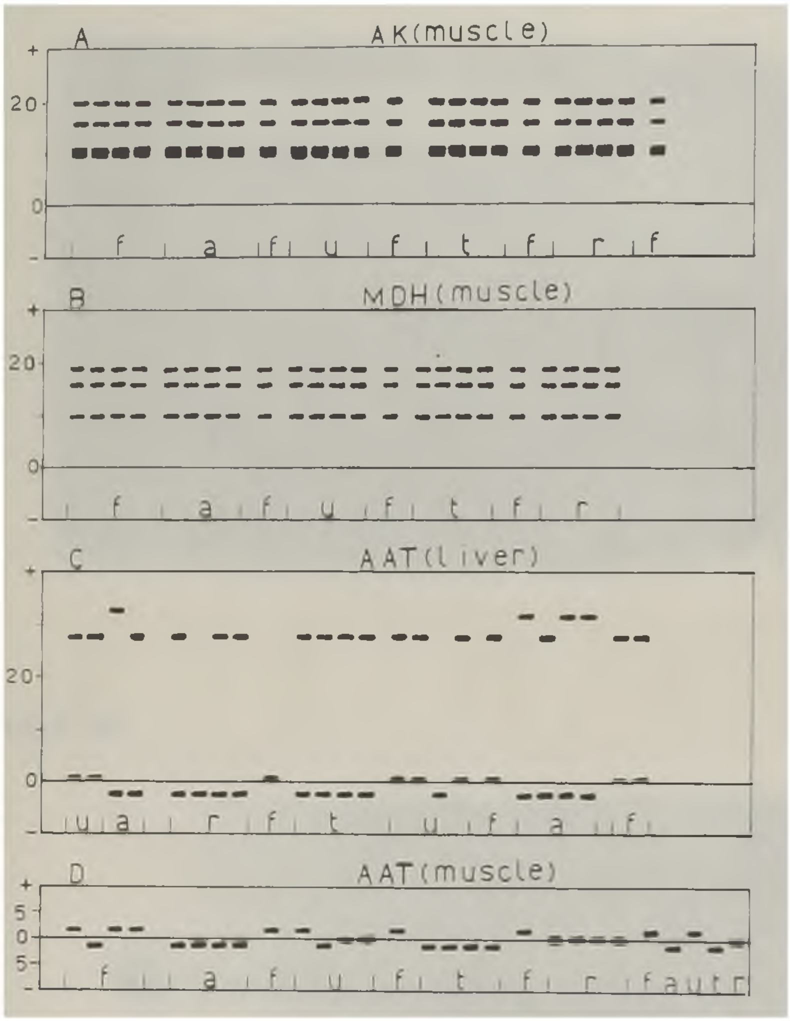


Fig. 2.8 : Diagrams of the zymogram patterns of some enzymes of species of *Saurida*. Legend follows Table 2.0 (p.25a).

Plate 15

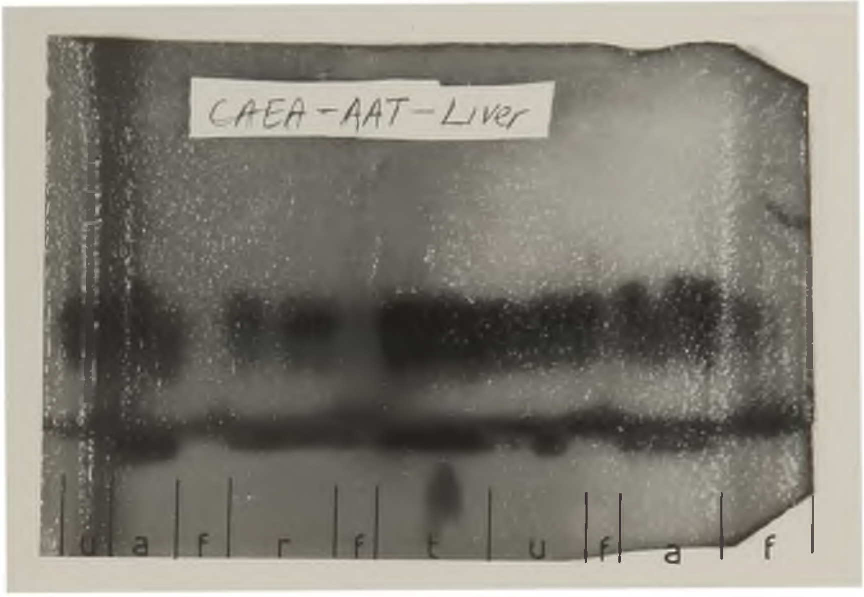
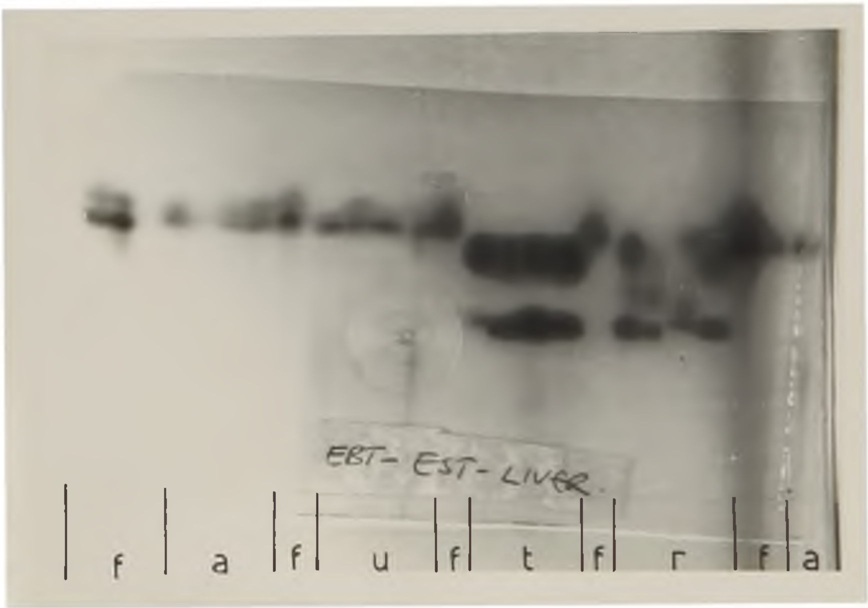


Plate 16



Plates 15 and 16: Comparison of zymogram patterns of AAT and EST of 5 species of *Saurida*. Legend follows Table 2.0 (p.25a).

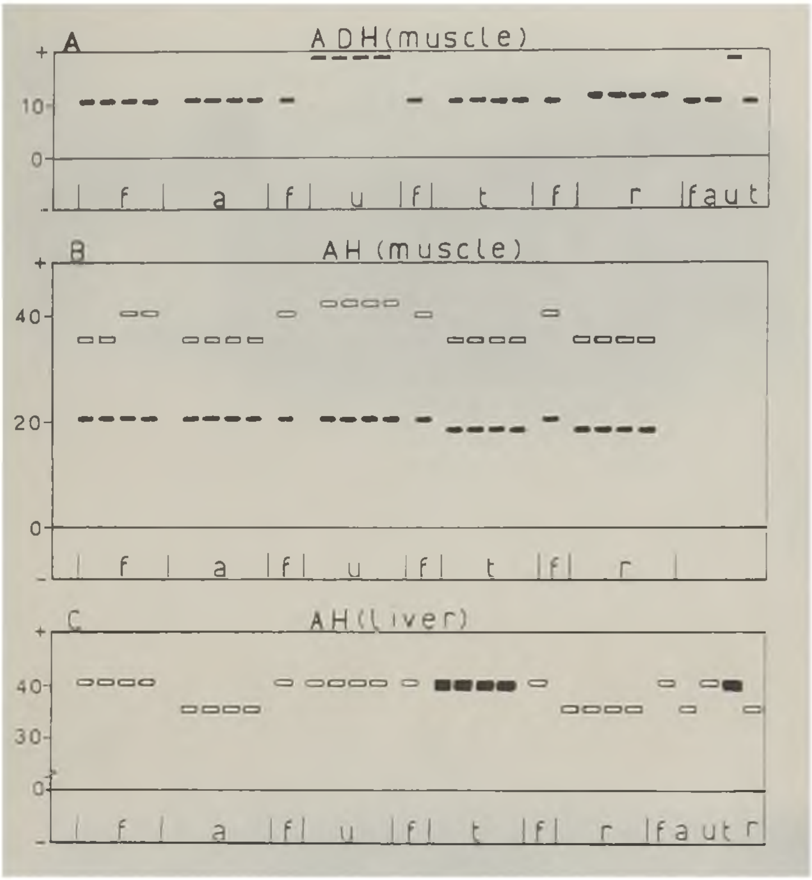
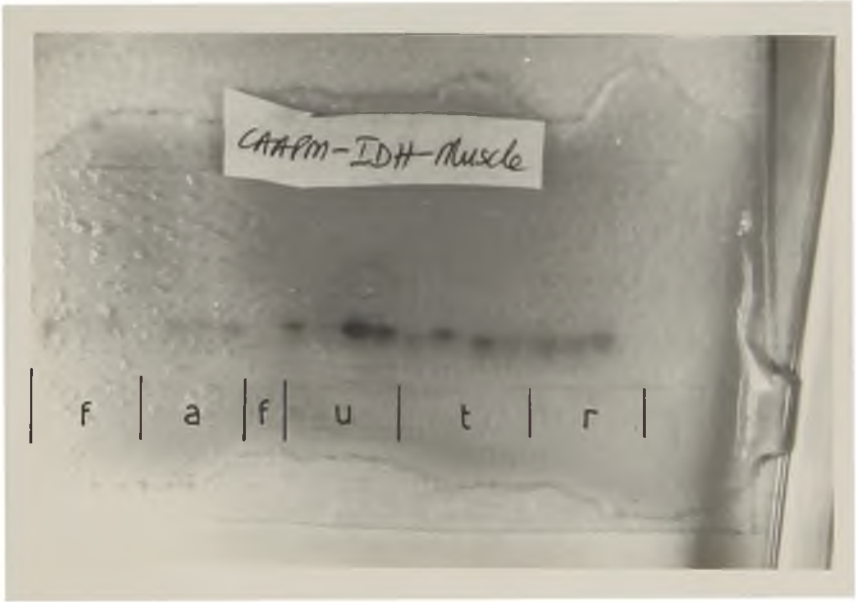


Fig. 2.9 : Diagrams of the zymogram patterns of some enzymes of species of *Saurida*. Legend follows Table 2.0 (p.25a).

Plate 17

Plate 18



Plates 17 and 18: Comparison of zymogram patterns of GDH and IDH of 5 species of *Saurida*. Legend follows Table 2.0 (p.25a).

G-6-PDH (CAEA)

Liver (Fig. 2.10A): This enzyme appears as a double-banded pattern except in *S. tumbil* (3-banded). *S. filamentosa, S. australis* and *S. argentea* had identical patterns. The second band of *S. argentea* indicated reduced activity.

GPI (EBT)

Three types of mobility were detected in the muscle (Fig. 2.10B) - fast in *S. filamentosa,* intermediate in *S. filamentosa* and *S. argentea,* and slow common to *S. australis, S. undosquamis* and *S. tumbil.*

IDH (CAAPM)

Muscle (Plates 18, Fig. 2.10C): *S. tumbil* exhibited two types of mobility - fast and slow. It shared the fast with *S. filamentosa, S. australis* and *S. undosquamis.* The slow band was in common with *S. argentea.*

The liver isozyme patterns were different in *S. australis, S. undosquamis* and *S. tumbil* but was not detected in *S. filamentosa* and *S. argentea.*

LDH (CAAPM)

Muscle (Plate 19A): The zymograms of the species except *S. undosquamis* were more or less identical and appeared as a 4 or 5 banded pattern. The zymogram of *S. undosquamis* was very distinct. This isozyme stained intensely and quickly.

Liver (Plate 19B): This isozyme had species specific patterns. These stained less intensely and slowly than the muscle isozyme except in *S. tumbil.*

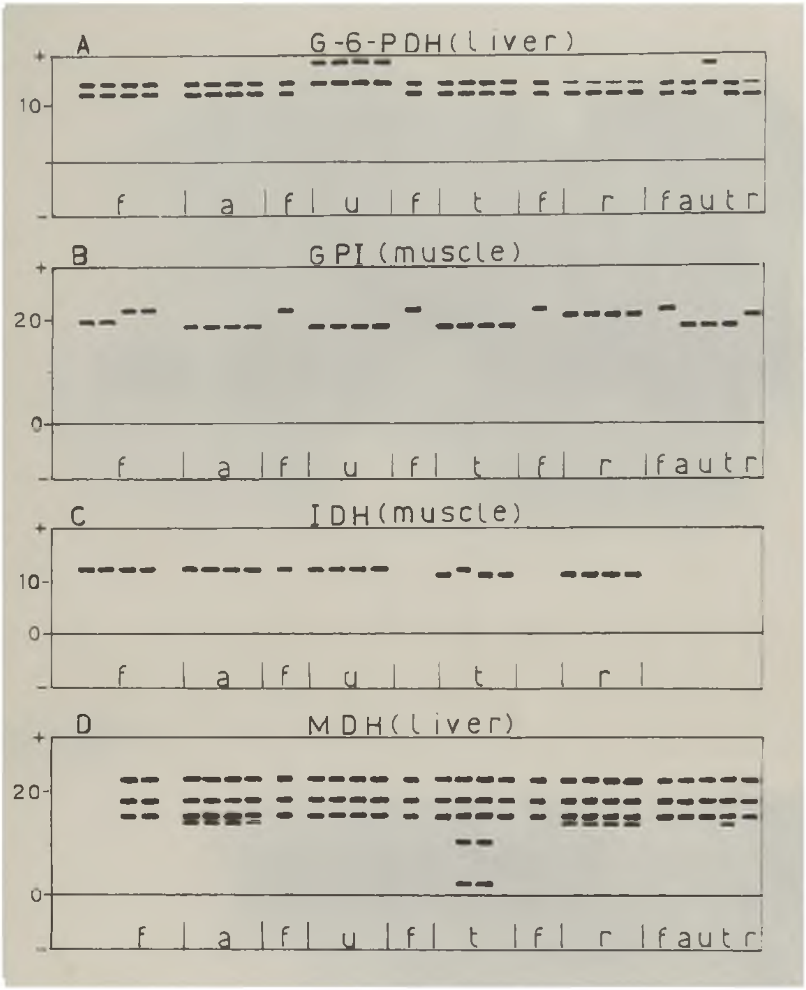


Fig. 2.10: Diagrams of the zymogram patterns of some enzymes of *Saurida* species. Legend follows Table 2.0 (p.25a).

Plate 19A

Plate 19B

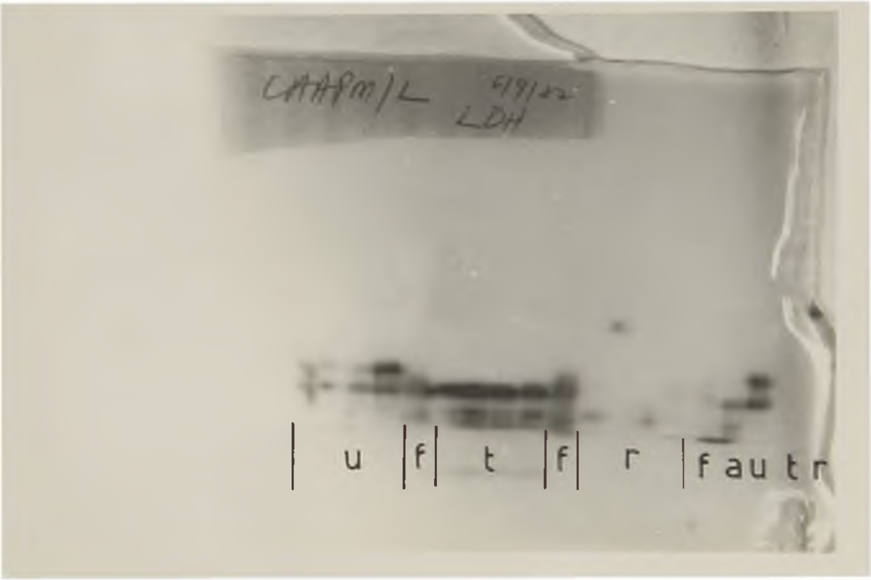


Plate 19: Comparison of zymogram patterns of muscle (A) and liver (B) LDH of 5 species of *Saurida*. Legend follows Table 2.0 (p.25a).

MDH (CAEA)

Liver (Plate 20 and Fig. 2.10D): *S. filamentosa* and *S. undosquamis*, *S. australis* and *S. argentea* shared 3 and 4 banded patterns respectively. *S. tumbil* was polymorphic with 3 and 5 banded forms.

ME (CAEA)

Muscle (Plate 21 and Fig. 2.11A): Two zones of enzyme activity were detected. One zone was common to all the species except *S. undosquamis*. Though *S. undosquamis* shared its first zone with *S. filamentosa* and *S. australis*, its second zone of activity consisted of three sub-units.

The liver isozyme stained very slowly. *S. tumbil* had the most anodal form.

MPI (PC-1)

Muscle (Fig. 2.11B). MPI stained faintly in muscle and three forms of mobility were detected - fast in *S. filamentosa*, *S. undosquamis*, *S. tumbil* and *S. argentea*; intermediate in *S. australis* and slow also in *S. undosquamis*.

Liver: MPI stained intensely, especially in *S. tumbil* and *S. undosquamis*. There were three types of mobility - fast in *S. filamentosa*, intermediate found in all but *S. argentea* which also had the slow band (Plate 22). The achromatic bands are probably due to dehydrogenase(s) as explained previously in this chapter.

Plate 20

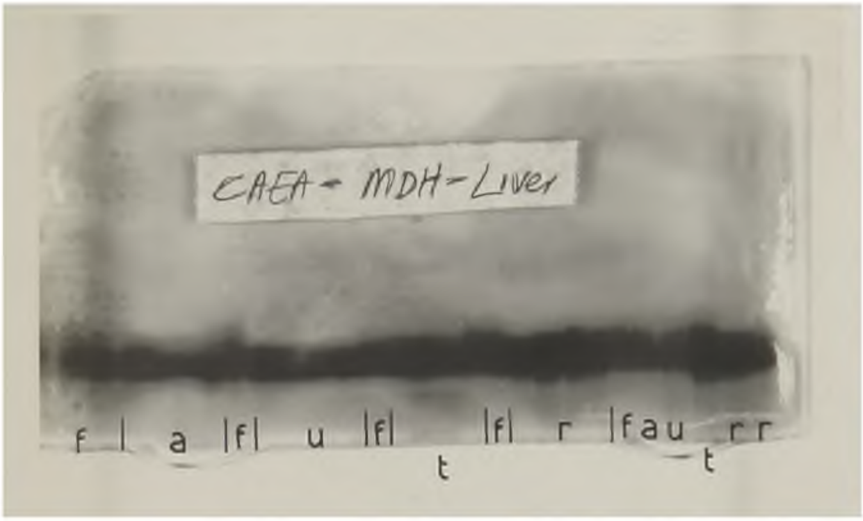
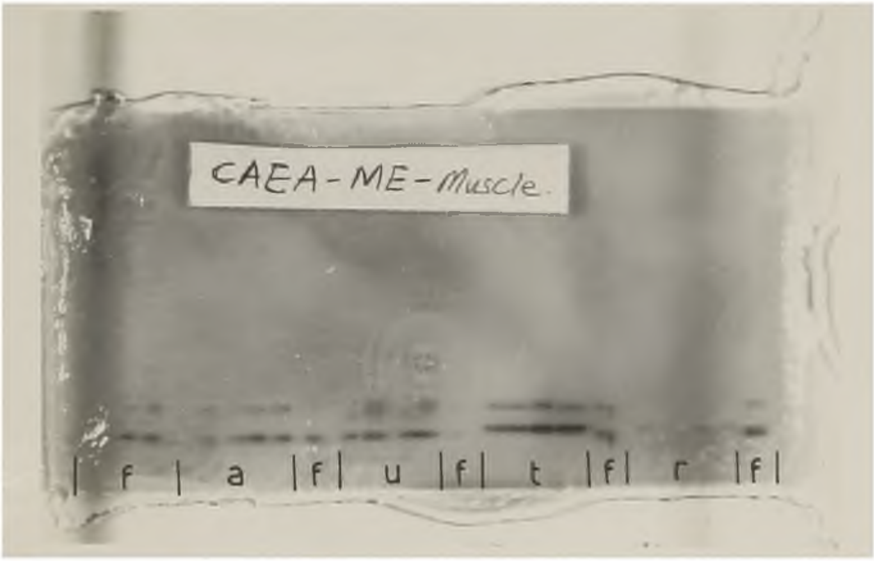


Plate 21



Plates 20 and 21: Comparison of zymogram patterns of MDH and ME of 5 species of *Saurida*. Legend follows Table 2.0 (p.25a)

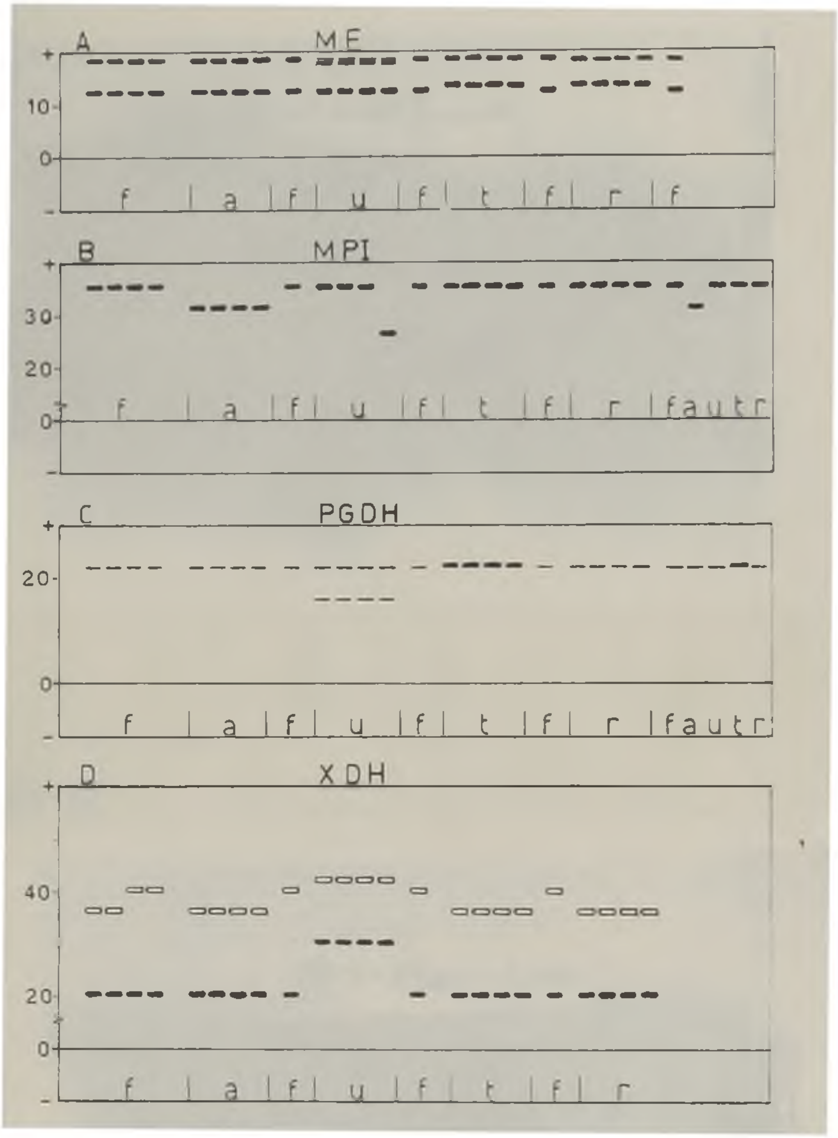


Fig. 2.11: Diagrams of the zymogram patterns of some muscle enzymes of *Saurida* species. Legend follows Table 2.0 (p.25a).

Plate 22

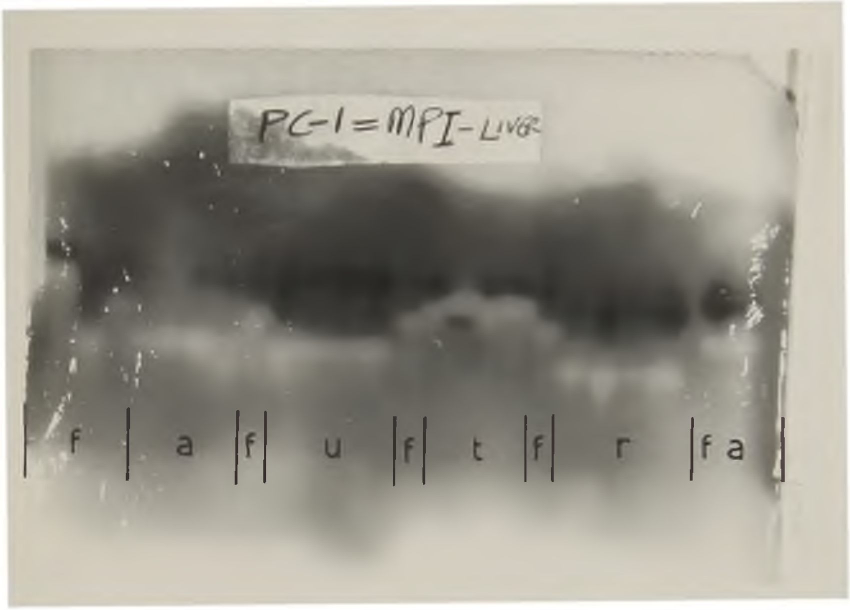
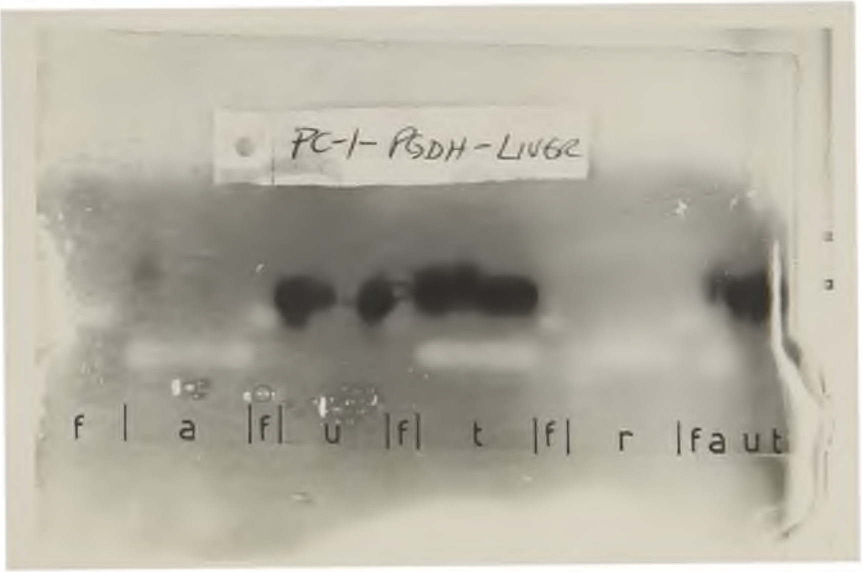


Plate 23



Plates 22 and 23: Comparison of zymogram patterns of MPI and PGDH of 5 species of *Saurida*. Legend follows Table (p.25a).

PGDH (CAEA)

Muscle (Fig. 2.11C): The enzyme was detected as a single or double (in *S. undosquamis*) banded form. All the species except *S. tumbil* showed reduced activity (i.e. low intensity or stain) by the enzyme.

The liver isozyme was only detected in *S. undosquamis* and *S. tumbil* - these two species exhibited a high staining rate indicating high activity of PGDH (Plate 23).

PGM (CAAPM)

Migration was only cathodal in muscle extracts, with the species exhibiting distinct array of bands. (Plate 24A).

The liver isozyme was only detected in *S. undosquamis* and *S. tumbil* (Plate 24B).

PK (CAAPM)

Muscle: Plate 25A shows a 3-banded pattern with one major zone of activity.

Liver: Isozyme poorly resolved in *S. undosquamis* and *S. tumbil* and not detected in the other species (Plate 25B).

SDH (PC-1)

Liver (Plate 26): Activity zones of this enzyme were achromatic and of three mobility types. The least anodal forms were found in *S. australis*, *S. tumbil* and *S. argentea*. *S. undosquamis* had the most anodal form and was well separated from the other species.

Resolution of muscle SDH was poor.

Plate 24A

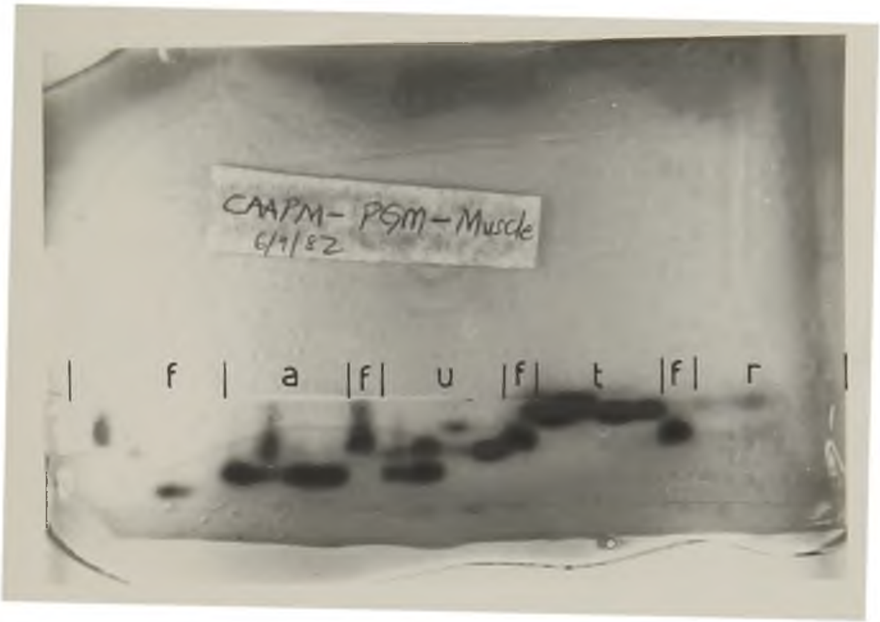


Plate 24B

Plate 24: Comparison of zymogram patterns of muscle (A) and liver (B) PGM of 5 species of *Saurida*. Legend follows Table 2.0 (p.25a).

Plate 25A

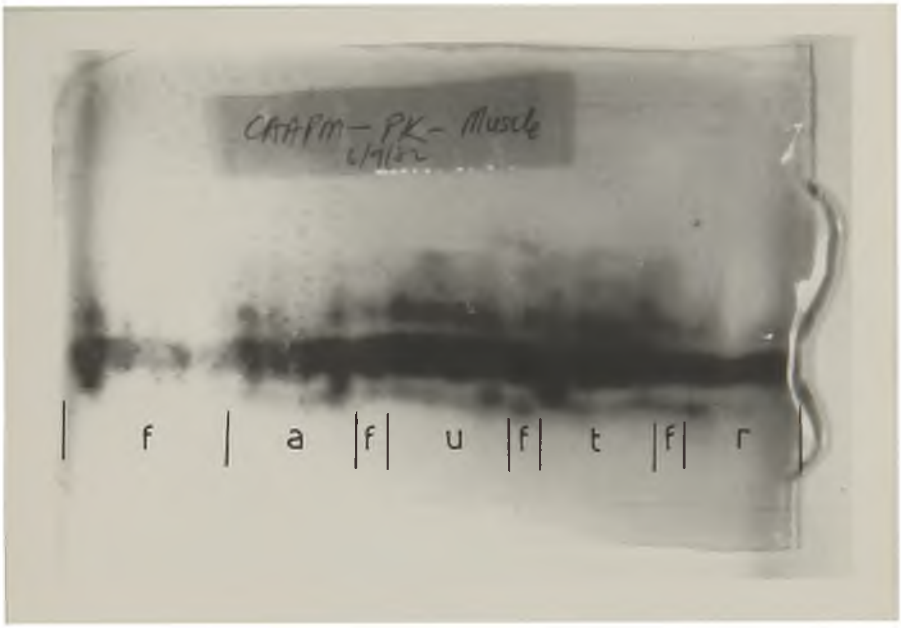


Plate 25B

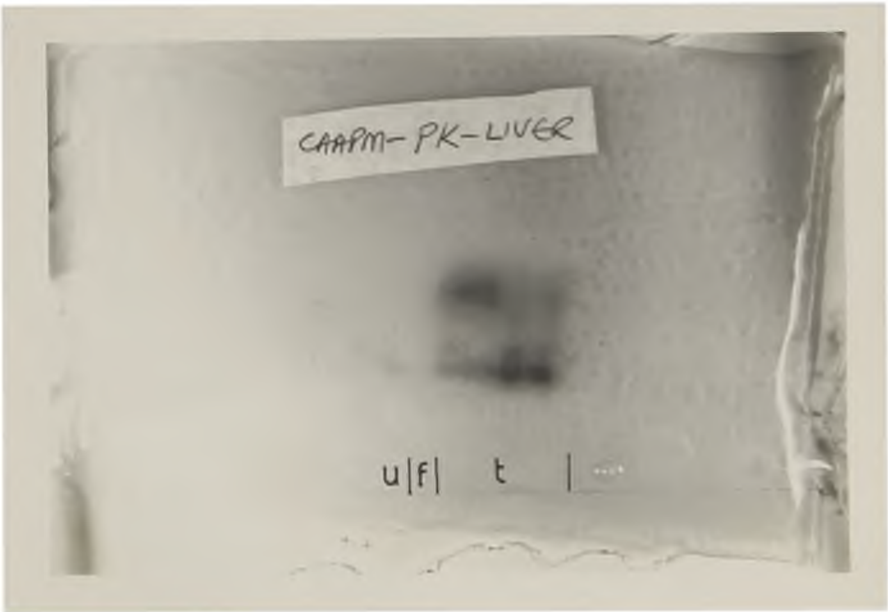


Plate 25: Comparison of zymogram patterns of muscle (A) and liver (B) PK of 5 species of *Saurida*. Legend follows Table 2.0 (p.25a)

Plate 26

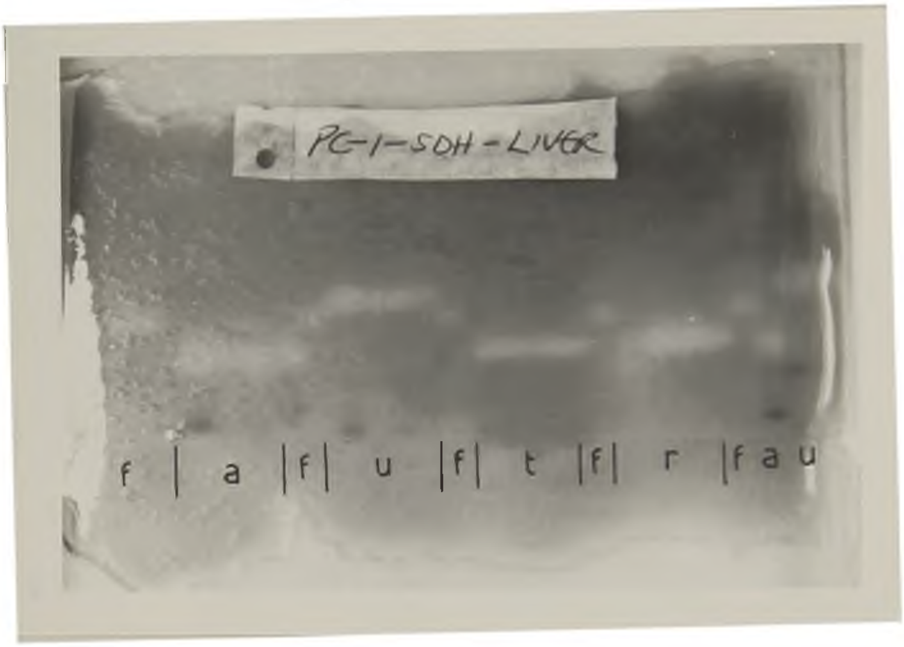
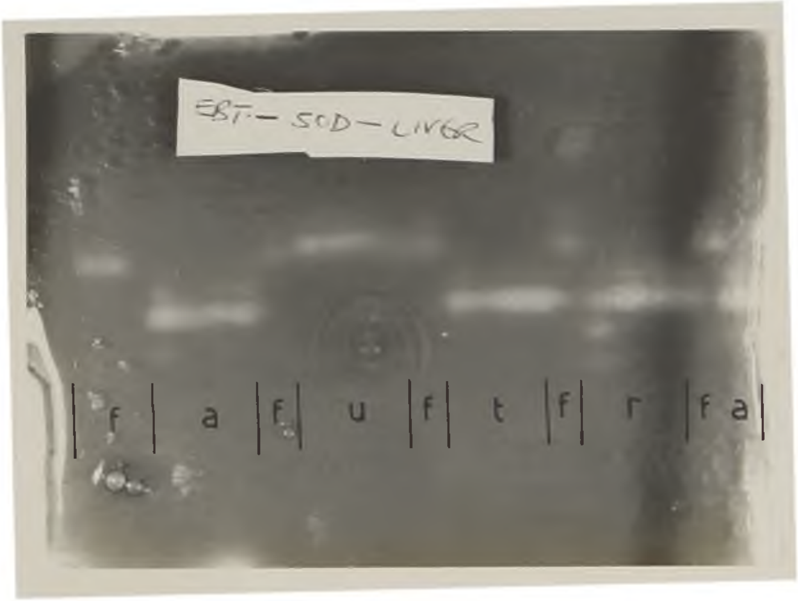


Plate 27



Plates 26 and 27: Comparison of zymogram patterns of SDH and SOD of 5 species of *Saurida*. Legend follows Table 2.0 (p.25a).

SOD (EBT)

Liver (Plate 27): The species exhibited the same patterns as with SDH except that *S. argentea* was found to be polymorphic for two co-dominant alleles.

UMB (EBT)

The bands were only visible under ultraviolet light - all the species except *S. filamentosa* shared a common band. *S. filamentosa* had the most anodal band.

XDH (TECB)

Muscle: All the species share a common band except *S. undosquamis* (Plate 28A, Fig. 2.11D).

The liver isozyme (Plate 28B) is poorly resolved and appears as a single or double banded pattern. The achromatic zones in the zymograms are due to some other dehydrogenase(s) probably ADH or SOD.

In the main polymorphisms characterized by two co-dominant alleles, were noted in a number of the following monomeric proteins:

enzyme	locus	species
AAT	liver	*S. australis* *S. undosquamis*
GPI	muscle	*S. filamentosa*
IDH	muscle	*S. tumbil*
MPI	liver	*S. australis* *S. undosquamis*
MPI	muscle	*S. undosquamis*

The only dimeric protein found to be polymorphic was SOD in *S. tumbil* and *S. argentea*.

PLATE 28A

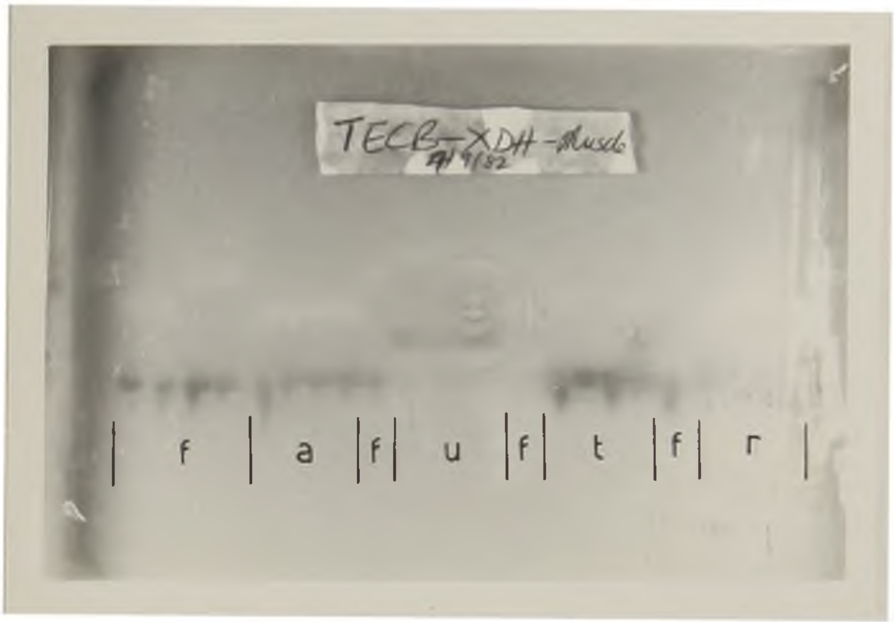


Plate 28B

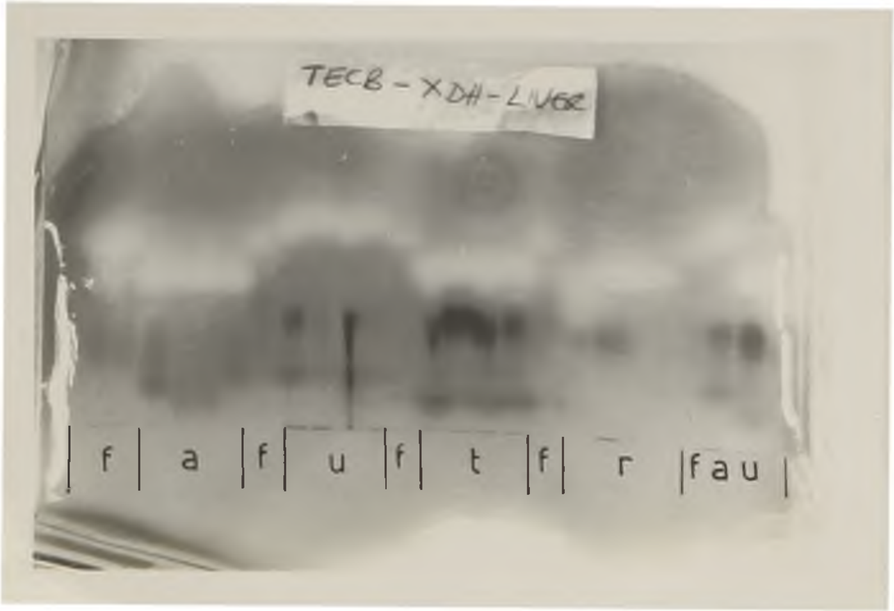


Plate 28: Comparison of zymogram patterns of muscle (A) and liver (B) XDH of 5 species of *Saurida*. Legend follows Table 2.0 (p.25a).

Though the results suggest considerable intra-specific variability, each individual could be assigned unequivocably to one of the species - the species apparently exhibit distinctive *phenotypes, notably, for CK (M,E), GAPDH (M), G-3-PDH (M,E), SOD (L,E) and to varying degrees for LDH (M,L,E), IDH (M,L), PGM (L,E), AH (L), SDH (L), EST (L) and AAT (M,L,E).

S. undosquamis and *S. australis* shared common electromorphs at AAT (M,L) AK (M), MDH (M) and IDH (M) but differed in ADH (M), ME (M), MDH (L), G-6-PDH (L), PK (M), MPI (L,M) and XDH (M). Likewise though *S. tumbil* and *S. argentea* were identical or similar in AAT (L), AK (M), MDH (M), ME (M), PK (M), and MPI (L), they differed in ADH (M), GPI (M), AAT (M) and MDH (L).

2.3.2 Morphological Systematics

2.3.2.1 Generic characters

Saurida: Two bands of palatine teeth on each side of palate. Vomerine teeth present or absent (see Plates 29-35 and Fig. 2.14). Nine pelvic fin rays, inner rays of which are subequal or slightly longer than outer rays **(Fig. 2.12C)

Polyspecific genus.

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* M - muscle, E - eye, L - liver.

** Adopted from Anderson, Gehringer and Berry 1966.

Trachinocephalus and *Synodus:* One band of palatine teeth on each side of palate. Vomerine teeth absent (See Plate 37). Eight pelvic fin rays, innermost rays distinctly longer than outermost rays, about two or more time longer *(Fig. 2.12 A,B).

Trachinocephalus: Anal fin base longer than dorsal fin base. Monotypic genus.

Synodus - Anal fin base shorter than dorsal fin base. Polyspecific genus.

2.3.2.2 Genus *Saurida*

Saurida: Cuvier and Valenciennes, 1849.

1849 *Saurida:* Cuv. and Val. Hist. Nat. Poiss. xii, 1849, p. 499; type species *Salmo tumbil* Bloch 1795, by subsequent designation of Jordan, Tanaka, and Snyder, J. Coll. Sci. Tokyo, 33(1), 1913: 53 *fide* Fowler, Bull. Amer. Mus. Nat. Hist., 70(2), 1936 : 1218.

Body elongate, sub-cylindrical, fins with no spines. Scales cycloid and of moderate size. Lateral line straight except for a slight curvature above pectoral fin base. Head lizard-like, oblong and depressed with an antero-supra-orbital bony ridge just after second nostril. Nostrils approximate, the first fringed by a nasal flap. Eye of moderate size and nearer tip of snout than posterior edge of head. Eye partly covered by an anterior and posterior eyelid. Dorsal fin nearly in the middle of standard length. Adipose fin small and set opposite to posterior

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* Adopted from Anderson, Gehringer and Berry 1966.

Fig. 2.12: Ventral view of pelvic fins of *Trachinocephalus (A)*, *Synodus (B)* and *Saurida (C)*. (Adopted from Anderson, Gehringer and Berry 1966)

Fig. 2.13: A,B - Snouts of *Saurida* species
C,D,E - Nasal flaps of *Saurida* species
G,H - Diagrams showing lengths of pectoral fins of *Saurida* species.

1 = *Saurida longimanus*

Fig. 2·12

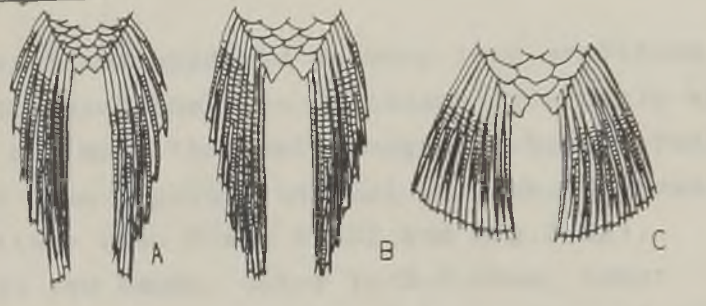
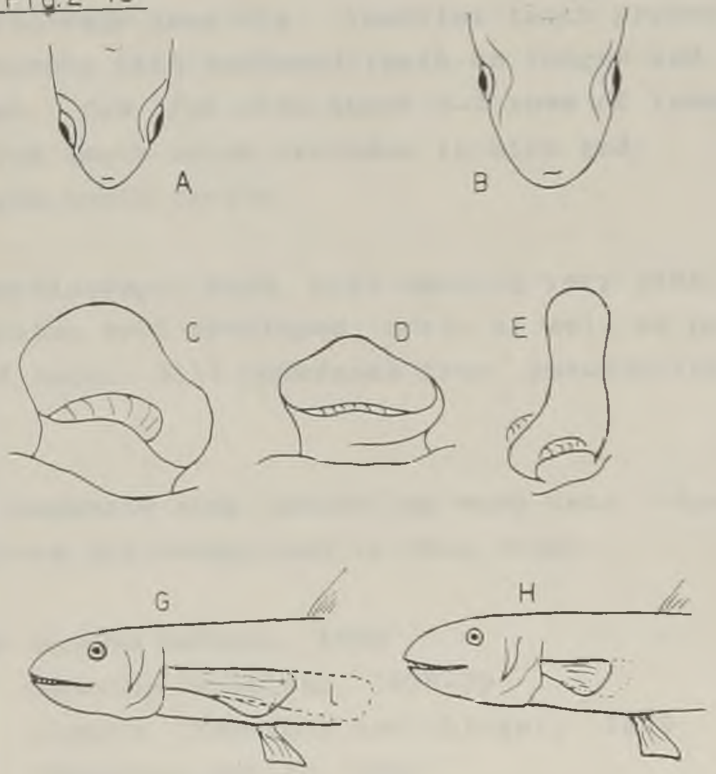


Fig. 2·13



half of anal fin. Pelvic fin base well behind pectoral fin base but inserted before dorsal fin. Tail tapering and covered with scales. Caudal fin bifurcate, pectoral falcate to subfalcate. Anal fin short. 3 or 4, and 5 scales row above and below lateral line respectively.

Mouth terminal and bordered by very long styliform intermaxillary to which the thin maxillary is closely adherent. Gape wide and more than half length of head. Teeth seriate; more or less regular, unequal in size, depressible, conical to sagittate (see Plate 29-35 and Fig.3.4A). Palatine teeth in two bands; outer is 2-4 rows, inner patch-like and pluriserial (see Fig. 2.14). Size of teeth in both bands increase inwardly. Vomerine teeth present or absent. Numerous fine caninoid teeth on tongue and branchial arches. Jaw lips with about 5-7 rows of inwardly slanting recurved teeth which increase in size and curvature towards mouth cavity.

13-16 branchiostegal rays, gill opening very wide. Opercular apparatus well developed, scaly as well as postorbital part of head. Gill membranes free, pseudobranchiae well developed.

Fishes of moderate size inhabiting warm seas. Species cryptic and eleven are recognized in this study:

1. *Saurida argentea* Macleay, 1882
2. *S. australis* Castelnau, 1878-79
3. *S. elongata* (Temminck and Schlegel), 1846
4. *S. filamentosa* Ogilby, 1910
5. *S. flamma* Waples, 1982
6. *S. gracilis* (Quoy and Gaimard), 1824
7. *S. isarankurai* Shindo and Yamada, 1972
8. *S. longimanus* Norman, 1939
9. *S. nebulosa* Valenciennes, 1849
10. *S. tumbil* (Bloch), 1795

11. *S. undosquamis* (Richardson), 1848

2.3.2.2.1 Important diagnostic characters of *Saurida*

2.3.2.2.1.1 Palatine teeth

Three types of teeth configuration in palatine bands and on vomer were established - each epitomized by the *patterns in *S. undosquamis*, *S. tumbil* and *S. nebulosa* respectively.

2.3.2.2.1.1.1 *S. undosquamis* type (Plate 29)

Other band teeth usually in 2 and occasionally 3 rows anteriorly. Inner band with 5-7 rows of teeth. Bands widely separated. Vomer with or without teeth; if present usually on flanks or wings of vomer.

Species - *S. undosquamis*, *S. filamentosa* (Plate 34), *S. australis*, *S. longimanus*, *S. isarankurai* (see Fig. 2.14).

2.3.2.2.1.1.2 *S. tumbil* type (Plate 30A)

Outer band teeth in three or four rows. Inner band with 5-8 rows of teeth. Bands narrowly separated. Vomerine teeth present and central (see Plate 30B)

Species - *S. tumbil*, *S. argentea* (Plate 32A, B) and *S. elongata* (see Fig. 2.14)

2.3.2.2.1.1.3 *S. nebulosa* type (Plate 31)

Outer band with a short neck, distal aspect divergent. Outer band teeth in 2 or 3 poorly arranged rows, first three or four teeth of innermost row in neck of outer bank very long and pointed. Inner band consists of

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* See description of species for specific palatine patterns.

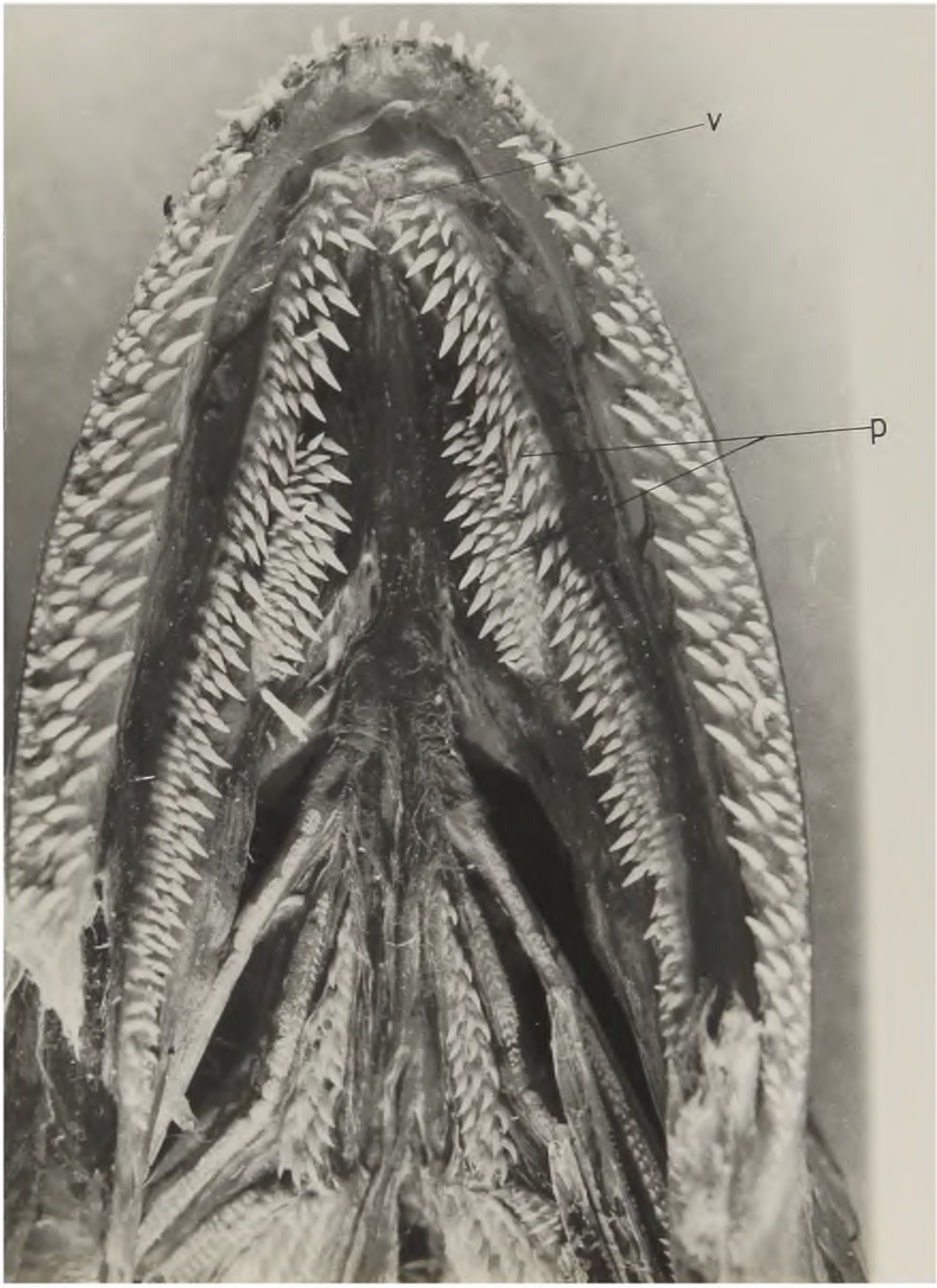
Plate 29

Teeth configuration in palatine (p) bands and on vomer (v) of *S. undosquamis*.


V
P

Plate 30A

Teeth configuration in palatine(p) bands and on vomer(v) of *S. tumbil*.


v
p

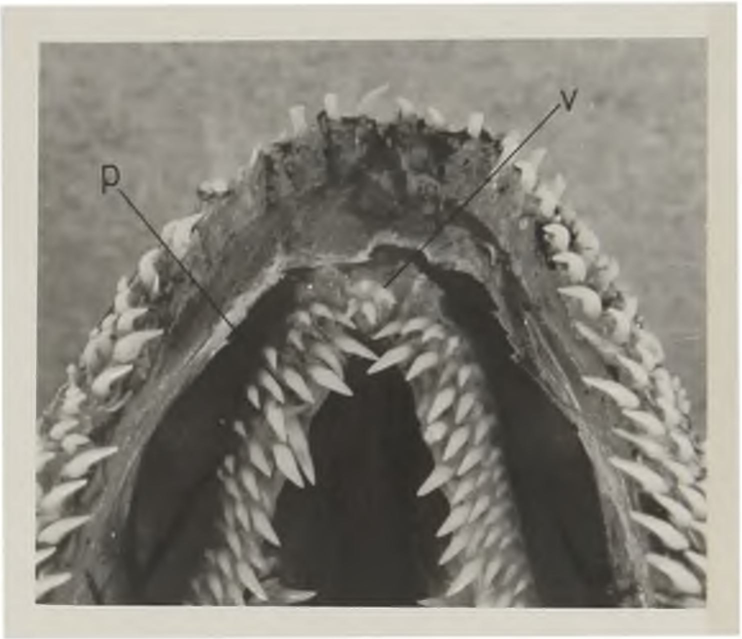


Plate 30B

Teeth configuration in palatine(p) bands and on vomer (v) of *S. tumbil*

Plate 31.

Teeth configuration in palatine (p) bands and on vomer (v) of *S. nebulosa.*

X = long and pointed teeth.

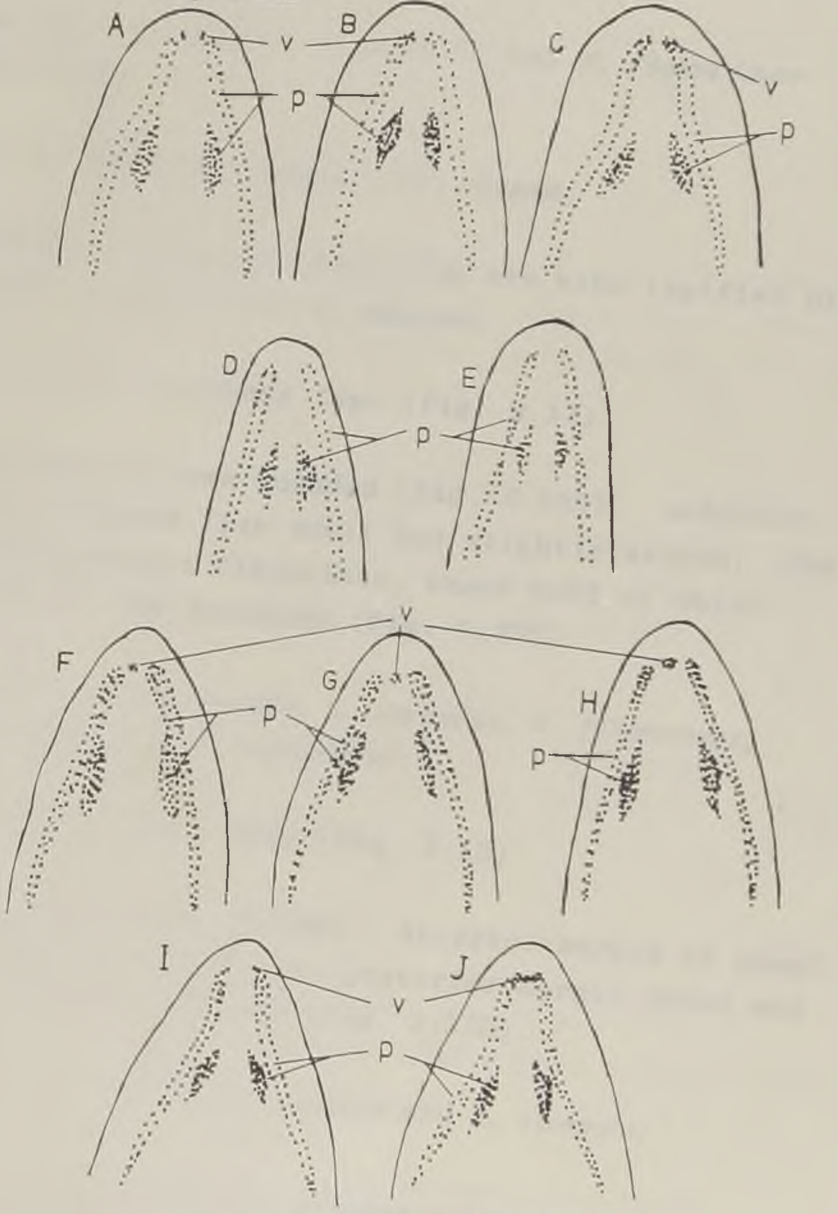

v
x
x
p


v
x
p

Fig. 2.14: Diagrams of palatine (p) and vomerine (v) teeth configurations in *Saurida* species

A	*S. undosquamis*
B	*S. australis*
C	*S. filamentosa*
D	*S. longimanus*
E	*S. isarankurai*
F	*S. tumbil*
G	*S. argentea*
H	*S. elongata*
I	*S. nebulosa* *S. flamma*
J	*S. gracilis*

Fig. 2·14



3-4 poorly defined rows. Bands narrowly separated. Vomerine teeth present, set centrally or 2-4 teeth on the wings of vomer (v, see Plate 31) and deceptively * alligned with outer band.

Species - *S. nebulosa, S. gracilis* and *S. flamma* (see Fig. 2.14)

2.3.2.2.1.2 Snout and nasal flap shapes

Shapes of snout and nasal flap are also typified by *S. undosquamis, S. tumbil* and *S. nebulosa.*

2.3.2.2.1.2.1 *S. undosquamis* type (Fig. 2.13)

Snout more or less rounded (Fig. 2.13B). Anterior margin of nasal flap small and slightly arched, the posterior margin flabellate, inner half of which is more or less produced (Fig. 2.13C).

Species - *S. undosquamis, S. australis, S. filamentosa, S. longimanus* and *S. isarankurai.*

2.3.2.2.1.2.2 *S. tumbil* type (Fig. 2.13)

Snout pointed (Fig. 2.13A). Anterior margin of nasal flap domed or arched, the posterior margin broad and more or less flabellate (Fig. 2.13D).

Species - *S. tumbil, S. argentea* and *S. elongata.*

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*Could be verified by slight probing and pushing - especially outward - with a seeker, viewed under a magnifying glass or microscope.

2.3.2.2.1.2.3 *S. nebulosa* type (Fig. 2.13)

Snout more or less pointed (Fig. 2.13A). Anterior margin of nasal flap very narrow, posterior margin prolonged and spatulate (Fig. 2.13E).

Species - *S. nebulosa, S. gracilis* and *S. flamma.*

2.3.2.2.1.3 Pectoral fin (Fig. 2.13)

The length of pectoral fin is also a good diagnostic feature. In *S. longimanus* the pectoral fin is long, reaching beyond the origin of the dorsal fin; about 78-103% of H.L. (Fig. 2.13G_1)

Pectorals of *S. undosquamis, S. filamentosa, S. australis, S. nebulosa, S. gracilis, S. flamma* and *S. isarankurai* are also long. Though not as long as in *S. longimanus,* they reach at least, to the level of pelvic fin base; 46-75% of H.L. (Fig. 2.13G).

Pectoral fin is short in *S. tumbil, S. argentea* and *S. elongata.* They were not found to reach beyond the pelvic fin base; 44-58% of H.L. (Fig. 2.13H).

2.3.2.2.1.4 Second and Third dorsal fin rays

The second and sometimes third dorsal fin rays filamentous in *S. filamentosa;* the second ray on average being about six times as long as the last ray; range : 4.1-8.3.

No other known species of *Saurida* possesses these filamentous dorsal rays.

2.3.2.2.1.5 Jaws

The upper jaw is slightly longer than or equal to the lower jaw in all species except *S. isarankurai* and three Atlantic species. The lower jaw of *S. isarankurai* is produced beyond the tip of the *upper jaw and is visible from above.

2.3.2.2.1.6 Colour

S. nebulosa, S. flamma and *S. gracilis* are variously mottled and blotched on body and fins. *S. elongata* is uniformly brown. The other species are variously brown to olive dorsally and silvery below the lateral line.

2.3.2.2.2 Specific Descriptions and Distributions (See Tables 2.1 - 2.4B)

2.3.2.2.2.1 *Saurida argentea* Macleay, 1882 (Silvery saury)

Saurida argentea Macleay, Proc. Linn. Soc. N.S. Wales, VI, 1882, p. 220. Endeavour River, North Queensland.

Saurida micropectoralis Shindo and Yamada, Uo. Jap. Soc. Ichthyol. No. 11, 1972, p. 11. Prachuap Khiri Khan Province, Gulf of Thailand.

* A specimen identical with *S. undosquamis* but with a longer lower jaw was found in Moreton Bay. It was considered an eberrant specimen of *S. undosquamis.*

Material examined (32 specimens, size range : 123-260mm)

Syntype: AMS I.16271-001, 2 specimens; 141, 133mm. Endeavour River, North Queensland. 15° 28'S, 145° 15'E. Other specimens (number examined in brackets) Queensland: AMS I.15421-014 (3), Magnetic Island; 19° 10'S, 146° 50'E. Hervey Bay (1), collected by Clive Keenan. Northern Territory (of Australia): DPPFD-ME30 (1), Melville Island. North-Western Shelf of Australia (18), collected by CSIRO ('SOELA'). Gulf of Thailand : ZUMT 54349 (1), Prachuap Khiri Khan Province. Hong Kong: SOSC Cat. No. 9454 (2). Sri Lanka : SOSC Ref. No. 553 (3). Indonesia : SI, HS-F242 (1), Halmahera Island.

Description

Counts: 11-12 dorsal fin rays; 10-11 anal fin rays; 13-15 pectoral fin rays; 53-58 scales in lateral line; 19-23 predorsal scales; 13-16 interdorsal scales and 9-12 scales between adipose and caudal fins.

Morphometry: Mean and range (in brackets) of characters calculated as percentages of

TABLE 2.1 : Meristic Characters of Lizardfish

(A) LATERAL LINE SCALES

Number of Scales → Species	*N	46	47	48	49	50	51	52	53	54	55	56	57	58	59
S. isarankurai	3			2?	1										
S. longimanus	17			6	5	5	1								
S. undosquamis	42	2	5	7	8	8	4	5	3						
S. filamentosa	71						4	13	24	25	5				
S. australis	28										8	16	4		
S. elongata	3													2	1
S. argentea	32								1	1	8	15	6	1	
S. tumbil	72				2	6	12	25	20	7					
S. flamma	8						1	2	4	1					
S. gracilis	8				2	3	2	1							
S. nebulosa	49		3	10	21	11	3								
T. myops	71						1	2	5	27	22	11	2		

* Number of specimens

TABLE 2.2 : MERISTIC CHARACTERS OF LIZARDFISH

(B) FIN RAYS

Species	N*	DORSAL						PECTORAL						ANAL								
		9	10	11	12	13	14	11	12	13	14	15	16	9	10	11	12	13	14	15	16	17
S. isarankurai	3			3					1	2						2	1					
S. longimanus	17			8	9				2	7	4	4			2	6	9					
S. undosquamis	42			13	23	6				8	25	9		3	13	21	5					
S. filamentosa	71			29	42					4	18	42	7		12	53	6					
S. australis	28		7	21							20	8			15	13						
S. elongata	3			2	1					1	1	1				3						
S. argentea	32			10	22					3	11	18			14	18						
S. tumbil	72			22	43	7					41	31		8	46	18						
S. flamma	8			8						2	6			1	6	1						
S. gracilis	8		2	6						2	6			3	5							
S. nebulosa	49	1	14	30	4				28	18	3			2	30	17						
T. myops	71			1	26	40	4	1	64	6									8	28	27	8

* Number of specimens

TABLE 2.3 : Scale Counts and Morphometry

Species	*S. australis*	*S. undosquamis*	*S. filamentosa*	*S. isarankurai*	*S. longimanus*	*S. tumbil*	*S. argentea*	*S. elongata*	*S. gracilis*	*S. nebulosa*	*S. flamma*	*T. myops*
Number of specimens	28	42	71	3	17	72	32	3	8	49	8	71
SCALE COUNTS												
Predorsal	16-21	16-20	15-21	20	16-20	18-24	19-23	21-25	15-16	13-17	16-21	13-17
Interdorsal	17-18	13-19	13-20	-	11-15	10-16	13-16	17-18	13-16	13-16	15-17	13-17
Between adipose and caudal fins	11-12	9-12	10-12	-	9-11	8-12	9-12	10-12	9-10	8-11	10-11	6-10
Above lateral line	4	4	4	4	4	4	4	4	3	3	3	3
In lateral line	55-57	46-53	51-54	48?-49	48-51	49-54	53-58	58-59	49-52	47-51	51-54	51-57
Below lateral line	5	5	5	-	5	5	5	5	4-5	4	4	5-6
Morphometry (Range and Mean)												
Eye in interorbital	1.0-1.3 1.2	0.8-1.6 1.1	0.9-1.7 1.1	0.8-1.0 0.9	0.6-1.0 0.9	0.7-1.4 1.1	1.0-1.3 1.1	1.2-1.6 1.4	1.0-1.2 1.1	0.9	0.8-1.3 1.0	0.5-0.9 0.7
Dorsal fin base L. / Anal fin base L.	1.1-1.3 1.2	1.2-2.9 1.4	1.1-1.7 1.4	1.2-1.3 1.2	1.1-1.5 1.3	1.1-2.0 1.6	1.3-1.6 1.4	1.2-1.3 1.3	1.4-1.7 1.5	1.3-1.7 1.5	1.3-1.5 1.4	0.6-0.7 0.7
Snout L./ Snout width	0.8-1.0 0.9	0.8-1.0 0.9	07.-1.0 0.8	-	0.8-0.9 0.9	0.8-1.1 0.9	0.9-1.1 1.0	0.9-1.0 1.0	0.9-1.1 1.0	0.9-1.2 1.0	0.9-1.0 1.0	0.6-0.8 0.7
Premaxillary / mandible width	1.3-2.1 1.8	0.9-2.6 2.2	0.9-2.6 2.0	-	1.7-2.8 2.5	1.3-2.4 1.7	1.5-2.5 2.1	1.9-2.3 2.1	1.9	1.8-2.6 2.1	1.7-2.5 2.0	1.0-1.8 1.3
Snout L. / Eye diameter	1.0-1.3 1.2	0.9-1.6 1.3	0.8-1.5 1.0	1.0-1.1 1.1	0.9-1.1 1.0	0.8-1.5 1.2	1.1-1.6 1.2	1.1-1.5 1.3	1.0-1.3 1.1	1.0-1.4 1.1	1.0-1.5 1.2	0.5-0.8 0.6
2nd Dorsal ray L. / 3rd Dorsal ray L.	1.0	1.0-1.1 1.0	1.0-1.9 1.4	1.1	1.0-1.1 1.0	1.0-1.1 1.0	0.7-1.1 1.0	1.0	1.0	1.0-1.1 1.0	1.0	0.9-1.3 1.0
2nd Dorsal ray L. / Last dorsal ray L.	2.7-3.9 3.0	2.0-4.9 3.4	4.1-8.3 6.0	-	3.1-3.5 3.3	1.8-4.4 3.7	3.2-3.9 3.8	3.9	2.3-2.4 2.4	2.1-2.8 2.5	2.1-2.4 2.3	1.6-2.2 1.9
2nd Dorsal ray L. / 1st Dorsal ray L.	1.8-2.5 2.2	1.2-2.4 2.0	2.3-4.1 3.2	-	1.8-1.9 1.8	1.4-2.3 1.8	1.8-2.1 1.9	1.8	1.6-1.7 1.6	1.6-1.8 1.7	1.5-1.8 1.7	1.6-3.2 2.1
Vent from Pelvic insertion / Vent from caudal	1.2-1.4 1.3	1.1-1.8 1.3	1.2-1.4 1.3	-	1.0-1.2 1.1	1.1-1.5 1.3	1.1-1.5 1.2	1.2-1.4 1.3	1.3-1.6 1.5	1.3-1.8 1.5	1.2-1.5 1.3	0.7-0.9 0.8

L = length

TABLE 2.4A : Mean and range of morphometric characters as percentage of standard length

Species (and number of specimens)	*S. australis* (28)	*S. undosquamis* (42)	*S. filamentosa* (21)	*S. isarankurai* (3)	*S. longimanus* (11)	*S. tumbil* (12)	*S. argentea* (32)	*S. elongata* (3)	*S. gracilis* (8)	*S. nebulosa* (49)	*S. flamma* (9)	*T. myops* (15)
Head L.	23.0-23.9 23.5	23.1-25.5 24.3	21.3-25.5 23.6	21.5-24.5 23.8	21.9-26.3 23.5	21.4-28.6 23.4	22.2-25.5 24.8	20.1-22.5 21.6	24.7-25.4 25.1	22.0-27.9 24.9	24.2-27.4 25.0	23.4-28.6 25.6
Pectoral fin L.	13.4-14.3 13.8	13.5-17.0 15.6	12.8-18.2 15.9	21.2	17.0-24.0 20.4	10.1-12.7 11.4	10.6-14.6 12.2	10.7-11.0 10.9	13.6-14.5 14.0	12.3-15.5 13.0	13.6-14.9 14.7	12.0-15.1 13.3
Pelvic fin L.	17.5-18.7 18.2	16.1-20.9 17.7	16.2-19.0 18.2	18.5-18.9 18.7	16.3-19.9 17.9	16.8-20.6 18.7	17.5-20.2 18.9	15.7-19.6 17.7	20.9-22.6 21.8	19.2-23.1 20.7	22.0-24.5 23.4	26.7-30.9 29.0
Dorsal fin L.	18.4-19.6 19.2	20.1-24.0 22.3	24.4-51.2 34.9	21.6	23.1-25.4 24.2	20.3-25.0 21.7	20.9-23.4 20.5	20.0-20.2 20.1	21.7-22.9 22.4	20.2-24.1 21.6	22.1-25.1 23.6	22.0-32.9 27.1
Interdorsal L.	25.8-29.9 27.5	20.9-27.9 25.4	23.3-28.6 26.9	23.3-26.5 24.9	21.6-27.3 23.0	22.5-28.7 26.5	25.0-28.8 26.2	27.5-30.0 28.5	25.4-26.2 25.8	23.7-27.7 25.3	24.8-27.8 26.8	20.6-29.9 25.9
Interventral L.	35.9-42.5 38.8	32.7-39.4 36.3	32.2-42.8 37.2	34.0-35.6 34.8	27.8-37.7 33.4	33.6-41.2 37.1	33.2-37.8 35.6	34.3-39.4 36.0	38.4-41.8 40.1	37.6-42.6 39.9	36.1-41.6 39.2	25.4-34.2 30.0
Caudal peduncle L.	16.6-18.8 17.9	14.8-18.6 17.0	12.8-19.8 17.1	19.6-20.0 19.8	15.4-20.2 18.5	15.6-19.8 17.4	15.2-18.9 16.6	14.7-18.4 16.5	15.6-16.7 16.1	15.0-18.6 16.7	15.7-18.0 17.0	14.6-18.8 16.4
Predorsal L.	40.6-41.5 41.1	40.8-44.6 42.8	36.4-42.5 40.3	43.0-43.2 43.1	38.8-45.7 43.5	40.8-43.6 42.2	41.2-43.6 42.6	38.6-43.5 41.6	41.2-42.7 42.0	39.3-45.6 42.9	39.8-43.4 41.4	36.4-44.5 40.3
Prepelvic L.	34.3-36.9 35.7	33.6-38.7 37.5	24.4-41.8 35.9	37.0-38.0 37.5	32.3-40.8 38.0	34.8-41.5 37.2	34.6-39.2 37.7	32.2-38.4 36.1	33.7-35.7 34.7	31.4-37.7 34.8	33.4-36.7 35.1	32.0-37.2 33.0
Prepectoral L.	23.9-24.8 24.4	23.1-26.9 25.1	21.2-26.0 24.0	23.2-24.7 24.0	21.0-27.0 25.0	22.9-27.4 24.0	22.9-26.0 24.6	22.2-23.9 23.2	25.1-26.6 25.9	21.0-28.6 25.3	24.2-26.8 25.2	23.2-28.1 25.1
Preanal L.	72.7-75.4 74.2	72.1-77.9 71.9	68.2-80.6 75.0	73.6-74.3 73.9	64.5-77.2 73.1	72.5-77.8 74.1	72.0-77.4 75.0	72.1-75.5 73.7	75.7-77.8 76.7	72.2-83.6 76.1	75.0-76.6 75.9	58.6-70.4 65.6
Dorsal fin base L.	11.4-12.4 11.9	12.1-15.3 13.7	11.0-16.6 13.4	11.8-14.9 13.7	11.4-15.9 14.2	11.8-15.1 13.7	11.6-14.2 13.1	12.3-12.6 12.4	14.4-15.1 14.8	12.1-16.5 14.4	11.7-15.6 15.0	15.6-19.7 17.4
Anal fin base L.	8.9-12.2 9.9.	4.5-12.1 9.8	8.0-13.8 10.3	10.8-11.8 11.3	9.8-12.4 11.3	7.2-14.2 8.8	8.2-10.5 9.6	9.2-10.0 9.7	8.8-10.6 9.8	9.0-11.7 9.9	10.0-11.6 10.5	20.8-28.5 25.3
Lengths as denoted by the characters indicated. (only means)												
Distal dorsal and caudal fin	45.8	43.5	45.4	-	43.2	45.0	44.0	47.5	43.3	42.7	43.9	43.3
Distal dorsal and snout tip	53.9	56.5	53.8	-	57.1	54.9	55.7	52.0	56.5	56.9	56.3	59.2
Vent and snout tip	71.0	72.9	71.2	-	71.4	72.2	72.2	70.6	74.0	73.4	72.3	65.7
Anal fin and head	50.2	51.3	51.0	-	49.3	53.5	52.2	53.5	50.2	52.0	52.0	45.6
Anal fin and caudal fin	17.0	15.6	16.3	-	16.8	16.7	16.0	15.9	15.1	14.9	16.4	11.9
Anal fin and snout tip	70.0	70.5	69.6	-	68.6	72.0	70.0	69.7	69.4	71.1	69.7	64.5
Anal fin and pelvic fin base	38.3	36.2	35.9	-	33.8	37.4	36.0	36.1	39.8	40.4	39.3	31.6
Anal fin and pectoral fin base	48.3	47.9	47.5	-	46.6	50.9	47.8	48.0	57.1	48.5	47.9	39.2
Anal fin and distal dorsal fin	20.0	19.2	21.0	-	15.6	20.8	19.9	19.6	19.1	19.0	20.6	6.9
Dorsal fin origin and adipose fin	39.2	37.6	40.1	38.4	36.2	39.9	38.8	40.5	39.7	39.0	40.1	44.0

TABLE 2.4B : Mean and range of morphometric characters as percentage of head length

Species	*S. australis*	*S. undosquamis*	*S. filamentosa*	*S. isarankurai*	*S. longimanus*	*S. tumbil*	*S. argentea*	*S. elongata*	*S. gracilis*	*S. nebulosa*	*S. flamma*	*T. myops*
Number of specimens	28	42	71	3	17	72	32	3	8	49	8	71
Eye diameter	17.0-24.0 20.0	15.5-23.2 19.5	14.6-22.1 19.9	20.3-21.0 20.6	18.0-24.8 21.8	14.2-23.5 18.6	16.5-20.0 18.5	16.7-16.8 16.7	18.0-22.1 20.1	15.7-23.3 19.5	17.1-24.1 19.7	15.6-25.6 19.7
Preorbital L.	16.9-22.9 21.1	19.8-24.7 21.4	16.6-23.4 21.0	20.9-22.8 21.8	20.0-23.7 22.2	19.4-23.6 21.6	21.0-25.7 22.3	19.5-26.3 23.3	17.1-23.7 21.4	18.7-24.7 21.9	21.9-25.5 23.8	9.9-14.7 12.5
Postorbital L.	58.7-62.5 60.4	55.9-62.0 59.4	54.7-66.4 60.3	59.5-59.7 59.6	51.9-58.9 56.1	51.4-63.8 60.8	55.6-64.0 59.0	57.7-62.1 59.9	56.5-57.2 58.3	50.4-63.9 58.5	52.5-59.5 56.3	58.9-76.1 67.6
Snout L.	21.5-23.1 22.3	20.0-25.9 21.7	17.1-25.5 20.0	-	19.8-24.5 22.5	18.0-24.6 22.0	20.0-24.2 22.1	19.0-25.2 22.1	21.9-27.7 23.1	19.9-25.5 22.3	21.4-26.1 23.6	11.4-14.6 12.9
Premaxillary L.	69.0-71.9 70.5	66.1-73.9 70.2	66.1-75.9 69.7	65.1-68.8 66.8	67.2-73.3 70.1	63.0-74.3 66.9	65.5-72.9 69.2	67.8-73.4 70.1	73.2-78.2 75.2	67.0-79.1 71.1	67.0-76.5 73.1	61.5-66.3 63.0
Pelvic fin L.	75.8-81.4 77.4	69.6-87.0 75.9	67.6-79.9 75.9	70.6-87.8 77.9	65.3-87.5 79.2	70.3-87.7 79.9	70.8-87.3 78.0	72.4-87.3 80.4	84.5-90.8 87.1	77.1-93.7 84.2	89.0-98.7 93.8	105.2-122.4 115.3
Pectoral fin L.	57.7-63.2 58.9	58.2-71.8 66.9	58.9-74.5 67.6	-	78.1-103.4 88.3	43.7-56.4 48.9	46.3-57.5 51.0	48.9-49.0 49.0	54.2-58.3 56.1	45.5-60.1 52.5	54.9-61.2 58.7	42.8-59.5 52.4

L = length

a) Standard length
Head 24.8 (22.2 - 25.5); pectoral fin 12.2 (10.6 - 14.6); pelvic fin 18.9 (17.5 - 20.2); dorsal fin 20.5 (20.9 - 23.4); interdorsal 26.2 (25.0 - 28.8); interventral 35.6 (33.2 - 37.8); predorsal 42.6 (41.2 - 43.6); prepelvic 37.7 (34.6 - 39.2); prepectoral 24.6 (22.9 - 26.0); preanal 75.0 (72.0 - 77.4); dorsal fin base 13.1 (11.6 - 14.2); anal fin base 9.6 (8.2 - 10.5).

b) Head length
Eye diameter 18.5 (16.6 - 20.0); preorbital 22.3 (21.0 - 25.7); postorbital 59.0 (55.6 - 64.0); snout 22.1 (20.0 - 24.2); premaxillary 69.2 (65.5 - 72.9); pelvic fin 78.0 (70.8 - 87.3; pectoral fin 51.0 (46.3 - 57.5).

Body moderately depressed, head flat and tapering to an obtusely pointed snout. Snout bears a mesial ossified protuberance which reduces posteriorly to a shallow fronto-occipital groove. Head profile slightly convex at nostrils. Adipose eyelid moderate. Posterior margin of nasal flap flabellate.

Lower jaw slightly inferior. Outer palatine band mostly in two rows of teeth posteriorly and usually in three or four rows anteriorly; outer band of a broad 'V' shape. Inner band in the form of a broad patch consisting of about six to seven rows of teeth at widest section. Vomerine teeth present. Teeth sagittate and slender (Plate 32A, B *, Fig. 2.14G)

* Syntype (AMS I.16271, 'wet' specimen)

Plate 32A.

Teeth configuration in palatine (p) bands and on vomer (v) of *S. argentea*.


v
p

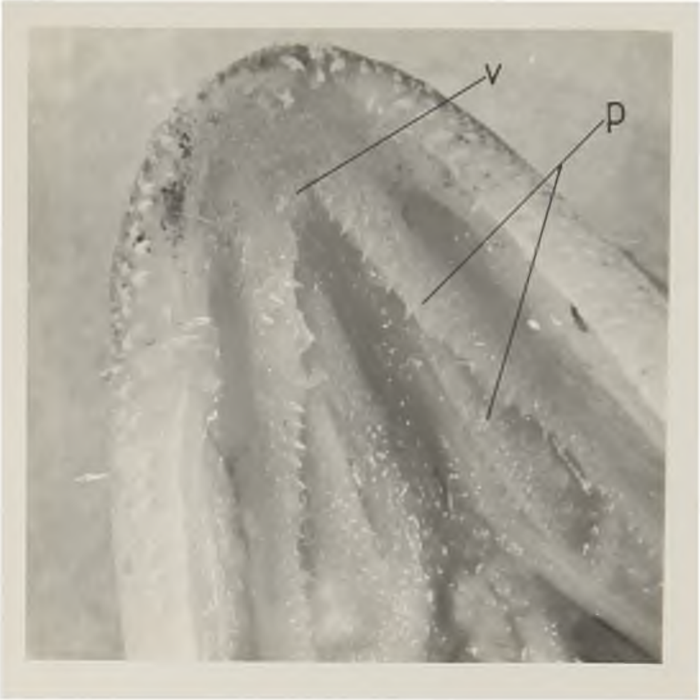

Plate 32B ('wet specimen').
Teeth configuration in palatine (p)
bands and on vomer (v) of
S. argentea

Caudal peduncle moderately depressed and carinate. Pectoral fin does not or just reaches base of pelvic fin.

Colour: Bluish-brown, whitish beneath, many scales with silvery centres. Inner and distal outer surface of pectoral dusky. Upper inner half of pelvic slightly dusky, outer surface clear. Tips of caudal rays dusky black; especially lower lobe. Last ventral ray of subcaudal sometimes with 3-4 dark or brown spots. Upper half of rounded adipose fin dark. Tips of dorsal rays black, leading edge of dorsal fin with very faint brown spots. About 7-8 light blotches along the lateral line.

Distribution: *S. argentea* has been reported mainly from the Central Indo-Pacific region (Fig. 2.15). It occurs on coral, muddy and sandy bottoms, and in estuarine or shallow water to a recorded depth of about 116m.

Size: Maximum reported is 380mm; 200-300mm being the common sizes (Fisher and Whitehead, 1974).

Remark: *S. argentea* was found to be conspecific with *S. micropectoralis* Shindo and Yamada 1972.

2.3.2.2.2.2 *Saurida australis* Castelnau 1878-79

Saurida australis Castelnau, Proc. Linn. Soc. N.S.W. Wales, 1878-79, p. 393. Port Jackson, N.S. Wales

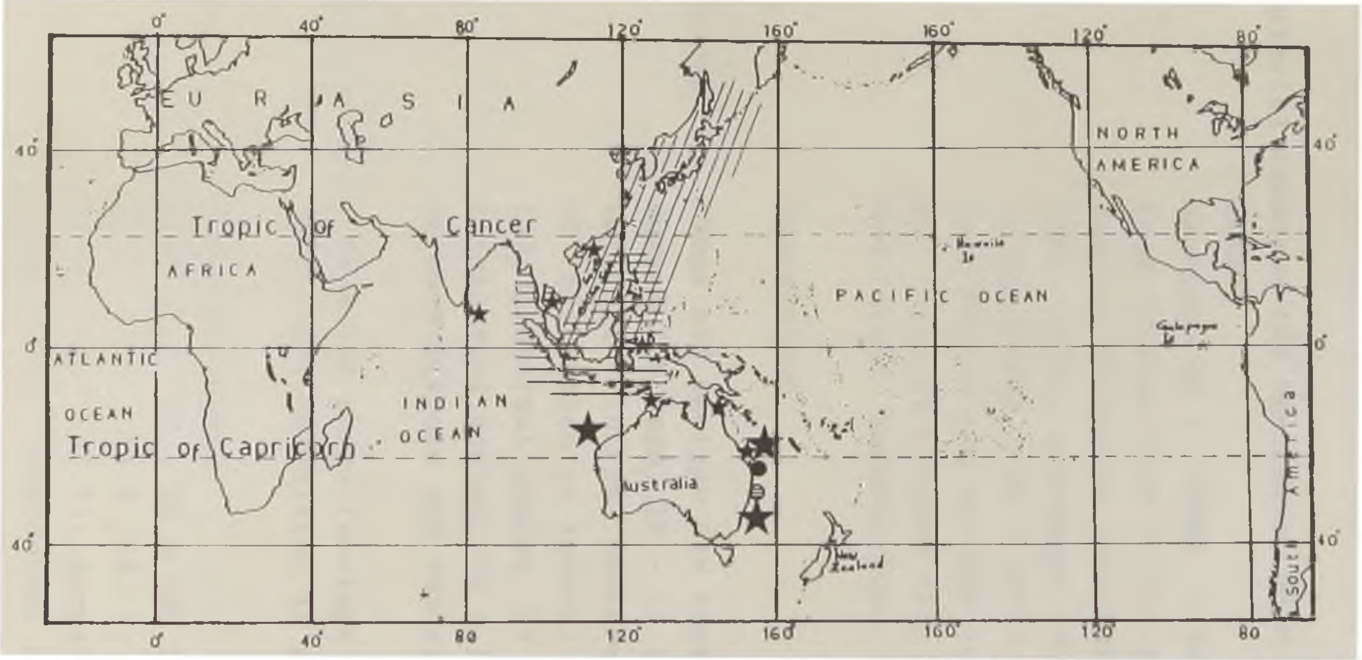

Fig. 2.15 : Distribution of *Saurida argentea* Macleay, 1882 (★, ☰)
S. elongata (Temminck and Schlegel), 1846 (★, ////)
and *S. australis* Castelnau, 1878-79 (●, ⊜).
Solid symbols represent localities of specimens examined; hatched areas are additional literature records.

Saurida tumbil McCulloch, 1929-30, p. 77, in part (Australia).

Material examined (28 specimens, size range : 207 - 300mm)

Neotype: QM I. 20691, 1,263mm; collected from between Lady Elliot and Fairfax Island, East of Bundaberg, Queensland, August 1981. Other specimens (number examined in brackets). QM I 20690 (14); between Lady Elliot and Fairfax Island, Hervey Bay (11), QM I.12054 (1), Q, I.3510 (1); Mud Island, Moreton Bay.

Description

Counts: Range and neotype (in brackets). 10 - 11 (11) dorsal fin rays; 10 - 11 (11) anal fin rays; 14 - 15 (14) pectoral fin rays: 55 - 57 (55) scales in lateral line; 16 - 21 (17) predorsal scales; 17 - 18 (17) interdorsal scales; 11 - 12 (12) scales between adipose and caudal fins.

Morphometry: Mean and range (neotype in brackets) of characters calculated as percentages of

a) Standard length

Head 23.5, 23 - 23.9 (23.2); pectoral fin 13.8, 13.4 - 14.3 (14.1); pelvic fin 18.2, 17.5 - 18.7 (17.3); dorsal fin 19.2, 18.4 - 19.6 (18.6); interdorsal 27.5, 25.8 - 29.9 (28.4); interventral 38.8, 35.9 - 42.5 (36.9); predorsal 41.1, 40.6 - 41.5 (40.9); prepelvic 35.7, 34.3 - 36.9 (36.2); pre-pectoral 24.4, 23.9 - 24.8 (23.9);

preanal 74.2, 72.7 - 75.4 (74.1); dorsal fin base 11.9, 11.4 - 12.4 (12.1); anal fin base 9.9, 8.9 - 12.2 (11.4).

b) Head length
Eye diameter 20.0,17.0 - 24.0 (21.5); preorbital 21.1, 16.9 - 22.9 (21.4); post-orbital 60.4, 58.7 - 62.5 (69.2); snout 22.3, 21.5 - 23.1 (20.9); premaxillary 70.5, 69.0 - 71.9 (69.2); pelvic fin 77.4, 75.8 - 81.4 (74.4; pectoral fin 58.9, 57.7 - 63.2 (60.6).

Body subfusiform, elongated and depressed. Fronto-occipital groove broad and concave. Slight mesial protuberance at snout tip. Predorsal profile slightly convex. Eyes large. Adipose eyelid well developed and broad. Nasal flap broad and slightly produced at inner half of posterior margin.

Upper jaw slightly superior; more or less equal with lower jaw. Outer palatine band mostly in 2 rows; in the shape of a broad 'V'. Inner band in 6 - 8 rows in the broadest section. 2 - 3 teeth on wings of vomer (Fig. 2.14B).

Pectoral fin reaches level of pelvic fin base. Scales in lateral line slightly keeled, especially on the caudal peduncle.

Colour (Plate 33 A,B): Generally olive green above lateral line with faint traces of at least two longitudinal silvery-blue lines more or less formed by the silvery centres of the scales. The silvery centres also given an impression of rather diffused or dispersed

A

B

Plate 33: *Saurida australis*

dorsal origin, 3 in length of dorsal fin and about 4 between dorsal fin and adipose fin. Sides of head more or less gilt. Four longitudinal narrow and silvery-blue bands alternating with three golden longitudinal bands below lateral line and extending from pectoral fin base to the crease of caudal fin - first silvery-blue band below lateral line the most conspicuous and broadest. About 8 dark blotches along the lateral line.

Leading edge of caudal and dorsal fins with 5 - 10 dark dots. Lobes of caudal fin more or less equal; tips black, especially so in the lower lobe. Caudal fin with a greenish tinge. Anal fin silvery-white. Proximal inner half of pelvic fin sparingly dusky, distal inner half and outer surface white or yellowish. Upper half of pectoral fin surface dusky, bottom half more or less silvery-white. Adipose fin with a terminal dark brown blotch.

Distribution (Fibs 2.15 & 2.16): *S. australis* has been recorded from Hervey and Moreton Bays, and Port Jackson. These disparate localities suggest the occurrence of the species on the eastern seaboard of Australia, delimited by the 24°S and 34°S latitudes.

Size: *S. australis* grows to over 350mm.

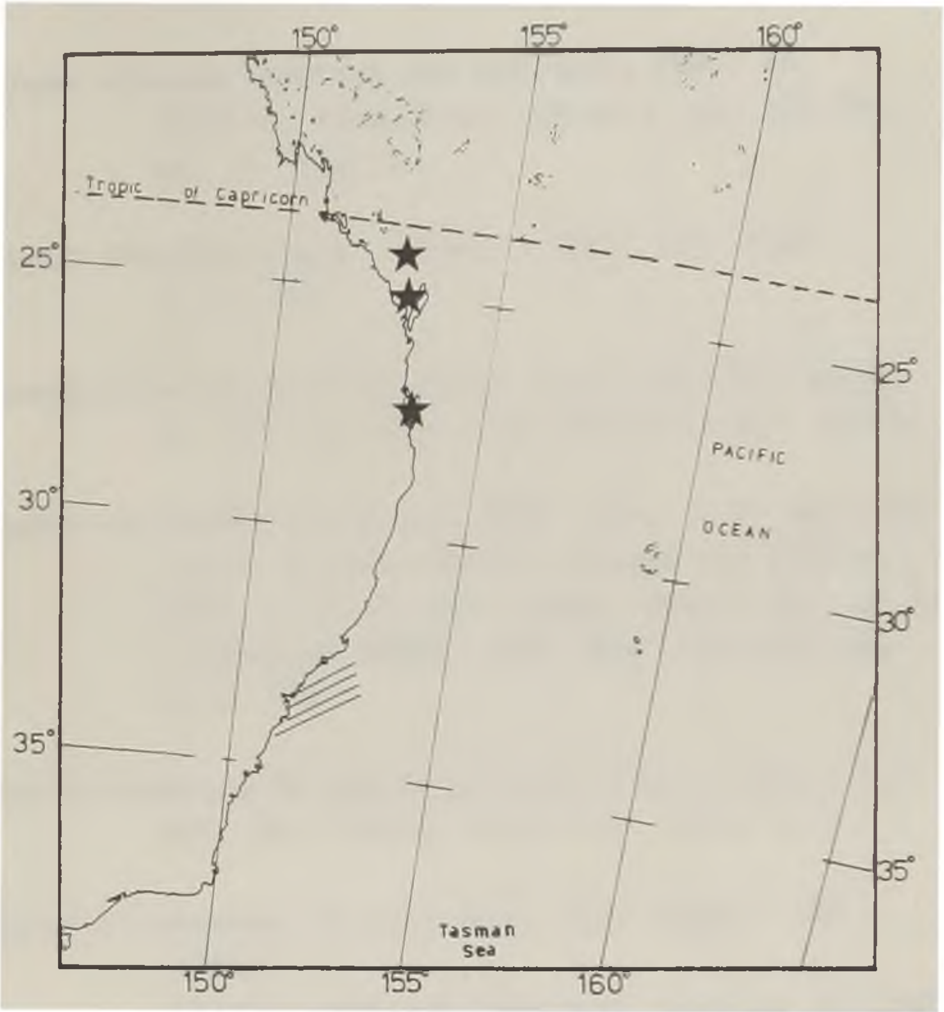

Fig. 2.16 : Distribution of *Saurida australis* Castelnau, 1878-79.
Solid symbols represent localities of specimens examined;
the hatched area is an additional literature record.

2.3.2.2.2.3 *Saurida elongata* (Temminck and Schlegel), 1846.

Aulopus elongatus Temminck and Schlegel, 1846, in Siebold, Faun. Japon. (Pisc.), pp. 233-234 pl. cv. fig. 2.

Saurida altipinnis (part) Gunther, 1864, Cat. Fish. v. p. 397.

Saurida truculenta Macleay, Proc. Linn. Soc. N.S. Wales, vi 1881, p. 219. Port Jackson, N.S. Wales.

Saurida eso Jordan and Herre, 1907, Proc. U.S. Nat. Mus. xxxii, p. 520; Jordan, Tanaka and Snyder, 1913, J. Coll. Sci. Tokyo, xxxiii (1), p. 53; Jordan and Hubbs, 1925, Mem. Carnegie Mus. x, p. 155.

Saurida microlepis Wu and Wang, 1931, Contri, Biol. Lab. Sci. Soc. China, Zool. Ser. viii, p. 1.

Material examined (3 specimens, size range : 226 - 412mm). (Number examined from each locality in brackets). AMS I.16270 - 001 (1), Port Jackson, NSW, 33° 50', 151° 15'E; CSIRO 118001 - 38 (1), Dampier, Western Australia; Hervey Bay (1), Queensland.

Description

Counts: 13 - 15 dorsal fin rays; 11 - 12 anal fin rays; 11 pectoral fin rays; 58 - 60 scales in lateral line; 21 - 25 predorsal scales; 17 - 18 interdorsal scales; 10 - 12 scales between adipose and caudal fins.

Morphometry: Mean length and range (in brackets) of characters calculated as percentages of

a) Standard length
Head 21.4 (20.7 - 21.7); pectoral fin 10.9 (10.7 - 11.0); pelvic fin 17.7 (15.7 - 19.6); dorsal fin 20.1 (20.0 - 20.2); interdorsal 28.5 (27.9 - 30.0); interventral 36.0 (34.3 - 39.4); predorsal 41.6 (38.6 - 43.5) ; prepelvic 36.1 (32.2 - 38.4); prepectoral 23.2 (22.2 - 23.9); preanal 73.7 (72.1 - 75.5); dorsal fin base 12.4 (12.3 - 12.6); anal fin base 9.7 (9.8 - 10.0).

b) Head length
Eye diameter 16.7 (16.7 - 16.8); preorbital 23.3 (19.5 - 26.3); postorbital 59.9 (57.7 - 62.1); snout 22.1 (19.0 - 25.2); premaxillary 70.1 (67.8 - 73.4); pelvic fin 80.4 (72.4 - 87.3); pectoral fin 49.0 (48.9 - 49.0).

Body elongate, more or less cylindrical, and slightly depressed. Snout obtusely pointed. Eyes large, adipose eyelids broad. Lower jaw subequal. Caudal preduncle depressed and carinate. Pectoral fin short, not reaching base of pelvic fin. Pectoral axillary long and broad. Outer palatine band consists of three irregular rows of teeth. The inner band has about 8 rows of teeth at its widest section. Vomerine teeth present; in a central patch of about 8 - 15 teeth (Fig. 2.14H).

Colour: Back and sides of uniform pale brown colour; no blotches or cross-bands. Very faint dusky spots on leading edge of dorsal and caudal fins. Inner surface of pectoral fin uniformly dusky, first dorsal ray tip black.

Distribution (Fig. 2.15): *S. elongata* occurs in the Sea Japan, South China and Phillipine (Western) Seas. Records of *S. elongata* from Dampier (Western Australia), Hervey Bay (Queensland) and Port Jackson (New South Wales) suggest a widespread distribution in the Central Indo-Pacific region.

Size: Maximum recorded is about 500mm, 250 - 380mm being the common sizes (Fisher and Whitehead, 1974).

2.3.2.2.2.4 *Saurida filamentosa* Ogilby, 1910
(Thread-fin saury)

Saurida filamentosa Ogilby, Proc. Roy. Soc. Queensland xxiii, p. 88. Off Cape Moreton, Queensland.

Saurida wanieso Shindo and Yamada, Uo Jap. Soc. Ichthyol. No. 11, 1972, p.8. East China Sea.

Material examined (71 specimens, size range : 163 – 575mm).
Isotypes: AMS I.12571, 176mm; QM I.481, 163mm; QM I.8917, 185mm, off Cape Moreton, Queensland.
Other specimens (number examined in brackets): AMS I.20319 - 010 (2), I.20444 - 005 (1), I.15525 - 002 (1). Off Cape Moreton (50), collected by Bob Sanderson. North-western Australia; Indian Ocean (12), collected by CSIRO ('SOELA'), 1981. East China Sea (3), collected by Shindo and Yamada. *ZUMT 52502 (1), East China Sea.

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* Examination and measurements done by Y. Tominaga of University of Tokyo Museum on request.

Description

Counts: 11 - 12 dorsal fin rays; 10 - 12 anal fin rays; 13 - 16 pectoral fin rays; 51 - 55 scales in lateral line; 15 - 21 predorsal scales; 13 - 20 interdorsal scales; 10 - 12 scales between adipose and caudal fins.

Morphometry: Mean length and range (in brackets) of characters calculated as percentages of

a) Standard length
Head 23.6 (21.3 - 25.5); pectoral fin 15.9 (12.8 - 18.2); pelvic fin 18.2 (16.2 - 19.0); *dorsal fin 34.9 (24.4 - 51.2); interdorsal 26.9 (23.3 - 28.6); interventral 37.2 (32.2 - 42.8); predorsal 40.3 (36.4 - 42.5); prepelvic 35.9 (24.4 - 41.8); prepectoral 24.0 (21.2 - 26.0); preanal 75.0 (68.2 - 80.6); dorsal fin base 13.4 (11.0 - 16.6); anal fin base 10.3 (8.0 - 13.8).

b) Head length
Eye diameter 19.8 (14.6 - 22.1); preorbital 19.8 (16.6 - 21.7); postorbital 60.2 (54.7 - 66.4); snout 20.0 (17.1 - 25.5); premaxillary 69.0 (66.1 - 75.9); pelvic fin 75.9 (67.6 - 79.9); pectoral fin 67.6 (58.9 - 74.5).

Body subfusiform, caudal peduncle without lateral ridge. Predorsal moderately depressed with a gentle convex profile. Fronto-occipital groove narrow and shallow, with a slightly domed mesial ossification at snout tip.

* Filamentous second and third rays included.

Eye subdorso-lateral. Adipose eyelid broad. Nasal flap broadest at inner half of posterior margin. Upper jaw a little longer than the lower jaw. Outer palatine band consists of two rows of teeth and bottle-neck shaped. Inner band has about 7 - 8 irregular rows at widest section. Vomer usually with 2 - 3 teeth set on each wing. Teeth strongly sagittate (Plate 34, Fig. 2.14C).

Pectoral fin reaches to beyond base of pelvic. Second and sometimes third dorsal ray filamentous; the second longest and sometimes reaching to or beyond the base of the adipose fin when laid back.

Colour: Dark brown above with a greenish tinge. 7 - 8 dark blotches along lateral line. Pale yellow ventro-laterally. Upper half of the pectoral fin violet or sometimes dusky black on both surfaces, especially the bottom half. Pelvic and anal fins clear, upper margin of adipose fin dusky black. Caudal fin dusky with black tips. Leading edge of caudal sometimes with dark spots.

Distribution (Fig. 2.17): Central Indo-Pacific. Coasts of India.

Deep water species, occurring down to 200m on fine sand or mud.

Size: Grows to over 575mm but commonly obtained in the 200 - 350 size range.

Remarks: *S. filamentosa* was found to be conspecific with *S. wanieso* Shindo and Yamada 1972.

Plate 34

Teeth configuration in palatine (p) bands and on vomer (v) of *S. filamentosa*


P
V

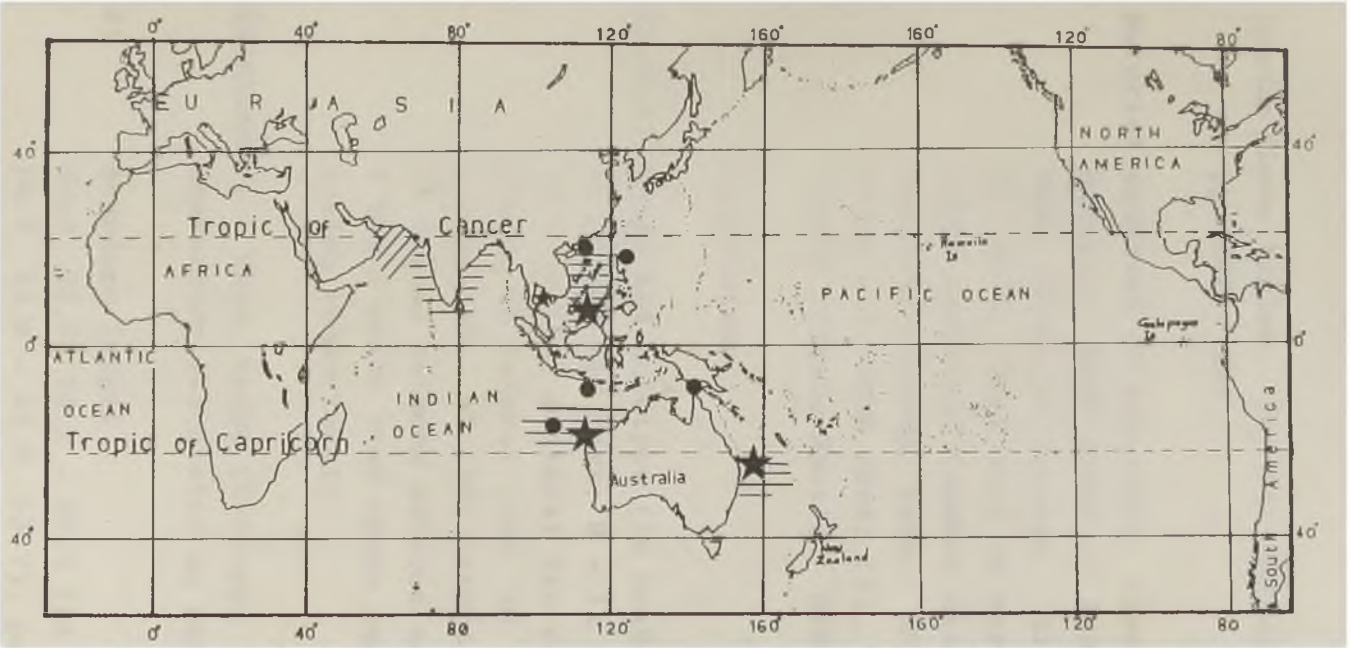

Fig. 2.17 : Distribution of *Saurida filamentosa* Ogilby, 1910 (★, ☰)
S. longimanus Norman, 1939 (●, ////)
S. isarankurai Shinda and Yamada, 1972 (★) .
The solid symbols represent localities of specimens examined; hatched areas are additional literature records.

2.3.2.2.2.5 *Saurida flamma* Waples, 1982
(The orangemouth lizardfish)

Saurida flamma Waples. Pacific Science, 35 (3), 1982, pp. 225 - 226.

Material examined (8 specimens, size range : 74 - 280mm). Holotype: BPBM 25942 (1,280mm), Kewalo Basin, Oahu, Hawaiian Islands. 21° 17' 27"N, 157° 51' 58"W. Sand next to coral ledges. 10m. Other specimens (number examined in brackets). Hawaiian Islands, Oahu: BPBM 25943 (3), BPBM 25944 (1), BPBM 25945 (1), BPBM 29546 (1). French Frigate Shoals: BPBM 25947 (1).

Description

Counts: Range and holotype (in brackets). 11 dorsal fin rays; 9 - 11 (10) anal fin rays; 13 - 14 (13) pectoral fin rays; 51 - 54 (53) scales in lateral line; 16 - 21 (16) predorsal scales; 15 - 17 (16) interdorsal scales; 10 - 11 scales between adipose and caudal fins; 3 and 4 scale rows above and below the lateral scales respectively.

Morphometry: Mean, range (holotype in brackets) of characters calculated as percentages of

a) Standard length
Head, 25.0, 24.2 - 27.4 (24.9); pectoral fin 14.7, 13.6 - 14.9 (13.7); pelvic fin 23.4, 22.0 - 24.5 (23.5); dorsal fin 23.6, 22.1 - 25.1; interdorsal 26.8, 24.8 - 27.8 (27.8); interventral 39.2, 36.1 - 41.6 (39.9); predorsal 41.4, 39.8 - 43.4 (41.3); prepelvic 35.1, 33.4 - 36.7 (35.2); prepectoral 25.2, 24.2 - 26.8 (25.7); preanal 75.9, 75.0 -

76.6 (76.8); dorsal fin base 15.0, 11.7 - 15.6 (14.5); anal fin base 10.5, 10.0 - 11.6 (10.2).

b) Head length
Eye diameter 19.7, 17.1 - 24.1 (18.1); preorbital 23.8, 21.9 - 25.5 (25.5); postorbital 56.3, 52.5 - 59.5 (58.1); snout 23.6, 21.4 - 26.1 (24.0); premaxillary 73.1, 67.0 - 76.5 (76.5); pelvic fin 93.8, 89.0 - 98.7 (94.3); pectoral fin 58.7, 54.9 - 61.2 (54.9).

Body subfusiform, caudal peduncle slightly carinate. Predorsal profile depressed to rounded. Snout more or less pointed, with a medio-lateral ossified slight protuberance by each pair of nostrils. The inner half of the posterior margin of nasal flap is produced as a spatulate process, the outer half more or less arched

Eye large and sub-lateral. Posterior adipose eyelid well developed, anterior narrow and usually absent from upper margin of orbit. Superior border of eye slightly higher than occipital region.

Lower jaw slightly shorter. Inner palatine band consists of four irregular rows, with 2 or 3 such rows in the outer band. The first three or four teeth of the innermost row long and pointed. Vomerine teeth are set on the flanks of vomer and deceptively alligned with the outer band (Fig. 2.14I, also see Plate 31).

Pectoral sub-falcate and reaches beyond level of pelvic fin base.

Colour: Mottled brown above, pale or pale rose below. all fins with spots and bars of dark pigment and a series of 8 - 9 bright orange bands on gums on each side of mouth. Opercle, lower jaw, and base of pectoral, pelvic, and caudal fins also tinged orange or red, particularly in larger specimens (Waples, 1982).

Distribution (Fig. 2.18): Hawaii and neighbouring islands. French Frigate Shoals. Reef species occurring over sandy or partly sandy bottoms. 10m.

Size: Grows to over 280mm.

2.3.2.2.2.6 *Saurida gracilis* Quoy and Gaimard, 1824.

Saurus gracilis Quoy and Gaimard 1824: P. 224, Hawaii and Mauritius.

Saurus minutus Lesueur, 1825b: 118, pl. v, Mauritius

Saurida nebulosa Valenciennes in Cuvier and Valenciennes, 1849: p. 504, in part, Mauritius.

Saurida gracilis Jenkins, 1904 (1902), p. 433, Hawaii.

**Saurida maculata nomen illegitimum*

Material examined (8 specimens, size range : 175 - 251mm). (Number of specimens examined in brackets). AMS I.17232 - 008 (1), Lord Howe Island. Queensland: *QM I.8903 (1); QM I.12089 (1), North of Swain Reef; QM I.427 (1), Moreton Bay; QM I.12112, Myora Bight, Moreton Bay;

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* Queensland Museum Records.

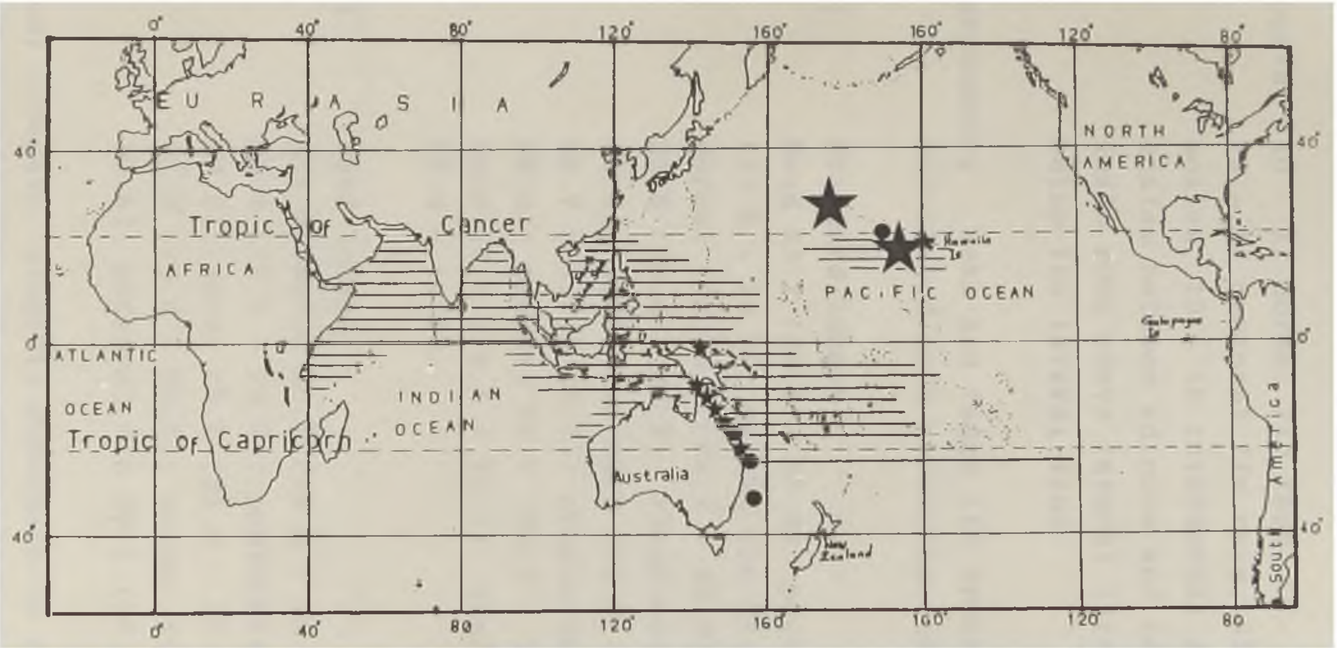

Fig. 2.18 : Distribution of *Saurida nebulosa* Valenciennes, 1849 (★)
S. gracilis Quoy and Gaimard, 1824 (●)
S. flamma Waples, 1982 (★).

The solid symbols represent localities of specimens examined; hatched areas are additional literature records of *S. nebulosa* and/or *S. gracilis* (*S. nebulosa* was removed from the synonymy of *S. gracilis* by Waples in 1982).

French Frigate Shoals: BPBM 27771 (2).

Counts: 10 - 11 dorsal fin rays, 9 - 10 anal fin rays; 13 - 14 pectoral fin rays; 15 - 16 predorsal scales; 13 - 16 interdorsal scales; 9 - 10 scales between adipose and caudal fins; 3 scale rows above lateral line and 4 or 5 scale rows below the lateral line.

Morphometry: Mean and range (in brackets) of characters calculated as a percentage of

a) Standard length

Head 25.1 (24.7 - 25.4); pectoral fin 14.0 (13.6 - 14.5); pelvic fin 21.8 (20.9 - 22.6); dorsal fin 22.4 (21.7 - 22.9); interdorsal 25.8 (25.4 - 26.2); interventral 40.1 (38.4 - 41.8); predorsal 42.0 (41.2 - 42.7); prepelvic 34.7 (33.7 - 35.7); prepectoral 25.9 (25.1 - 26.6); preanal 76.7 (75.7 - 77.8); dorsal fin base 14.8 (14.4 - 15.1); anal fin base 9.8 (8.8 - 10.6).

b) Head length

Eye diameter 20.1 (18.0 - 22.1); preorbital 21.4 (17.1 - 23.7); postorbital 58.3 (56.5 - 57.2); snout 23.1 (21.9 - 27.7); premaxillary 75.2 (73.2 - 78.2); pelvic fin 87.1 (84.5 - 90.8); pectoral fin 56.1 (54.2 - 58.3).

Body elongate, slightly depressed to rounded. Snout pointed, a medio-lateral ossified slight protuberance by each pair of nostrils. The inner half of the posterior margin of nasal flap is produced as a spatulate process, the outer half more or less arched.

Eye subdorso-lateral. Adipose eyelid very narrow, interorbital space slightly concave. Superior border of eye at level of dorsal surface.

Jaws more or less equal. Inner and outer palatine teeth in 2 - 3 irregular rows; outer palatine bands converge anteriorly and are bridged by a patch of vomerine teeth. The first three or four teeth of innermost row of outer band long and pointed (Fig. 2.14J).

Pectoral fin more or less falcate, reaches to level of the pelvic base. A terminal dark brown spot on the posterior of adipose fin. Caudal peduncle slightly carinate.

Colour: Pale brown irregularly variegated with dark cross-bands. Head similarly mottled but darker dorso-laterally; variegation extending to 4 or 5 scales below lateral line. About ten blotches in lateral line, fins with dark cross-bands. Lips of jaw with dark brown blotches interspersed with pale yellow.

Distribution (Fig. 2.18): Known from the coast of East Africa, the Red Sea and throughout the Central Indo-Pacific region. Hawaii.

Size: Medium size species.

2.3.2.2.2.7 *Saurida isarankurai* Shindo and Yamada, 1972

Saurida isarankurai Shindo and Yamada, Uo, Jap. Soc. Ichthyol. No. 11, 1972, p. 7. Prachuap Khiri Khan Province, Gulf of Thailand.

Material examined (3 specimens, size range : 103 - 111mm).

Holotype ZUMT 52501 (1,111mm). Paratypes ZUMT 54347 (1,106mm), ZUMT 54348 (1,103mm). Prachuap Khiri Khan Province, Gulf of Thailand.

Description

Counts (*Holotype and paratypes (in brackets)):
11 (11) dorsal fin rays, 11 (11, 12) anal fin rays; 13 (12, 13) pectoral fin rays; 49 48**, 49**) scales in lateral line; 20 (19**) predorsal scales.

Morphometry (Holotype and paratypes (in brackets)):
values of characters calculated as percentages of

a) Standard length
Head 24.5 (21.5, 22.1); pectoral fin 21.2; pelvic fin 17.3 (18.5, 18.9); dorsal 21.6; interdorsal (23.3, 26.5); interventral (34.0, 35.6); predorsal 43.0 (43.0, 43.2); prepelvic 37.0; prepectoral 24.7 (23.2, 24.6); preanal 71.1 (73.6, 74.3); dorsal fin base 14.4 (11.8, 13.7); anal fin base 11.7 (10.8, 11.8).

b) Head length
Eye diameter 21.0 (20.3, 20.8); preorbital (20.9, 22.8); postorbital (59.5, 59.7); snout 19.1; premaxillary 65.1 (68.0, 68.8); pelvic fin 70.6 (83.6, 87.8); pectoral fin 86.4.

* Measured on request by Y. Tominaga of University of Tokyo Musuem.

** Scales lost but scale pockets counted.

Body cylindrical and elongated. Snout slightly rounded Lower jaw longer than upper, distinctly visible from above when mouth is closed. Palatine teeth in two bands; outer band in two rows anteriorly and posteriorly, and in a single row about midway; inner band in form of a broad patch of three or four rows of teeth. Vomer toothless (Fig. 2.14E). Pectoral fin long and extending beyond base of pelvic fin; reaching to about the origin of dorsal fin. Scales deciduous.

Colour: 9 - 10 distinct brownish blotches along lateral line. Upper margin of dorsal fin dusky, upper half of inner side of pectoral fin dusky, whole surface of lower lobe of caudal fin dusky.

Distribution (Fig. 2.17): Prachuap Khiri Khan Province. Gulf of Thailand.

Size: Small size species; largest specimen recorded - 117mm.

2.3.2.2.2.8 *Saurida longimanus* Norman, 1939

Saurida longimanus Norman, in Jordan Murray Expedition (1933-34) Scientific Reports, 7 (1-3) pp. 23 - 24.

Material examined (17 specimens, size range : 72 - 185mm). (Number of specimens examined in brackets). AMS I.21617 - 004 (1), North-West Shelf, Western Australia. *PJPW 791 (1), Bali, Indonesia. SI Field No. BBC-1681 (4), off mouth of Fly River, Gulf of Papua, Papua New

* Dr Peter Whitehead of BMNH's collection.

Guinea, 08° 45.0'S, 144° 05.8', 7 June 1979. SI 9450 (1), Hong Kong. SI Cat. No. 136050 (10, off Luzon, Phillippines, 13° 23' 10"N, 123° 45' 19"E, 4 June 1909. *TGT 3150(1), Bali, Indonesia.

Description

Counts: 11 - 12 dorsal fin rays; 10 - 12 anal fin rays; 12 - 15 pectoral fin rays; 48 - 51 scales in lateral line; 16 - 20 predorsal scales; 11 - 15 interdorsal scales; 9 - 11 scales between adipose and caudal fins.

Morphometry: Mean and range (in brackets) of characters calculated as percentages of

a) Standard length

Head 23.5 (21.9 - 26.3); pectoral fin 20.4 (17.0 - 24.0); pelvic fin 17.0 (16.3 - 19.9); dorsal 24.2 (23.1 - 25.4); interdorsal 23.9 (21.6 - 27.3); interventral 33.4 (27.8 - 37.7); predorsal 43.5 (38.8 - 45.7); prepelvic 38.0 (32.3 - 40.8); prepectoral 25.0 (21.0 - 27.0); preanal 73.1 (64.5 - 77.2); dorsal fin base 14.2 (11.4 - 15.9); anal fin base 11.3 (9.8 - 12.4).

b) Head length

Eye diameter 21.8 (18.0 - 24.8); preorbital 22.2 (20.0 - 23.7); postorbital 56.1 (51.9 - 58.9); snout 22.5 (19.8 - 24.5); premaxillary 70.1 (67.2 - 73.3); pelvic fin 79.2 (65.3 - 87.5); pectoral fin 88.3 (78.1 - 103.4).

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* Thomas Gloerfelt-Tarp's Collection.

Body cylindrical and elongated. Snout broader than long, more or less rounded at tip. Eyes large and prominent. Adipose eyelids moderate. Bony ridges rise from occiput along interorbital edge to about the anterior edge of orbit.

Outer bands of palatine teeth, more or less straight, in two bands and set close to the lips of jaw; anterior teeth large and recurved inwards. Inner band set about midway of upper jaw with about 4 rows of teeth in the widest section. Teeth more or less sagittate (Plate 35, Fig. 2.14D).

Pectoral fin long, extending beyond origin of dorsal fin when laid back.

Colour: Brownish above, silvery white below; distal parts of dorsal, caudal and pectoral fins blackish. Traces of dark marks sometimes along leading edge of caudal.

Distribution (Fig. 2.17): Central Indo-Pacific and Gulf of Oman. These disparate areas suggest a widespread distribution of *S. longimanus* in the Indo-West Pacific region.

S. longimanus occurs down to about 200m.

2.3.2.2.2.9 *Saurida nebulosa* Valenciennes, 1849

Saurida nebulosa Valenciennes in Cuvier and Valenciennes, 1849, p. 504, in part. Mauritius.

Synodus sharpi Fowler, 1901, p. 497. Hawaii.

Plate 35 ('wet' specimen)

Teeth configuration in palatine (p) bands and on vomer (v) of *S. longimanus*

Saurida gracilis Gosline and Brock, 1960, p. 99, in part Hawaii.

Material examined (49 specimens, size range : 42 - 190mm).
(Number examined in brackets).
Queensland/Great Barrier Reef: AMS I.18755 - 014 (3), between Palfrey and Lizard Islands; QM I.1502 (1), Darnley Is., Torres Strait; QM I.9576 (7), Heron Is., QM I.10956 (1), Palm Is., QM 11741 (1), One Tree Is., QM I. 13787 (1), Noosa River; QM I.15383 (2), Clack Reef; QM I.15630 (4), Nymph Is., 14° 36'S, 145° 14'E; QM I.15690 (11), Nymph Is., 14° 33'S, 145° 06'E; QM I.16016 (1), Tijou Reef, 13° 05'S, 143° 57'E; QM I.16201 (1), Decapolis Reef, Cape Flattery, 14° 50'S, 145° 17'E.

Papua New Guinea: KFR F01299 (13), Fairfax Harbour; USNM 220015 (1), Ninigo Is.. Hawaii Is: BPBM 27770 (2), Kaneohe Bay, Oahu, 21° 26' 20"N, 157° 45' 45"W.

Description

Counts: 9 - 12 dorsal fin rays; 9 - 11 anal fin rays; 12 - 14 pectoral fin rays; 47 - 50 scales in lateral line; 13 - 17 predorsal scales; 13 - 16 interdorsal scales; 10 - 11 scales between adipose and caudal fins; 3 and 4 scales above and below the lateral line respectively.

Morphometry: Mean and range (in brackets) of characters calculated as percentages of

a) Standard length
Head 24.9 (22.0 - 27.9); pectoral fin 13.0 (12.3 - 15.5); pelvic fin 20.7 (19.2 - 23.1); dorsal fin 21.6 (20.2 - 24.1); interdorsal 25.3 (23.7 - 27.7); interventral 39.9 (37.6 - 42.6); predorsal 42.9 (39.3 - 45.6); prepelvic 34.8 (31.4 - 37.7); prepectoral 25.3 (21.0 - 28.6); preanal 76.1 (72.2 - 83.6); dorsal fin base 14.4 (12.7 - 16.5); anal fin base 9.9 (9.0 - 11.7).

b) Head length
Eye diameter 19.5 (15.7 - 23.3); preorbital 21.9 (18.7 - 24.7); postorbital 58.5 (50.4 - 63.9); snout 22.3 (19.9 - 25.5); premaxillary 71.1 (67.0 - 79.1); pelvic fin 84.2 (77.1 - 93.7); pectoral fin 52.5 (45.5 - 60.1).

Body elongate, slightly depressed and more or less slender. Snout pointed, a medio-lateral ossified slight protuberance by each pair of nostrils. The anterior margin of nasal flap is semi-circular, inner half of the posterior margin villi-form to spatulate; the outer half more or less arched.

Adipose eyelid very narrow. Superior border of eye at level of dorsal surface, interorbital space sloping gently to nasal area.

Lower jaw slightly shorter than upper. Outer band of palatine teeth of 2 or 3 poorly defined rows of teeth; the first three or four teeth of innermost row long and pointed. Inner band consists of about 3 poorly defined rows. Vomerine teeth set on wings of vomer and deceptively aligned with outer band (Plate 31, Fig. 2.14I).

Pectoral fin reaches to level of pelvic base.

Colour: Dorsal aspect greenish brown, irregularly variegated with dark cross-bands; pale ventro-laterally. Dark blotches also on ventral sides of lower jaw and sometimes extend to near base of pelvic fin. Fins, except anal fin, also with dark cross-bands. Anal fin usually clear.

Distribution (Fig. 2.18): Widely distributed in the Indo-West Pacific region. Hawaii Islands.

Size: A small species, common sizes being 80 - 130mm.

2.3.2.2.2.10 *Saurida tumbil* (Bloch), 1795
(The common or yellow-banded grinner)

Salmo tumbil Bloch, 1795, Naturg. Ausl. Fische., ix, p. 112, pl. ccccxxx.; Schneider, 1801, in Bloch, Syst. Ichth, p. 405.

Osmerus tumbil Lacepede, 1803, Hist. Nat. Poiss. v. pp. 230, 236.

Saurus tumbil Cuvier, 1817, R. Anim. ii p. 169.

Saurus badi Cuvier, 1829, R. Anim. ed. 2, ii, p. 314; Cantor, 1850, J. Asiat. Soc. Bengal, xviii (1849), p. 1252.

Saurus milii Bory de St. V., 1829, Dict. Class, H.N. xv, p. 189, pl. civ. fig. 2.

Saurus badimottah Rüppel, 1837, N. Wirbelth, Abyssin. (2), p. 77.

Laurida tumbel Swainson, 1839, N. H. Fishes etc. ii, p. 288,

Saurus argyrophanes Richardson, 1846, 15 Rept. Brit. Assoc. Adv. Sci. (Cambr. 1845), p. 302.

Saurida tombil Cuvier and Valenciennes, 1849, Hist. Nat. Poiss, xxii, p. 500; Bleeker, 1851, Nat. Tijdschr. Ned. Ind. ii, p. 214; Bleeker, 1852, Verh. Batav. Gen. xxiv, Chirocentr. p. 20.

Saurida tumbil, 1859, Nat. Tijdschr. Ned. Ind. xviii, p. 356; Gunther, 1864, Cat. Fish. v. p. 399 (etc. See Norman, 1935).

Material examined (72 specimens, size range 52 - 327mm). (Number examined in brackets) Queensland: QM I.6763 (1), Cape Cleveland; QM I.8536 (1), Chinamans Bay; QM I.12111 (1), Moreton Bay; QM I.16200 (1), Decapolis Reef, Cape Flattery, 14° 50'S, 145° 17'E; QM I. 16263 (1), Torres Strait, 9° 51'S, 142° 49'E; QM I.18150 (1), 12° 35'S, 143° 25' 7"E. *'Curlew' Collection: Burkitt Is. (4), Innisfail (4), East of Wilkie Is., between Magpie and Nobody Reefs (4), Cape Melville (4), Brampton Beach (4); Moreton Bay (39); Hervey Bay (4).

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* Collected by Bryan Wallis of Innisfail, skipper of the 'Curlew'.

Bali (Indonesia): *PJPW 109(2); *PJPW 721(1); *PJPW 721a(1). Papua New Guinea: KFR F0626(3), South of Ramu River.

Description

Counts: 11 - 13 dorsal fin rays; 9 - 11 anal fin rays; 14 - 15 pectoral fin rays; 49 - 54 scales in lateral line; 18 - 24 predorsal scales; 10 - 16 interdorsal scales; 8 - 12 scales between adipose and caudal fins.

Morphometry: Mean and range (in brackets) of characters calculated as percentages of

a) Standard length

Head 23.4 (21.4 - 28.6); pectoral fin 11.4 (10.1 - 12.7); pelvic fin 18.7 (16.8 - 20.6); dorsal fin 21.7 (20.3 - 25.0); interdorsal 26.5 (22.5 - 28.7); interventral 37.1 (33.6 - 41.2); predorsal 42.2 (40.8 - 43.6); prepelvic 37.2 (34.8 - 41.5); prepectoral 24.0 (22.9 - 27.4); preanal 74.1 (72.5 - 77.8); dorsal fin base 13.7 (11.8 - 15.1); anal fin base 8.8 (7.2 - 14.2).

b) Head length

Eye diameter 18.6 (14.2 - 23.5); preorbital 21.6 (19.4 - 23.6); postorbital 60.8 (51.4 - 63.8); snout 22.0 (18.0 - 24.6); premaxillary 66.9 (63.0 - 74.3); pelvic fin 79.9 (70.3 - 87.7); pectoral fin 48.9 (43.7 - 56.4).

Body elongate, sub-cylindrical, and anteriorly slightly depressed. Snout conical and short, preorbital profile more or less straight and steep. Interorbital concave.

* Dr. Peter Whitehead of BMNH's collection.

Occipito-caudal profile convex, caudal peduncle slightly depressed and carinate; especially in large sizes. Adipose eyelid moderate. Nasal flap arched on both anterior and posterior margins, the latter being broader.

Upper jaw slightly longer than lower jaw. Outer palatine of three irregular rows, 3 - 4 rows anteriorly. Each outer band of a 'stretched-out' sigmoid shape. Inner band set close to outer band and consists of about 6 rows of teeth at the widest section. 3 - 7 vomerine teeth present. Teeth strongly sagittate and stout (Plate 30 A, B, Fig. 2.14F).

Pectoral fin short, not or just reaching to level of pelvic fin base. Opercular membrane sometimes covers base of pectoral fin.

Colour: Dusky brown with a greenish tinge dorsally. Pale yellow ventrally. Inner surfaces of upper half of pectoral and outer half of pelvic fins dusky black. Anal clear. Distal ends of dorsal and caudal fins dusky black. 7 - 9 dark blotches along lateral line. Traces of three cross bands on dorsal aspect of body; one each at origin and posterior of dorsal fin base, the third posterior to adipose fin base. Adipose fin dusky black. Faint dark spots on leading edge of dorsal fin.

Distribution (Fig. 2.19): Widely distributed in the Indo-West Pacific Region.

Size: Grows to over 450mm. Common size range - 200 - 300mm.

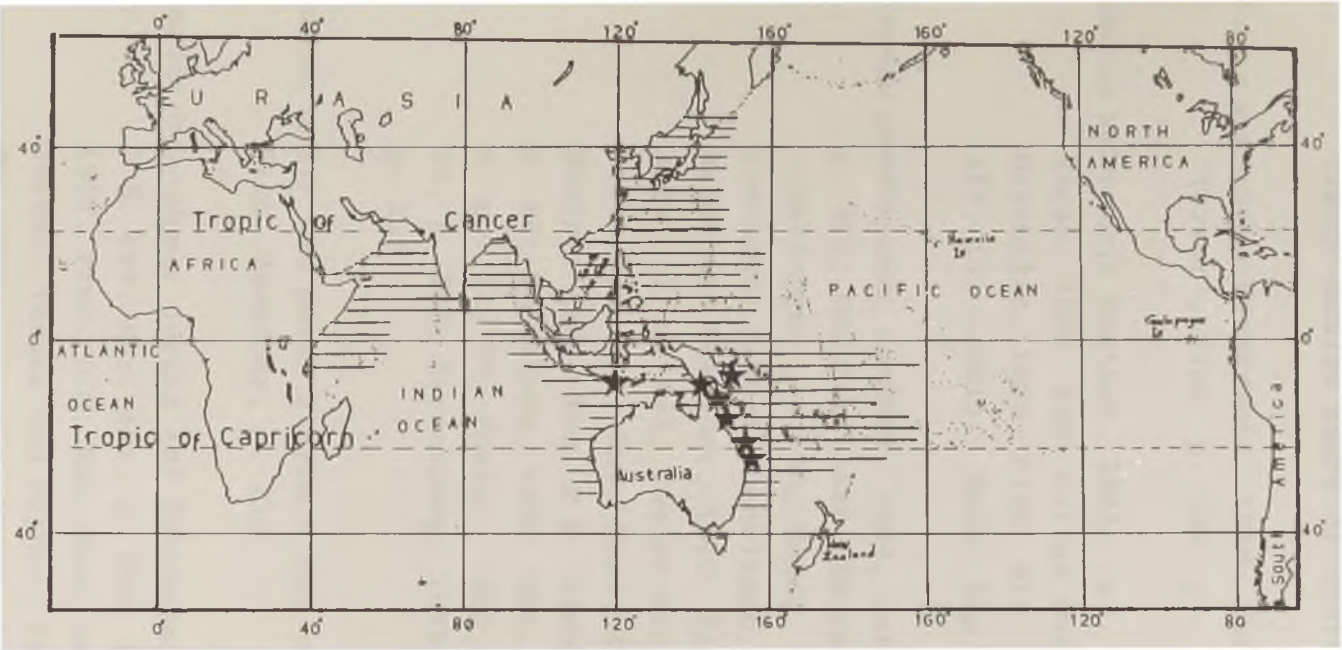

Fig. 2.19 : Distribution of *Saurida tumbil* (Bloch), 1795. Solid symbols represent localities of specimens examined; hatched areas are additional literature records.

2.3.2.2.2.11 *Saurida undosquamis* (Richardson), 1848
(Large-scaled saury or spotted-tail grinner)

Saurus undosquamis Richardson, 1848, Zool. 'Erebus' and 'Terror', Fish. p. 138. pl. 1., figs. 1 - 6.

Saurida undosquamis Gunther, 1864, Cat. Fish. v, p. 400; Regan, 1918, Ann. Durban Mus. ii, p. 76; Gilchrist, 1922, Fish. Mar. Biol. Survey S. Afr. ii, (1921). Spec. Rep. iii, p. 55.

Saurida grandisquamis Gunther, 1864, Cat. Fish. v, p. 400; Gunther, 1880, Shore Fishes 'Challenger', p. 50; Weber, 1911, Abh. Senckenb. Naturf. Gesellsch, xxxiv, p. 22; Weber and Beaufort, 1913, Fish. Indo-Austral. Arch. ii, p. 141; Fowler and Bean, 1922, Proc. U.S. Nat. Mus. lxii, Art. 2, p. 3; Fowler, 1928, Mem. B.P. Bishop Mus. x, p. 66; McCulloch, 1929, Mem. Austral. Mus. v. pp. 71, 78; Fowler, 1929, Ann. Natal Mus. vi, p. 249; Hardenberg, 1933, Treubia, xiv, p. 220.

Saurida tumbil (in part) Playfair and Gunther, 1866, Fish. Zanzibar, p. 116.

Saurida argyrophanes Jordan and Evermann, 1902, Proc. U.S. Nat. Mus. xxv, p. 329; Jordan and Herre, 1907, Proc. U.S. Nat. Mus. xxxii, p. 519; Jordan, Tanaka and Snyder, 1913, J. Coll. Sci. Tokyo, xxxiii (1), p. 53; Jordan and Hubbs, 1925, Mem. Carnegie Mus. x, p. 155.

Saurida tumbil Regan, 1908, Trans. Linn. Soc. London, Zool. xii, p. 219; Gilchrist and Thompson, 1909, Ann. S. Afric. Mus. vi, p. 265; Barnard, 1925, Ann. S. Afric. Mus. xxi, p. 225.

Saurida macrolepis Tanaka, 1916, xxix, p. 39?

Material examined (42 specimens, size range : 100 - (300mm). (Number examined in brackets). AMS I.12569 (1), Croker Is., Northern Territory; BMNH 1847.2.30.13 (1); BMNH 1977. 4.22.1 (1). Northern Western Australia; Queensland: QM I.12422 (1), Mouth of Proserpine R; QM I.12983 (1), N.W. Cape Moreton; QM I. 13735 (1), Noosa River, Munna Point; QM I.15070 (1), Torres Strait; QM I. 16170 (1), Hannibal Is., 11° 33'S, 142° 57'E; QM I.18300 (1), 12 faths, 14° 10.7', 144 2.3'; Hervey Bay (4), collected by Clive Keenan, and Greg Campbell, 1981; Moreton Bay (22); Western Australia: QM I.13681 (1); Bali (Indonesia): *PJPW 712 (3); **TGT 3212A (1); Papua New Guinea: KFR F0834 (2), Girra Garra Bay, Jones Reef, Portlock Harbour.

Description

Counts: 11 - 13 dorsal rays; 9 - 12 anal fin rays; 12 - 13 pectoral fin rays; 46 - 53 scales in lateral line; 16 - 20 predorsal scales; 13 - 19 interdorsal scales; 9 - 12 scales between adipose and caudal fins.

* Dr. Whitehead of BMNH's collection

** Thomas Gloerfelt-Tarp collection.

Morphometry: Mean and range (in brackets) of characters calculated as percentages of

a) Standard length
Head 24.3 (23.1 - 25.5); pectoral fin 15.6 (13.5 - 17.0); pelvic fin 17.7 (16.1 - 20.9); dorsal fin 22.3 (20.1 - 24.0); interdorsal 25.4 (20.9 - 27.9); interventral 36.3 (32.7 - 39.4); predorsal 42.8 (40.8 - 44.6); prepelvic 37.5 (33.6 - 38.7); prepectoral 25.1 (23.1 - 26.9); preanal 71.9 (72.1 - 77.9); dorsal fin base 13.7 (12.1 - 15.3); anal fin base 9.8 (8.0 - 12.1).

b) Head length
Eye diameter 19.5 (15.5 - 23.2); preorbital 21.4 (19.8 - 24.7); postorbital 59.4 (55.9 - 62.0); snout 21.7 (20.0 - 25.9); premaxillary 70.2 (66.1 - 73.9); pelvic fin 75.9 (69.6 - 87.0); pectoral fin 66.9 (58.2 - 71.8).

Body moderately depressed and predorsal more or less rounded. Snout rounded with a mesial ossified protuberance. Fronto-occipital groove wide and shallow, slightly more concave at occiput. Dorsal profile slightly convex. Adipose eyelid broad. Nasal flap broader and slightly produced at inner half of posterior margin.

Jaws more or less equal. Teeth of outer band in 2 rows and occasionally in 3 rows anteriorly. Outer band slightly bottle-necked; each arm more or less straight except at anterior portion. Inner band with 5 - 7 rows of teeth. Vomer with or without teeth; if present 1 or 2 teeth set on each wing of vomer. Teeth short and sagittate (Plate 29, Fig. 2.14A).

Plate 36: *S. undosquamis* (general body colour).
s = rounded snout.
d = black spots on leading edges of caudal and dorsal fins.

Fig. 2.20 : Distribution of *Saurida undosquamis* (Richardson), 1848. Solid symbols represent localities of specimens examined; hatched areas are additional literature records.

Body slender, head large, both more or less compressed. Interorbital space concave, occipital regions very rugose. Adipose eyelids narrow. Snout blunt and very short; its length always shorter than eye diameter. Lower half of operculum prolonged backward, edge generally covering the base of pectoral fin. Pseudobranchiae well developed.

Lower jaw usually extending beyond upper jaw when mouth is closed. Teeth conical, depressible and closely set; a single band of teeth on each side of palate (Plate 37). Vomerine teeth absent.

Scales cycloid. Scales on cheeks and opercular. Anal fin base long, about 1½ times dorsal fin base. Pectoral fin extending much beyond pelvic fin base and usually reaching dorsal origin. Pelvic fin large, long and with 8 rays, the first ray the shortest. Caudal fin deeply forked, lobes subequal. Anus nearer to origin of pelvic than to caudal fin.

Monotypic genus, widely distributed in the Atlantic, Indian and Pacific Oceans. Closely related to *Synodus*.

2.3.2.3.1 **Trachinocephalus myops* (Bloch and Schneider) 1801 (**Painted saury or grinner)

Salmo foetens (non Linnaeus), Bloch, 1794, Naturgesch. Ausl. Fische. vii. p. 118, pl. ccclxxxiv fig. 2; Schneider, 1901, in Bloch, Syst. Ichth. p. 404.

* An extensive synonymy and list of references are included in Anderson, Gehringer and Berry (1966).

** Known as snakefish in the United States and Canada (See American Fisheries Society Special Publication, 1980).

Salmo myops Schneider (ex Forster MS), 1801, in Bloch, Syst. Ichth. p. 421.

Osmerus lemniscatus Lacepede, 1803, Hist. Nat. Poiss. V, p. 230, pl. vi. fig. 1.

Saurus truncatus Spix, 1829, Pisc. Brazil. p. 82, pl. xlv.

Laurida foetens Swainson, 1839, N.H. Fishes, etc. ii, p. 288.

Saurus limbatus Eydoux and Souleyet, 1842, in Vaillant, Voyage 'Bonite', Zool. 1, p. 199.

Saurus lemniscatus Richardson, 1846, 15 Rept. Brit. Assoc. (Cambr. 1845), p. 301.

Saurus trachinus Temminck and Schlegel, 1846, in Siebold, Faun. Japon. (Pisc.), p. 231. pl. cvi. fig. 2. etc.

Saurus myops Cuvier and Valenciennes, 1849, Hist. Nat. Poiss. xxii, p. 485 etc.

Saurus brevirostris, 1861, Poey, Mem. Hist. Nat. Cuba, ii, p. 305.

Trachinocephalus myops Gill, 1861, Proc. Acad. Nat. Sci. Philad., Suppl. (Cat. Fish. East Coast N. Amer.), p. 53; Jordan, 1890, Proc. U.S. Nat. Mus. xiii, p. 314 etc.

Synodus myops Bleeker, 1875, Atl. Ichth. vi. p. 153, Saurid, pl. ii, fig. 3; Jordan and Gilbert, 1883, Bull. U.S. Nat. Mus. xvi, p. 281.

Goodella hypozona Ogilby, Proc. Linn. Soc. N.S. Wales, xxii, 1897, pp. 250 and 253.

Trachinocephalus hypozona Ogilby in Whitley (1948), W. Australia Fish. Dept. Fish. Bull. No. 2, p. 13.

Material examined (71 specimens, size range : 49 - 233mm).

(Number of specimens examined from each locality in brackets).

Queensland/Great Barrier Reef: QM I.12114 (1), Broadhurst Reef; QM I.16219 (1), Lizard Is., 14° 38'S, 145° 24'E; QM I.17283 (1), Dalrymple Islet, Torres Strait. Moreton Bay (30). QM I.10268 (2), Exmouth Gulf, Western Australia. BPBM 19855 (6), Red Sea, N.W. Shore of Gulf of Aqaba. BPBM 20553 (1), Madras, India. Hawaiian Is.: BPBM 24049 (8), Molokai,; BPBM 23896 (16), Oahu. KFR F0139 (5), South East of Ramu River.

Additional specimens given qualitative but limited quantitative examination. Queensland: Moreton Bay - QM I.8896/901; I.13084; I.13094; I.12930; I.9537. Pt Cartwright, 26° 43'S, 153° 15'E - QM I.9953; I.10000. Fraser Is. - QM I.8; I.8904. Caloundra - QM I.9959; I.9995. QM I.11370, Maroochydore. QM I.17307, Mooloolaba. QM I.3302, Currumbin. Torres Strait - QM I.16259, Stephen to Bramble Bay; QM I.16261, 9° 56'S, 142° 25'E.

Description

Counts: 11 - 14 dorsal fin rays; 14 - 17 anal fin rays; 11 - 13 pectoral fin rays; 51 - 58 scales in lateral line; 13 - 17 predorsal scales;

13 - 17 interdorsal scales; 6 - 10 scales between adipose and caudal fins; 3, and 5/6 scales above and below the lateral line respectively.

Morphometry: Mean and range (in brackets) of characters calculated as percentages of

a) Standard length
Head 25.4 (23.4 - 28.6); pectoral fin 13.3 (12.0 - 15.1); pelvic fin 29.0 (26.7 - 30.9); dorsal fin 27.1 (22.0 - 32.9); interdorsal 25.9 (20.6 - 29.9); interventral 30.0 (25.4 - 34.2); predorsal 40.3 (36.4 - 44.5); prepelvic 33.0 (32.0 - 37.2); prepectoral 25.1 (23.2 - 28.1); preanal 65.6 (58.6 - 70.4); dorsal fin base 17.4 (15.6 - 19.7); anal fin base 25.3 (20.8 - 28.5).

b) Head length
Eye diameter 19.7 (15.6 - 25.6); preorbital 12.5 (9.9 - 14.7); postorbital 67.6 (58.9 - 76.1); snout 12.9 (11.4 - 14.6); premaxillary 63.0 (61.5 - 66.3); pelvic fin 115.3 (105.2 - 122.4); pectoral fin 52.4 (42.8 - 59.5).

Body elongate and sturdy. Head blunt, sloping abruptly downward to preorbital area. Snout shorter than eye. Upper surface and occipital regions of head strongly rugose. Interorbital space deeply concave. Adipose eyelid rudimentary. Jaws subequal, lower jaw slightly longer. Only one band of two rows of teeth on each side of palate (Plate 37). No vomerine teeth. Pectoral fin extending beyond base of pelvic fin, which is longer than head.

Plate 37

Teeth configuration in palatine (p) bands of *T. myops*.

Colour: An oblique black scapular patch above pectoral fin base. Four blue-grey longitudinal bands distributed on body as follows:

- one from just behind origin of pectoral fin but below scapular patch and running below lateral line to the base of the lower lobe of caudal
- one running from just behind eye through scapular patch and just above lateral line to mid-portion of caudal lobe, fading towards caudal lobe from about the adipose fin
- one originating from about just above the scapular patch to the base of upper caudal lobe
- one originating from post-ocular portion of head coalescing with its *opposite number before and again behind adipose fin.

First three longitudinal bands edged dark brown. Pairs of short bands on dorsal aspect - three pairs in predorsal length; third at origin of dorsal fin, two pairs in dorsal fin base. Two pairs and one fused patch before adipose fin, and another fused patch after.

Dorsal fin with two prominent golden brown stripes on a silvery blue hue, pelvic fin with a golden brown band running vertically from first ray to the tip of last ray, either side of band violet (bluish). Inner side of pectoral and caudal fins dusky yellow, anal bluish and edged by a golden brown band. Caudal fin tips black.

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* from other side of body.

Distribution (Fig. 2.21): Almost circumtropical. It has been reported from disparate areas in the Indian, Pacific (and Atlantic) Oceans - however no records are available from the western seaboard of the Americas. *T. myops* occurs in a wide range of depths, from shallow water to over 100m. Gibbs (1959) found *T. myops* at over 2000m in or near the Gulf Stream.

Size: Grows to over 250mm. Common size range 140 - 220mm.

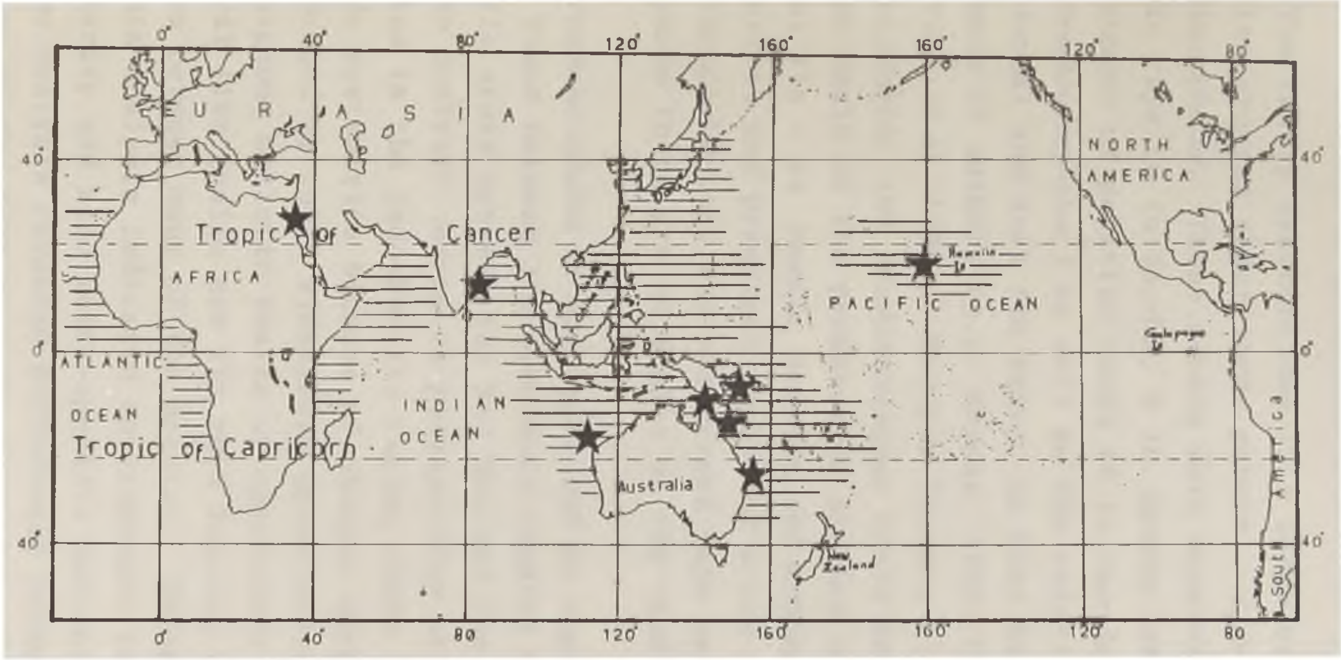

Fig. 2.21 : Distribution of *Trachinooephalus myops* (Bloch and Schneider) 1801. Solid symbols represent localities of specimens examined; hatched areas are additional literature records.

2.4 DISCUSSION

The family Synodontidae is a large one of very similar species grouped under three genera - *Saurida, Synodus* and *Trachinocephalus*. These genera were separated on account of pelvic rays (9 in *Saurida,* 8 in *Synodus* and *Trachinocephalus*) and number of palatine bands (2 in *Saurida,* 1 in *Synodus* and *Trachinocephalus*) as well as the relative lengths of the dorsal and anal fin bases, as have been reported by a number of authors (e.g. Norman, 1935; Chen and Yeh, 1964; Anderson *et al* 1966). However Cressey (1981) found that *Synodus, Saurida* and *Trachinocephalus* could be separated easily on the basis of the presence or absence of scales on the caudal fin - in *Saurida, Harpodon,* and *Bathysaurus* each procurrent and principal rays bear a row of scales. In *Trachinocephalus* only the procurrent rays bear a row of scales. In *Synodus* there are no scales on the caudal fin rays.

Trachinocephalus is monotypic and no apparent differences were found between its specimens studied from various Indo-Pacific areas between the Red Sea and the Hawaiian Is. On the contrary *Saurida* is polyspecific with 11 cryptic species in the Indo-Pacific region alone. Difficulties in *Saurida* systematics because of similar morphologies were compounded by their widespread distribution and supposedly unambiguous meristic traits or characters like number of lateral line scales and fin rays falling into overlapping ranges between many of the species. Though general protein analysis indicated considerable inter-specific similarity and also intra-specific variability, specific enzyme analysis revealed differences between some or all species in the following enzymes - CK, GAPDH, G-3-PDH, SOD, LDH, IDH, PGM, AH, SDH, EST and AAT.

Distinctive phenotypes were also recognized in the most cryptic pairs of *S. undosquamis* and *S. australis*, and *S. tumbil* and *S. argentea*. Similar results were obtained by Waples (1982). Waples *(op cit)* used electrophoretic analysis to confirm the presence of three species - *S. gracilis*, *S. nebulosa* and *S. flamma* - where only a single species, *S. gracilis*, had previously been recognized.

Three groups of species with similar morphologies with regards to palatine and vomerine teeth configuration, pectoral fin length, shapes of nasal flap and snout and general body colour were evident - *S. undosquamis*, *S. tumbil* and *S. nebulosa* types as described previously.

From the description and analyses of morphological and meristic characters *S. gracilis*, *S. nebulosa* and *S. flamma* closely resemble each other. The most distinctive feature of *S. gracilis* is the patch of vomerine teeth (central) that bridges the gap between the outer rows of palatine teeth. The striking reddish-orange coloration on the mouth and body of *S. flamma* and its higher scale count, 50 - 54, as opposed to 47 - 50 in *S. nebulosa* identifies *S. flamma* (Waples, 1982).

In the *S. undosquamis* group, *S. longimanus* is readily recognized from any other species by 1) its longer pectoral fin - the longest in all Indo-Pacific and Atlantic Saurida; 2) the narrower inner bands of palatine teeth, outer band set close to lips, and 3) its elongated body. *S. isarankurai* is the only known Indo-Pacific species with a lower jaw longer than upper jaw and visible from above when mouth is closed. The Atlantic species: *S. suspicio* Breder 1927, *S. caribbaea* Breder 1927, *S. brasiliensis* Norman 1935 all possess a longer lower jaw. However as Shindo and Yamada (1972) also reports ' *S. isarankurai* have fewer scales in lateral line, 47 - 50 (mode 59), whereas *S. suspicio* and *S. caribbaea* have 51 - 60 scales. *S. isarankurai* has nine to ten marked brownish blotches along the lateral line, while *S. brasiliensis* has about six faint blotches; and upper half of pectorals dusky in the former, and there are a few spots of pigment on lower portion of pectoral in the latter. In addition to these, *S. isarankurai* has a somewhat longer lower lobe than the upper of the caudal fin, while in *S. brasiliensis* both lobes are nearly of equal length.'

There are slight colour variations amongst *S. tumbil* and *S. undosquamis* taken from along the Queensland Coast. The northern specimens of *S. tumbil* and *S. undosquamis* were found to be of lighter coloration than the southerners. Yamada and Ikemoto (1979) found that *S. undosquamis* which distribute in the waters from the Southern East China Sea down to the warm Thai, Philippine and Hong Kong waters have clear dots on the upper edge of caudal, whereas those found in the northern waters (north of the Central East China Sea, Kii channel and Wakasa Bay) have none.

Shindo and Yamada (1972) considered *S. wanieso* a distinct species from *S. filamentosa*. However, examination of the holotype and paratypes indicated that *S. wanieso* is conspecific with *S. filamentosa*. The only difference apparent between the two seems to be in coloration - the violet coloration of the upper half of the pectoral fin of *S. filamentosa* - which is not uncommon amongst widely distributed species.

The most distinctive character of *S. filamentosa* is its elongated and filamentous second and sometimes third dorsal ray. In this study, *S. australis* Castelnau, 1878 - 79 has been removed from the synonymy of *S. tumbil* (see McCulloch,1929-30). *S. australis* is rather very similar to *S. undosquamis*, especially in palatine and vomerine dentition and meristic characters, as Castelnau (1878-79) reports: 'The number of the fin rays seems to unite this species (i.e. *S. australis*) with *undosquamis*, but the pectorals are much shorter, and are far from extending to near the vertical of the origin of the dorsal'. The percentage values of the pectoral length relative to the standard length (mean in brackets) are 13.4 - 14.3 (13.8) and 13.5 - 17.0 (15.6) for *S. australis* and *S. undosquamis* respectively. The other point worth of mention is the distinct range of lateral line scales of the two species: 46 - 53 in *S. undosquamis* and 55 - 57 in *S. australis*. Richardson (1848) states that 'there are about fifty-seven rows of scales between the gill-opening and caudal fin....' However the examination of the lectotype (most of its scales lost) suggested that Richardson's count probably included scales on caudal fin which were ignored in this study. *S. australis* also possesses a rather elongated body with a peculiar coloration. In the biochemical regime, *S. australis* and *S. undosquamis* were found to exhibit distinctive *phenotypes for ADH (M), ME (M), MDH (L), G-6-PDH (L), PK (M), MPI (L,M) and XDH (M,L) which is indicative of the maintenance of their gene pool integrity though circumstantial evidence suggests they are sympatric at least in/or between Hervey and Moreton Bays. Thus they are not interbreeding naturally and should therefore be considered as two distinct biological species.

The *S. tumbil* group comprises *S. tumbil*, *S. argentea* and *S. elongata*. *S. micropectoralis* Shindo and Yamada (1972) was found to be conspecific with *S. argentea* and the assertion by Shindo and Yamada 1972 that the pectoral fin of *S. micropectoralis* (i.e. *S. argentea*) is 'the shortest in all Indo-Pacific species' is not valid. Short pectorals are common to the *S. tumbil* group. The percentage values (mean in brackets) relative to standard length for the 72 *S. tumbil*, 32 *S. argentea* and 3 *S. elongata* specimens examined are 10.1 - 12.7 (11.4), 10.6 - 14.6 (12.2) and 10.7 - 11.0 (10.9) respectively. *S. elongata* is readily recognized by the

* M - muscle, L - liver.

uniformity of its colour (brown) and higher scale count of over 59. Wu and Wang (1931), Chen and Yeh (1964) and Shindo and Yamada (1972) reported of 59 - 71 lateral line scales in *S. elongata*. The respective ranges for *S. tumbil* and *S. argentea* are 49 - 54 and 53 - 58. Teeth of *S. tumbil* are stout but slender in *S. argentea*. The latter species is silvery blue below lateral line, whereas the former silvery white.

S. ferox as described by Ramsay in 1883 appears to be a *nomen dubium*. With regards to the present study and the relevant literature, the taxonomic key for *Saurida* species is thus revised as follows:

1. a. Outer bands of palatine teeth usually in 2 and occasionally 3 rows anteriorly 2
   b. Outer bands of palatine teeth in three of four rows. Vomerine teeth present and central. Pectoral fin short 9

2. a. Outer palatine band consists of 2 or 3 poorly arranged rows of teeth; anteriormost 3 or 4 teeth of innermost row conical, elongated and pointed. Outer and inner bands narrowly separated. Body and fins variously mottled and blotched. Posterior margin of nasal flap more or less spatulate 3
   b. Outer palatine band consists of well defined rows of teeth. Outer and inner bands well separated. Teeth in each row more or less equal, sagittate and short. Vomerine teeth present (on 'wings' of vomer) or absent. Posterior margin of nasal flap more or less flabellate 5

3. a. Outer palatine bands converging anteriorly and bridged by a patch of vomerine teeth. 49 - 52 lateral line scales.

S. gracilis

b. Outer bands (deceptively) aligned with vomerine teeth on 'wings' of vomer 4

4. a. 50 - 54 lateral line scales; reddish-orange coloration on the mouth and body.

S. flamma

b. 47 - 50 lateral line scales; colour generally buff.

S. nebulosa

5. a. Pectoral fin long, extending beyond origin of dorsal fin when laid back. Outer palatine band in two rows of teeth and set closely to lips of jaw. Vomerine teeth absent. 48 - 51 lateral line scales.

S. longimanus

b. Pectoral reaching to at least base of pelvic fin but not extending beyond origin of dorsal fin.................................. 6

6. a. Second and sometimes third dorsal ray filamentous, the second longest and sometimes reaching to or beyond the base of the adipose fin when laid back. 51 - 55 lateral line scales. Vomerine teeth usually present. Teeth strongly sagittate.

S. filamentosa

b. No dorsal ray filamentous 7

7. a. Outer palatine band in at least two rows in its entire length. Vomerine teeth present or absent..8

b. Outer palatine band in two rows anteriorly and posteriorly, and in a single row about midway. Vomerine teeth absent. 47 - 50 lateral line scales.

S. isarankurai

8. a. 55 - 57 lateral line scales. Body with silvery-blue bands alternating with golden brown bands running below the lateral line to the caudal section. Vomerine teeth present.

S. australis

b. 46 - 53 lateral line scales. Body generally olive dorsally and silvery white below lateral line. Vomerine teeth present or absent.

S. undosquamis

9. a. 58 - 71 scales in lateral line. Back and sides uniform, no blotches or cross bands on back and sides.

S. elongata

b. Scales in lateral line less than 59 10

10. a. 53 - 58 lateral line scales. Teeth sagittate and slender. Bluish-brown to light brown dorsally, whitish ventro-laterally.

S. argentea

b. 49 - 54 lateral line scales. Teeth sagittate and stout. Dusky-brown with a greenish tinge dorsally, pale yellow or white ventro-laterally.

S. tumbil

3. FOOD, FEEDING HABITS AND ADAPTATIONS

3.1 INTRODUCTION

The basic functions of an organism - its growth, development, reproduction etc. - all take place at the expense of energy (food) (Nikolsky, 1963).

An organism could be described as a conduit of energy in the ecosystem. The organism obtains and disburses energy amongst its life-sustaining activities - as decreed by a compromise between its genotype and the ever-changing environment - for optimal returns on its energy outlays. The developing embryo draws on a limited supply of energy in the form of food reserves, which it receives from the maternal organism (Nikolsky, 1963). After exhausting its energy reserves in the initial stage of growth, the young, and also later as an adult organism, must obtain both materials and energy from the environment by feeding.

The acquisition of food by fish is a process that usually involves searching, detection, capture, and ingestion. A hungry fish performs searching activities that increase the probability that it will discover food (Keenleyside, 1979). In his review of problems and approaches in the analysis of motivation of animal behaviour Colgan (1973) proposed a model which states that "Hunger is presumed to be determined jointly by the metabolic debt (systemic need) of the fish and the amount of food in the stomach .... For a given environmental condition, hunger determines the probability that an encountered item is eaten and the interval between encounters."

Fishes are adapted to a wide variety of foods (Lagler, Bardach and Miller, 1962; Nikolsky, 1963) and knowledge of these foods and feeding habits is of prime importance in fishery management and population studies. Every species of fish is adapted to feeding on a particular combination of food (Nikolsky, 1963). In varying or uncertain environments, extreme specialization for a few types of food or of the structural attributes are few. This flexibility reflects the environment, for it is advantageous for all species to be able to take advantage of temporarily super-abundant resource (Keast and Webb, 1966). Very few fish are stenophagous and diet may change with growth, size, environment and sometimes with sex.

The literature on food and feeding habits of fish dates back to the days of Aristotle (384 - 322BC). In his exhaustive study of the digestive system and feeding habits of about 150 species of fish Suyehiro (1941), also provided an excellent historical review of food studies on fish.

The common methods of studying food and feeding habits of fish - occurrence (volume and weight measurements, number, fullness) have evolved from the analyses of stomach contents either qualitatively (usually relying on list of items and their percentages e.g. Suyehiro, 1941; Hynes, 1950; Hiatt and Strasburg, 1960; Kuthalingam, 1959; Maitland, 1965; Keast and Webb, 1966; Thomas, 1966; Godfriaux, 1969, 1970a, 1970b; Chen and Lee, 1980; Collins, 1981) or quantitatively (usually using more complex mathematical models or equations e.g. Darnell and Meierotto, 1962; Keast and Welsh, 1968; Atmar and Stewart, 1972; Moriarty and Moriarty, 1973; Eggers, 1977; Diana, 1979; Jobling, 1981).

Many of the determinations of the 24 hour chronology of feeding intensity in natural populations have been based on the analyses of -

1. Frequency of prey species found in stomachs of a sample of fish (e.g. Diana, 1979)

2. Weight or volume of food found in the stomachs (Keast and Welsh, 1968; Atmar and Stewart, 1972)
3. Daily variation in the level of food in the stomach based on weight of food and the rate of digestion (evacuation) (Darnell and Meierotto, 1962; Moriarty and Moriarty, 1973; Eggers, 1977; Collins, 1981; Jobling, 1981).

Hynes (1950) made a critical review of the methods in common use and stated that "For any fish with a generalized diet, provided a large number of specimens is examined, any of the commonly accepted methods of assessing the composition of the diet of fish from gut contents will give substantially the same results. Those food items important in a diet will always stand out clearly from those that are occasional or rare and so unimportant and the variation between the different methods will probably not be greater than that between different samples of fish .... although the volume or weight methods are probably the most satisfactory, the points method is a short cut to the same result and that the simpler occurrence or dominance methods are likely to give the same result as the points method."

The majority of fish are carnivorous and generally capture of their food requires elaborate techniques because potential prey organisms have a wide range of behavioural and structural adaptations for avoiding capture (Keenleyside, 1979). Many morphological features of fish have been intimately connected with specific modes of feeding relationships. The feeding habits of carnivorous fish (especially the trapping of prey) is mostly controlled by the structure of the mouth (Yasuda, 1960c); the mouth and its component structures as well as other body structures have evolved adaptively to ensure an efficient procurement of food. Ridewood (1896) and Gregory (1959) have extensively studied the teeth and skull respectively. In many instances the morphologies of teeth and skull are pointers to the feeding habit of fish. For example, Keast and Webb (1966), Yazdani (1969), Nikol'skaya and Verigina (1974), have investigated and correlated the functioning of mouth and body structures with the feeding habits of 14 cohabiting fish species, flatfish and flounders respectively. In most of these works, the attempt has been to understand the mechanical nature of evolutionary adaptations by relating to the mechanics to specific functions. Smith (1982) argues that "A more justifiable orientation would be to evaluate the constraints which limit the mechanical efficiency of structures." Nonetheless, the primary task of a theory of feeding strategies is to specify for a given animal that complex of behaviour and morphology best suited to gather food energy in a particular environment (Schoener, 1971).

The species of the family Synodontidae take their collective vernacular names -

1) lizardfish - from their reptilian look (more or less flattened lizard-like heads
2) grinners - from their large mouths with rows of sharp, long and depressible teeth (not covered by lips), the teeth even showing when the mouth is closed thus expressing a permanent 'grin' (Marshall, 1964; Wheeler, 1975; Thomson, 1977; Grant, 1978).

Lizardfish are euryphagous. They feed on crustaceans, cephalopods and (mainly) on other fish (Okada and Kyushin, 1955; Toriyama, 1958; *Chervinsky, 1959; Hanoaka, Hayashi, Murakami, Takahashi and Yamaguchi, 1959; Tung, 1959; Hayashi, Yamaguchi and Hanoaka, 1960; Bograd-Zismann, 1965; Tatara, 1965; Budnichenko, 1974; Sainsbury and Whitelaw, 1981; Rowling, unpublished). However Hiatt and Strasburg (1960) and Matsumiya, Kinoshita and Oka (1980) found only fish in the stomach of *Saurida undosquamis*.

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* Quoted in Ben-Yami and Glaser, 1974.

Lizardfish are voracious (Marshall, 1964; Arnold, 1951; Hanoaka et al, 1959; Tung, 1959; Sweatman, manuscript). Hanoaka et al (1959) and Tatara (1965) discussed selection of prey sizes by different size groups of *S. undosquamis.* Budnichenko (1974) found variation in the food composition of *S. undosquamis* and *S. tumbil* with size of predator, depth, and seasons. Tatara (1965) reported variations in food composition with different areas. Diurnal activity and variations in feeding of *S. undosquamis*, *S. tumbil* and *S. elongata* have been investigated by Toriyama (1958), Tung (1959), Hayashi et al (1960), Tatara (1965), Budnichenko (1974) and Rowling (unpublished).

Descriptions of morphological or osteological features of lizardfish *per se* have been made by many authors (e.g. Norman, 1935; Gregory, 1959; Agarwala, 1968; Shindo and Yamada, 1972; Rao, 1977; Yamada and Ikemoto, 1979; Waples, 1982 and many others). The burying and hunting behaviour of lizardfish have also been described by Breder (1944), Hiatt and Strasburg (1960) and Sweatman (manuscript). To date little or no attempt has been made to investigate any possible correlation between the striking teeth configuration and body structures and the food and feeding behaviour of lizardfish. Also apart from the works of Sweatman (manuscript), Rowling (unpublished) and general knowledge in books (e.g. Marshall, 1964; Carcasson, 1977 and others) there is no available information on the food and feeding habits of any species of Synodontidae from Australian waters.

The object of this chapter is first and foremost to investigate the food and feeding habits of four local species, and then to describe and inter-relate morphological structure with way of life, food and feeding habits. The study draws upon a three-year study of the food of 8470 specimens of *Saurida* and *Trachinocephalus* and the study of the feeding and digestive system of 14 species of the aforementioned genera and *Synodus*. Various aspects of the morphology which have an important bearing on the success and efficiency of the feeding complex (morphology and behaviour) have been investigated and an attempt is made to draw correlations between the components of the feeding complex.

3.2 METHODS AND MATERIALS

5411, 1340, 612 and 1107 specimens of *Saurida undosquamis*, *S. tumbil*, *S. filamentosa* and *T. myops* respectively were used in the study of food and feeding habits. *S. undosquamis* and *S. tumbil* were collected monthly over a period of 26 months, mainly from Moreton Bay. *S. filamentosa* and *T. myops* collections were made in 15 and 17 months respectively off Cape Moreton. All samples were obtained by forty-minute bottom trawls and were preserved in 5% formalin as previously described in Chapter One (i.e. the general introduction). The sampling covered a wide area, from muddy and sandy or silty bottoms of varying depths (10 - 40m) in different parts of the Bay (see Fig. 1.1) to provide reliable data on the basic food and feeding habits of lizardfish.

The variation of feeding with prey abundance was also investigated:- The survey ran concurrently with baseline studies on the effects of enlargement of the Brisbane Airport upon trawled biota, by Stephenson, Chant and Cook (manuscript) between November 1979 and March 1981. Samples were collected at intervals of lunar months (28) days. At each site at each month three other sampling variables were involved: port and starboard nets, trawling with and against the tide for fifteen minutes, and sampling at midday and dusk. For each sample, counts were made of the species collected. 60 species were considered.

No incision was made into the body wall before preservation in formalin because the preliminary survey showed -

1) that the species feed on quite large items which are to a large extent unaffected by digestion during the time lag until formalin actually seeped into the stomach to stop digestion.
2) substantial loss of body fluids (via incision) and consequent loss in whole body weight and distortion of ratios incorporating whole body weight.

Diurnal feeding and activity surveys were attempted on the following days off Tangalooma Point (see Fig. 1.1).

<u>Summer</u>
17 January 1980
4 December 1980

<u>Autumn</u>
3 March 1980
13 May 1981

<u>Winter</u>
17 June 1980

<u>Spring</u>
10 September 1980
6 November 1980
10 November 1980
21 October 1981

Adequate data were obtained on only 17 June 1980, 10 September 1980 and 21 October 1981. The other surveys were curtailed with little or no data because of bad weather. The samples were collected at approximately hourly intervals unless otherwise stated. Monthly and hourly samples were kept separate.

In the laboratory, the fish were washed free of excess formalin and dried with paper towels as previously described in the general introduction. After whole body weight and standard length have been measured, the alimentary canal of the fish was removed from the abdomen by making an incision of the body wall between the anus and branchiostegals, severing the oesophagus from the pharynx, lifting out the entire alimentary canal and severing the rectum at the anus. Each alimentary canal was kept separately in a 150ml bottle. The sex of each fish was determined by examining its gonad under a dissecting microscope.

Digestion was found to be well advanced in the intestine so examination of food items was confined to the stomach. Stomachs were cut open and items were taken out and identified to the lowest systematic level possible. Fish identifications were according to Marshall (1964), Carcasson (1977) and Grant (1978). Invertebrate identifications followed Meglitsch (1972), Barnes (1974) and Grant ((Penaeidae; prawns) 1978). The isopod genus *Anilocra* was identified by Dr. Neil Bruce.

The stomachs were given points of fullness:-

0 - empty
5 - with little food
10 - half full
15 - quite full
20 - full and distended
20++ - greatly distended.

This system is a modification of the Swynnerton and Worthington (1940) points method. Here each stomach was allotted a number of points of fullness instead of on categories of food in the stomach. This method, though more or less subjective, was considered appropriate for the study. Compared to other methods, it is rapid and easy and requires no special apparatus for measurement.

Large samples and several months of such analysis undoubtedly diminished the subjectivity in the method considerably. The occurrence method was also considered appropriate in assessing the relative importance of prey items. Each stomach scored only once for each type of prey notwithstanding the numerical strength or size of the prey in the stomach. Thus the composition of food of lizardfish was reduced to percentages of occurrences of prey in stomach.

The Feeding Index; F.I., was calculated as -

$$\text{F.I.} = \frac{\text{Number of fish with items in stomach}}{\text{Total number of fish}} \times 100\%$$

The number of species and their numbers examined precluded measurement of stomach contents of each individual fish. Only whole or sometimes large items were measured for length and weight. The orientation of the head or tail of the prey (if discernible) in the stomach (i.e. swallowed head-first or tail-first) was also noted.* It is likely that some food items were taken in the trawl and **Bograd-Zismann (1961-62) regarded this as "as result of panicky indiscriminate attacking in the trawl cod end." Budnichenko (1974) and Rowling (unpublished) discarded stomachs with perfectly preserved prey for the above reason. No stomach was rejected in this study because -

1) the large number of fish with empty stomachs caught almost always with large numbers of prey and potential prey during the preliminary study indicated that "panicky indiscriminate attacking", if it occurred at all, did so at a low frequency.
2) the premise for rejection of some stomachs - perfect preservation of prey, is spurious because -
    (i) lizardfish swallow prey entire, and

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* Between February 1981 and February 1982

** Quoted in Ben-Yami and Glaser, 1974.

(ii) it more or less implies very fast or instant breakdown of prey taken under "natural" conditions; this is contrary to their findings and those in this study.

A simplified approach was taken: Every item found in the stomach was regarded as a food item. Prey items found stuck in mouth or pharynx were discarded.

The following measurements were also taken of the lizardfish -

a) lengths of head and premaxillary
b) width of premaxillary at posterior edge of eye and size of eye
c) depth and width of body at origin of dorsal fin
d) the triangular base of each half of caudal fin and the span of the caudal fin.

The Aspect Ratio (A.R.) of the caudal fin is defined as the span of the foil/chord; this is often more conveniently stated as span^2/area (Nursall, 1958).

Mouth, jaws, lips, teeth, gill rakers, the entire gut, body form, pectoral and pelvic fins, caudal peduncle and fin were examined macroscopically. A number of heads of lizardfish were boiled and the muscles and skin removed. The maxillary, premaxillary, angular and dentary were then cleaned with a hard brush and studied.

Several attempts to keep some lizardfish specimens in an aquarium in the laboratory for feeding behaviour studies were unsuccessful.

3.3 RESULTS

3.3.1 Feeding Patterns of Lizardfish

The feeding patterns of lizardfish were estimated from the percentage occurrence of (potential) prey items in the stomach.

About 50% or more of the stomachs of the species looked at were empty: specifically 58.5, 67.9, 50.8 and 48.4 percent of *S. undosquamis*, *S. tumbil*, *S. filamentosa* and *T. myops* respectively (see Appendix 1).

The most important component (by frequency of occurrence) were fish; in over 85% of stomachs, Crustacea; 5 - 16% and cephalopods (mainly squids); up to about 7% depending on species of lizardfish (Table 3.1). Prey items were swallowed whole and many stomachs were distended. The frequencies of occurrence of prey items indicate that lizardfish fed mainly on fish and, amongst other, crustaceans and cephalopods.

The food composition included items of many divergent shapes and sizes; some were cylindrical and more or less fusiform (e.g. Sillaginidae, Synodontidae), flattened and depressed (e.g. Callionymidae, Platycephalidae, Heterosomata), compressed and deep-bodied (e.g. Apogonidae, Carangidae, Chaetodontidae, Leiognathidae, Macroramphosidae, Priacanthidae, Sparidae, Trachichthyidae), others were rounded (e.g. Engraulidae), or rectangular; box-like (e.g. Tetraodontidae).

The prey items were also representatives of families inhabiting equally divergent *habitats; pelagic, benthic and benthopelagic: shallow and inshore/coastal waters (e.g. Apogonidae, Callionymidae, Cepolidae, Clupeidae,

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* See Marshall, 1964 and Wheeler, 1975.

TABLE 3.1 : LIST OF STOMACH ITEMS OF LIZARDFISH

Qualitative composition of items	Percentage occurrence (+) of items in stomach (%)							
	S. undosquamis		*S. tumbil*		*S. filamentosa*		*T. myops*	
* n =	1938		318		296		639	
(A) PISCES								
1. Antennaridae (Angler-fish)							+	0.3
2. Apogonidae (Cardinal fish)	+	3.9	+	5.3				
Apogon quadrifasciatus Cuvier and Valenciennes	+		+					
A. auritus	+		+					
Apogonichthys elliοti (Day)			+					
3. Callionymidae (Dragonets)	+	0.1	+	0.3	+	0.3	+	8.4
Callionymus calcaratus			+					
C. limiceps			+				+	
other *Callionymus sp*	+		+				+	
4. Carangidae (Jacks, trevallies etc)	+	0.2	+	0.9	+	1.0	+	0.6
Caranx sp	+							
5. Cepolidae(Band-fish)	+	0.3	+	0.9	+	2.4		
Cepola australis Ogilby	+		+		+			
6. Chaetodontidae (Butterfly fish)			+	0.3				
Parachaetodon ocellatus Cuvier and Valenciennes			+					
7. Clupeidae (Herrings, Sardines etc)	+	0.1	+	0.6				
8. Engraulidae (Anchovies)	+	0.3	+	0.9				
Amentum devisi Whitley	+		+					
9. Heterosomata	+	0.4	+	2.5	+	0.3	+	0.5
Bothidae (Flounders)	+		+		+			
Arnoglossus sp.					+			
Pseudorhombus sp.	+							
Cynoglossidae (Tongue - soles)	+		+					
Cynoglossus bilineatus (Lacepede)	+							

n - Number of stomachs examined.

Table 3·1 Contd

Qualitative composition of items	*S. undosquamis*		*S. tumbil*		*S. filamentosa*		*T. myops*	
10. Leiognathidae (Pony-fish)	+	5.1	+	7.5	+	0.3		
Leiognathus moretoniensis Ogilby	+		+		+			
11. Macroramphosidae (Bellows-fish)					+	3.7		
Macroramphosus elevatus Waite					+			
12. Mullidae (goat-fish)	+	0.1	+	0.3				
Upeneus vittatus	+							
13. Opisthognathidae (Smilers or jawfish)	+	0.3						
Merogymnus eximius Ogilby	+							
14. Parapercidae (weevers)	+	0.8			+	3.0	+	.02
Parapercis cylindrica (Bloch)	+				+		+	
15. Platycephalidae (flatheads)	+	0.1			+	0.7	+	.05
Platycephalus longispinus Mackay	+				+		+	
16. Polynemidae (Threadfins or tassel-fish)	+	0.1						
Polynemus multiradiatus Gunther	+							
17. Priacanthidae (Bulls eyes or big eyes)			+	0.3	+	0.7		
18. Scorpaenidae (Scorpionfish)	+	0.1			+	0.7	+	.05
Centropogon marmoratus (Gunther)	+							
Marilliicosta whitleyi Eschmeyer and Poss					+		+	
19. Sillaginidae (whitings)	+	0.1	+	0.6			+	.02
Sillago maculata Quoy and Gaimard			+					
Sillago robusta Stead							+	
Sillago sp.	+							
20. Sparidae (Snapper and Sea Bream)					+	2.7		
Allotaius spariformis Ogilby					+			

Table 3.1 Cont'd

Qualitative composition of items	*S. undosquamis*		*S. tumbil*		*S. filamentosa*		*T. myopa*	
21. Synodontidae (lizardfish)	+	0.3	+	1.6			+	0.7
Saurida undosquamis (Richardson			+					
Synodus sp.							+	
22. Plectognathi (triggerfish, box fish etc)							+	0.2
Tetraodontidae (Toados)					+	.07	+	6.9
Chelonodon sp							+	
Spheroides sp					+			
23. Theraponidae (Grunters or trumpeter perch)	+	0.1						
Pelates quadrilineatus (Bloch)	+							
24. Trachichthyidae (Roughies)					+	.03		
Hoplostethus elongatus (Gunther)					+			
25. Triglidae (Gurnards)					+	1.4		
Lepidotrigla grandis					+			
26. SEMI-DIGESTED FISH	+	73.7	+	69.5	+	77.0	+	71.0
(B) CRUSTACEA	+	7.1	+	5.0	+	13.2	+	16.3
1. Alphaeidae	+		+					
2. Amphipoda	+							
3. Cymothoidae	+		+					
Anilocra sp.	+		+					
4. Copepoda	+							
5. Ostracoda	+							

Table 3.1 Cont'd

Qualitative composition of items	*S. undosquamis*		*S. tumbil*		*S. filamentosa*		*T. myops*	
6. Penaeidae	+		+		+		+	
Metapenaeus bennettae Racek and Dall	+		+					
M. endeavouri (Schmitt)							+	
M. macleayi (Haswell)	+							
Parapenaeopsis sculptilis (Heller)	+		+				+	
Penaeus merguiensis de Man	+		+				+	
P. plebejus Hess			+					
7. Stomapoda	+				+			
Squilla granti Stephenson	+							
Squilla sp.			+					
(C) CEPHALOPODA	+	7.0	+	1.9	+	3.0	+	0.6
Decapoda	+		+		+		+	
Loligo sp.	+		+		+		+	
Octopoda					+			
(D) MISCELLANEOUS								
1. Annelida (Segmented worms)	+	0.2					+	0.3
2. Detritus (sand, mud etc)	+	0.5	+	0.3			+	0.2
3. Echinodermata (eg Sand dollars, Sea Stars)	+	0.1	+	0.3				
4. Sea weeds	+	2.1	+	0.3				
5. Sipuncula (Peanut worms)							+	0.2

Leiognathidae, Priacanthidae, Synodonthidae *Saurida undosquamis*), deep water (e.g. Triglidae, Macroramphosidae, Synodontidae (*Synodus sp*)). Some live or feed in seagrass beds (e.g. Antennaridae, Parapercidae, Tetraodontidae), in or on sandy bottoms/flats (e.g. Platicephalidae, Theraponidae, Mullidae, Scorpaenidae), or in mud bottoms or burrows (e.g. Annelida, Alphaeidae, Opisthognathidae) and some like the Clupeidae and Engraulidae are pelagic.

*Locomotory abilities of the items ranged from the sedentary or crawling (e.g. Antennaridae, Triglidae) to the rapid swimming cephalopods (e.g. *Loligo*) and the powerful, active and fast swimming fish (e.g. Carangidae). Some of the prey species too were representatives of families that concealed themselves by total camouflage (e.g. Antennaridae, Scorpaenidae) or by burying themselves in the bottom (Platycephalidae).

The respective averages and ranges of percentage sizes of prey relative to the four lizardfish species are:

*S. undosquamis*** - 41.5, 23.9 - 78.7%
S. tumbil - 46.7, 16.3 - 84.3%
S. filamentosa - 42.4, 18.3 - 80.2%
T. myops - 38.5, 25.7 - 62.8%

Thus the distention of the stomachs, the various forms and types of prey, the divergent shapes and relative size ranges, various habitats and locomotory abilities indicate that lizardfish are voracious, that they search for food and probably select prey by relative prey size than by prey species.

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* See Marshall, 1964 and Wheeler, 1975

** Also see Table 3.2.

TABLE 3.2 : Relative Percentage (%) Prey Sizes

Prey item	*S. undosquamis*			*S. tumbil*		
	S.L	%	F.	S.L	%	F.
L. moretoniensis	189	30.2	10	261	19.5	15
	162	35.2	15	265	18.9	15
	180	31.7	15	225	22.2	20
	200	28.5	20	306	16.3	15
	172	31.4	20	172	30.2	15
	157	34.4	15	183	27.3	20
	187	24.1	20	180	28.9	15
	145	30.4	20	173	30.1	20
Apogonidae	212	33.5	20	215	33.5	15
	177	36.7	20			
	160	39.4	15			
	180	33.3	15			
	190	34.2	20			
	158	41.1	20			
	197	43.1	20+			
S. undosquamis	110	59.1	20+	182	22.0	10
	165	25.4	10	215	23.3	10
	177	33.9	15	275	61.8	20+
	140	42.9	10	317	43.6	20+
	178	78.7	20+			
Loligo sp.	266	56.4	20+	270	59.3	20+
	147	37.4	15			
	140	53.6	15			
	148	60.8	20			
	81	43.2	15			
	176	56.8	20			
	227	30.8	20+			
Merogymnus sp.	167	47.9	20			
Cynoglossus sp.	174	57.5	20			
Pseudorhombus sp.	146	41.1	10			
Parapercidae	188	23.9	10	170	18.8	10
Parapercidae	170	31.2	10	182	17.6	10
Platycephalus longispinus	280	43.9	20+			
Engraulidae	204	49.0	20			
Mullidae	197	45.7	20+	252	43.7	20
	165	55.8	20+			
Pelates quadrilineatus	172	39.0	20+			
Sillago maculata				172	84.3	20+
				255	64.7	20+
Carangidae				317	42.5	20+
Semi-digested fish	157	44.6	20	243	39.1	20
	196	40.8	20			

S.L Standard length
F Fullness of stomach

3.3.2 Orientation of Item in Stomach

The orientation of whole prey in the stomach; headfirst or tail-first, was noted and Chi squared test of the observed *183 cases in *S. undosquamis* indicated no significant difference ($p > 0.05$) from the expected 1:1 ratio. The number of cases of *S. tumbil*, *S. filamentosa* and *T. myops* were statistically too small for such analysis. The prey items involved with *S. undosquamis* were Apogonidae, Leiognathidae, Carangidae, Parapercidae, Mullidae, Callionymidae, Platycephalidae, Synodontidae, Heterosomata, fish larvae, semi-digested fish, *Loligo sp.* and prawns.

3.3.3 Variation of Feeding and Prey Abundance

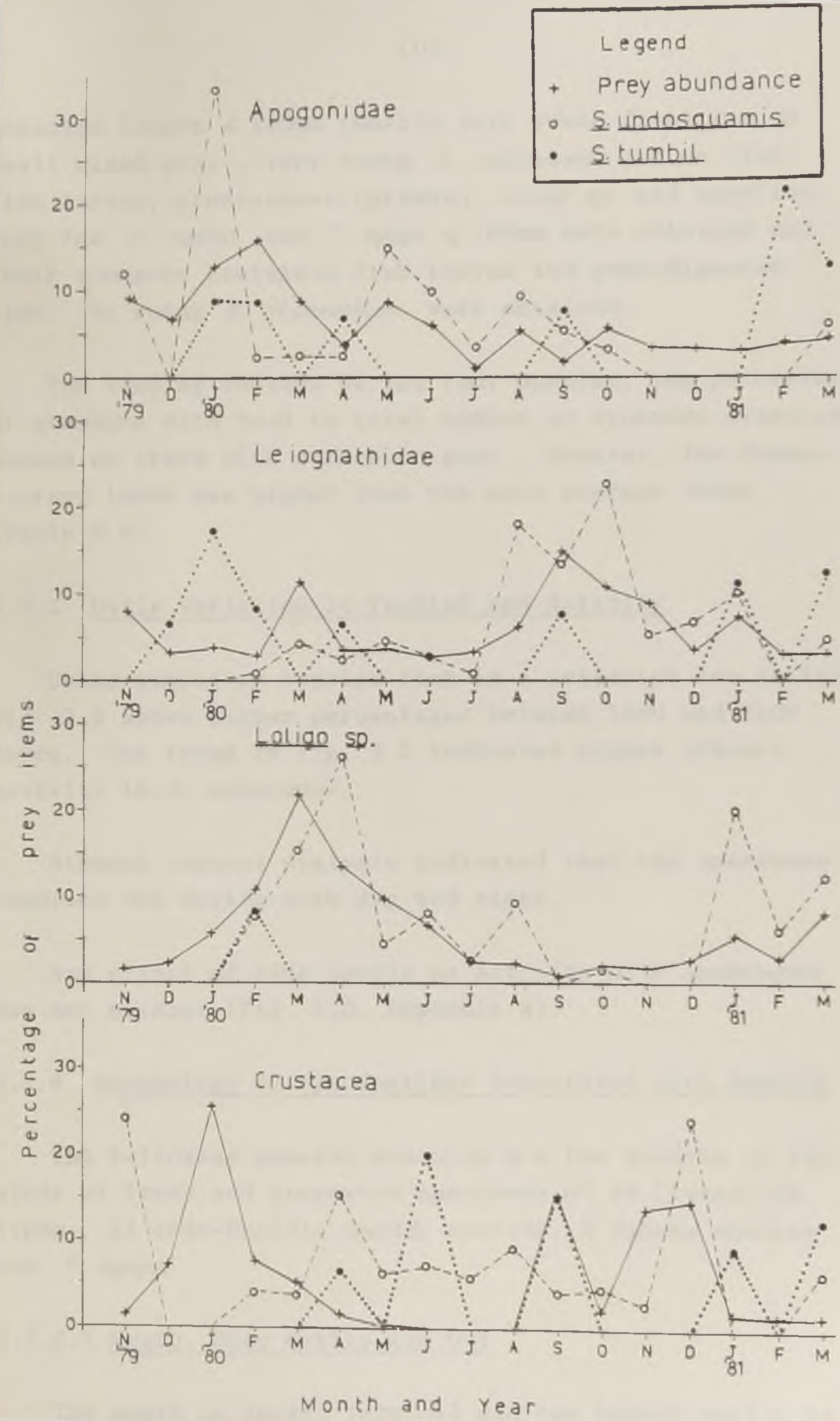
Apogonidae, Leiognathidae, *Loligo sp.* and Crustacea occurred quite frequently in the stomachs of *S. undosquamis* and *S. tumbil* compared to other trawled biota. The population profiles of these items were correlated with percentage occurrences in stomachs (Fig. 3.1 , also see Appendix 2). Fig. 3.1 shows a positive correlation between the abundance of the prey and its percentage occurrence in *S. undosquamis* and *S. tumbil* stomachs, especially in the former. This indicates that lizardfish are more or less responsive to variation in numbers of prey item.

3.3.4 Variation of Feeding and Food Composition with Sex, Length and Month

There was no trend in the variation of the composition of food items with size (length) or sex in fish. Fish of

* Number of headfirst = 97
Number of tailfirst = 86
X^2 = 0.6612, 1df.

Fig. 3.1 : Monthly variation of prey abundance and frequency of occurrence in lizardfish stomachs.


Legend
+ Prey abundance
○ S. undosquamis
● S. tumbil
Apogonidae
Leiognathidae
Loligo sp.
Crustacea
Percentage of prey items
0
10
20
30
N '79
D
J '80
F
M
A
M
J
J
A
S
O
N
D
J '81
F
M
Month and Year

standard length ≤ 100mm (mostly very young fish) fed on small sized prey - very young *S. undosquamis* fed on fish, fish larvae, crustaceans (prawns), *Loligo sp.* and annelids. Very few *S. tumbil* and *T. myops* ≤ 100mm were obtained and their stomachs contained fish larvae and semi-digested fish. No young *S. filamentosa* were obtained.

The feeding indices of the four species; the percentage of stomachs with food to total number of stomachs examined, showed no trend with season or year. However, the female average index was higher than the male average index (Table 3.3).

3.3.5 Daily Variation in Feeding and Activity

Using number of trawled fish as a criterion for activity, Fig. 3.2 shows higher percentages between 1000 and 1800 hours. The trend in Fig. 3.2 indicates higher diurnal activity in *S. undosquamis*.

Stomach content analysis indicated that the specimens examined fed during both day and night.

Any effect of tide levels on activity of *S. undosquamis* was not evident (Fig. 3.2, Appendix 3).

3.3.6 Morphology of Synodontidae Associated with Feeding

The following general accounts are the results of the study of fresh and preserved specimens of 14 lizardfish types: 11 Indo-Pacific *Saurida* species, 2 *Synodus* species and *T. myops*.

3.3.6.1 Mouth, Body Cavity and Gut

The mouth is large, terminal and the buccal cavity is small. The premaxillae are elongated; about 61 - 76% of

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Fig. 3.2 : Daily activity of *S. undosquamis*

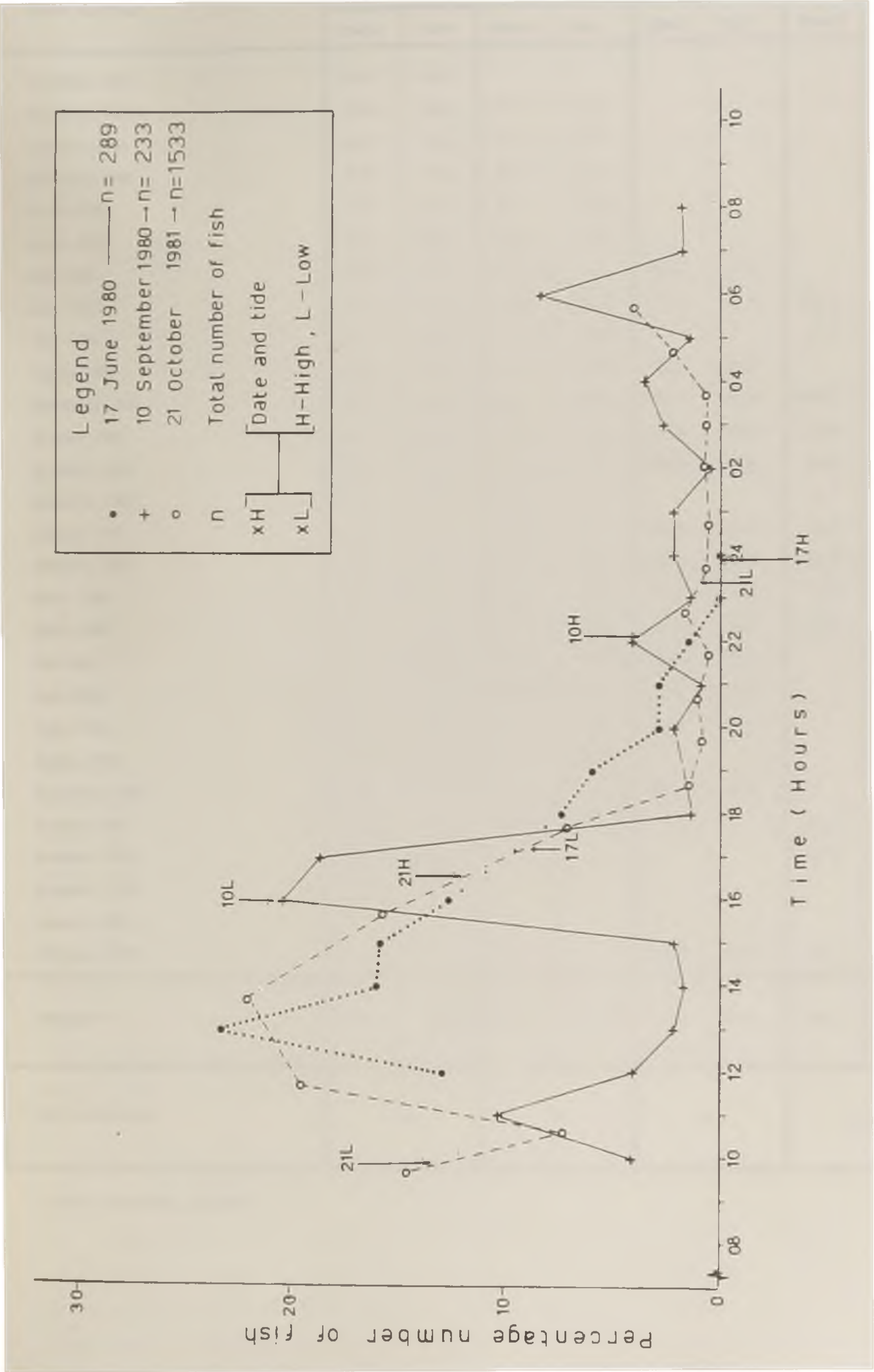

Legend
• 17 June 1980 —— n= 289
+ 10 September 1980 – n= 233
o 21 October 1981 – n=1533
n Total number of fish
xH Date and tide
xL H-High , L-Low
Percentage number of fish
0
10
20
30
08
10
12
14
16
18
20
22
24
02
04
06
08
10
Time (Hours)
21L
10L
21H
17L
10H
21L
17H

TABLE 3.3 : Feeding Indices

Month and Year	*S. undosquamis*		*S. tumbil*		*S. filamentosa*		*T. myops*	
	female	male	female	male	female	male	female	male
November 1979	84.4	66.7						
December 1979	9.5	10.0	64.7	55.6				
January 1980	18.2	8.3	40.5	22.6				
February 1980	70.8	78.5	38.9	26.3				
March 1980	58.2	57.2	31.3	50.0				
April 1980	26.6	28.2	85.0	88.9				
May 1980	35.9	27.3	0.0	0.0	40.0	0.0		
June 1980	29.3	37.1	15.8	12.5	76.5	0.0	100.0	0.0
July 1980	36.5	31.6	4.3	0.0			66.7	0.0
August 1980	54.2	35.3	0.0	0.0	36.4	33.3		
September 1980	51.0	39.1	79.1	80.0	58.8	33.3	100.0	100.0
October 1980	65.5	55.4	0.0	0.0	0.0	60.0	55.6	42.9
November 1980	29.4	37.1	0.0	6.7	100.0	100.0	63.1	40.0
December 1980	35.5	41.4	0.0	6.0			79.7	63.6
January 1981	5.0	8.3	47.2	27.4	66.0	50.7	95.9	31.3
February 1981	50.0	45.6	50.0	25.0	38.9	20.0	25.0	50.0
March 1981	47.4	42.5	14.3	18.2	44.4	33.8	0.0	100.0
April 1981	35.4	39.6	36.7	34.6	0.0	0.0	20.0	18.2
May 1981	32.5	23.5	41.4	36.8	42.0	62.5		
June 1981	37.9	25.9	28.6	41.7	40.0	50.0		
July 1981	16.5	25.6	7.1	9.5	66.7	100.0		
August 1981	32.2	25.7	8.7	16.7				
September 1981	41.8	42.2	26.3	16.7	66.7	50.0		
October 1981	30.8	32.5	22.2	30.8			59.2	50.6
November 1981	45.2	22.6					57.1	65.2
December 1981	36.8	61.5						
January 1982								
February 1982					33.3	100.0	76.1	40.5
Average *	39.1	36.5	29.0	27.5	49.6	41.6	69.8	48.5
Very young fish	57.8		16		0		71.9	

* Very young fish excluded

the length of the head (see Table 2.4B) and the premaxillae articulate further behind the orbit with the angular bones. The maxillae are rudimentary and also excluded from the gape (Fig. 3.3B).

The gill arches extend far into the mouth, well in advance of the angle of the gape. The first four lower jaw arches each has an additional joint (Fig. 3.3C). The anterior section of the lower jaw is movable (downwards only) about two joints at the base of the first and fourth gill arches. This structural frame further increases the gape of the mouth. The gill rakers are rudimentary; pads of teeth-like setae.

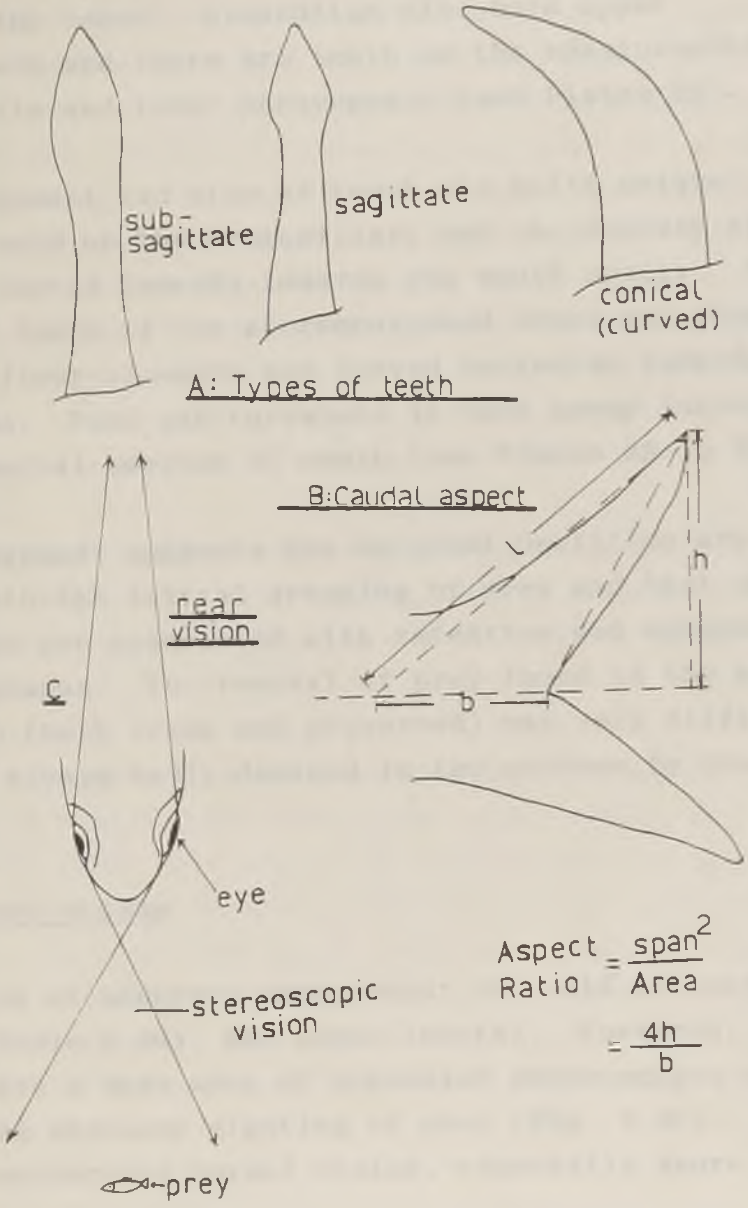
The body is muscular and slender, rounded and fusiform or slightly depressed. The ratio of the width to depth at dorsal fin origin is about unity. The lizardfish has a rather large body cavity. The oesophagus and intestine are short. The stomach is "7" shaped *in situ, sensu* Suyehiro (1941). The oesophagus and stomach have very thick walls, the inner section with thick longitudinal folds. The oesophagus has two bands of bristles, each overlaid by a thick bundle of muscle fibres.

Lizardfish have about 13 - 21 pyloric appendages. Liver lobes are thick, and the left lobe a little longer. They have no swim bladder. The thick wall of the oesophagus and stomach allows the great distensibility of the gut; especially of the stomach.

3.3.6.2 Teeth

The teeth of lizardfish are moderately sized, sharp, conical to sagittate (Fig. 3.4A) and depressible. The premaxillary and dentary carry about 3 - 6 bands of teeth. The roof and floor of the mouth bear a number of groups of teeth: roof - the palatine has one (in *Synodus* and

Fig. 3·4


sub-sagittate
sagittate
conical (curved)
A: Types of teeth
B: Caudal aspect
h
b
rear vision
C
eye
stereoscopic vision
prey
Aspect Ratio = span² / Area
= 4h / b

Trachinocephalus) and two (in *Saurida*) band(s) of teeth. There are teeth on the endopterygoid and ectoterygoid and sometimes on the vomer. Lizardfish also have upper pharyngeal teeth and there are teeth on the brasibranchials, ceratobranchials and lower phanyngeals (see Plates 29 - 37).

The arrangement and size of teeth are quite unique. The lateral teeth on the premaxillary and the dentary are more or less curved inwards towards the mouth cavity. The anterior-most teeth of the aforementioned bones and those of the roof and floor of mouth are curved backwards towards the oesophagus. Size and curvature in each group increases towards the medial section of mouth (see Plates 29 to 37).

The arrangement suggests the marginal dentition are associated with the initial grasping of prey and that the teeth in mouth are associated with retention and movement towards oesophagus. The removal of prey found in the mouth of lizardfish (both fresh and preserved) was very difficult - the prey was always badly damaged in the process by the sharp teeth.

3.3.6.3 Sensory organs

The eye is of moderate size; about 18 - 21% of head length (see Table 2.4B), and dorso-lateral. Forwards, lizardfish have a wide area of binocular stereoscopic vision vital for long distance sighting of prey (Fig. 3.4C). They also have considerable dorsal vision, especially above the head.

The nostrils are paired and oval. The anterior nostril has a dermal flap on its posterior margin. The lateral line is straight and runs from above the pectoral fin to the base of the caudal fin.

3.3.6.4 Fins

The pectoral fins are sub-falcate to falcate. They are very short in the *S. tumbil* type and elongated; reaching to or beyond the base of pelvics in *S. undosquamis* type. The pelvics are more or less rectangular and stout and relatively long. The shapes and sizes of the pectoral and pelvic fins indicate more stability and manoeuvreability than speed. The caudal fins are forked (Fig. 3.4B) with aspect ratios ranging between 3.0 and 4.4; an indication of a moderate swimming ability.

3.3.6.5 Colour

Lizardfish have obliterative colour patterns relative to their usual habitat. They are generally of dark colour above lateral line and pale yellow to silvery-white below lateral line.

The reef species *S. flamma*, *S. nebulosa* and *S. gracilis* are pale brown with variegated dark cross-bands. The relatively deep water species, *S. filamentosa* and *T. myops* have some bright colorations in addition to the dark colour variegations: *T. myops* has silver-blue stripes edged with dark brown and also an "eye spot"; an oblique black blotch on each shoulder girdle. The tips of the caudal rays and the upper half of the pectoral finds of *S. filamentosa* (S.E. Qld) are violet.

The relatively shallow water species: *S. undosquamis*, *S. tumbil* and *S. australis*, occurring in muddy or sandy areas or in seagrass beds, are more or less dusky brown with a greenish tinge. Their bodies have about 7 - 10 dark blotches along the lateral line.

3.4 DISCUSSION

Lizardfish are wide-ranging benthic carnivores. Fish is the predominant component of the diet of *S. undosquamis, S. tumbil, S. filamentosa* and *T. myops*. The other two major *components are crustaceans and cephalopods. This is consistent with findings by Bograd-Zismann (1965) in the Mediterranean Sea, Budnichenko (1974) in the Arabian Sea (Coast of Oman), Sainsbury and Whitelaw (1981) in the North West Shelf of Australia, Rowling (unpublished) on the Coast of North Queensland and with several others in the Seas of China and Japan (Okada and Kyushin, 1955; Toriyama, 1958, Hanoaka et al, 1959; Tung, 1959; Hayashi et al, 1960; Tatara, 1965). In each of the above reports, fish constituted about 80% of diet. Hiatt and Strasburg (1960) and Matsumiya et al (1980) found only fish in the stomachs of *S. undosquamis*.

About 50% of the 8470 stomachs of *S. undosquamis, S. tumbil, S. filamentosa* and *T. myops* were empty. Rowling (unpublished) found 76% of 975 stomachs of *S. undosquamis* and *S. tumbil* empty. The disparity is probably due to the difference in numbers of lizardfish examined.

The more stable the feeding conditions of the species, the smaller the range of foods to which it is adapted, and conversely, the more variable the food supply, the greater the variety of foods eaten by the species (Nikolsky, 1963). In South East Queensland waters, at least 26 families of fish plus many more of crustaceans and cephalopods are eaten by *S. undosquamis, S. tumbil, S. filamentosa* and *T. myops*.

* Seagrass and detritus occurred quite frequently in stomachs of *S. undosquamis* and *S. tumbil* and were most probably taken by chance with the capture of prey.

A perusal of the literature reveals many more *'new' families as prey items:

A. Okada and Kyushin (1955); East China and Yellow Seas.
   1. Branchiostegidae
B. Tung (1959); Taiwan Straits.
   2. Sphyraenidae
C. Hayashi et al (1960); Kii Channel and Inland Sea of Japan.
   3. Syngnathidae
D. Bograd-Zismann (1965); Mediterranean.
   4. Dussumieridae
   5. Serranidae
   6. Maenidae
   7. Blennidae
E. Tatara (1965); Inland Sea of Japan and adjacent waters.
   8. Argentinidae
   9. Apodes
   10. Scombridae
   11. Acropomidae
   12. Champsodontidae
   13. Ammodytidae
   14. Gobiidae
   15. Bregmacerotidae
F. Rowling, unpublished; North Queensland.
   16. Eleotridae
   17. Nemipteridae
   18. Chromidae
   19. Trichiuridae

Thus lizardfish can exploit at least 45 families of fish alone as food! These families undoubtedly reflect

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* Families already recorded in South East Queensland or elsewhere were not counted again in other areas.

a diversity of shapes, sizes, mobility* and habitats*.

The prey size ranges for the four species were between 16 and 84% of the predators' standard length. This broad range and the large number of families of prey items eaten indicate that lizardfish do not select prey types but sizes. Sweatman (manuscript) wrote of the hunting of *Synodus englemani* - "For an attack to be successful, the species of prey seemed to be unimportant so long as it was of **manageable size." Ashmole (1968) found that though five terns on Christmas Island fed on similar diet, they exhibited ecological segregation. This he explained as, "It is more probable that the birds have evolved responsiveness to the appearance at the (sea) surface of any animal of **appropriate size, and that they are essentially non-selective with respect to the taxonomic affinities of the prey." The four species of lizardfish occupy distinct habitats. *S. tumbil* was found only in the Bay, *S. filamentosa* was only obtained in deep water, and *T. myops* was obtained from the transitory zone. However, *S. undosquamis* was found in all 3 areas. These differences in habitat and the size ranges of prey taken suggest ecological segregation and low levels of competition.

Hanoaka et al (1959); working on *Synodus macrops* Tanaka, *S. undosquamis*, *S. tumbil* and *S. elongata* and Tatara (1965); working on *S. undosquamis*, reported that shape and size of prey eaten varied considerably with size of predator. Small sized groups fed on smaller size prey. In addition, Tatara *(op cit)* found that small sized groups preferred those preys lower in body height and circular in section, and that large groups fed on even those higher in body height. In the Mediterranean Sea, Bograd-Zismann (1965)

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* Lizardfish disperse and migrate over wideareas, especially during spawning. See Chapter on Reproduction.

** Emphasis mine.

found that *S. undosquamis* ate more of red mullets, Leiognathidae, gobies than *Triglida* though the latter occurred in large numbers in the trawl. This is probably because it is easier for *S. undosquamis* to swallow gobies *et cetera* than *Triglida* which has a large head, more or less completely encased with rough bony plates and armed with spines. In Moreton Bay, Leiognathidae, Apogonidae and *Loligo sp.* were taken more often than Callionymidae by *S. undosquamis* and *S. tumbil* probably because of a similar reason - Callionymidae species have preopercles with well developed spines; some armed with recurved hooks.

Many predatory fish eat fish which are up to 40% of their own length or about 6% of their volume (Alexander, 1967). Lizardfish are voracious carnivores and very often take prey greater than 40% of their standard length (see Table 3.4). Marshall (1964) reported that a specimen of *Saurida* measuring 279.4mm (11 ins) had a 114.3mm (4½ ins) *Sillago sp.* in its stomach (the *Sillago* length was 40.9% of the *Saurida's* standard length). *Synodus englemani* take a mean prey size of *36% of total length (Sweatman, manuscript). Arnold (1951) observed the feeding of *Synodus foetens* at Wickford Harbor, Rhode Island and reported that, "One lizardfish leaped into a skiff while in frenzied pursuit of silversides. Large numbers of this species were observed here, voraciously feeding on silversides and small menhaden. The lizardfish, which has the same general shape and feeding habits as the barracuda, is no doubt often mistaken for that predator." Breder (1944) also described the feeding of a tank-reared specimen as 'vigorous' and 'notably voracious'. The voraciousness of lizardfish in South East Queensland as gauged from their attack on bait has been described as 'fierce' or 'vigorous' by many fishermen and Clive Keenan (pers comm). *S. undosquamis, S. tumbil* and *S. filamentosa* were found to be cannibalistic too.

* Percentage relative to standard length will be higher than 36%

TABLE 3.4: Dimensions of prey relative to lizardfish (predator)

	PREDATOR		PREY				
	Length (mm)	Weight (g)	Species	Length (mm)	% Lth of predator	weight	% weight of predator
Saurida undosquamis	178	64.5	*S. undosquamis*	140	78.7	32.0	49.6
	110	14.0	*S. undosquamis*	65	59.1	3.4	24.3
	280	169.1	*Platycephalus longispinus*	137	49.0	45.0	26.6
	197	83.3	*Upeneus vittatus*	90	45.7	28.7	34.5
	165	43.1	*U. vittatus*	92	55.8	30.0	69.6
Saurida tumbil	270	245.5	*Loligo* sp	160	59.3	41.1	16.7
	172	64.1	*Sillago maculata*	145	84.3	55.5	86.6
	255	181.1	*S. maculata*	165	64.7	66.2	36.6
	275	255.7	*Saurida undosquamis*	170	61.8	42.3	16.5
	317	387.0	*S. undosquamis*	138	43.6	23.5	6.1

Okada and Kyushin (1955), *Chervinsky (1959), Tung (1959), Budnichenko (1974) have also observed cannibalism in *S. undosquamis* and *S. tumbil*. However, Ben-Yami and Glaser (1974) reported that *Bograd-Zismann (1961-62) explained this as "a result of panicky indiscriminate attacking in the trawl cod end".

Because of natural fluctuations in abundance, any one food organism is not of constant availability to fishes. Such fluctuations of forage organisms are often cyclic and due to factors of their life histories or to climatic or other environmental conditions (Lagler, Bardach and Miller, 1962). Thus, abundance and type of forage organisms may be seasonal, annual or may even vary with time of day. In Moreton Bay there appears to be a correlation between the abundance of Apogonidae, Leiognathidae, and *Loligo sp.* on the one hand, and their occurrences in the stomachs of *S. undosquamis* and *S. tumbil*. Tatara (1965), working on *S. undosquamis* in the Sea of Japan, observed that the number of prey species found in stomach corresponded to the number of possible prey species. Thus, there is a large element of opportunism in the feeding of lizardfish; its dominant prey usually being the food resource that is most abundant at the time. Thus, the combination of feeding on food of "manageable size" and not a particular food type and responsiveness to variation in the abundance (availability) of the food, was probably a significant factor in the success of *S. undosquamis* in the Levant Basin of the Suez Canal to the detriment of its main competitor, the hake; *Merluccius merluccius*, since its invasion of the Canal (see Ben-Yami and Glaser, 1974).

Diet of lizardfish varies with a number of conditions. In Moreton Bay, *Loligo sp.* occurred more frequently in *S. undosquamis* stomachs from late summer to winter. On the

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* Quoted in Ben-Yami and Glaser, 1974

other hand, Leiognathidae had relatively high occurrences in stomachs between late winter and late summer (Fig. 3.1). Tatara (1965) reported that the composition of food of *S. undosquamis* differed between sub-populations; i.e. between localities. Budnichenko (1974) found that the diet of *S. undosquamis* varied in relation to depth and also with the seasons - squids formed the major food at a depth of 80 - 100 metres and fish predominated at depths below 100m. Also that in summer the food consisted mainly of *Sardinella longiceps* whilst *Loligo sp.* predominated during winter.

The four species did not show any variation in feeding with size (length) or time (of year). However, the female fish had higher feeding indices (Table 3.3). Tatara (1965), concluded from his studies of the bilogy of *S. undosquamis* in the Inland Sea of Japan and its adjacent waters that "feeding activities of this species depend first, on the conditions of the individual fish - such as sex, size, age and spawning - and also, on its own density both in shoal and population levels as well as the qualitative and quantitative feature of prey environment." He found that 200mm males and 180 - 210mm females had the largest feeding rate and Budnichenko (1974), reported that fish between 100 - 200mm fed intensively in the shallowest areas (60 - 80m). Budnichenko (1970) also reported that the feeding rate in summer was slightly higher than in winter. Tung (1959) found that *S. tumbil* had a high feeding index during and immediately after spawning.

The periodicity in food consumption is not the same for all fish. The diurnal rhythm of feeding is to a considerable extent related to the method by which the fish orientates itself towards its food. The light intensity is a significant factor which, on the one hand, assists a predator that orientates itself visually in finding its prey and, on the other hand, enables the prey to observe the predator better (Nikolsky, 1963).

Though *S. undosquamis* showed a marked trend in high diurnal activity in Moreton Bay, the stomachs contained as much food in the night as during the day. Budnichenko (1974), Hayashi et al (1960) and Rowling (unpublished) also reported intermittent and intensive feeding at any time of day or night by *S. undosquamis, S. tumbil* and *S. elongata.* Sweatman (manuscript) also found a decline in the hunting activity of *Synodus englemani* in the evening twilight though he did not investigate night-time feeding. Toriyama (1958) reported quite active feeding in the morning during one or two hours after sunrise by *S. undosquamis.* On the other hand, Budnichenko (1974) found that the highest feeding rate of juvenile *S. undosquamis* and *S. tumbil* was in the hours of darkness in his work along the Coast of Oman.

The tide was not considered as a variable during the study and no relationship was found between activity of *S. undosquamis,* as gauged from the number caught, with tide (see Fig. 3.2 and Appendix 3). However Stephenson, Chant and Cook (manuscript) reported higher catches of *S. undosquamis* trawling with the tide.

Teleosts can suck in food or gather it with their jaws. The raking action of the pharyngeal teeth represents a most efficient swallowing mechanism when working in co-ordination with the directed water currents controlled by changes in volume of the pharyngeal and opercular cavities (Liem, 1977). The width and length of the mouth of a predator sets limits on the size of the prey: the "proper size" of the prey (its body depth or width) is the size which is almost equal to (the size of) the *length of the mouth of the predator (Yasuda, 1960c). An efficient

* Yasuda (1960c) referred to it as breadth.

trapping mouth must be able to open widely enough to accommodate prey and of necessity retain and swallow it.

The buccal cavity of the lizardfish is small. However, this is compensated by a very wide gape and an efficient grasping configuration of teeth. The maxillary is rudimentary and has been excluded from the gape. Its place has been taken by the premaxillary, which has been elongated and moved backwards to articulate with the angular instead of the articular. Furthermore, there is an additional joint in each of the first four lower gill arches, and also the anterior lower jaw is movable about two joints at the base of the first and fourth gill arches. These joints enable the mouth to be opened more widely.

The peripheral teeth of the premaxillary and dentary serve to catch the prey and those on the roof and floor of the mouth to prevent the prey's escape. The teeth are depressible and curved, and allow entrance but not the exit of prey. (No disgorgement of food was observed as reported by Rowling (unpublished). Disgorgement appears to be functionally improbable). *S. tumbil* and *S. undosquamis* did not show any preference to the orientation of head or tail when swallowing. On the contrary, Rowling (unpublished) reported that, "During the examination of stomach contents it was observed that both species of grinner swallowed the majority of their prey fishes whole, and tail-first. Those prey that were swallowed head-first generally had their caudal fins severed, and some were completely chopped in half. This indicates that the grinners probably pursue their prey from behind, the direction that would give the prey the least chance of detecting the approaching predator. In cases where the grinner cannot overtake and capture a prospective prey organism, it appears that the predator's sharp teeth are used to sever the caudal peduncle, thus immobilising the prey and giving the grinner time to turn trapping mouth must be able to open widely enough to accommodate prey and of necessity retain and swallow it.

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Yasuda (1960a) studied the feeding mechanism in young fishes and concluded that:

1. In the feeding mechanism of fish in their young stages, the mouth structure, especially the *cleft and the *breadth are very important factors.
2. In the development of the cleft and the breadth there can be observed two types. One, where the cleft length and the breadth cross at some stage after hatching. The other, where the crossing does not occur or is not clearly visible.
3. In the first type, during the stage before the crossing has occurred, the fish is not active in its feeding habits and only feeds on non-active micro food particles. However, the other type begins feeding actively immediately after hatching.

Figure 3.5 shows a type 2 development from the regression of width at posterior edge of eye and length of premaxillary with standard length of young *S. undosquamis;* ≤ 100mm. This indicates that young *S. undosquamis* feed actively immediately after hatching *sensu* Yasuda (1960a). Feeding begins with the transformation of the prolarvae into postlarvae in the congeneric species; *S. tumbil* (Kuthalingam, 1959): "The fish begins on a diet of copepod eggs, nauplii and adults during larval stages, but gradually changes over to larger organisms as it grows and finally subsists on planktonic as well as nectonic organisms when they become adults." The prolarvae depend on yolk for food.

* In this study 'cleft' is width and 'breadth' is length.

Fig. 3.5 : Regression of width and length of premaxillary on standard length of *S. undosquamis*.

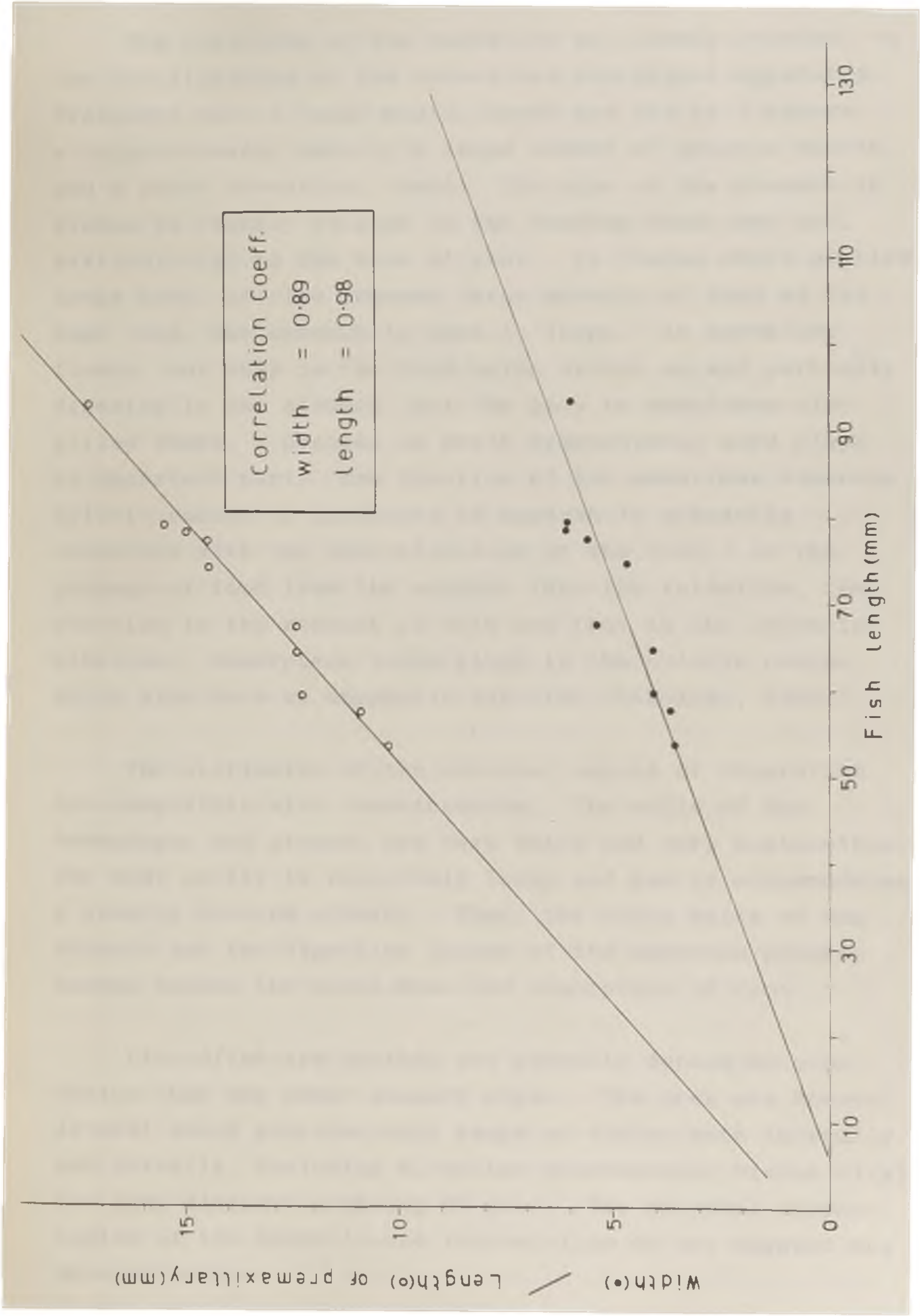
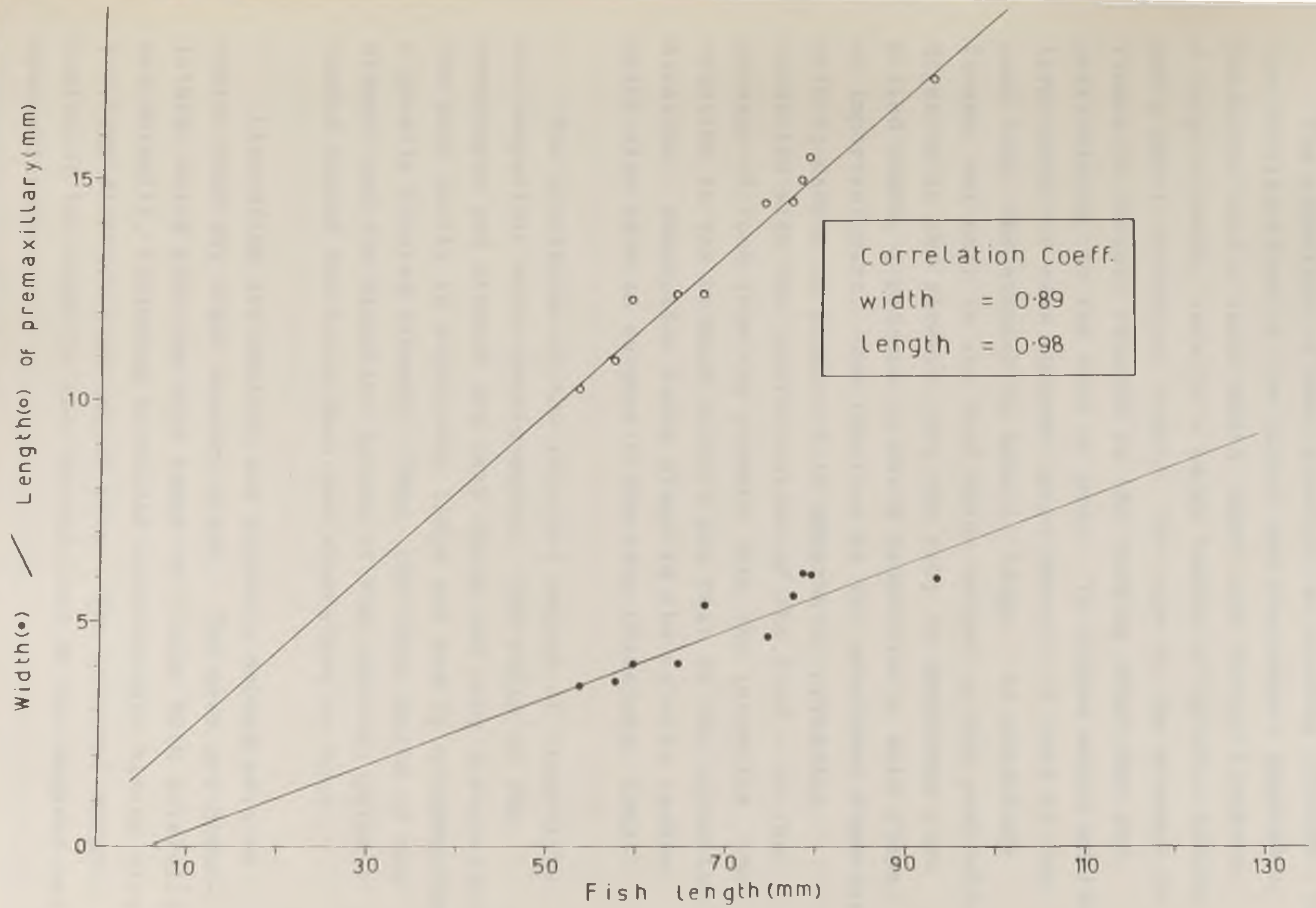

Correlation Coeff.
width = 0·89
length = 0·98
Fish length (mm)
0
10
30
50
70
90
110
130
5
10
15
Width(•) / Length(○) of premaxillary (mm)

Fig. 3.5 : Regression of width and length of premaxillary on standard length of *S. undosquamis*.


Correlation Coeff.
width = 0·89
length = 0·98
Width(•) / Length(o) of premaxillary(mm)
0
5
10
15
10
30
50
70
90
110
130
Fish length(mm)

The structure of the intestine is closely related to the peculiarities of the buccal and pharyngeal apparatus. Predators have a large mouth, short and few gill-rakers, a large stomach, usually a large number of pyloric caecae, and a short intestinal tract. The size of the stomach in fishes is closely related to the feeding behaviour and, particularly, to the size of prey. In fishes which swallow large prey, or else consume large amounts of food at the same time, the stomach is usually large. In predatory fishes, not only is the food bolus broken up and partially digested in the stomach, but the prey is sometimes also killed there, a process in which hydrochloric acid plays an important part. The function of the sometimes numerous pyloric caecae in predators is apparently primarily connected with the neutralization of the food - in the passage of food from the stomach into the intestine, the reaction in the stomach is acid and that in the intestine alkaline. Absorption takes place in the pyloric caecae, which also have an enzymatic function (Nikolsky, 1963).

The attributes of the internal organs of lizardfish are compatible with voraciousness. The walls of the oesophagus and stomach are very thick and very distensible. The body cavity is relatively large and easily accommodates a greatly bloated stomach. Thus, the thick walls of the stomach and the digestive juices of the numerous pyloric caecae ensure the break down and absorption of food.

Lizardfish are benthic and probably depend more on vision than any other sensory organ. The eyes are dorso-lateral which provides wide range of vision both laterally and dorsally, including binocular stereoscopic vision vital for long distance sighting of prey. The external morphologies of the nostrils and lateral-line do not suggest any specialization.

In a world where vision is a crucial sense for most animals, it can be a great advantage to be inconspicuous. Being hard to see can help hide predators from the animals they hunt or aid quarry to elude their pursuers. But being inconspicuous is useless if combined with ostentatious movement and the making of loud noises - truly effective camouflage is a mixture of both body structure and behaviour. For a predatory carnivores, good camouflage confers two sorts of advantage. It can make ambushing a tenable technique and, for predators that stalk and chase their prey, can allow the hunter to close in nearer to its intended victim before the prey starts to run. Even a few feet or so gained can tip the balance of the chase in the predator's favour. And because most predators are themselves prey to yet larger predators, camouflage gives added protection against capture (Whitfield, 1978).

Because many prey animals have colour vision, any predator will have difficulty in coming shoulder-to-shoulder with its prey if its colour contrasts with the landscape. The acquisition of body colours similar to those of their background is thus a common means of camouflage (Whitfield, *op cit)*.

Lizardfish use countershading - shaded dorsal sections, and disruptive camouflage - dark blotches and colour variegations, as strategies in concealment. Behre (1933) studied colour changes in *Synodus foetens*. In her preliminary test, she found that *S. foetens* varied in colour under different background conditions. When it was tested in a dark box with coloured lights against darkness and against full illumination, it showed considerable capacity to change, but with no stable specific response to a particular stimulus. Colour changes during hunting have also been reported in *Saurida gracilis* (Hiatt and Strasburg, 1960), and *S. englemani* (Sweatman, manuscript).

Lizardfish lie motionless close to the bottom, propped up at an angle on their stout pelvics or partially bury themselves and wait for prey species to chance by. When prey species, mostly small fish, come within a few feet of them they dart upward very rapidly and seize them (Breder, 1944; Hiatt and Strasburg, 1960; Budnichenko, 1974 and Wheeler, 1975). However, Sweatman (manuscript) described *Synodus englemani* as active hunters, who changed position about every four minutes and attacked a prey about every 35 minutes - "At Lizard Island, *S. englemani* almost always rests on dead coral rock, and the species coloration is cryptic against this generally brown substrate. Individuals move frequently and unobstrusively over distances of about 1.5m between raised pieces of rock, and scan the nearby area for prey. While scanning, the lizardfish has its head raised, but when a potential prey is sighted the posture changes and the head is kept low to the substrate. The lizardfish may then make short stalking moves or remain motionless for some minutes before striking which suggests that the timing of the strike is critical. If the attack is unsuccessful, or if the prey is relatively small, the patterns of movement and scanning begins again shortly thereafter. .... For an attack to be successful, the species of prey seemed to be unimportant so long as it was a manageable size, but the prey had either to be unaware of the presence of the predator and be facing away so that the lizardfish was already close and moving fast when it was detected, or else the prey had to be too far from cover to be able to escape even though the lizardfish may have been seen early in the strike."

There is no published literature on the swimming abilities of lizardfish. However, the more or less fusiform body, subfalcate to falcate pectoral fin and the caudal aspect ratio (3.0 - 4.4) indicate a moderate swimming ability.

4. AGE AND GROWTH

4.1 INTRODUCTION

The ultimate aim of a species; the propagation of its kind, is a synergism of an iterative process of capable individuals producing offspring and the offspring also reproducing later in life. The fulcrum of this iterative process is the maturity of the individual. And the prerequisite for the state of maturity is the attainment of a minimum size by the acquisition of materials and energy: growth.

Growth: the change in linear dimension and/or mass with time (Nikolsky, 1963, 1969; Royce, 1972), can be somatic or gonadal. It is the manifestation of excess energy after metabolism, somatic repairs and excrement (Nikolsky, 1963, 1969; Pitcher and Hart, 1982).

The growth of fish, like many other aquatic animals is a highly irregular and asymptotic process affected by many factors which seldom act independently (Nikolsky, 1963, 1969; Royce, 1972). These factors may be biotic, abiotic, endogenous or exogenous and may act on any stage of growth from the embryonic stage through maturation to senility. In general, growth may vary with species, population size, sex, age, reproduction cycle and the environment *in toto*. Growth is especially irregular during larval and post-larval periods as rapid changes take place in body form. The life span of fish is species specific. And a good understanding of this growth pattern is central to an efficient management of fisheries resources - this is directly or indirectly emphasized by the large volume of work on (age and) growth of fish.

Fish do not grow all the time. In certain seasons of the year the fish grows rapidly, in others it grows more slowly or ceases to grow altogether.

The evaluation of growth in fish is commonly by age (time) in relation to length (size) or weight (mass). The most frequently used method of age determination is the interpretation and counting of growth zones or growth checks - 'bands or rings' - that are formed in certain hard tissues: scales, otolith and vertebrae. Changes in the growth pattern of the individual may be reflected in the character and distribution of the circuli; one manifestation is the fast and slow growing zones represented by wider spacing, and closely arranged circuli respectively (Menon, 1953; Nikolsky, 1963, 1969; Royce, 1972; Bagenal, 1974; Bagenal and Tesch, 1978; Pitcher and Hart, 1982). The factors or events that cause the formation of growth marks may vary with species and environment. Whereas in the temperate zone the pattern of growth is clearly associated with the marked annual cycle in water temperature (e.g. Le Cren, 1947; Hellawell, 1971, 1974; Jessop and Power, 1973; Westrheim, 1973; Gunderson, 1974; Linfield, 1974; Casselman, 1974), in the tropics temperature fluctuations are less drastic and less likely to produce cyclic interruptions in growth and growth in tropical fish was once presumed to be more or less continuous. However, Menon (1953), in his review of age and growth rates in tropical and subtropical waters repudiated the above notion - "It is to be regarded as highly injudicious to accept that the growth of a fish in the tropics is uniform and that there is no rhythm in its growth in the year. There is periodicity in the physico-chemical and biological factors of the tropical waters. There is periodic rhythm of spawning. It is not possible in the face of the periodicity of these factors to accept that there is no periodicity in growth alone." Growth marks due to salinity (Fagade, 1974;

Ezenwa and Ikusemiju, 1981), spawning (Pannella, 1974) and temperature (Bruger, 1974) have since been reported from the tropics. Dunstan (1959) showed barramundi had 2 annuli per year, and since then a number of Indian fishes have similarly been found to have 2, and in both cases interruption to growth is associated with the change of monsoons. Casselman (1974) working in the temperate zone noted that "in the mature pike annulus formation represents a combination of a cessation in growth related to decreasing water temperatures, accumulation of reproductive products and an interruption in the resumption of growth caused by spawning."

Van Oosten (1929) as reported in Bruger (1974) established that the validity of the scale ageing technique depends on

1) That the scales remain constant in number and (retain their) identity throughout the life of the fish.
2) That the annual increment in the length (or some other dimension which must then be used) of the scale maintains, throughout the life of the fish, a constant ratio with the annual increment in body length.
3) That the annuli are formed yearly and at the same time each year (or that some other discoverable relation exists between their formation and increment of time).

The above conditions also hold for the other hard tissues.

The first age determination was made by a Swedish clergyman over 200 years ago - by counting the rings on vertebrae of the pike *(Esox lucius)*; and other species (*Hederström, 1959; original version 1759). Many more age determinations by vertebrae (or other bones) ring

* Quoted by Ricker, 1975.

counts have been reported ever since (e.g. Le Cren, 1947; Bilton and Jenkinson, 1969; Fagade, 1974; Ezenwa and Ikusemiju, 1981). The scale method, however, is by far the most common (e.g. Hellawell, 1971, 1974; Jessop and Power, 1973; Hofstede, 1974; Steinmetz, 1974; Bruger, 1974; Chen and Lee, 1980; Pollock, 1981). The next common to the scale method is the otolith method (e.g. Ling, 1958; Westrheim, 1973; Liew, 1974; Pannella, 1974). In certain situations the above methods may give rather unreliable results, which make it necessary for accuracy to use two or more different methods simultaneously. In the extreme case ageing in a tagged fish of known age may be followed.

The length composition of a population will often exhibit modes especially among the smaller fish. The modes will be most pronounced in fish with a short spawning season and rapid and uniform growth. And under the basic assumption that most biological data are normally distributed, several methods have been proposed for the analysis of length frequencies in the determination of age of fish. The first and the very basic method, the Petersen Method ((1982) reported in e.g. Ricker, 1975; Royce, 1972; Bagenal and Tesch, 1968, 1978) depends on the assumption that each well marked mode of length distribution corresponds to an age-group. It is useful for broods of animals that have been spawned during a single, short period and that grow individually at nearly the same rate.

Buchanan-Wollaston and Hodgson (1929) noted that "length frequency curves of fish measurements drawn from samples limited to a very small time - space area are, with certain definite exceptions, almost invariably either markedly skew or very irregular and jagged having several closely adjacent maxima". Buchanan-Wollaston and Hodgson (1929) obtained the arithmetic mean sizes by smoothing out closely adjacent maxima to one main mode; each subsequent mode corresponding to an age-group.

Harding (1949) and Cassie (1954) described a method by which component groups may be extracted from a polymodal size frequency sample - Normally distributed data when plotted as cumulative frequencies on probability paper fall on a straight line. The position of this straight line is determined by the mean, and its slope by the standard deviation. With the bimodal and polymodal distributions, the plot produces a curve which is the resultant of two or more straight lines. The linear transformation (equivalent to the probit) allows the overlapping flanks to be more readily detected, thereby giving a wider range of points which may be used in curve-fitting (Cassie, 1954). At older ages, the modes tend to coalesce and separation by the probability graph is less reliable. Mathews (1974) cautioned that "Cassie (1954) method may be quite reliable and sometimes gives very good results indeed; however for some population it may give quite erroneous estimates. Some Cassie curves may be very sensitive to slight changes in the points chosen as separating lines between age groups, but other curves may be very much less sensitive. There is always an element of subjectivity involved in interpreting Cassie curves, so that wherever possible growth estimates obtained from Cassie's method should be confirmed by some independent technique. However, with these limitation, Cassie's method can be most useful and can occasionally be used alone." In 1953, Tanaka estimated age-composition by double sampling (using length for stratification). Later in 1956, Tanaka separated year classes of polymodal samples by fitting parabolas to logarithms of length frequencies.

In a review of methods of analysis of age-groups from size frequency data, MacDonald and Pitcher (1979) proposed the use of "'conventional efficient statistical methods' such as maximum likelihood as more effective than the commonly used graphical methods of dissecting a mixed distribution." They further noted that, "In our experience these *methods offer some improvement over the 'Petersen' inspection of modes, but the interpretation of the graphs still leaves much to the imagination of the user, especially when the original size-frequency distribution is not clearly polymodal. The more elaborate of these methods involve a great deal of calculation which cannot easily be automated on a computer, although McCammon (1976) has done so using iterative computer graphics. **The most serious deficiency is that results are not reproducible and it is quite possible for two workers to obtain very different answers from the same set of data." Notwithstanding these drawbacks, the graphical methods have been used in the determination of the ages of many fish (e.g. Gunderson, 1974; Matthews, 1974; Thomas, 1975; Narasimham, 1976; Appukuttan, Nair and Kunhikoya, 1977).

Age data in conjunction with length and weight measurements can give information on stock composition, age at maturity, life span, mortality and production (e.g. Bagenal and Tesch, 1968, 1978; Ricker, 1975, 1977; Gulland, 1977; Pitcher and Hart, 1982). However because of the specific but irregular nature of growth no comprehensive mathematical description of growth has yet been made. Ricker (1975) has compiled and reviewed various growth models in his book - "Computation and Interpretation of Biological Statistics of Fish Populations".

* i.e. graphical methods

** emphasis mine

The classical equations in fisheries work are -

$L_t = L_\infty \; (1 - e^{-K(t-t_o)})$ (....equation 4.1)

$W_t = W_\infty \; (1 - e^{-K(t-t'_o)})$ (....equation 4.2)

and $W = aL^b$ (....equation 4.3)

where L_t and W_t denote length (L) and weight (W) at time; t.

L_∞ and W_∞ denote asymptotic length and weight respectively.

K is the rate at which length and weight approach L_∞ and W_∞ respectively.

t_o/t'_o is the theoretical age at the beginning of growth according to equations 4.1 or 4.2; called the Von Bertalanffy growth equations.

$\underline{a}$ and $\underline{b}$ (equation 4.3) are constants.

When b=3, the fish's growth is isometric. Among fish, an exponent of 3 is the exception. Values of 2 to 3.5 are commonly found (Royce, 1972). Values other than 3 indicate allometric growth; if $b > 3$, the fish becomes disproportionately heavier as it grows larger. Equations 4.1 and 4.2 assume that fish grow towards some theoretical maximum length and weight, and that the closer the length or weight gets to the maximum, the slower the rate of change or size or weight; the corollary being the larger K, the faster W_∞ or L_∞ is reached.

The above classical equations usually describe central tendency or mean value behaviour; they do not acknowledge stochastic variation of the individual fish and provide no explicit construction for moving from observable characteristics of individual fish to an aggregate representation of biomass (Cohen and Fishman, 1980). Cohen and Fishman (*op cit*) proposed a model designed to approximate the real world. They "attempted to shift the emphasis in characterizing of fish population from a pre-occupation with 'average' behaviour to an awareness of distributional considerations in length, weight and biomass through time." However exactitude in growth models such as that proposed by Cohen and Fishman (1980) is probably more academic than practical. Errors in age determination and the effect on growth estimations have been discussed by, amongst others, Brander (1974), Carlander (1974) and Ricker (1981).

Studies on the growth of Synodontidae species as deduced from the available literature have been on only two species: *Saurida undosquamis* and *S. tumbil* of the Indo-Pacific region where they are the basis of important commercial fisheries.

The scale method has been used to estimate ages in populations of *S. undosquamis* (Tatara, 1953, 1965; *Bograd-Zismann, 1961-62; Budnichenko and Nor, 1978) and of *S. tumbil* (Tung and Liu, 1965; Okada and Kyushin, 1955; Yeh, Lai and Liu, 1977; Budnichenko et al, 1978); all in the temperate region. Sinoda and Intong (1978) and Rao (unpublished) working in the tropics found the scales of *S. undosquamis* unsuitable for age determination and relied on length-frequency analysis. Sinoda et al (1978) reported a "single" prominent mode which seems to consist of several groups" in their preliminary results on *S. undosquamis*, whilst Rao (unpublished) noted an indication of a number of broods in the year class of *S. tumbil*. Sainsbury and Whitelaw (1981) supplemented otolith readings with length-frequency analysis in the estimation of ages of *S. undosquamis* in the North-West Shelf of Australia.

Time of ring formation in scales have been correlated with spawning in *S. tumbil* in the Yellow and East China

* Quoted by Ben-Yami and Glaser, 1974

Seas, and Taiwan Strait (Okada et al, 1955; Tung et al, 1965; Yeh et al, 1977) and in the Arabian Sea (in also *S. undosquamis*, Budnichenko et al, 1978.)

Maximal increase in size have been observed in these species in the early years of life (Budnichenko et al, 1978; Tatara, 1965) and differences in growth due to sex have been reported by (Okada et al, 1955; Tatara, 1965; Budnichenko et al, 1978).

The asymptotic lengths reported after the fitting of data to the Von Bertalanffy equation range from about 640 to 790mm in *S. tumbil* (Yeh et al, 1977; Tung et al, 1965; Rao, unpublished) and 400 to 571mm in *S. undosquamis* from the inner Gulf of Thailand and the North-West Shelf of Australia (Sinoda et al, 1978; Sainsbury and Whitelaw, 1981).

The only information available on the age and growth of lizardfish species in Australian waters is the report submitted at CSIRO Divisional Research Seminar by Sainsbury and Whitelaw (*op cit*). The purpose of this study is to fit observed data on *S. tumbil*, *S. undosquamis*, *S. filamentosa* and *Trachinocephalus myops* to the classical growth equations, and relate their features of growth to their life histories.

4.2 METHODS AND MATERIALS

Measurements of length, weight and the determination of sex followed the same procedures as described in Chapter One. After having noted the above, scales were taken and cleaned in water. These were then mounted between two microscope slides and examined under a dissecting microscope with transmitted light at a magnification of 60x or 120x.

On the other hand, vertebrae were sectioned with a sharp scalpel and the cut surfaces were examined under the microscope in glycerol against a black background using reflected light. Otoliths were examined whole using transmitted light.

The criterion for selection of tissues was the clarity of rings. Scales were chosen for the determination of ages in *S. tumbil*, *S. undosquamis* and *T. myops*, whereas vertebrae were chosen for *S. filamentosa*. Otoliths were rejected because they were decalcified during preservation which resulted in the blurring of the ring patterns. The scales had in addition to the clear rings (i.e. complete breaks in circuli) cutting or crossing over of crowded circuli within the basi-lateral and lateral areas (see Fig. 4.1). These were ignored. On the other hand, dark zones alternating with translucent zones were seen on the cut surfaces of vertebrae of *S. filamentosa*. These were assumed to represent annual growth marks.

In order to *fulfil Van Oosten's (1929) conditions for validity of age determination techniques -

1) analysis of variation in scale morphology with portion or site of body was undertaken to find site with least variation
2) recognition of rings was based only on complete break(s) in ring circuli which could be traced all round the scale, and
3) periodicity of ring formation was investigated using the formula -

$$\alpha = \frac{R - r_n}{r_n - r_{n-1}} \times 100\% \quad (\ldots\text{equation } 4{,}4)$$

where R is the radius of scale r_n and r_{n-1} are radii of ultimate and penultimate rings respectively. α is the monthly change of the growth rate of marginal region of scale.

* was very difficult in the case of vertebrae.

Fig. 4·1 Scale of Lizardfish

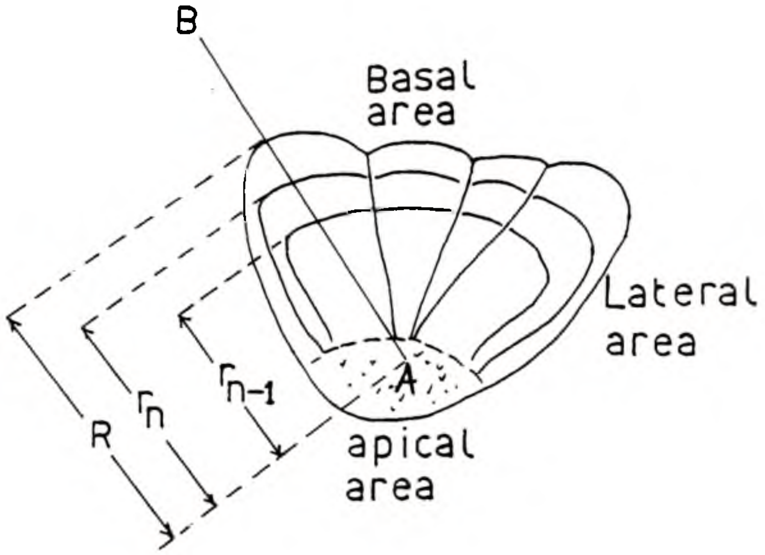
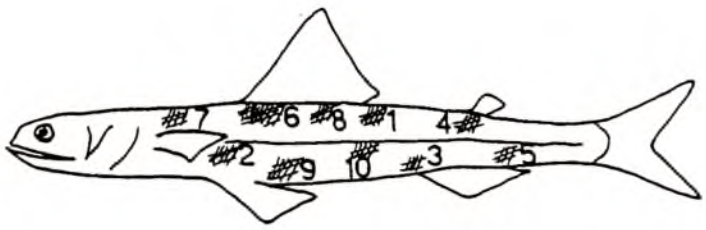


Fig. 4·2 : Scale and Body sites



Scales were taken from the same row from the left side of each fish. Regenerated or lost scales were made up with scales taken from the same row on the right side of the fish (see Fig 4.2).

Scale radius and ring radii were measured (along the line AB, Fig. 4.1) with an ocular micrometer mounted with the right eye-piece. The ocular micrometer had a conversion factor of 1 unit = 0.8mm at a magnification of 60x; calculated from a graduated stage micrometer. Alizarin treatment of scales after having washed scales in 5% sodium hydroxide and generous amounts of water did not significantly enhance readability of rings and was thus discontinued. Samples of ringed scales were photographed.

The age-length determination as obtained from ring counts on scales and vertebrae were compared to age-modal mean lengths from the Cassie (1954) Curve. The growth patterns of the four species were described in terms of Von Bertalanffy and other growth parameters.

Statistical analysis followed Senter (1969) and Sokal and Rohlf (1969).

4.3 RESULTS

4.3.1 Variation of scale morphology with body site

The scales of the four species are cycloid with 3 to 6, but usually 3 radial grooves from the focus which is about a third of the diameter of the scale from the apical margin. The circuli are concentric (see Plate 38).

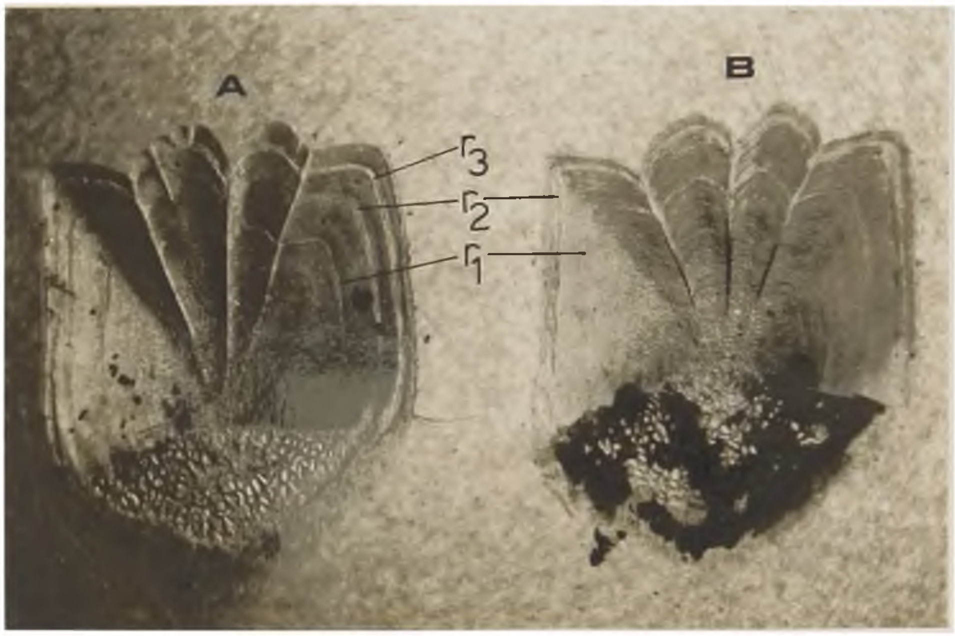


Plate 38: *S. tumbil* scales with annuli (r_n).

A = 3 year old scale
B = 2 year old scale

The regularity of scale morphology with body site was investigated by comparing scale sizes from the various sites (see Fig. 4.2). Coefficients of variation per body site were calculated for groups of six scales' radii for a number of fish specimens. Site 10 was chosen as site from which scales were taken for study because it had the least coefficients of variation and least probability of regeneration (Appendices 4A, 4B, 4C).

4.3.2 Definition of rings on scale, time of ring formation and age determination

4.3.2.1 Definition of rings on scale

Regression analyses of *ring radii on scale radii for 4-, 3-, and 2-ringed scales of specimens of *S. tumbil* showed significant relationships - the degree of relationship ranged from moderate to very high correlation; all significant at $p \leqslant 0.02$ (Fig. 4.3, Tables 4.1A, 4.1B).

The t test for differences between the mean radii of contiguous rings also indicated significant differences between means in the 3-ringed female, 2-ringed male and the first three rings of the 4-ringed female scales (Tables 4.1A, 4.1B). The difference between means of the third and fourth ring radii of the 4-ringed female was only significant at a higher probability level (i.e. $p \geqslant 0.1$). This was probably due to slowing down of growth after the third ring had been laid down and thus a disproportionate little spacing between the third and fourth rings compared to spacing between the first three rings. 3-ringed male scales showed no significant differences between means of

---

* Though similar rings were found on scales of *S. undosquamis* and *T. myops*, the smallness of their samples with 2 or more rings precluded satisfactory statistical analyses.

Table 4.1A: *S. tumbil* - Definition of rings on scale

FEMALE

Age	4+				3+		
N	16				37		
Mean scale radius	8.15625				7.3622		
Standard deviation	± 0.861292				± 0.773646		
n^{th} ring	First	Second	Third	Fourth	First	Second	Third
Mean radius of ring	5.14375	6.28750	6.99375	7.65625	5.19189	6.24054	6.93784
Standard deviation of ring	0.9280580	0.800729	0.894031	0.880885	0.952009	0.681689	0.689344
Correlation of ring to scale radius	0.5874	0.8836	0.9496	0.9543	0.7731	0.8742	0.9221
t-test of rings 1^{st} vrs 2^{nd}	3.4795				4.9905		
2^{nd} vrs 3^{rd}		2.1700				3.6224	
3^{rd} vrs 4^{th}			1.9891				
Critical value of t	$t_{.05(30)} = 2.042$, $t_{.10(30)} = 1.697$				$t_{.05(120)} = 1.980$, $t_{.001(120)} = 3.373$		

Table 4.1B: *S. tumbil* - Definition of rings on scale

MALE

Age	3+			2+	
N	6			60	
Mean scale radius	5.9167			5.7250	
Standard deviation	±0.53072			±0.37445	
n^{th} ring	First	Second	Third	First	Second
Mean radius of ring	4.4500	5.3000	5.6667	4.6317	5.4617
Standard deviation of ring	0.9354	0.4000	0.4803	0.5601	0.3823
Correlation of ring to scale radius	0.8843	0.9798	0.9913	0.5134	0.9328
t-test of rings 1^{st} vrs 2^{nd}	1.8017			6.6228	
2^{nd} vrs 3^{rd}		0.9572			
1^{st} vrs 3^{rd}	1.2441				
Critical value of t	$t_{0.1(10)} = 1.812$			$t_{0.01(120)} = 3.373$	

ring radii (even at $p = 0.1$). This was probably due to the small number of fish in the sample Table 1B).

The regression of ring radii on scale radius for the samples were governed by the equation-

$$r_n = I + CR \qquad (\ldots.\text{equation } 4.5)$$

where r_n is the n^{th} ring radius

I; a constant

C; the regression coefficient and

R; the scale radius.

The equations obtained were:-

<u>4-ringed scales, female, N=16</u>

$r_1 = -0.0864 + 0.6412\ R\ (r = 0.5874)$

$r_2 = -0.5007 + 0.8007\ R\ (r = 0.8836)$

$r_3 = -1.1522 + 0.9987\ R\ (r = 0.9496)$

$r_4 = -0.4097 + 0.9889\ R\ (r = 0.9543)$

<u>3-ringed scales, females, N=37</u>

$r_1 = -1.8121 + 0.9520\ R\ (r = 0.7731)$

$r_2 = 0.5698 + 0.7703\ R\ (r = 0.8742)$

$r_3 = 0.8891 + 0.8216\ R\ (r = 0.9221)$

<u>3-ringed scales, male, N=6</u>

$r_1 = -4.7716 + 1.5586\ R\ (r = 0.8443)$

$r_2 = 0.9308 + 0.7385\ R\ (r = 0.9798)$

$r_3 = 3.5917 + 0.8970\ R\ (r = 0.9913)$

2-ringed scales, male, N=60

$r_1 = 0.2354 + 0.7679\ R\ (r = 0.5134)$

$r_2 = 1.0027 + 0.9523\ R\ (r = 0.9328)$

N is number of fish specimens in sample, and r is the correlation coefficient.

4.3.2.2 Time of ring formation

The determination of time of ring formation as deduced from the equation;

$$= \frac{R - r_n}{r_n - r_{n-1}} \times 100\%$$

was only possible in *S. tumbil* (female) because only few monthly samples of two or more ringed scales were obtained for the other species.

The trend in the monthly growth rate (α) of the marginal region of the scales indicate slow growth with the onset of the *spawning season (Fig. 4.8A). This thus suggests that a ring is laid down every year at the beginning or during the early part of the spawning season.

The significant differences observed between ring radii of scales and the annual nature of their formation indicate that counting of rings on scales is a reliable method for the estimation of ages in *S. tumbil* (Plate 38).

4.3.2.3 Age and standard length

The ages of *S. tumbil*, *S. undosquamis* and *T. myops* were estimated by counts of number of rings formed on the scale. *S. filamentosa* was aged by counts of rings on the cut surfaces of vertebrae.

* *S. tumbil* spawns between September and April.
See Chapter on Reproduction.

There were substantial overlaps between the lengths of the age-groups (Table 4.2). For each species the mean size per age was larger in the female - the species were dimorphic. The predominant age group was 1+. The observed maximum ages were 4+, 5+ and 3+ and 12+ (female, 575mm) for *S. tumbil*, *S. undosquamis*, *T. myops* and *S. filamentosa* respectively.

4.3.3 Scale radius and standard length

Covariance analyses indicated significant differences between sexes of *S. tumbil*, *S. undosquamis* and *T. myops* in the relationship of scale radius to standard length (Table 4.3). The relationship followed the regression equation -

$$SL = I' + C'R \qquad (\ldots\ldots \text{ equation } 4.6)$$

where SL is standard length

I'; the intercept on the Y-axis
C'; the regression coefficient
and R; the radius of the scale.

The correlations between standard length and scale radius were highly significant (*Figs. 4.3E, 4.3F, 4.4A-D, Table 4.3).

The intercepts of the equations mean that in theory scales were formed when the postlarvae of the species reached lengths of 18, 39 and 20mm in females of *S. tumbil*, *S. undosquamis* and *T. myops* respectively. The corresponding values for the males are 51, 45 and 58mm. All lizardfish species have scale-less postlarvae (Wheeler, 1975).

4.3.4. Back-calculation of standard length at time of ring formation in *S. tumbil*

* The graphs were drawn from mean values when pairs of SL and R $>$ 100. Regression equations parameters were however estimated from all the raw data.

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Fig. 4.3 *S. tumbil* : 1. - Relationship between ring radii and scale radius (A.B.C.D.).

2 - Relationship between standard length and scale radius (E,F).

n = Number of specimens examined.

	Sex	Age	n
A	female	4+	16
B	male	3+	6
C	female	3+	37
D	male	2+	60
E	female	-	291
F	male	-	322

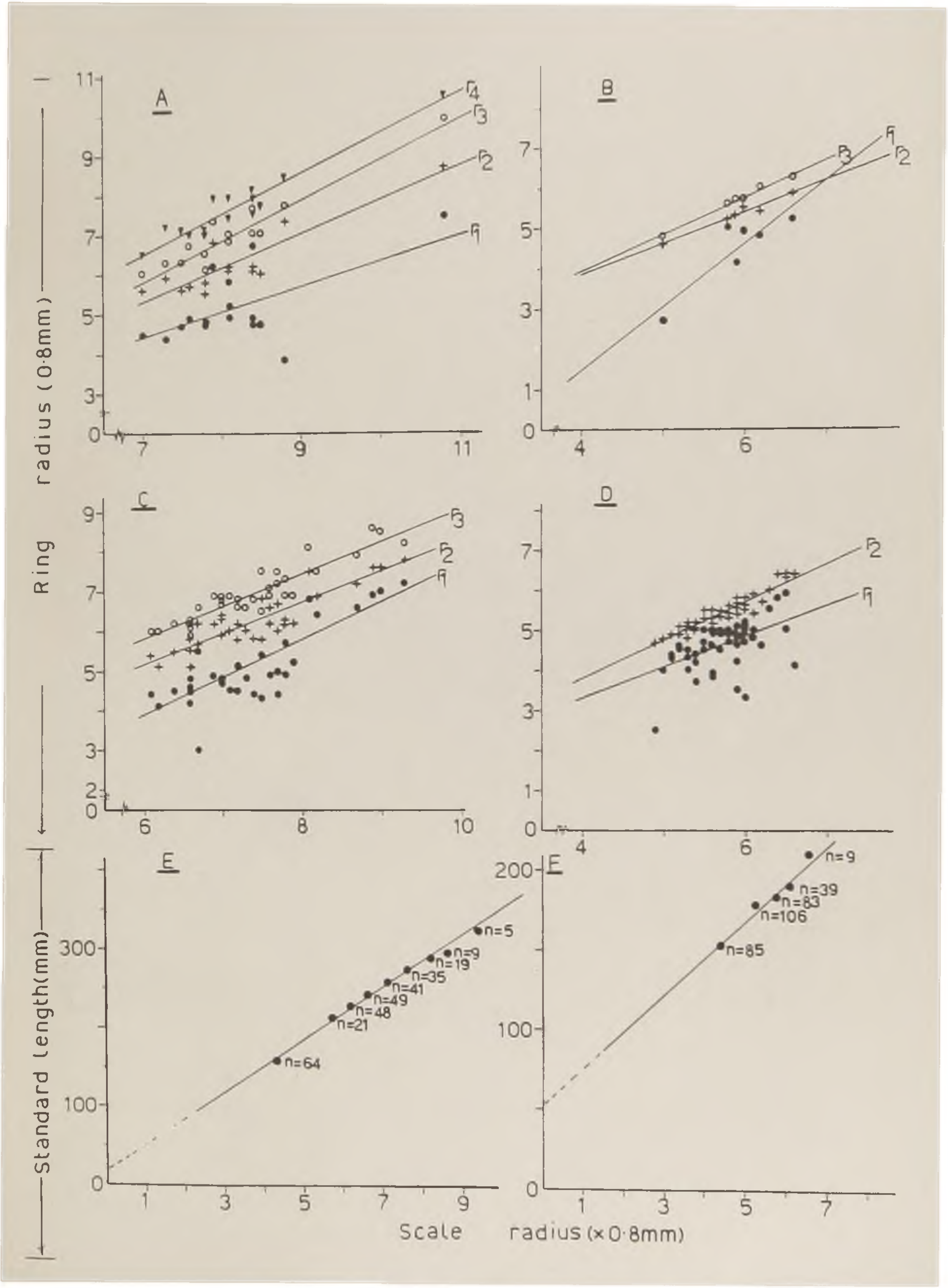
Ring radius (0·8mm)
Standard length(mm)
Scale radius (×0·8mm)
A
r4
r3
r2
r1
B
r1
r2
r3
C
r3
r2
r1
D
r2
r1
E
n=5
n=9
n=19
n=35
n=41
n=49
n=48
n=21
n=64
F
n=9
n=39
n=83
n=106
n=85

FIG. 4.4 Relationship between standard length and scale radius of *S. undosquamis* (A,C) and *T. myops* (B,D).
A,B - female. C,D - male

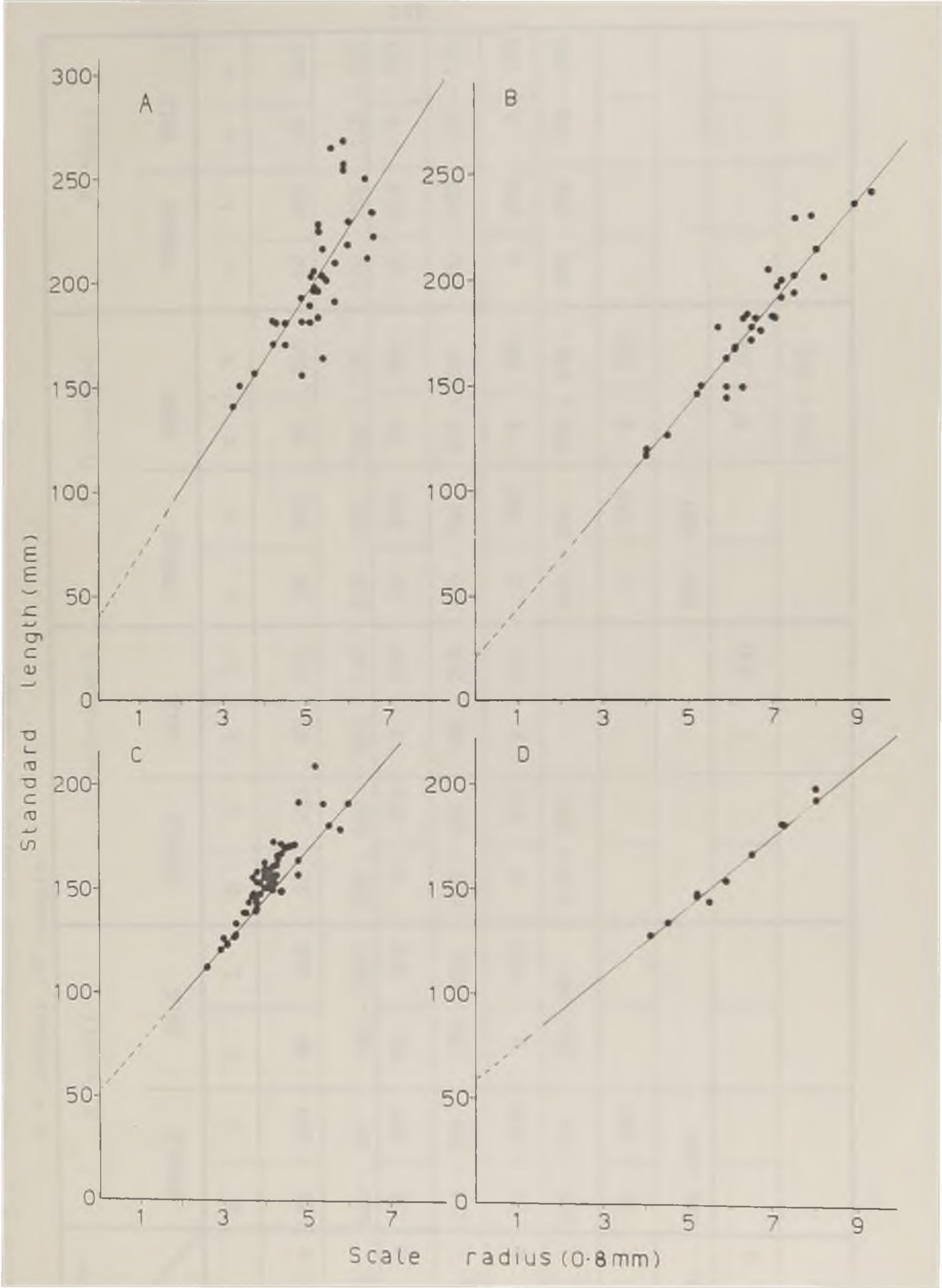
A
B
C
D
300
250
200
150
100
50
0
1
3
5
7
9
Standard length (mm)
Scale radius (0·8 mm)

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FIG. 4.4 Relationship between standard length and scale radius of *S. undosquamis* (A,C) and *T. myops* (B,D).
A,B - female. C,D - male

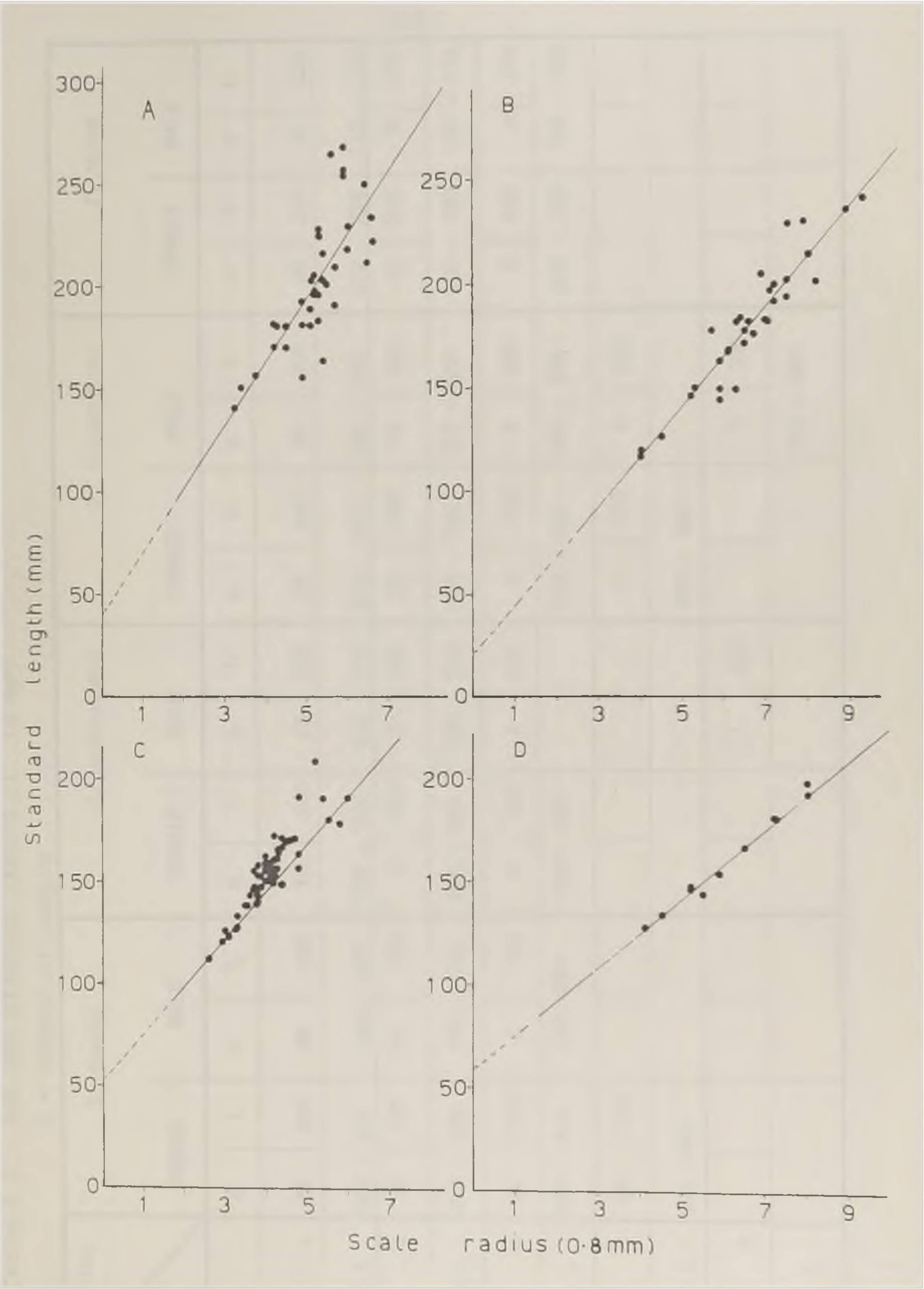

A
B
C
D
300
250
200
150
100
50
0
1
3
5
7
9
Standard length (mm)
Scale radius (0·8mm)

FIG. 4.4 Relationship between standard length and scale radius of *S. undosquamis* (A,C) and *T. myops* (B,D).
A,B - female. C,D - male

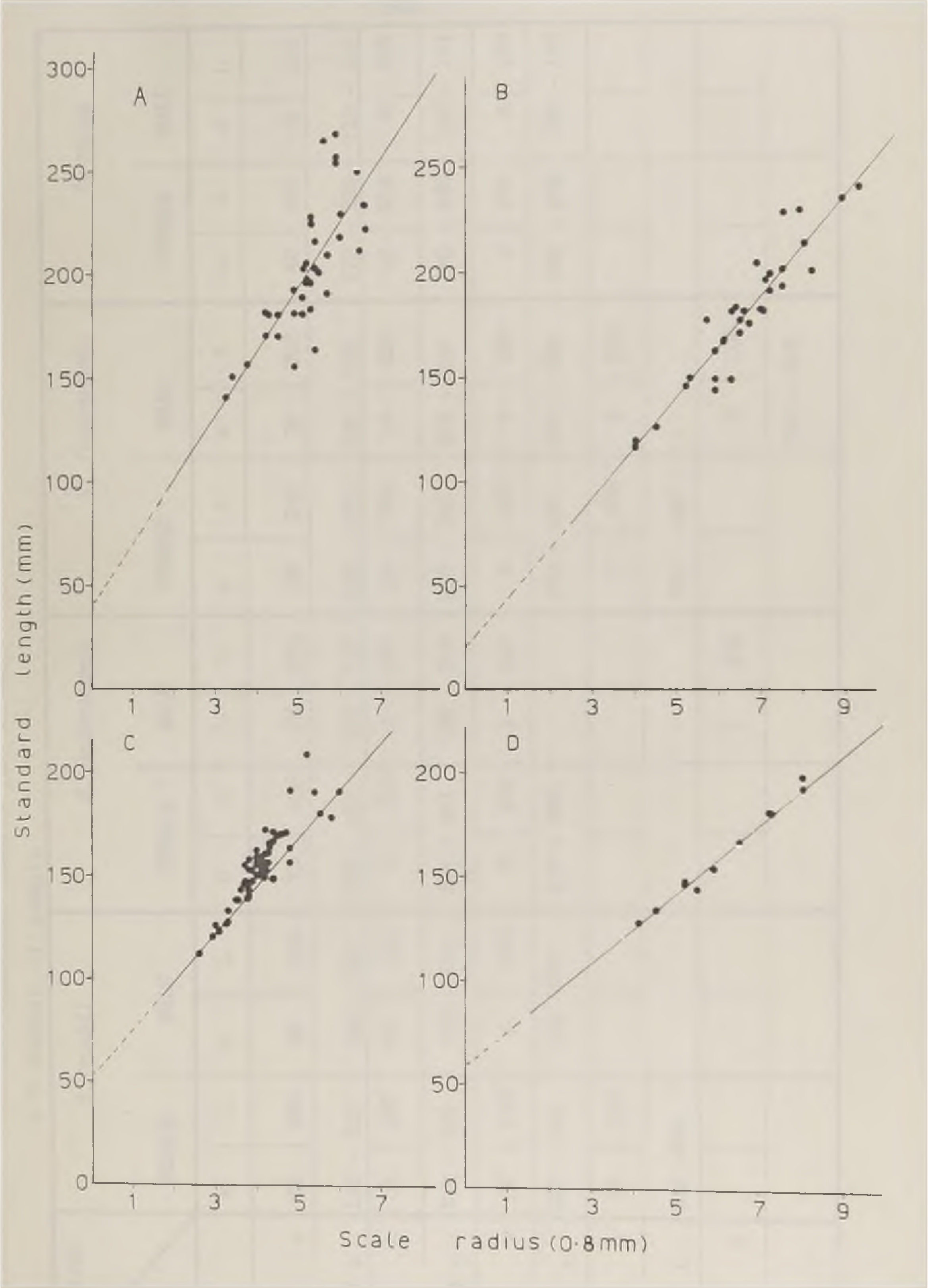

A
B
C
D
300
250
200
150
100
50
0
1
3
5
7
9
Standard length (mm)
Scale radius (0·8mm)

Table 4.2 : AGE AND STANDARD LENGTH (L, in mm)

n = number of sample

Species / Age		*S. tumbil*				*S. undosquamis*				*S. filamentosa*				*T. myops*			
		FEMALE		MALE		FEMALE		MALE		FEMALE		MALE		FEMALE		MALE	
		n	L	n	L	n	L	n	L	n	L	n	L	n	L	n	L
1+	n	51	243	96	165	10	250	63	155	38	240	30	205	40	193	51	125
	range of L	190 - 255		142 - 189		231 - 269		142 - 197		219 - 276		199 - 246		179 - 228		112 - 155	
2+	n	58	257	60	204	3	273	3	200	31	290	18	233	12	218	8	155
	range of L	214 - 276		172 - 239		269 - 281		199 - 203		235 - 336		217 - 258		190 - 240		145 - 174	
3+	n	37	270	6	234	3	293	1	237	5	350	2	268	8	239	8	179
	range of L	228 - 310		230 -245		279 - 320				344 - 361		260 - 276		228 - 253		159 - 193	
4+	n	16	280							3	385	2	289				
	range of L	272 -345								370 - 420							
5+	n							1	300			3	305				
	range of L											295 - 325					

Table 4.3 : Relationship between standard length (SL in mm) and scale radius(R).

Species	Sex	I'(mm)	C'	Number of pairs	Correlation	F values	
						Calculated	Critical
S. tumbil	female	18.4676	33.0955	291	0.9479	F_{α} (1,609) =7,9479	$F_{.05(1,1000)}$ =3.85
	male	50.9550	23.4869	322	0.8121		$F_{.01(1,1000)}$ =6.66
S. undosquamis	female	39.1383	30.8861	77	0.6719	F_{α} (1,138) =7.12	$F_{.05(1,150)}$ =3.89
	male	45.0432	26.8235	65	0.8768		$F_{.01(1,150)}$ =6.81
T. myops	female	19.9885	24.0070	290	0.9306	F_{α} (1,466) =8.03	$F_{.05(1,1000)}$ =3.85
	male	58.2885	16.6849	180	0.9782		$F_{.01(1,1000)}$ =6.66

Table 4.4A: Mean ring *radius (n^{th} ring) of *S. tumbil*

n^{th} ring	Sample No	Mean scale radius	Radius of ring 1st	2nd	3rd	4th
FEMALE						
2nd	58	6.5048	4.7545	6.0818		
3rd	37	7.3622	5.1919	6.2405	6.9378	
4th	16	8.1563	5.1438	6.2875	6.9938	7.6563
MALE						
2nd	60	5.7250	4.6317	5.4617		
3rd	6	5.9167	4.4500	5.3000	5.6667	

Table 4.4B: Back-calculated lengths(L)

n^{th} ring	Sample No	Mean observed L	L_1	L_2	L_3	L_4
FEMALE						
2nd	58	257	193	241		
3rd	37	270	196	232	256	
4th	16	280	183	220	243	264
Mean back-calculated length			190.7	231	249.5	264
MALE						
2nd	60	204	175	197		
3rd	6	234	189	215	226	
Mean back-calculated length			182	206	226	

* in micrometer units

The standard length for each age represented by a ring were calculated from a modification of the standard length-scale radius relationship ((Fraser, 1916; Lee, 1920) as reported by Bagenal and Tesch (1978)):

$$SL_n = \frac{R_n}{R} \times (SL-I) + I \qquad (\text{....equation } 4.7)$$

where SL_n = length of fish when ring 'n' was formed

SL = mean length of fish from which scale samples were taken

R_n = mean radius of ring 'n' (at fish length SL_n.)

S = total scale radius (Table 4.4A)

The mean back-calculated lengths for the age-groups of female *S. tumbil* were consistently smaller than the observed means (Tables 4.4B, 4.5A). This difference called Lee's phenomenon was probably due to selective natural and fishing mortalities that favoured greater survival of smaller fish. In the male, the back-calculated length for the 1+ age-group was larger than the observed value; the reverse of what occurred in the female. By inference there was probably a greater selective mortality on smaller fish (i.e. the 0-1+ age groups of the male).

4.3.5 Cassie's length frequency method for the estimation of age

The size frequency distributions of the lengths of the four species indicated polymodal distributions or single prominent modes which appeared to consist or consisted of several age groups (Fig. 4.5). The mean length of these modal groups were obtained from plots on probability paper (Figs. 4.6A-H, Table 4.5A).

Fig. 4.5 Size frequency distribution of lizardfish. n = total number of specimens.

A - *S. undosquamis* , females, n = 2606
B - *S. undosquamis* , males , n = 2492
C - *S. tumbil* , females, n = 478
D - *S. tumbil* , males , n = 475
E - *T. myops* , females, n = 510
F - *T. myops* , males , n = 534
G - *S. filamentosa* , females, n = 350
H - *S. filamentosa* , males , n = 278

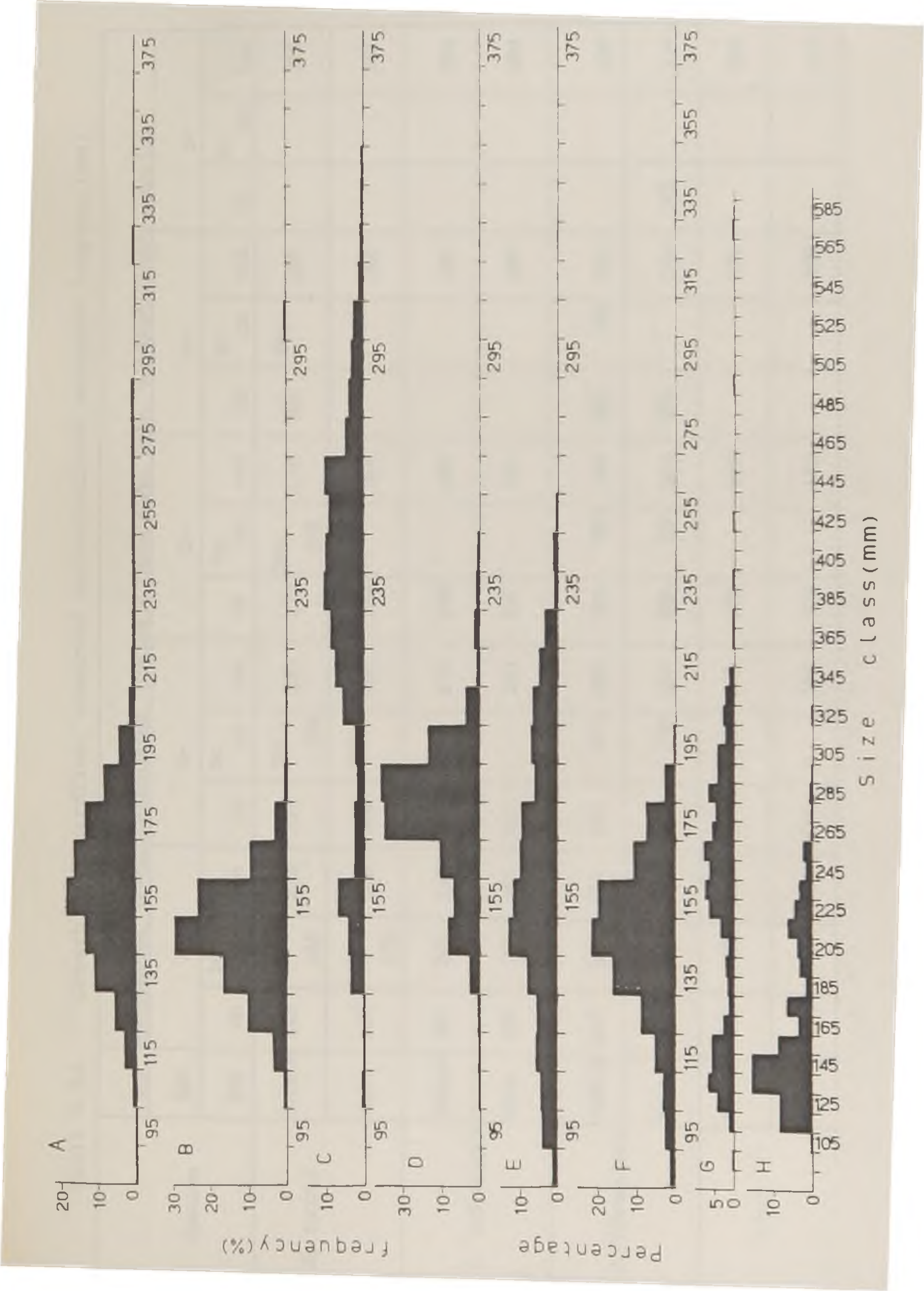

A
B
C
D
E
F
G
H
20
10
0
30
20
10
0
10
0
30
10
0
10
0
20
10
0
5
0
10
0
95
115
135
155
175
195
215
235
255
275
295
315
335
355
375
105
125
145
165
185
205
225
245
265
285
305
325
345
365
385
405
425
445
465
485
505
525
545
565
585
Frequency (%)
Percentage
Size class (mm)

Table 4.5A : Growth of lizardfish; observed and calculated standard lengths.(mm)

Species	Key	ob=observed, bc=back-calculated, cc=Cassie Curve modal mean, von=Bertalanffy equation													
	Age	1+			2+			3+			4+			5+	
	Sex	ob	bc cc	von	ob	bc cc	von	ob	bc cc	von	ob	bc cc	von	ob	bc cc	von
S. tumbil	female	243	191 215	219	257	231 248	250	270	250 278	276	280	264	298			316
	male	165	182 170	180	204	206	206	234	226	228			246			261
S. undosquamis	female	250	245	246	273		273	293		296			316			334
	male	155	167	155	200		200	237		237			267			292
S. filamentosa	female	240	228	232	290	277	294	350	320	346	385	363	391			429
	male	205	165	182	233	206	227	268	243	264	289		294	305		319
T. myops	female	193	142	188	218	196	219	239		243			264			282
	male	125	134	124	155		155	179		180			200			216

Table 4.5B : Growth of lizardfish; calculated #whole body weight (g).

Species	Key	observed length=ob	calculated whole body weights as from the following rl=regression line, von=Bertalanffy equation, *exp=exponential equation													
	Age	1+			2+			3+			4+			5+		
	Sex	ob	rl	von exp	ob	rl	von exp	ob	rl	von exp	ob	rl	von exp	ob	rl	von exp
S. tumbil	female	243	174.7	76.2 156.4	257	207.9	210.9 193.3	270	242.4	325.7 235.2	280	271.3	423.7 273.6			
	male	165	52.5	58.6 48.1	204	101.5	129.3 86.7	234	155.4	188.1 136.5						
S. undosquamis	female	250	169.8	101.8 171.6	273	222.3	222.4 255.7	293	276.0	327.3 361.7						
	male	155	39.3	51.5 33.1	200	85.8	176.5 72.1	237	144.2	279.3 137.0						
*S. filamentosa**	female	240	148.0	176.7 113.3	290	268.4	656.2 203.3	350	485.0	1015.9 410.0	385	654.7	1714.9 617.3			
	male	205	90.1	73.0 76.5	233	134.8	232.4 117.4	268	209.4	363.8 200.5	289	265.4	472.3 276.5	305	314.6	561.7 353.2
T. myops	female	193	109.8	78.8 103.0	218	161.6	210.8 172.2	239	216.4	321.7 265.2						
	male	125	27.7	31.5 25.4	155	54.8	96.7 47.1	179	86.5	148.9 77.2						

* Exponential values calculated from separate male and female equations.

See Appendices 5A-D for observed mean whole body weight.

Fig. 4.6A,B : Cassie curves for 478 females (A) and 475 males (B) of *S. tumbil*. Each continuous curve represents the percentage cumulative frequency of each (whole) sample, and the oblique straight lines represent the percentage cumulative frequency in each age group. Arrows (↓) indicate points chosen as dividing the successive age groups.

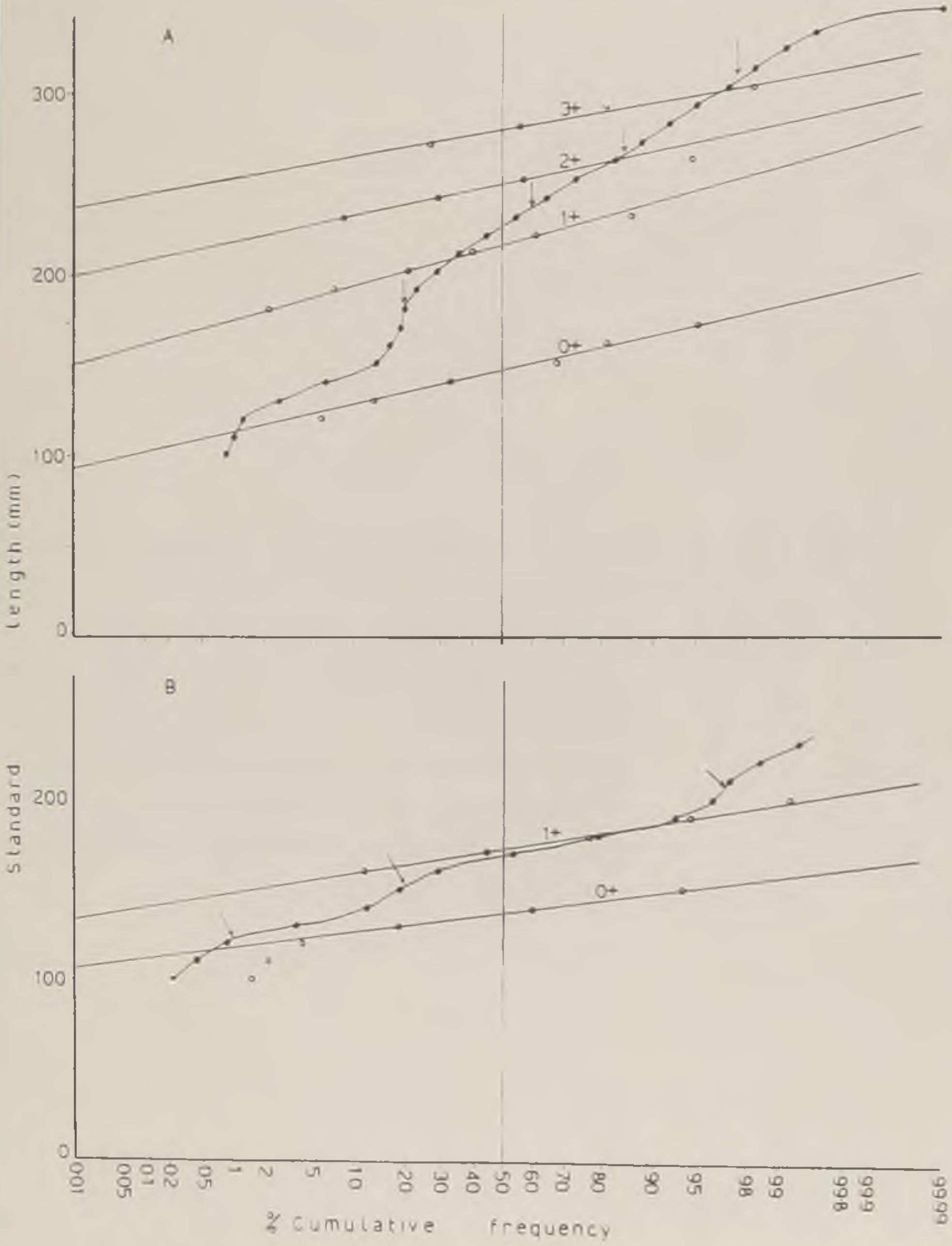

A
300
200
100
0
3+
2+
1+
0+
B
200
100
0
1+
0+
Standard Length (mm)
001
005
01
02
05
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
998
999
9999
% Cumulative frequency

Fig. 4.6C,D : Cassie curves for 2606 females (C) and 2492 males (D) of *S. undosquamis*. Each continuous curve represents the percentage cumulative frequency of each (whole) sample, and the oblique straight lines represent the percent cumulative frequency in each age group. Arrows(↓) indicate points chosen as dividing the successive age groups.

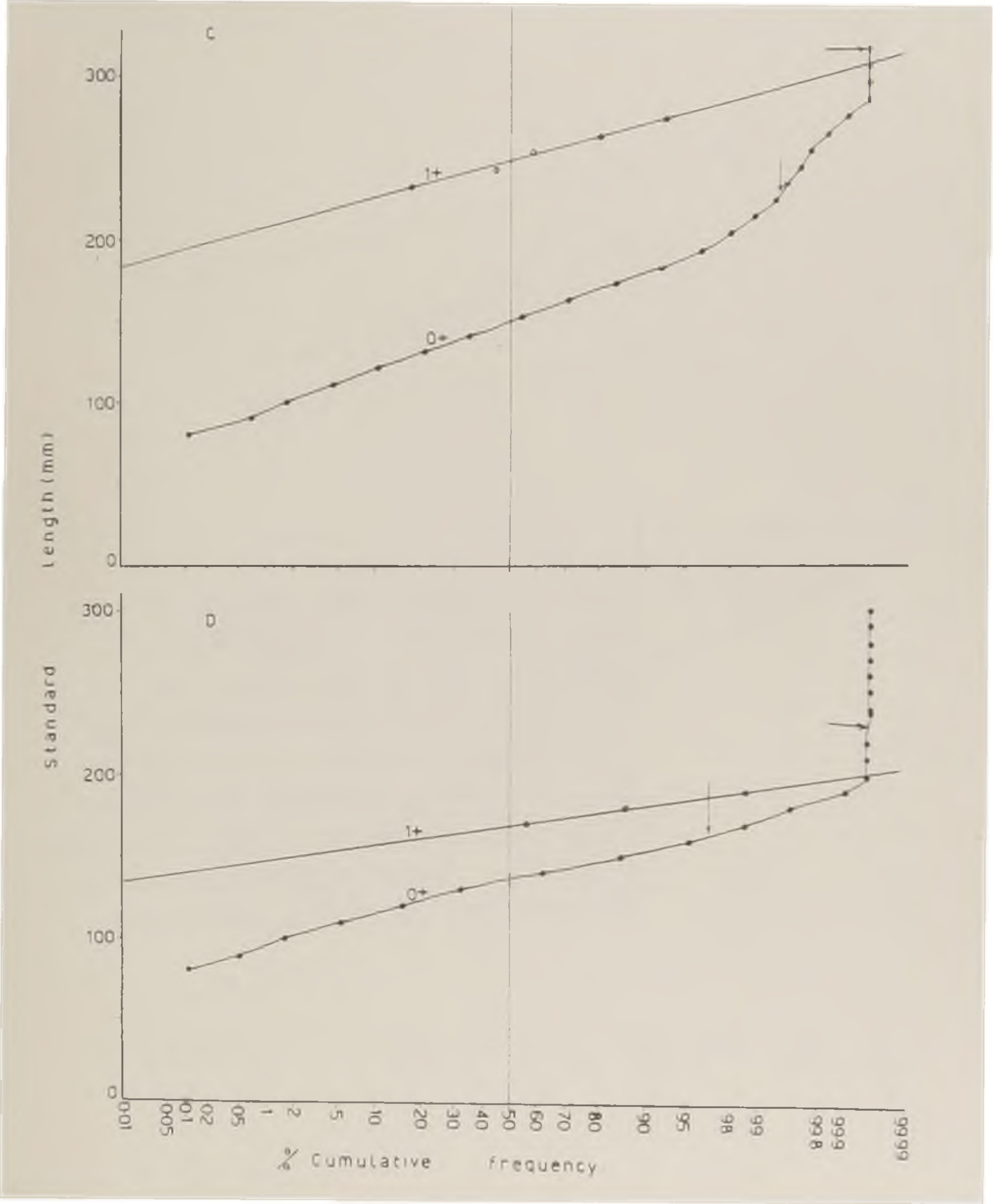

C
D
Standard length (mm)
300
200
100
0
1+
0+
% Cumulative frequency
001
005
01
02
05
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.9
99.99

Fig. 4.6E,F : Cassie curves for 497 females (E) and 537 males (F) of *T. myops*. Each continuous curve represents the percentage cumulative frequency of each (whole) sample, and the oblique straight lines represent the percent cumulative frequency in each age group. Arrows(↓) indicate points chosen as dividing the successive age groups.

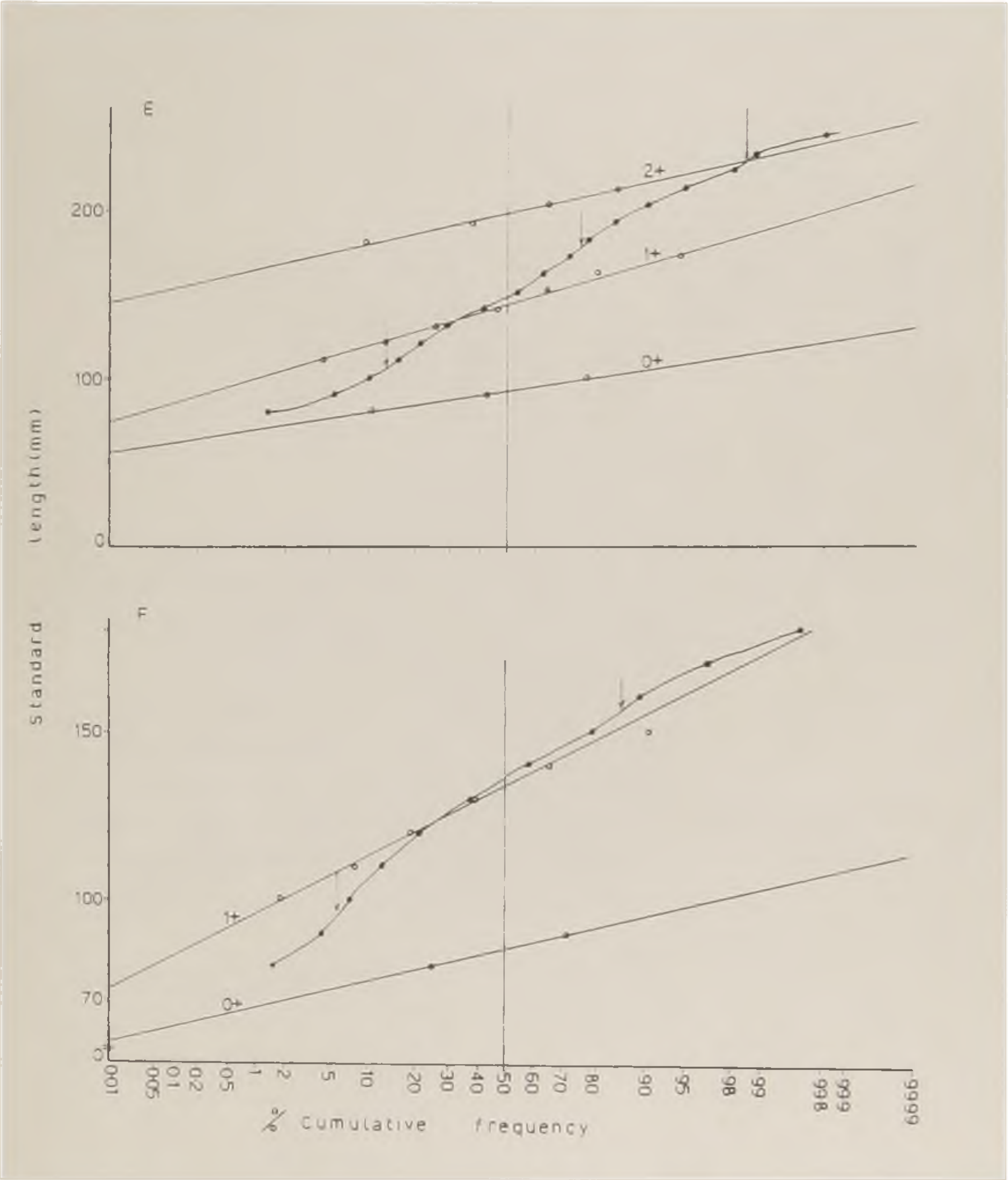
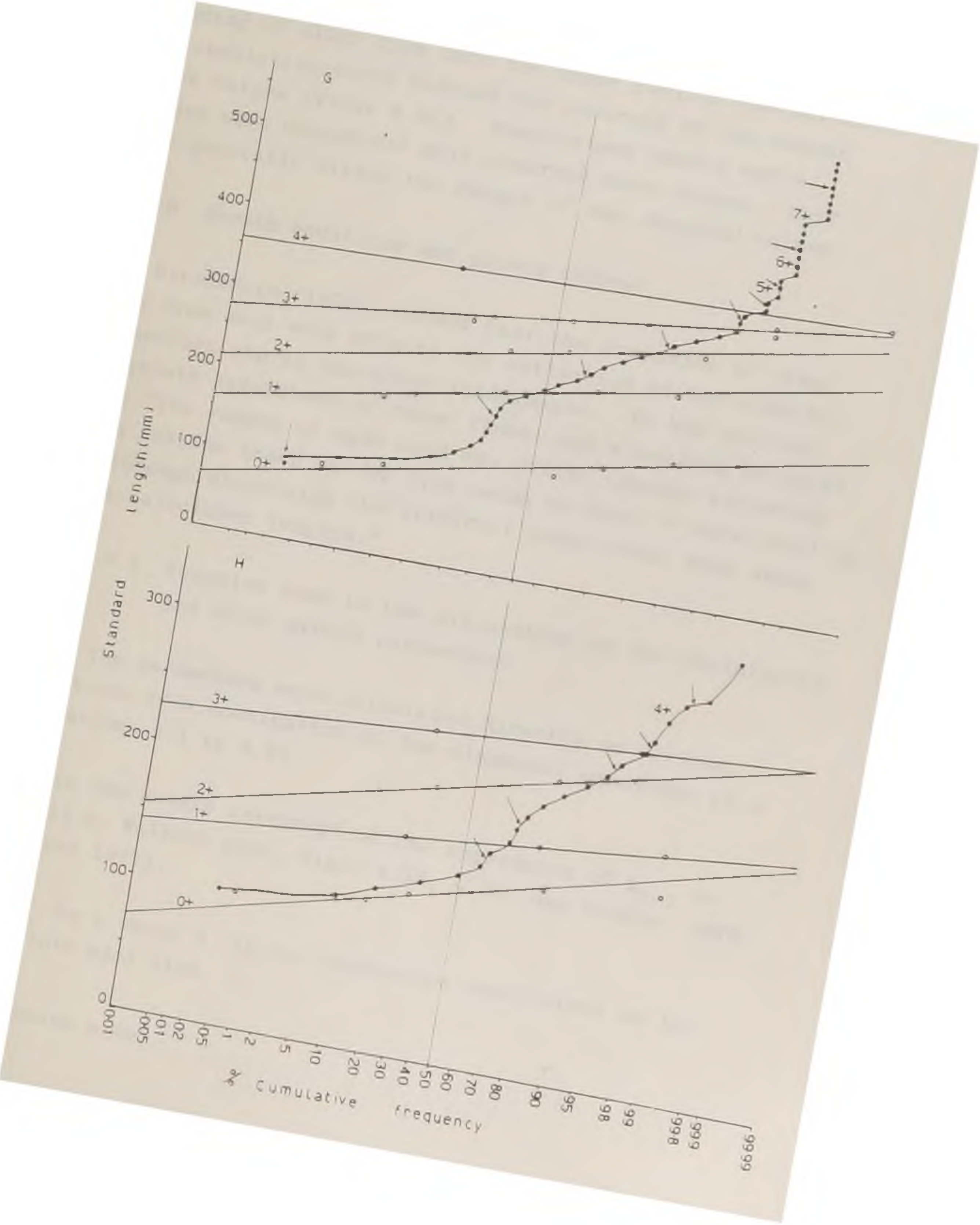

E
2+
1+
0+
200
100
0
F
1+
0+
150
100
70
0
Standard length(mm)
% Cumulative frequency
001
005
01
02
05
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
998
999
9999

Fig. 4.6G,H : Cassie curves for 350 females (G) and 278 males (H) of *S. filamentosa*. Each continuous curve represents the percentage cumulative frequency of each (whole) sample, and the oblique straight lines represent the percent cumulative frequency in each age group. Arrows (↓) indicate points chosen as dividing the successive age groups.


G
H
500
400
300
200
100
0
Standard length (mm)
7+
6+
5+
4+
3+
2+
1+
0+
001
005
01
02
05
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
998
999
9999
% Cumulative frequency

The lengths of contiguous age-groups overlapped considerably (Fig. 4.5, 4.6A-H). The overlaps and the crowding of older fish into the upper part of the percentage cumulative curve reduced the accuracy of the Cassie curve values (Table 4.5A). Nonetheless Cassie curve values were concurrent with observed mean values - they were generally within the ranges of the observed values.

4.3.6 Growth equations and growth curves

Hirschhorn (1974), showed that the exclusion of older ages from data sets affects the estimation of Bertalanffy parameters and is therefore inadvisable. In his studies of growth parameters of three fishes and a mollusc he noted that "The ranges of ages used may differ through excluding mean lengths based on few fish owing to their *'unreliability' or through abandoning the difficult outer rings when using back-calculated lengths."

4.3.6.1 Formalae used in the calculation of Von Bertalanffy and other growth parameters.

The parameters were calculated directly or derived from one or a combination of the classical equations (i.e. equations 4.1 to 4.3).

L is the X-axis intercept of the regression of L_{t+1} on L_t (i.e. Walford plot, Figs. 4.7A, 4.7B, see Ricker, 1975; Ricker 1977).

K = -Ln b where b is the regression coefficient of the Walford plot line.

* Quotes mine.

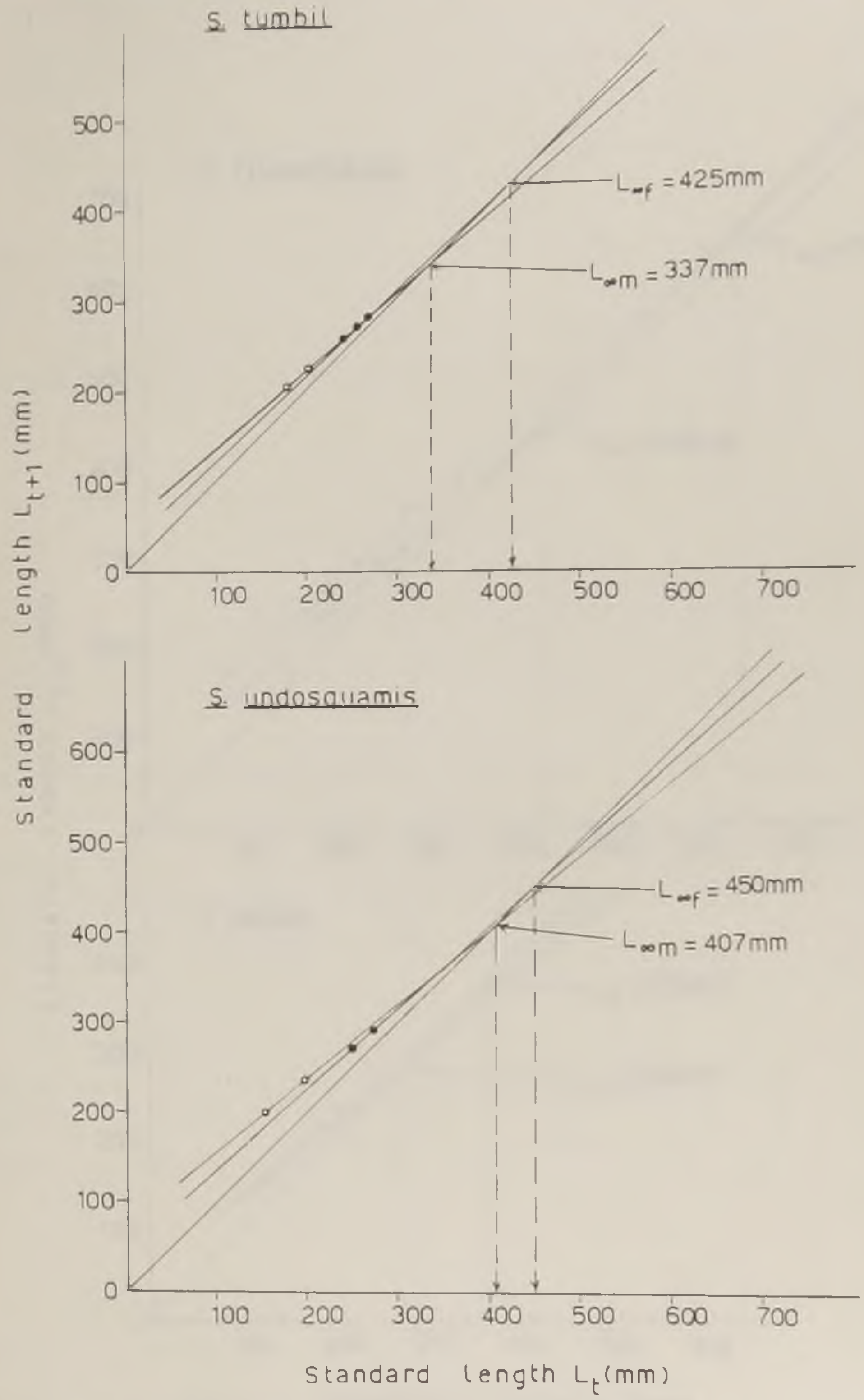


Fig. 4.7A. Walford plots of lizardfish
(●- female, ○- male)

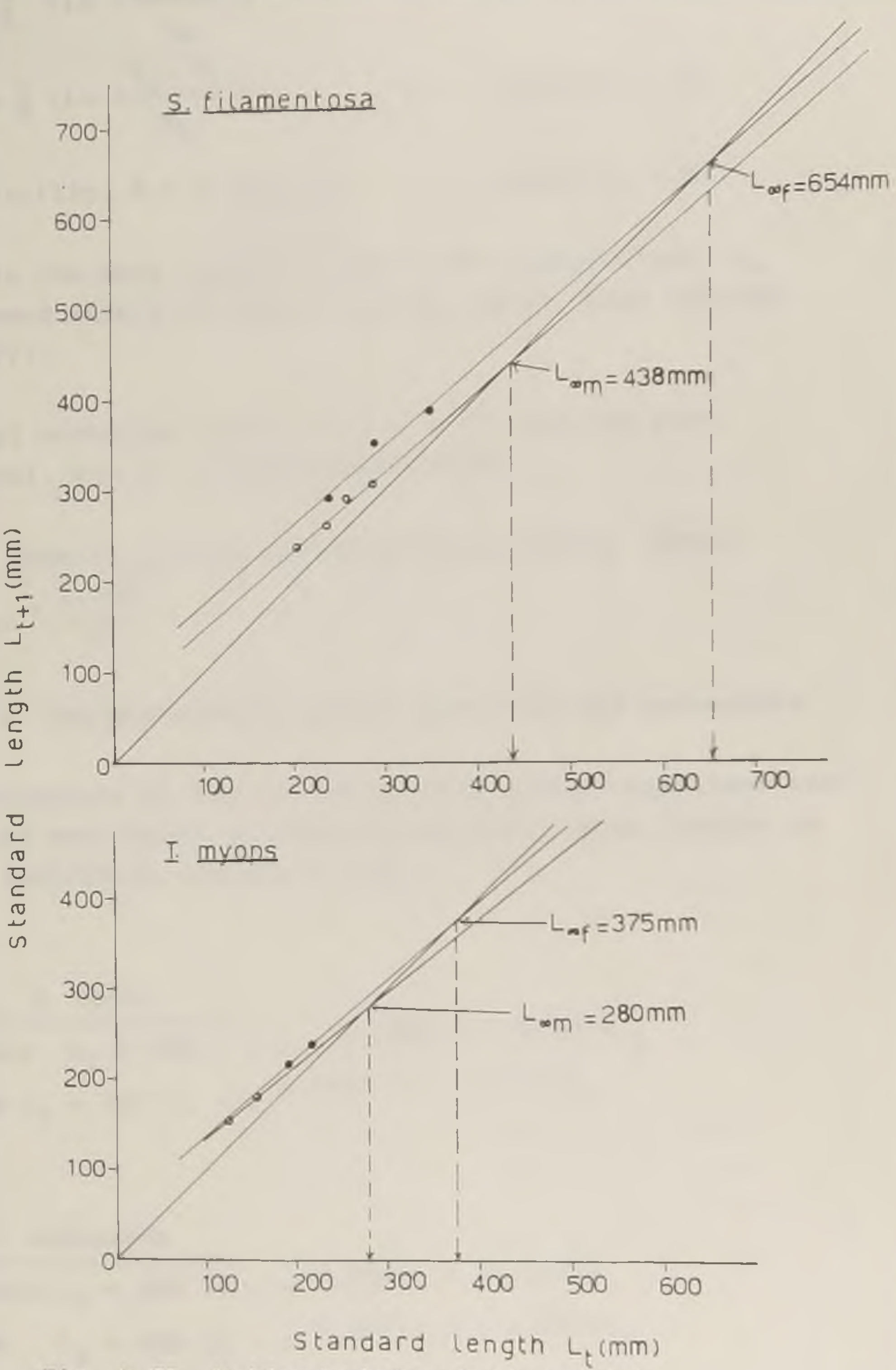


Fig. 4.7B. Walford plots of lizardfish.
(●- female, ○-male)

$$t_o = t + \frac{1}{K} \left(\text{Ln} \left(\frac{L_\infty - L_t}{L_\infty} \right) \right) \qquad (\ldots\ldots\text{equation } 4.8)$$

$$t'_o = t + \frac{1}{K} \left(\text{Ln} \left(\frac{W_\infty - W_t}{W_\infty} \right) \right) \qquad (\ldots\ldots\text{equation } 4.9)$$

Total mortality; $Z = K \frac{(L_\infty - \bar{l})}{(\bar{l} - l_c)}$ (.....equation 4.10)

where $\bar{l}$ is the mean length in the catch (sample) and l_c is the mean length of entry into the catch. (See Gulland 1968; 1977)

The annual mortality rate; $A = 1 - e^{-Z}$ and the rate of survival; $S = 1 - A$ (See Ricker 1975).

The life span ($A_{.95}$) was calculated *sensu* Taylor (1958):

$$A_{.95} = t_o + \frac{2.996}{K}$$

4.3.6.1.1 Von Bertalanffy growth equations and parameters

Computations of the Von Bertalanffy growth equations and parameters were based on observed age-group mean lengths in lieu of individual lengths at age:

S. tumbil

Female $L_t = 425 (1 - e^{-0.1592 (t + 3.5619)})$

Male $L_t = 337 (1 - e^{-0.1823 (t + 3.1784)})$

S. undosquamis

Female $L_t = 450 (1 - e^{-0.1398 (t + 4.6691)})$

Male $L_t = 407 (1 - e^{-0.1957 (t + 1.4551)})$

S. filamentosa

Female $L_t = 654 (1 - e^{-0.1574 (t + 1.7847)})$

Male $L_t = 438 (1 - e^{-0.1927 (t + 1.7815)})$

T. myops

Female $L_t = 375 (1 - e^{-0.1744 (t + 2.9845)})$

Male $L_t = 280 (1 - e^{-0.2331 (t + 1.6120)})$

The females had larger asymptotic lengths and longer life spans (Table 4.6, Figs. 4.7A, 4.7B) which suggest sexual dimorphism. This is corroborated by the larger mean size per age group and predominance of females in the larger size groups. The K values also indicate that the rates of approach to these asymptotes are slower in the females.

Theoretically t_o values suggest that growth in size according to the Von Bertalanffy equation began more or less at birth. t'_o were however larger and suggest that growth in weight started later than growth in linear size. This might be a strategy of ensuring larger young lizardfish; making them less vulnerable to predation and therefore the survival of a higher percentage of the young.

L , K and t_o estimated from back-calculated lengths of *S. tumbil* (female) were considerably lower than those estimated from observed values (Fig. 4.7C). This further substantiates the operation of Lee's phenomenon on the female population.

Table 4.6 : Von Bertalanffy and other growth parameters. (A)

Species	Sex	L (mm)	K	t_o(yr)	W (g) regr. line exp.eq.	t'_o(yr)	Life Span (yr) *sensu** Taylor
S. tumbil	female	425	0.1592	-3.5619	991.3 2448.3	0.4978	15.25
	male	337	0.1823	-3.1784	482.3 647.5	0.2889	13.26
S. undosquamis	female	450	0.1398	-4.6691	1026.3 5500.5	0.2530	16.76
	male	407	0.1957	-1.4551	754.7 2610.1	0.6388	13.85
S. filamentosa	female	654	0.1574	-1.7847	3469.1 14329.2	0.6678	17.25
	male	438	0.1927	-1.7815	982.5 2703.2	0.5995	13.77
T. myops	female	375	0.1744	-2.9845	903.7 4346.7	0.4769	14.19
	male	280	0.2231	-1.6120	357.6 616.2	0.5865	11.82

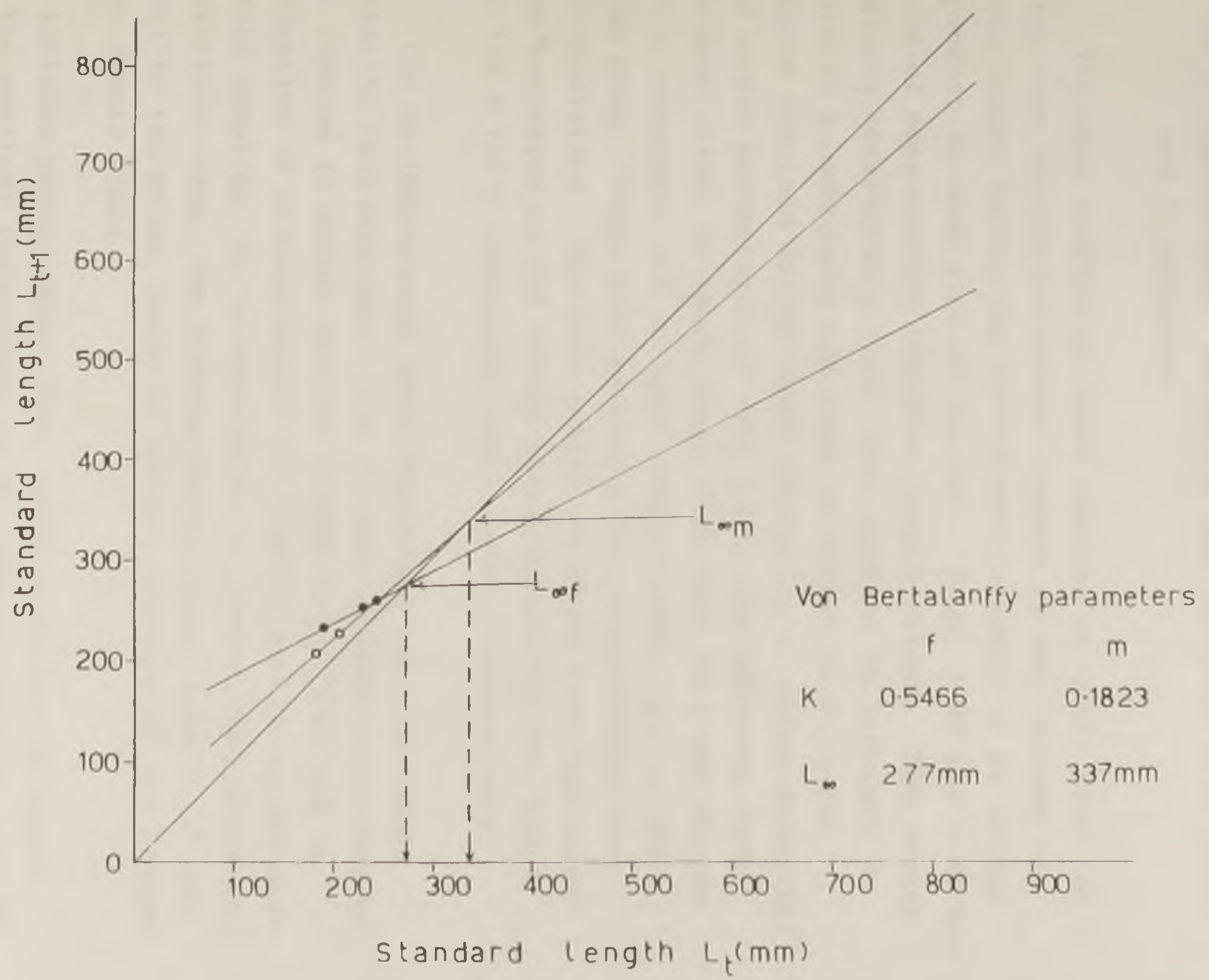
* Value does not include very young

Table 4.6 Von Bertalanffy and other growth parameters. (B)

Species	Sex	Total mortality, Z	Annual mortality, A	Rate of survival, S	Mean length (mm)	Mean length (mm) at entry	Mean length (mm) in catch
S. tumbil	female	0.4151	0.3397	0.6603	223.2	95.8	193.8
	male	1.1087	0.6700	0.3300	172.8		
S. undosquamis	female	1.1382	0.6796	0.3204	156.9	90.4	148.3
	male	2.1767	0.8866	0.1134	144.5		
S. filamentosa	female				264.7		237.9*
	male				203.5		
T. myops	female				158.9		149.1*
	male				143.8		

* Value does not include very young

Fig. 4.7C. Walford plot of back-calculated lengths of *S. tumbil* (● - female, ○ - male)


Standard length L_{t+1} (mm)
0
100
200
300
400
500
600
700
800
Standard length L_t (mm)
100
200
300
400
500
600
700
800
900
$L_\infty m$
$L_\infty f$
Von Bertalanffy parameters
f
m
K 0·5466 0·1823
L_∞ 277mm 337mm

4.3.6.2 *Recruitment, mortality and survival in *S. tumbil* and *S. undosquamis*

The mean lengths of these species at entry into the catch were calculated without regard to sex because the sizes caught during the survey were assumed to be solely dependent on mesh size of the net. Figs. 4.8B and 4.8C are plots of mean monthly standard length values. The trends indicate considerably lower mean lengths in February to March in *S. undosquamis* and June to August in *S. tumbil*. Samples obtained during these months (i.e. after spawning) had larger percentages of very young and immature fish. The mean values of these young fish were 90.4 and 95.8mm for *S. undosquamis* and *S. tumbil* respectively; all of the 0+ age group. These were probably the recruitments into the population. The mean length at entry into the catch were**estimated as the lowest monthly mean length; 120.9 and 145.8 for *S. undosquamis* and *S. tumbil* respectively.

The estimated male total mortality and the annual mortality rate were about 2 to 3 times greater than that of the females in either species (Table 4.6). Whereas no estimation of fishing effort or fishing mortality was made during sampling, it is reasonable to assume that above the recruitment size, the fishing mortality of females if not equal to the males, would be greater because of the larger mean female sizes.

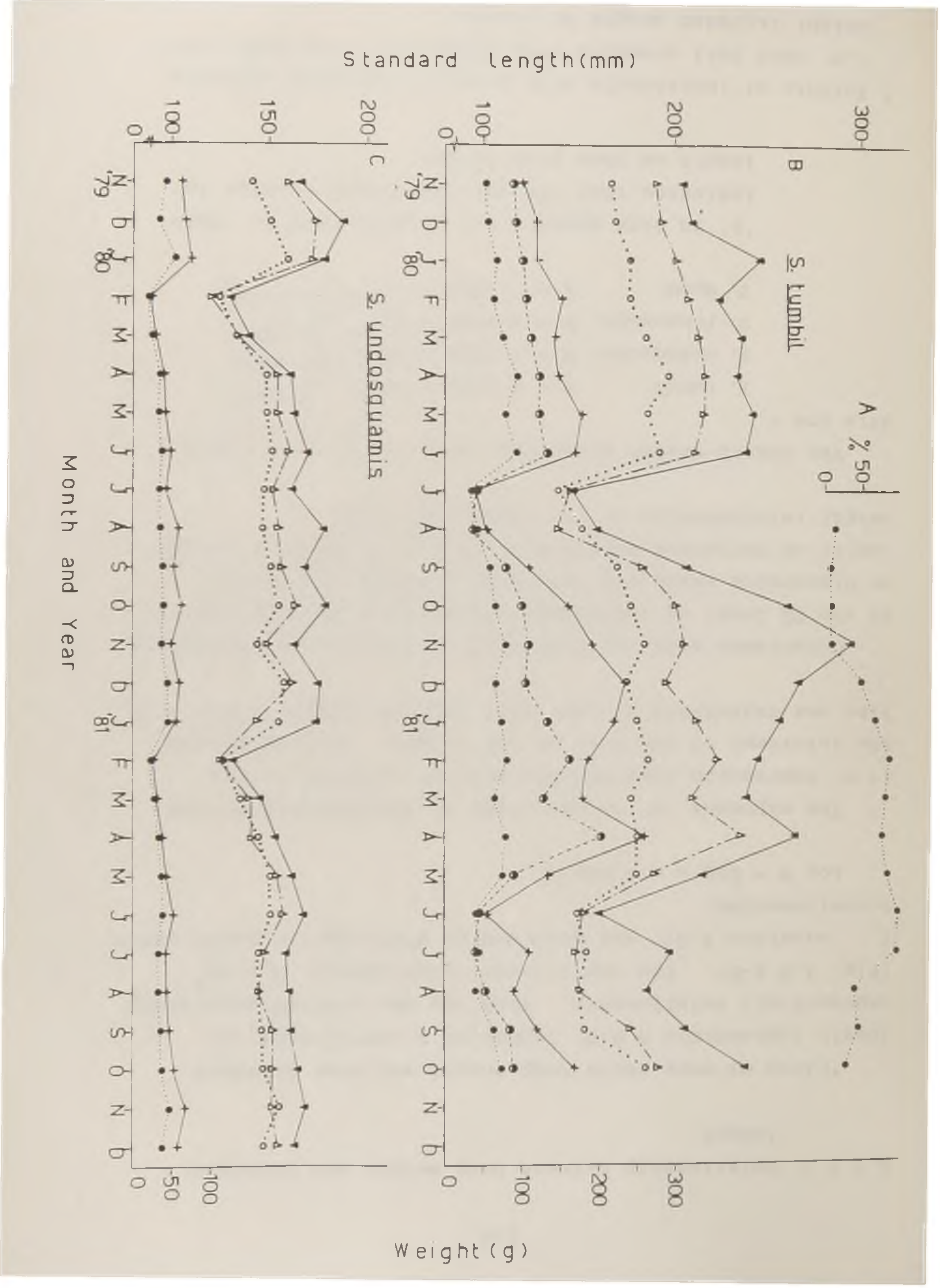
* Includes young; about 90mm, which could not be sexed. The smallest individuals in the samples were 61, 74, 97 and 70mm for *S. undosquamis*, *S. tumbil*, *S. filamentosa* and *T. myops* respectively.

** No such estimation was possible in *S. filamentosa* and *T. myops* because of missing monthly samples.

Fig. 4.8 Time of ring formation (A) and mean monthly standard length and weight (B,C) of lizardfish.

Legend for B and C

	Standard length	Weight
female	▼	+
male	○	●
female + male + very young (sex indeterminate)	Δ	◓


A
% 50
0
B
S. tumbil
C
S. undosquamis
Standard length(mm)
300
200
150
100
0
Weight (g)
300
200
100
50
0
N D J F M A M J J A S O N D J F M A M J J A S O N D
'79 '80 '81
Month and Year

4.3.6.3 Relationship between body weight and standard length

*Plots of mean whole body weight and mean standard length (Appendices 5 A-D) indicated a curvilinear (or exponential) relationship. Each sex was plotted separately (Fig. 4.9 A-D). The curvilinear relationship; $W = aL^b$ (....equation 4.3), was analysed by plotting its logarithmic transformation:

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

The exponent 'b' is the slope of the regression line (i.e. regression coefficient) and the constant 'a' is the intercept of the line on the Y-axis. The regression line was calculated by the least squares method (Table 4.7).

Covariance analyses indicated no significant difference at the 5% level of confidence (Table 4.8) thus the scatter or dispersion among the two sexes was well within the limits of variation expected by virtue of peculiar length-weight relationships of the individual fish.

The length-weight equations resulting from the pooled data are -

S. tumbil	$W = 6.8368 \times 10^{-6} (L^{3.1051})$
S. undosquamis	$W = 7.7836 \times 10^{-6} (L^{3.0605})$
S. filamentosa	$W = 4.7831 \times 10^{-6} (L^{3.1470})$
T. myops	$W = 6.1359 \times 10^{-6} (L^{3.1733})$

'b' in each species was greater than 3. This indicates that the species became heavier for length as they grew larger.

---

* Weights of individuals with greatly distended stomachs, i.e. very full stomachs were discarded. The whole body weight included weight of gonads.

Fig. 4.9A. Relationship of weight to standard length of *S. tumbil*. (● -female, +- male)

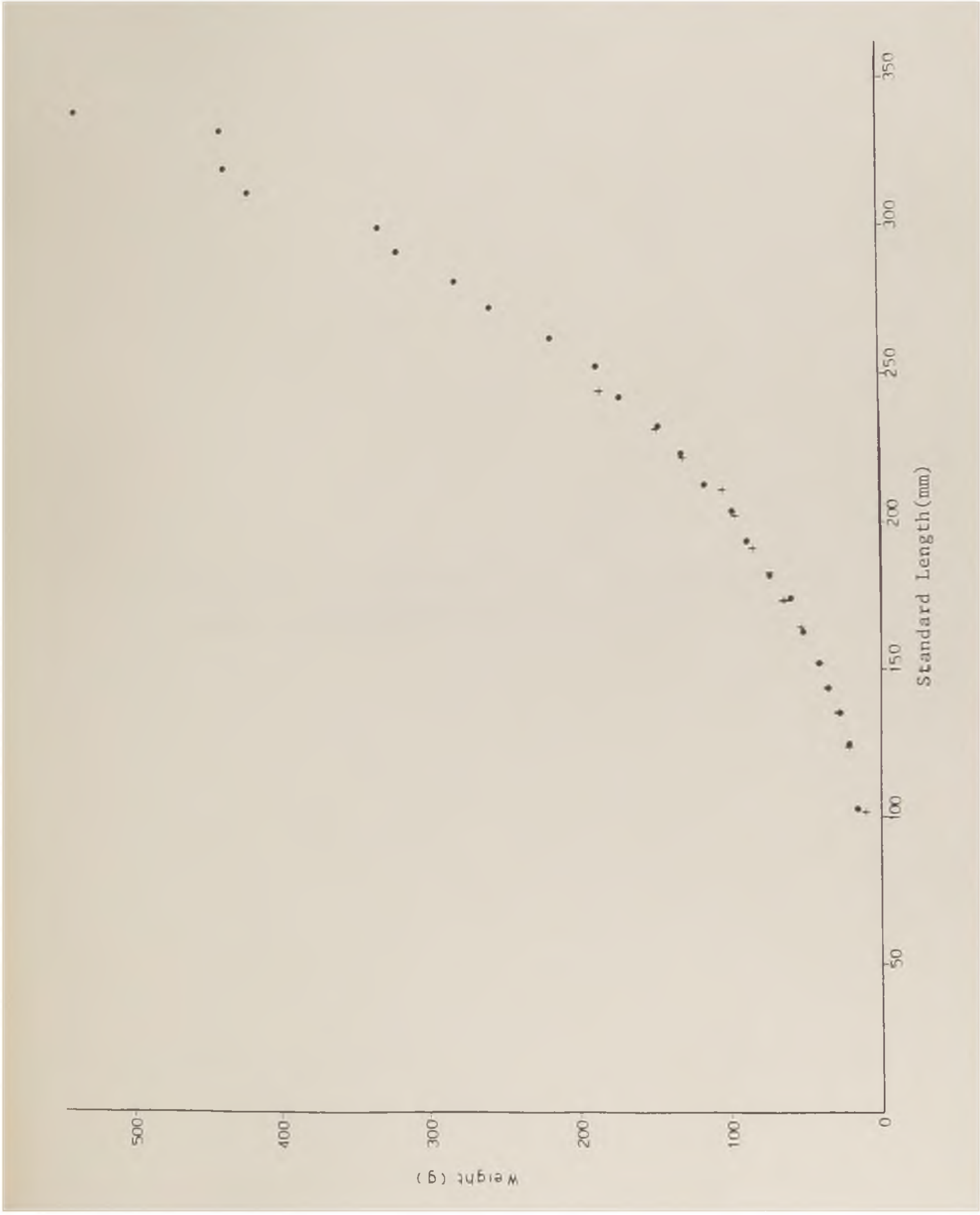
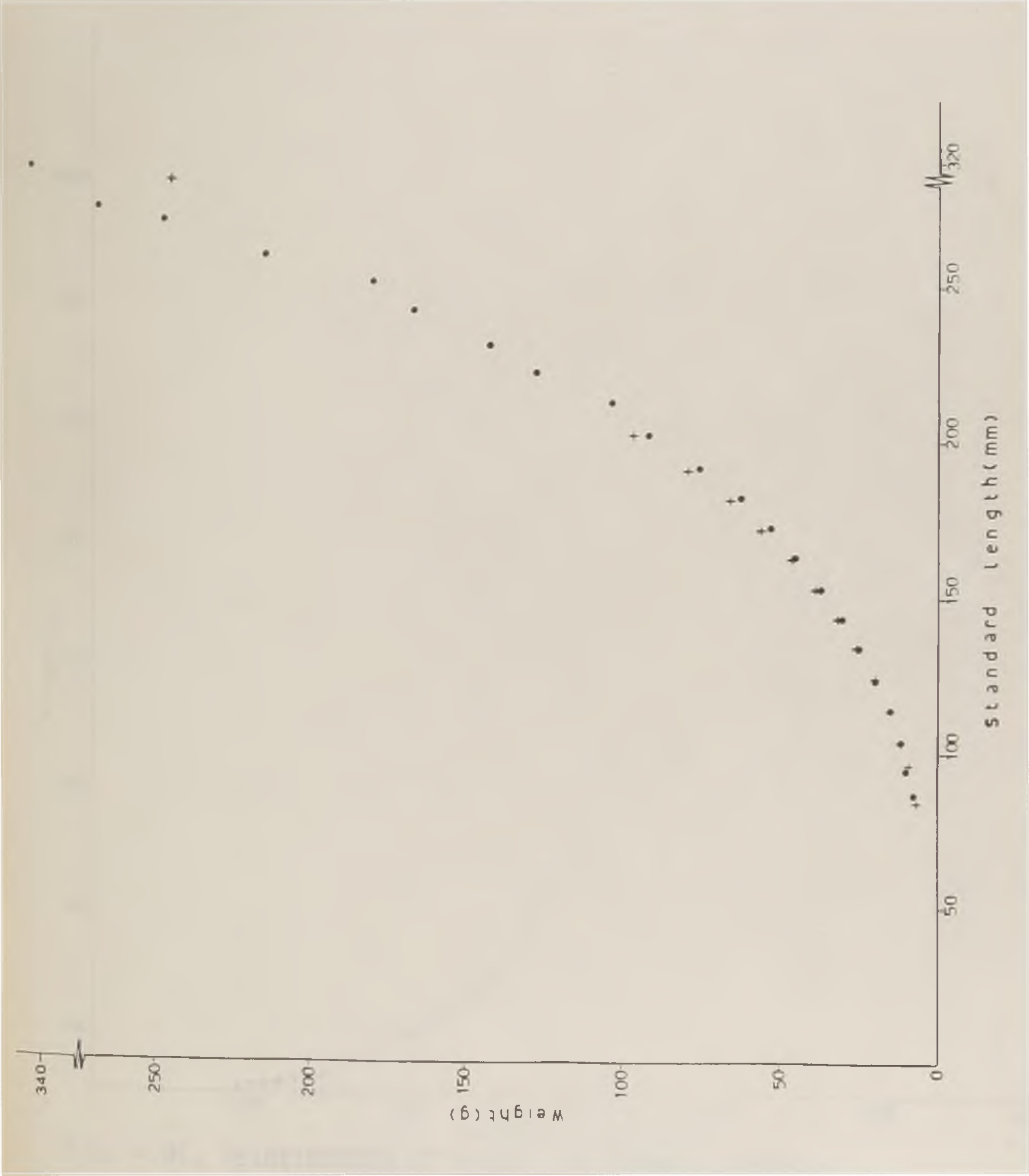

Weight (g)
0
100
200
300
400
500
Standard Length (mm)
0
50
100
150
200
250
300
350

Fig. 4.9B. Relationship of weight to standard length of *S. undosquamis*. (●-female, +- male)


Weight (g)
0
50
100
150
200
250
340
Standard length (mm)
50
100
150
200
250
320

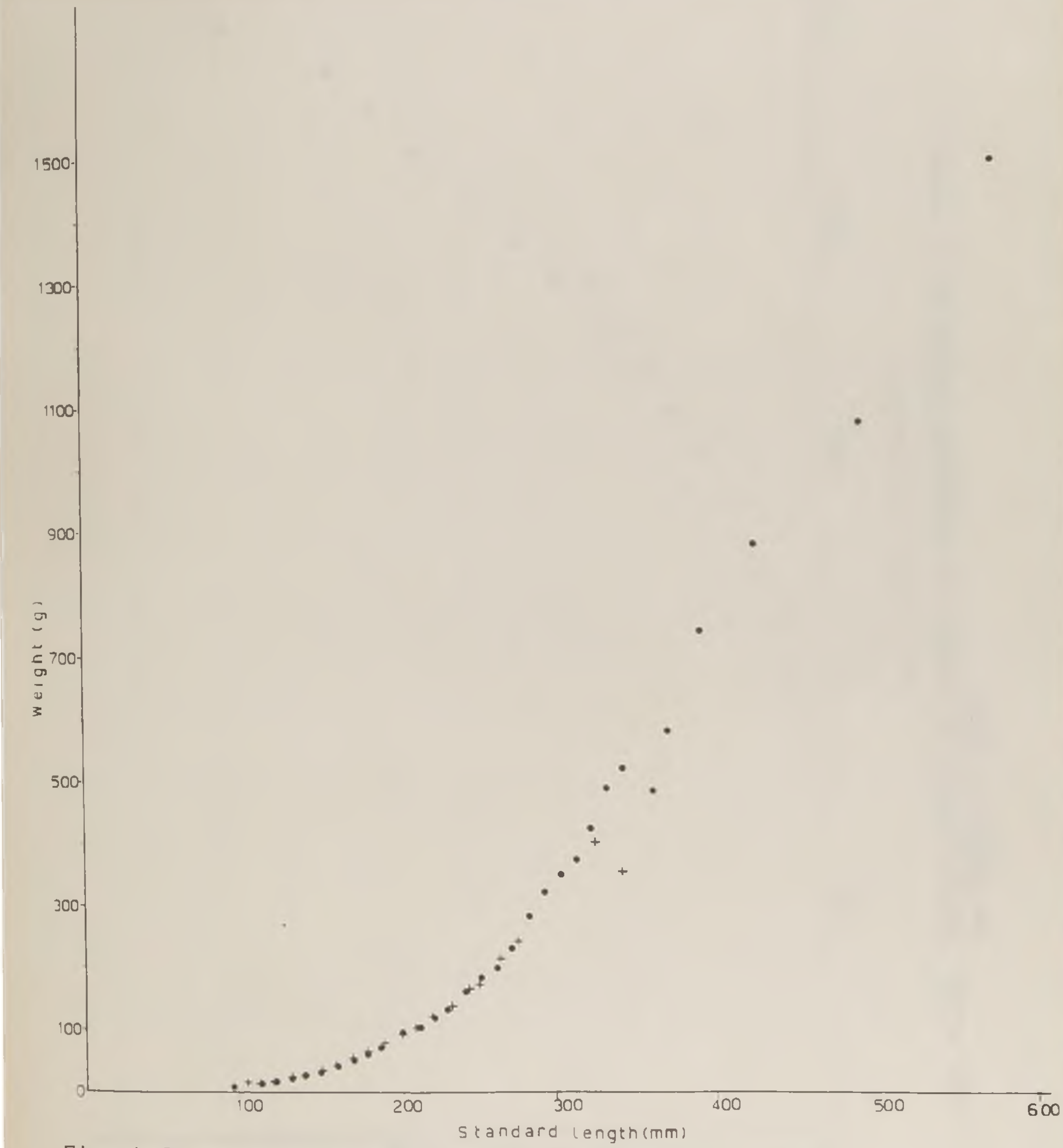


Fig. 4.9C. Relationship of weight to standard length of *S. filamentosa* (● - female, + - male)

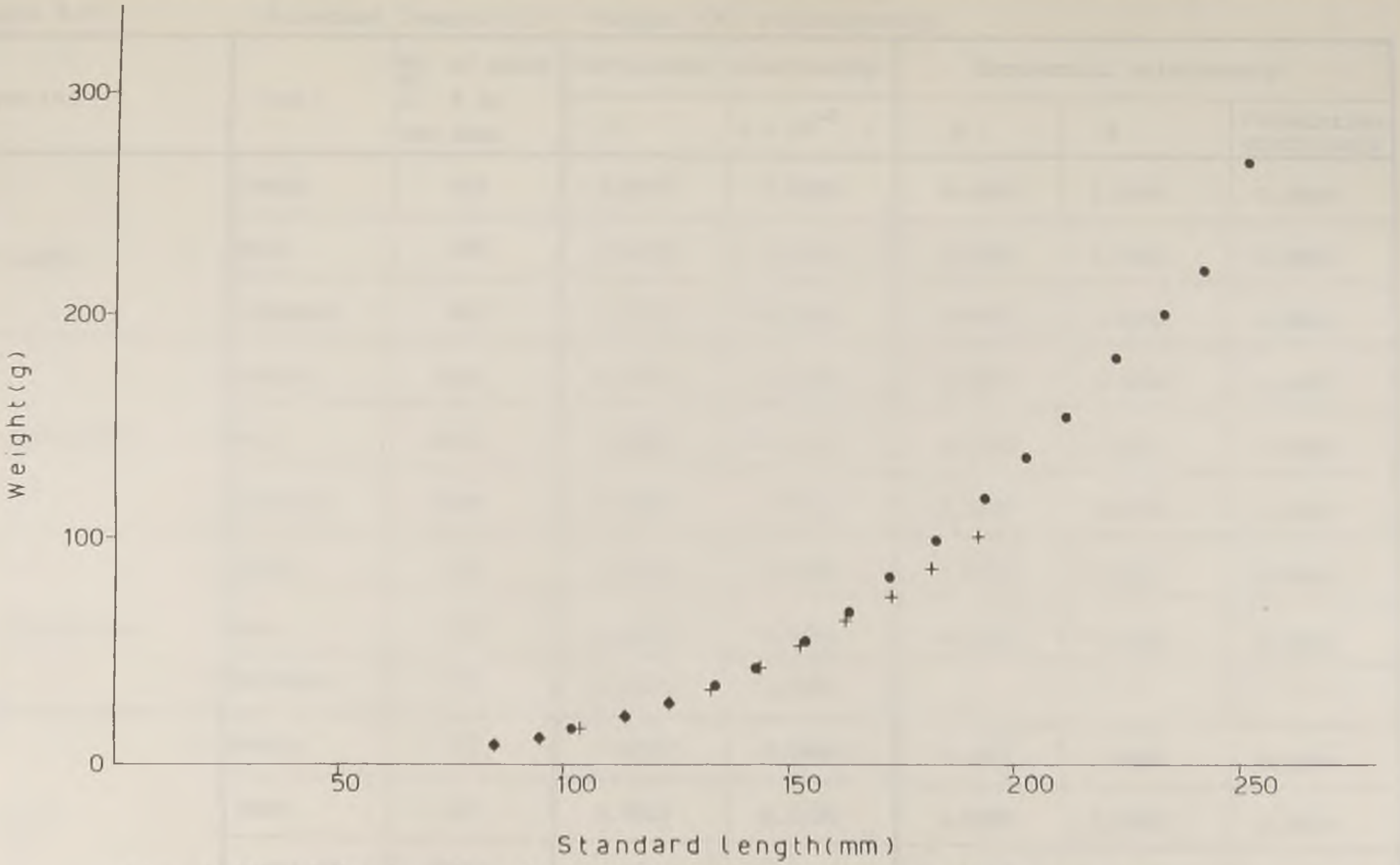


Fig. 4.9D. Relationship of weight to standard length of *T. myops*.
(● - female, + - male)

Table 4.7: Standard length (L) - Weight (W) relationship

Species	Sex	No. of pairs of L - W in raw data	Curvilinear relationship		Exponential relationship		
			b	a x 10^{-6}	A	B	Correlation coefficient
S. tumbil	female	478	3.0775	7.9670	4.4406	1.0147	0.9909
	male	475	3.1612	5.0814	2.1755	1.0188	0.9871
	combined	953	3.1051	6.8368	3.9735	1.0152	0.9864
S. undosquamis	female	2606	3.0867	6.8240	2.2857	1.0174	0.9877
	male	2492	2.9945	10.7416	2.1747	1.0177	0.9653
	combined	5098	3.0605	7.7836	2.2505	1.0175	0.9820
S. filamentosa	female	350	3.1709	4.1806	6.8520	1.0118	0.9449
	male	278	3.0937	6.3590	3.3191	1.0154	0.9794
	combined	628	3.1470	4.7831	–	–	–
T. myops	female	497	3.1867	5.7994	2.1097	1.0202	0.9884
	male	537	3.0915	9.0106	1.4071	1.0232	0.9920
	combined	1034	3.1733	6.1359	1.9450	1.0208	0.9884

Table 4.8: Analysis of Covariance in Length-Weight relationship between sexes.

Species	F - test		Critical values		
	$F_{P(1,n)}$	Calculated F value x 10^{-3}	$F_{p(1,n')}$	p = 0.05	p =0.01
S. tumbil	1,34	3.8515	1,40	4.08	7.31
S. undosquamis	1,32	6.6513	1,40	4.08	7.31
S. filamentosa	1,47	5.6881	1,50	4.03	7.17
T. myops	1,28	4.5805	1,30	4.17	7.56

The asymtotic weights were estimated from equation 3 and their corresponding Von Bertalanffy growth equations are

S. tumbil

Female $W_t = 991.34\ (1 - e^{-0.1592\ (t - 0.4978)})$

Male $W_t = 482.34\ (1 - e^{-0.1823\ (t - 0.2889)})$

S. undosquamis

Female $W_t = 1026.32\ (1 - e^{-0.1398\ (t - 0.2530)})$

Male $W_t = 754.73\ (1 - e^{-0.1957\ (t - 0.6388)})$

S. filamentosa

Female $W_t = 3469.06\ (1 - e^{-0.1574\ (t - 0.6678)})$

Male $W_t = 982.46\ (1 - e^{-0.1927\ (t - 0.5995)})$

T. myops

Female $W_t = 903.65\ (1 - e^{-0.1744\ (t\ -\ 0.4769)})$

Male $W_t = 357.60\ (1 - e^{-0.2231\ (t\ -\ 0.5865)})$

The mean length-weight relationship also followed the exponential equation $A.B.^L$ where A and B are constants. The correlations between observed weights and lengths were highly significant (Table 4.7).

4.3.6.4 Growth Curves

The fastest growth in length and weight was achieved during the first year of life. Thereafter increase in length gradually decreased with age.

In each species, the female growth rate was larger than the male growth rate (Tables 4.5 A,B; Figs. 4.10 and 4.11). Because both male and female were governed by the same relationship between length and weight, the critical difference between the sexes was in the rate of increase in length.

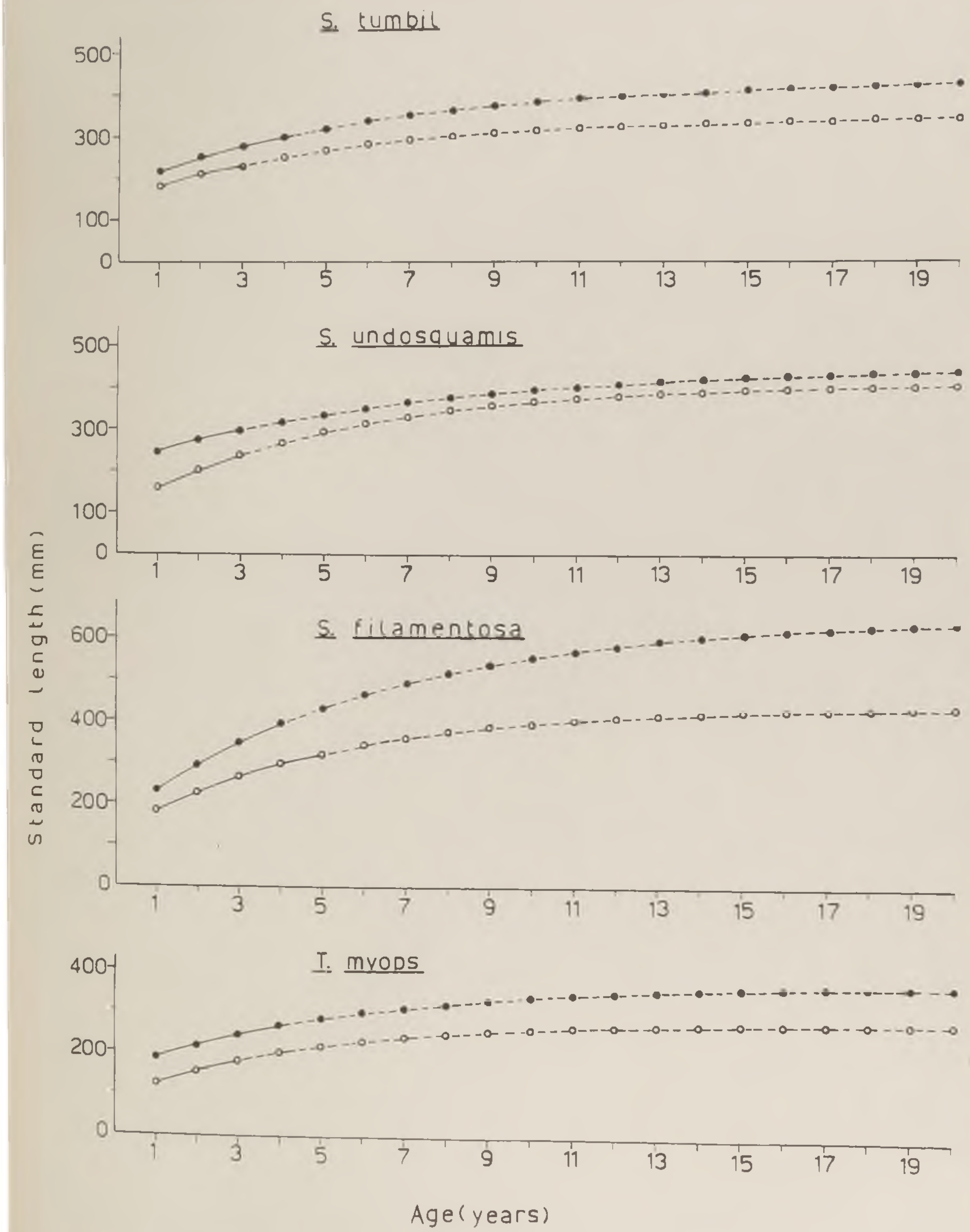


Fig. 4.10. Von Bertalanffy growth curves of lizardfish (●- female, o- male).

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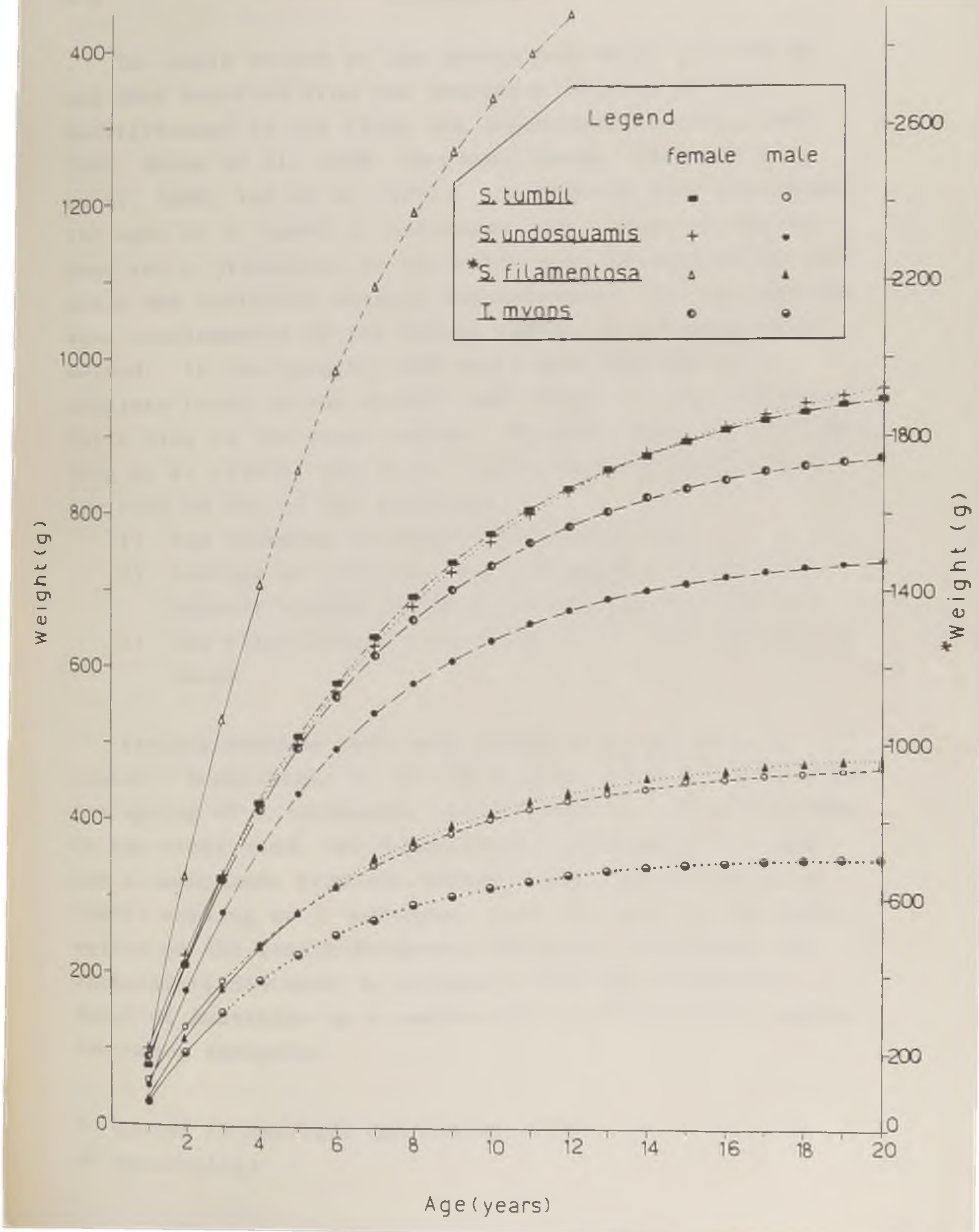
Fig. 4.11. Von Bertalanffy growth curves of lizardfish.


Legend
female
male
S. tumbil ■ ○
S. undosquamis + •
*S. filamentosa △ ▲
T. myops ◎ ●
Weight (g)
400
1200
1000
800
600
400
200
0
*Weight (g)
2600
2200
1800
1400
1000
600
200
0
2
4
6
8
10
12
14
16
18
20
Age (years)

4.4 DISCUSSION

The scale method of age determination in lizardfish has been reported from the temperate regions of the Mediterranean to the China and Japan Seas (Tatara, 1953, 1965; Okada et al, 1955; *Bograd-Zismann, 1961-62; Tung et al, 1965; Yeh et al, 1977). In **South East Queensland, the ages of *S. tumbil*, *S. undosquamis* and *T. myops* on the one hand and *S. filamentosa* on the other were determined by the scale and vertebrae methods respectively. The two methods were supplemented by the Cassie (1954) length-frequency method. In the species from South East Queensland a complete break in the circuli was chosen as the criterion for a ring in the scale method. However Okada et al (1955), Tung et al (1965), Yeh et al (1977) based recognition of the ring on any of the following:

1) the crowding of circuli in basal area
2) cutting or crossing over of these crowded circuli within the basi-lateral and lateral area
3) the ring circuli associated with irregularities or break.

Various methods have been employed in the tropical region - Budnichenko et al (1978) used the scale method in the ageing of *S. undosquamis* and *S. tumbil* in the Arabian Sea. On the other hand, Rao (unpublished) working on *S. tumbil* and *S. undosquamis* from the Indian coast, and Sinoda et al (1978) working on *S. undosquamis* from the Gulf of Thailand, relied on the length-frequency analysis. Sainsbury and Whitelaw (1981) aged *S. undosquamis* from the North-west Shelf of Australia by a combination of otolith and length-frequency analysis.

* Quoted in Ben-Yami and Glaser, 1974.

** Subtropical

The drop in the increment of the marginal growth rate of scales of *S. tumbil* early in the spawning season indicated the laying down of a growth ring at the beginning or during the spawning season. This is consistent with results obtained by Okada et al (1955) and Yeh et al (1977) in the East China and Yellow Seas, Tung et al (1965) in the Taiwan Straits and Budnichenko et al (1978) in the Arabian Sea. However, Budnichenko et al (1978) noted that the formation of annual rings in juveniles was a reflection of the feeding pattern.

All lizardfish postlarvae are scaleless (Wheeler, 1975). The scale-length relationship obtained for *S. tumbil*, *S. undosquamis* and *T. myops* were linear and suggested that scales were formed when the larvae reached between 18-39 and 45-58mm in females and males respectively. The results of Yeh et al (1977) indicate that scales are formed at *birth in females, and between **zero and 23.81mm in the male. Tung et al (1965) expressed the relationship of scale radius to standard length with two linear equations; divided by the point of the size at first maturity. Their results indicate that scales are formed at lengths $\leqslant$ 32 and $\leqslant$ 18mm in females and males respectively. On the other hand, Okada et al (1955) expressed the scale radius-standard length relationship as an exponential equation.

$$L = aR^b + C$$

where 'C' is a constant.

Fish vary considerably in size and their life span. The maximum age, size and age composition of stock are specific for every species. Within limits of the species, there are variations among the different attributes of the population in relationship to the environmental conditions. A broader size range enables the population to utilise a greater

* i.e. -31mm (female), -11mm (male).

** i.e. -14mm.

range of foods and also the species mature in a broader range of sizes and ages (Nikolsky, 1963, 1969).

The scale method and length-frequency analysis indicated that the variation in length in each age class of the South East Queensland species is large. The species are sexually *dimorphic. The females attain larger sizes; the male predominate at lengths between minimum size at maturity and SL_{50} (male). The four species do not **select prey types but sizes; the size ranges of prey being between 16 and 84% of the predators length. Thus the large variation in lizardfish size and their selection of prey sizes maximises the availability of food to the population. This is consistent with results obtained by Tatara (1953, 1955), Okada et al (1955), Liu et al (1959), ***Bograd-Zismann 1961-62), Tung et al (1965), Yeh et al (1977), and Budnichenko et al (1978).

The maximum age observed in the species were 5,4, 12 and 3 for *S. undosquamis*, *S. tumbil*, *S. filamentosa* and *T.myops* respectively. However, the predominant age-group in each species was 1+. Budnichenko et al (1978) and Sainsbury et al (1981) reported a maximum of 6 years whereas Rao (unpublished) estimated a maximum of 3 years in *S. undosquamis*. For *S. tumbil*, the reported maximum ages are between 6 and 9 years (Tung et al, 1965; Yeh et al, 1977; Budnichenko et al 1978; Rao, unpublished). 2-3+ age-groups are common in *S. undosquamis* and *S. tumbil* is best represented by the 3-4+ age-groups in the Arabian Sea (Budnichenko et al, 1979).

Each of the life periods of a fish is characterized by a particular character of growth. The period of most rapid linear growth usually occurs before the onset of maturity.

* See Chapter on Reproduction.

** See Chapter on Food and Feeding.

*** Quoted in Ben-Yami and Glaser, 1974

This is an important adaptation which ensures that the fish escapes the influence of predators. Small fish are much more easily available to predators than large ones. Adult fish usually show a more rapid increase in body mass, which provides for increased fecundity of the population (Nikolsky, 1963, 1969).

The growth of lizardfish is asymptotic. The fastest growth of the four species was in the first year. Okada et al (1955), Tatara (1965) and Budnichenko et al (1978) also noted maximal increases in the size of *S. tumbil* and *S. undosquamis* in the 0-1+ age group.

Asymptotic size was larger in the female for all the four species. The opposite was found in the rate of approach to the asymptotic state; K, and t_o; the initial time of fish growth according to the Von Bertalanffy equation. The t'_o values suggest that growth in weight is secondary to linear growth. This suggestion is substantiated by the exponent of growth; b, of the length-weight relationship being greater than 3 - an indication of allometric growth as manifested in the absolute values of L_∞ and W_∞ of the species. Yeh et al (1977) and Rao (unpublished) also found 'b' to be greater than 3.

Gonads require materials and energy input for their development and will compete with somatic growth for resources. Each kind of growth has costs and benefits which are intimately related to fitness. Bigger females have more eggs thus it is advantageous to the species to delay or slow down growth in weight early in life, and instead put all available energy into somatic growth. This is a sensible strategy if the probability of the fish dying is high during the period of early somatic growth.

Springer (1946) found *T. myops* as the most abundant prey in the stomachs of two species of shark; *Carcharinus milberti* (Valenciennes) and *C. obscurus* (LeSueur), off Salerno, Florida (USA). The rapid linear growth in lizardfish is thus probably a strategy to reduce the effect of predation on young - Sharks and other species higher in trophic level than lizardfish are abundant in South East Queensland waters.

*Lizardfish mature early and during the spawning season the gonads may account for up to 24% and 8% of the female and male body weights respectively. The length-weight relationships are however governed by the same equation in both sexes. This suggests that the difference in gonad weight is probably due to differential re-allocation of energy and body materials between body organs at spawning. On account that in the four species -

1) growth is allometric
2) there is sexual dimorphism in size and consequently in weight
3) *fecundity is in a curvilinear relationship with either length or weight
4) mature early and
5) there are large variations in size per age -

the species have large potential reproduction capacities.

Among marine species in the northern hemisphere, the more southern populations are smaller, with shorter life spans. All southern populations also mature earlier (Nikolsky, 1963, 1969). Taylor (1958) investigated the growth of cod with temperature and suggested that the asymptotic length and the life span will be considerably affected by slight changes in temperature. In a critique on Taylor's (1958) article, Holt (1959) acknowledged the

* See Chapter on Reproduction

Table 4.9: Von Bertalanffy growth parameters vrs latitude.

Species					*S. undosquamis*		*S. tumbil*	
Sex					female	male	female	male
Author	Area	Latitude	Method	Parameters				
Adjei	South East Queensland (Moreton Bay)	27^o 26'S	scale and length-frequency	L_∞ (mm)	450	407	425	377
				K	0.1398	0.1957	0.1592	0.1823
				t_o (yr)	-4.6691	-1.4551	-3.5619	-3.1784
Yeh et al (1977)	Gulf of Tonkin	17^o N	scale	L_∞ (mm)			794.6	782.9
				K			0.0965	0.0790
				t_o (yr)			-1.5430	-1.7934
	Southern East China Sea	27^o N	"	L_∞ (mm)			742.4	686.9
				K			0.1043	0.1177
				t_o (yr)			-1.4160	-1.3953
Tung et al (1965)	Taiwan Straits	23^o N	"	L_∞ (mm)			644	479
				K			0.3169	0.3486
				t_o (yr)			-0.2486	- 0.1021
Sainsbury et al (1981)	North-West shelf of Australia	15^o S	otolith and length-frequency	L_∞ (mm)	571	466		
				K	0.39	0.50		
				t_o (yr)	0.2	0.8		
Rao (unpublished)	Coast of India	15^o N	Length-frequency	L_∞ (mm)			637	
				K			0.249	
				t_o (yr)			-0.334	
Sinoda et al 1978	Gulf of Thailand	10 - 12 N	Length-freq.	L_∞ (mm)	400			

effect of temperature but stressed that "L_∞ would decrease but rather slowly with increasing temperature". In Table 4.9 trends, if any, are obscured probably by the different methods used by the authors and also the sensitivity of L_∞ to the slope of the Walford Line, *"K". The data however suggest larger L_∞ in the northern hemisphere; especially in the more northern populations.

The numbers of any animal population change considerably in time. In fishes the variability of the annually recruiting year-classes provides the main source of such temporal fluctuations. Recruitment is highly variable in *S. undosquamis* (Tatara, 1965; Sainsbury et al, 1981).

Recruitment sizes(and age) in *S. undosquamis* and *S. tumbil* in Moreton Bay were estimated to be about 90.4 (and 0+) and 95.8mm (and 0+) respectively. The recruits appeared after the spawning season. Okada et al (1955) and Sinoda et al (1978) also reported recruitment after the spawning season. However Sinoda et al (1978) estimated the mean size at recruitment of *S. undosquamis* to be about 150mm in total length in the Gulf of Thailand. Ben-Yami and Glaser (1974) on the other hand estimated recruitment of this species to be between 200-300mm and 2-3+ along the Mediterranean Coast of Israel from the analysis of Bograd-Zismann's (1961-62) data.

The calculated total mortalities in male and female *S. undosquamis* and *S. tumbil* were 2.1767, 1.1382, 1.1087 and 0.4151 respectively and are probably due to a number of factors. *S. undosquamis* and *S. tumbil* were hosts to a number of parasites. The most common parasite was the trypanorhynch tapeworm *Callitetrarhynchus gracilis*. **In a preliminary analysis, no significant correlation was found

* K = -Ln Slope.

** See Chapter on Parasites.

between a number of parasites and length of the lizardfish. However the truncated form of the negative binomal distribution fitted to the frequency distributions suggested that some heavily infected fish were missing from the samples and most probably due to the adverse effects of the larvae on the general fitness of the fish. The males were affected by lesser numbers of larvae than the females. This difference probably contributes to or reflects in the differences in total mortality between the sexes.

In South East Queensland, lizardfish form a large percentage of 'trash' fish taken with prawns and other resource fisheries (pers. comm., Les Wale, Bob Sanderson, Bryan Wallis, personal observation). And the large number of boats involved in these fisheries must therefore indicate substantial fishing mortality. Comparing male and female total mortalities, supposing that there were no differences between sexes in fishing mortality, the differences in total mortality between sexes would be due to natural mortality. The larger mean sizes of females probably makes them more susceptible to fishing mortality thus Rosa Lee's phenomenon in females. Tatara (1965) found higher total and natural mortalities in males but the same fishing mortality in both sexes in his investigation of sub-populations of *S. undosquamis* in the seas of Japan. Sainsbury et al (1981) reported that total mortality in *S. undosquamis* increased with age.

5. REPRODUCTION OF FOUR LOCAL SPECIES

5.1 INTRODUCTION

Reproduction is the cornerstone for the continuation of species. As any other life process, reproduction demands three basic elements: energy, materials and time. Availability of the first two elements are constrained within limits imposed by the species genotype and environment. The strategy adopted by an animal or plant is a compromise allocation of energy to the various aspects of its life-history, each of which contributes to total fitness (Begon and Mortimor, 1981).

Fish species live under a great variety of conditions and have of necessity evolved adaptive reproductive strategies that guarantee the perpetuity of their type. These strategies usually relate to the egg and larva (Nikolsky, 1963). The literature on the reproduction of fish is immense. Hickling and Rutenberg (1936) studied the ovary as an indicator of the spawning period of four species. They suggested that measurement of the diameters of eggs may provide information as to the spawning habits of fish. Many researchers (e.g. Radhakrishnan, 1963; Kagwade, 1970-72; Hislop and Hall, 1974; Morse, 1981) have since used this method to establish spawning periods of many fish. Russell (1976) described the eggs and planktonic stages of fish in the British Isles.

Nikolsky (1963) discussed the various aspects of reproduction and development of fish. He noted that fecundity of fish varied with species, size, age, environmental conditions, food and population size. The course of maturation of gonads as manifested in changes in the gonad index (G.I.; the weight of the gonad as a percentage of the weight of the whole body), rises with the approach of spawning, peaks and decreases after spawning. Time, duration and the place of spawning are adaptations which ensure the most favourable conditions for the development of the eggs and larvae. Hubbs (1943) and Balon (1975a) considered the terminology of the early stages, whereas ecological groupings or guilds have been proposed by Kryzhanovsky (1949) and Balon (1975a) based on reproductive strategies. Bagenal and Braum (1968) compiled methods of investigation on development and reproduction.

The standard references on reproduction have been developed for fishes from the temperate regions and Qasim (1973) discusses these methods with special reference to works from the tropical Indian sub-continent. He suggested that "studies should not be restricted to sketchy observations on spawning, but should be planned to develop an understanding of the maturation process of the population in a particular area".

With exception of two species, the literature on the reproduction and larvae of lizardfish species consist of anecdotes (Norman, 1935; Delsman, 1938; Gopinath, 1946; Nair, 1952; Gibbs, 1959; Mito, 1961; Mead, 1966, *Tiews, 1972; and Ben-Yami and Glaser, 1974).

The two species which have been studied most are *Saurida undosquamis* and *S. tumbil*. Budnichenko and Nor (1978) and Budnichenko and Dimitrova (1979) reported an extended spawning season for *S. undosquamis* in the Arabian Sea. However, Sinoda and Intong (1978) concluded from studies in the Gulf of Thailand that *S. undosquamis* spawns all through the year. Chervinsky (1959)** and Bograd-Zismann (1961-62)** reported the occurrence of ripe, nearly ripe and spent females almost throughout the year in the Mediterranean

* Quoted in Budnichenko and Dimitrova, 1979.

** Quoted in Ben-Yami and Glaser, 1974.

Sea. Tatara (1965) on the one hand found different extended spawning periods for two sub-populations of *S. undosquamis* in the East China Sea. *S. tumbil* has also been found to undergo extended spawning in the Arabian (Annigeri, 1963; Budnichenko and Nor, 1978; Budnichenko and Dimitrova, 1979) and East China Seas (Yamada, 1968a,b; Yamada, Tagawa and Mako, 1968).

Significant differences have been found in sex ratios and sizes amongst males and females of *S. undosquamis* (Tatara, 1965; Latif and Shenouda, 1973; Budnichenko and Nor, 1978; Budnichenko and Dimitrova, 1979) and *S. tumbil* (Yamada, 1968a; Budnichenko and Nor, 1978; Budnichenko and Dimitrova, 1979) especially during the spawning season. Yamada (1968b) reported on diseased ovaries and *S. tumbil* has been described as sexually dimorphic; the male having a prolongation of the second soft dorsal ray at lengths greater than 250-300mm by Okada and Kyushin (1955) and Liu and Tung (1959).

A number of aspects of the reproductive ecology of four local species were studied and are reported on in this chapter.

5.2 METHODS AND MATERIALS

The four species - *S. undosquamis*, *S. tumbil*, *S. filamentosa* and *T. myops* - were collected by bottom trawls and treated with formalin as previously described in the main introduction.

Each fish was measured for length and then was dissected to determine the sex and state of gonad development. The gonads were weighed as discussed previously. Data on each fish were kept separate under its species, reference number, month and year.

Gonads and ova were examined under a dissecting microscope with reflected and transmitted light respectively. Four types of ova were distinguished: immature, maturing, mature and ripe ova. Fifty of each type of ova were randomly selected from ovaries in each stage of maturity and measured along their diameters on a graduated micrometer.

Unlike the female, the stages of development of testes were difficult to establish. In the female, the stages were based on types and quantities of ova present, whereas in the male discrimination depended only on the macroscopic appearance and texture of the testes. Fresh specimens of ovaries and testes at the various stages which were available during the preliminary investigation were labelled and preserved. These were subsequently used as standard references. In the preserved testis the texture was the main discriminating feature between the stages of development.

The stages of gonad maturity or development recognised were modified from Kesteven's (1960) general classification of maturity stages. In the preliminary survey, Stage II of the ovaries and testes were found to weigh only about 0.2g or less, the accuracy of the weighing machine being ± 0.1g. Each of these, for the convenience of speed and also for inclusion in the calculation of the gonad index was given an arbitrary weight of 0.2g if found to be less.

The estimation of fecundity was complicated by -

1) ova being of four types and sizes
2) fractional spawning by the species.

Absolute fecundity - the number of ova contained in the ovary of a fish (Nikolsky, 1963) - was estimated with Stage IV ovaries. This stage of maturity of the ovary had predominantly mature ova with a few tiny immature ova in the interstices. Partial fecundity - defined here as the number of ripe eggs to be released at the next fractional spawn - was estimated from the average of the sub-samples taken consistently from 3 sections of the ovary: the distal, middle and proximal regions. All fecundity estimations were by the gravimetric method (see Bagenal and Braum, 1968) using average counts and weights of sub-samples in proportion to weight of ovaries. Ova were counted in a counting chamber under a dissecting microscope with transmitted light.

An attempt was made to grow artificially fertilized eggs of *S. tumbil.* However, whereas many of the ova were damaged by mechanical disturbance and temperature changes during transportation to the laboratory, the few which survived did not develop any further than the first few cell divisions.

Gonad index, G.I. or the coefficient of maturity, expresses the weight of the gonad as a percentage weight of the whole body (Nikolsky, 1963). The relative fecundity. R.F., is the ratio of the partial fecundity to the standard length or whole body weight.

S. undosquamis, S. tumbil and *T. myops* were aged by scale reading, whereas *S. filamentosa* was aged by the vertebrae. Data on water temperatures and rainfall were supplied by the Department of Science, Bureau of Meteorology, Brisbane. Since water temperatures can be expected to lag behind air temperatures, mean monthly minimum and maximum temperatures between 1958 and 1981 at Cape Moreton Lighthouse were used as approximations of those which prevailed during the study. The mean rainfalls at Cape Moreton Lighthouse were also used as an indicator of monthly outwash into Moreton Bay from the Brisbane River watershed.

Statistical analysis followed Sokal and Rohlf (1969) Senter (1969) and Finney (1952).

5.3 RESULTS

5.3.1 Ova types

Four identical types of ova were described for the four species based on size and yolk content.

a. Immature ova (type D) - Tiny, angular to ovoid and transparent with a single central distinct nucleus. Ova were yolkless and measured up to 0.16mm in diameter.

b. Maturing ova (Type C) - Yolk deposition just began or had already taken place but not complete. Ova centrally opaque, nucleus not visible. The size range was 0.16 - 0.32mm.

c. Mature ova (Type B) - Ova densely yolked and opaque. Ova were pale yellowish.

d. Ripe ova (Type A) - Fresh ova were transparent and spherical. They floated on seawater.

Microscopic examination of preserved ova at 500x magnification showed that -

1. Perivitteline space was small.
2. Yolk was a paste-like semi-fluid with several scattered oil droplets.
3. The egg membrane was sculptured in the form of streaks of short lines in a maze of hexagonal figures.

S. filamentosa had the largest ova (Type A) and *S. undosquamis* the smallest. *S. tumbil* ova sizes were intermediate between those of *S. undosquamis* and *S. filamentosa*. *T. myops* ripe ova were ciliated and similar to *S. undosquamis* in diameter (Table 5.1).

Table 5.1 : Ova diameters (in mm) of *Saurida* and *Trachinocephalus*

Species	Type A		Type B	
	range	mean	range	mean
S. undosquamis	0.62-1.08	0.89	0.36-0.62	0.47
S. tumbil	0.80-1.44	1.20	0.32-0.80	0.57
S. filamentosa	1.08-1.46	1.35	0.54-0.77	0.68
T. myops	0.85-1.23	1.05	0.23-0.69	0.45

5.3.2 Maturity stages

The maturity stages were identical in all four species though two genera were involved: *Saurida* and *Trachinocephalus*. These stages were based on a) types and quantities of ova present and b) texture and macroscopic appearance, in ovaries and testes respectively. Eight stages of maturity were established for the ovaries and six for the testes. Determination of sex at even 500x magnification was impossible in some small fish, usually less than 100mm. Their gonads were small and thread-like and were assigned to Stage 1. Immature ova were observed in all stages of ovarian maturity.

5.3.2.1 Stages of maturity of ovaries

Stage II:	Ovaries long, slender and colourless with tiny blood vessels. Only immature ova were present. Preserved specimens were translucent.
Stage III:	Maturing ovaries. Ovaries were reddish due to ramification of blood capillaries. The main blood vessel was dorsal and extended to about one-third the length of the ovaries from the proximal end. Maturing ova were present. Preserved specimens had tinge of red.
Stage IV:	Mature ovaries. Ova consisted predominantly of mature types. Ovum angular to ovoid and attached to each other. Pronounced ramification of blood capillaries over ovaries. Ovaries reddish-yellow in fresh specimen but pale in the preserved specimen.
Stage V:	Ripening ovaries. Ovaries with extensive ramification of blood capillaries. Ripe and mature ova present. Ripe ova were not free from the ovarian tissue and were seen as translucent round spots on a generally orange-yellow gonad. These spots were more or less evenly distributed.
Stage VI:	Gravid. Ova ripe and transparent but not running. Ovaries were swollen and laid along the entire length of the body cavity. Ova sometimes ran when light pressure was applied to the thoracic region. The ratios of mature to ripe ova were between 3 and 7.

Stage VII:	Spawning or running ripe. Ripe and mature ova present. Ripe ova free of ovarian tissue and aggregated inside the ovary or disposed towards the medial and adjacent sections of the two pairs of ovary starting from the proximal end. In the latter, the inner medial sections were more or less translucent and the outer sections opaque (due to opaque mature ova).
Stage VIII:	Spent. Ovaries bloodshot, flaccid or shrunken. The mature and ripe ova present were small and not free from ovarian tissue and in a state of resorption.
Stage IX:	Recovering spent. More or less bloodshot ovaries with immature and maturing ova. Ovaries had several tiny blood vessels.

5.3.2.2 Stages of maturity of testes

Stage II:	Immature. Testes grey and longer than broad. Thin blood vessel ramification. Texture more or less 'fibrous' and 'plastic' in preserved specimen.
Stage III - IV:	Mature. Testis was reddish-white. Accumulation of milt slight and proximal and whitened dorsally. Texture 'fibrous' and brittle in preserved specimen.
Stage V:	Ripening. Testis pinkish distally. Proximal end white and soft as a result of accumulation of milt. This accumulation was usually up to half the length of testis. Drops of milt were exuded when slight pressure was applied to the thoracic

region. A median dorsal blood vessel gave off branches to each pair of testes. The preserved specimens were paler and of a fluffy texture proximally.

Stage VI - VII: Running ripe.

Milt ran freely from fresh testes. Testes wholly white, soft and swollen. Testicular matter more or less fluid.

Stage VIII: Spent.

Testes bloodshot, more or less empty and flaccid.

Stage IX: Recovering spent.

Testes reddish with considerable blood vessel ramification.

The changes in size and yolk content of ova from the immature to the ripe stage indicated continuous asynchronous maturation. Stage IV contained predominantly mature and some immature ova, a fraction of which ripened through Stages V to VII. Only a few small mature but relatively many immature ova were observed in the spent condition. These suggest -

1) that there is differential or continuous ripening of mature ova.
2) fractional or serial spawning.
3) yolked ova in Stage III and above were all part of the stock released in a spawning season or period.

Nematode and cestode parasites were found within and without some mature ovaries. Parasites are discussed in the next chapter.

Table 5.2 : Length at Maturity

N = Total number of mature fish; n = number per class size

Class sizes (mm)	*S. undosquamis*						*S. tumbil*						*T. myops*					
	Female, N=292			Male, N=483			Female, N=359			Male, N=362			Female, N=307			Male, N=461		
	n	%	cum. %	n	%	cum. %	n	%	cum. %	n	%	cum. %	n	%	cum. %	n	%	cum. %
100–119																10	2.2	2.2
120–139	3	1.0	1.0	45	9.3	9.3							10	3.3	3.3	112	24.3	26.5
140–159	56	19.2	20.2	335	69.4	78.7	1	0.3	0.3	7	1.9	1.9	71	23.1	26.4	219	47.5	74.0
160–179	95	32.5	52.7	80	16.5	95.2	0	0.0	0.3	152	42.0	43.9	91	29.6	56.0	103	22.3	96.3
180–199	82	28.1	80.8	19	3.9	99.1	14	3.9	4.2	171	47.2	91.1	58	18.9	74.9	17	3.7	100.0
200–219	34	11.6	92.4	1	0.2	99.3	57	15.9	20.1	20	5.5	96.6	49	16.0	90.9			
220–239	11	3.8	96.2	1	0.2	99.5	80	22.3	42.4	10	2.8	99.4	22	7.2	98.1			
240–259	6	2.1	98.3	0	0	99.5	84	23.4	65.8	2	0.6	100.0	6	2.0	100.1			
260–279	4	1.4	99.7	0	0	99.5	70	19.5	85.3									
280–299	0	0	99.7	1	0.2	99.7	30	8.4	93.7									
300–319	0	0	99.7	1	0.2	99.9	15	4.2	97.9									
320–339	1	0.3	100				6	1.7	99.6									
340–359	0	0	100				2	0.6	100.2									

cum. % = cumulative frequency

Table 5.3:

S. filamentosa : Length at Maturity

N = Total number of mature fish; n = number per class size

Class Sizes	FEMALE, N = 156			MALE, N = 68		
	n	%	cum. %	n	%	cum. %
160-179	1	0.6	0.6	1	1.5	1.5
180-199	2	1.3	1.9	6	8.8	10.3
200-219	7	4.5	6.4	23	33.8	44.1
220-239	14	9.0	15.4	16	23.5	67.6
240-259	26	16.7	32.1	13	19.1	86.7
260-279	19	12.2	44.3	6	8.8	95.5
280-299	34	21.8	66.1	0	0	95.5
300-319	22	14.1	80.2	1	1.5	97.0
320-339	19	12.2	92.4	1	1.5	98.5
340-359	4	2.6	95.0	1	1.5	100.0
360-379	4	2.6	97.6			
380-399	1	0.6	98.2			
400-419	0	0	98.2			
420-439	1	0.6	98.8			
440-459	0	0	98.8			
460-479	0	0	98.8			
480-499	1	0.6	99.4			
500-519	0	0	99.4			
520-539	0	0	99.4			
540-559	0	0	99.4			
560-579	1	0.6	100.0			

cum. % = cumulative frequency

5.3.3 Length at maturity

Stages IV and III - IV were the first mature stages towards spawning in the ovaries and testes respectively as discussed above. Length at maturity (i.e. $S.L_{50}$ = length at which 50% of the fish were mature) was estimated using probit analysis (Finney, 1952) of mature fish collected during the study period. (See Figs 5.1 and 5.2). Fish were grouped into size classes of 20mm intervals. Tables 5.2 and 5.3 list size classes (mm), percentage (%) and cumulative percentage (cum. %) of mature fish. N is the total number of mature fish per sex and n; the number per size class.

The largest females were larger than the largest males and in different size classes: 320, 345, 575 and 253mm for females in *S. undosquamis*, *S. tumbil*, *S. filamentosa*, and *T. myops* respectively. Their male counterparts were 300, 242, 342 and 195 mm respectively.

Table 5.4

Relative Sizes (mm) of Mature and Immature Lizardfish

Species	$S.L_{50}$		Smallest Mature		Largest Immature	
	female	male	female	male	female	male
S. undosquamis	178	158	132	128	218	195
S. tumbil	245	183	154	163	258	202
S. filamentosa	282	229	168	175	275	245
T. myops	176	149	130	104	135	179

Fig. 5.1 Probit analysis; estimation of length at maturity (S.L_{50}) of female lizardfish. Very extreme probits (outside range 2.5-7.5) carry little weight and are disregarded.

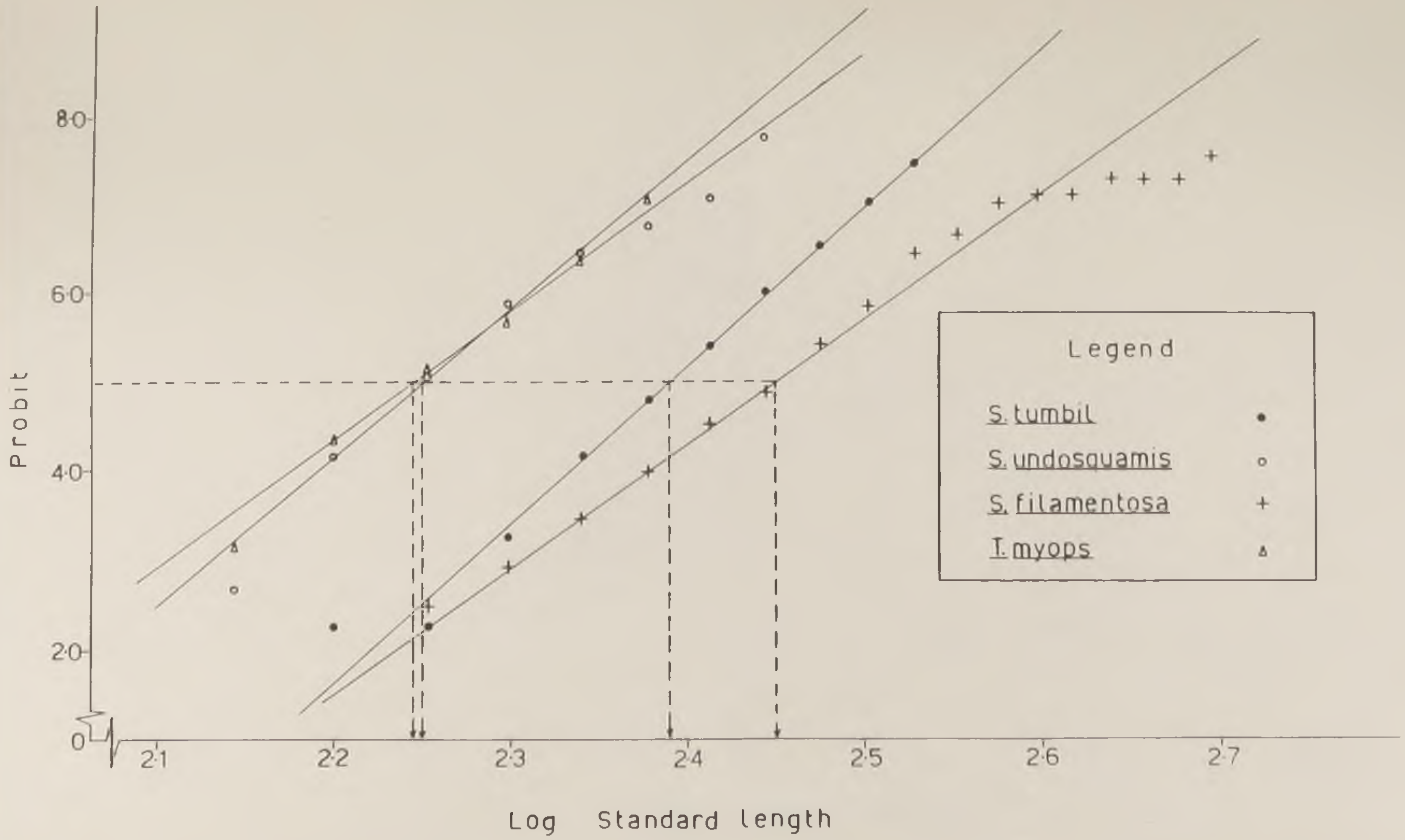
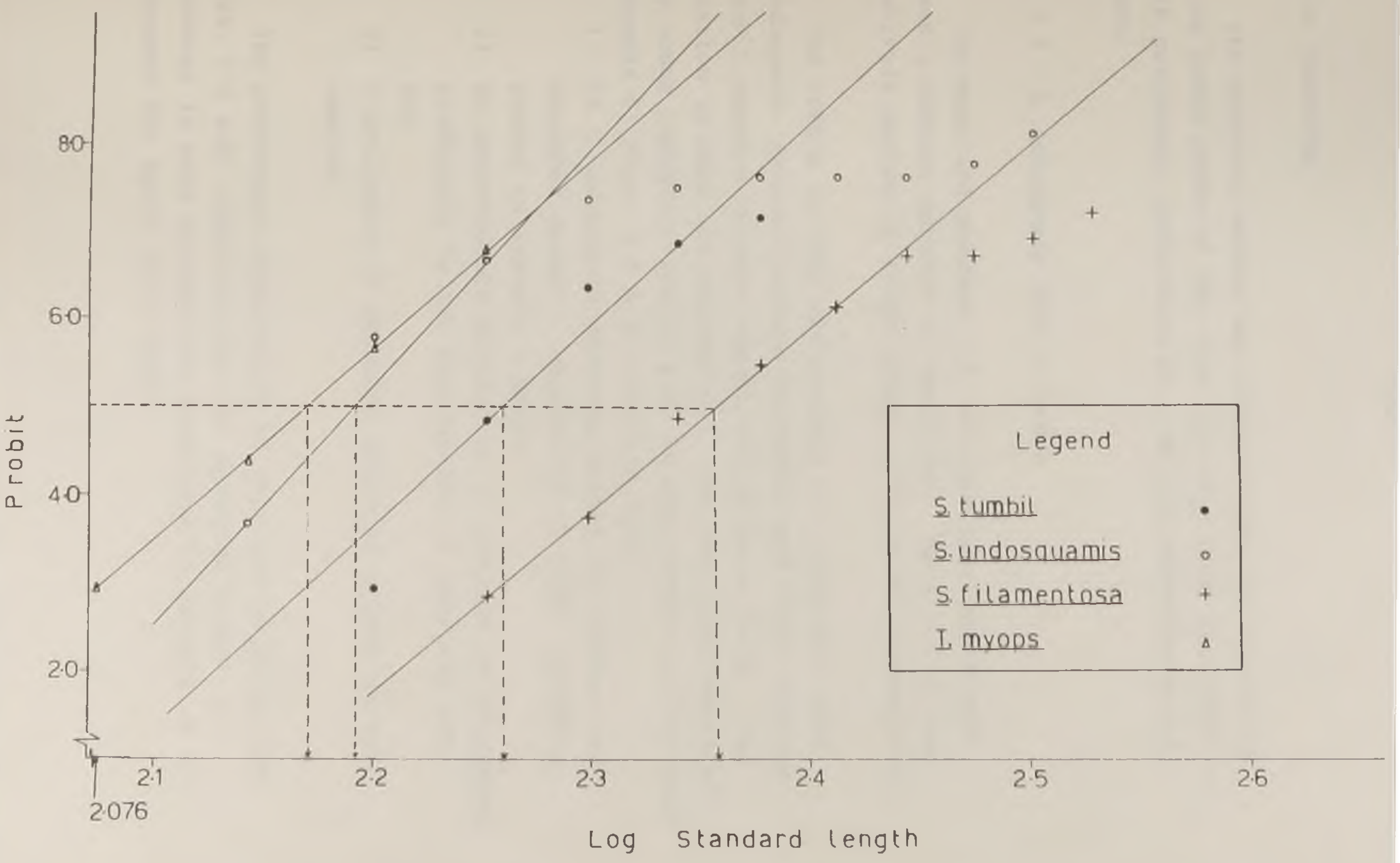

Probit
8·0
6·0
4·0
2·0
0
2·1
2·2
2·3
2·4
2·5
2·6
2·7
Log Standard length
Legend
S. tumbil ●
S. undosquamis ○
S. filamentosa +
I. myops ▵

Fig. 5.2. Probit analysis; estimation of length at maturity ($S.L_{50}$) of male lizardfish. Very extreme probits (outside range 2.5-7.5) carry little weight and are disregarded.


Probit
80
60
40
20
2·1
2·076
2·2
2·3
2·4
2·5
2·6
Log Standard length
Legend
S. tumbil ●
S. undosquamis ○
S. filamentosa +
I. myops ▵

5.3.4 Spawning

The spawning season was deduced from the variation in the gonad index of the fish and also from the month to month percentage occurrence of ripe and spawning gonad stages.

5.3.4.1 *S. undosquamis* and *S. tumbil*

The mean and maximum G.I. of both male and female showed a similar pattern of variation. Male G.I.s were relatively narrow in range (Figs. 5.3 A,B and Appendix 6).

The trends in mean and maximum G.I. indicate that *S. undosquamis* spawned between September and June, whereas *S. tumbil* spawned between August and probably July. The variation in mean and maximum G.I. and the occurrences of very young (unidentifiable) fish in many months of the year (Appendix 6; Figs. 5.4 A-D) indicate that -

1) In *S. undosquamis* spawning peaked in October and December-January, whereas in *S. tumbil* spawning peaked in January - March.
2) An asynchronous maturation of ovaries as discussed previously in the development of immature ova, and
3) A prolonged or extended spawning season in each species.

The percentage occurrences of ripe and running fish (Figs. 5.4 A-D) indicate that the spawning began in September in both species and continued to January in *S. undosquamis* but April in *S. tumbil*.

Fig. 5.3A. Monthly mean gonad index of (female) lizardfish.

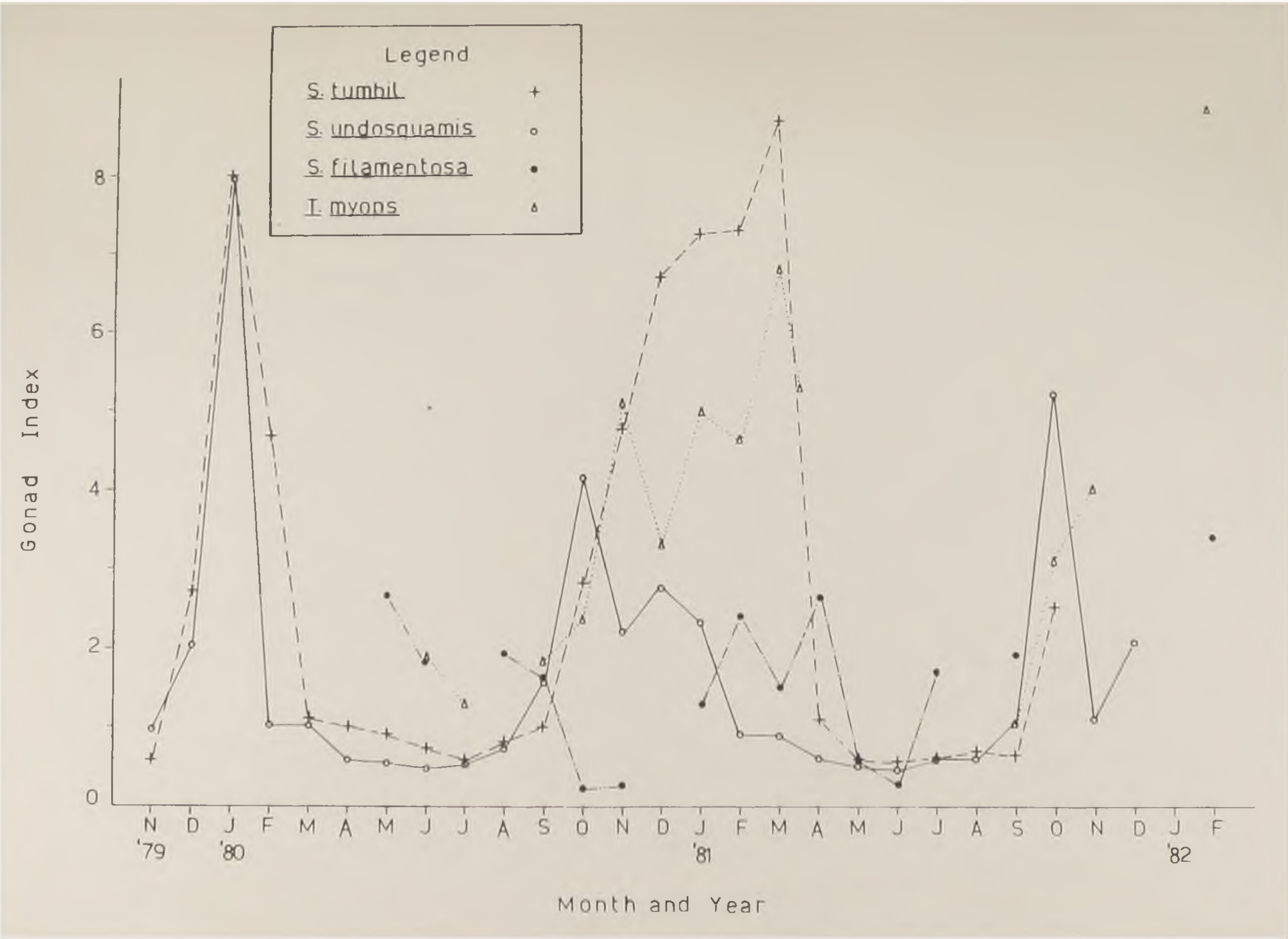

Legend
S. tumbil +
S. undosquamis ○
S. filamentosa ●
I. myops △
Gonad Index
0
2
4
6
8
N D J F M A M J J A S O N D J F M A M J J A S O N D J F
'79
'80
'81
'82
Month and Year

Fig. 5.3B. Monthly mean gonad index of (male) lizardfish.

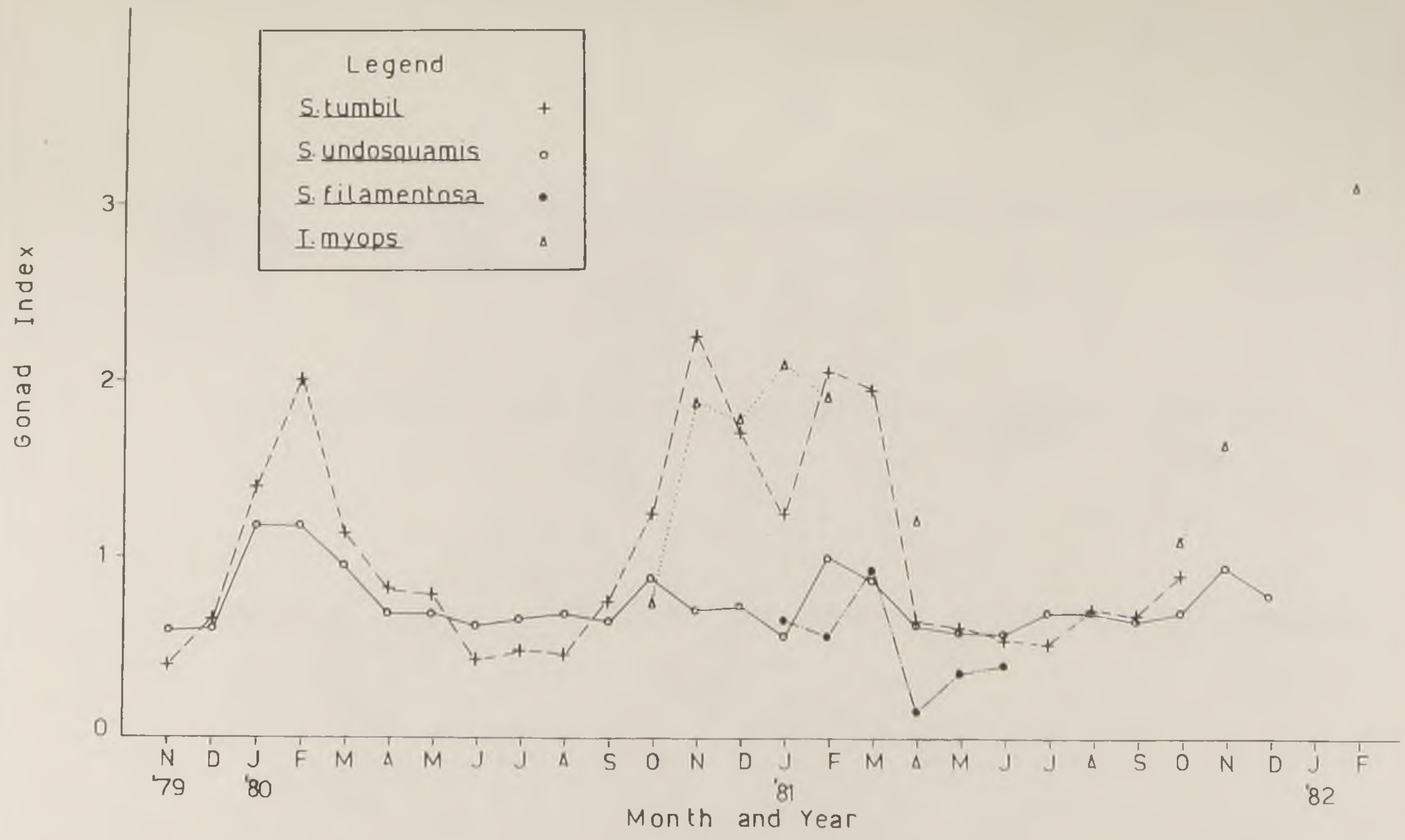

Legend
S. tumbil +
S. undosquamis ○
S. filamentosa ●
I. myops △
Gonad Index
0
1
2
3
N D J F M A M J J A S O N D J F M A M J J A S O N D J F
'79
'80
'81
'82
Month and Year

Fig. 5.4A Frequencies of stages of maturity of ovaries of *S. undosquamis* obtained between November 1979 and December 1981. (Number of specimens examined per month in brackets.)

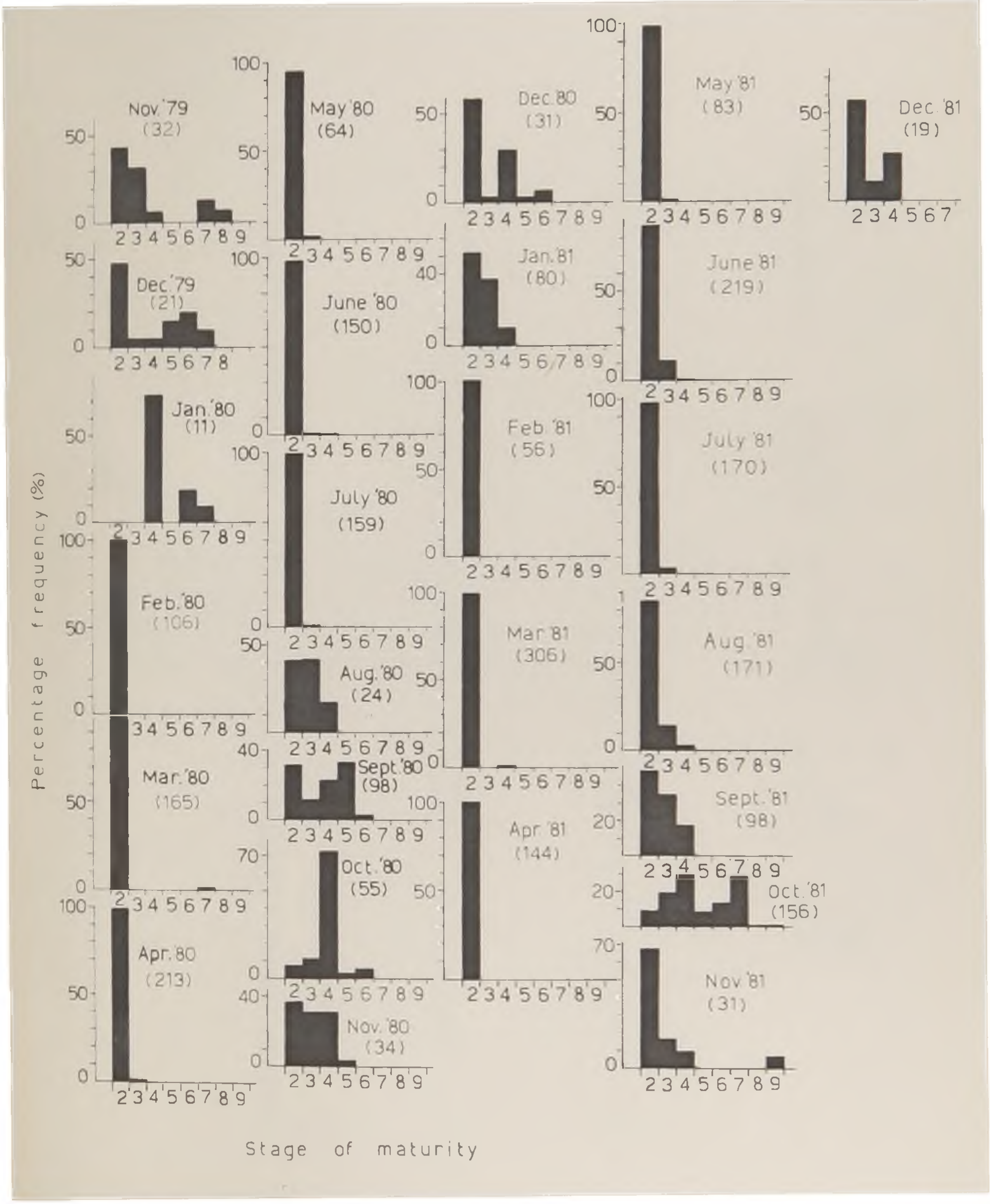

Percentage frequency (%)
Stage of maturity
Nov.'79 (32)
Dec.'79 (21)
Jan.'80 (11)
Feb.'80 (106)
Mar.'80 (165)
Apr.'80 (213)
May '80 (64)
June '80 (150)
July '80 (159)
Aug.'80 (24)
Sept.'80 (98)
Oct.'80 (55)
Nov.'80 (34)
Dec.'80 (31)
Jan.'81 (80)
Feb.'81 (56)
Mar.'81 (306)
Apr.'81 (144)
May '81 (83)
June '81 (219)
July '81 (170)
Aug.'81 (171)
Sept.'81 (98)
Oct.'81 (156)
Nov.'81 (31)
Dec.'81 (19)
0
20
40
50
70
100
2 3 4 5 6 7 8 9

Fig. 5.4B. Frequencies of stages of maturity of testes of *S. undosquamis* obtained between November 1979 and December 1981. (Number of specimens examined per month in brackets.)

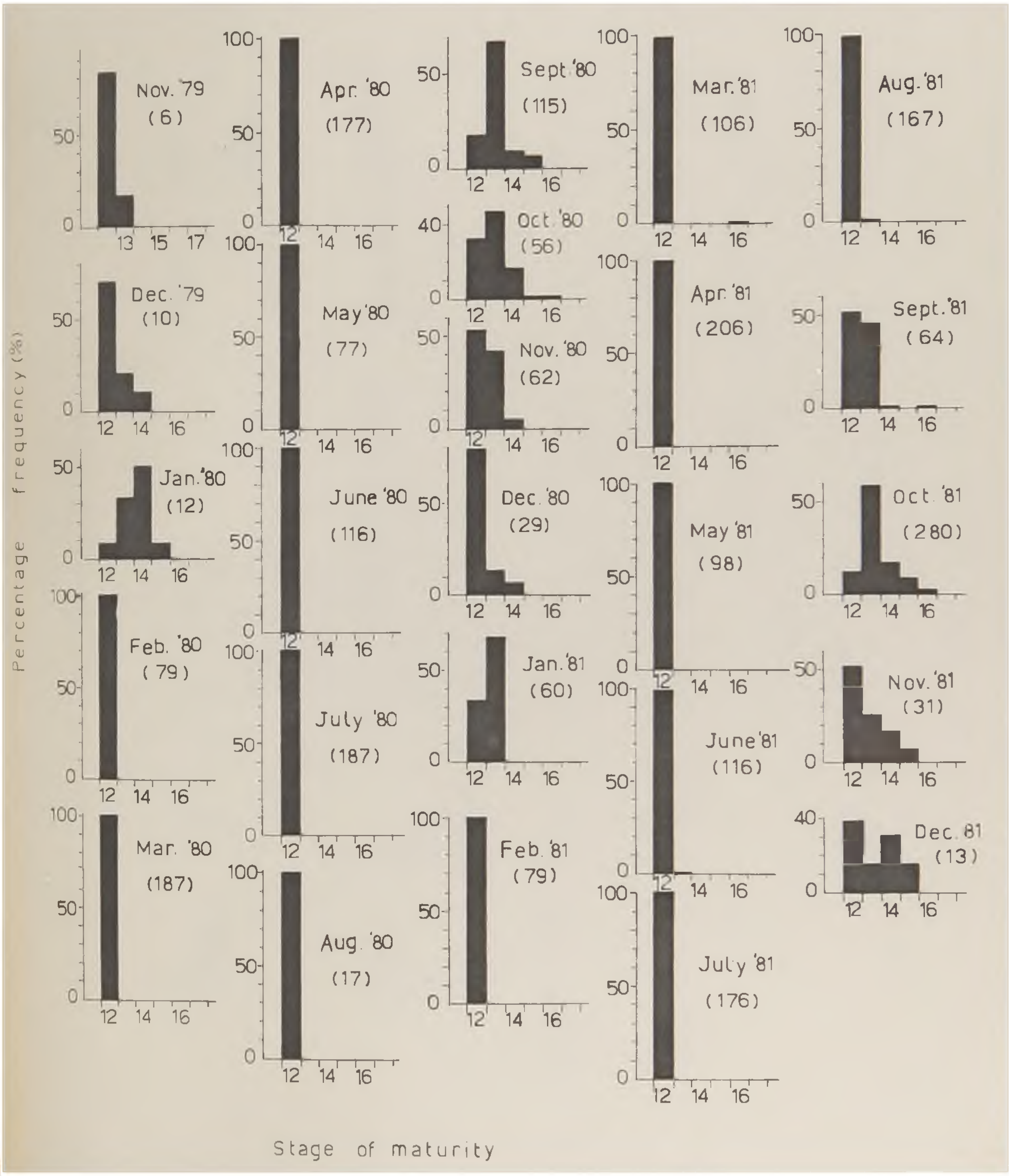

Nov. '79 (6)
Dec. '79 (10)
Jan. '80 (12)
Feb. '80 (79)
Mar. '80 (187)
Apr. '80 (177)
May '80 (77)
June '80 (116)
July '80 (187)
Aug. '80 (17)
Sept '80 (115)
Oct. '80 (56)
Nov. '80 (62)
Dec. '80 (29)
Jan. '81 (60)
Feb. '81 (79)
Mar. '81 (106)
Apr. '81 (206)
May '81 (98)
June '81 (116)
July '81 (176)
Aug. '81 (167)
Sept. '81 (64)
Oct. '81 (280)
Nov. '81 (31)
Dec. '81 (13)
0
40
50
100
12
13
14
15
16
17
Percentage frequency (%)
Stage of maturity

Fig. 5.4C Frequencies of stages of maturity of ovaries of *S. tumbil* obtained between November 1979 and October 1981. (Number of specimens examined per month in brackets.)

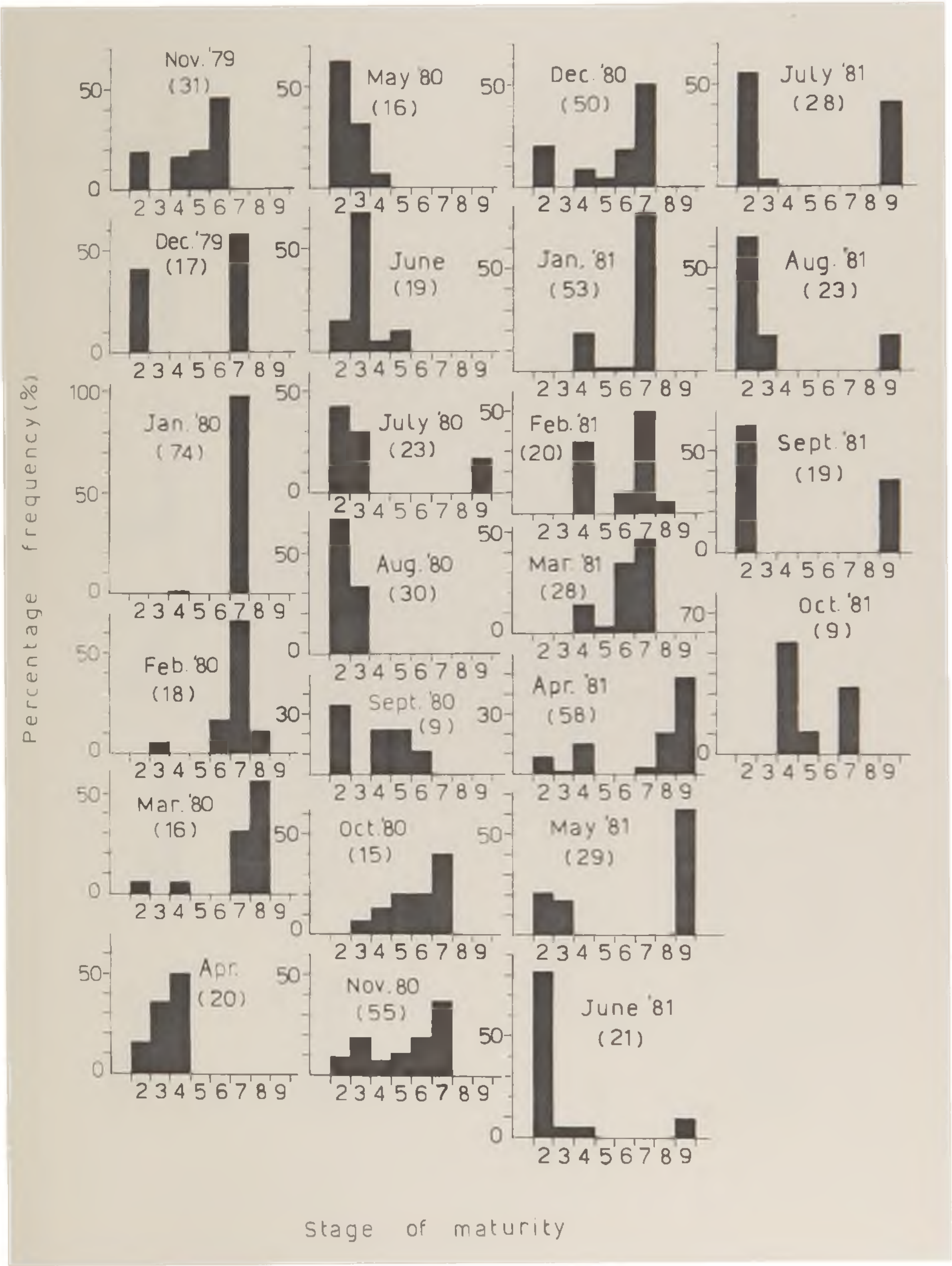

Nov. '79
(31)
Dec. '79
(17)
Jan. '80
(74)
Feb. '80
(18)
Mar. '80
(16)
Apr.
(20)
May '80
(16)
June
(19)
July '80
(23)
Aug. '80
(30)
Sept. '80
(9)
Oct. '80
(15)
Nov. 80
(55)
Dec. '80
(50)
Jan. '81
(53)
Feb. '81
(20)
Mar. '81
(28)
Apr. '81
(58)
May '81
(29)
June '81
(21)
July '81
(28)
Aug. '81
(23)
Sept. '81
(19)
Oct. '81
(9)
0
30
50
70
100
2 3 4 5 6 7 8 9
Percentage frequency (%)
Stage of maturity

Fig. 5.4D Frequencies of stages of maturity of testes of *S. tumbil* obtained between November 1979 and October 1981. (Number of specimens examined per month in brackets.)

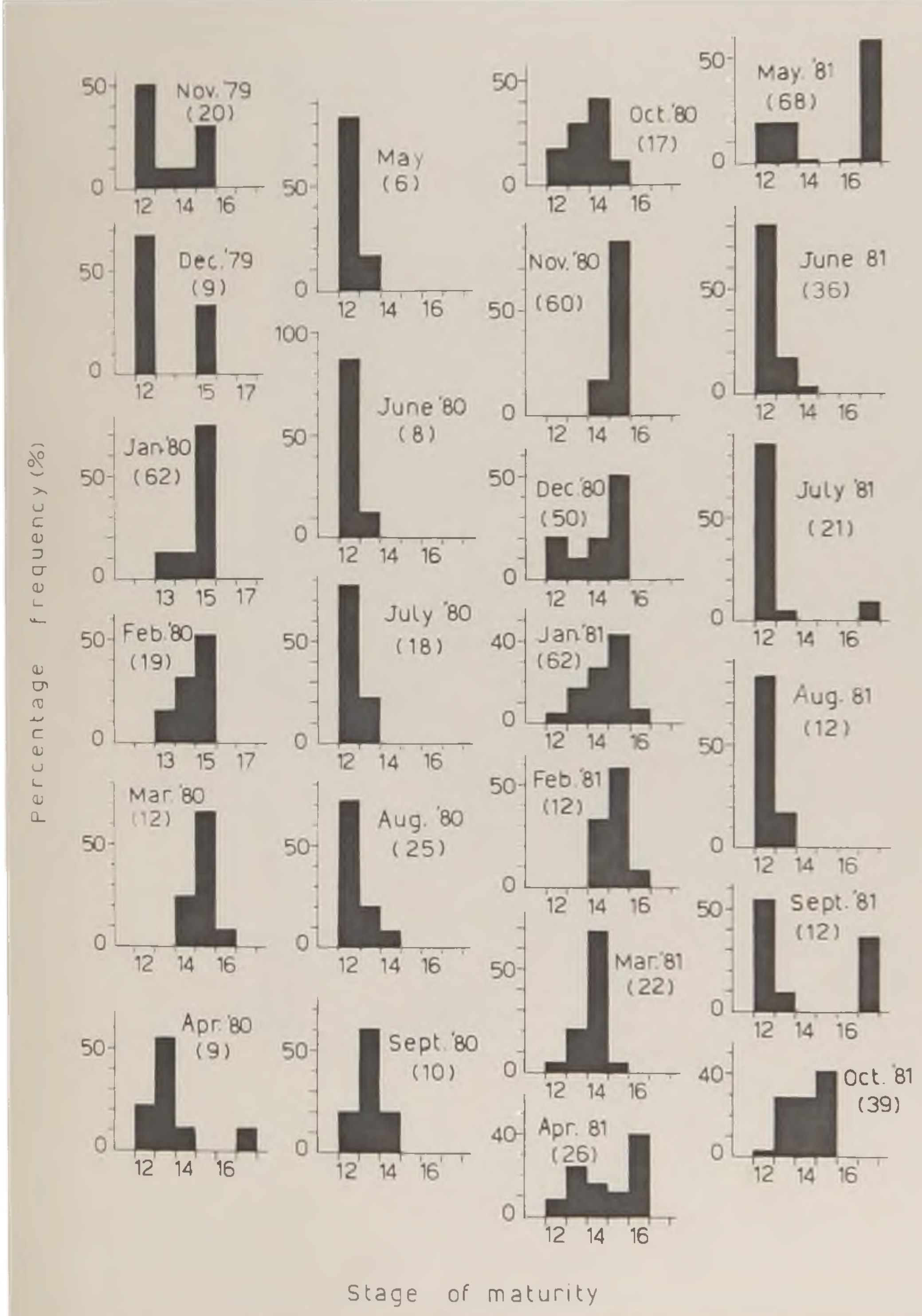

Percentage frequency (%)
Nov. '79 (20)
Dec. '79 (9)
Jan. '80 (62)
Feb. '80 (19)
Mar. '80 (12)
Apr. '80 (9)
May (6)
June '80 (8)
July '80 (18)
Aug. '80 (25)
Sept. '80 (10)
Oct. '80 (17)
Nov. '80 (60)
Dec. '80 (50)
Jan. '81 (62)
Feb. '81 (12)
Mar. '81 (22)
Apr. '81 (26)
May. '81 (68)
June '81 (36)
July '81 (21)
Aug. '81 (12)
Sept. '81 (12)
Oct. '81 (39)
0
40
50
100
12
13
14
15
16
17
Stage of maturity

Fig. 5.4E Frequencies of stages of maturity of ovaries of *S. filamentosa* obtained between May 1980 and February 1982. (Number of specimens examined per month in brackets; nd = no data.)

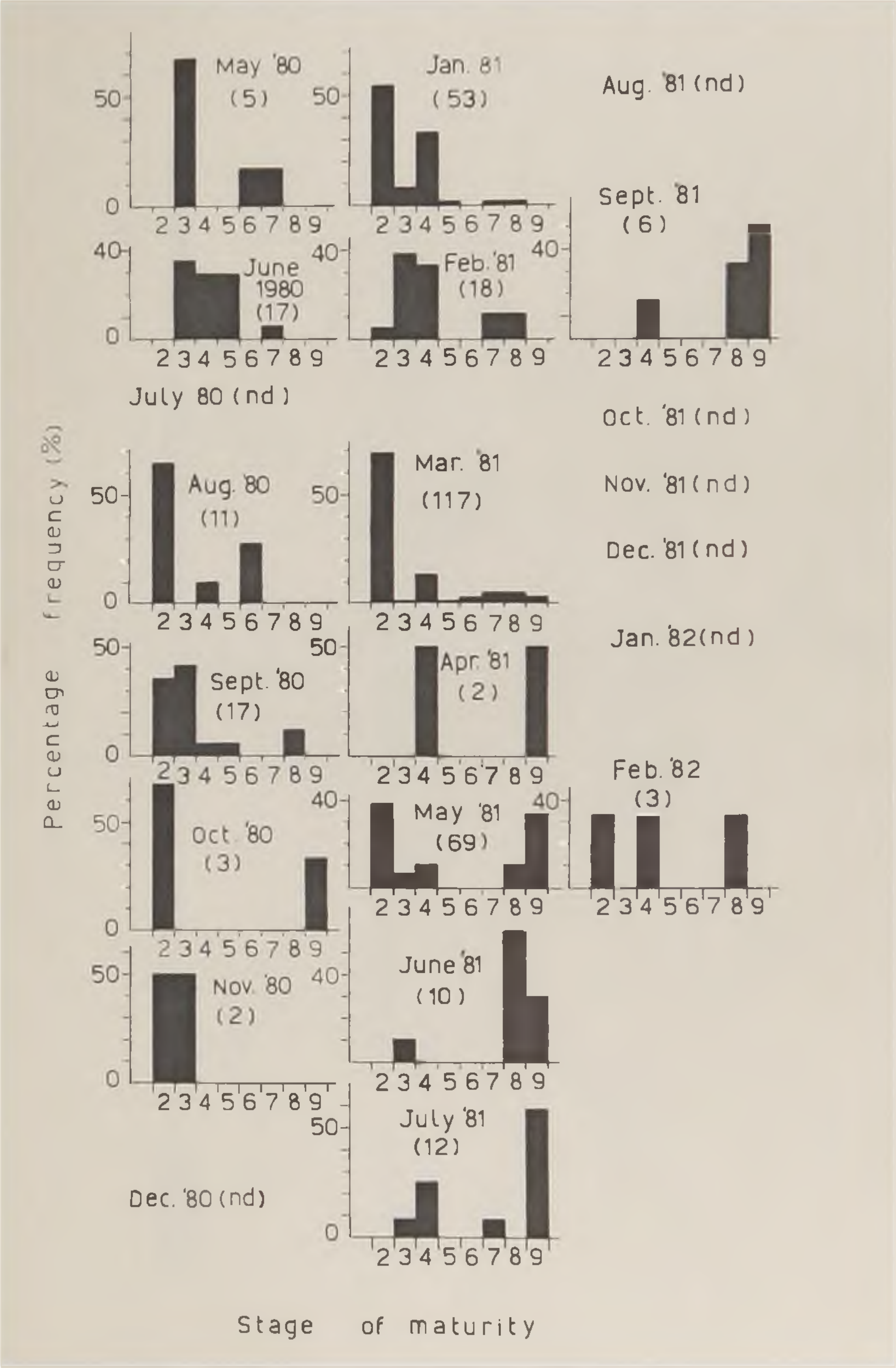

May '80
(5)
Jan. 81
(53)
Aug. '81 (nd)
June
1980
(17)
Feb. '81
(18)
Sept. '81
(6)
July 80 (nd)
Oct. '81 (nd)
Aug. '80
(11)
Mar. '81
(117)
Nov. '81 (nd)
Dec. '81 (nd)
Jan. '82 (nd)
Sept. '80
(17)
Apr. '81
(2)
Feb. '82
(3)
Oct. '80
(3)
May '81
(69)
Nov. '80
(2)
June '81
(10)
July '81
(12)
Dec. '80 (nd)
0
40
50
2 3 4 5 6 7 8 9
Percentage frequency (%)
Stage of maturity

Fig. 5.4F. Frequencies of stages of maturity of testes of *S. filamentosa* obtained between May 1980 and February 1982. (Number of specimens examined per month in brackets; nd = no data.)

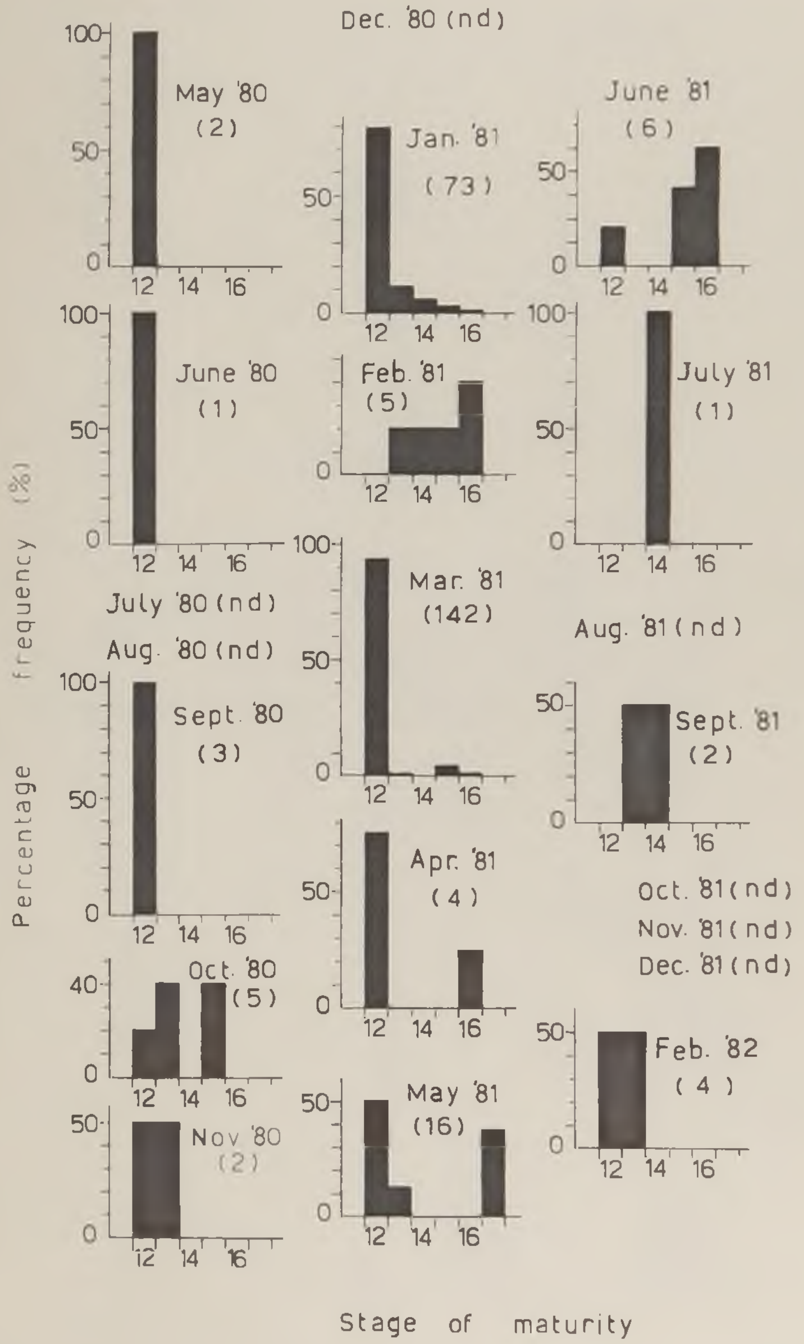

Dec. '80 (nd)
May '80
(2)
June '80
(1)
July '80 (nd)
Aug. '80 (nd)
Sept. '80
(3)
Oct. '80
(5)
Nov. '80
(2)
Jan. '81
(73)
Feb. '81
(5)
Mar. '81
(142)
Apr. '81
(4)
May '81
(16)
June '81
(6)
July '81
(1)
Aug. '81 (nd)
Sept. '81
(2)
Oct. '81 (nd)
Nov. '81 (nd)
Dec. '81 (nd)
Feb. '82
(4)
100
50
40
0
12
14
16
Percentage frequency (%)
Stage of maturity

Fig. 5.4G. Frequencies of stages of maturity of ovaries of *T. myops* obtained between June 1980 and February 1982. (Number of specimens examined per month in brackets; nd = no data.)

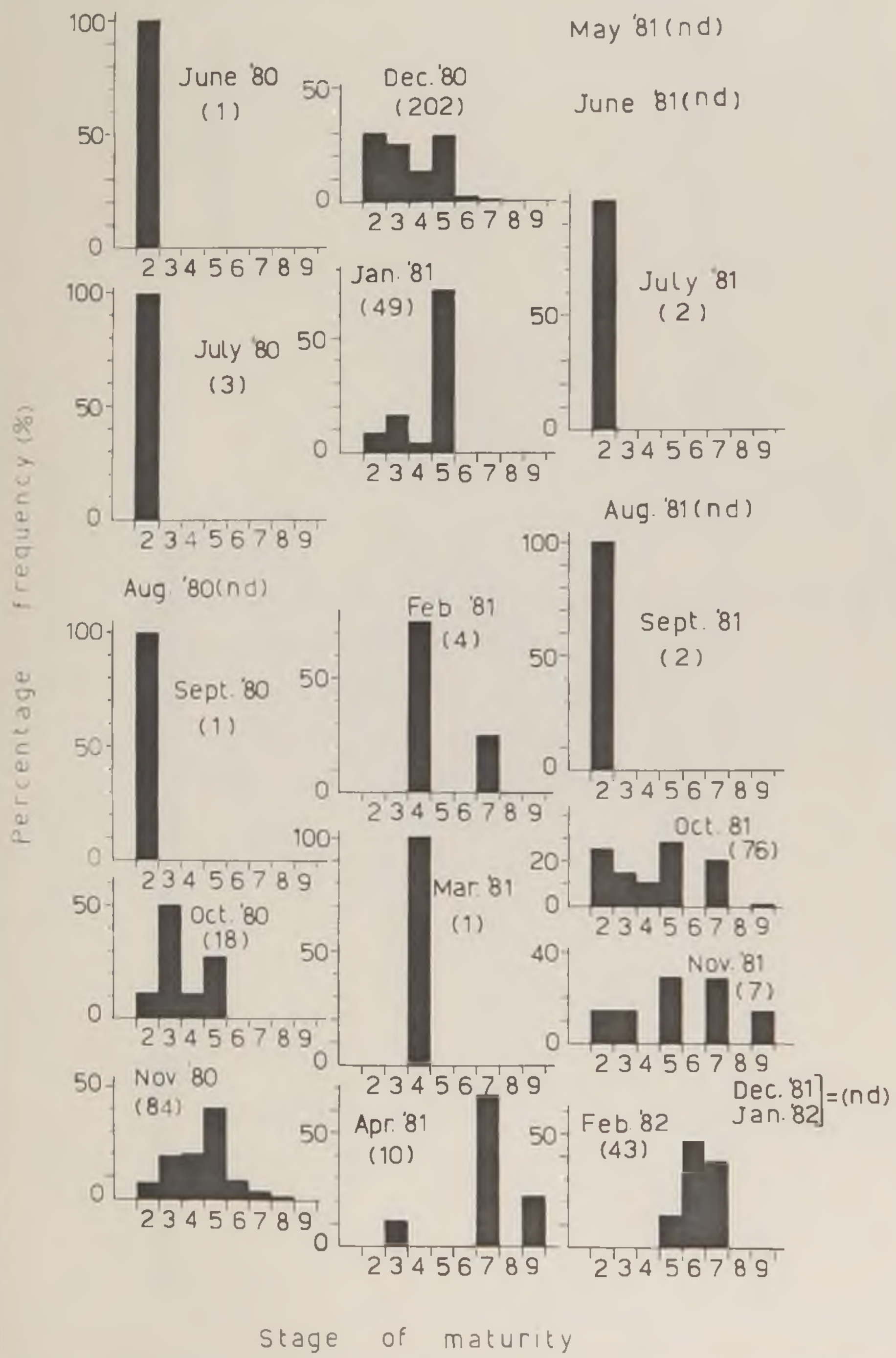
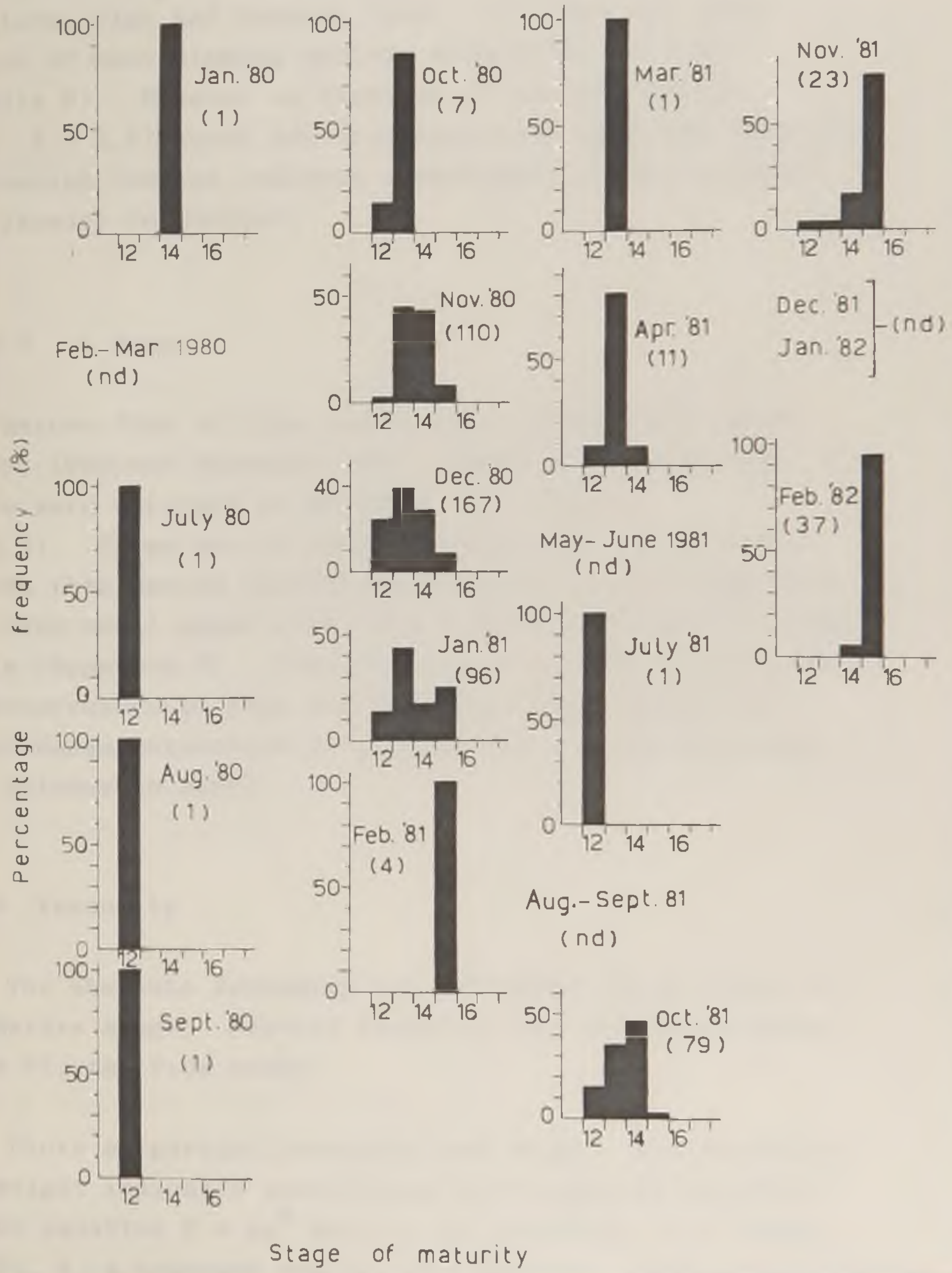

June '80 (1)
Dec. '80 (202)
May '81 (nd)
June '81 (nd)
July '80 (3)
Jan. '81 (49)
July '81 (2)
Aug. '80 (nd)
Aug. '81 (nd)
Sept. '80 (1)
Feb '81 (4)
Sept. '81 (2)
Oct. '80 (18)
Mar. '81 (1)
Oct. '81 (76)
Nov. '81 (7)
Nov. '80 (84)
Apr. '81 (10)
Feb. '82 (43)
Dec. '81
Jan. '82
=(nd)
100
50
40
20
0
2 3 4 5 6 7 8 9
Percentage frequency (%)
Stage of maturity

Fig. 5.4H. Frequencies of stages of maturity of testes of *T. myops* obtained between January 1980 and February 1982. (Number of specimens examined per month in brackets; nd = no data.)


Percentage frequency (%)
Stage of maturity
Jan. '80 (1)
Feb.– Mar. 1980 (nd)
July '80 (1)
Aug. '80 (1)
Sept. '80 (1)
Oct. '80 (7)
Nov. '80 (110)
Dec. '80 (167)
Jan. '81 (96)
Feb. '81 (4)
Mar. '81 (1)
Apr. '81 (11)
May– June 1981 (nd)
July '81 (1)
Aug.– Sept. 81 (nd)
Oct. '81 (79)
Nov. '81 (23)
Dec. '81
Jan. '82
(nd)
Feb. '82 (37)
0
40
50
100
12
14
16

5.3.4.2 *S. filamentosa*

Two years (1980-82) data were combined in the estimation of the spawning season based on the occurrence of mature, ripe and running fish. G.I. was not used because of many missing monthly data (Figs. 5.3 A,B; Appendix 6). However an overview of pooled results (Figs. 5.4 E,F) about the occurrences of ripe and spawning and running females indicate a prolonged spawning season from January to October.

5.3.4.3 *T. myops*

Mature fish of this species were observed between October 1980 and February 1982. Spent and recovering stages were obtained in November 1981 (Figs. 5.4 G,H). These are in agreement with the trend in G.I. between this period (pooled data; Figs. 5.3 A,B; Appendix 6). Very small sized fish made 8.1% of the December 1980 sample (Appendix 7). Thus the trend in mean, maximum G.I. and occurrences of ripe and spawning fish indicate an asynchronous maturation of ovaries and a spawning season from October to April.

5.3.5 Fecundity

The absolute fecundity was estimated using Stage IV; the mature stage. Partial fecundity was estimated using Stage VI; the ripe ovary.

Plots of partial fecundity and length, and fecundity and weight indicated curvilinear relationships governed by the equation $F = ax^b$ where F is fecundity, x = length/ weight, a, a constant and b = an exponent. Each relationship was analysed by plotting its logarithmic transformation : log F = log a + b log x (Table 5.5A).

Table *5.5A : Constants in Fecundity equation

Species	a		b	
	SL	WT	ST	WT
S.undosquamis	2168.4	3107.7	0.3152	0.3142
S. tumbil	0.301	451.4	2.0082	0.7151
T. myops	470.4	641.4	0.4894	0.4886

Fecundity increased with increase in weight or length (Figs. 5.5 A-C). The estimated number of spawns per spawning season was calculated as the ratio of the absolute to partial fecundity.

The absolute fecundity range calculated for *S. filamentosa* was 401,855 (345mm) - 1,288,576 (575mm), whereas the partial fecundity range was 30796 (168mm) - 54823 (322mm). The other three species also have high absolute and relative fecundities (Table 5.5B). Considering only specimens from the bay, *S. undosquamis* was found to be more fecund and also more abundant (Appendix 7) than *S. tumbil*.

* SL = Standard length and WT = whole body weight

Fig. 5.5A. Scatter diagram showing the relationship between fecundity and standard length (●)/weight (+) of *S. undosquamis*.

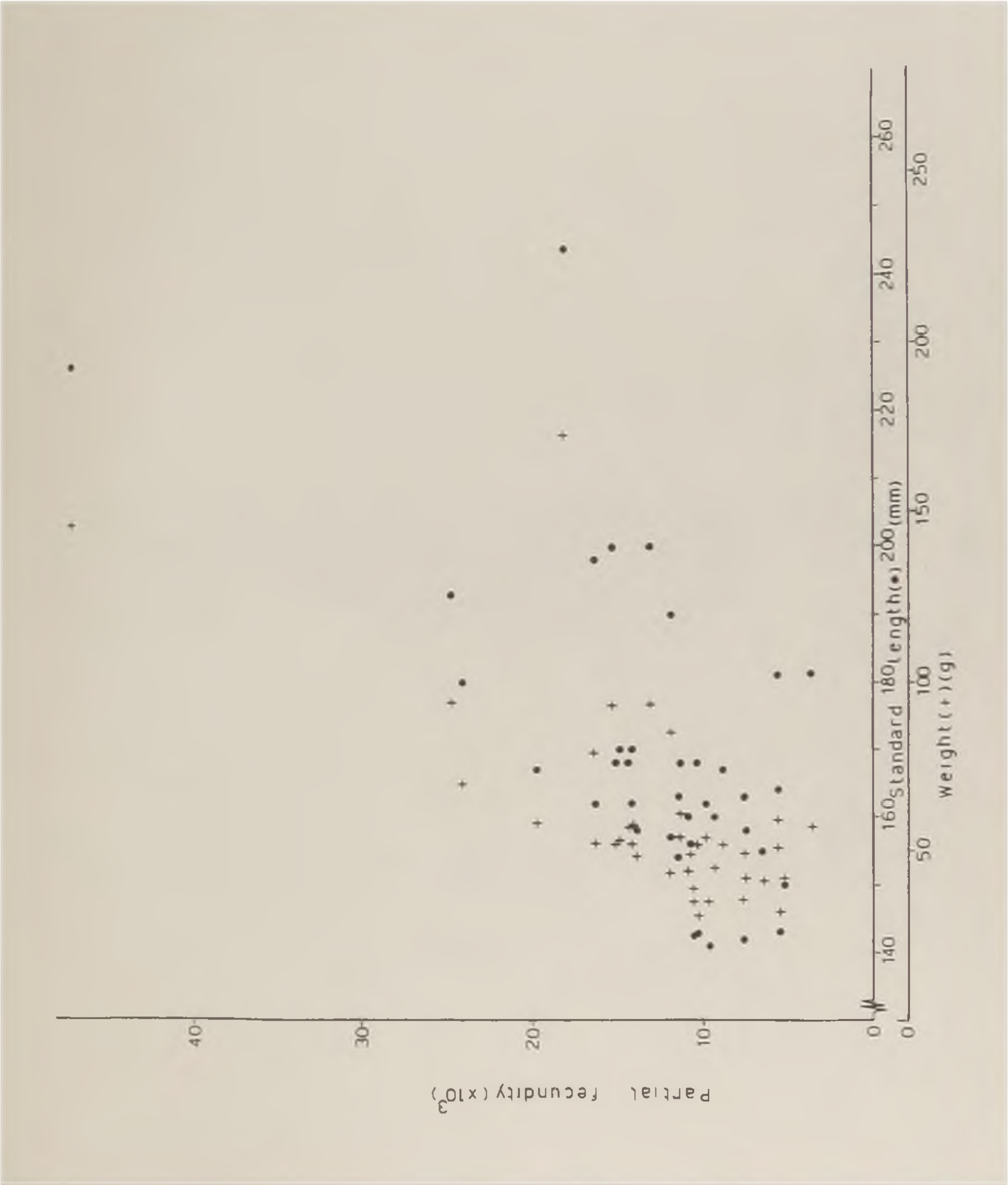

Partial fecundity (x10^3)
0
10
20
30
40
Standard length (•) (mm)
140
160
180
200
220
240
260
Weight (+) (g)
0
50
100
150
200
250

Fig. 5.5B. Scatter diagram showing the relationship between fecundity and standard length (●)/weight (+) of *S. tumbil*.

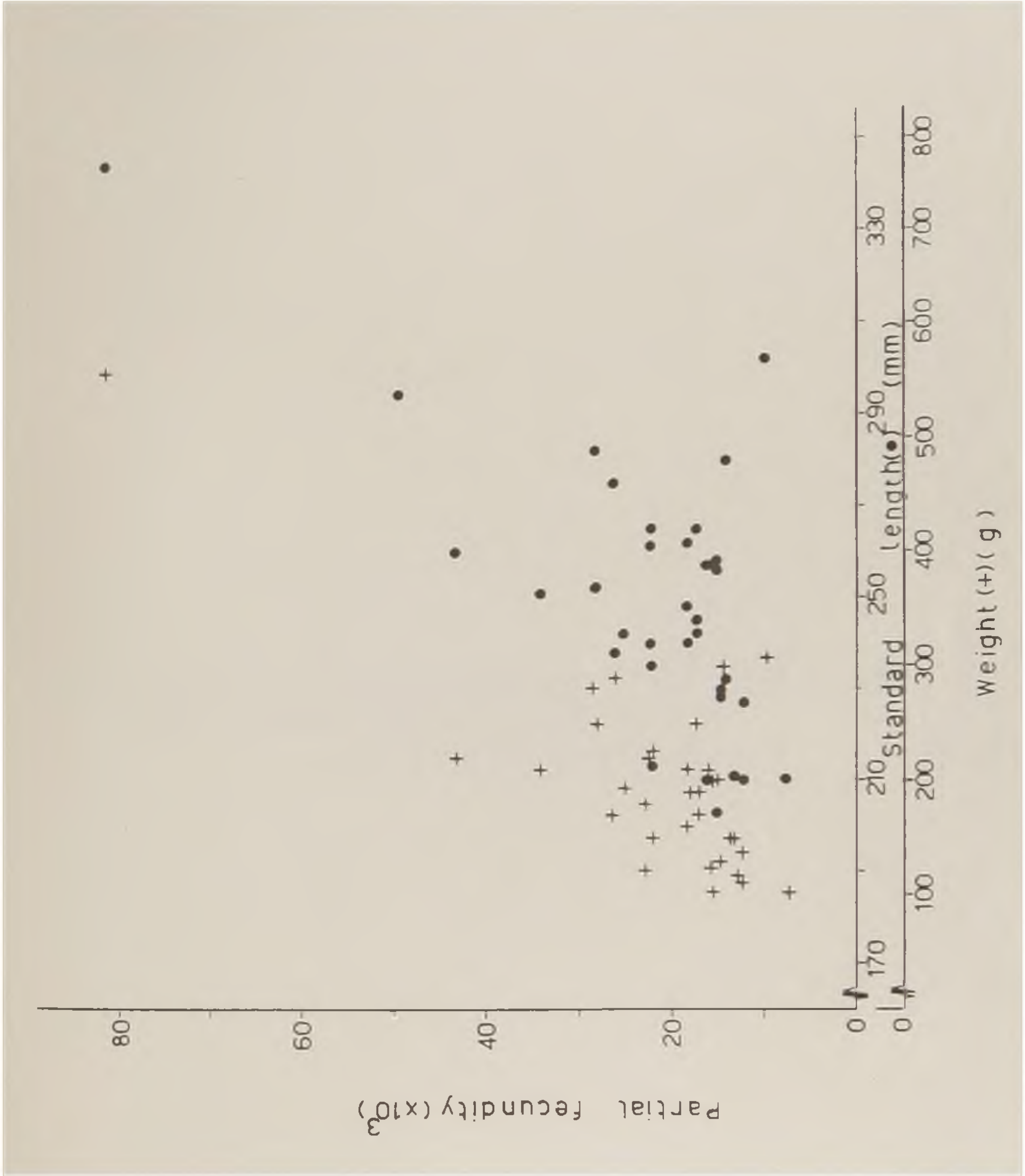

Partial fecundity (x10^3)
0
20
40
60
80
Standard length (●) (mm)
0
170
210
250
290
330
Weight (+) (g)
0
100
200
300
400
500
600
700
800

Fig. 5.5C. Scatter diagram showing the relationship between fecundity and standard length (●)/weight (+) of *T. myops*.

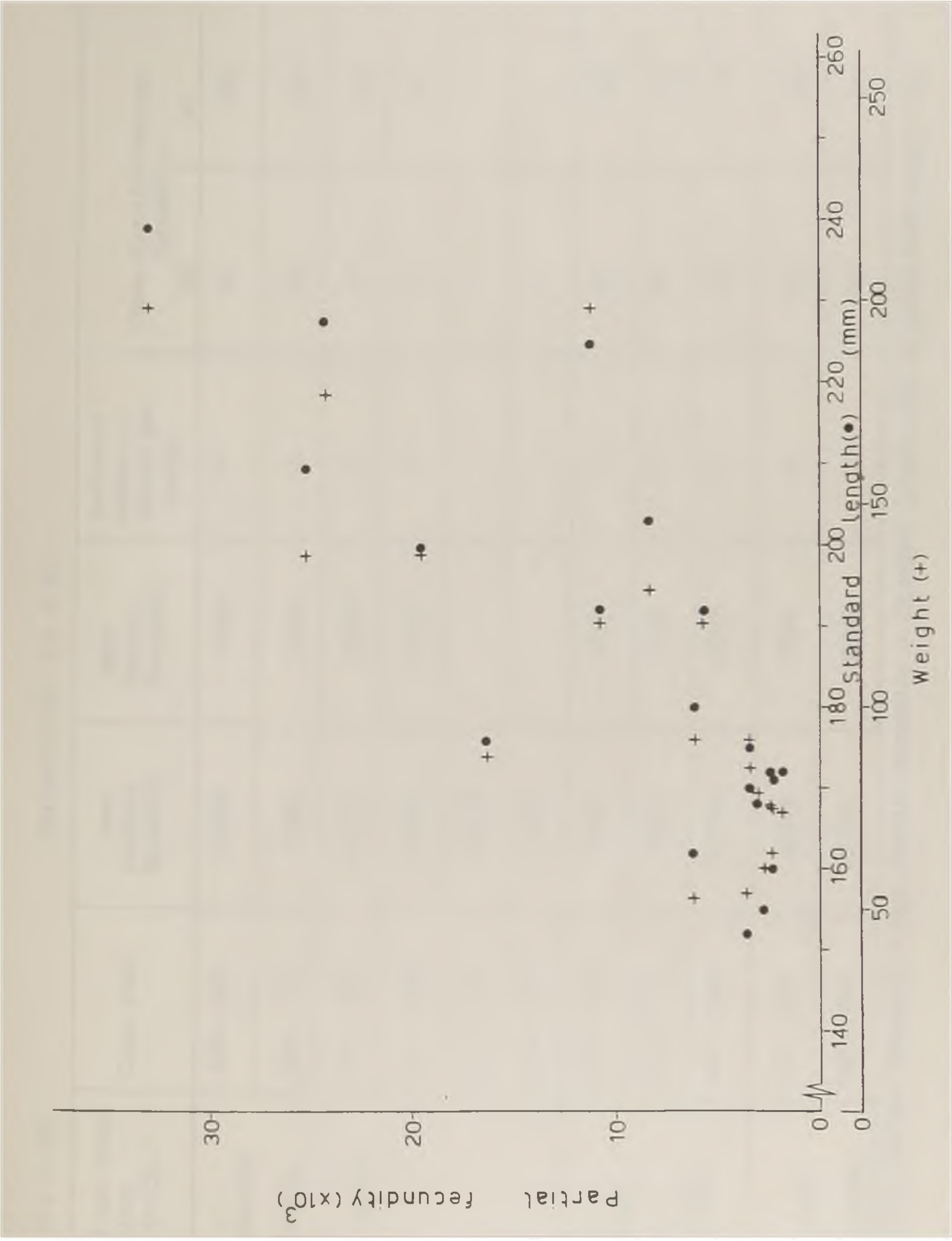

Partial fecundity (x10^3)
0
10
20
30
Standard length(●) (mm)
140
160
180
200
220
240
260
Weight (+)
0
50
100
150
200
250

Table 5.5B FECUNDITIES (N = 6)

Species and range of Absolute fecundity (SL)	Class size	Mean Absolute fecundity	Mean Partial Fecundity	Estimated number of spawns per season	*Mean Specific Partial fecundity SL	*Mean Specific Partial fecundity WT
S. undosquamis 19374 (154mm) to 190800 (263mm)	140 - 159	38022	9245	4	61	234
	160 - 179	23661	12094	2	73	227
	180 - 199	113264	14379	8	77	185
	200 - 219	66666	14145	5	71	151
	220 - 239	170934				
	260 - 279	190800				
S. tumbil 42433 (208mm) to 121701 (282mm)	200 - 219	42433	14591	3	69	126
	220 - 239	53545	17437	3	75	113
	280 - 299	121701	21334	6	76	74
T. myops 79490 (203mm) to 109200 (200mm)	200 - 219	93415	17641	5	86	129
	240 - 259	103156	32888	3	137	164

*Mean Specific Partial fecundity = Mean Partial Fecundity ÷ Standard length (SL) or whole body weight (WT)

Table 5.6

Chi-squared (x^2) ($p > 0.05$, 1 df = 3.841)

Test of Sex Ratios

PERIOD	*S. undosquamis*				*S. tumbil*			
	F_{fo}	M_{fo}	fe	X^2	F_{fo}	M_{fo}	fe	X^2
March '80 – August '80 (May '80 – August '80)	881	840	860.5	0.9768	78	67	72.5	0.8345
March '81 – August '81 (May '80 – August '81)	1149	1002	1075.5	10.0460	101	137	119.0	5.4453
September '80 – Jan. '80 (Sept. '80 – April '81)	298	322	310	0.9200	288	259	273.5	1.5370
1st year Nov. '79 – Oct. '80	1098	1039	1068.5	1.6289	278	225	251.5	5.5840
Nov. '80 – Oct. '81	1548	1497	1522.5	0.8542	374	421	397.5	2.2778
Study Period Nov. '79 – Dec. '81	2646	2536	2591	2.3350	652	646	649	0.0280

F – female
M – male
fo – number observed
fe – number expected
Period of *S. tumbil* in brackets.

5.3.6 Sex Ratio

Sex reversal was not observed in any of the four species studied.

5.3.6.1 *S. undosquamis*

The male to female monthly ratio varied considerably (Appendix 8). In the general population, chi squared tests indicated significant differences ($p > 0.05$) from the expected Mendelian ratio of 1:1 in many months. Sex ratio were then calculated by seasons and year to determine possible variation related to migration, natural mortalities or different distribution of sexes during the main spawning and non-spawning seasons. There was little evidence for any of the above. In the spawning season (September 1980 - January 1981), mature males outnumbered mature females at a ratio of 1.58 : 1.00. A significant trend was evident when sex ratios were calculated at 20mm intervals (Table 5.7). Males dominated intervals between 120 - 159mm and were poorly represented in samples greater than 200mm. Females dominated intervals between 160 - 300mm; an indication of sexual dimorphism in sizes. The largest male and female were 300 and 320mm respectively.

5.3.6.2 *S. tumbil*

In the general population, the sex ratios between April to August showed varying trends (Table 5.6). Chi squared tests demonstrated significant distribution of size by sex when sex ratios were calculated at 20mm size class intervals (Table 5.7). Males were essentially absent in samples greater than 260mm in length. Females were more abundant in all class sizes greater than 200mm; the males dominated the

Table 5.7

SEX RATIO DURING SPAWNING SEASON

Class sizes (mm)	*S. undosquamis*				*S. tumbil*			
	Fish numbers			Chi-squared value	Fish numbers			Chi squared value
	observed female	observed male	expected		observed female	observed male	expected	
60 – 79	0	0	–					
80 – 99	3	1	2	1.0000	0	1		
100 – 119	14	14	14	0	4	1	2.5	1.8000
120 – 139	54	124	89	27.5281	1	3	2	1.0000
140 – 159	171	400	285.5	91.8406	10	18	14	2.2857
160 – 179	161	87	124.0	22.0806	11	134	72.5	104.3379
180 – 199	106	24	65.0	51.7230	16	139	77.5	96.6064
200 – 219	38	1	19.5	35.1026	59	15	37	26.1622
220 – 239	9	1	5	6.40	60	7	33.5	41.9254
240 – 259	4	0			85	2	43.5	79.1839
260 – 279	4	0			68	0		
280 – 299	0	1			26	0		
300 – 319	0	0			15	0		
320 – 339	0	0			5	0		
340 – 359	0	0			2	0		

Table 5.8

MONTHLY SEX RATIO DURING SPAWNING SEASON

Month and Year	*S. filamentosa*				*T. myops*			
	Fish numbers			Chi-squared value	Fish numbers			Chi-squared value
	observed female	observed male	expected		observed female	observed male	expected	
October 1980					18	7	12.5	4.840
November 1980					84	110	97	3.485
December 1980					202	162	182	4.396
January 1981	53	73	63	3.175	49	96	72.5	15.234
February 1981	18	5	11.5	7.347	4	4	4	0
March 1981	117	142	129.5	2.413	1	1	1	0
April 1981	2	4	3	0.667	10	11	10.5	0.048
May 1981	69	16	42.5	33.047				
June 1981	10	6	8	1.000				
July 1981	12	1	6.5	9.308				
September 1981	6	2	4	2.000				
Spawning season	287	249	268	2.694	368	385	376.5	0.384

range 160-199mm. Mature females outnumbered mature males at a ratio of 1.10:1.00. The largest male observed was 246mm. The evidence suggests sexual dimorphism in sizes.

5.3.6.3 *S. filamentosa* and *T. myops*

These two species could not be analysed for yearly or seasonal differences in sex ratios because of the absence of many monthly data. Therefore these findings should be considered preliminary.

Chi squared tests of observed monthly sex ratio in the spawning season showed significant differences ($p > 0.05$) (Table 5.8). The observed sex ratios of the spawning season as a whole did not however show any significant differences in the two species. In the mature population, males were found to be significantly more abundant in sizes equal to or less than 179mm and 239mm in *T. myops* (Table 5.2) and *S. filamentosa* (Table 5.3) respectively. The females dominated sizes equal to or less than 180mm and 240mm, also respectively. This is evidence for sexual dimorphism in the two species.

The second and third dorsal rays of *S. filamentosa* are usually elongated and filamentous (Ogilby, 1910; Norman, 1935; Shindo and Yamada, 1972; and personal observation). The percentage ratios of the length of second and third dorsal rays to the standard length were calculated to determine possible variation related to standard length or sex (Table 5.9).

Table 5.9 : Percentage ratios of second and third dorsal rays to standard length of *S. filamentosa* (N) = number of fish sampled.

Standard Length (mm)	Second Dorsal Ray (%)						Third Dorsal Ray (%)					
	Male			Female			Male			Female		
	min.	mean	max.	min.	mean	max.	min.	mean	max.	min.	mean	max
200	18	(90) 27	40	20	(49) 26	31	16	(114) 22	32	19	(61) 22	25
201-300	27	(17) 34	38	22	(70) 32	39	18	(28) 23	28	18	(90) 22	28
300				23	(18) 30	38				16	(22) 20	25
*211-265	39	(9) 42	48				23	(6) 25	28			
**216-300				37	(18) 41	46				21	(23) 11	25
301**				38	(2) 40	41				22	(2) 24	25

* Males)
** Females) Fish with second dorsal ray reaching to or beyond adipose fin.

The sex did not have any effect on the length of any of the two rays. However, the means of the two ratios of fish below 300mm showed increases with increasing fish length (see Table 5.9).

In some of the fish, the second dorsal ray extended to or beyond the origin of the dorsal adipose fin when laid back. In these fish; equal to or more than 200mm in length, the mean ratios were about 40%.

5.4 DISCUSSION

Saurida and *Trachinocephalus* ova are pelagic. Similar results were obtained by Delsman (1938); Nair (1952); Kuthalingham (1959) and Mito (1961). However none of the above workers reported the presence of tiny scattered oil droplets in the yolk in the above genera. Oil droplets have however been reported in the third genus; *Synodus*, by Sanzo (1915).*

The ova of *T. myops* are probably identical with "...... few pelagic eggs of unknown origin but evidently belonging to species more or less related to the Myctophoidea .... and characterised by the peculiar design of the egg membrane which bears on its surface a great number of short appendages giving it a prickly appearance" (Delsman, 1938). The hexagonal meshes and cilia probably confer rigidity and protection against damage whilst floating on the currents. The oil droplets might be of nutritional value since the development of Synodontidae egg is slow (Delsman, 1938; Nair, 1952; and Kuthalingam, 1959).

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* Quoted in Breder, 1944.

Ripe ova sizes ranged from 0.62mm to 1.35mm in the four species (Table 5.1). These are consistent with the findings of Delsman (1938) in the Java Sea, Kuthalingam (1959) in the Bay of Bengal, Mito (1961) in Japanese waters and Annigeri (1963) in the Arabian Sea. However, Buchichenko and Dimitrova (1979) reported a maximum of 1.6mm for *S. undosquamis* in the Arabian Sea. This is probably an indication of the large sizes they worked on - up to a maximum of 490mm, whereas the largest obtained in this study was 320mm.

The stages of maturity were derived from a combination of types, quantities and macroscopic appearance of the gonads. There were eight and six stages of identifiable gonads for females and males respectively. Budnichenko and Dimitrova (1979) described six stages of ovaries. The disparity is due to their lumping together of 1) maturing and mature stages as Stage III and 2) ripening, gravid and running ripe as Stage IV. Latif and Shenouda (1973) described five stages *sensu* Hjorts (1910).

The time of onset of maturity varies amongst the species (Nikolsky, 1963). The range of $S.L_{50}$ for males and females of the species indicate *S. undosquamis* and *T. myops* attain sexual maturity within or just after the first year, and 1 - 2 years in *S. tumbil* and *S. filamentosa*. Budnichenko and Dimitrova (1979) reported sexual maturity of *S. undosquamis* at 1+, 110 - 120mm and 2+, 150 - 160mm for males and females respectively from samples collected in the Arabian Sea. Latif and Shenouda (1973), reporting from a similar latitude as for the present investigation, noted that fish of 160mm long or more in body length and at 1 - 2+ were sexually mature.

S. tumbil attains sexual maturity at 180 - 190mm, 1 or 2+ in males and 200 - 210mm, 2 or 3+ in females in the Arabian Sea (Budnichenko and Nor 1978, Budnichenko and Dimitrova, 1979). However, Yamada (1968a) reported the average and minimum size of *S. tumbil* at first maturity as 310mm and 203mm in fork length in females, and 250mm and 240mm in males in the East China Sea.

Using data provided in Liu and Tung (1959) on what they thought was *S. tumbil* but *S. filamentosa,* I estimated $S.L_{50}$ of the males and females to be 290 - 200mm and 400 - 410mm respectively. The evidence suggests that sizes of the four species bear a relationship to $S.L_{50}$. For instance, the smaller $S.L_{50}$, the lower the minimum size observed as mature (Table 5.4).

In the majority of widely distributed species, maturity usually sets in later at higher latitudes than at lower ones (Nikolsky, 1963). Available evidence suggests that $S.L_{50}$ varies with latitude (Fig. 5.6). Sinoda and Intong (1978) noted that "the significant difference of sizes between temperate and tropical lizardfish seems to be due to influence of temperature on the growth parameter." However the abundance of food exerts a direct influence upon the time of onset of maturity (Nikolsky, 1963). The rates of growth and of maturation of *S. undosquamis* and *S. tumbil* are slower in the north-east region of the Arabian Sea than in the north-western region (Budnichenko and Nor, 1978). *Maksimov (1972) reported that the slow rate of growth in the eastern part of the Arabian Sea is the result of sub-normal productivity which appears to be correlated with the scarcity of nutrients. Thus, the evidence suggests that though $S.L_{50}$ varies with latitudes (temperature?) it is greatly influenced by food supplies.

Saurida and *Trachinocephalus* species are sexually dimorphic in size. The females attain larger sizes. Males are abundant between minimum size at maturity and $S.L_{50}$ (male).

* Quoted in Budnichenko and Nor, 1978.

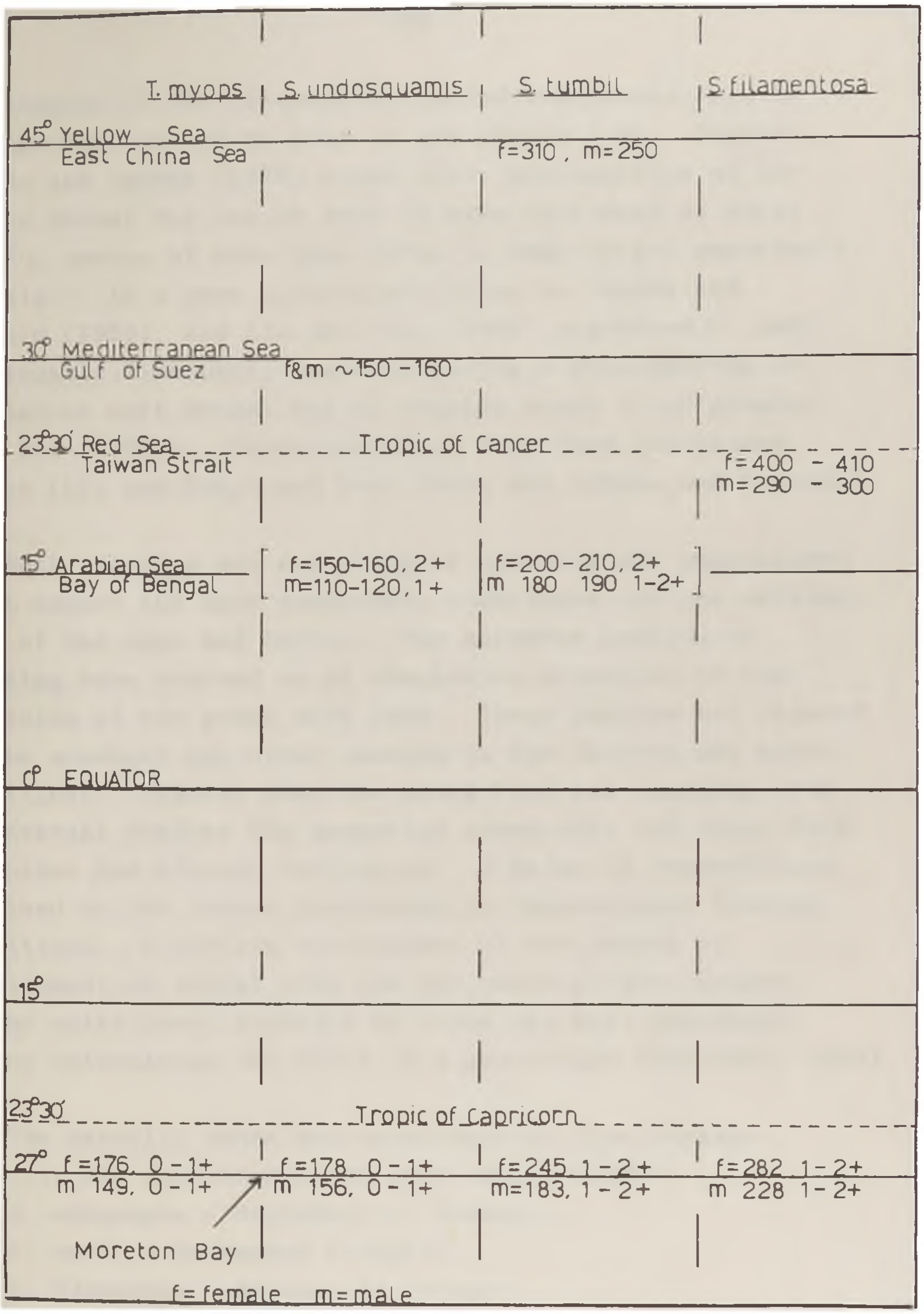

Fig. 5.6. S.L$_{50}$ and Latitude

The lengths of the filamentous second and dorsal rays of *S. filamentosa* showed no bias in sex (Table 5.9). However, Shindo and Yamada (1972) noted that "prolongation of the second dorsal ray can be seen in many specimens of adult of * *S. wanieso* of more than 300mm in body length especially in male." In a case of misidentification, Okada and Kyushin (1955), and Liu and Tung (1959) described *S. tumbil* as sexually dimorphic; the male having a prolongation of the second soft dorsal ray at lengths equal to or greater than 250 - 300mm. Their specimens were from the Taiwan Strait (Liu and Tung) and East China Sea (Okada and Kyushin).

Both the time and the place of spawning are adaptations which ensure the most favourable conditions for the development of the eggs and larvae. The calendar periods of spawning have evolved as an adaptation primarily to the provision of the young with food. These periods are related to the seasonal and other changes in the abiotic and biotic conditions. Usually when the young fish are changing over to external feeding the essential planktonic and other food organisms are already developing. A delay in reproduction may lead to the larvae developing in impoverished feeding conditions. A certain coincidence of the course of development of larval fish and the phase of development of the nutritional plankton is often the most important factor determining the yield of a generation (Nikolsky, 1963).

The maturity index and occurrence of ripe females indicate the species spawned over long periods:

S. undosquamis - September to January.
S. tumbil - September to April
S. filamentosa - January to October
(and probably all year round)
T. myops - October to April.

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* Conspecific with *S. filamentosa*

The onset of maturation (Figs. 5.3 A,B) and spawning (Figs. 5.3 A,B: 5.4 A-D, G, H) coincide with the rise in mean air temperatures and rainfall respectively (Fig. 5.7). It should be noted that mean air temperature profiles are consistent with water temperatures obtained in Moreton Bay by Stephenson, Cook and Raphael (1977).

Unlike many other pelagic fish eggs, the development of eggs of *Saurida* is very slow and the eggs take between 48 and 120 hours to hatch (Delsman, 1938; Nair, 1952; and Kuthalingam, 1959). Feeding begins after transformation of prolarva into postlarva; about 3 days after hatching and diet is planktonic (Kuthalingam, 1959). This means there is a time lag of about seven days from spawning to post-larval feeding. Thus in Moreton Bay, the continual outwash of the Brisbane River loaded with good supplies of nutrients - well distributed by the movements of the water - coupled with warm temperatures ensure abundance of plankton for, amongst those of other fish, the larvae of *S. undosquamis*, *S. tumbil* and *T. myops* from September to April and probably beyond. Nutrients are also continually released and replenished by wave disturbance of the sediments by strong winds accompanying the period. Thus, though the onset of spawning coincides with the rise in rainfall (Fig. 5.7), the slow development of the ova guarantees the prior availability of plankton before the emergence of larvae.

The evidence for the importance of food in spawning habits of *T. myops* and *S. filamentosa* within and without Moreton Bay is less convincing because of inadequate data. Very few small and immature *T. myops* and no *S. filamentosa* were collected in Moreton Bay. They were obtained off-shore. Further work off-shore is required to determine stimuli to spawning and other factors important to survival of their larvae. Availability and abundance of food might trigger maturation and spawning. For it is probable that the larvae

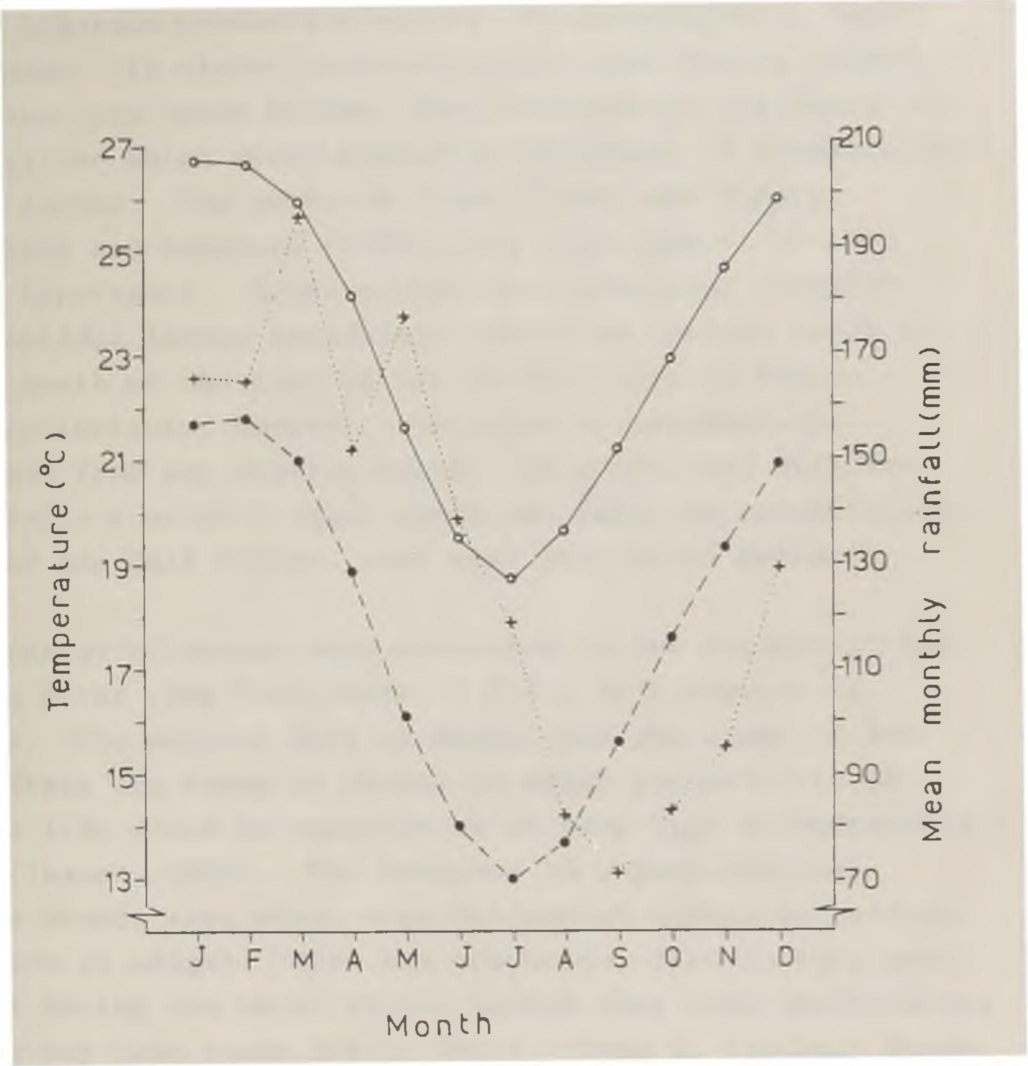


Fig. 5.7 Mean monthly rainfall (+), mean monthly minimum (●) and maximum (○) temperatures recorded at Cape Moreton Lighthouse weather station by the Bureau of Meteorology between 1958 and 1981

move down the water column to take advantage of relatively great plankton production within the discontinuity layer in summer. In winter, convection and wind mixing extend deep into the water column, thus bringing up nutrients to the surface which would guarantee abundance of plankton to their larvae. The works of Gibbs (1959) and Tabery, Ricciardi and Chambers (1978) give some support to the above hypothesis. Gibbs (1959) collected many Atlantic Synodontidae larvae including *T. myops* from shallow water in every month of the year in the Western Gulf of Mexico. Some collections, however, were made at considerable distance from any shallow water. He noted that this was especially true of *T. myops* which was taken on occasion, in or near the Gulf Stream, over more than 2,000 metres!

Larvae of *Synodus* were collected in the estuary of the Hudson River (New York State, U.S.A.) by Tabery et al (1978). The western Gulf of Mexico and the coast of New York State are areas of mixing in which productivity of marine life would be expected to be very high or moderately high (Isaacs, 1969). The Sargosso is a semi-tropical marine desert area where even horizontal mixing by surface currents is slight. Here the production rate is very poor, except during the brief winter period when some convectional mixing may take place (Tait, 1981). Thus in the Gulf Steam, *T. myops* larvae must descend to great depths for their food supplies.

The works of several others too indicate a correlation between the onset of spawning, spawning and the occurrence of larvae on the one hand, and the food supplies on the other.

Budnichenko and Dimitrova (1979) noted that the spawning in *S. undosquamis* and *S. tumbil* in the Arabian Sea reach a maximum in the winter monsoon. Tait (1981) reported that in the north Indian Ocean, upwelling occurred in the northern-most part of the Arabian Sea during the winter north-east monsoon, and off the Arabian and Somali coast in summer when the monsoon current developed. This is substantiated materially by Fursa (1969, 1976)* who provided data showing that larger numbers of lizardfish hatchlings occurred in winter than in summer in waters of Western Hindustan (Eastern Arabian Sea).

Saurida species spawn between June (onset of spring) and September (onset of autumn) in the Japanese (Tatara, 1965), East China (Yamada, 1968a) and Mediterranean (Bograd-Zismann, 1961-62**; Chervinsky, 1959**) Seas. This period is characterized by favourable combination of temperature, light, nutrient supply (from mixing (Isaacs, 1969)) and stable water column and a subsequent enormous increase in the quantity of plankton (Tait, 1981).

In the tropics, Sinoda and Intong (1978), after analysing size frequency distribution of the *S. undosquamis* from the east coast of the inner Gulf of Thailand, concluded that *S. undosquamis* spawns all through the year. And in the off-shore waters of the Madras Coast; Bay of Bengal, where there is little or no seasonal variation in sea water temperature (Varadarajan and Subramoniam, 1982), *S. tumbil* spawns from November to February (Annigeri, 1963); a period of high nutrient content due to upwelling (Muthu, 1956)***. From the foregoing, the *Saurida* in the Arabian Sea, the Bay of Bengal and Gulf of Thailand, all in the tropics, have various spawning times and durations. Thus, the general conclusion is that whereas in the temperate areas temperature and food availability determines onset and duration of spawning, in the tropics it appears that only the availability of food is critical.

* Quoted in Budnichenko and Dimitrova, 1974.

** Quoted in Ben-Yami and Glaser, 1974.

*** Quoted in Varadarajan and Subramoniam, 1982.

Intra- and inter-species spawning periods were also reported from the East China Sea. Tatara (1965) found different spawning times in two sub-populations of *S. undosquamis:* May to August for the eastern sub-population and June to September for the western sub-population. The period of *S. tumbil*, April to June, overlapped the above two. Here in Moreton Bay the peaks and durations of *S. tumbil* and *S. undosquamis* though overlapping, were quite different. *S. filamentosa* spawned all year in the open sea.

Fecundity of lizardfish is quite high, and in a curvilinear relationship with either standard length or weight (Figs. 5.5A - 5.5C). Table 5.10 lists relative fecundities.

Table 5.10

Relative Fecundity (R.F.) and Number of Spawnings of Lizardfish

Species	per gram total weight	per mm standard length	Number of spawns per season
S. undosquamis	906	340	2 - 8
S. tumbil	387	296	3 - 6
T. myops	569	420	3 - 5

The high ova production to body weight is maintained by serial spawning as a result of asynchronous maturation. The number of spawnings per season was approximated as the multiple factor of mean partial fecundity in the mean absolute fecundity per size class (Table 5.5B).

Similar results have been found in the Arabian Sea (Budnichenko and Dimitrova, 1979) and in the East China Sea (Yamada, 1968a). However, Latif and Shenouda (1973) reported a straight line relationship between fecundity and any of the following variables: length, weight and age. And also a straight line relationship between length and R.F (S.L) but found R.F (Wt) to be constant.

S. tumbil and *S. undosquamis* spawn in Moreton Bay and circumstantial evidence suggests that the latter probably also occurs and spawns off-shore: One spent male* and one mature female* were collected off-shore from 80 - 160m. Similar results found elsewhere support the above hypothesis. In the Gulf of Thailand, *S. undosquamis* greater than 210mm migrate to deeper waters (Sinoda and Intong, 1978). Ben-Yami and Glaser (1974) reported that lizardfish spread over deeper trawling grounds during the warm season in the Levant Basin of the Red Sea. From the Sea of Japan, Tatara (1965) reports that "Distribution of *S. undosquamis* changed little by little as its age advances, it occurred mainly in the Channel waters in larval and fry stages, and then covered all the Inland Sea in immature stage, range of migration became wider in adult stage. Its distribution in winter was limited to the Channel waters, but its range expanded both in spawning and feeding seasons." Budnichenko and Dimitrova (1969) found *S. undosquamis* and *S. tumbil* in depths down to 500m and 300m respectively in the Arabian Sea.

The monthly seasonal and yearly variation in sex ratios of *S. undosquamis* and *S. tumbil* suggests differential natural mortalities of sexes assuming equal fishing mortalities. Latif and Shenouda (1973) found an inverse relationship between percentages of males and females in *S. undosquamis* in the Gulf of Suez in 19 months sampling. Tatara (1965)

* The largest obtained during the study.

reported differences between sexes in natural mortalities in two sub-populations in the Sea of Japan - with the males having high natural mortality (Table 5.11).

Table 5.11*
Annual mortalities in *S. undosquamis*
(M = male, F = female)

Sub-population	Sex	Total Mortality	Fishing Mortality	Natural Mortality
Eastern	M	0.96	0.69	0.87
	F	0.87		0.59
Western	M	0.88	0.45	0.87
	F	0.72		0.59

The larger class sizes either consisted exclusively of females or were dominated by them. This is the result of differential growth rate between the sexes and greater maximum age of females (Tatara, 1965; Budnichenko and Nor, 1978; Sainsbury and Whitelaw, 1981). Maximal increase is observed in 1+ group; in succeeding year groupings the rate of increase decreases (Budnichenko and Nor, 1978). These differences in growth rate and natural mortality are reflected in the calculated asymptotic lengths of 571mm for females and 466mm for males (Sainsbury and Whitelaw, 1981). The dominance of males in the small size groups (Table 2 and 3) and the differences in $S.L_{50}$ (Tables 5.4) for males and females appear to maintain a 1:1 sex ratio in the spawning population (Tables 5.6 to 5.8).

In *S. undosquamis* and *S. tumbil* the sex ratios for mature males and mature females were different, 1.58:1.00 and 1.00:1.10 respectively. Thus, *S. undosquamis* has a dominance

* Adopted from Tatara, 1965.

of males and *S. tumbil* , females. Yamada (1968a) observed that *S. tumbil* females were always more numerous and larger than males; fish equal or greater than 400mm were almost all female. On the other hand, Budnichenko and Nor (1978) reported that in spawning populations of younger fish, males outnumbered the females but in older age groups, females outnumbered the males in the Arabian Sea. Thus, it appears both length at maturity and differential sex ratios by length combine to produce equal male and female reproductive capacities in the spawning stock.

S. undosquamis outnumbered *S. tumbil* in Moreton Bay by a ratio of about 4:1. This is probably due to the relatively high fecundity of *S. undosquamis* per size (Table 5.5). In the Arabian Sea, the comparative numbers of *S. undosquamis* were greater than for *S. tumbil*, on the average 1-2 times as many (Budnichenko and Dimitrova, 1979). Here too Budnichenko and Dimitrova (1979) related the difference to the greater number of ova produced by the former on account of its greater population.

6. THE PARASITES OF FOUR LOCAL LIZARDFISH INCLUDING AN ANALYSIS OF THE FREQUENCY DISTRIBUTION OF THE CESTODE *C. GRACILIS* (LARVAE) (WITH REFERENCE TO THE NEGATIVE BINOMIAL DISTRIBUTION)

6.1 INTRODUCTION

Many organisms are parasitic on fishes. In the marine environment the common parasites are the helminths - trematodes, cestodes, nematodes and acanthocephalans (Lager, Bardach and Miller, 1962; Sindermann, 1966). Usually it is as larvae that the helminths are of greatest significance. Adults occur in the digestive tract and the larvae are usually found in the flesh or in the viscera (Sindermann, 1966). These parasites, as any others, may act directly or indirectly either to increase host susceptibility to predation or to diseases or to reduce competitive fitness (Anderson, 1982).

Parasitism is an ecological relationship that can be expressed quantitatively in terms of populations. One of the few methods of expressing this quantitative relation is the frequency distribution of the parasite in its host (Crofton, 1971). Individuals of any one kind (or species) are seldom, if ever, randomly disposed in space. Most commonly the distribution is overdispersed (i.e. variance > mean), implying a partially determinate pattern of distribution and thus a reservoir of information about the behaviour of the organisms concerned which could then be described in terms of empirical or fundamental mathematical models (Cassie, 1962). Cassie *(op cit)* states that "Empirically, it is desirable to condense the sample data, so that any given population may be described by a few parameters, which are readily comparable with the corresponding parameters of another population.... In such an application, the theory behind the model is relatively unimportant, provided it 'fits' the data in hand. The fundamental model, on the other hand, is based on some hypothesis of real biological significance. If it fits the data better than other possible models, it provides some justification for the hypothesis concerned." Cassie (1962) however cautioned that the same distribution may often be generated by different, and even contradictory, set of postulates.

Crofton (1971) pioneered and also justified the use of the negative binomial from amongst other similar models to describe the frequency distribution of parasites among hosts. Crofton *(op cit)* states that the negative binomial distribution can arise as a result of:

1) A series of exposures to infection in which each exposure is random but the chances of infection differs at each exposure or wave of infection.
2) The infective stage not being randomly distributed.
3) Infection increasing the chances of further infections occurring.
4) Infection decreasing the chances of further infection.
5) The variation in host individuals which makes the chances of infection unequal.
6) The chances of infection of individual hosts changing with time.

The negative binomial distribution is defined in terms of two parameters: 'k' and 'p'. The mean and variance of the negative binomial distribution can be calculated as follows:

mean; $\bar{X} = \frac{kq}{p}$ (.... equation 6.1)

variance; $V = \frac{kq}{p^2}$ (.... equation 6.2)

and $p = \frac{\bar{X}}{V}$ (.... equation 6.3)

The parameter 'p' must lie between zero and one, and 'k' may assume any positive value.

The negative binomial distribution is given by the expression $(q - p)^{-k}$ and the number of parasites can take the form

$$p_j = \binom{k + j - 1}{j} p^k q^j \qquad (j = 0,1,2,3,4...)$$

(.... equation 6.4)

Because $\binom{k-1}{o}$ = and

$$p_{j+1} = ((k+j)\, q/(j+1))\, p_j$$

(.... equation 6.5)

The fitted frequencies (F_j) may be calculated in the following manner:

$F_o = N_o p^k q^o$ and

$F_j = F_{(j-1)}\ (k+j-1)q/j$

where F_o and F_j are frequencies of zero and j parasites. (See Pollard, 1977 pp. 114-117)

The quantitative relationship between parasite and host is investigated by the application of the non-truncated and the truncated forms of the negative binomial distribution (Crofton, 1971). A good fit of observed data to the non-truncated form suggests the parasites probably had little effect on host mortality. The truncated form is dependent on the assumption that the parasite can kill their hosts and that the lethal effect is a function of the number of parasites in an individual host. A good fit to the truncated form therefore lends support to the latter hypothesis, in which case the observed data shows an abrupt fall in frequencies at higher infection levels when compared to the theoretical distribution (Crofton, 1971).

F, p and k are estimated by successive iteration, usually by computer. In finding the truncation point the usual procedure is to start with the low classes (e.g. 0,1,2, 3 ...) and determine values of F, p and k. The latter is referred to as truncation at 3. F, p and k can then be determined for 0-4 (truncation at 4), 0-5 and so on.

When the operation has proceeded until the last recorded frequency in the sample has been included the values for F, p and k should be the same as or identical to those obtained by fitting a negative binomial distribution to the whole of the observed data. If no truncation has occurred then the successive values of F, p and k should be constant. There will always be variation because the sample is finite and usually small, but in practice the estimates of F appear to be the best point of reference for quick inspection. If truncation has occurred this can be observed by reference to changes in F as well as in p and k. A precise truncation point is not easy to determine because tests for goodness of fit after iteration present considerable difficulties. In most cases, however, a specific level of truncation is rarely necessary because the values of F, p and k can be expressed in terms of narrow ranges (Crofton, 1971).

Pennycuick (1971d) satisfactorily fitted the non-truncated negative binomial to the frequency distribution of parasites in a population of three-spined sticklebacks, *Gasterosteus aculeatus* L. On the other hand Lester (1977) found that the best fit of the negative binomial to the trematode frequency distribution in a population of yellow perch, *Perca flavescens* was the truncated form - indicating the 'loss' of heavily infected fish from the sample. Lester *(op cit)* ascribed the 'loss' to higher mortality in the heavily infected fish.

The parasitic fauna of lizardfish are diverse but in the main the literature on these parasites are taxonomic descriptions or records. Little is known about the effect of these parasites on lizardfish populations.

The parasites of lizardfish include several species of protozoa (Narasimhamurti and Kalavati, 1972; Jensen, Moser and Heckmann, 1979), monogenean (Unnithan, 1972) and digenean trematodes, cestodes, acanthocephalans, nematodes (Overstreet, 1968; Rees, 1969; Parukhin, 1974; Jensen and Heckmann, 1977; Jensen, Moser and Heckmann, 1979), and ecto-parasitic crustaceans (Avdeev, 1977; Cressey and Cressey, 1979). Parukhin (1974) recorded 27 species of helminths in populations of five species of lizardfish in the Indian Ocean. Cressey and Cressey (1979) found 18 species of copepod parasites on 14 Indo-West Pacific lizardfish species.

The digestive tract and the gills of lizardfish harbour several species of trematodes. Unnithan (1972) reported a monogenetic trematode, *Sauricotyle sprostoni* on the gills of *S. tumbil* from the Arabian Sea. Species of *Lecithochirium*, *Sterrhurus* and several other digenean trematode genera have been reported to occur in the stomachs of *Synodus foetens*, *S. lucioceps*, *S. variegatus*, *Saurida undosquamis*, *S. gracilis*, *S. tumbil* and *Trachinocephalus myops* (Overstreet, 1968; Parukhin, 1974; Jensen, Moser and Heckmann, 1979). Several species of cestodes have also been found in lizardfish. Overstreet (1968) reported the occurrence of tetraphyllidean larvae in the body cavity and viscera of *Synodus foetens*. The adult pseudophyllidean, *Anantrum tortum* was found in the intestines of *S. foetens* (Overstreet, 1968) and *S. intermedius* (Rees, 1969). *S. lucioceps* plays host to adult *Anantrum histocephalum*, larval tetraphyllideans; *Scolex pleuronectis*, *Phyllobothrium sp.* and larval trypanorhynch; *Grillotia smarisgora*, *Lacistorhynchus tenuis* and *Callitetrarhynchus gracilis* (Jensen, Moser and Heckmann, 1979). Trypanorhyncha larvae also occur in *Saurida undosquamis*, *S. gracilis*, *S. tumbil*, *Synodus variegatus* and *Trachinocephalus myops* (Parukhin, 1974). Larval stages of nematodes (e.g. *Anisakis sp*) have been found in *Synodus foetens* (Overstreet, 1968), *S. lucioceps* (Jensen, Moser and Heckmann, 1979), *S. variegatus*, *Saurida undosquamis*, *S. gracilis* and *S. tumbil* (Parukhin, 1974).

The only quantification of a relationship between lizardfish and a parasite have been done on *Synodus foetens* - parasitic fauna from South Florida by Overstreet (1968). However this was limited to estimations of incidence and intensity of infection and associations among parasites. In this study, many members of the parasitic fauna of four local species were identified. The effect of the most common parasite in Moreton Bay lizardfish, *C. gracilis* (Rudolphi) 1819 on lizardfish population numbers was investigated by fitting the negative binomial to parasite-frequency distributions.

6.2. METHODS AND MATERIALS

The parasitic fauna of *Saurida tumbil*, *S. undosquamis*, *S. filamentosa* and *T. myops* were studied between November 1979 and December 1981. The process of preservation, measurement of length and the determination of sex of lizardfish followed the same procedures as described previously in the main introduction unless otherwise stated.

The presence of parasites was determined by direct examination of each fish. The general condition of each fish was noted and the external surface of the body and gills were carefully examined for parasites. Each fish was measured and sexed. The fish was cut open and the body and pericardial cavities and viscera were searched for parasites. The gut was slit along its length and also thoroughly searched for parasites under a binocular microscope - the search of the stomach and gonads were done concurrently with food item and gonad studies. In each case the parasites were removed and identified to the lowest systematic level possible. The position of each parasite in the host was also noted.

The number of species and individuals of lizardfish, and the initial fixation of many of the parasites by formalin (used to preserve lizardfish), precluded specific identification of many parasites. However some samples of lizardfish were periodically frozen in the field and identifications of the 'fresh' parasites made.

'Fresh' helminths (adults) were fixed in Berlund's fixative for specific identification. With regards to cestode larvae, the capsules of the cysts were broken and larvae left in distilled water for about 15+ minutes for the evagination of the hooked tentacles; important taxonomic features. These larvae were then fixed in 10% formalin for about two weeks and then transferred to 70% alcohol. Photographs were taken of the cestode larvae, some *in situ* (i.e. by the aorta).

Dr. Lester identified the cestodes and nematodes, whereas Dr. D.I. Gibson Museum of Natural History identified trematodes taken from the stomachs of *S. undosquamis*. Dr. Neil Bruce identified the crustacean parasites.

Initially only specific identifications of the parasites were envisaged. However, on account of the frequency of occurrence of the larvae of the cestode *C. gracilis* in *S. tumbil* and *S. undosquamis* during the preliminary survey, notes of the larvae distribution and location were incorporated into the main survey. Negative binomials were fitted to the frequencies of the larvae after having obtained k, p and q from equations 6.1 to 6.3. k was varied until the least variation between expected and observed distribution was obtained.

6.3 RESULTS

6.3.1 Parasite Fauna

Parasitological findings are summarized in Table 6.1. The most common parasites were trematodes and cestode larvae.

Table 6.1 : Parasites found in Lizardfish

Parasite	Site of Infection			
TREMATODES — Lizardfish Species =	*S. tumbil*	*S. undosquamis*	*S. filamentosa*	*T. myops*
Lecithochirium magnus Yamaguti 1938	ST?	ST		
Other digeneans (including Hemiuridae)	ST	ST	ST	ST
CESTODES				
Trypanorhych				
Larval *Callitetrarhychus gracilis* (Rudolphi, 1819)	AO,M,BC,LA,MU,OE,PC	AO,M,BC,L,A,MU,OE,PC		
Larval *Nybelinia*	BC	BC		
Pseudophyllidea				
Adult *Onchodiscus sauridae*	I	I?		
ACANTHOCEPHALANS	M	M		
NEMATODA Larval *Anisakis* Type 2	BC,ST,OT	BC,ST,OT	BC,ST,OM	BC,ST,O
ECTOPARASITIC CRUSTACEANS (ISOPODA)	G	G	G	G
Cymoithoidae				
Nerocila saurida Avdeev 1977	SR			
Anilocra cavicauda Richardson 1910	SR			
Gnathidea				
Gnathia, Larval Praniza			G	

Abbreviations:

A, anus	L, liver	SR, scapula region
AO, by aorta	O, ovary	ST, stomach
BC, body cavity	OE, stuck in oesophageal or stomach wall	M, mesentary
G, gills	PC, by pyloric caeca	MU, muscle
I, intestines		

6.3.1.1 Trematodes

All trematodes were obtained from the stomach. In a few instances up to 100+ trematodes were counted in individual stomachs. Specifically 67 trematodes were counted in a specimen of *T. myops* in December 1980. On the other hand as many as 85, 123 and 146 were counted from three *S. undosquamis* specimens in December 1979 - these individuals harboured no other parasites. Table 6.2 shows the percentage incidence of trematodes in various samples.

Table 6.2: Percentage incidence of trematodes in lizardfish samples.

Species	Percentage (%) Incidence	Sample Number
S. undosquamis	2.1	5411
S. tumbil	3.7	1343
S. filamentosa	19.1	612
T. myops	43.6	1343

The trematodes obtained from *S. filamentosa* were different from those obtained from shallow-water lizardfish - these digenean trematodes were considerably bigger; about 2-4mm in length and about 1.5mm wide.

6.3.1.2 Cestodes

Larval trypanorhynch, *C. gracilis* were the most prevalent of the parasites in *S. tumbil* and *S. undosquamis* (also see Table 6.1)

The percentage incidence of *C. gracilis* larvae in the two populations were 53.4 and 9.9 in *S. tumbil* and *S. undosquamis* respectively; many of the larvae occurring by the aorta (Table 6.3).

Table 6.3: Incidence of *C. gracilis* in *S. tumbil* and *S. undosquamis*

Location	Percent incidence in			
	S. tumbil		*S. undosquamis*	
	Female	Male	Female	Male
Whole fish	55.9	50.9	11.7	8.4
By aorta*	84.6	89.8	77.0	72.4

The trend in monthly percentage incidence indicates high occurrences of the larvae in the *S. undosquamis* population in Moreton Bay between May and September (Fig. 6.1B). The trend is however less discernible in *S. tumbil* population (Fig. 6.1A).

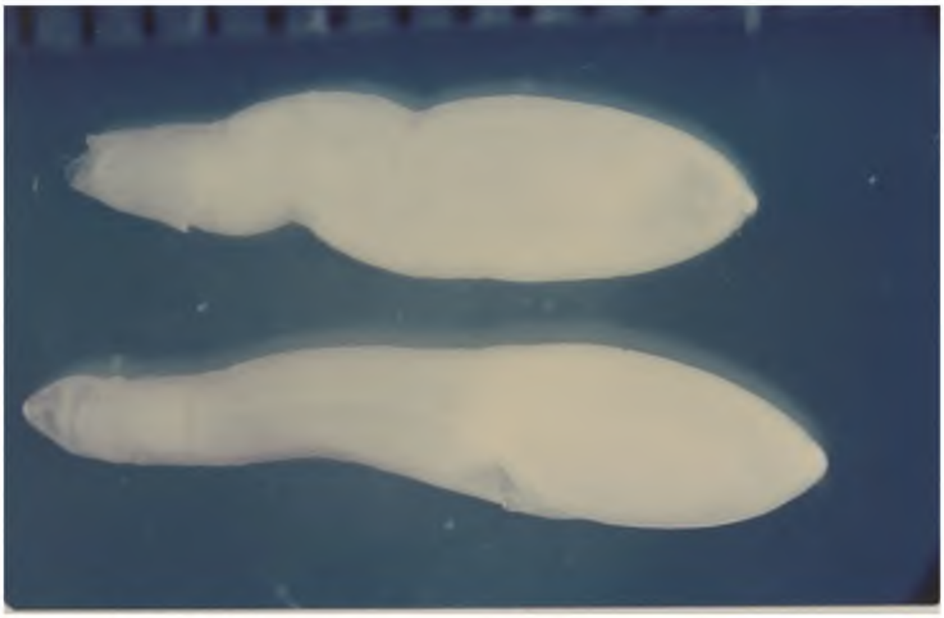
Intensity of infestation was different in the sexes (Tables 6.4A,B; 6.6). The highest infestations per individual were found in the females. There was no correlation between number of larvae and length of fish in either of the two lizardfish species:

	Species	Correlation Coefficient
S. tumbil	Female	-0.05634
	Male	-0.06777
S. undosquamis	Female	-0.004382
	Male	-0.003411

---

* See Plates 39 A,B,C.

A



C. gracilis larvae

B

C. gracilis (in situ) by aorta in *S. tumbil*

Plates 39A and B

Plate 39C: *C. gracilis* (in situ) by aorta in
S. tumbil; expanded view

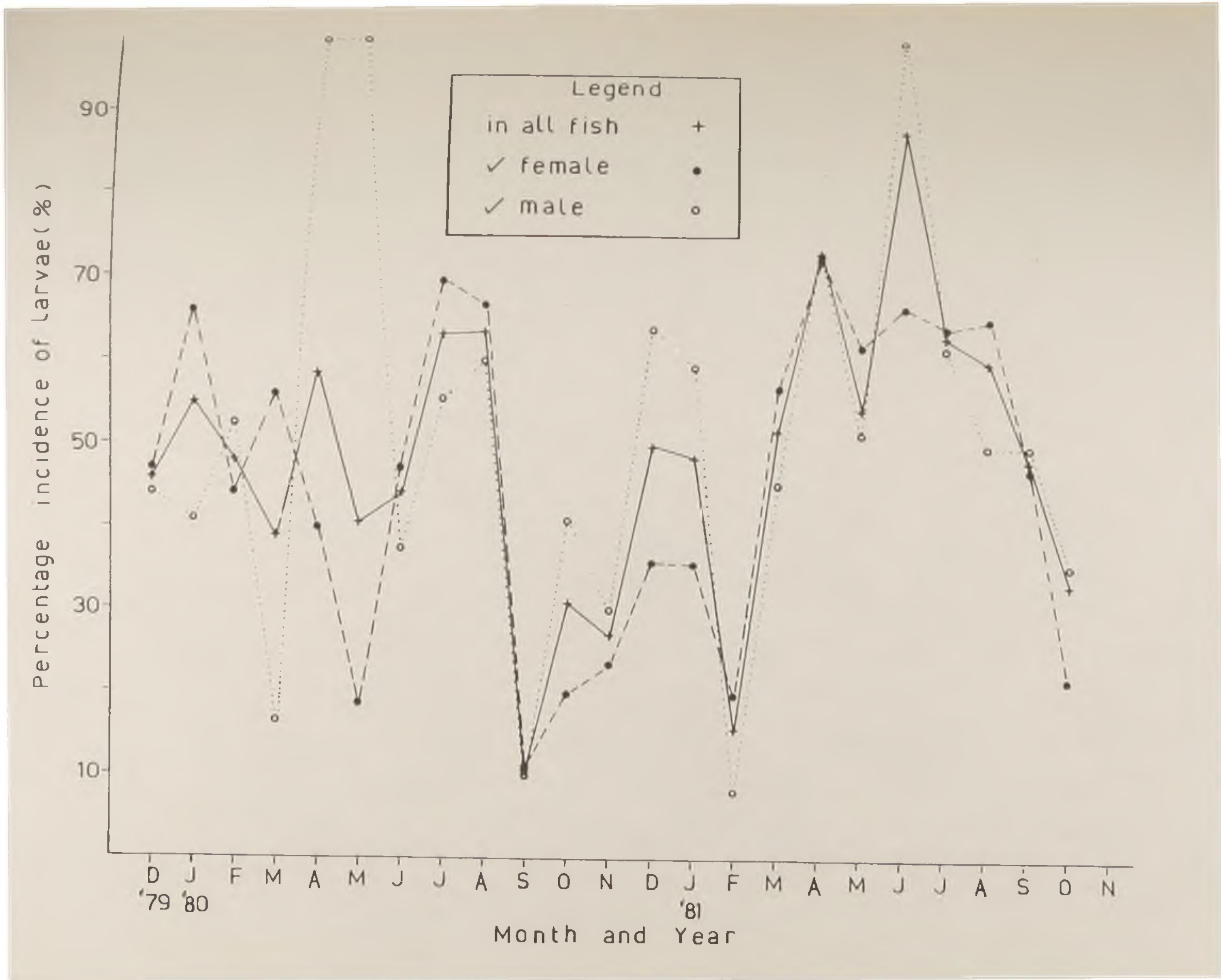

Legend
in all fish +
✓ female ●
✓ male ○
Percentage incidence of Larvae (%)
90
70
50
30
10
D J F M A M J J A S O N D J F M A M J J A S O N
'79 '80
'81
Month and Year

Fig. 6.1B. Incidence of *C. gracilis* larvae in population of *S. undosquamis* in Moreton Bay

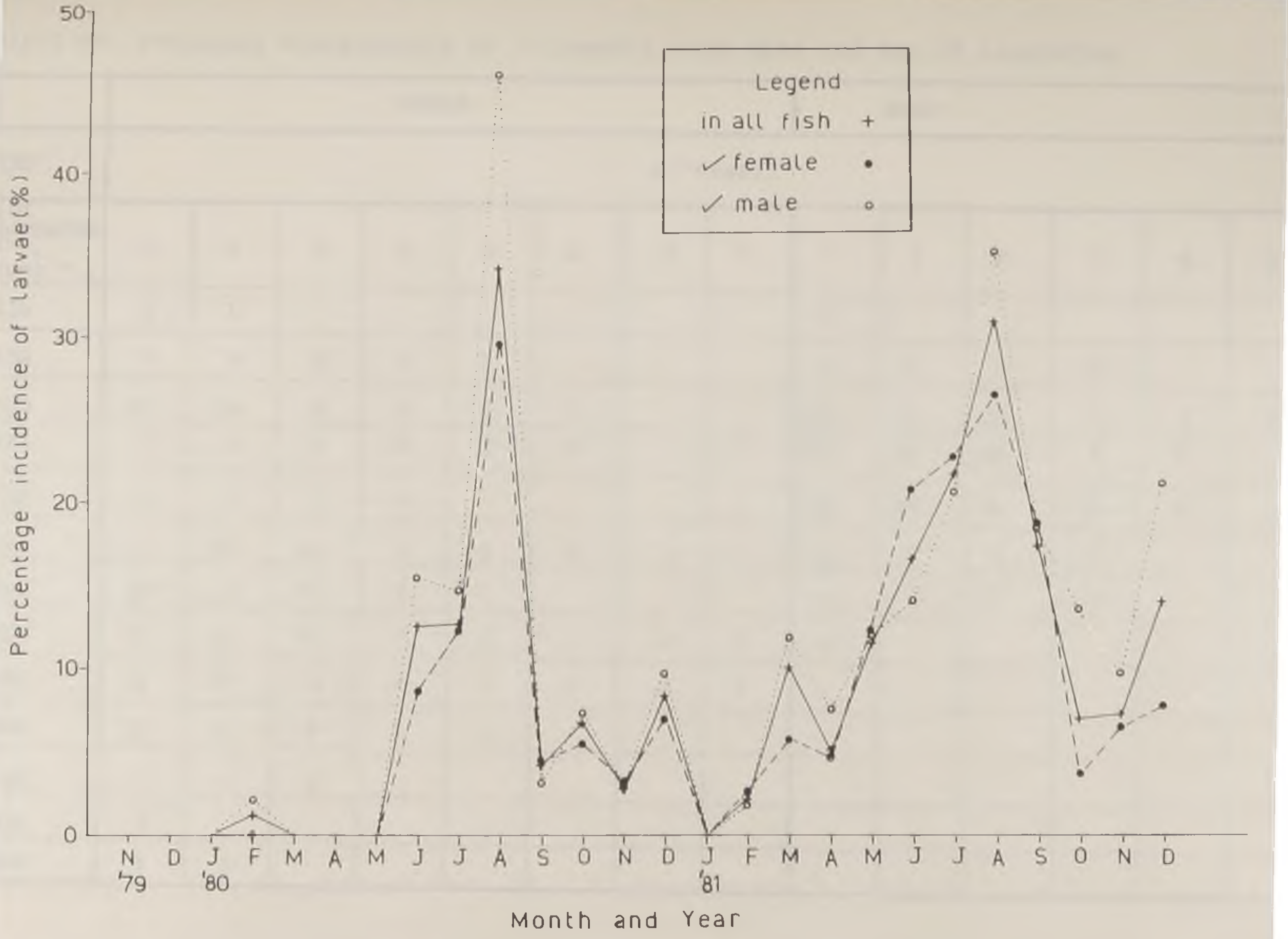

Legend
in all fish +
✓ female ●
✓ male ○
Percentage incidence of larvae(%)
0
10
20
30
40
50
N
D
J
F
M
A
M
J
J
A
S
O
N
D
J
F
M
A
M
J
J
A
S
O
N
D
'79
'80
'81
Month and Year

Table 6.4A: Frequency distribution of *C. gracilis* with size and sex of lizardfish

SEX	FEMALE								MALE					
SPECIES	*S. tumbil*													
No of parasites / size class (mm)	0	1	2	3	4	5	6	7	0	1	2	3	4	5
100–119	3	1							2					
120–139	2	3	0	3	1				4	5	2	2		
140–159	18	14	8	4	2	1			23	17	18	8	2	2
160–179	7	5	4	2	2	2			100	46	12	6	1	
180–199	10	9	2	1					85	50	21	11	0	1
200–219	29	11	11	4	3	0	1	1	8	7	4	2		
220–239	49	9	13	7	5				4	3	5	1		
240–259	39	21	12	7	4	1	0	2	2					
260–279	24	23	5	8	0	0	2	1						
280–299	12	11	6	1	2									
300–319	6	7	2											
320–339	4													
340–359	1	1												

Table 6.4B : Frequency distribution of *C. gracilis* with size and sex of lizardfish

SEX	FEMALE								MALE					
SPECIES	*S. undosquamis*													
No of parasites / Size class (mm)	0	1	2	3	4	5	6	7	0	1	2	3	4	5
80-90	18								13					
100-119	102	2	0	1					126	1				
120-139	437	20	3						642	39	20	1	1	
140-159	802	49	22	4	2				1248	82	17	5		
160-179	703	74	27	3	2	1			331	19	2	1		
180-199	286	28	13	0	0	0	0	1	33	6				
200-219	58	7	0	1	1				1					
220-239	13	1	1	0	0	1			1					
240-259	5	1							0					
260-279	5								1					
280-299	2													

Table 6.5 : Statistics of Frequency Distribution of *C. gracilis* in Lizardfish

SPECIES	Sex of fish	Location of larvae	Mean number of *C. gracilis* larvae per fish	Variance
S. tumbil	female	a	1.100222717	11.00893101
		b	1.168466523	14.6842485
	male	a	0.8127753304	5.763393755
		b	0.8577586207	5.613623413
S. undosquamis	female	a	0.1402077151	16.5382042
		b	0.1692698874	16.34376309
	male	a	0.08914728682	5.65135809
		b	0.1108139091	8.674876843

Abbreviations
a = Incidence of larvae by aorta
b = Incidence of larvae in whole fish.

6.3.2 Negative binomial distribution and the frequency distribution of *C. gracilis* larvae

C. gracilis had overdispersed distributions in the samples of *S. tumbil* and *S. undosquamis* (Table 6.5). There were no differences in the shape of the distributions with sex in the two species. However, the male curves ended abruptly at about 4 or 5 larvae per fish, whereas the female curve tapered off to 7 or 8 larvae depending on species (Table 6.6, Fig. 6.2). The negative binomial was fitted to the observed data using the reiterative method discussed previously in the introduction. The closeness of fit was obtained by comparison between the observed and expected frequencies; the smaller the *x^2 value the better the fit.

Tables 6.7 A-H show the results of fitting negative binomials as discussed previously to data on larvae in the whole fish and also by the aorta. The results in Table 6.8** were obtained using 'k' determined by the method of maximum likelihood and 'p' from $\bar{x}/k$ (see Lester, 1977; Adjei, Barnes and Lester, in press).

In all cases (i.e. Tables 6.7 A-H) the fit of the non-truncated negative binomial to the observed data was very poor. This is probably because the larvae "'killed' the lizardfish, the lethal effect being a function of a critical number of parasites in an individual lizardfish" - thus a deviation of the observed distribution from the expected or theoretical distribution. The truncated negative binomials gave much better approximations to the observed data. Inspections of Tables 6.7 A-D shows that truncation at 3 in the male and 4 in the female of *S. tumbil* give the best fit or approximation to the theoretical distributions - at or below the truncation point there is close fitting. Above the truncation point the x^2s

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* Chi-squared

** Using only frequencies of larvae by aorta.

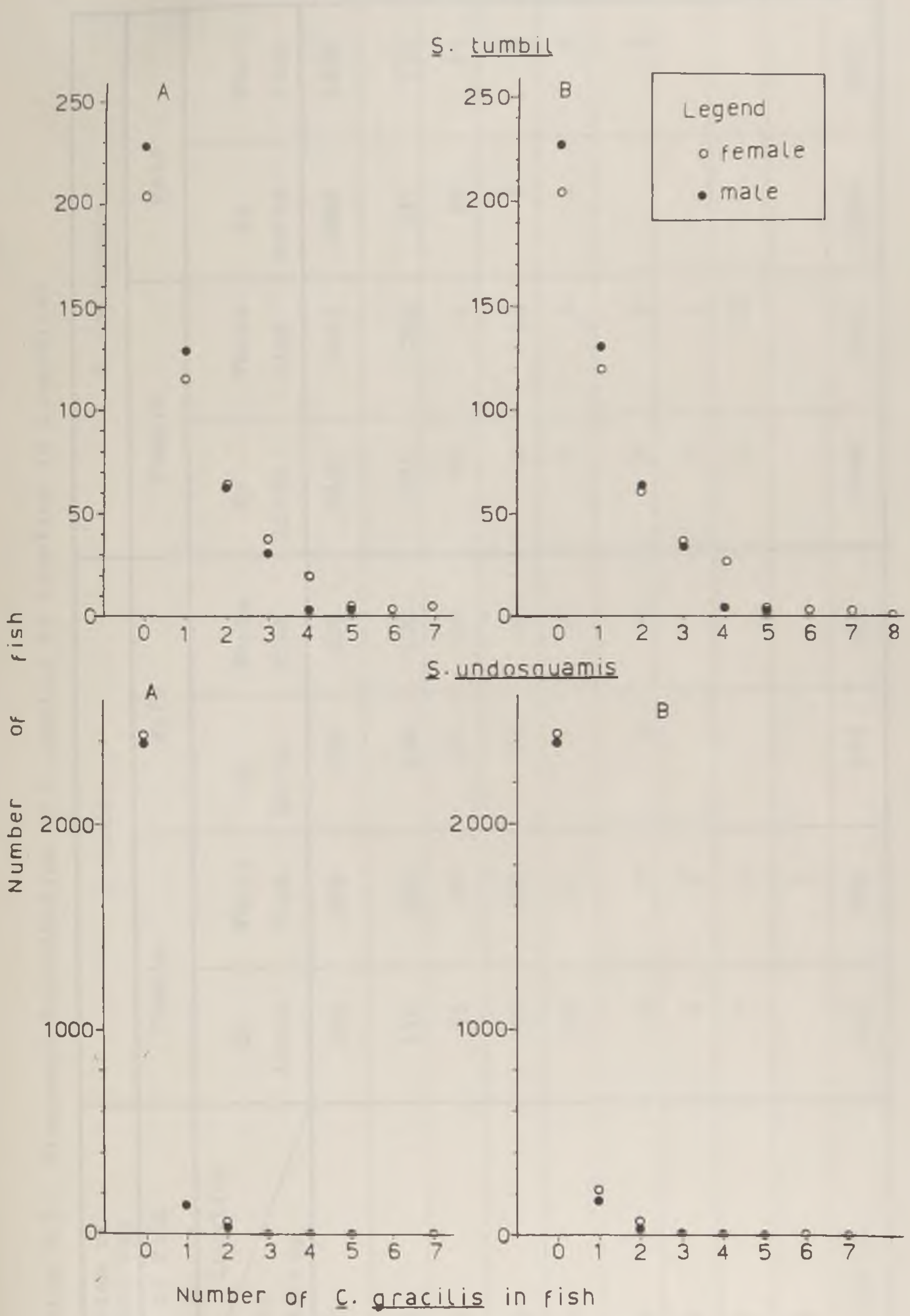

Fig. 6.2 Frequency distribution of *C. gracilis* in *Saurida spp.* by Aorta (A) and in whole fish (B)

Table 6.6 : Frequency Distribution of *C. gracilis* by location in Lizardfish

Species of Lizardfish	*S. tumbil*				*S. undosquamis*			
Sex of Fish	Female		Male		Female		Male	
Location / No of parasites	By Aorta	Whole Fish	By Aorta	Whole Fish	By Aorta	Whole Fish	By Aorta	Whole Fish
0	204	204	228	228	2431	2431	2396	2396
1	115	120	128	130	182	223	147	173
2	63	62	62	63	66	75	29	34
3	37	37	30	34	9	13	7	8
4	19	27	3	5	5	6	1	5
5	4	5	3	4	2	2		1
6	3	4			0	1		
7	4	3			1	2		
8		1						
Totals	449	463	454	464	2696	2753	2580	2617

TABLE 6.7A : Negative Binomial Distribution: *C. gracilis* by aorta in female *S. tumbil*

Observed Distribution		Non-truncated distribution						Truncated distribution at							
								2		3		4		5	
N	F	F_c	X^2	F_c	X^2	F_c	X^2	F_c	X^2	F_c	X^2	F_c	X^2	F_c	X^2
0	204	339	53.6864	204	0	191	0.9278	190	1.0556	195	0.4348	193	0.6068	197	0.2830
1	115	37	162.1815	63	43.2212	64	41.0525	118	0.0739	107	0.5270	94	4.4622	79	16.5846
2	63	18	103.7372	37	16.4987	39	14.1409	49	3.8214	57	0.7235	55	1.1077	47	5.1047
3	37	11	52.2451	27	3.9918	28	2.8673	17	22.6346	29	2.0026	40	0.2680	32	0.8805
4	19	8	13.3060	20	0.0564	21	0.2422	5	33.6971	15	1.0181	21	0.2832	22	0.4785
5	4	6	8.0753	16	8.7021	17	9.6947	2	3.5421	8	1.7894	14	6.9257	16	9.0709
6	3	4	6.7447	12	7.283	13	8.1558	0	14.2576	4	0.2219	10	3.9217	12	6.5835
7	4	**4	1.3066	10	3.8089	11	4.4989	0	121.3675	2	1.9953	6	0.5644	9	2.6239
X^2		386.6513		83.5622		81.5801		a = 4.9508 b = 200.4498		a = 3.6880 b = 8.7126		a = 6.7279 b = 18.1397		a = 32.4022 b = 41.6096	
K		*0.12216422611		0.342		0.3718		2.900		1.100		0.720		0.500	
Range of K for low X^2		0.370 - 0.380						2.50 - 3.50		1.00 - 1.30		0.70 - 0.80		0.45 - 0.55	
P		0.09993910544						0.785755538		0.498432766		0.3207846789		0.1977271866	
q		0.9000608946						0.214244462		0.501567234		0.6792153211		0.8022728134	

Abbreviations:

N = No. of *C. gracilis* per fish

F = observed frequency

F_c = estimated frequency

* calculated K

X^2 = Chi-squared

a = X^2 = X^2 excluding X^2 after truncation point (bold lines)

b = X^2 (all)

** = approximate F_c

TABLE 6.7B . Negative Binomial Distribution . C. gracilis in female S. tumbil

Observed distribution		Non-truncated distribution						Truncated distribution at							
								2		3		4		5	
N	F	F_c	X^2	F_c	X^2	F_c	X^2	F_c	X^2	F_c	X^2	F_c	X^2	F_c	X^2
0	204	359	66.6122	204	0	191	0.8963	132	38.9182	196	0.3026	192	0.7384	212	0.2801
1	120	33	225.2944	61	57.7166	62	55.6340	126	0.2915	108	1.2233	101	3.4934	83	16.5642
2	62	17	120.4586	37	16.8861	38	14.8087	73	1.7791	57	0.3983	60	0.0994	49	3.6098
3	37	11	62.5955	26	4.2823	28	3.2408	34	3.2333	30	1.7893	36	0.0140	32	0.8428
4	27	8	47.5955	20	2.3161	21	1.5634	13	13.8531	15	8.9489	22	0.9084	22	1.2318
5	5	6	0.1278	16	7.6058	17	8.4766	5	6.7797	8	1.0288	14	5.8433	15	7.0090
6	4	5	0.7584	13	6.3253	14	7.1039	2	3.5158	4	0	9	2.6649	11	4.4972
7	3	4	0.1264	11	5.7211	12	6.4263	1	12.0398	2	0.4510	6	1.2110	8	3.1584
8	1	3	1.3407	9	7.2884	10	7.9566	0	4.5520	**1	0.0014	4	1.8401	6	4.0742
X^2		524.2479		108.1427		106.1067		a = 43.6122 b = 75.2795		a = 3.7135 b = 14.1437		a = 5.2538 b = 16.8131		a = 29.5378 b = 41.2675	
K		*0.1010162799		0.323		0.350		4.500		1.100		0.810		0.500	
Range of K for low X^2		0.300 - 0.370						4.00 - 5.00		0.99 - 1.30		0.75 - 0.85		0.45 - 0.55	
P		0.07957278324						0.7881858044		0.4975951143		0.3495987208		0.2164822161	
q		0.9204272168						0.2118141956		0.5024048857		0.6504012792		0.7835177839	

Abbreviations

N = No. of *C. gracilis* per fish

F = observed frequency

F_c = estimated frequency

* Calculated K

** approximate F_c

X^2 = chi-squared

a = X^2 is X^2 excluding X^2 after truncation point

b = X^2 (all)

TABLE 6.7C : Negative Binomial Distribution; *C. gracilis* by aorta in male *S. tumbil*

Observed distribution		Non-truncated distribution						Truncated distribution at					
								2		3		4	
N	F	F_c	X^2	F_c	X^2	F_c	X^2	F_c	X^2	F_c	X^2	F_c	X^2
0	228	350	42.2804	229	0.0022	209	1.7238	212	1.2127	215	0.7855	221	0.2364
1	128	40	192.9698	69	51.0297	71	45.5434	124	0.1572	106	4.4928	82	25.7400
2	62	20	92.5808	40	12.2838	43	8.8048	53	1.6660	57	0.4985	47	4.7834
3	30	12	27.4506	27	0.3753	29	0.0196	20	5.4398	31	0.0339	30	0
4	3	8	3.1399	19	13.7654	21	15.7483	9	2.1655	13	11.3133	20	14.7079
5	3	6	1.2740	14	9.0464	16	10.6646	2	0.2395	10	4.5312	14	8.6971
X^2		359.6956		86.5029		82.5045		a = 3.0359 b = 10.8607		a = 5.8106 b =22.0552		a = 45.4679 h = 54.1650	
K		*0.1334386295		0.350		0.39599		2.170		0.860		0.480	
Range of K for low X^2		0.370 - 0.410						1.900 - 2.600		0.790 - 0.900		0.450 - 0.550	
P		0.1410237379						0.731303631		0.4258602479		0.2257851016	
q		0.8589762621						0.268696369		0.5741397521		0.7742148984	

Abbreviations

N = No. of *C. gracilis* per fish

F = observed frequency

F_c = estimated frequency

* Calculated K

X^2 = chi-squared

a = X^2 is X^2 excluding X^2 after truncation point

t = X^2 (all)

TABLE 6.7D : Negative Binomial Distribution; *C. gracilis* in male *S. tumbil*

Observed distribution		Non-truncated distribution						Truncated Distribution at					
								2		3		4	
N	F	F_c	X^2	F_c	X^2	F_c	X^2	F_c	X^2	F_c	X^2	F_c	X^2
0	228	347	40.7958	227	0.0025	212	1.2738	211	1.2894	215	0.7423	214	0.9086
1	130	45	157.0981	73	44.1676	75	40.4781	126	0.1381	111	3.3741	88	20.5749
2	63	22	74.6743	43	9.5744	45	7.1937	54	1.6071	59	0.2685	51	2.7880
3	34	14	30.9421	29	0.9615	31	0.3474	20	9.9621	32	0.1447	33	0.0476
4	5	9	1.8081	21	11.7916	22	13.3719	7	0.4885	18	8.7395	22	13.0941
5	4	6	0.8797	15	8.3186	17	9.6154	2	1.4161	10	3.1208	15	8.1603
X^2		306,1982		74.8164		72.2803		a = 3.0345 b = 14.9013		a = 4.5296 b = 16.3899		a = 37.4132 b = 45.5735	
K		*0.1547036939		0.380		0.418		2.300		0.930		0.540	
Range of K for low X^2		0.380 - 0.450						1.900 - 2.700		0.800 - 0.980		0.500 - 0.600	
P		0.152799459						0.741311041		0.4473998268		0.242522637	
q		0.847200541						0.258688959		0.5526001732		0.757477363	

Abbreviations

N = No. of *C. gracilis* per fish

F = observed frequency

F_c = estimated frequency

* Calculated K

X^2 = chi-squared

a = X^2 is X^2 excluding X^2 after truncation point

b = X^2 (all)

TABLE 6.7E : Negative Binomial Distribution; *C. gracilis* by aorta in female *S. undosquamis*

Observed distribution		Non-truncated distribution						Truncated Distribution at					
								2		3		4	
N	F	F_c	X^2	F_c	X^2	F_c	X^2	F_c	X^2	F_c	X^2	F_c	X^2
0	2431	2681	23.2458	2431	0	2168	31.8463	2247	15.0803	2225	19.1586	2196	25.1898
1	182	3	10034.8214	52	321.6138	98	71.5520	145	9.7110	126	24.9557	118	34.9656
2	66	2	2623.8315	26	58.9168	51	4.4806	71	0.3601	64	0.0634	61	0.4759
3	9	** 1	60.4796	18	4.2777	34	18.7667	45	28.8539	42	26.0614	41	24.5141
4	5	** 1	22.9035	13	5.1446	26	16.9427	32	22.5643	31	21.7306	30	21.0147
5	2	** 1	3.0955	11	6.9527	21	17.0354	24	19.9385	24	20.2530	24	20.0501
6	0	** 1	0.5103	9	8.7752	17	17.3796	18	18.4577	19	19.4876	20	19.6291
7	1	0	0.7390	7	5.6184	15	12.9501	15	12.7761	16	14.2473	17	14.6243
X^2		12769.6266		411.2992		190.9535		a = 25.1515 b = 127.7422		a = 70.2391 b = 145.9576		a = 106.1602 b = 160.4637	
K		*0.001198817392		0.0217		0.04567		0.070		0.059		0.055	
Range of K for low X^2		0.044 - 0.055						0.060 - 0.080		0.05 - 0.080		0.050 - 0.060	
P		0.008477807711						0.08105729096		0.04045912539		0.02445403075	
q		0.9915221923						0.918942709		0.9595408746		0.9755459693	

Abbreviations

N = No. of *C. gracilis per fish*

F = observed frequency

F_c = estimated frequency

* Calculated K

** approximate F

X^2 = chi-squared

a = X^2 is X^2 excluding X^2 after truncation point

b = X^2 (all)

TABLE 6.7F : Negative Binomial Distribution; *C. gracilis* in female *S. undosquamis*

Observed distribution		Non-truncated distribution						Truncated distribution at					
								2		3		4	
N	F	F_c	X^2	F_c	X^2	F_c	X^2	F_c	X^2	F_c	X^2	F_c	X^2
0	2431	2731	32.9140	2432	0.0001	2400	0.3930	2238	16.6970	2220	20.0800	2193	25.8482
1	223	5	9946.3125	65	381.5628	71	323.0883	172	15.2634	148	38.2739	136	55.2908
2	75	2	2222.6965	33	52.8192	36	41.1925	84	1.0003	75	0	70	0.3096
3	13	2	83.4120	22	3.7927	24	5.2706	53	30.0378	49	26.7746	47	24.5639
4	6	** 1	20.0966	16	6.7719	18	8.2076	37	25.7857	36	25.0229	35	23.9477
5	2	** 1	1.2611	13	9.5367	15	10.8188	27	23.3081	28	24.0322	28	23.6902
6	1	** 1	0.0754	11	9.0648	12	10.1491	21	18.8387	22	20.4579	23	20.6080
7	2	** 1	2.8441	9	5.7784	10	6.6754	16	12.5686	18	14.7013	19	15.1821
X^2		12309.6122		469.3273		405.7953		a = 32.9607 b = 143.4996		a = 85.1291 b = 169.3434		a = 129.9601 b = 189.6404	
K		*0.001771449307		0.0271		0.030		0.085		0.070		0.064	
Range of K for low X^2		0.027 - 0.035						0.080 - 0.090		0.065 - 0.080		0.060 - 0.070	
P		0.01035684906						0.09679976828		0.04891423934		0.02943325566	
q		0.9896431509						0.9032002317		0.9510857607		0.9705667443	

Abbreviations

N = No. of *C. gracilis* per fish
F = observed frequency
F_c = estimated frequency
* calculated K
** approximate F_c
X^2 = chi-squared
a = X^2 is X^2 excluding X^2 after truncation point
b = X^2 (all)

TABLE 6.7G : Negative Binomial Distribution; *C. gracilis* by aorta in male *S. undosquamis*

Observed distribution		Non-truncated distribution						Truncated distribution at			
								2		3	
N	F	F_c	X^2	F_c	X^2	F_c	X^2	F_c	X^2	F_c	X^2
0	2396	2565	11.1030	2396	0	2195	18.4976	2220	13.9604	2204	16.7179
1	147	4	5700.9786	42	262.7082	84	46.7647	105	16.6537	93	30.9275
2	29	2	416.9319	21	3.0229	43	4.5966	52	10.3791	47	7.1162
3	7	** 1	29.1516	14	3.4400	29	16.5124	34	21.3026	31	18.9485
4	1	** 1	0.0221	10	8.4330	22	19.5909	24	22.4962	23	21.2799
X^2		6158.1872		277.6042		105.9622		a = 40.9932 b = 84.7919		a = 73.7102 b = 94.9901	
K		*0.001428791362		0.0178		0.039		0.050		0.0435	
Range of K for low X^2		0.030 – 0.045						0.045 – 0.055		0.040 – 0.050	
P		0.01577448914						0.05265853562		0.02700666522	
q		0.9842255109						0.9473414644		0.97299334	

Abbreviations

N = No. of *C. gracilis* per fish

F = observed frequency

F_c = estimated frequency

* Calculated K

** approximate F_c

X^2 = chi-squared

a = X^2 is X^2 excluding X^2 after truncation point

b = X^2 (all)

TABLE 6.7H : Negative Binomial Distribution: *C. gracilis* in male *S. undosquamis*

Observed distribution		Non-truncated distribution						Truncated distribution at					
								2		3		4	
N	F	F_c	χ^2	F_c	χ^2	F_c	χ^2	F_c	χ^2	F_c	χ^2	F_c	χ^2
0	2396	2601	16.0991	2396	0	2151	27.8309	2203	16.8528	2189	19.4883	2174	22.6166
1	173	4	7740.8478	48	325.4511	96	62.7442	124	19.3780	108	38.9232	100	52.9064
2	34	2	565.4651	24	3.9925	49	4.7437	62	12.3861	55	8.0314	51	5.9051
3	8	1	38.3038	16	4.0536	33	19.0980	40	25.3014	36	22.1824	34	20.2645
4	5	1	18.8948	12	4.0662	25	15.9281	28	19.3534	27	17.8331	26	16.6684
5	1	** 1	0.1231	10	7.6134	20	17.9556	22	19.7315	21	19.1548	20	18.4405
χ^2		8379.7337		345.1769		148.3005		a = 48.6169 b = 113.0031		a = 88.6254 b = 125.6133		a = 118.3609 b = 136.8015	
K		*0.001442287019		0.0203		0.0450		0.060		0.051		0.047	
Range of K for low χ^2		0.040 - 0.050						0.050 - 0.070		0.043 - 0.055		0.040 - 0.050	
P		0.01284817292						0.06213507833		0.03165919577		0.01953787869	
q		0.9871518271						0.9378649217		0.9683408042		0.9804621213	

Abbreviations

N = No. of *C. gracilis* per fish

F = observed frequency

F_c = estimated frequency

* Calculated K

χ^2 = chi-squared

a = χ^2 is χ^2 excluding χ^2 after truncation point

b = χ^2 (all)

** - approximate F_c

Table 6.8: *Negative Binomial Distribution of *C. gracilis* larvae by aorta in lizardfish using $p = \bar{x}/k$

	S. tumbil						
A.	Males						
No. of parasites	0	1	2	3	4+		
Actual no. of fish	226	128	62	30	6		
Truncated at 3	227	125	63	30	26		
Truncated at 2	227	126	63	31	28		
B.	Females						
No. of parasites	0	1	2	3	4	5	6+
Actual no. of fish	201	114	63	37	19	4	7
Truncated at 3	201	114	64	36	20	11	14
Truncated at 2	200	117	61	31	15	7	7
	S. undosquamis						
C.	Males						
No. of parasites	0	1	2	3+			
Actual no. of fish	2396	147	29	8			
Truncated at 2	2393	147	28	9			
D.	Females						
No. of parasites	0	1	2	3	4+		
Actual no. of fish	2431	182	66	9	8		
Truncated at 3	2430	191	53	18	12		
Truncated at 2	2428	183	65	29	32		

* Adjei, Barnes and Lester, in press.

The underlined figure indicates deviation from observed frequency.

indicate that the calculated frequencies are significantly higher than the observed values. Thus Tables 6.7 A-D, 6.8 A,B suggest the 'loss' of some *S. tumbil* males and females harbouring about 4+ and 5+ larvae respectively. This 'loss' was probably due to death resulting directly from the damaging effects of the larvae or indirectly through reduction in fitness of the individual and consequently an increase in susceptibility to predation and/or diseases. However it must be noted that no inflammation or lesions were found at the location of the larvae.

The truncation point in the *S. undosquamis* sample is rather less obvious. In Tables 6.7 E-H inspection shows that there is poor approximation of the truncated negative binomials to the observed data. However the trend in $*x^2$ values suggests even lower truncation points than in *S. tumbil*. Table 6.8D shows that the closeness of fit of the female data is affected by truncation at 2 or 3 parasites, whereas Table 6.8C indicates a close approximation of the larvae distribution in male *S. undosquamis* to the negative binomial when truncated at 2 parasites. The situation seen in *S. undosquamis* might probably be due to any or a combination of the following factors:

1) non-representative samples of *S. undosquamis*
2) migration of *S. undosquamis* offshore from the bay
3) the application of the 'wrong' mathematical model
4) *C. gracilis* larvae having a greater effect on mortality in *S. undosquamis* than in *S. tumbil*.

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* Chi-squared values

6.4 DISCUSSION

The parasitic fauna of lizardfish is diverse, probably reflecting their range of habitats and food and feeding strategies. The range of habitats - shallow, muddy/sandy to deep water, and the food and feeding strategies of coupling a great diversity in diet with range of sizes of prey and exploitation of abundant prey resources must expose lizardfish to many types of parasites directly or indirectly through intermediate hosts.

The incidence of parasites and intensity of infestation were different in the four species studied from South East Queensland (See Table 6.1). Hemiurid trematodes, nematodes and parasitic isopods were found in/on all the four species. *Lecithochirium magnus*, larval trypanorhynchs, adult pseudophillideans and acanthocephalans were found in only *S. tumbil* and *S. undosquamis*. The cestode larva found most frequently in *S. tumbil* and *S. undosquamis* was *C. gracilis*. Jensen, Moser and Heckmann (1979) recorded it as an occasional helminth in *Synodus lucioceps*. With regards to ecto-parasitic crustaceans, larval *Anisakis* and larval praniza (Gnathidae) were only obtained from *S. filamentosa*. Only S. tumbil was found as host of *Nerocila saurida* Avdeev 1977 and *Anilocra cavicauda* Richardson 1910.

Cressey and Cressey (1979) found the parasitic copepod species of *Metataeniacanthus* to be very specific to Indo-Pacific *Synodus* and Parukhin (1974) reported helminth - specificity between *Saurida* species on the one hand, and *Synodus* and *Trachinocephalus* on the other. Parukhin *(op cit)* explained this as due to "differences in ecology and nutrient relation to the fish genera". Differences in ecology and food relations also seem to explain the specificty of *C. gracilis* to *S. tumbil* and *S. undosquamis* in Moreton Bay. Nakajima and Egusa (1969a, 1972a) studied the source and route of infection of *Callitatrarhynchus sp.* parasitic on cultured yellow-tail; *Seriola quinqueradiata* and suggested the anchovy, *Engraulis japonica* (Houttuyn) as the intermediate host. Anchovies occur in Moreton Bay and *Amentum devisi* Whitley was found only in the stomachs of *S. tumbil* and *S. undosquamis.* Also the two just mentioned lizardfish species occur in similar habitats, more or less distinct from the habitats of *T. myops* or *S. filamentosa.*

The presence and numbers of a parasite may increase or decrease the possibility of the presence of other parasitic species. *S. tumbil* and *S. undosquamis* had very low infestation of trematodes but over 70% infestation of *C. gracilis.* No *C. gracilis* was found in *S. undosquamis* specimens with high counts of *Lecithochirium magnus.* However the significance of this observation would only be known with further field and experimental studies. Overstreet (1968) working on *Synodus foetens* from South Florida found that all autopsied specimens were infested by one or more species of parasites and also two significant associations between
1) *Sterrhurus* and *Stomachicola* (both digenean trematodes), and
2) *Sterrhurus* - *Stomachicola* - *Goezia* (a nematode). Parukhin (1974) found that the extensity and intensity of parasitism in lizardfish in the Indian Ocean depended on the age of the fish.

In natural communities most hosts harbour few parasites, while few hosts harbour the majority of the parasite population. Many factors can generate this pattern of distribution (i.e. overdispersion), including demographic and environmental influences. The main factor in natural communities is thought to be heterogeneity within the host population in the rates at which parasites establish, survive and reproduce within individual hosts. These distribution patterns have important effects on the dynamics of host-parasite interactions. It is possible that overdispersion of parasite population in the host population may just be a consequence of chance differences in transmission, but it is equally possible that the heavily infected individuals are those that are genetically susceptible and do not mount immune responses (Anderson, 1982; Kennedy, 1982). Tissue invading parasites generally possess means of survival or multiplication or both. As a consequence most of these organisms cause tissue injury ranging from minor to fatal (Frenkel, 1982).

Lizardfish examined ranged from 80 to 340mm in length and there was no correlation between fish length and degree of infestation by *C. gracilis* ($r = 0.003$ to 0.07). However *C. gracilis* had an overdispersed distribution in *S. tumbil* and *S. undosquamis*. Both species and especially sex of fish showed similar distribution of the parasites; it was not therefore just heterogeneity of the fish population which gave rise to this type of distribution. The parasite distribution in the lizard population is probably dictated by the number of infected intermediate hosts eaten by individual lizardfish and therefore the intensity of infestation in the intermediate host.

C. gracilis was extensively distributed in the two species. It invaded the viscera and body cavity and was most frequently found by the aorta. Nakajima and Egusa (1969a, b; 1972a) found that *C. gracilis* larvae penetrate the stomach wall within short periods and move to various parts of the body. There they encyst with tissue membrane from host and develop into plerocercus.

Analysis of the observed data showed that *C. gracilis* larvae were distributed as the truncated negative binomial in the two lizardfish species. It also indicated that the numbers of male and female lizardfish (except the male *S. undosquamis*) harbouring the critical number (or more) of larvae were fewer than expected. In *S. tumbil*, the critical number of parasites were 4 and 5 for the male and female respectively. The female of *S. undosquamis* was affected by 2 or 3 larvae. Hosts with one parasite are unlikely to be affected seriously because this would result in no host-parasite relationship (Crofton, 1971).

The critical number in male *S. undosquamis* was 2, but there was no 'loss' in numbers of fish. There was circumstantial evidence of *migration offshore by *S. undosquamis* . If migration did occur, the distribution of the larvae in *S. undosquamis* in the Bay would be distorted to an extent dictated by the type of migration, number of emigrants and the distribution of larvae within emigrants. Also, Crofton (1971) states that "death is rarely if ever instantaneous and is never synchronous with the achievement of a 'lethal' infection; death does not ensue from a simple interaction between host and parasite but is the resultant of a complex interaction involving several factors."

The parasitism of *C. gracilis* larvae in *S. tumbil* and *S. undosquamis* is not necessarily the direct cause of the 'loss' of some 'heavily' infected fish because factors causing mortality may be closely interrelated in their functioning and to consider them independently may be misleading. The 'loss' was most probably due to the adverse effects of parasites causing a decrease in fitness and consequently an increase in susceptibility to predation or diseases. In the absence of evidence of injury (inflammation) at locations of larvae and experimental evidence of adverse effects on metabolism of lizardfish, one plausible explanation is numbers or mass *per se* of *C. gracilis* larvae could have caused (some) occlusion or constriction of the aorta (See Plates 39A, B, C) leading to distress and thereby a general weakness of the fish rendering them more vulnerable to predation or disease or even death. If the larvae had no effect on lizardfish, each lizardfish would have equal

* See Chapter on Reproduction.

chance of being eaten by a predator, regardless of the number of parasites it contained. In such a case the observed data would, on the contrary, have been adequately described by the non-truncated negative binomial. In a study of the metacercariae of *Diplostomum adamsi* distribution in the perch *Perca flavescens,* experimental results suggested that the low number of heavily infected fish was due to an increased host mortality; probably through selective removal by predators (Lester, 1977). Nakajima and Egusa (1969a, b; 1972a, b, c) examined the number of adult *C. gracilis* and also followed the growth of experimentally introduced plerocercus in the intestine of the shark *Triakis scyllia* and concluded that -

1) The adult *Callitetrarhynchus* is harmful to host (definitive) - of the 35 sharks studied 12 died during the course of the experiment. The dying animals always showed an abnormal movement a few days before death and severe intestinal inflammation was observed in all the dying or dead sharks.
2) The adult stage, which would continue to grow without killing the host was limited in number.

Thus it is very probable that *C. gracilis* larvae are harmful to *S. tumbil* and *S. undosquamis*.

7. GENERAL DISCUSSION

Species of the genera *Saurida* and *Trachinocephalus* are widely distributed in the Indo-Pacific region - in an area delimited by the Hawaiian Islands in the eastern Pacific and the eastern seaboard of Africa in the west, the Sea of Japan in the north (about 40°N) and New Zealand (about 40°S) in the south (e.g. Norman, 1935; Gosline and Brock, 1960; Marshall, 1964; Grant, 1965, 1978; Shindo and Yamada, 1972; Carcasson, 1977; Lui and Lai, 1980; Waples, 1982). They have also been reported from the Red and Mediterranean Seas (Ben-Tuvia, 1953; Latif and Shenouda, 1973; Ben-Yami and Glaser, 1974). *Saurida* and *Trachinocephalus* also occur widely in the Atlantic Ocean (Norman, 1935; Gibbs, 1959; Anderson, Gehringer and Berry, 1966, 1975). They have been found as far north as off Cape Cod (42°N) in the United States of America and as far south as in the waters of Brazil. One point worth noting is the areas of occurrence of lizardfish are predominantly areas with warm ocean currents (see Bisacre, Carlisle, Robertson and Buch, 1979; Barton, 1980). Warm seas or currents probably have a direct influence on the distribution of lizardfish - Markle, Scott and Kohler (1980) explained the occurrence of what they termed "subtropical/tropical expatriated fishes" including *Trachinocephalus myops* and *Synodus sp.* obtained from the Scotian Shelf of Canada (about 43°N) as temporary habitation especially in summer. Synodontidae are unknown from the Western seaboard of the Americas which is washed by the colder Peru and California currents. *T. myops* is common to both the Atlantic and Indo-Pacific regions. However the two regions have different *Saurida* fauna. Carcasson (1977) reports that the tropical eastern Pacific together with the Caribbean and the tropical Atlantic forms a distinctive zoogeographic unit known as the Atlanto-East Pacific Region. Carcasson *(op cit)* further states the tropical Indo-Pacific, also called the Indo-West Pacific Region, and the Atlanto-East Pacific Region have completely different faunas and only an insignificant proportion of pelagic species are common to both areas.

Saurida species and *T. myops* occur on sandy or muddy bottoms (e.g. *S. undosquamis, S. tumbil),* on reefs and corals *(S. nebulosa, S. gracilis* and *S. flamma),* in estuarine or shallow water (e.g. *S. argentea),* and deep water *(S. filamentosa). T. myops* has been found at depths of over 2000m in the Gulf Stream (Gibbs, 1959). Thus species of the genera *Saurida* and *Trachinocephalus* by the immense expanse of the Indo-Pacific region must be exposed to a myriad of habitats or niches or both.

The blueprint of speciation is the preservation of genetic integrity either by physical or ecological separation (distances, barriers etc.), physiological incompatibility with other members of the population or by specific behaviour. It is therefore probable that with the widespread distribution of the many species of lizardfish and their concomittant occupation of most probably different habitats as a result of local environmental peculiarities, there will be demes or races and even subspecies more or less isolated from each other by mere distance(s) or physical barrier(s).

Trachinocephalus is a monotypic genus and *Saurida* is polyspecific (Norman, 1935; Marshall, 1964; Grant, 1965, 1978; Shindo and Yamada, 1972; Cressey, 1981). Many of their morphological features are variable and often of limited value in establishing taxonomic relationships. Lewis (1982) encountered similar problems with the cichlid species of Lakes Victoria, Tanganyika and Malawi in East Africa. He reported that the "'explosive speciation' that has taken place amongst cichlid species has resulted in the proliferation of reproductively isolated but morphologically similar species which are extremely difficult to separate on anatomical grounds alone."

The number of synonyms and the results of the study of the somatic chromosomes of *S. undosquamis* and *S. elongata* by Nishikawa and Sakamoto (1978) underscore the similarity in *Saurida*. Nishikawa and Sakamoto *(op cit)* found 48 diploid chromosomes in both species and concluded that "... the karyotypes consist of simple telecentric chromosomes and are very similar to each other. This may suggest that these two species are closely related to each other."

Eleven species of *Saurida* were described based on exploratory electrophoretic investigation and comprehensive conventional taxonomic analysis. Staining for general proteins gave preliminary indication of the presence of inter- and intra-specific variation in *Saurida* species. This was confirmed by further starch-gel electrophoresis of specific proteins which revealed biochemical differences and similarities consistent with intra- and inter-species morphological variation. In each case, each individual specimen could be assigned unequivocably to one species despite intra-specific variation. *S. australis* which had until now been synonymized under *S. undosquamis* was shown by electrophoretic analysis to be different from *S. undosquamis* in at least seven enzyme systems. Waples (1982) removed *S. nebulosa* from the synonymy of *S. gracilis* on a similar basis. Ferguson (1974) found the occurrence of three separate and distinct patterns in general proteins and independently in three enzymes in coregonid fishes of Britain and Ireland to be indicative of three distinct species.

Conventional taxonomic analysis involved the consideration of differences and similarities in meristic traits and morphological features - scale and fin ray counts, snout and nasal flap shapes, markings on body and fins, length of fins and particularly configuration of palatine and vomerine teeth. The coupling of these features as illustrated in the 'Identification Key' made separation of the species relatively easier and non-subjective as against other keys as exemplified by Chen and Yeh (1964) - "In the course of this study, we have found that morphology of scale from different parts of the body is a good key character for such classification."

Three groups of species with close affinities were established:

1) *S. undosquamis*
S. australis
S. filamentosa
S. longimanus
S. isarankurai

2) *S. tumbil*
S. argentea
S. elongata

3) *S. nebulosa*
S. gracilis
S. flamma

Apart from exhibiting some biochemical differences from *S. undosquamis*, *S. australis* also exhibits some distinct morphological features from the latter species - an elongated body, higher lateral line scale counts and a peculiar body coloration. *S. australis* and *S. undosquamis* are *sympatric. Lewis (1982) has shown conclusively that two sympatric cichlid species *Petrotilapia tridentiger* Trewavas and *Pseudotropheus tropheops* Regan are "complexes of morphologically similar but reproductively distinct species." He emphasized that "species coloration is of paramount importance in preventing miscegenation and thus maintaining specific distinctness."

* Circumstantial evidence.

S. micropectoralis and *S. wanieso* both described by Shindo and Yamada (1972) are in error and were found to be conspecific with *S. argentea* Macleay 1882 and *S. filamentosa* Ogilby 1910 respectively. Shindo and Yamada (1972) were unaware of the valid publication of *S. argentea*. By priority, *S. argentea* is thus the senior synonym. On the other hand, *S. wanieso* appears to be a geographical race of *S. filamentosa*. *S. filamentosa* is commonly found off the coast of South-East Queensland and northern New South Wales and has recently been reported from the north and north-western waters of Australia.

S. wanieso however appears to be confined to the South China Sea (Shindo and Yamada, 1972) and probably the coast of India (see Rao, 1977). The only difference between the two 'species' is in coloration: Upper half of pectoral fins violet and upper caudal ray sometimes with dusky spots in *S. filamentosa*, whole surface of inner side of pectoral fin dusky and upper caudal ray without any dusky spots in *S. wanieso*. Lewis (1982) noted geographical variation in coloration in many species of Lake Malawi cichlids and postulated that "Such variation is invariable disjunct and probably represents early stages in allopatric speciation". His explanation probably also holds for *S. filamentosa* and *S. wanieso*. However Lewis *(op cit)* further stated that "When sympatric forms display colour differences their specific status can readily be proved or disproved by field observation. But when members of geographically separated populations have similar anatomy but differ in coloration it is not possible to tell whether the colour differences would be sufficient to serve as a partial or total barrier to mating if the two populations came into contact under natural conditions. The decision as to whether anatomically similar but differently coloured members of geographically distinct populations are considered as species, subspecies or geographical races rests with the researcher and can only be intuitive."

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Ideally the revision of the biochemical and conventional taxonomy should include samples from several disparate areas for a comprehensive investigation of inter- and intra-specific variation. Shaklee, Tamaru and Waples (1982) advocate for biochemical keys "especially when the species under study are so morphologically similar as to preclude the use of anatomical characters in species identification". Full quantitative analyses (i.e. calculation of allelic and genotype frequencies, genetic identity and distance) of specimens from disparate localities would clarify species inter-relationships and specificity. These analyses were not possible in this study for several reasons - mainly financial (high cost of chemicals), logistics and time.

It is impossible to understand the ecology of living animals without a detailed knowledge of how they relate to their environment. Each living species is beset with a unique set of problems depending on its environment. Sooner or later every population must encounter either difficult environmental conditions or shortages of its requisites for reproduction. The environment is constantly changing and perfect adaptation is never achieved and if the species is to propagate its kind in the long run, it must be genetically primed to stay adapted to the environment. Thus each species must evolve a repertoire of strategies that is compatible with the vagaries of the environment to survive and to reproduce with some degree of success. The forms (e.g. polymorphisms), colours (e.g. in mimicry and camouflage), activities (including behaviour) and even number(s) of individuals (i.e. population dynamics) of a species are components of a complex of adaptive responses to the basic problems of survival.

Lizardfish species exhibit identical adaptive strategies to food and feeding, growth and reproduction consistent with or reflecting their profound morphological similarities.

Lizardfish are wide ranging carnivores and like other predators must be opportunist if they are to survive. They must be able to adapt to changing climates, altering patterns of competition and drastic upheavals in the abundance of their common prey. Lizardfish, like all - or nearly all - creatures that consume animal food must thus be able, if the occasion demands, to change their feeding habits or prey species. The food and feeding strategies of lizardfish instead of specialization to a few food items consist of adaptability to a wide range of food items, food sizes and environmental conditions. Their adaptability guarantees the attainment of food and then survival in a wide range of habitats and environmental conditions - the great diversity in diet coupled with a range of sizes of prey and the exploitation of abundant prey resources maximises the probability of lizardfish obtaining food.

The wide mouth of lizardfish, fringed with curved inward-pointing teeth and backward-pointing teeth on roof and floor of mouth, is an efficient trapping mechanism. The teeth are not used to hack at prey, but simply to make escape impossible. The depressible teeth allow large prey to be taken in, but the only way out of the mouth is down the greatly distensible oesophagus and stomach. Breakdown in stomach is affected by an equally efficient digestive system.

The dorso-lateral position of the eyes of lizardfish bestows binocular stereoscopic vision which increases the range over which a prey can be located and the obliterative colour patterns of lizardfish make stalking or initial approach to prey quite undetectable by prey, and ambushing a tenable technique.

The growth strategy of lizardfish is an aggregate of a number of features -

1) Very rapid linear growth of immature fish. This diminishes the availability of the young to predators.

2) Early maturity and annual growth which ensures a rapid replacement in the population.

3) A broad range of size classes per age.
    a. This increases the range of sizes and kind of food eaten; it maximises availability of food to the population;
    b. This also results in a broad range of sizes at maturity and spawning individuals and thus a uniform replacement in the population; and

4) Allometric growth - a rather rapid increase in body mass in adults or mature individuals increases fecundity.

Natural selection recognizes only one currency: successful offspring. Yet even though all living organisms have presumably been selected to maximize their own lifetime reproductive success, they vary greatly in exact modes of reproduction (Pianka, 1978).

In *Saurida* and *Trachinocephalus* species, reproductive strategies are such that they (i.e. strategies) correspond to the optimum (food supplies and warm temperatures) that maximizes reproductive potential and success.

A combination of extended spawning season (with variable duration amongst species), early maturation, high fecundity and serial spawning maximizes reproductive success, reduces intra- and inter-specific competition and thus avoids catastrophe. The prolonged spawning seasons reduce the extent of annual fluctuations in year class and also the chances of a large proportion of the spawning products being liberated during a particularly unfavourable period of environmental conditions. Thus larval crowding is avoided and impact of predators and others are reduced. The migration patterns reduce pressure on food resources, whilst at the same time leads to other areas with relatively abundant food supplies. Migration also disperses ova over large areas. The onset and duration of spawning of *Saurida* and *Trachinocephalus* coincide with increase or renewal of nutrients and the resultant abundance of plankton. Thus, the timing of spawning assures a high probability of adequate food supplies for larvae and juveniles.

The above set of strategies obviously must favour the establishment of *Saurida* and *Trachincoephalus* in the tropics and many sub-tropical areas. Lizardfish have not been recorded, however, from the eastern Pacific, specifically the western seaboard of the Americas. *Saurida undosquamis* and some species of the related genus *Synodus* have penetrated the Red Sea and Suez Canal and into the Mediterranean Sea (Ben-Tuvia, 1953; Latif and Shenouda, 1973; Ben-Yami and Glaser, 1974). A synergistic coupling of the adaptive strategies enumerated above might be responsible for the success of *S. undosquamis* in the Levant Basin of the Suez Canal to the detriment of its main competitor, the hake; *Merluccius merluccius*, since its (i.e. *S. undosquamis)* invasion of the Canal (see Ben-Yami and Glaser, 1974). However no such records of any species of the Atlantic *Saurida* or related genera in the Panama Canal (Central America) are available.

In the main, lizardfish are parasitized by helminths and ecto-parasitic isopods. The parasites probably act in synergism with other processes to decrease the competitive fitness of individual lizardfish and consequently their deaths in the extreme case. Thus the control or suppression of the lizardfish populations. In Moreton Bay, *C. gracilis* larvae appear to be the most important in populations of *S. tumbil* and *S. undosquamis*. The effects of the aggregated distribution of the larvae on the species and/or sex might explain the differences in their total mortalities - higher in males. In the absence of direct experimental evidence any interpretation of the data presented must be made with caution.

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APPENDIX 1.

LIZARDFISH: Percentage (%) of empty stomachs in total sample.

Month and Year	*S.undosquamis*	*S. tumbil*	*S.filamentosa*	*T. myops*
Nov. 1979	17.9	–		
Dec. 1979	–	48.1		
Jan. 1980	87.0	68.5		
Feb. 1980	28.3	67.6		
March 1980	45.2	65.5		
April 1980	69.4	51.7		
May 1980	68.0	–		
June 1980	58.6	82.1	31.6	
July 1980	66.1	–		
Aug. 1980	53.2	–		
Sept. 1980	55.0	43.4	40.9	
Oct. 1980	41.2	–		46.2
Nov. 1980	61.4	–		50.0
Dec. 1980	62.5	–		28.9
Jan. 1981	47.4	59.6	42.3	54.4
Feb. 1981	53.8	60.0	66.7	
March 1981	54.3	85.4	62.9	
April 1981	61.7	64.8		81.0
May 1981	72.7	62.6	55.0	
June 1981	66.2	67.2	56.3	
July 1981	78.9	91.8		
Aug. 1981	70.1	87.5		
Sept. 1981	59.5	74.4		
Oct. 1981	68.2	73.4		45.8
Nov. 1981	64.3	–		40.0
Dec. 1981	52.8	–		
Jan. 1982				
Feb. 1982				41.1

APPENDIX 2: ABUNDANCE (N), AND PERCENTAGE (%) OCCURRENCE OF PREY ITEMS IN STOMACHS OF *S. undosquamis* (S.U) and *S. tumbil* (S.T)

Year		FIRST YEAR												SECOND YEAR				
		1979		1980										1980		1981		
Month		November	December	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March
Apogonidae	N	905	646	1274	1565	872	364	855	591	90	516	157	547	314	317	270	379	446
	%	9.0	6.4	12.6	15.5	8.6	3.6	8.5	5.8	0.9	5.1	1.6	5.4	3.1	3.1	2.7	3.7	4.4
	% in S.U	12.1	0	33.3	2.3	2.4	2.4	14.9	9.8	3.3	9.1	5.1	3.0	0	0	0	0	5.9
	% in S.T	0	0	8.7	8.3	0	6.7	0	0	0	0	7.7	0	0	0	0	21.4	12.5
Leiognathidae	N	1344	513	620	473	1908	563	597	477	546	1038	2487	1827	1499	589	1217	516	540
	%	8.0	3.1	3.7	2.8	11.4	3.4	3.6	2.9	3.3	6.2	14.8	10.9	8.9	3.5	7.3	3.1	3.2
	% in S.U	0	0	0	0.6	4.3	2.4	4.3	2.7	0.8	18.2	13.4	22.7	5.4	6.9	10.0	0	4.9
	% in S.T	0	6.7	17.4	8.3	0	6.7	0	0	0	0	7.7	0	0	0	11.6	0	12.5
Loligo sp	N	158	209	519	1002	2020	1255	905	609	211	205	72	194	175	245	515	266	746
	%	1.7	2.2	5.6	10.8	21.7	13.5	9.7	6.5	2.3	2.2	0.8	2.1	1.9	2.6	5.5	2.9	8.0
	% in S.U	0	0	0	7.9	15.3	26.0	4.3	8.0	2.5	9.1	0	1.5	0	0	20.0	6.0	12.3
	% in S.T	0	0	0	8.3	0	0	0	0	0	0	0	0	0	0	0	0	0
Crustacea	N	124	627	2282	670	476	124	6	7	3	10	1368	182	1220	1313	168	132	139
	%	1.4	7.1	25.8	7.6	5.4	1.4	30.1	30.1	0	0.1	15.5	2.1	13.8	14.8	1.9	1.5	1.6
	% in S.U	24.2	0	0	4.0	3.8	15.4	6.4	7.1	5.8	9.1	4.1	4.5	2.7	24.1	0	0	6.4
	% in S.T	0	0	0	0	0	6.7	0	20.0	0	0	15.4	0	0	0	9.3	0	12.5

APPENDIX 3. A. DAILY VARIATION IN FEEDING AND ACTIVITY OF *Saurida undosquamis*.

Day	17 June 1980		10 September 1980				21 October 1981		
Time (Hours)	Number of Fish	Percent of Total	Number of Fish	Percent of Total	Percent stomach with food	Percent stomach at least half-full	Time (Hours)	Number of Fish	Percent of Total
1000			9	4.0	33.3	33.3	0940	221	14.4
1100			24	10.3	29.2	20.8	1035	111	7.2
1200	37	12.8	9	4.0	77.7	44.4	1140	297	19.4
1300	67	23.2	5	2.1	0.0	0.0	1200	*	-
1400	46	15.9	4	1.7	25.0	25.0	1340	335	21.9
1500	45	15.6	5	2.1	0.0	0.0	1540	239	15.6
1600	36	12.5	47	20.2	39.1	17.4	1740	107	7.0
1700	*		43	18.5	46.5	41.8	1840	22	1.4
1800	21	7.3	3	1.3	33.3	33.3	1940	13	0.8
1900	17	5.9	*				2040	15	1.0
2000	8	2.8	5	2.1	100.0	100.0	2140	8	0.5
2100	8	2.8	2	0.8	100.0	100.0	2240	24	1.6
2200	4	1.4	9	4.0	44.4	22.2	2340	10	0.6
2300	0	0.0	3	1.3	66.7	66.7	0040	8	0.5
2400	0	0.0	5	2.1	40.0	20.0	0205	11	0.7
0100			5	2.1	100.0	100.0	0300	10	0.6
0200			1	0.4	0.0	0.0	0340	10	0.6
0300			6	2.6	50.0	16.7	0440	32	2.1
0400			8	3.4	71.4	57.1	0540	60	3.9
0500			3	1.3	66.7	66.7			
0600			19	8.2	47.4	31.6			
0700			4	1.7	50.0	50.0			
0800			4	1.7	20.0	0.0			
S. tumbil	6 specimens caught between 1200 and 1600 Hrs. 5 of them between 1500 and 1600 Hrs.		20 specimens obtained in all; 15 between 1200 and 2300 Hrs, 12 of these at 1600 Hrs.				Time Number 0940 1140 44 1340 - 1540 6 at 2240 2		

* OTTER BOARDS TANGLED WITH NETS.

2, 3 and 7 *T. myops* were obtained on 17 June 1980, 10 September 1980 and 21 October 1981 respectively.

B. TIDES

June 1980	16th		17th		18th	
	HOURS	METRES	HOURS	METRES	HOURS	METRES
	0501	0.4	0547	0.4	0048	2.2
	1045	2.0	1130	1.8	0734	0.6
	1649	0.3	1727	0.4	1321	1.6
	2313	2.5	2356	2.4	1900	0.7

September 1980	9th		10th		11th	
	HOURS	METRES	HOURS	METRES	HOURS	METRES
	0334	0.3	0403	0.3	0431	0.3
	0924	1.9	0957	1.9	1030	2.0
	1525	0.3	1600	0.3	1634	0.3
	2136	2.2	2207	2.2	2237	2.1

October 1981	20th		21st		22nd	
	HOURS	METRES	HOURS	METRES	HOURS	METRES
	0236	1.4	0402	1.4	0520	1.5
	0830	0.4	0952	0.5	1112	0.5
	1518	2.0	1633	2.0	1739	2.0
	2214	0.5	2326	0.4		

APPENDIX 4A *Saurida tumbil* Variation in scale size with body site (See Fig. 4.2)

Standard length of fish (mm)	Statistic \ Body site	1	2	3	4	5	6	7	8	9	10
225	Range	4.8-5.8	4.1-5.9	5.1-5.8	5.2-5.5	5.2-5.8	4.0-5.1	4.0-4.5	4.3-4.8	5.7-6.5	5.9-6.4
	Mean	5.42	5.07	5.47	5.38	5.33	4.50	4.27	4.57	6.07	6.20
	C.V.	6.75	14.38	5.63	2.17	4.38	8.66	4.61	4.52	5.18	3.23
180	Range	4.6-5.3	4.3-5.3	4.9-5.4	4.7-5.4	4.9-5.4	4.1-4.6	3.3-4.0	4.4-5.1	5.4-6.4	5.6-6.1
	Mean	5.00	4.83	5.18	5.07	5.23	4.35	3.70	4.68	5.80	5.83
	C.V.	5.06	8.14	3.54	5.54	3.55	.78	6.40	5.64	6.07	3.00
290	Range	7.2-8.3	7.2-8.3	6.8-8.2	6.9-7.6	7.7-8.4	6.1-7.2	5.8-6.5	6.4-7.5	8.5-9.2	8.5-8.9
	Mean	7.83	7.77	7.68	7.27	8.08	6.60	6.25	6.93	8.77	8.65
	C.V.	5.69	6.65	6.66	3.33	3.07	6.71	4.02	7.16	2.95	1.59
272	Range	6.4-6.9	6.5-8.1	6.4-7.3	6.4-7.3	6.6-7.4	6.3-7.1	5.5-5.8	5.8-6.5	7.4-7.8	7.4-7.8
	Mean	6.67	7.50	6.83	6.87	7.13	6.70	5.60	5.95	7.57	7.87
	C.V.	3.51	8.27	4.69	5.80	3.93	5.08	1.96	4.60	1.81	3.74
283	Range	7.2-7.8	6.9-7.8	6.8-7.7	6.7-7.3	6.2-7.5	5.9-7.2	5.4-6.6	6.2-7.6	7.7-8.9	7.9-8.5
	Mean	7.33	7.38	7.35	7.02	7.13	6.62	6.05	7.08	8.25	8.33
	C.V.	3.19	4.72	4.61	3.30	6.67	8.19	7.59	8.35	5.24	2.81
264	Range	6.4-7.2		6.1-7.1	6.0-6.6	6.5-6.8	6.0-6.5	6.0-6.5	6.1-7.0	7.7-8.1	7.2-7.8
	Mean	6.83	–	6.77	6.40	6.67	6.30	6.12	6.53	7.86	7.57
	C.V.	4.00		5.18	3.42	1.82	2.84	3.34	5.27	1.87	3.09
228	Range	4.8-5.9	4.8-6.3	5.8-6.1	5.4-5.7	5.5-6.1	4.6-5.9	4.5-5.7	5.0-6.0	6.2-6.8	6.1-6.6
	Mean	5.40	5.83	5.97	5.55	5.82	5.25	5.20	5.43	6.60	6.30
	C.V.	6.83	10.32	1.73	2.21	3.83	8.41	8.43	6.45	3.18	2.94
262	Range	6.3-7.0	6.3-7.4	6.5-7.3	6.0-7.0	6.5-7.1	5.8-6.2	5.0-5.8	5.9-6.6	6.8-7.2	7.3-7.7
	Mean	6.66	6.92	6.85	6.33	6.80	6.00	5.52	6.27	7.07	7.50
	C.V.	4.52	6.16	5.28	5.44	3.22	2.79	5.31	4.81	2.13	2.23
250	Range	6.9-7.3	6.4-7.6	6.5-7.0	6.4-7.0	6.0-7.0	6.1-6.8	5.3-6.2	5.8-6.9	7.5-8.1	8.0-8.6
	Mean	7.05	8.88	6.73	6.68	6.67	6.60	5.71	6.38	7.82	8.3
	C.V.	1.96	8.19	2.92	3.20	5.82	4.18	5.79	6.82	2.96	1.50
233	Range	5.3-6.2	5.4-6.8	6.1-6.6	5.8-6.4	5.9-6.4	5.3-6.2	5.0-5.4	5.3-6.2	6.5-7.0	6.4-6.8
	Mean	5.75	5.87	6.28	6.08	6.12	5.70	5.18	5.75	6.80	6.61
	C.V.	6.10	8.33	3.09	3.93	3.17	6.45	3.09	6.10	2.94	2.34
252	Range	5.7-6.4	5.7-6.7	6.2-7.1	5.7-5.9	6.3-7.0	5.6-6.0	5.2-5.8	5.0-6.0	6.4-7.2	6.8-7.4
	Mean	6.05	6.20	6.65	6.08	6.56	5.75	5.51	5.52	6.90	7.1
	C.V.	4.27	7.77	5.27	4.46	3.81	2.85	4.64	7.64	4.29	2.73
242	Range	6.3-7.2	6.5-7.3	6.1-7.2	6.6-7.3	7.0-7.3	6.3-7.5	6.7-7.5	7.3-7.6	6.6-7.5	7.9-8.2
	Mean	6.85	6.9	6.75	7.04	7.03	6.92	7.2	7.01	7.10	8.03
	C.V.	3.37	5.27	5.50	2.38	1.53	8.64	5.59	8.29	1.90	1.50

C.V. - Coefficient of Variation

APPENDIX 4B. *Saurida undosquamis* : Variation in scale size with body site (See Fig.4.2)

Standard length of fish (mm)	Statistic \ Body site	1	2	3	4	5	6	7 -	8	9	10
184	Range	-	-	3.8-4.6	3.8-4.2	4.0-4.9	-	-	-	4.2-4.9	4.2-4.8
	Mean			4.23	4.02	4.37				4.6	4.53
	C.V.			6.46	4.29	8.15				4.91	4.56
244	Range	5.3-5.6	5.5-6.8	5.6-6.0	5.0-5.6	5.4-5.9	4.6-5.3	-	4.6-5.2	5.2-5.6	6.1-6.4
	Mean	5.42	6.43	5.82	5.32	5.72	4.98		4.83	5.3	6.22
	C.V.	2.41	7.40	2.29	5.10	5.00	7.11		4.66	2.36	2.14
186	Range	4.7-5.2	5.7-6.4	4.5-5.9	4.6-5.0	5.1-5.5	4.8-5.0	-	4.5-5.0	4.8-5.1	-
	Mean	4.98	5.93	5.02	4.80	5.33	4.93		4.66	5.0	
	C.V.	3.90	4.08	9.80	4.37	2.82	3.05		4.21	3.30	
153	Range	-	5.4-6.5	4.9-5.5	4.6-5.2	-	-	-	4.4-5.0	5.5-6.3	5.3-5.7
	Mean		5.84	5.22	4.87				4.72	5.8	5.50
	C.V.		7.33	4.27	4.80				5.69	4.15	2.30
198	Range	6.5-6.8	5.3-5.6	4.8-5.1	4.2-4.8	4.5-5.0	3.8-4.4	4.3-4.8	4.0-4.5	5.1-5.4	5.6-5.9
	Mean	6.58	5.50	4.95	4.52	4.88	4.07	4.55	4.25	5.22	5.65
	C.V.	2.02	1.99	3.32	5.32	3.97	5.75	4.56	3.87	2.55	2.44
197	Range	4.0-4.6	5.3-5.8	4.6-5.2	4.2-5.0	4.5-5.0	-	-	-	-	5.3-5.6
	Mean	4.38	5.56	5.03	4.40	4.82					5.50
	C.V.	4.88	3.73	4.47	6.89	4.44					2.30
185	Range	4.1-4.5	4.2-5.0	4.4-5.3	4.0-4.7	4.3-4.9	3.4-4.2	3.8-4.2	-	4.8-5.3	5.0-5.3
	Mean	4.23	4.70	4.78	4.32	4.65	3.70	4.04		4.98	5.12
	C.V.	4.40	6.02	8.51	5.75	4.66	8.20	4.50		3.90	2.29
176	Range	4.0-4.2	4.5-5.2	4.7-4.8	3.7-4.3	4.4-4.9	3.7-4.2	3.4-4.1	3.6-4.0	4.6-5.0	4.9-5.2
	Mean	4.13	4.95	4.77	3.93	4.63	3.78	3.70	3.73	4.75	5.03
	C.V.	1.98	5.07	1.08	6.16	4.02	5.40	6.84	4.03	2.90	2.40
176	Range	4.0-4.5	4.8-5.6	4.6-4.9	4.2-4.7	4.5-4.8	3.2-4.3	3.6-4.3	3.7-4.1	4.5-5.3	4.7-5.3
	Mean	4.20	5.13	4.73	4.53	4.57	3.88	4.07	3.88	4.90	5.00
	C.V.	4.99	7.36	2.18	3.86	2.65	10.73	6.53	4.13	5.32	4.38
182	Range	4.5-4.9	-	4.3-5.3	4.2-5.0	5.0-5.5	4.0-4.6	3.9-4.9	4.1-.49	5.1-5.5	5.6-6.0
	Mean	4.68		4.95	4.68	5.27	4.30	4.45	4.67	5.33	5.82
	C.V.	3.42		8.16	5.95	3.32	5.88	8.50	8.34	2.82	2.53

C.V. - Coefficient of Variation

APPENDIX 4C. *Trachinocephalus myops* : Variation in scale size with body site (See. Fig. 4.2)

Standard length of fish (mm)	Body site / Statistic	1	2	3	4	5	6	7	8	9	10
242	Range	7,8-9,0	9.3-10.4	6.3-7.8	6.9-7.7	6.7-8.0	8.0-9.0		7.9-8.9	8.5-8.8	9.7-10.6
	Mean	8.15	10,12	6.90	7.23	7.41	8.48	-	8.27	8,62	10.28
	C.V.	5.31	4.21	7.56	4.07	6.23	5.13		5.23	1.54	3.28
174	Range	5.2-5.7	5.3-6.1	4.3-5.2	4.2-4.4	4.0-4.5	5.3-5.8	5.0-5.9	5.3-5.9	5.5-5.6	5.7-6.1
	Mean	5,47	5.83	4.77	4.33	4.22	5.67	5.37	5.58	5.55	5.88
	C.V	3.60	5.49	6.18	1.88	4.35	4.42	5.61	4.15	0.99	2.26
93	Range	2.9-3.2	3.2-3.5	2.7-3.0	2.4-2.6	2.0-2.5	2.5-3.2		3.0-3.4	2.7-3.0	3.2-3.5
	Mean	3.02	3.38	2.85	2.53	2.35	2.83	-	3.08	2,88	3.28
	C.V.	4.88	2.91	4.84	3.22	7.96	8.54		5.20	4.05	3.56
200	Range	6.7-7.3	7.0-8.0	5.5-6.7		5.0-5.9	6.8-7.8	5.8-6.9		6.6-7.3	7.9-8.7
	Mean	6.97	7.37	5.97	-	5.45	7.37	6.42	-	6.87	8.32
	C.V.	3.82	5.06	7.77		6.00	5.34	5.95		3.98	3.76
140	Range	5.0-5.3	4.6-5.7	4.3-4.8	4.3-4.6	3.8-4.2	5.1-5.4	4.7-5.5	4.9-5.4	4.1-4.8	4.9-5.5
	Mean	5.18	5.28	4.63	4.52	3.97	5.23	5.08	5.17	4.63	5.25
	C.V.	2.26	7.32	4.46	2.94	4.12	2.61	5.89	3.60	5.73	4.13
160	Range	5.0-5.4	5.7-6.0	3.6-4.9	4.2-4.6	4.0-4.5			4.9-5.7	4.9-5.2	5.7-5.9
	Mean	5.15	5.82	4.42	4.47	4.32	-	-	5.22	5.02	5.83
	C.V.	2.68	2.53	11.04	3.37	4.50			5.99	2.33	1.40
217	Range	7.1-7.5	7.3-8.2	5.0-6.2	5.9-6.2	5.7-6.6	6.8-7.7	6.5-7.4	6.7-7.7	6.8-7.4	8.2-8.4
	Mean	7.27	7.82	5.73	6.03	6.07	7.20	6.93	7.08	6.93	8.30
	C.V.	1.88	3.92	9.60	1.71	5.48	5.20	5.89	5.82	3.37	0.76

C.V. = Coeff. of Variation

Appendix 5A: Mean standard length (L) and mean whole body weight (W) of *S. tumbil*.

Sex	Female			Male		
Total number of samples	478			475		
Size class	No. of samples	Mean L (mm)	Mean W (g)	No. of samples	Mean L (mm)	Mean W (g)
100 - 109	3	103.0	15.87	1	102.0	10.50
120 - 129	2	125.0	20.65	1	124.0	21.60
130 - 139	7	135.7	26.91	14	136.0	28.30
140 - 149	18	144.6	34.23	39	144.6	35.52
150 - 159	32	152.8	40.95	35	152.5	41.66
160 - 169	13	163.6	51.44	49	164.7	53.51
170 - 179	12	174.4	59.87	119	173.5	64.19
180 - 189	8	182.4	73.29	121	183.3	73.26
190 - 199	9	193.6	88.40	53	191.8	84.36
200 - 209	27	204.3	98.67	17	202.2	96.60
210 - 219	37	213.2	116.73	4	211.5	105.40
220 - 229	41	223.8	132.54	6	222.3	131.38
230 - 239	48	233.3	147.61	4	232.8	149.68
240 - 249	47	243.2	173.09	3	245.0	186.35
250 - 259	43	253.8	189.78			
260 - 269	48	263.0	219.29			
270 - 279	23	273.6	259.01			
280 - 289	20	282.6	282.08			
290 - 299	14	292.8	321.75			
300 - 309	11	301.9	333.34			
310 - 319	3	313.7	421.03			
320 - 329	4	322.5	437.38			
330 - 339	2	335.00	439.80			
340 - 349	2	342.5	549.25			

Appendix 5B: Mean standard length (L) and mean whole body weight (W) of *S. undosquamis*.

Sex	Female			Male		
Total number of samples	2606			2492		
Size class	No. of samples	Mean L (mm)	Mean W (g)	No. of samples	Mean L (mm)	Mean W (g)
80 - 89	3	87.3	7.33	3	84.7	6.40
90 - 99	16	94.9	9.92	10	96.6	8.97
100 - 109	26	104.6	11.10	27	104.0	11.81
110 - 119	79	114.5	14.70	99	114.7	14.81
120 - 129	154	124.3	19.24	253	125.0	19.41
130 - 139	294	134.5	24.72	421	134.6	25.47
140 - 149	355	144.2	29.98	740	144.2	31.71
150 - 159	491	153.9	36.98	582	153.5	38.74
160 - 169	434	164.0	44.94	244	163.3	46.45
170 - 179	342	173.7	52.97	79	172.9	56.16
180 - 189	209	183.0	62.33	22	182.2	66.06
190 - 199	109	192.9	75.62	9	191.7	79.56
200 - 209	42	203.3	91.53	1	203.0	96.90
210 - 219	22	214.2	103.19			
220 - 229	13	224.2	127.63			
230 - 239	4	233.3	142.03	1	237.0	144.20
240 - 249	4	244.5	166.35			
250 - 259	2	254.0	179.05			
260 - 269	3	263.3	214.10			
270 - 279	2	275.5	247.00			
280 - 289	1	280.0	269.10			
300 - 309				1	300.0	238.80
320 - 329	1	320.0	340.70			

Appendix 5C: Mean standard length (L) and mean whole body weight (W) of S. *filamentosa*.

Sex	Female			Male		
Total number of samples	350			278		
Size Class	No. of samples	Mean L (mm)	Mean W (g)	No. of samples	Mean L (mm)	Mean W (g)
90 - 99	1	96.0	7.10			
100 - 109				1	105.0	14.80
110 - 119	4	115.0	12.70	23	114.2	13.58
120 - 129	15	124.7	17.17	23	123.4	16.65
130 - 139	24	133.7	22.45	43	134.6	22.29
140 - 149	20	142.5	26.59	43	142.8	26.89
150 - 159	20	152.9	32.63	25	153.3	35.14
160 - 169	10	163.5	42.98	10	162.9	41.72
170 - 179	5	173.4	52.30	19	173.7	55.75
180 - 189	6	182.5	62.17	5	183.0	63.82
190 - 199	7	190.4	73.91	9	193.6	79.84
200 - 209	5	204.6	95.38	11	204.4	91.37
210 - 219	11	215.3	104.65	17	213.1	104.8
220 - 229	22	224.6	119.32	13	223.1	122.36
230 - 239	25	232.8	134.62	9	235.4	138.03
240 - 249	22	243.0	160.67	5	246.4	167.84
250 - 259	27	253.1	184.22	6	252.0	173.02
260 - 269	19	263.9	199.96	1	265.0	216.00
270 - 279	17	272.9	232.88	1	276.2	242.24
280 - 289	24	283.5	284.27			
290 - 299	15	293.2	323.03	2	295.0	283.20
300 - 309	15	303.1	348.90			
310 - 319	8	313.5	371.03			
320 - 329	10	322.7	420.71	1	325.0	399.80
330 - 339	8	332.8	484.90			
340 - 349	4	342.0	518.25	1	342.0	353.70
360 - 369	1	361.0	579.90			
370 - 379	1	370.0	576.50			
390 - 399	1	390.0	737.60			
420 - 429	1	424.0	872.80			
490 - 499	1	490.0	1066.60			
570 - 579	1	575.0	1483.20			

Appendix 5D: Mean standard length (L) and mean whole body weight (W) of *T. myops*.

Sex	Female			Male		
Total number of samples	497			537		
Size Class	No. of samples	Mean L (mm)	Mean W (g)	No. of samples	Mean L (mm)	Mean W (g)
80 – 89	6	85.8	8.50	8	85.9	8.50
90 – 99	20	95.0	11.47	13	95.3	11.53
100 – 109	20	102.8	15.39	17	104.5	16.14
110 – 119	27	114.7	20.83	28	114.8	21.07
120 – 129	28	124.1	26.59	46	124.5	27.04
130 – 139	38	134.5	34.46	83	133.9	33.78
140 – 149	65	143.8	42.83	114	144.2	42.91
150 – 159	59	154.8	54.15	106	153.8	52.53
160 – 169	48	164.3	67.28	62	163.4	64.98
170 – 179	46	173.8	82.33	42	173.2	74.63
180 – 189	29	183.2	98.31	16	182.2	87.64
190 – 199	32	194.2	117.97	2	192.5	100.00
200 – 209	31	203.7	135.11			
210 – 219	22	212.4	153.60			
220 – 229	16	223.6	179.79			
230 – 239	4	234.8	199.23			
240 – 249	5	243.0	218.06			
250 – 259	1	253.0	267.60			

APPENDIX 6: GONAD INDICES OF SYNODONTIDAE.

Month and Year	*S. undosquamis*						*S. tumbil*						*S. filamentosa*						*T. myops*					
	Male			Female			Male			Female			Male			Female			Male			Female		
	Min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max
Nov.'79	0.43	0.57	0.68	0.27	0.97	8.46	0.30	0.40	0.50	0.40	0.57	0.90												
Dec.'79	0.50	0.60	0.90	1.26	2.02	2.77	0.35	0.65	1.85	0.29	2.71	7.84												
Jan.'80	0.60	1.18	2.53	2.09	7.96	17.12	0.26	1.40	3.88	0.46	8.00	21.41							1.0	1.0	1.0			
Feb.'80	0.50	1.18	2.60	0.29	1.01	2.56	0.86	2.00	3.25	0.30	4.68	12.90												
Mar.'80	0.41	0.95	3.28	0.29	1.02	13.01	0.14	1.14	3.29	0.10	1.17	5.38												
Apr.'80	0.36	0.69	2.38	0.23	0.58	5.07	0.16	0.82	2.24	0.49	1.02	4.30												
May '80	0.39	0.68	1.06	0.20	0.55	1.34	0.30	0.79	1.54	0.36	0.90	2.40	0.20	0.35	0.50	0.20	2,64	6.30						
Jun.'80	0.23	0.62	1.37	0.21	0.47	1.13	0.31	0.43	0.61	0.24	0.72	2.03	0.23	0.23	0.23	0.15	1.80	9.20				1.90	1.90	1.90
Jul.'80	0.30	0.65	1.39	0.22	0.52	1.15	0.34	0.48	0.75	0.50	0.60	0.79							1.40	1.67	1.80	1.20	1.30	1.40
Aug.'80	0.37	0.69	1.91	0.28	0.72	2.41	0.38	0.47	0.75	0.51	0.81	1.01	0.20	0.60	1.20	0.30	1.93	12.9	1.40	1.40	1.40			
Sept.'80	0.28	0.64	1.37	0.30	1.58	12.11	0.42	0.77	1.07	0.52	1.00	1.33	0.16	0.22	0.31	0.12	1.62	19.08	1.00	1.00	1.00	1.80	1.80	1.80
Oct.'80	0.37	0.89	1.89	0.43	4.15	10.16	0.81	1.25	5.62	1.73	2.81	5.01	0.20	0.52	1.00	0.10	0.23	0.40	0.36	0.76	1.21	0.37	2.35	7.39
Nov.'80	0.11	0.71	1.20	0.34	2.21	14.47	3.10	2.25	7.50	2.80	4.76	7.40	0.30	0.30	0.30	0.20	0.25	0.30	0.54	1.88	4.96	0.39	5.10	14.77
Dec.'80	0.28	0.73	1.94	0.30	2.75	13.89	0.40	1.72	3.20	4.21	6.70	10.82							0.32	1.81	4.04	0.39	3.31	11.88
Jan.'81	0.30	0.57	1.04	0.32	2.32	8.75	0.34	1.26	3.60	2.73	7.25	15.84	0.18	0.65	2.14	0.12	1.32	9.18	0.50	2.10	4.31	0.57	5.00	11.55
Feb.'81	0.41	1.00	3.77	0.36	0.92	2.94	1.31	2.06	2.66	2.92	7.84	18.72	0.15	0.56	1.12	0.28	2.42	8.54	1.70	1.93	2.10	2.40	4.65	6.30
Mar.'81	0.33	0.88	2.35	0.26	0.85	9.54	0.45	1.96	5.61	1.65	8.71	18.52	0.18	0.94	1.68	0.15	1.50	9.56	0.60	0.60	0.60	6.80	6.80	6.80
Apr.'81	0.31	0.63	2.27	0.25	0.61	2.86	0.24	0.66	1.45	0.18	1.12	5.68	0.10	0.15	0.20	0.4	2.65	4.90	0.51	1.23	2.26	0.00	5.30	17.11
May '81	0.34	0.59	2.22	0.24	0.50	1.17	0.18	0.59	1.76	0.27	0.60	1.47	0.16	0.36	1.48	0.10	0.55	5.73						
Jun.'81	0.31	0.58	1,43	0.18	0.46	1.50	0.41	0.55	0.73	0.41	0.59	1.27	0.15	0.40	0.79	0.16	0.29	0.45						
July'81	0.26	0.70	2.02	0.21	0.60	1.70	0.27	0.52	0.77	0.23	0.61	1.29	0.50	0.50	0.50	0.20	1.70	8.00	0.7	0.7	0.7	0.40	0.60	0.80
Aug.'81	0.30	0.69	2.38	0.25	0.60	2.20	0.29	0.72	1.91	0.40	0.68	1.31												
Sept.'81	0.29	0.62	1.20	0.29	1.04	5.60	0.24	0.68	2.56	0.09	0.65	1.30	0.20	0.30	0.40	0.20	1.90	10.10				0.50	1.00	0.50
Oct. '81	0.26	0.70	2.75	0.19	5.22	24.11	0.24	0.91	2.17	0.95	3.02	5.65							0.34	1.12	2.29	0.00	3.19	13.20
Nov.'81	0.39	0.95	2.06	0.39	1.12	3.38	0.70	0.70	0.70	0.60	0.60	0.60							0.88	1.67	2.56	0.55	4.07	7.13
Dec.'81	0,31	0.80	1.33	0.25	2.07	9.72																		
Jan.'82																								
Feb.'82													0.30	0.30	0.30	0.30	3.40	9.50	1.06	3,14	5.46	4.01	8.86	15.04

min - minimum
max - maximum

Appendix 7: Monthly Trawl Catches of Lizardfish.

MONTH AND YEAR	*S.undosquamis*			*S. tumbil*			*S. filamentosa*			*T. myops*		
	*F	M	V	*F	M	V	*F	M	V	*F	M	V
November 1979	32	6	0	31	20	0						
December 1979	21	10	0	17	9	0						
January 1980	11	12	0	74	62	0				0	1	0
February 1980	106	79	54	18	19	0						
March 1980	165	187	6	16	12	0						
April 1980	213	177	0	20	9	0						
May 1980	64	77	1	16	6	0	5	2	0			
June 1980	150	116	2	19	8	3	17	1	0	1	0	0
July 1980	159	187	3	23	18	0				3	3	0
August 1980	24	17	6	30	25	2	11	3	0	0	1	0
September 1980	98	115	3	9	10	2	17	3	0	1	1	0
October 1980	55	56	4	15	17	1	3	5	0	18	7	0
November 1980	34	62	1	55	90	0	2	2	0	84	110	0
December 1980	31	29	5	50	50	0				202	162	32
January 1981	80	60	4	53	62	0	53	73	1	49	96	0
February 1981	56	79	4	20	12	0	18	5	0	4	4	0
March 1981	306	106	11	28	22	0	117	142	0	1	1	0
April 1981	144	260	17	58	26	2	2	4	0	10	11	0
May 1981	83	98	0	29	68	0	69	16	0			
June 1981	219	116	0	21	36	0	10	6	0			
July 1981	170	176	2	28	21	0	12	1	0	2	1	0
August 1981	171	167	1	23	12	12						
September 1981	98	64	8	19	12	3	6	2	0	2	0	0
October 1981	156	280	0	9	39	0				76	79	0
November 1981	31	31	2	1	1	0				7	23	0
December 1981	19	13	1									
February 1982							3	4	0	43	37	0

* F - Female. M - Male. V - Very young fish.

Appendix 8: *SAURIDA*: MONTHLY SEX RATIOS.

MONTH AND YEAR	*S. undosquamis*				*S. tumbil*			
	* frequency (f)			Chi-square	* frequency (f)			Chi-square
	$f_{o(F)}$	$f_{o(M)}$	f_e		$f_{o(F)}$	$f_{o(M)}$	f_e	
Nov. 1979	32	6	19	17.789	31	20	25.5	2.372
Dec. 1979	21	10	15.5	3.903	17	9	13	2.461
Jan. 1980	11	12	11.5	0.043	74	62	68	1.059
Feb. 1980	106	79	92.5	3.941	18	19	18.5	0.027
March 1980	165	187	176	1.375	16	12	14	0.571
April 1980	213	177	195	3.323	20	9	14.5	4.172
May 1980	64	77	70.5	1.999	16	6	11	4.550
June 1980	150	116	133	4.346	19	8	13.5	4.481
July 1980	159	187	173	2.266	23	18	20.5	0.610
Aug. 1980	24	17	20.5	1.195	30	25	27.5	0.455
Sept. 1980	98	115	106.5	1.357	9	10	9.5	0.53
Oct. 1980	55	56	55.5	0.009	15	17	16	0.125
Nov. 1980	34	62	48	8.167	55	60	57.5	0.217
Dec. 1980	31	29	30	0.067	50	50	50	0
Jan. 1981	80	60	70	2.857	53	62	57.5	0.704
Feb. 1981	56	79	67.5	3.919	20	12	16	2.00
March 1981	306	106	206	97.087	28	22	25	0.720
April 1981	144	260	202	33.307	58	26	42	12.190
May 1981	83	98	90.5	1.243	29	68	48.5	15.680
June 1981	219	116	167.5	31.668	21	36	28.5	3.947
July 1981	170	176	173	0.104	28	21	24.5	1.000
Aug. 1981	171	167	169	0.047	23	12	17.5	3.457
Sept. 1981	98	64	81	7.135	19	12	15.5	1.581
Oct. 1981	156	280	218	35.266	9	39	24	18.750
Nov. 1981	31	31	31	0	1	1	1	0
Dec. 1981	19	13	16	1.125				

$f_{o(F)}$ = observed (female). $f_{o(M)}$ = observed (male). f_e = expected.