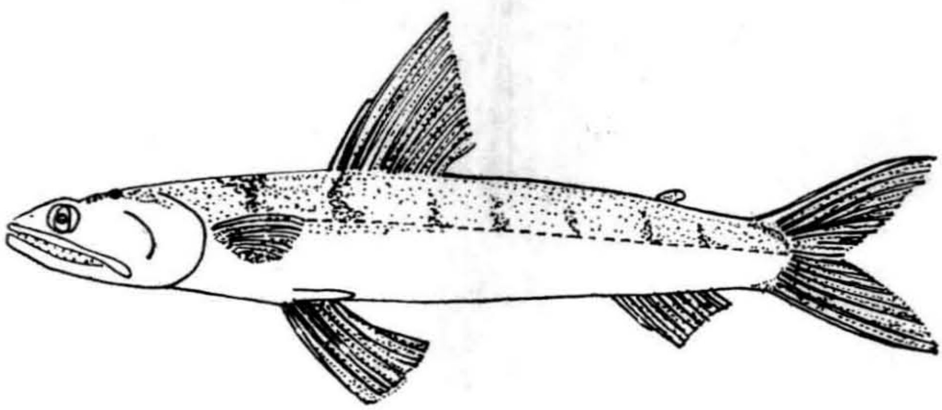
STUDIES ON THE FISHERY AND BIOLOGY OF THE LIZARDFISH, *SAURIDA* SPP. FROM THE KARNATAKA COAST



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MARINE BIOLOGY

DEPARTMENT OF MARINE BIOLOGY
POST GRADUATE CENTRE
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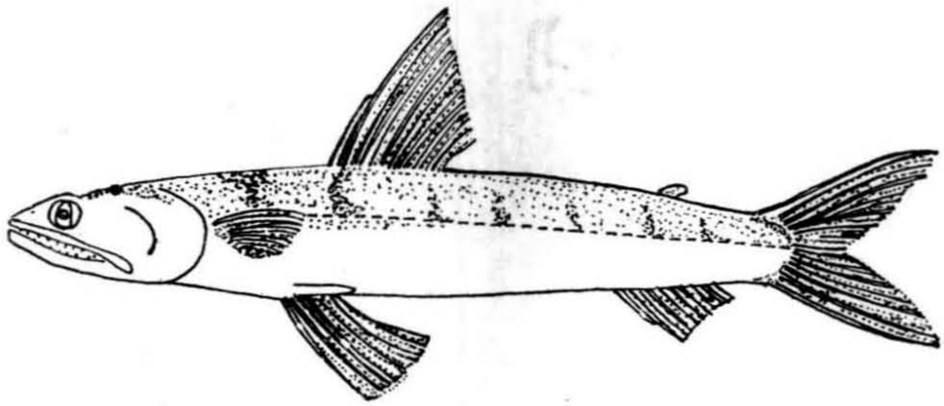

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Thesis submitted to the Karnatak University, Dharwad
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1994

KARNATAK UNIVERSITY

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CERTIFICATE

This is to certify that the thesis entitled **"STUDIES ON THE FISHERY AND BIOLOGY OF THE LIZARDFISH, *SAURIDA* SPP. FROM THE KARNATAKA COAST"** submitted by **Mr. C. Muthiah** for the award of Degree of Doctor of Philosophy in Marine Biology of Karnatak University is based on the results of experiments carried out by him under my supervision. The thesis or a part thereof has not been previously presented for any Diploma or Degree.

12/2/94

(B. NEELAKANTAN)

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CONTENTS

GENERAL INTRODUCTION

GENERAL INTRODUCTION

India possesses a long coastline of 7,517 km bordering the Arabian Sea, Bay of Bengal and the oceanic islands of Lakshadweep and Andaman Nicobar. The continental shelf area between 0 and 200 m depth is estimated at about 0.5 million km^2 and the total area of Exclusive Economic Zone (EEZ), as 2.02 million km^2. The fishery resources in these seas are rich, diverse and typical of tropical waters. The marine fishing activities prior to independence were, however, only at a subsistence level with a low quantum of production. Concerted efforts for the development of the marine fisheries of the country were initiated after the country became independent in 1947. Through the various programmes relating to introduction of mechanised fishing vessels, improvement of fishing implements, establishment of infrastructural facilities for preservation, processing, storage, transportation and for landing and berthing of crafts, and the development of an export trade - implemented during different national schemes, the marine fisheries of the country expanded rapidly, playing a major role in supplying protein food, earning foreign exchange and promoting coastal rural development. The marine fish production of the country consequent upon these developmental programmes, increased gradually from 0.534 million tonnes in 1951 to the present yield level of 2.3 million tonnes, contributing to over 1.5% of the total income from agricultural sector and earning Rs. 1767 crores from the export trade of fish and fishery products.

Before the introduction of mechanised fishing vessels, the fishery was supported, by and large by the resources harvested from the shallow coastal waters by the traditional gears. With the large scale introduction of fishing vessels, modern gears and improved fishing methods, the fishing activities gradually expanded and extended to the inner half of the continental shelf locating rich grounds for prawn and finfishes. The demersal fishery assumed greater importance besides increased exploitation of pelagic fishes from the fishing grounds within the 50 m depth zone.

The important varieties of marine fishes exploited at present from these grounds are clupeids formed of wolf-herring, oil sardine, other sardines, *Hilsa*, anchovies, *Coilia*, *Setipinna*, *Stolephorus*, *Thrissina*, and *Thryssa*; Bombayduck, half-beaks and full-beaks, flyingfishes, ribbonfishes, carangids, Indian mackerel, seerfishes, tunnies, bill-fishes, barracudas, mullets and others, belonging to the pelagic group and eels, catfishes, lizardfishes, perches, goat-fishes, silver-bellies, big-jawed jumper, pomfret, flatfishes, penaeid prawns, non-penaeid prawns, lobsters, crabs, stomatopods and cephalopods of demersal group. The status of the fishery resources of the country is reviewed from time to time (Rao, 1973 ; Silas *et al.* 1976; George *et al.* 1977; Alagaraja, 1987; James *et al.* 1987; James, 1988 and James and Alagaraja, 1991) and the most recent being by the Working Group on Revalidation of Potential Marine Fish Resources of EEZ of India (Anon., 1991).

The trend of marine fish production over the years has shown a four fold increase during the four decadal period of 1951-1990, with a quantum growth rate of 5.9% during 1961-70. Although the production showed an overall upward trend in the following decade of 1971-80, the growth rate decreased to 0.8% indicating the approaching of optimum level of exploitation of the resources in the inshore waters (0-50 m). Despite a production of 2.2 million tonnes in 1989, in the decadal period of 1981-90, the rate of increase of production was not appreciable *vis-a-vis* the effort put in, further showing that the intensification of exploitation of these resources in the narrow inshore belt would not realise further increase in production. The results of several studies carried out on the biological and population characteristics of certain important individual stocks of fish constituting region-wise and centre-wise fisheries and those made by the Working Group on Revalidation of Potential Marine Fisheries Resources of EEZ of India (Anon., 1991) also confirm that the exploitation of the marine fishery resources within 50 m depth zone has reached the optimum level. In consideration of these situations, the strategy for the development of the marine fisheries in the presently exploited region calls for pragmatic management of resources rather than increase of exploitation and intensive studies on the biology and population dynamics of constituent species in the multispecies complex supporting and contributing to the fishery in these grounds.

Among the demersal fish resources, lizardfishes belonging to the family Synodontidae (Class: Osteichthyes; Order: Myctophiformes) occupy an important place world-wide. The group includes 40 species under four genera. Of these, two species of the genus *Saurida* Cuvier, namely, *Saurida tumbil* (Bloch) and *Saurida undosquamis* (Richardson) are commercially important, together forming 49.69% of the world lizardfish catch during 1982-91. The lizardfishes are distributed mainly in the Indo-Pacific waters and their world production has been ranging between 40,564 t and 67,127 t with an annual average of 50,576 t during the 10-year period of 1982-91. The principal lizardfish producing countries are Egypt, Ethiopia, North Yemen, India, Burma, Thailand, Malaysia, Singapore, Vietnam, Philippines, Hong Kong, Taiwan, China and Japan. Consequent upon their importance in the regional fisheries of these countries, several studies and reports are available on the biology and exploitation of the species constituting the fisheries. Thus, mention may be made of Weber and de Beaufort (1913), Norman (1935,1939), Matsubara and Iwai (1951), Munro (1955), Anderson *et al.* (1966), Shindo and Yamada (1972), Russell and Cressey (1979), Yamada and Ikemoto (1979), Waples (1981), Shaklee *et al.* (1982), Cressey (1981) and Waples and Randall (1988) on the systematics of lizardfishes.

Delsman (1938) and Mito (1961) reported on the eggs and larvae of *S. tumbil* (?) from the Java Sea and Japanese waters respectively, Sufei and Ziyi (1986) on the early development of *Trachinocephalus myops* and *S. tumbil* from South Fujian and Taiwan fishing grounds; Yamada *et al.* (1965), Yamada (1968) and Liu and Yeh (1974) on the maturation and spawning of *S. tumbil* from the China Seas, Tiews *et al.* (1972) on the biology of the species from the Philippine waters, Latif and Shenouda (1973) on the gonads of *S. undosquamis* from the Gulf of Suez, Budnichenko and Dimitrova (1981) on the sexual cycle and fecundity of *S. undosquamis* and *S. tumbil* from the Arabian Sea; Thresher *et al.* (1986) on the life-history strategies and changes in population structure of *Saurida* spp. in the Australian northwest shelf; Okada and Kyushin (1955) and Yamada *et al.* (1966) on the food and feeding habits of *Saurida spp.* from the East China Sea, Budnichenko (1974) and Qiyong and Ganlin (1986) from Oman and South Fujian and Taiwan waters respectively and Wu (1984) on the food of *S. elongata* from Hong Kong; Okada and Kyushin (1955), Yeh *et al.* (1977), Shindo (1972) on the age and growth of *S. tumbil* from the East China Sea, Lee *et al.* (1986) and Lee and Yeh (1989) on S. *undosquamis* from Taiwan Strait, Xucai and Qiyong (1986) on *T. myops* from the Fujian and Taiwan Bank; Hamada (1986) on *S. wanieso* from the East China Sea; Kühlmorgen-Hille (1970) and Sinoda and Intong (1978) on the size distribution of *S. undosquamis* from Thailand; Budnichenko and Nor (1978) and Sanders *et al.* (1984) on the growth parameters of the species from the Arabian Sea and Oman respectively; Boonwanich (1991) on the growth parameters of *S. elongata* and *S. undosquamis* from the Gulf of Thailand; Shindo (1972) and Okada and Kyushin (1955) on the stocks of *S. tumbil* from the East China Sea, Sanders *et al.* (1984) and Boonwanich (1991) on the population dynamics of *S. undosquamis* from the Gulf of Suez and Thailand respectively.

In India, lizardfishes occur along both the east and west coasts and contribute to about 18,725 t of annual production during 1982-91 forming 37% of the World lizardfish production. With the present production of 28,432 t (1991) they form about 1.32% of all marine fish production of the country and 2.86% of the demersal production. West coast produces over 75% of the Country's lizardfish catch. State-wise, Kerala accounted for 45.04% of the total lizardfish landings of the country followed by Tamil Nadu (16.47%), Maharashtra (13.26%), Gujarat (7.42%), Andhra Pradesh (7.11%), Karnataka (5.77%) Goa (2.64%), Pondicherry (1.17%) and West Bengal & Orissa (1.02%). With the rapid expansion of trawl fisheries during the last two decades, the catch of lizardfish in India has shown an increasing trend. The annual average catch of 9,373 t during the decadal period of 1972-81, almost doubled to 18,725 t in the following decade, 1982-91. The catch attained a peak in 1992 with 28,939 t (CMFRI, 1982; 1981-91; 1993).

The lizardfishes in India are represented by 3 genera namely *Saurida*, *Synodus* and *Trachinocephalus* comprising of about 20 species. Among them, the genus *Saurida* is commercially important and is represented by about 10 species. However, only two species, *S. tumbil* and *S. undosquamis*, are of economic importance, while, the others are taken only occasionally in insignificant quantities. They are considered good quality fishes with more flesh content and good flavour. They are relished in fresh as well as in dried form. Sometimes they are utilized in processed form. They are also used as fish meal and manure.

Karnataka state on the southwest coast of India produces about 1446 t of lizardfishes annually forming 7.72% of the all India lizardfish catch during the 10 year period of 1982-91. They are landed exclusively by small and medium trawlers of 6.75-15 m overall length (OAL) operated in the relatively deeper waters of 20-60 m depth area during the trawl fishing season, November - May. Fishery is supported by the genus *Saurida*, comprising of three species, *S. tumbil*, *S. undosquamis* and *S. isarankurai*. The general trend of the lizardfish fishery in the state is similar to that observed in the all-India marine fish landings. The average annual catch during the 10 year period of 1972-81 was 176 t which increased to 1,446 t in the next 10 year period of 1982-91. The landings varied between nil catch (1973) and 508 t (1980) in the first decadal period and between 250 t (1982) and 2,967 t (1988) in the second. The percentage contribution of lizard fish to 'all fish' catch of the State varied from 0.16% (1982) to 1.40% (1988) during 1982-91. They formed 3.14% of the demersal marine fish catch of the state during the five year period of 1987-91 (CMFRI, 1982; 1982-91).

A general persual of the literature on lizardfishes of India reveals that most of the earlier works pertain to the systematics and distribution of these fishes along our coast. Among them, contributions of Day (1878), Weber and de Beaufort (1913) are most significant. Recent works of Rao (1964 and 1977), Dutt (1973), Misra (1976), Fishcher and Whitehead (1974), Nanda and Ramamoorthi (1982), Dutt and Vidya Sagar (1981), Talwar and Kacker (1984), Waples (1983) and Muthiah and Neelakantan (1991) have added considerably to our knowledge on the taxonomy of the group. Information on the fishery and biology of lizardfishes of India is rather limited. Gopinath (1946) described the post larvae of *S. tumbil* from the Trivandrum coast. Later, Nair (1952) and Raju (1963) made observations on the eggs of the species from the Madras and Waltair coasts respectively. Vijayaraghavan (1957) and Kuthalingam (1959) reared the eggs of the species upto larval stages, while, Basheeruddin and Nayar (1962) reported on the juveniles of the species from Madras. Dileep (1977) gave an account on the larval development and distribution of *S. tumbil* off the southwest coast of India. Annigeri (1963) made notes on the intraovarian eggs of the species from the Mangalore waters. Rao (1964) briefly discussed the food items of *S. tumbil* and *S. undosquamis* from Bay of Bengal. These works, after a gap of more than one decade were followed by Dighe (1977) who worked on the biology of *S. tumbil* from Bombay waters. Rao (1981, 1983a and 1984) took up studies on various aspects of the biology of *S. tumbil* and briefly on *S. undosquamis* from the northwestern part of Bay of Bengal. Rao (1982) also studied the population of *Saurida tumbil* from the Indian waters. Almost during the same time, Nanda and Ramamoorthi (1980) reported on the maturation and spawning of *S. tumbil* in Porto Novo waters, on the east coast. Recently Nair *et al.* (1992) discussed the lizardfish fishery of the different maritime states along the west coast of India during monsoon and compared with that of premonsoon and postmonsoon seasons.

From the above, it is evident that though certain studies have been carried out on the biology of lizardfishes of the Indian waters, comprehensive information on the biology, fishery and population characteristics of lizardfishes supporting the fishery is limited. Further, most of the work so far carried out from India is restricted to a single species, *S. tumbil* that too, mainly from the east coast. However, the two dominant species (*S. tumbil* and *S. undosquamis*) of lizardfishes from the west coast contribute to 75% of India's lizardfish production and the fishery biological information on their population is very meagre. Practically, there is no information on the population dynamics of *Saurida* spp. from the Indian waters. Considering the increasing importance of lizardfish fishery in the country and the prospects of their increased exploitation in the deeper waters, (100-200 m) where appreciable resources have been located, the present investigations on the biology and resource characteristics of *Saurida* spp. with particular reference to their fishery in Karnataka on the mid-west coast of India is taken up and the results obtained are embodied in this thesis.

The thesis is presented in six chapters. The systemic position of four species of the genus *Saurida* occurring along the Karnataka coast and their distinguishing characters for identification together with a note on their geographical distribution are presented in Chapter I.

A study on the month-wise and species-wise catch and effort of the lizardfish at the four important fish landing centres of the State *viz.*, Mangalore, Malpe, Bhatkal and Karwar has been carried out during the two fishing seasons of 1989-90 and 1990-91 (November - May) and the results are included in Chapter II.

The food and feeding habits of *S. tumbil*, *S. undosquamis* and *S. isarankurai* are studied and compared, and the salient features alongwith the qualitative and quantitative analyses of the stomach contents and the intensity of feeding with reference to sex, size, maturity stages and season are discussed in Chapter III.

The results of the studies on age and growth and length-weight relationship of the three species formed the subject matter of Chapter IV. The growth parameters have been determined using the length frequency distribution employing different methods. The growth characteristics of the species are compared and discussed not only among these species, but also with the other species of the same genus from other parts of the world.

Chapter V deals with the reproduction of the species which includes studies on maturity stages, length at first maturity, spawning season, recruitment pattern, development of ova to maturity, spawning periodicity, relative condition factor, fecundity and sex ratio for the three species.

Chapter VI presents the studies made on the population dynamics of the species which include the estimation of the total instantaneous fishing mortality (Z), the natural mortality co- efficient (M) and the fishing mortality co-efficient (F), the exploitation rate (U), the exploitation ratio (E), the total stock, the standing stock, the maximum sustainable yield, yield per recruit, optimum age of exploitation and potential yield per recruit using the standard methods.

Each Chapter of the thesis contains introduction, material and methods, results and discussion. Results are presented in the form of tables and graphs appropriately. A summary of the studies is appended at the end followed by the literature referred to and cited in the text.

It may be mentioned that the results of these investigations and the original contributions made in the thesis have considerably enhanced our existing knowledge of the biology and fishery of the commercially important lizardfishes of India in general and of Karnataka in particular. The information on age, growth, food and feeding and on reproduction gathered at present would be useful to improve the stock through better understanding of the biological process of the species. Similarly the findings presented on the fishing, natural and total mortalities of the population and on the estimation of maximum sustainable yield would help in the rational management and exploitation of lizardfish fishery of the country. It is also hoped that the data presented would further help in the management of the complex multispecies fishery prevailing in the region, as lizardfishes co-exist in the same ground where several other demersal fishes are also exploited.

Chapter I

SYSTEMATICS

INTRODUCTION

The correct identification of fishes is an essential pre- requisite in the investigations of biology, fishery and distribution of the concerned species. The major contributions on the taxonomy of fishes from the Indo-Pacific region are by Day (1878), Weber and de Beaufort (1911-1936, 1953 and 1962), de Beaufort (1940), de Beaufort and Chapman (1951), Smith (1961), Munro (1955), Fischer and Whitehead (1974), Misra (1976), Jones and Kumaran (1980), Talwar and Kacker (1984) and Fischer and Bianchi (1984).

Regan (1911), in his taxonomical studies of fishes included the lizardfishes in the family Synodontidae under the Order Iniomi and Sub-order Myctophoidea. Later, Berg (1940) considered them in the family Synodidae under the Order Scopeliformes. While, most authors have dealt with lizardfishes under the family Synodontidae, some (Dutt, 1973; Dutt and Vidya Sagar, 1981; Talwar and Kacker, 1984) have included them under the family Synodidae. The family name Synodontidae formerly used for the family of African catfishes is now called Mochocidae (Norman, 1935).

At present over 40 species of lizardfishes (Shaklee *et al.,* 1982) of the family Synodidae are placed under four genera *viz., Synodus* Gronow, *Saurida* Cuvier and Valenciennes, *Trachinocephalus* Gill and *Xystodus* Ogilby. Of these, *Xystodus* is known only from Australia and the other three are known to occur in the Atlantic, Pacific and Indian Ocean (Anderson *et al.* 1966).

The earliest systematic study of lizardfishes from the Indian waters is by Day (1878). He has described 6 species under the family Scopelidae and in 4 genera *viz., Saurus, Saurida, Harpodon* and *Scopelus.*

The genus *Saurida* was first described by Cuvier and Valenciennes (1849) with two species, *S. tumbil* (Bloch) and *S. nebulosa* C. and V., from the Indo-Australian waters. Day (1878) and Munro (1955) described these species from the Indian waters and the Seas of Ceylon respectively. Both authors synonimised *S. nebulosa* with *S. gracilis* (Quoy and Gaimard). These two species along-with a third one, *S. grandisquamis* Gunther were described by Weber and Beaufort (1913) from the Indo-Australian Archipelago. Norman (1935) in his revision of lizardfishes of the genus *Saurida* from the Indo-Pacific region recognised 5 species *viz., S. gracilis* (Quoy and Gaimard) *S. tumbil*, (Bloch), *S. undosquamis* (Richardson), *S. filamentosa* Ogilby and *S. elongata* (Temminck and Schlegel). Later, Norman (1939) reported a new species, *S. longimanus* from the Gulf of Oman. Subsequently, Shindo and Yamada (1972) described three new species *viz., S. isarankurai, S. micropectoralis* and *S. wanieso*, the first two species from the Gulf of Thailand and the third from the East China Sea. Waples (1981 and 1983) in his studies on the group, established *S. nebulosa* C. and V. as a separate species. In 1981 Dutt and Vidya Sagar described a new species *S. pseudotumbil* from Indian coastal waters. In addition to the above 12 species of the genus *Saurida*, one more species, *S. argentea*, is known to occur from the East Indian Ocean (Fischer and Whitehead, 1974).

Of the total 13 species of genus *Saurida* from the Indo- Pacific region, the following nine species are known to occur in the Indian waters (Day, 1878; Munro, 1955; Rao, 1977; Dutt and Vidya Sagar, 1981; Nanda and Ramamoorthi, 1982; Fischer and Whitehead, 1974 and Waples, 1983).

1. *S. tumbil*
2. *S. undosquamis*
3. *S. gracilis*
4. *S. nebulosa*
5. *S. micropectoralis*
6. *S. wanieso*
7. *S. isarankurai*
8. *S. longimanus*
9. *S. pseudotumbil*

MATERIAL AND METHODS

Specimens were collected from the catches of trawlers operating at a depth of 20-60 m off Mangalore, Malpe, Bhatkal and Karwar in the mid-west coast of India during November-May period of 1989-90 and 1990-91. The colour and pigmentation of fresh specimens were noted. For detailed observations, formalin preserved fishes were used. Morphometric and meristic data were recorded following Hubbs and Lagler (1958). Standard length was measured from tip of snout to the end of vertebral column (excluding urostyle). A total of 22 morphometric characters and 8 meristic characters was recorded. The different body proportions were expressed in percentage of standard length or head length with their range and mean to facilitate better comparison.

SYSTEMATIC DESCRIPTION

The taxonomic position of lizardfishes has been frequently reviewed by various taxonomists. In the present study the taxonomic key given by Nelson (1984) has been considered.

Class	:	Osteichthyes
Sub-class	:	Actinopterygii
Division	:	Halecostomi
Sub-division	:	Teleostei
Super order	:	Scopelomorpha
Order	:	Aulopiformes
Sub-order	:	Alepisauroidei
Family	:	Synodontidae
Genus	:	*Saurida*

Characters of the family Synodontidae

Body elongate, almost cylindrical, covered with fairly large cycloid scales. Head lizard-like, mouth very wide and terminal with rows of numerous small slender and pointed teeth visible even when mouth is closed; teeth also on palate and tongue, those on palate in 1 or 2 bands on each side. Branchiostegals numerous. Lateral line present. Dorsal fin consisting of 9 to 14 soft rays; adipose dorsal fin present. Pelvic fins fairly large,in abdominal position.Caudal forked.

Key to genera occurring in the Indian waters

1. (a) Pelvic fins with 9 rays, the inner rays not much larger than the outer ones; pelvic bones with short laminar posterior processes, two bands of teeth on each side of the palate, the outer one elongate and the inner short.. *Saurida.*

   (b) Pelvic fins with 8 rays, the inner rays much longer than the outer ones; pelvic bones with slender posterior processes. Palatine teeth in a single band on each side.. 2.

2. (a) Snout somewhat pointed, as long as or longer than eye; eye opposite midpoint of upper jaw; anal fin base shorter than dorsal fin base.. *Synodus.*

   (b) Snout short and blunt shorter than eye; eye nearer to anterior end of upper jaw; anal fin base longer than dorsal fin base
   .... *Trachinocephalus.*

All the four species studied during the present investigation belong to the genus *Saurida*.

Characters of the genus *Saurida*

Saurida Valenciennes, 1849. *Hist. Nat. Poiss.* **22**: 499 (type species: *Salmo tumbil* Bloch)

Body elongate, almost rounded, the head and caudal region some what depressed. Body covered with cycloid scales of moderate size. Lateral line straight. Snout bluntly pointed; eyes with anterior and posterior adipose eyelid; inter-orbital space more or less flat. Mouth very wide, oblique teeth visible when mouth is closed. Teeth in jaws and several series, largest teeth inner most row; teeth thin, pointed, depressible sometimes with hastate tips. Teeth on palate in one or two bands on each side, inner band much shorter than outer; small teeth sometimes present on the head of the vomer; teeth also on tongue and bronchial arches. Gill openings very wide; gillrakers rudimentary;

branchiostegals 13-16. Dorsal fin with 10-13 rays, the first two simple, fin lying approximately at mid-length of body; adipose fin very small above the short anal fin with 9-12 rays. Pectoral fins 11-16 rays, lying somewhat higher than mid line of body. Pelvic fin with 9 rays,placed close behind pectorals, the inner ray not much longer than the outer ones; pelvic bones with short, plate like posterior processes. Caudal fin forked. Vent posterior, closer to base of caudal fin than to insertion of pelvic fin.

SPECIES DESCRIPTION

1. *Saurida tumbil* (Bloch, 1795)

Plate 1

Salmo tumbil Bloch, 1795. *Naturg. ausland. Fische* **9**: 112, Pl. 430 (type -locality: Malabar).

Saurida tumbil (Bloch): Norman, 1935. *Proc. Zool. Soc.* London: 99-135 (with synonymy).

Material: 190 specimens of length range 161-416 mm standard length (200-431 mm total length).

Description

B. 14-16; D. 11-14; A. 10-12; P. 14-15; V. 9;

L.l. 49-54; L. tr. 4.5/5-7; Pyl.Caecae, 16-20;

Vertebrae 51-52; Predorsal scale 16-21, Number of scales from dorsal to adipose fin 15-17.

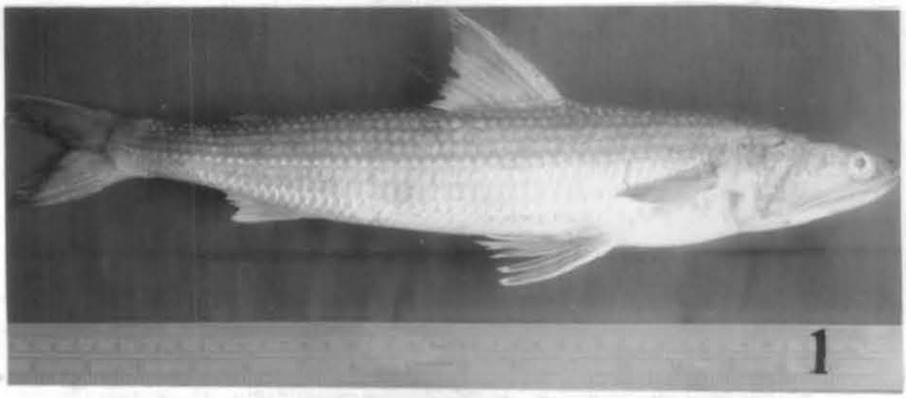
The various body proportions are given in Table 1.1. Body elongate, sub-cylindrical with lizard-like head; head and caudal peduncle depressed. Snout obtusely pointed. Mouth large; teeth in jaws several rows; 2 bands of teeth on palate on each side, inner bands smaller, outer bands elongate and in 3 or more rows anteriorly and narrowly separated; a small patch of teeth on the

Plate 1. *Saurida tumbil* (Bloch, 1795).

Plate 2. *Saurida undosquamis* (Richardson, 1848).

Plate 3. *Saurida isarankurai* Shindo and Yamada, 1972 .

Plate 4. *Saurida longimanus* (Norman, 1939). (Photograph from formalin preserved specimen-caudal damaged).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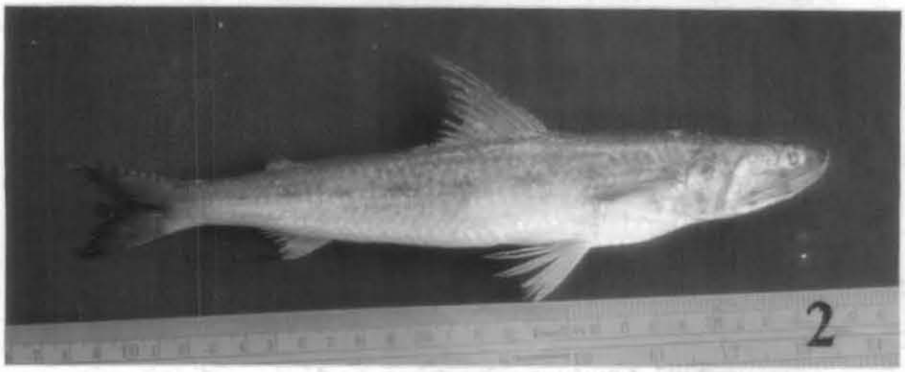
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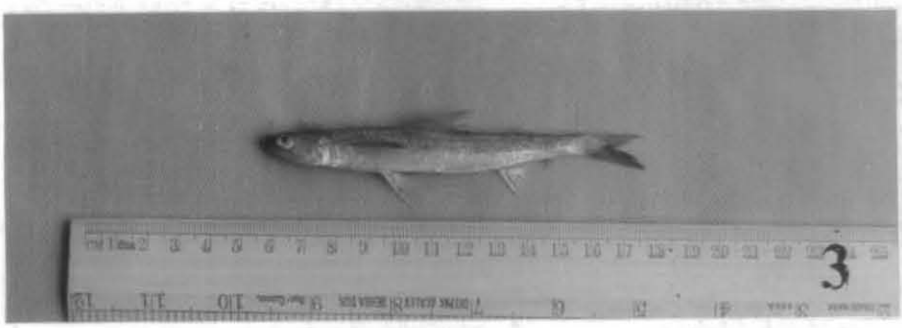
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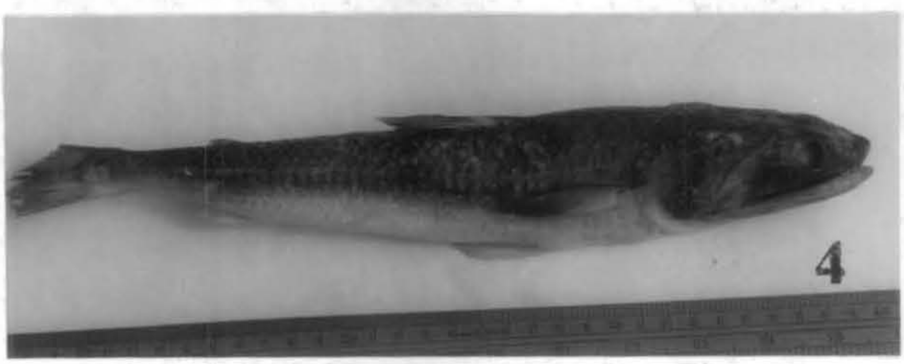
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head of vomer. Pectoral fin generally reaching base of pelvic, pectoral axil scale long and pointed.

Colour: Brownish above lateral line, silvery below, sometimes 8- 10 faint brown blotches visible along lateral line. Dorsals, pectorals blackish; posterior part of caudal particularly on the lower lobe and inner border of upper lobe blackish; parts of pelvics whitish, the middle part blackish or dusky; anal yellowish. Anterior edge of dorsal fin and upper edge of caudal fin without row of black spots.

Distribution: East coast of Africa (excluding Kenya and Somalia), Madagascar, Red Sea, the "Gulf", Pakistan, East and West coast of India, Sri Lanka, Malay Archipelago, East Indies, Australia, Gulf of Thailand, Philippines, China Sea, Taiwan and Japan.

Remarks: This species is the most commonly occurring saurid in the area presently studied. Dutt and Vidya Sagar (1981) reported and described a new species, *Saurida pseudotumbil* from the Indian coastal waters. They have pointed out that this species superficially resembles *S. tumbil* but differs in pectoral fin not reaching pelvic origin. According to them both *S. tumbil* and *S. pseudotumbil* do not have blotches on their flanks, but they have noted indistinct bars on the first two dorsal rays in some specimens of *S. pseudotumbil*. *S. tumbil* in the Karnataka coast differs from *S. pseudotumbil* in having longer pectoral fins reaching almost to the base of pelvics and in the presence of 8-10 brown blotches on lateral line. The present specimens agree well with the descriptions given by Norman (1935), Shindo and Yamada (1972), Waples (1983) and Talwar and Kacker (1984).

2. *Saurida undosquamis* (Richardson, 1848)

Plate 2

Saurida undosquamis Richardson 1848. Zool. *"Erebus and Terror"*, Fishes: 138, Pl. 51. Figs. 1-6 (type locality: north west Australia).

Saurida undosquamis: Rao, 1964. *J. mar. biol. Ass. India* **6(2)**: 265-267. Fig.; Misra, 1976. *Fauna of India.*Pisces (2^{nd} ed.) **2**: 296.

Saurida undosquamis: Norman 1935. *Proc. Zool. Soc.* London: 99-135 (with synonymy).

Material: 60 specimens ranging in size from 176 to 316 mm in standard length (143-261 mm total length).

Description

B. 14-15; D. 10-12; A. 44-50; P. 13-15; V. 9;

L.l. 44-50; L.tr. 3.5/5-6; Pyl. caecae 11-17;

Vertebrae 45-47.

The different body proportions are presented in Table 1.1. Body elongate, subcylindrical with lizard-like head; head and caudal peduncle depressed; snout rounded, mouth large. Teeth in jaws in several rows; teeth on palate in two bands on each side, inner bands smaller, the outer bands elongate and in two rows anteriorly and vomer toothless. Pectoral fin extending to about dorsal fin origin and reaching pelvic fin origin.

Colour: Brownish or greyish above, silvery white below; a row of 8 to 10 dark spots along each side; dorsal and caudal yellowish tinge and blackish distally; pectorals more blackish; pelvics and anal light lemon yellowish, sometimes pale white; anterior edge of the dorsal and upper edge of the caudal with a series of black spots.

Distribution: East coast of Africa (excluding Kenya and Africa), Red Sea, "the Gulf", Pakistan, India, Sri Lanka, Seychelles, Maldives, Chagos Islands, Malay Archipelago, Australia, China Sea, Gulf of Thailand, Philippines, Taiwan, Korea and Japan. Eastern Mediterranean through Suez.

Remarks: This species can be distinguished from the other known *Saurida* species by a series of black spots in the front edge of dorsal and upper edge of caudal and 9 to 10 brownish blotches on sides of body along the lateral line. This species is closely related to *S. longimanus* but differs from the latter by having smaller head, comparatively shorter pectoral fin and 9 to 10 brownish blotches on sides of body.

3. *Saurida isarankurai* Shindo and Yamada 1972.

Plate 3

Saurida isarankurai Shindo and Yamada, 1972. U O 11: 1-13, **12**: 1-14 (type locality : Gulf of Thailand).

Saurida isarankurai Shindo and Yamada: Dutt and Vidya Sagar, 1981. *Proc. Indian natn. Sci. Acad. B47 (6): 845-851;* Nanda and Ramamoorthi, 1982. *Matsya* **8**: 67-68; Muthiah and Neelakantan, 1991. *J. Bombay Nat. Hist. Soc.,* **88(3)**: 461-463.

Material: 53 specimens of length range 51-116 mm in standard length (62-126 mm in total length).

Description

B. 14-15; D. 11-13; A. 10-12; P. 12-13; V. 9;

L. l. 45-49; L. tr. 4/5-6; Vertebrae 45-47.

The various body proportions are given in Table 1.1. Body elongate and cylindrical, head depressed. Lower jaw longer than upper jaw and visible from above when mouth is closed. Teeth in jaws in several rows; palatine teeth in two bands on each side, the inner bands shorter than outer; outer bands in two rows anteriorly and posteriorly and in between in single row; vomer toothless. Pectoral fin tip extending well beyond origin of pelvic and almost reaching base of dorsal fin origin. Lower caudal lobe longer than upper lobe.

Colour: Dorsal side and upper flanks brownish mottled with grey, lower flanks and belly silvery white. A row of 8-10 indistinct dark spots along sides. Dorsal fin brownish yellow with scattered dark pigments; its anterior upper corner blackish. Upper part of pectoral fin dark, lower part whitish. Upper lobe of caudal yellowish with black pigment spots, lower lobe blackish, pelvic and anal fin without markings.

Distribution: West Central Pacific, coast of India through Gulf of Thailand.

Remarks: This is the first record of the species from the west coast of India. *S. isarankurai* can be easily identified from other *Saurida* species by longer lower jaw visible from above when mouth is closed, longer lower pectoral fin reaching beyond pelvic fin origin or almost extending to base of dorsal fin origin and longer lower lobe of caudal than upper lobe. According to Norman (1935) and Anderson *et al.* (1966), there were no other species having the most significant character of the lower jaw longer than upper visible from above when mouth is shut except the Atlantic species *viz., S. suspicio* Breder, 1927, *S. caribbaea* Breder, 1927 and *S. brasiliensis* Norman, 1935. But *S. isarankurai* can be distinguished from *S. suspicio* and *S. caribbaea* in having fewer lateral line scales, i.e., 47-50 (mode 49), whereas, it is 51-60 scales in the former two species. It differs from *S. brasiliensis* in having 9-10 prominent brownish blotches along the lateral line instead of about 6 faint blotches in the former. Also, *S. isarankurai* has longer lower lobe of caudal fin than upper lobe, while, in *S. brasiliensis* both lobes are almost equal.

The present description of *S. isarankurai* from the west coast of India fully agrees with the same species from Gulf of Thailand originally described by Shindo and Yamada (1972) except the difference in the length of pectoral fin. In the present observation, the pectoral length is 18.3% of standard length (SL) instead of 21.5% as recorded by Shindo and Yamada. The pectoral fin length of 18.2% of SL as given by Nanda and Ramamoorthi (1982) for Porto Novo (East coast of India) specimen is identical with the present observation. This indicates that the specimens of *S. isarankurai* from the Indian waters have slightly shorter pectoral fin than those from the Gulf of Thailand.

4. *Saurida longimanus* Norman, 1939

Plate 4

Saurida longimanus Norman. **1939**. *Fishes. Sci. Rept. John Murray Exped.*, **7(1)**: **23-24** (type locality: Gulf of Oman).

Saurida longimanus: Rao. 1977. *Indian J. Fish.* 24 (1-2): 143-171.

Material: 12 specimens of size range 156-261 mm standard length, 194-316 mm total length . In all specimens the caudal fins were found damaged at the time of collection .

Description

B. 16-18; D. 10-12; P. 13-14; V. 9; A. 9-11, L.l. 46-51;

Lt. tr. 3.5/5-6; Pyl. Caecae 15-17.

The various body proportions are presented in Table 1.1. Body elongate, subcylindrical, head large, snout round. Mouth large, teeth in jaws several rows; two bands of teeth on each side of palate; outer bands in 2 series anteriorly where the two bands are widely separated; inner bands shorter and well separated from the outer bands and in 2 or more rows; vomer toothless; pectoral fin very long extending to about middle of dorsal fin base.

Colour: Dark brownish above, silvery white below, head dark brown, dorsal fin blackish distally with light yellowish tinge on webs. Pectorals and caudal blackish. Pelvics white or light yellowish; anal fin whitish. Branchiostegals light yellowish. Black dots on upper ray of caudal and 2nd ray of dorsal. No black spots visible on flanks.

Distribution: Gulf of Oman, Arabian Sea and Bay of Bengal (Western side).

Remarks: This species has so far not been recorded from the west coast of India. The present 12 specimens were collected on a single occasion on 3.1.91 from the Mangalore fish landing centre. They were observed along with the other deeper water fishes like *Nemipterus* spp. and *Priacanthus* sp. They were reportedly caught from 60-75 m depth. Rao (1977) has collected specimens of this species from trawl catches off Puri, Waltair and Kakinada on the east coast of India from 70-100 m depth during February-April period.

Table 1.1: Body porportions of *S. tumbil, S. undosquamis, S. isarankurai* and *S. longimanus* in percentage of standard length and head length

Species	*S. tumbil*		*S. undosquamis*		*S. isarankurai*		*S. longimanus*	
Character	Range	Mean	Range	Mean	Range	Mean	Range	Mean
As percentage of standard length:								
Head length	23.76 - 27.85	25.59	24.36 - 27.71	25.88	22.40 - 25.45	23.75	27.04 - 30.81	29.73
Snout length	5.00 - 6.76	5.67	5.18 - 6.79	5.96	4.50 - 6.03	5.24	5.65 - 6.86	6.43
Eye diameter	3.62 - 5.55	4.29	4.22 - 5.65	4.91	4.10 - 5.80	4.90	4.54 - 5.13	4.86
Interorbital distance	4.34 - 6.38	5.33	4.49 - 5.92	5.25	3.33 - 5.17	4.11	5.13 - 6.91	6.34
Post-orbital length	14.35 - 17.46	16.11	14.04 - 16.46	14.94	12.80 - 14.86	13.79	18.18 - 20.17	18.95
Pre-maxillary length	14.89 - 19.26	17.02	16.84 - 18.53	17.94	13.76 - 17.39	15.71	18.63 - 20.52	19.58
Distance from snout tip to origin of dorsal fin	41.35 - 46.41	43.82	43.31 - 47.16	44.93	41.53 - 48.55	44.54	45.02 - 47.23	45.88
Distance from snout tip to origin of anal fin	73.61 - 80.80	76.39	75.29 - 81.00	78.18	71.83 - 79.71	74.86	78.23 - 81.22	79.26
Distance from snout tip to origin of adipose fin	80.22 - 84.92	82.63	79.81 - 86.33	83.53	77.56 - 85.51	81.95	82.35 - 86.32	83.97
Distance from snout tip to origin of pectoral fin	24.79 - 29.22	26.84	26.20 - 29.17	27.27	22.22 - 28.09	25.66	31.06 - 33.04	31.76
Distance from snout tip to origin of pelvic fin	37.40 - 42.21	39.46	37.58 - 43.01	40.20	35.36 - 42.03	39.22	40.47 - 43.06	41.50
Greatest body depth	13.69 - 18.42	15.89	12.81 - 15.97	14.14	10.53 - 13.27	11.86	13.99 - 16.42	15.17
Depth at anal fin origin	10.63 - 14.49	12.31	9.60 - 12.41	11.18	8.45 - 11.67	10.05	9.53 - 11.22	10.50
Depth at caudal peduncle	6.16 - 7.94	7.02	6.18 - 7.00	6.59	5.76 - 7.39	6.61	5.65 - 6.61	6.16
Height of dorsal fin	19.65 - 24.76	22.07	19.32 - 24.29	21.55	20.51 - 25.55	22.92	19.74 - 21.98	20.65
Dorsal base	12.75 - 15.93	13.87	12.50 - 15.16	13.92	11.76 - 14.43	13.34	12.18 - 14.23	13.40
Pectoral length	11.22 - 14.35	12.62	13.57 - 16.40	14.97	15.75 - 20.79	18.27	17.71 - 19.89	19.01
Pelvic length	15.00 - 19.18	17.36	15.16 - 18.78	16.90	14.95 - 19.09	16.82	15.83 - 18.62	17.04
Anal height	9.50 - 11.94	10.93	9.50 - 11.36	10.22	11.63 - 15.15	13.03	9.15 - 10.89	9.91
Anal base	8.53 - 11.91	9.44	9.18 - 11.01	9.88	8.38 - 13.13	10.41	8.70 - 9.36	8.99
Length of upper caudal lobe	21.25 - 23.91	23.25	20.32 - 25.76	23.09	20.99 - 24.72	23.35	*	*
Distance from dorsal fin origin to adipose fin origin	38.11 - 43.25	40.30	38.33 - 41.33	39.77	29.58 - 40.58	37.53	37.64 - 40.60	39.27
As percentage of head length:								
Snout	19.20 - 25.71	22.14	20.39 - 25.42	23.00	20.00 - 25.45	21.99	18.71 - 23.35	21.67
Eye diameter	14.19 - 19.35	16.77	16.51 - 22.34	19.00	17.02 - 23.80	20.65	14.97 - 18.98	16.42
Inter-orbital distance	17.51 - 24.76	20.83	18.10 - 23.39	20.35	13.50 - 21.82	17.33	17.14 - 23.27	21.08
Post-orbital length	56.99 - 66.49	62.22	54.55 - 61.54	58.48	53.13 - 60.56	56.62	60.58 - 65.54	62.92
Premaxillary length	63.16 - 70.41	66.48	66.25 - 72.34	69.41	60.60 - 72.22	66.18	61.79 - 67.88	65.52
Pectoral length	45.11 - 54.55	49.41	51.75 - 63.64	57.85	65.38 - 87.27	77.06	62.14 - 69.34	64.92

* In all 12 specimens used for the study, the caudal fins were found damaged. Hence, measurments on the same could not be made

Chapter II

FISHERY

INTRODUCTION

Lizardfishes are widely distributed in different parts of the world and are represented by a number of species. The world production of lizardfishes ranged between 40,564 t to 67,127 t with an annual average of 50,576 t during the 10 year period of 1982-91 (FAO, 1993). India, with an average annual landing of 18,725 t, (CMFRI, 1982-91) during the same period contributed to about 37% of the world lizardfish production.

The lizardfish fishery of the country is supported by the genus, *Saurida* comprising of about nine species. This group constitutes an important component of the demersal fish resources exploited along both the coasts of India. During 1951-1965, they were obtained occasionally, in small quantities all along the coast (Rao, 1973). During the decadal period of 1972-81, with an estimated average annual catch of 9,373 t, they contributed to 0.73% of the marine fish landing of the country (CMFRI, 1982). In the next decade (1982-91), their annual average catch almost doubled to 18,725 t forming 1.05% of the marine fish landing of the country (CMFRI, 1982-91). This was mainly due to the augumented fleet strength of trawlers over the years.

As in the case of the other exploited marine fishery resources, the lizardfish fishery has been showing appreciable annual fluctuation from year to year (CMFRI, 1982; 1983; 1986; 1989). The landing was below 5,000 t during 1972-73 which shot upto 13,000 to 14,000 t level in 1974-75. There was a fall in their production in 1976 (5,292 t). The catch showed an increasing trend in the subsequent years reaching the highest catch of 28,432 t in 1991, constituting 1.32% of the all India marine production. From the above, it is observed that the lizardfish fishery is emerging as one of the important demersal fishery resources of India.

The west coast contributes a sizable proportion of the lizard fish catch of India. Its share was 75.37% of the country's lizardfish production, with an annual average landing of 10,589 t during the 20 year period of 1972-91

(CMFRI, 1982; 1982-91). The average annual catch of 7,663 t during the 10 year period of 1972-81, rose to 13,715 t in the next decade (1982-91).

The east coast is comparatively less productive for lizardfish with an average annual catch of 3,460 t, forming 24.63% of the all India lizardfish catch during 1972-91. The annual catch varied from 1,095 t (1976) to 3,189t (1979) and from 3,611 t (1985) to 8,230 t (1991) during the 1st and 2nd decadal period respectively. Their percentage ranged from 9.20 (1975) to 33.66 (1973) in the 1st period and from 23.70 (1989) to 37.26 (1987) in the second period (CMFRI, 1982, 1982-91).

The major contribution to the lizardfish catch on the west coast of India is from Kerala, followed by Maharashtra, Gujarat and Karnataka. On the east coast, the bulk of the catch of lizardfish comes from Tamil Nadu and Andhra Pradesh. The state- wise percentage contribution to the all India lizardfish catch is as follows: West Bengal & Orissa 1.02, Andhra Pradesh 7.11, Tamil Nadu 16.47, Pondicherry 1.17, Kerala 45.04, Karnataka 5.77, Goa 2.64, Maharashtra 13.26 and Gujarat 7.42 (CMFRI, 1982, 1982- 91).

Karnataka state with a coastline of 270 km spread over two districts *viz.*, Dakshina Kannada and Uttara Kannada, ranks fifth among the maritime states of India with regard to marine fish production contributing to about 10% of the country's marine fish catch (Panikkar and Sathiadhas, 1993). The continental shelf area is about 25,000 sq. km. and 88% of the area lies between 0-72 m depth (Anon., 1978). At present only about 20% of the shelf area is exploited (George et al., 1977). A number of rivers drain into the coastal waters making the inshore sea productive. The salinity and temperature during the southwest monsoon (June-September) remain low and show an increasing trend from September - October and again from February - May. The average rainfall in the region is 300 cm, of which 75% is received between June and July.

There are about 100 fish landing centres along the coast of the state, of which 7 are major fish landing centres with harbour facilities. The major fishing gears of the state are trawl, purse seine and gillnet, besides several indigenous gears. Small to medium size boats (6.7-9.75 m) are used for trawling, purse- seining and gillnetting whereas dugout canoes and plank built boats with or without outboard engine are employed for fishing with indigenous gears. Fishing by purse seine, trawl and gillnet is done during September - May, whereas, the indigenous gears are operated throughout the year though at a slackening pace during the southwest monsoon period (June - September)

The coastal waters of the state is known for its pelagic fisheries constituted principally by mackerel and oil sardine. The success or failure of the fishery in the state is determined by the landings of these two species. The other important resources include carangids, anchovies, threadfin breams, flatfishes, lizardfishes, catfishes, tuna, seerfishes, cephalopods, prawns, squilla and crabs. The marine fish production of the state is characterised by wide fluctuations. The landings during the 10 year period, 1982 - 91 varied from 1,11,599 t (1983) to 2,51,012 t (1989) with an annual average of 1,40,440 t forming 9.64% of the all India marine fish production (CMFRI, 1982, Panikkar and Sathiadhas, 1993).

The average annual catch of lizardfish of the state during the 10 year period 1972-81 was 176 t which increased to 1,446 t in the next 10 year period of 1982-91. It contributed 0.5% and 7.72% to the all India lizardfish catch during these two periods respectively. The landing varied between nil catch (1973) to 508 t (1980) in the 1st decadal period and between 250 t (1982) to 2,967 t (1988) in the second period. Thus, the production showed a general increasing trend over the years with fluctuations. Its percentage contribution to the total marine fish catch of the state during 1982-1991 varied from 0.16 in 1982 to 1.40 in 1988. It formed 3.14% of the demersal fish catch of the state during the 5 year period 1987-91 (CMFRI, 1982, 1982- 91).

MATERIAL AND METHODS

Data on catch and effort and species composition by weight were collected on weekly basis from 10 to 20% of the single night to multi-day trawlers (as *Saurida* spp. in the area are not caught by the single day operating trawlers which normally fish in the inshore waters of 0-20 m depth area) from the fish landing centres, Mangalore, Malpe, Bhatkal and Karwar (Fig. 2.1). The boat's absence from port for 12 hours period was taken as one unit effort. The average weight of the species-wise catch per boat of the observed units on the observation day was multiplied by the total number of units operated on that day. The total species-wise catch and effort on the observation days were raised to the month based on the number of actual fishing days to get the monthly species-wise catch and effort estimates.

CRAFT AND GEAR

Though a variety of gears *viz.,* trawl net, purse siene, boat siene, shore siene, gillnet and hook and line and fishing crafts, both mechanized (trawlers, purse seiners and gillnetters) and non-mechanised (dugout canoes and plank built boats) are used for capturing the multispecies resource in the area, the lizardfishes are being caught exclusively by single night or multi-days trawling in the deeper waters (20-60 m depth). There are two types of trawlers, *viz.,* small trawlers of length varying from 6.7-9.5 m OAL with engine power of 20 to 96 HP and the medium trawlers of 9.75-15 m OAL with 53-102 HP engine, using otter trawls with rectangular otterboards of different sizes (65- 85 kg). The cod end mesh size of the trawl net varies from 25- 28 mm in shrimp trawl and 30-40 mm in fish trawl in the Mangalore-Malpe area and 15-30 mm in shrimp trawl in the Bhatkal and Karwar area. Normally the smaller trawlers conduct day fishing whereas, the medium size trawlers go for 2-3 night/day fishing.

FISHING AREA AND SEASON

Trawling duration extends from a single night or day to 2- 3 nights/days. The operations are in relatively deeper distant grounds in the 20-60 m depth by the single night or 2-3 nights/days trawlers, whereas, single day trawlers operate in the inshore waters within 20 m depth.

Trawling season commences after the end of southwest monsoon from September and extends upto May. There is no trawl fishing during the southwest monsoon period (June-August) due to inclement weather conditions and government ban on trawling during this period. In the beginning of the season only smaller trawlers go for day fishing. Night trawling starts from the end of November and continues upto May. All quality fishes caught are preserved in ice boxes while the economically unimportant components of the catch are dumped on the deck itself. Each boat makes 1-3 hauls of 2-3 hours duration during day fishing and 4-5 hours duration during night fishing.

RESULTS

The lizardfish fishery in the four centres studied was represented by three species *viz., Saurida tumbil* (Bloch, 1795), *S. undosquamis* (Richardson, 1848) and *S. isarankurai* Shindo and Yamada, 1972. Rarely seen in the area are a few specimens of *Trachinocephalus myops* (Schneider).

The total *Saurida* spp. catch during the two seasons of 1989-90 and 1990-91 (November-May) from the four centres together was 2,356 t by an estimated 1,63,074 units with a catch-per-unit- effort (cpue) of 14.45 kg. The average annual catch was 1,178 t by 81,537 units. *Saurida* spp. contributed to 6.16% of the 'all fish' catch (Table 2.1).

The catch was estimated at 840 t during the 1st season and 1,516 t in the second season for a total effort of 67,453 units and 95,621 units respectively. *Saurida* spp. formed 5.27% and 6.79% of total catch during these years. The catch per unit effort was 12.45 kg in the 1st season and 15.86 kg in the second season.

The average month-wise catch data during the period indicates that the peak period for *Saurida* spp. fishery is January- May when more than 90% of the annual catch is realised. The catch ranged from a minimum of 4.05 t in November to a maximum of 285.7 t in March. The period of abundance was February-March when it contributed 44.65% of the season's catch (Table 2.1).

Fishery at Mangalore

The *Saurida* spp. formed 6.85% of the 'all fish' catch by the single night as well as multi-days trawlers. The estimated catch and effort and cpue for the two seasons, 1989-90, 1990-91 and the average for the two seasons are shown in Table 2.2. and 2.3. The landing was 259 t during the first season for an effort of 38,271 units at a catch rate of 6.75 kg/unit. In the next season, the landing, the total effort and the cpue showed appreciable increase. They were estimated at 975 t, 48,954 units and 19.91 kg respectively. The average annual catch was 617 t for an average effort of 43,613 units.

The month-wise average catch and effort data showed a minor peak in December (64 t, cpue 11.03 kg) and a major peak during February-March (around 150 t and cpue 20 kg each month) with an overall average monthly catch of 88 t (Table 2.3 & Fig. 2.2).

Fishery at Malpe

Saurida spp. accounted for 5.41% of the catch by single night-multidays trawlers. The fishery was better during the first year (1989-90). The catch was estimated at 528 t for a total effort of 21,485 units at a catch rate of 24.6 kg/unit (Table 2.4). In the following season, though the effort showed 45% increase, the catch and catch rate declined by 29% and 61% respectively. The landing was 372 t for an effort of 38,886 units at a catch rate of 9.6 kg/unit (Table 2.4). The average annual effort and catch were 30,186 units and 450 t (Table 2.5).

The monthly average catch and effort data indicated two peaks of abundance, the first one in January (85 t) and the second in May (99 t), whereas, the cpue showed a single peak in April (24.2 kg). The average monthly effort and catch were 4,312 units and 64.3 t (Fig. 2.2).

Fishery at Bhatkal

Saurida spp. contributed to 3.2% of the single night trawlers catch (there is no multi-day fishing by trawlers at the centre). The fishery showed improvement during the second season (1990-91). The catch during the first season (1989-90) was 4.5 t for an effort of 1,255 units at a catch rate of 3.5 kg/unit (Table 2.6). An estimated 42.2 t were landed for an effort of 3,358 units with cpue of 12.5 kg in 1990-91 (Table 2.6). The average annual catch was 23.3 t for an effort of 2,307 units (Table 2.7).

The monthly average catch and effort data analysis indicated that the peak abundance was in March (14.3 t, cpue 24.6 kg) when 61% of the season's catch was obtained. The catch was generally poor in other months, the monthly average catch and cpue being 3.9 t and 10.1 kg respectively (Fig. 2.3).

Fishery at Karwar

Saurida spp. formed 8.2% of the night trawlers catch at this centre. A total of 49 t was landed during the first season for an effort of 6,442 units at a catch rate of 7.58 kg/unit (Table 2.8). The fishery showed considerable improvement in the next year (1990-91). Inspite of 31.34% decline in the effort, the landing increased by 160%. The catch was estimated at 127 t for a total effort of 4,423 units with cpue of 28.7 kg (Table 2.8). The average annual catch for the two year period was 88 t for an average effort of 5,433 units (Table 2.9).

The month-wise average catch and effort data indicated a peak in March (35.7 t, cpue 24.4 kg) while the monthly average catch and effort was 12.5 t and 776 units (Fig. 2.3).

SPECIES COMPOSITION

As mentioned earlier, the *Saurida* spp. fishery along the Karnataka coast is constituted by three species *viz., S. tumbil, S. undosquamis* and *S. isarankurai*. Of these, the first two species are commercially important and their catch estimates are available in the various reports and publications of CMFRI. The present investigation revealed for the first time the occurrence of the third species, *S. isarankurai* in the fishery along the Karnataka coast. This species was hitherto unknown from the west coast of India. As the species attains a maximum size of 14 cm only, and is caught along with a number of juvenile fishes including those of *S. tumbil* and *S. undosquamis*, the species would have gone undetected or unrecognised and grouped under the juveniles of the above two species and hence, there is no record of their previous occurrence and fishery importance.

Though, there is not much variation in the species composition during the first and second seasons, fluctuations in their monthly catches are evident. The average catch composition of the three species from the four centres indicated that *S. tumbil* contributed to the bulk of the catch forming 65%, followed by *S. undosquamis* (18%) and *S. isarankurai* (17%) giving a cpue of 9.33 kg, 2.64 kg and 2.48 kg respectively (Table 2.1 and Fig. 2.4 E).

S. tumbil

At Mangalore, *S. tumbil* was the dominant species forming 52%, with an annual average catch of 319 t at a catch rate of 7.32 kg/unit. The catch of 503 t was the highest in the second season (1990-91) with cpue of 10.3 kg. The landing was generally good during February-May, forming 47% of the season's total *Saurida* spp. catch. The highest catch, 84.7 t was obtained in February with cpue of 12 kg, followed by March (76.6 t, cpue 9.7 kg) (Tables 2.2 & 2.3 and Fig. 2.4 A).

At Malpe also, this species was predominant, contributing to around 77.5%, the annual average catch and cpue being 349 t and 11.55 kg respectively.

The catch was 411 t (cpue 19 kg) in the first season (1989-90) which declined to 286 t (cpue, 7.36 kg) in the next year (1990-91). The landing was uniformly good during January-May, forming 74% of the total *Saurida* spp. catch at the centre. The peak period of abundance was May with 82.3 t at a catch rate of 12.33 kg. (Tables 2.4 and 2.5 and Fig. 2.4 B).

At Bhatkal also, *S. tumbil* was the chief species forming 83.2% of the *Saurida* spp. catch. The average annual catch during the period was 19.4 t with cpue of 8.41 kg. The fishery was very poor in the 1989-90 season, with 4.4 t (cpue, 3.48 kg). It showed good improvement in the next season with 34.4 t (cpue 10.25 kg). The productive month for this fish at this centre was March with 11.3 t (cpue 19.5 kg) forming about 49% of the season's total *Saurida* spp. catch. The catch was very poor in May and December and in other months (January, February and April) the catch was around 2.5 t in each month. (Tables 2.6 and 2.7 and Fig. 2.4 C).

As in the above centres, at Karwar also, *S. tumbil* was the principal species forming 83.3% of the *Saurida* spp. catch with an annual average catch of 73.2 t and cpue of 13.5 kg. During 1989-90, the catch was 44.7 t (cpue 6.9 kg) which increased to 101.7 t in the next year with cpue of 23 kg. The maximum catch was recorded in March with 27.7 t and cpue of 19 kg. (Tables 2.8 and 2.9 and Fig. 2.4 D).

S. undosquamis

At Mangalore, this species contributed to nearly 28% of the *Saurida* spp. catch and formed the second important species among the *Saurida* spp. in abundance. The annual average catch was 171 t (cpue 3.93 kg). The catch was highest in the second season (1990-91) with 281 t and cpue of 5.74 kg. Month-wise, the highest catch was taken in February 53.6 t with cpue of 7.57 kg, followed by March, 45 t (cpue 5.72 kg). Percentage wise, January recorded good catch (Tables 2.2 and 2.3 and Fig. 2.4 A).

At Malpe this species accounted for 7.44% of the *Saurida* spp. catch with an annual average of 33.5 t (cpue, 1.11 kg). The landing showed a reduction in the second season (1990-91). The catch was 51.4 t (cpue, 2.4 kg) in 1989-90, which dropped to 15.5 t (0.4 kg) in 1990-91. The highest average catch of 14.3 t with cpue of 3.71 kg was recorded in February (Tables 2.4 & 2.5 and Fig. 2.4 B).

At Bhatkal, it formed 14.61% of the *Saurida* spp. catch. The catch was very insignificant in the first season with just 94 kg. However, it was better in the following season with 6.71 t and cpue of 2 kg. The highest catch of 2.9 t was recorded in March with cpue of 5 kg. (Tables 2.6 and 2.7 and Fig. 2.4 C).

At Karwar, the species formed 8% of the *Saurida* spp. catch with an annual average catch of 7t and cpue of 1.3 kg. The second season (1990-91) was more productive with 12.3 t at a catch rate of 2.78 kg. The catch during the first season was just 1.7 t (cpue 0.26 kg). The highest catch (2.8 t) and cpue (1.95 kg) was recorded in March (Tables 2.8 and 2.9 and Fig. 2.4 D).

S. isarankurai

At Mangalore, this species constituted 20.42% of the *Saurida* spp. catch with an annual catch of 126 t at a catch rate of 2.89 kg. The second season (1990-91) was more productive with 191 t and cpue of 3.91 kg. The period of abundance was December with 45.3 t of catch and a cpue of 7.81 kg, followed by March-April with more than 25 t and cpue around 3.5 kg in each month. Percentage-wise also December was the peak month of production (Tables 2.2 and 2.3 and Fig. 2.4 A).

At Malpe, the species formed 15.05% of the total *Saurida* spp. catch. The average annual landing was 67.7 t with cpue of 2.24 kg. The catch was 65.2 t (cpue, 3.03 kg) in 1989-90 which, increased marginally to 70.2 t (cpue, 1.81 kg) in 1990-91. The peak period of occurrence was March with 27.7 t (cpue, 5.72 kg) (Tables 2.4 and 2.5 and Fig. 2.4 B).

At Bhatkal it formed 2.19% of the *Saurida* spp. catch. It occurred during the second season (1990-91) only. The catch was 1.02 t at a catch rate of 0.3 kg in 1990-91. Almost the entire catch was taken in January with cpue of 2.7 kg. (Tables 2.6 and 2.7 and Fig. 2.4 C).

At Karwar, the species constituted about 9% of the *Saurida* spp. catch, the annual average catch being 7.7 t and cpue of 1.41 kg. It was caught more abundantly during the second season (1990-91). The catch was 2.5 t (cpue, 0.39 kg) in 1989-90 which increased to 12.8 t (cpue, 2.91 kg) in 1990-91. March was the peak month of occurrence for this species. (Tables 2.8 and 2.9 and Fig. 2.4 D).

CATCH DISPOSAL AND UTILISATION

Though the lizardfishes are considered to be good quality fishes with more flesh content, they are not preferred by the local population, mainly because of the odd appearance of their heads similar to that of snakes and lizards. At Mangalore, almost the entire catch of lizardfishes are packed in ice and transported to the neighbouring states of Tamil Nadu and Kerala, where there is good demand for this fish. Inspite of poor demand locally, it is highly priced, fetching Rs. 5-12 per kg because of its higher remunerative price in the neighbouring states. Bigger sized *S. tumbil* and *S. undosquamis* are sold at higher rates than the smaller ones. The small growing *S. isarankurai* caught along with other 'trash fishes' are used for fish manure. At Malpe also, there is no local demand for this variety. Part of the catch is ice-preserved and sent to the neighbouring states and interior places of the state. Part of the catch comprising bigger sized *S. tumbil* and *S. undosquamis* are used by the canning industry, while the smaller sized fishes are either salt cured or sun dried for marketing in the interior places or used as fish manure. At Bhatkal, the catch of lizardfish being small, bigger sized fishes are consumed fresh by the poor people and smaller fishes are sun- dried for fish manure. At Karwar, *Saurida* spp. fetch comparatively lower price than at Mangalore and Malpe. Part of the catch is salt cured for marketing and the rest is packed in ice and transported to the interior towns where they fetch high price.

DISCUSSION

Saurida spp. are caught along the Karnataka coast by the single night as well as multi-day fishing trawlers from the 20- 60 m depth area during November-May season. The overall *Saurida* spp. landings from the four important fish landing centres, Mangalore, Malpe, Bhatkal and Karwar, during 1989-90 and 1990-91 were 840 t and 1516 t respectively, indicating an increasing trend in their production. Centre-wise also it showed an increasing trend in their catch in all centres in the second year except at Malpe where the catch and catch rates showed decline in the second season. Of the four centres, Mangalore stands first in the production of *Saurida* spp. with an average catch of 617 t, followed by Malpe 450 t, Karwar 88 t and Bhatkal 23 t, indicating gradual reduction in their production from Mangalore to Karwar. The contribution of *Saurida* spp. to the total 'all fish' catch was higher at Karwar (8.22%), followed by Mangalore (6.85%), Malpe (5.41%) and Bhatkal (3.18%).

The annual cpue of *Saurida* spp. was highest at Karwar, 16.17 kg and lowest at Bhatkal, 10.10 kg. At Mangalore and Malpe, the cpue was more or less same, around 14 kg.

The period of abundance for *Saurida* spp. along the Karnataka coast is January-May. The peak period of abundance was February-March at Mangalore, April-May at Malpe and March at Bhatkal and Karwar.

The species composition from the four centres in general, indicated that *S. tumbil* was the most dominant species forming 65%. *S. undosquamis* and *S. isarankurai* shared the rest almost on an equal basis. Similarly, centre-wise catch composition also showed *S. tumbil* was the dominant species in all the centres. It formed 51.77% of the total *Saurida* spp. catch at Mangalore, 77.51% at Malpe and about 83% each at Bhatkal and Karwar, indicating that its percentage contribution increased from south (Mangalore) to north (Karwar), whereas it was reverse in the cases of *S. undosquamis* and *S. isarankurai*.

Rao *et al.* (1993), while studying the trawl fishery of the midshelf off Mangalore coast during 1979/80-1987/88 reported that the lizardfish formed one of the major components, ranking sixth among the demersal resources forming 5.9% of the total trawl catch. They further indicated that the peak period of abundance of *Saurida* spp. was May and the dominant species was *S. tumbil* forming 82% of the lizardfish catch. The present study from Mangalore showed that the peak period of abundance during 1989-90 and 1990-91 was February-March and the contribution of *S. tumbil* was 52% of the *Saurida* spp. catch. The lower percentage of the species in the present study as compared to that of Rao *et al.* (1993) might be due to the non-inclusion of *S. isarankurai* by them among the *Saurida* spp. catch as it was not known to occur at Mangalore at that time.

Most of the present yield of lizardfishes come from 0-50 m depth and the offshore areas are not fully exploited. Exploratory survey conducted by the Fishery Survey of India along the North Kerala and Karnataka (between lat. 11° N and lat. 15° N) coast, between 50-500 m indicated that *Saurida* spp. are more abundant in 100-200 m depth belts. The percentage of lizardfishes in the total catch was 3.58, 6.37 and 12.70 in the 20-50 m, 50-100 m and 100-200 m depths respectively. It formed the next dominant variety to nemipterids in the offshore waters (Philips and Joseph, 1988). Based on the catch rates, they have estimated the total demersal stock at 50,000 t in a shelf area of 18,000 km^2 available for trawling within 50-200 m depth belt between lat. 12° N and 15° N covering the areas of the state and adjacent waters. In consideration of the percentage contribution of *Saurida* spp. in those depth zones, their share in the overall estimated resource would be about 9535 t.

Table 2.1: Average monthwise effort, catch, catch per unit effort and species composition of *Saurida* landed by trawlers at Mangalore, Malpe, Bhatkal and Karwar (pooled for all centres) during 1989/90 - 1990/91

Month	Effort (No. of units)	*Saurida* spp. catch (kg)	Catch Per unit of Effort (kg)	Total fish catch (kg)	Percentage of *Saurida* spp.	Species Composition					
						S. tumbil		*S. undosquamis*		*S. isarankurai*	
						Catch (kg)	%	Catch (kg)	%	Catch (kg)	%
November	2179	4053	1.86	703860	0.58	3449	85.10	534	13.17	70	1.73
December	11047	87360	7.91	2640090	3.31	20800	23.81	16925	19.37	49635	56.82
January	14329	162399	11.33	4228700	3.84	111895	68.90	37774	23.26	12730	7.84
February	12595	240232	19.07	2938305	8.18	147473	61.39	69637	28.99	23122	9.62
March	14790	285697	19.32	3214275	8.89	169686	59.39	53343	18.67	62668	21.94
April	12370	213050	17.22	2593415	8.22	162995	76.51	13389	6.28	36666	17.21
May	14227	185021	13.00	2801375	6.60	144302	77.99	23743	12.83	16976	9.18
Total	81537	1177812	14.45	19120020	6.16	760600	64.58	215345	18.28	201867	17.14

Table 2.2: Monthwise estimated effort, catch, catch per unit of effort and species composition of *Saurida* landed by trawlers at Mangalore during 1989-90 and 1990-91.

Month	Effort (No. of units)	*Saurida* spp. catch (Kg)	Catch Per Unit of Effort (Kg)	Total fish catch	Percentage of *Saurida* spp.	Species Composition					
						S. tumbil		*S. undosquamis*		*S. isarankurai*	
						Catch (Kg)	%	Catch (Kg)	%	Catch (Kg)	%
1980-90											
November 89	480	3630	7.56	90980	3.99	2812	77.47	748	20.60	70	1.93
December 89	5014	29705	5.92	1049976	2.83	1616	5.44	27155	91.42	934	3.14
January 90	6784	13417	1.98	1091238	1.23	5593	41.69	6403	47.72	1421	10.59
February 90	6051	43217	7.14	1030899	4.19	22757	52.66	8236	19.06	12224	28.28
March 90	6887	53021	7.70	1064192	4.98	27013	50.95	8467	15.97	17541	33.08
April 90	7675	66930	8.72	1149940	5.82	35502	53.04	5035	7.52	26393	39.43
May 90	5380	48595	9.03	963230	5.05	40610	83.57	5815	11.97	2170	4.46
Total	38271	258515	6.75	6440455	4.01	135903	52.57	61859	23.93	60753	23.50
1990-91											
November 90	1341	4013	2.99	304236	1.32	3814	95.04	159	3.96	40	1.00
December 90	6595	98367	14.92	1237741	7.95	4972	5.05	3695	3.76	89700	91.19
January 91	7808	103842	13.30	1936050	5.36	39300	37.85	56037	53.96	8505	8.19
February 91	8099	262177	32.37	2332233	11.24	146603	55.92	98919	37.73	16655	6.35
March 91	8924	250239	28.04	2299692	10.88	126100	50.39	81988	32.76	42151	16.84
April 91	7348	134727	18.34	1471983	9.15	100773	74.80	7607	5.65	26347	19.55
May 91	8839	121532	13.75	1978399	6.14	81067	66.70	32696	26.90	7769	6.39
Total	48954	974897	19.91	11560334	8.43	502629	51.56	281101	28.84	191167	19.60

Table 2.3: Average monthwise effort, catch, catch per unit of effort and species composition of *Saurida* landed by trawlers at Mangalore during 1989/90-1990/91.

Month	Effort (No. of units)	*Saurida* spp. Catch (Kg)	Catch Per Unit of Effort (Kg)	Total Fish Catch (Kg)	Percentage of *Saurida* spp.	Species Composition					
						S. tumbil		*S. undosquamis*		*S. isarankurai*	
						Catch (Kg)	%	Catch (Kg)	%	Catch (Kg)	%
November	910	3822	4.20	197608	1.93	3313	86.68	454	11.88	55	1.44
December	5805	64036	11.03	1143858	5.60	3294	5.14	15425	24.09	45317	70.77
January	7296	58630	8.04	1513644	3.87	22447	38.29	31220	53.25	4963	8.46
February	7075	152697	21.58	1681566	9.08	84680	55.45	53578	35.09	14439	9.46
March	7905	151630	19.18	1681942	9.02	76557	50.49	45227	29.83	29846	19.68
April	7512	100828	13.42	1310962	7.69	68137	67.58	6321	6.27	26370	26.15
May	7110	85063	11.96	1470815	5.78	60838	71.52	19255	22.64	4970	5.84
Total	43613	616706	14.14	9000395	6.85	319266	51.77	171480	27.81	125960	20.42

Table 2.4: Monthwise estimated effort, catch, catch per unit of effort and species composition of *Saurida* landed by trawlers at Malpe during 1989-90 and 1990-91.

Month	Effort (No. of units)	*Saurida* spp. Catch (Kg)	Catch Per Unit of Effort (Kg)	Total Fish Catch (Kg)	Percentage of *Saurida* spp.	Species Composition					
						S. tumbil		*S. undosquamis*		*S. isarankurai*	
						Catch (Kg)	%	Catch (Kg)	%	Catch (Kg)	%
1989-90											
November 89	1585	323	0.20	839815	0.04	185	57.28	123	38.08	15	4.64
December 89	1672	7946	4.75	694975	1.14	3242	40.80	2162	27.21	2542	31.99
January 90	3098	54904	17.72	1614443	3.40	37771	68.79	9443	17.20	7690	14.01
February 90	3522	108158	30.71	1014826	10.66	77064	71.25	27314	25.25	3780	3.49
March 90	4140	124095	29.97	1235710	10.04	83107	66.97	3818	3.08	37170	29.95
April 90	3630	129036	35.55	1385863	9.31	108445	84.04	7571	5.87	13020	10.09
May 90	3838	103265	26.91	1220473	8.46	101263	98.06	1023	0.99	979	0.95
Total	21485	527727	24.56	8006105	6.59	411077	77.90	51454	9.75	65196	12.35
1990-91											
November 90	949	139	0.15	172202	0.08	86	61.87	37	26.62	16	11.51
December 90	7595	30940	4.07	1934850	1.60	24786	80.11	537	1.74	5617	18.15
January 91	7333	114725	15.65	2873487	3.99	108006	94.14	1091	0.95	5628	4.91
February 91	4199	38237	9.11	823447	4.64	25942	67.85	1366	3.57	10929	28.58
March 91	5539	44073	7.96	985166	4.47	25145	57.05	778	1.77	18150	41.18
April 91	3758	49818	13.26	564658	8.82	39073	78.43	3864	7.76	6881	13.81
May 91	9513	94199	9.90	1275839	7.38	63338	67.24	7828	8.31	23033	24.45
Total	38886	372131	9.62	8629649	4.31	286376	76.96	15501	4.16	70254	18.88

Table 2.5: Average monthwise effort, catch, catch per unit effort and species composition of *Saurida* landed by trawlers at Malpe during 1989/90-1990/91.

Month	Effort (No. of units)	*Saurida* Spp. Catch (Kg)	Catch Per Unit of Effort (Kg)	Total Fish Catch (Kg)	Percentage of *Saurida* Spp.	Species Composition					
						S. tumbil		*S. undosquamis*		*S. isarankurai*	
						Catch (Kg)	%	Catch (Kg)	%	Catch (Kg)	%
November	1267	231	0.18	506009	0.05	135	58.44	80	34.63	16	6.93
December	4634	19443	4.20	1314913	1.48	14014	72.08	1349	6.94	4080	20.98
January	5216	84815	16.26	2243965	3.78	72889	85.94	5267	6.21	6659	7.85
February	3860	73197	18.96	919136	7.96	51503	70.36	14340	19.59	7354	10.05
March	4840	84084	17.37	1110438	7.57	54126	64.37	2298	2.73	27660	32.90
April	3694	89427	24.21	975260	9.17	73759	82.48	5718	6.39	9950	11.13
May	6675	98732	14.79	1248156	7.91	82300	83.36	4426	4.48	12006	12.16
Total	30186	449929	14.91	8317877	5.41	348726	77.51	33478	7.44	67725	15.05

Table 2.6: Monthwise estimated effort, catch, catch per unit of effort and species composition of *Saurida* landed by trawlers at Bhatkal during 1989-90 and 1990-91.

Month	Effort (No. of units)	*Saurida* spp. Catch (Kg)	Catch Per Unit of Effort (Kg)	Total Fish Catch (Kg)	Percentage of *Saurida* spp.	Species Composition					
						S. tumbil		*S. undosquamis*		*S. isarankurai*	
1989-90						Catch (Kg)	%	Catch (Kg)	%	Catch (Kg)	%
November 89	- No fishing -										
December 89	- No fishing -										
January 90	768	942	1.23	281290	0.33	848	90.02	94	9.98	-	-
February 90	410	3164	7.72	131216	2.41	3164	100.00	-	-	-	-
March 90	12	330	27.50	2982	11.07	330	100.00	-	-	-	-
April 90	20	-	-	3480	-	-	-	-	-	-	-
May 90	45	23	0.51	8340	0.28	23	100.0	-	-	-	-
Total	1255	4459	3.55	427308	1.04	4365	97.89	94	2.11	-	-
1990-91											
November 90	- No fishing -										
December 90	483	843	1.74	153027	0.55	689	81.73	103	12.22	51	6.05
January 91	353	5908	16.74	151620	3.90	4455	75.41	495	8.38	958	16.21
February 91	722	2194	3.04	178538	1.23	2122	96.72	61	2.78	11	0.50
March 91	1148	28208	24.57	366676	7.69	22284	79.00	5924	21.00	-	-
April 91	479	4908	10.25	147117	3.34	4785	94.49	123	2.51	-	-
May 91	173	98	0.57	41355	0.24	88	89.80	10	10.20	-	-
Total	3358	42159	12.55	1038333	4.06	34423	81.65	6716	15.93	1020	2.42

Table 2.7: Average monthwise effort, catch, catch per unit effort and species composition of *Saurida* landed by trawlers at Bhatkal during 1989/90 - 1990/91

Month	Effort (No. of units)	*Saurida* spp. catch (kg)	Catch Per Unit of Effort (kg)	Tota fish catch (kg)	Percentage of *Saurida* spp.	Species Composition					
						S. tumbil		*S. undosquamis*		*S.isarankurai*	
						Catch (kg)	%	Catch (kg)	%	Catch (kg)	%
November	- No Night Fishing -										
December	242	421	1.74	76514	0.55	344.0	81.71	51.5	12.23	25.5	6.06
January	561	3425	6.11	216455	1.58	2651.5	77.42	294.5	8.60	479.0	13.98
February	566	2679	4.73	154877	1.73	2643.0	98.66	30.5	1.14	5.5	0.20
March	580	14269	24.60	184829	7.72	11307.0	79.24	2962.0	20.76	-	
April	249	2454	9.86	75298	3.26	2392.5	97.49	61.5	2.51	-	
May	109	61	0.56	24848	0.24	56.0	91.80	5.0	8.20	-	
Total	2307	23309	10.10	732821	3.18	19394.0	83.20	3405.0	14.61	510.0	2.19

Table 2.8: Monthwise estimated effort, catch, catch per unit of effort and species composition of *Saurida* landed by trawlers at Karwar during 1989-90 and 1990-91.

Month	Effort (No. of units)	*Saurida* spp. Catch (Kg)	Catch Per Unit of Effort (Kg)	Total Fish Catch (Kg)	Percentage of *Saurida* spp.	Species Composition					
						S. tumbil		*S. undosquamis*		*S. isarankurai*	
1989-90						Catch (Kg)	%	Catch (Kg)	%	Catch (Kg)	%
November 89	No fishing										
December 89	125	425	3.4	12610	3.37	225	52.94	75	17.65	125	29.41
January 90	990	1980	2.0	96253	2.06	1114	56.26	371	18.74	495	25.00
February 90	1457	8289	5.69	214559	3.86	6804	82.08	756	9.12	729	8.79
March 90	1777	18783	10.57	251020	7.48	17659	94.02	74	0.39	1050	5.59
April 90	1440	17857	12.40	366379	4.87	17408	97.48	355	1.99	94	0.53
May 90	653	1500	2.30	111779	1.34	1470	98.00	30	2.00	-	-
Total	6442	48834	7.58	1052600	4.64	44680	91.49	1661	3.40	2493	5.11
1990-91											
November 90	3	-	-	486	-	-	-	-	-	-	-
December 90	610	6494	10.65	197000	3.30	6070	93.47	124	1.91	300	4.62
January 91	1525	29080	19.07	413019	7.04	26703	91.83	1614	5.55	763	2.62
February 91	729	15028	20.61	150892	9.96	10490	69.80	2622	17.45	1916	12.75
March 91	1154	52646	45.62	223112	23.60	37733	71.67	5638	10.71	9275	17.62
April 91	389	22824	58.67	97411	23.43	20004	87.64	2223	9.74	597	2.62
May 91	13	829	63.77	3336	24.85	746	89.99	83	10.01	-	-
Total	4423	126901	28.69	1085256	11.69	101746	80.18	12304	9.70	12851	10.12

Table 2.9: Average monthwise effort, catch, catch per unit effort and species composition of *Saurida* landed by trawlers at Karwar during 1989/90 - 1990/91

Month	Effort (No. of units)	*Saurida* spp. catch (kg)	Catch per unit of Effort (kg)	Total fish catch (kg)	Percentage of *Saurida* *spp.*	Species Composition					
						S. tumbil		*S. undosquamis*		*S. isarankurai*	
						Catch (kg)	%	Catch (kg)	%	Catch (kg)	%
November	2	-	-	243	-	-	-	-	-	-	-
December	368	3460	9.41	104805	3.30	3147.5	90.97	99.5	2.88	213.0	6.15
January	1258	15530	12.35	254636	6.10	13908.5	89.56	992.5	6.39	629.0	4.05
February	1093	11659	10.67	182726	6.38	8647.0	74.16	1689.0	14.49	1323.0	11.35
March	1465	35714	24.37	237066	15.07	27696.0	77.55	2856.0	8.00	5162.0	14.45
April	914	20340	22.25	231895	8.77	18706.0	91.96	1289.0	6.34	345.0	1.70
May	333	1165	3.50	57557	2.02	1108.0	95.11	57.0	4.89	-	-
Total	5433	87868	16.17	1068928	8.22	73213.0	83.32	6983.0	7.95	7672	8.73

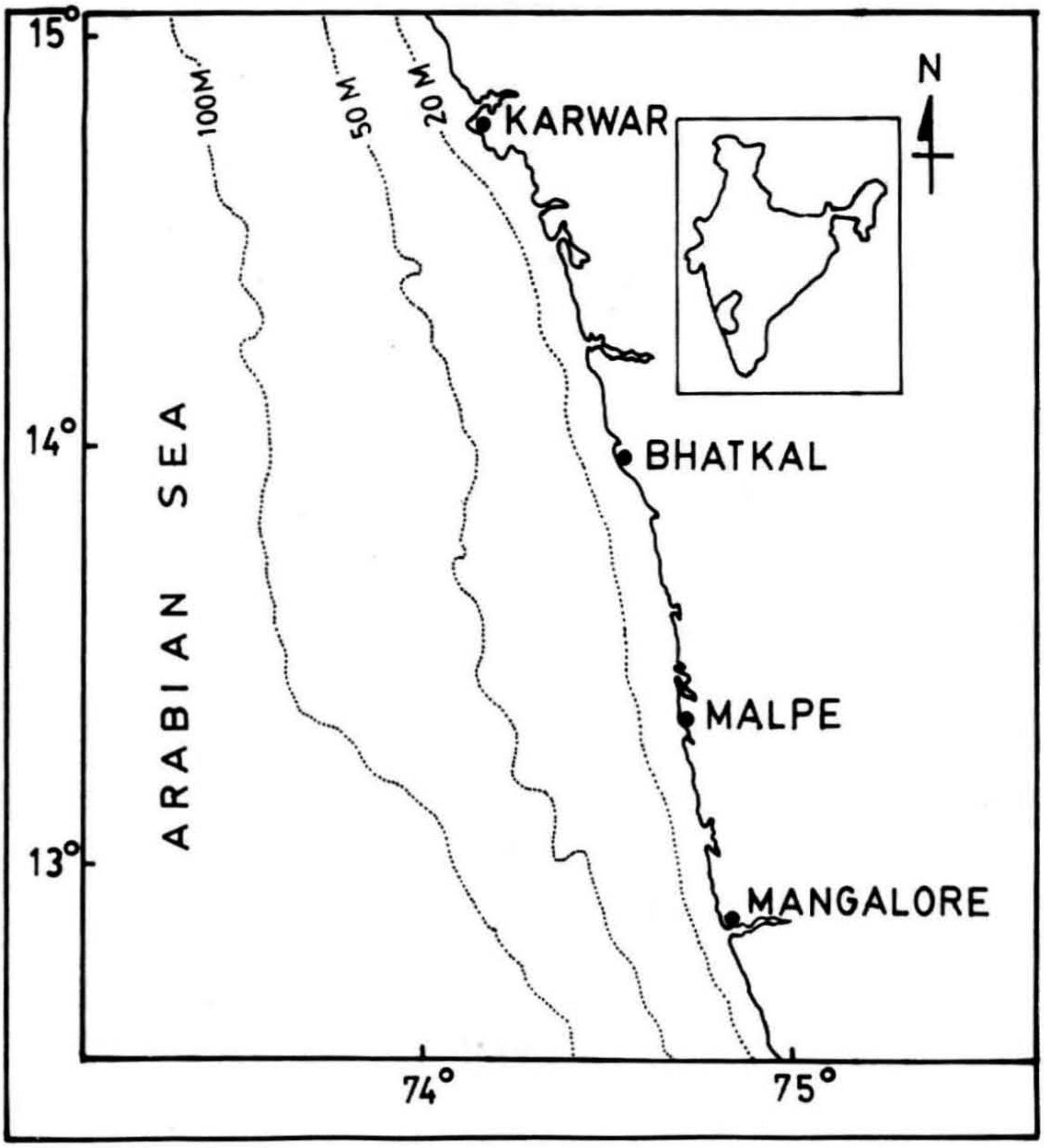

Fig. 2.1 Map showing the sampling centres along the Karnataka coast.

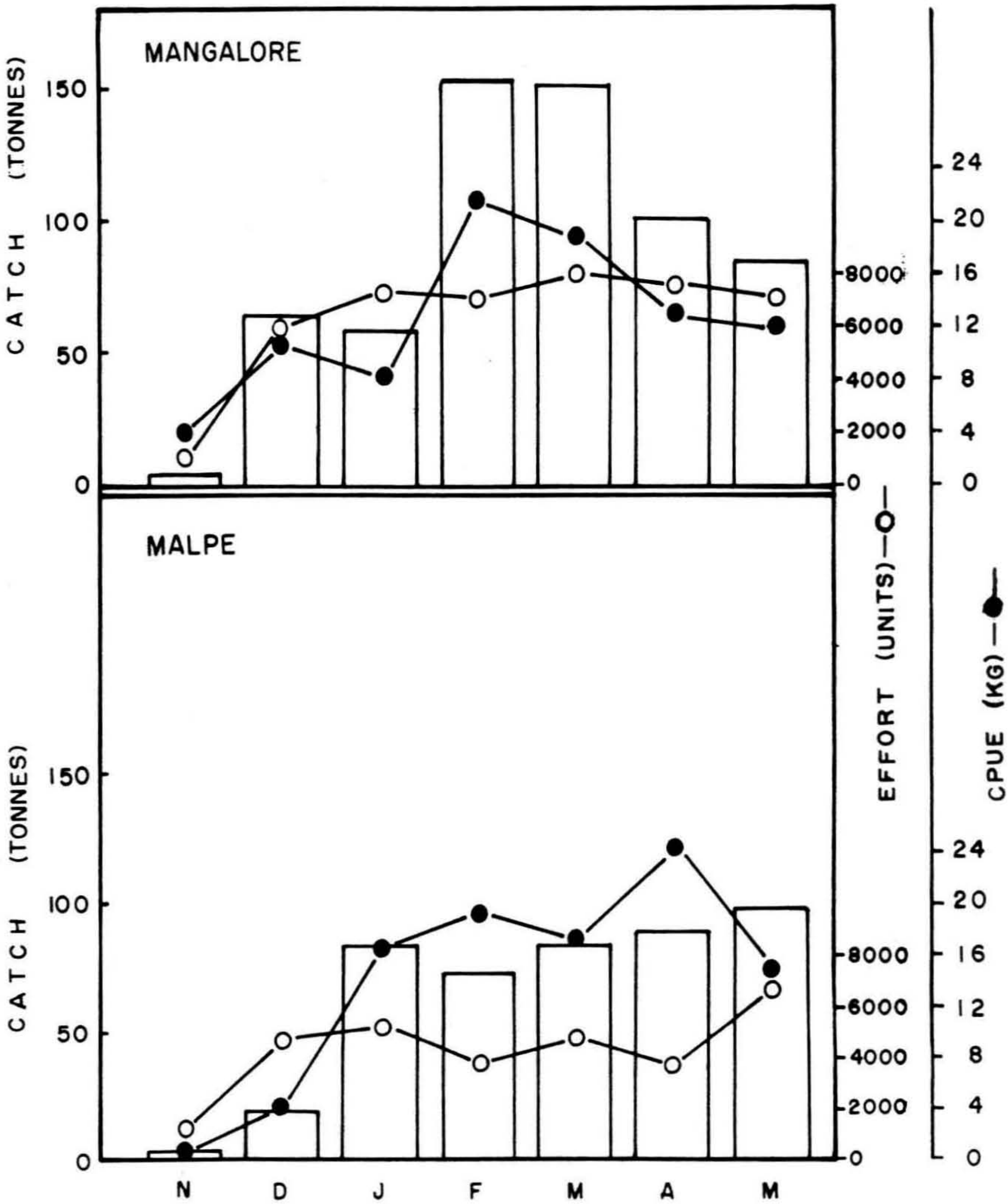

Fig. 2.2 Monthwise average effort, catch and catch per unit effort (CPUE) for *Saurida* spp. during 1989-90 and 1990-91 at Mangalore and Malpe.

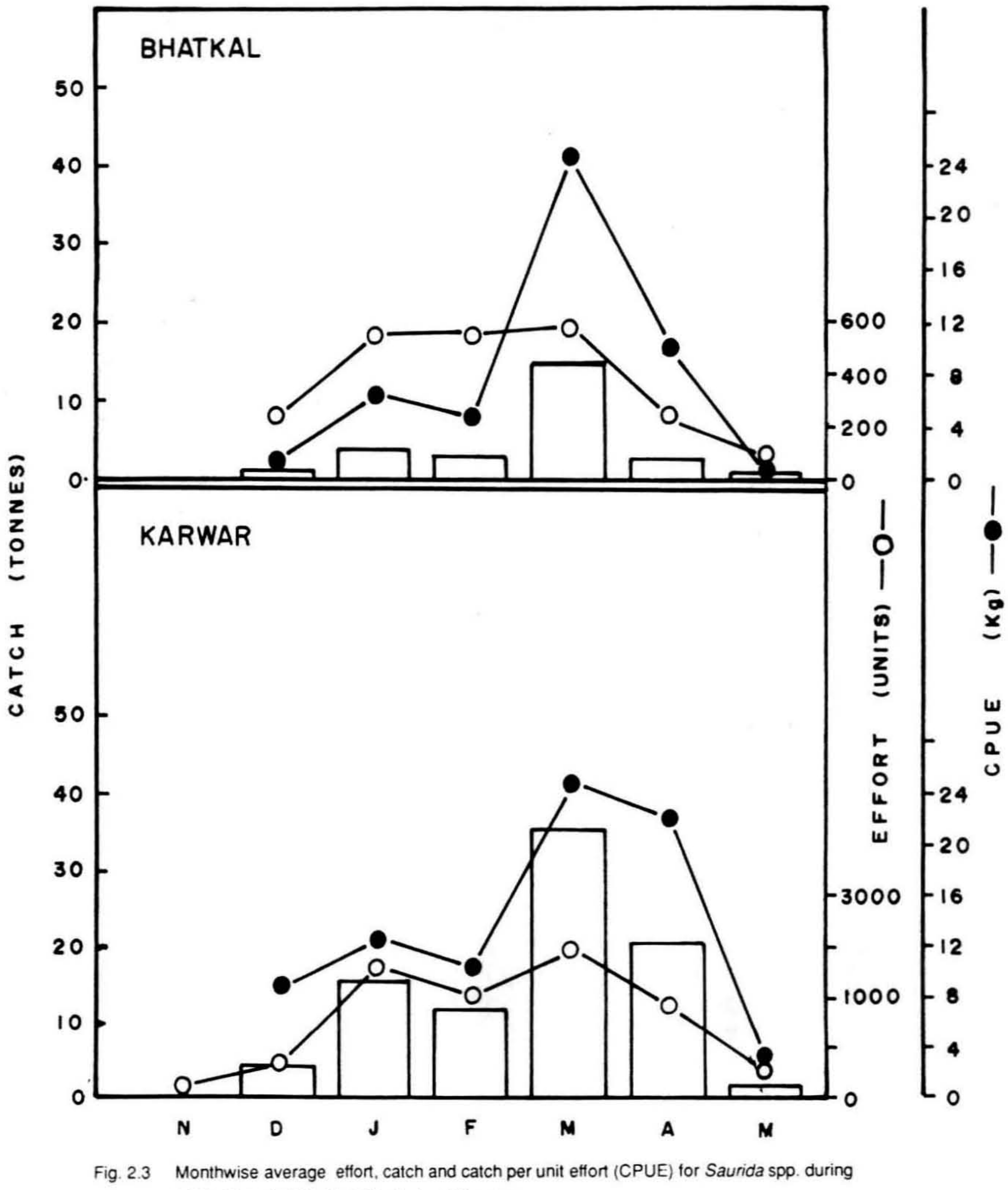

Fig. 2.3 Monthwise average effort, catch and catch per unit effort (CPUE) for *Saurida* spp. during 1989-90 and 1990-91 at Bhatkal and Karwar.

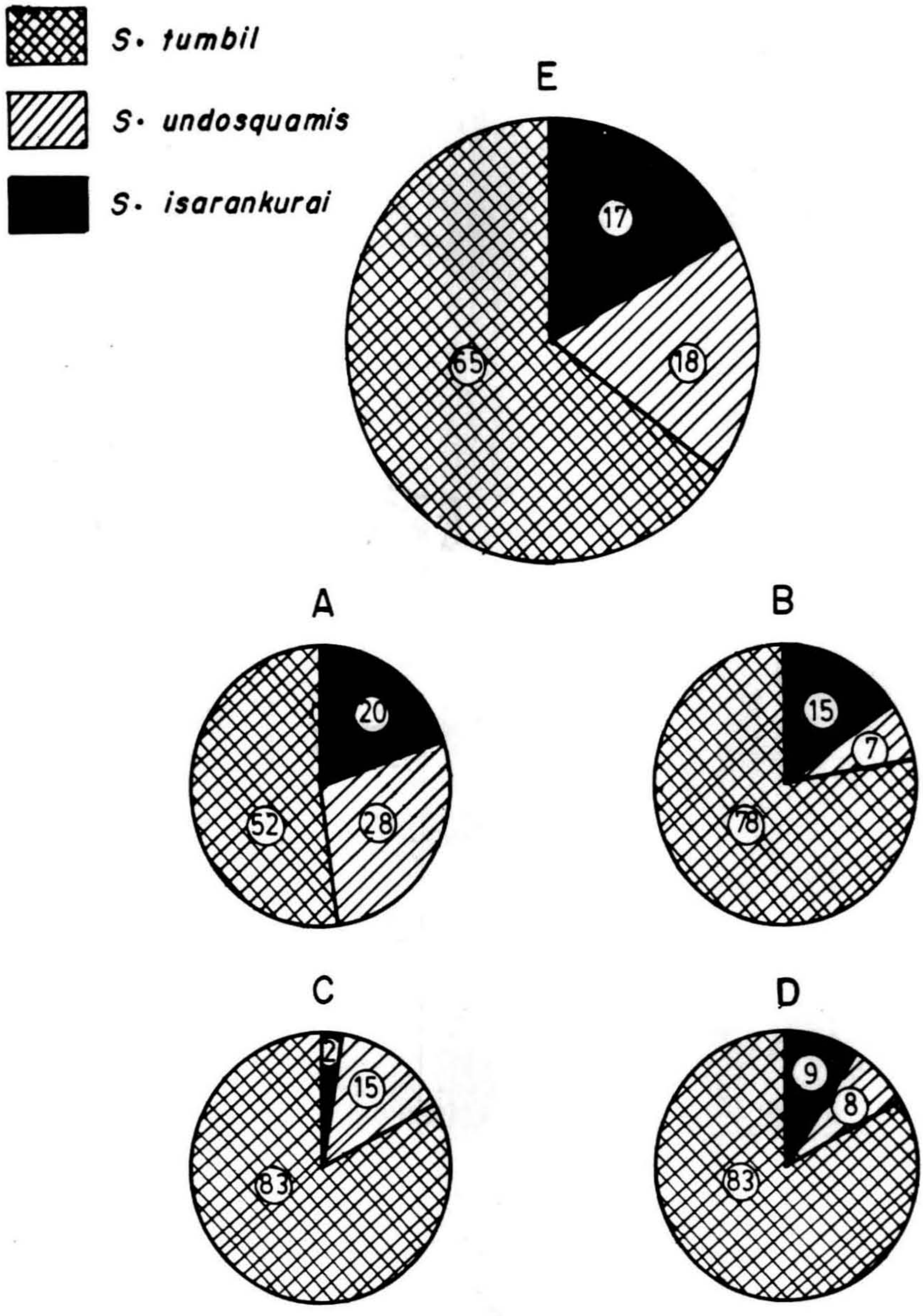

Fig. 2.4 Species composition of lizardfishes at Mangalore (A), Malpe (B), Bhatkal (C), Karwar (D) and combined for all centres (E) during 1989-90 and 1990-91. Numerals indicate percentage.

Chapter III

FOOD AND FEEDING

INTRODUCTION

The study of food and feeding habits of commercially important fishes is essential for understanding the various aspects of biology such as growth, development, reproduction, migration and condition. Knowledge on the diet of fishes is important in fundamental community analysis for studies of food-webs, trophodynamics, resource partitioning and ecological energetics (Ivlev, 1961 and Landenberger, 1968). Also an understanding of the relationship between fishes and food organisms especially the favourite food items and their seasonal distribution may help to locate the potential feeding grounds *per se* provide clue for the prediction and exploitation of fish stocks.

The earliest significant contribution on the study of food and feeding was made by Day (1882). Some of the important works that followed are by Herdman and Corbin (1892), Scot (1902), Johnstone (1906), Lebour (1919), Hardy (1924), Neill (1938), Swynnerton and Worthington (1940), Frost (1943 and 1946), Hynes (1950) and Maitland (1965).

From India, following the pioneering work of Hornell and Nayudu (1924) on the food of *Sardinella longiceps*, a number of workers have contributed to the knowledge on food habits of Indian fishes. The important ones are of Devanesan (1932), Job (1940), Natarajan and Jhingran (1961), James (1967), Qasim (1972), Devaraj (1977), Neelakantan (1981) and Kusuma (1983).

From outside Indian waters, the food and feeding habits of *Saurida* spp. have been studied by Okada and Kyushin (1955) from East China and Yellow Sea, by Tung (1959), from Taiwan, by Hanaoka *et al.* (1959) Hayashi *et al.* (1960) and Hayashi (1983) from Japan, by Yamada *et al.* (1966) from East China Sea, by Zuyev and Salekova (1970) from the northern part of Arabian Sea, by Tiews *et al.* (1972), from Philippines, by Budnichenko (1974), from Oman, by Wu (1984), from Hong Kong and by Qiyong and Ganlin (1986) from Fuji and Taiwan.

Investigations on the food and feeding habits of lizardfishes from Indian waters are limited and related mostly to *Saurida tumbil* from the east coast.

Vijayaraghavan (1957) observed the food of larvae of *S. tumbil* from the Madras coast. Kuthalingam (1959) and Basheeruddin and Nayar (1962) have studied the food of juveniles of this species from the same area. Rao (1964) has analysed its food composition from the Bay of Bengal. Rao (1981) in addition to his detailed studies on the food and feeding habits of *S. tumbil* from north western part of Bay of Bengal has also briefly made similar studies on *S. undosquamis* and *S. longimanus*. The only study from the west coast of India on *S. tumbil* was by Dighe (1977) from the Bombay coast. While, the present study on the food and feeding habits of *S. tumbil* and *S. undosquamis* from the mid-west coast of India is aimed at gathering additional information, the study on *S. isarankurai* is first of its kind as there is no information available on this species from any part of the world.

Several methods such as occurrence method, numerical method, points method, volumetric method and gravimetric method are available for analysing fish stomach contents,(Hynes, 1950; Borutsky *et al.,* 1952; Pillai,1952; Lagler, 1956; Windell, 1968; Windell and Bowen, 1978). However, the choice of the method should suit the diet of the fish to be investigated. For example, the volumetric method is accepted as the most suitable one for the food analysis of carnivorous fishes (James,1967). While reviewing the available methods for analysing fish stomach content, Hyslop (1980) has concluded that the best measure of dietary importance is the one where both the amount and bulk of a food category are recorded. Qasim (1972) in his critical analysis on the dynamics of food and feeding habits of some marine fishes quotes, from Natarajan and Jhingran (1961) that a combination of numerical and volumetric methods would give better picture of food than when each of these methods is applied in isolation. A composite index known as the "Index of Preponderance" formulated by Natarajan and Jhingran (1961) takes into account both the occurrence as well as volume (quantity) providing a definite and measurable basis for grading different food items. This method is found to be suitable for studying the food habits of carnivorous fishes and many workers from India have adopted this method.

Since the prevailing high temperature in tropical waters accelerates the digestion process, the food remains in recognizable state more in the stomach than in the gut. Hence, the diet studies are to be made from stomachs and the rest of the gut could be ignored unless there are special reasons for doing so (Qasim, 1972).

MATERIAL AND METHODS

Saurida spp. were sampled fortnightly from trawlers at Mangalore, Malpe, Bhatkal and Karwar during the fishing seasons of 1989-90 and1990-91 (November-May). Samples were not available during June-August due to non-operation of trawlers during southwest monsoon and during September-October due to non-fishing by trawlers in deeper waters from where the *Saurida* spp. are taken along with other demersal fishes. Immediately after collection, the samples were brought to the laboratory, washed and used for food analysis. After recording the total length and weight of individual fish, fish was dissected out to note the sex and stage of maturity. Based on visual examination of the distension of stomachs and the amount of food contained in them, they were graded as full, 3/4 full, 1/2 full, 1/4 full, trace and empty to study the intensity of feeding. After cutting open the stomach, the contents were emptied into a petridish and the food items were identified as far as possible upto generic/species level and their individual volumes were measured by the displacement method. A total of 3,169 specimens of *S. tumbil*, 2, 785 specimens of *S. undosquamis* and 2,960 specimens of *S. isarankurai* was used for the study. The fishes with full and 3/4 full stomachs were categorised as actively fed, 1/2 full as moderately fed and 1/4 full and trace as poorly fed. Diet analysis was done in relation to months, sexes, maturity stages and size groups. For the purpose of study with reference to size groups, the data were analysed for each 20 mm size group for the large species, *S. tumbil* and *S. undosquamis* and for each 10 mm size group for the smaller species, *S. isarankurai*. For maturity stage-wise analysis, fishes of stages I & II were grouped under immature category, stages III & IV as maturing and mature, stages V and VI as gravid (ripe) and stages VIIa & VIIb as spent. The month-wise data from all the four centres and for the two fishing seasons were pooled together for arriving at a gross picture of the diet. The index of preponderance method of Natarajan and Jhingran (1961) expressed as -

$$I_i = \frac{V_i \times O_i}{\Sigma V_i \times O_i} \times 100$$

was employed for the food analysis, where V_i and O_i are the volume and occurrence indices of food items respectively presented in percentage. Selectivity of food organisms by fishes is generally arrived at by comparing the percentages of food items in the diet and the abundance of forage in the catch. Ivlev (1961) while reviewing the work of Scott (1920), Savage (1931) and Larsen (1936) concludes that the above procedure is not satisfactory and has proposed an expression as -

$$E = \frac{r_i - p_i}{r_i + p_i}$$

where E is an index of electivity, r_i, the relative abundance of an ingredient in the ration and p_i, the relative abundance of the same in the food supply of the environment.

RESULTS

Diet Composition

The food items of the three species can be broadly classified into three groups -

1. Fishes
2. Cephalopods
3. Crustaceans

Of these, fishes constituted the major food item of *S. tumbil* and *S. undosquamis* and almost entirely comprised the food of *S. isarankurai*, with the respective indices being 71.75, 73.83 and 99.92.

Cephalopods formed next important food item only in *S. tumbil* and *S. undosquamis* with the indices values of 28.24 and 26.07 respectively. They were very rarely encountered in *S. isarankurai* (Table 3.1).

Crustaceans were most insignificant in the diet of all the three species, the index being 0.01 in *S. tumbil*, 0.10 in *S. undosquamis* and 0.04 in *S. isarankurai*.

The common fishes encountered in the food of *S. tumbil* and *S. undosquamis* belonged to the genera, *Stolephorus*, *Saurida*, *Nemipterus*, *Platycephalus*, *Leiognathus* and *Cynoglossus*. Occasionally fishes belonging to the genera, *Upeneus*, *Apogon*, *Lactarius*, *Decapterus*, *Rastrelliger*, *Bregmaceros*, *Sardinella*, *Gobius* and *Caranx* were also common in these two species. Some of the food items like eel, L eptocephalus, Lagocephalus *sp.*, *Fistularia* sp., barracuda and *Triacanthus* sp. were noticed rarely only from the stomachs of *S. undosquamis*. Likewise, *Epinephelus* sp., *Therapon* sp. and mud were recorded exclusively from the stomachs of *S. tumbil*. In the case of *S. isarankurai*, the fish food was constituted mainly by the genera, *Bregmaceros*, *Stolephorus* and *Saurida* and occasionally by the genera, *Platycephalus*, *Cynoglossus*, *Leiognathus* and *Gobius*.

The cephalopod food was made up mostly of *Loligo duvauceli*. *Sepia* spp. were noticed rarely in very insignificant proportion.

The crustacean diet was formed of prawns, crab and *Squilla*. While, *Parapenaeopsis stylifera* was recorded from the stomachs of *S. tumbil*, *Acetes* sp. and *Solenocera crassicornis* were recorded in the stomachs of *S. undosquamis*, and Acetes sp. from *S. isarankurai*.

Selectivity of food items

Ivlev's (1961) index of electivity (E) was followed to test whether any feeding selectivity of organisms exists. For this purpose, the monthly percentage of all species in the catches of trawlers and the monthly percentage of food items (volume) in the stomachs were used and the results are given in Tables3.2-3.4. It can be seen that the index showed positive values for *Stolephorus* spp. in all the months for all three species. Besides, *S. tumbil* showed noticeable preference to *Loligo duvauceli*, *Decapterus* spp., *Nemipterus*, spp., *Saurida* spp. *Platycephalus* spp. and *Upeneus* spp. *S. undosquamis* indicated preference for *Loligo duvauceli*, *Saurida* spp. and *Sardinella* spp. *S. isarankurai* favoured *Saurida* spp.

Diet composition in relation to month

Stolephorus spp. principally, *S. devisi* constituted one of the chief food items in all the three species in almost all months of the fishery. The index of preponderance for this group in *S. tumbil* ranged from 0.99 in May to 56.98 in February and the peak months of their consumption were December- February. In *S. undosquamis*, the index value varied from 17.34 in February to 66.29 in April. They were taken predominantly in April and May. They formed the food in good proportion in the stomach of *S. isarankurai* during January, the index being 39.47. In other months they represented poorly, varying from 0.60 in May to 6.30 in February (Table 3.5).

Saurida spp. especially the smaller species, *S. isarankurai*, and the juveniles of *S. undosquamis* were found in the stomachs of all three species in almost all months, implying their cannibalistic nature of feeding. The indices ranged from 0.06 in January to 2.20 in March in *S. tumbil*, from 0.13 in January to 8.8 in May in *S. undosquamis* and from 0.03 in December to 2.57 in May in *S. isarankurai* (Table 3.5).

Nemipterus spp. formed one of the common food items in all months in *S. tumbil* and *S. undosquamis*. The index values, ranged from 0.18 in February to 4.11 in January in *S. tumbil* and 0.09 in April to 9.65 in January in *S. undosquamis*. In *S. isarankurai* this food item was observed only in January in insignificant amount.

Platycephalus spp. were observed in the stomachs of *S. tumbil* and *S. undosquamis* in almost all months. The index was highest in May (2.77) for *S. tumbil* and in March (2.27) for *S. undosquamis*. The lowest index was in February for both species. In *S. isarankurai*, juveniles of *Platycephalus* spp. were encountered only in February.

Cynoglossus spp. were recorded in the diet of *S. tumbil* in all months except in March and November and were present during December-April in *S. undosquamis*. The index was highest in April in *S. tumbil* and December in *S. undosquamis*. Juvenile soles were observed in the food of *S. isarankurai* in January.

Leiognathus spp. were present in the stomach of *S. undosquamis* in all months, and were encountered more frequently and in good amounts than in the stomachs of *S. tumbil* (January-February and April-May). The index ranged from 0.16 to 3.78 in the former and from 0.02 to 0.72 in the latter. This food item occurred in the stomachs of *S. isarankurai* in small quantity discontinuously (January and April only).

Upeneus spp. were recorded in the diet of *S. tumbil* during February-April and November and the index ranged from 0.01 in April to 1.25 in November. This item was scarce in the food of *S. undosquamis* and recorded only in January with an index of 0.02. They were not noticed from the stomach of *S. isarankurai*.

Apogon spp. were found in the stomach of *S. tumbil* and *S. undosquamis* during March-May. The index was high in May in both species.

Gobius sp. was consumed more frequently in good amount by *S. tumbil* (March-May) than by the other two species. The index ranged from 0.15 (March) to 1.08 (April) in *S. tumbil*.

Bregmaceros sp. was observed in the diet of *S. tumbil* and *S. undosquamis* occasionally whereas, it formed as one of the principal food items of *S. isarankurai* in all months except in November. The index in this species varied from 0.63 (May) to 49.73 (December).

Decapterus spp. were ingested during January, May, November and December in *S. tumbil*, and in February, and November-December in *S. undosquamis*. The index ranged from 0.02 (January) to 5.11 (November) for *S. tumbil* and from 0.09 (February) to 54.01 (November) for *S. undosquamis*.

Caranx spp. occurred in the diet of *S. tumbil* in December (0.39) and during January (0.17) and November (0.77) in *S. undosquamis*.

Sardinella spp. were found more commonly and in appreciable volume in *S. undosquamis*. The index varied from 0.06 (January) to 1.41 (February). In *S. tumbil* this was found rarely and in negligible quantity in January (0.01) and March (0.03).

Fish in semidigested state were found in good quantities in all months in all three species. The index for this category ranged from 10.81 in December to 58.31 in November for *S. tumbil*. In *S. undosquamis* the index ranged from 3.30 in November to 53.3 in February. In *S. isarankurai* it varied from 39.61 in January to 100 in November.

The index of preponderance for *Loligo duvauceli* in *S. tumbil* fluctuated from 6.42 in February to 66.95 in May. In *S. undosquamis* it ranged from 3.35 in April to 57.21 in March. In *S. isarankurai* this food item appeared in almost all months except in November, though in very meagre amounts.

Crustacean food represented by prawns, *Squilla* and crab figured in the diet of all three species in all months but in negligible proportion.

Diet composition in relation to sex

The qualitative composition of the diet of both sexes of *S. isarankurai* does not show any difference (Table 3.6). The food composed almost exclusively of fishes which had an index value of 99.92 each in males and females. In the other two species, *S. tumbil* and *S. undosquamis*, the diet composition showed marked variation between sexes. In males of both these species, the major item of food was fishes, the index being 89.05 for *S. tumbil* and 94.38 for *S. undosquamis* and the cephalopods constituted the rest. In contrast to the high index value for fish food item as observed in males in both species, in females the index for fish diet decreased to 44.56 in *S. tumbil* and 61.36 in *S. undosquamis* whereas, the cephalopod intake increased and comprised the rest of the food (Tabl••3.7 & 3.8).

Diet composition in relation to size

In immature fishes of *S. tumbil* of 80-240 mm size constituting zero year class, the diet consisted mainly of fishes and to a lesser extent cephalopods, *Stolephorus* spp., *Saurida* spp., *Cynoglossus* spp. and fish remains were the principal items in this size group. The indices of fish diet ranged from 92.63 to 100 in different size groups. The cephalopods had indices ranging from 0.05 to 7.30. As the fish increased in length, the proportion of fish diet decreased markedly whereas, that of cephalopod increased. This was seen in 260-380 mm sizes. The index for fish food item varied from 11.64 to 58.37 and for cephalopod from 40-68 to 88.36 in different size classes. In this group, the intake of *Stolephorus* spp. decreased sharply and the deficiency was made good by the ingestion of other fishes mainly *Nemipterus* spp. and *Platycephalus* spp. In fish of larger size (420-440 mm) the diet constituted exclusively of fishes especially, *Nemipterus* spp. and *Platycephalus* spp., showing piscivorus tendency again. Crustaceans, though in small amounts were encountered more frequently in the larger size groups than in the smaller size groups (Table 3.9).

In *S. undosquamis* also, the diet of immature fish of 60- 179 mm sizes (0 - year class) consisted principally of *Stolephorus* spp. fish remains, *Saurida* spp. and *Leiognathus* spp. whose collective index varied from 98.09 to 100. With growth, the fish diet decreased progressively and the cephalopod diet increased. This could be seen from 200 mm size group onwards till 300 mm. The index for cephalopod diet in different size groups ranged from 13.63 to 95.51. Though the index for crustacean food item was low, it occurred more commonly in 60-179 mm size group (0.01 to 1.91) than in fish above 180 mm (0.02 to 0.78) (Table 3.10).

In *S. isarankurai* fish formed the chief food in all size groups. Nevertheless, the intake of *Bregmaceros* sp. was high up to 120-129 mm size group and above this size, it decreased and that of *Stolephorus* spp. increased. The predation on *Saurida* spp. also was higher by fish above 120 mm. Crustaceans and cephalopods were observed in meagre amounts in fish above 70 mm (Table 3.11).

Feeding condition in males

In general, feeding intensity in males was better in *S. undosquamis*, moderate in *S. tumbil* and poor in *S. isarankurai*. The percentage of empty stomachs was 52.64 in *S. undosquamis*, 55.61 in *S. tumbil* and 68.13 in *S. isarankurai*. Moderately and actively fed fishes put together were 11.7%, 7.82% and 4.09% respectively in the three species.

In males of *S. tumbil*, empty stomachs were highest in November (74.47%) and lowest in December (45.68%). Higher feeding intensity was observed in December and February when spawning activity of the species was at its peak. For *S. undosquamis* the percentage of empty stomachs was higher in November (58.02), January (57.41) and March (57.74) and lowest in April (41.73). Active and moderate feeding were more during December-March, coinciding with spawning months of the species. Compared to above two species, feeding intensity was very poor in *S. isarankurai* and the empty stomachs varied between 42.86% in November and 75.59% in January. Feeding condition was better in May, November and December. (Fig. 3.1).

Generally, smaller fishes were better fed in all the three species. In *S. tumbil*, as the size of the fish increased, occurrence of empty stomachs also increased. The feeding activity from initial higher values declined in

180-199 mm size group. Thereafter, an irregular trend was noticed in various size groups. However, actively and moderately fed fish were more in the adult group of 240-259 mm, 280-299 mm and 300-319 mm (Fig. 3.2).

In *S. undosquamis* the occurrence of empty stomach varied from 44.4% in 140-159 mm to 69.2% in 260-279 mm. Above 120 mm size, the percentage of empty stomach increased gradually. However, feeding condition was relatively better in 140-159 mm and 220-239 & 240 - 259 mm size groups (Fig. 3.2).

In *S. isarankurai* the percentage of empty stomachs showed a steady increase with growth from 80-89 mm size onwards. Moderate and actively fed fish were more in 60-79 and 120-129 mm size groups (Fig. 3.2).

Feeding condition in females

Overall, feeding rate in females was similar to males of the respective three species. It was better in *S. undosquamis*, moderate in *S. tumbil* and poor in *S. isarankurai* and the percentage of empty stomach was 52.15, 56.45 and 61.18 respectively. The occurrence of moderately and actively fed fishes together accounted for 17.87%, 13.08% and 9.28% respectively.

In *S. tumbil*, empty stomachs ranged from 47.62% in November to 66.50% in March. During November-February, the percentage of moderate and actively fed stomachs was higher indicating better feeding during these months. This period coincided with active spawning months of the species (Fig. 3.3.).

In *S. undosquamis* the highest percentage of empty stomach was in November (66.07) and lowest in January (45.45). Actively fed fish were abundant during December (27.87%) and January (24.79%) when peak spawning occurred in the species (Fig. 3.3).

For *S. isarankurai*, the highest percentage of empty stomach was in February (65.74) and lowest in November (33.3). Fish with actively fed condition was more common in November (22.22%), December (14.29%) and January

(13.08%). These months were found to be the main spawning period for the species (Fig. 3.3.).

The feeding intensity was higher in the large sized females. Feeding intensity picked up from the minimum size at first maturity in all the three species. In *S. tumbil* empty stomachs ranged from 31.2% (140-150 mm) to 88.9% (400-419 mm). The percentage of moderately and actively fed fish increased from 240-259 mm group (minimum size at first maturity) till 380- 399 mm. In the next size group the feeding intensity was poor. High feeding intensity was noticed in the larger fishes (420- 459 mm) (Fig. 3.4).

In *S. undosquamis*, empty stomachs varied from 20% in 300- 319 mm size group to 54.5% in 220-239 mm and 280-299 mm size groups. Feeding was better from the length of 200-219 mm (minimum size at first maturity) and good in the large sized fish of 300-319 mm size (Fig. 3.4).

In *S. isarankurai* empty stomachs fluctuated from 32% in 60-69 mm to 100% in 140-149 mm size. Feeding was relatively better from 80-89 mm (minimum size at first maturity).The same trend continued till 130-139 mm size (Fig. 3.4).

Feeding intensity in relation to maturity stages

In *S. tumbil* the occurrence of empty stomachs was 54.2% in immature fish (stages I & II), 57.1% in maturing and mature (stages III & IV), 53.2% in ripe (gravid) fish (stages V & VI) and 59.92% in spent (stages VIIa & VIIb) fish. Feeding intensity was better in gravid fishes, moderate in maturing and mature group and spent fishes and poor in immature fishes.

In *S. undosquamis* the maturing, mature and ripe individuals fed actively; while moderate feeding was noticed in other stages. Empty stomachs recorded around 50% in all the groups.

Spent *S. isarankurai* fed relatively better than in the other stages and the percentage of empty stomachs ranged from 57.6 in immature stage to 71.4 in ripe fish.

Feeding in relation to maturity stages in males

Among immature males of all three species, *S. undosquamis* seemed better fed. In *S. tumbil* occurrence of empty stomachs among immature fish varied from 37.5% in November to 71.9% in May. Better fed fish were in November-December and February. In *S. undosquamis*, empty stomachs ranged from 44.2% in April to 100% in December and better feeding months were January-February and May. In *S. isarankurai* empty stomachs varied from 50% in April to 88.9% in May. Actively fed fish were observed more in January-February and moderately fed fish in May (Fig. 3.5).

Among the maturing and mature males, feeding intensity was high in *S. undosquamis*. Empty stomach in *S. tumbil* varied from 44% in December to 87.5% in March and the relatively better fed months were April-May and November-December. In *S. undosquamis*, empty stomach ranged between 20% in May and 67.3% in February with better fed condition in April-May. For *S. isarankurai* moderately fed fish were abundant in May and November. The percentage of empty stomachs varied from 16.7 in May to 81.5 in January (Fig. 3.6).

Among ripe males, feeding intensity was higher in *S. tumbil* than the other two species. Ripe specimens were encountered during November-February and the empty stomachs varied from 50% in January to 69.6% in November. Actively fed fish were observed in January and November. In *S. undosquamis*, ripe individuals occurred during January - March and November-December. The empty stomachs in these months ranged from 48.6% in January to 70.6% in December and active feeding was recorded in November and February. Ripe *S. isarankurai* were recorded in all months except in May and the percentage of empty stomachs ranged from 62.8 in December to 89 in

January. Moderate and actively fed few individuals were more in December (Fig. 3.7).

Among spent males of all the three species, feeding was higher in *S. undosquamis*. Generally feeding was better in this category of fishes in all three species, as compared to the level of feeding in other categories. The percentage of empty stomachs fluctuated from 46.2 in April to 66.7 in November in *S. tumbil*. The percentage of actively fed condition was high in April-May. In *S. undosquamis*, empty stomachs varied from 48.8% in December to 66.7% in April. Actively fed fish were recorded in all months except May and their percentage of occurrence was comparatively higher in November-December and March. In *S. isarankurai* empty stomachs were 50% each in March and April and around 80% each in May and December. Active feeding was met with in May and December (Fig. 3.8).

Feeding intensity in relation to maturity stages in females

Immature females of *S. undosquamis* seemed better fed than in the same group of *S. tumbil* and *S. isarankurai*. In *S. tumbil*, empty stomachs ranged from 47.6% in January to 62.9% in December. Actively fed and moderately fed fish were more in May, November and December. In *S. undosquamis*, the percentage of empty stomach was higher in March (60%) and lowest in May (47.1%). Better feeding was in January and December. For *S. isarankurai* empty stomachs ranged from 40% in March to 73.1% in May with better feeding during December-February (Fig. 3.9).

Among fishes of stage III and IV, feeding was comparatively intensive in *S. undosquamis*, moderate in *S. tumbil* and poor in *S. isarankurai*. For *S. tumbil*, the percentage of empty stomach ranged from 51.7 in May to 100 in April. Actively fed fish were recorded in more numbers in November-December. In *S. undosquamis*, empty stomachs varied from 33.3% in April to 100% in May. Feeding rate was uniformly better in all months except April-May. Highest feeding rate was in March and December. In *S. isarankurai*, empty stomach ranged from 25% in November to 100% in May. Actively fed fish were observed in all the months except in May, their percentage being highest in November (Fig. 3.10).

In ripe fish category, feeding condition was better in *S. undosquamis* and *S. tumbil* and moderate in *S. isarankurai*. Ripe *S. tumbil* occurred during November-February and the occurrence of empty stomach was around 50% in these months. Feeding rate was higher in January and February. In *S. undosquamis*, ripe individuals were encountered during November-March and the empty stomachs varied from 23.1% in February to 100% in March. Actively fed fish were higher in February. For *S. isarankurai*, ripe fish were met with in all months except in May and the percentage of empty stomach ranged from 25 in November to 73.2 in January. Feeding rate was better in November-December (Fig. 3.11).

Among spent females, feeding intensity was better in all the three species. In *S. tumbil* the empty stomachs fluctuated from 31.4% in November to 71.1% in March. The percentage of actively fed fishes was higher in November. In *S. undosquamis*, empty stomach was highest in April (85.7%) and the lowest in December (33.3%). Feeding condition was better in December-January. For *S. isarankurai*, all fish were with empty stomachs in January and March and the lowest percentage of empty stomach was observed in December. Actively fed fish were more in December and February (Fig. 3.12).

DISCUSSION

The present study shows that the two larger species, *S. tumbil* and *S. undosquamis* feed mainly on fishes (more than 70%) and cephalopods (28%) and the smaller species, *S. isarankurai* prefers fish diet almost in entirety (99.92%). The food of *S. tumbil* in the East China Sea composed of 66% fish, 24% molluscs (mostly squid) and 10% crustaceans (mostly small shrimp) (Yamada *et al.*, 1966). The main food items of *S. undosquamis* and *S. tumbil* along the Oman coast were fishes (60-80%), cephalopods (30-40%) and crustaceans (up to 20%) (Budnichenko, 1974). According to Qiyong and Ganlin (1986), *S. tumbil* and *S. undosquamis* from South Fujian and Taiwan Bank fed chiefly on fish and cephalopods and to a lesser extent on macrura, brachyura and stomatopod. Tiews *et al.* (1972) found the favourite food of *S. tumbil* in the Philippine waters to be fish. While, *S. tumbil* from the Bombay coast fed mainly on fishes, molluscs were next important and crustacean the third (Dighe, 1977). The food of *S. tumbil*, *S. undosquamis* and *S. longimanus* from Bay of Bengal consisted of 80% fishes and the rest of the food items were *Loligo* sp. and crustaceans (Rao, 1981).

The present observations have shown that *Stolephorus* spp. and *Loligo duvauceli* as the most preferred food item of *S. tumbil*. This is evident from their dominance in the food in all months and also as indicated by the selectivity index study. The next favoured diet seemed to be *Decapterus* spp., *Nemipterus* spp., *Saurida* spp. and *Upeneus* spp. However, Kuthalingam (1959) recorded prawn as the major food item of *S. tumbil* alongwith teleostean larvae and adults (*Stolephorus* sp., *Engraulis* sp., *Trichiurus* sp. and *Leiognathus* sp.) and small amounts of copepods, cirripede larvae, decapod larvae and *Sagitta* spp. from Madras waters. Rao (1981) did not find any of the latter items in the stomachs of *S. tumbil* from Bay of Bengal. In the present observation also these items were never met with. From the above it is clear that anchovies are the preferred diet of *S. tumbil* as observed by different workers from various waters (Rao, 1964, Yamada *et al.*, 1966, Tiews *et al.*, 1972 and Dighe, 1977).

Budnichenko (1974) reported that *S. undosquamis* in Oman waters, fed chiefly on *Loligo* sp., *Sardinella longiceps*, Champsodontidae, Bregmacerotidae, Callionymidae, *Squilla* spp., Nemipteridae and Carangidae. Qiyong and Ganlin (1986) showed that this species from Taiwan waters fed mainly on pisces and to a lesser extent on cephalopods and prawns. Rao (1981) found the major food item of *S. undosquamis* in the Bay of Bengal as *Sardinella* spp., *Stolephorus* spp., *Leiognathus* spp., *Saurida* spp., *Rastrelliger kanagurta*, *Loligo* sp. and crustaceans. The present study shows *Stolephorus* and *Loligo duvauceli* as the most dominant food item. The feeding selectivity index also has indicated a high positive values for these two items in all months.

The food items of the larger species, *S. tumbil* and *S. undosquamis* were almost similar qualitatively and quantitatively. However, *S. tumbil* has a restricted dietary composition, as the number of taxa present in their diet is lesser than that of *S. undosquamis*. The presence of items like mud, crab and *Epinephelus sp.* only in the food of *S. tumbil* suggests to its greater inclination for bottom feeding habit. The record of items such as *Leptocephalus*, *Fistularia* sp., *Lagocephalus* sp., and barracuda in the food of *S. undosquamis* and their absence in the diet of *S. tumbil* shows that the former resorts more for pelagic feeding than the latter. *S. isarankurai* has a greater diet restriction than the other two species and feeds mainly on juvenile fishes. Juveniles of *Bregmaceros* sp., *Stolephorus* spp., and *Saurida* spp. were the dominant food items of *S. isarankurai* in the order of abundance in almost all months. The selectivity index showed positive values for *Stolephorus* spp. and *Saurida* spp. *Bregmaceros* sp. in the diet could not be subjected to selectivity test as their catch estimates are not available. However, the length of *Bregmaceros* sp. retrieved from the stomach ranged from 20 to 50 mm.

The qualitative analysis of food in relation to sex showed that while there was no difference in the diet composition between the sexes of *S. isarankurai*, significant variation in the diet occurred between the sexes of *S. tumbil* and *S. undosquamis*. In the latter two species, the females showed reduction in the fish food intake and the shortage was made good by increased ingestion of *Loligo duvauceli*.

According to Yamada *et al.* (1966), juveniles of *S. tumbil*, less than 24 cm size, fed mainly on stargazer, shrimp and juvenile jackmackerel. As the fish grows to small or medium size (24-28 cm), they fed on anchovy and cuttlefish and the larger fish (above 38 cm) fed on small jackmackerel, hairtail and cardinalfish. Budnichenko (1974) also observed variation in the diet composition among different size groups of *S. tumbil* and *S. undosquamis*. He observed the food of small individuals to consist predominantly of Bregmacerotidae, Callionymidae, Champsodontidae, juvenile Trichiuridae, juvenile *Squilla* sp. and *Loligo* sp. and the larger fishes to feed on *Loligo* sp., Clupeidae, Carangidae, Sparidae and Nemipteridae. Dighe (1977) reported that while *S. tumbil* in all stages of growth feed on fishes, crustaceans were consumed more by younger fish (80-120 mm in SL) and molluscs by those in advanced stages of growth. Rao (1981) has reported that the food of *S. tumbil* and *S. undosquamis* of less than 16 cm composed of small fish mainly of *Stolephorus* spp., *Leiognathus* spp., *Sardinella* spp. Fish of 16-30 and 31-45 cm size groups fed more on larger sized *Trichiurus* spp., *Leiognathus* spp., *Upeneus* spp., *Rastrelliger Kanagurta* and carangids. The percentage of crustaceans and cephalopods in the diet was more in the 16-30 cm size group than in the 31-45 cm size group. According to Qiyong and Ganlin (1986), in *S. tumbil* and *S. undosquamis* of $<$160 mm size, pisces formed the principal diet followed by cephalopods and prawns. In the 160-300 mm and>300 mm size group the diet of fish item increased appreciably and cephalopod diet was steady, whereas, the prawn intake reduced to low level. The percentage of intake of cephalopod was high in fish upto 300 mm and low in the large sized *S. tumbil* (>300 mm) whereas, it was reverse in *S. undosquamis*. In the present observation, in both *S. tumbil* and *S. undosquamis*, the proportion of fish diet was high in the smaller sized fishes (0-year class upto 259 mm in *S. tumbil* and upto 179 mm in *S. undosquamis*) and with growth, while, the fish diet decreased, cephalopod diet increased. In *S. isarankurai* diet variation has been observed from 120-129 mm size group onwards. *Bregmaceros* sp. constituted the principal diet upto 110-119 mm and above this length, this diet decreased and the diet of *Stolephorus* spp. increased.

Low feeding activity during the spawning period was observed in *S. tumbil* from the Bombay waters (Dighe, 1977) and from the northwestern part of Bay of Bengal (Rao, 1981). In contrast, high feeding intensity was recorded in both sexes of *S. tumbil* during the spawning period (Tung, 1959;

Yamada *et al.*, 1966 and Qiyong and Ganlin, 1986). However, Tiews *et al.* (1972) could not find any seasonal variation in feeding intensity. The present study has shown that in both sexes of three species, feeding condition was relatively higher during spawning period.

Sex-wise feeding intensity indicated better feeding in both sexes of *S. undosquamis*, moderate feeding in *S. tumbil* and poor feeding in *S. isarankurai* and females were comparatively better fed than males in all three species. The percentage of empty stomachs increased with advancement of growth in all the three species. Generally, feeding intensity picked up from the minimum size at maturity and in both *S. tumbil* and *S. undosquamis*, individuals in gravid stages (V & VI) fed better, than those in other stages. In *S. isarankurai* fish in spent and spent-recovering conditions were better fed.

Wu (1984) was of the opinion that the high percentage of empty guts in, *Saurida elongata* and *Platycephalus indicus* may reflect a high degree of inter and intraspecific competition in these species. The high percentage of empty stomachs in the three species of *Saurida* studied presently conform to the above, since all these species appear to forage at the same trophic level and compete for the same food item, i.e., *Stolephorus* spp.

The electivity index studies indicated that all three species showed selective feeding on certain animals. Although items like prawns, *Squilla* sp., carangids, soles, *Trichiurus* sp. and sciaenids were recorded in good proportion in trawl catches along with *Saurida* spp., they were either poorly represented or completely absent in the stomachs of *Saurida* spp. Items like *Trichiurus* sp. and sciaenids formed an important diet of *S. tumbil* and *S. undosquamis* in the Bay of Bengal (Rao, 1981). Also, the proportion of prawns and *Squilla* was in higher order as compared to the same in the west coast as revealed from the present study. Rao (1981) found *Leiognathus bindus* as the dominant food of *S. tumbil* and the selectivity test applied also confirmed the preference of this item. In the present observation, positive values for *Leiognathus* spp. were obtained only in April in *S. tumbil* and during April- May in *S. undosquamis*. This shows that in the west coast, *S. tumbil* does not prefer *Leiognathus* spp., though they are available in the environment in good quantity.

The cannibalistic nature of *Saurida* spp. reported by several workers (Tiews *et al.*, 1972, Yamada *et al.*, 1966, Qiyong and Ganlin, 1986, Wu, 1984 and Rao, 1981) has also been observed in the present study in all three species. Feeding on their own kind appears not be accidental but as one of the preferred items. This is evident from the positive values of 'E' recorded in almost all months in the three species.

Some believe that *Saurida* spp. live near the bottom, and lie in wait for their prey as they are incapable of sustained migrations (Anon. ,1972 as quoted by Budnichenko, 1974). But the presence of pelagic item in the stomachs of *Saurida* spp. led Budnichenko (1974) to conclude that *Saurida* spp. are capable of pursuing their prey actively for more distance and even making short vertical migrations. However, Hayashi (1983), remarked that lizardfish resorts to change of feeding behaviour between sit-and-wait feeding on benthic prey and mobile searching behaviour for pelagic prey based on the prey resource in the environment. The present observation of *Saurida* spp. feeding mainly on pelagic prey in the area shows that they indulge in more mobile searching behaviour than of sit-and-wait mode for benthic prey.

Table 3.1: Index of Preponderance of food items of *Saurida tumbil, S.undosquamis* and *S.isarankurai*

Food items/Species	*S.tumbil*	*S.undosquamis*	*S.isarankurai*
Stolephorus devisi	36.64	35.58	4.45
Stolephorus spp.	0.47	0.32	0.48
Nemipterus spp.	1.95	1.75	*
Saurida spp.	0.56	1.28	0.89
Platycephalus spp.	0.32	0.34	*
Cynoglossus spp.	0.27	0.09	*
Bregmaceros spp.	*	*	17.10
Other teleostean fishes	0.48	1.04	-
Fish remains	31.06	33.43	77.00
Loligo duvauceli	28.24	26.07	0.04
Crustaceans	0.01	0.10	0.04

* In fractions only

Table 3.2: Monthwise Index of Selectivity of *S.tumbil* for different food items

Food items	Jan.	Feb.	Mar.	Apr.	May	Nov.	Dec.
Stolephorus spp.	+ 0.93	-	+ 0.93	+ 0.84	+ 0.35	+ 0.59	+ 0.60
Sardinella spp.	- 0.33	-	+ 0.95	-	-	-	-
Decapterus sp.	+ 0.31	-	-	-	+ 0.59	+ 0.98	+ 0.64
Rastrelliger kanagurta	- 0.61	+ 0.69	- 0.38	- 0.20	-	-	- 0.71
Caranx spp.	-	-	-	-	-	-	- 0.26
Saurida spp.	- 0.35	+ 0.42	+ 0.18	- 0.15	+ 0.31	+ 0.73	+ 0.51
Nemipterus spp.	+ 0.37	- 0.73	- 0.01	+ 0.09	- 0.33	+ 0.62	+ 0.30
Platycephalus spp.	+ 0.12	- 0.71	- 0.56	+ 0.54	+ 0.54	- 0.31	+ 0.16
Cynoglossus spp.	- 0.71	- 0.63	-	- 0.21	- 0.07	-	- 0.82
Leiognathus spp.	- 0.55	- 0.03	-	+ 0.12	- 0.19	-	-
Upeneus spp.	-	+ 0.49	+ 0.70	+ 0.74	-	+ 0.99	-
Apogon sp.	-	-	-	-	-	-	-
Epinephelus sp.	+ 0.65	-	-	-	-	-	-
Lactarius lactarius	+ 0.90	-	-	-	-	-	+ 0.61
Loligo duvauceli	+ 0.67	+ 0.49	+ 0.50	+ 0.62	+ 0.75	+ 0.95	+ 0.87
Squilla sp.	- 0.97	-	- 0.99	-	-	- 0.98	- 0.99
Prawns	- 0.98	- 0.98	- 0.99	- 0.98	-	-	-

Table 3.3: Monthwise Index of Selectivity of *S.undosquamis* for different food items

Food items	Jan.	Feb.	Mar.	Apr.	May	Nov.	Dec.
Stolephorus spp.	+ 0.78	+ 0.93	+ 0.88	+ 0.92	+ 0.86	+ 0.73	+ 0.72
Sardinella spp.	- 0.02	-	+ 0.98	-	-	-	+ 0.93
Decapterus sp.	-	-	-	-	-	+ 0.99	+ 0.88
Caranx spp.	- 0.46	-	-	-	-	- 0.68	-
Rastrelliger kanagurta	-	+ 0.69	- 0.89	- 0.13	-	-	-
Barracuda	-	-	- 0.02	-	-	-	-
Saurida spp.	- 0.14	+ 0.42	+ 0.23	+ 0.25	+ 0.50	+ 0.93	- 0.12
Nemipterus spp.	+ 0.55	- 0.73	- 0.51	- 0.65	- 0.20	-	- 0.21
Platycephalus spp.	- 0.19	- 0.71	+ 0.36	- 0.02	+ 0.30	-	- 0.45
Cynoglossus spp.	- 0.66	- 0.63	- 0.95	- 0.87	-	-	- 0.70
Leiognathus spp.	- 0.16	- 0.03	- 0.09	+ 0.39	+ 0.28	-	-
Upeneus spp.	- 0.10	+ 0.49	-	-	-	-	-
Lactarius lactarius	-	-	- 0.72	-	-	-	-
Loligo duvauceli	+ 0.68	+ 0.49	+ 0.75	+ 0.20	+ 0.42	-	+ 0.80
Squilla sp.	- 0.98	-	-	-	-	-	- 0.94
Prawns	- 0.86	- 0.98	- 0.93	- 0.67	- 0.68	-	- 0.58

Table 3.4: Monthwise Index of Selectivity of *S.isarankurai* for different food items

Food items	Jan.	Feb.	Mar.	Apr.	May	Nov.	Dec.
Stolephorus spp.	+ 0.92	+ 0.91	+ 0.89	+ 0.84	+ 0.57	-	+ 0.68
Saurida spp.	+ 0.58	+ 0.61	+ 0.69	+ 0.27	+ 0.57	-	+ 0.28
Nemipterus spp.	- 0.63	-	-	-	-	-	-
Platycephalus spp.	-	- 0.56	-	-	-	-	-
Cynoglossus spp.	- 0.66	-	- 0.95	-	-	-	-
Leiognathus spp.	- 0.88	-	-	+ 0.05	-	-	-
Loligo duvauceli	- 0.55	- 0.95	- 0.50	- 0.97	+ 0.12	-	- 0.60
Squilla sp.	-	- 0.97	-	-	-	-	-
Prawns	- 0.97	- 0.61	- 0.78	- 0.84	- 0.91	-	- 0.98

Table - 3.5 Monthwise distribution of Index of Preponderance of different food items of *S. tumbil*, *S. undosquamis* and *S. isarankurai*

Food items	*S. tumbil*							*S. undosquamis*							*S. isarankurai*						
	Jan.	Feb.	Mar.	Apr.	May	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Nov.	Dec.
Stolephorus devisi	49.70	56.33	27.47	26.58	0.43	7.21	42.84	23.06	16.86	22.17	66.22	53.68	33.61	37.07	34.50	6.21	0.86	0.60	-	-	2.59
Stolephorus bataviensis	0.02	0.30	0.03	0.09	0.42	0.05	0.04	0.01	0.34	0.01	0.07	-	-	0.05	-	-	-	-	-	-	-
Stolephorus indicus	-	0.02	0.26	0.13	-	-	-	-	-	-	-	0.24	-	-	-	-	-	-	-	-	-
Stolephorus macrops	-	-	0.02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stolephorus spp.	0.15	0.033	0.51	0.06	0.14	6.46	0.01	0.41	0.14	0.15	-	-	1.80	0.57	4.97	0.09	0.03	0.05	0.60	-	0.74
Sardinella spp.	0.01	-	0.03	-	-	-	-	0.06	1.41	0.28	-	*	-	0.22	-	-	-	-	-	-	-
Nematalosa sp.	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Decapterus spp.	0.02	-	-	-	0.14	5.11	0.32	-	0.09	-	-	-	54.01	2.07	-	-	-	-	-	-	-
Carangids	-	-	-	-	-	-	0.39	0.17	-	-	-	-	0.77	-	-	-	-	-	-	-	-
Rastrelliger kanagurta	0.01	0.07	0.03	0.06	-	-	-	-	0.06	*	0.03	-	0.30	-	-	-	-	-	-	-	-
Bregmaceros sp.	-	*	-	-	*	-	*	*	0.03	-	-	0.04	-	0.02	18.67	6.50	8.39	24.73	0.63	-	49.73
Barracuda	-	-	-	-	-	-	-	-	-	0.03	-	-	-	-	-	-	-	-	-	-	-
Fistularia sp.	-	-	-	-	-	-	-	-	0.01	-	-	-	-	-	-	-	-	-	-	-	-
Lagocephalus sp.	-	-	-	-	-	-	-	0.01	0.14	0.01	-	-	-	-	-	-	-	-	-	-	-
Triacanthus sp.	-	-	-	-	-	-	-	-	-	0.01	-	-	-	-	-	-	-	-	-	-	-
Leptocephalus	-	-	-	-	-	-	-	-	-	-	-	-	2.25	-	-	-	-	-	-	-	-
Eel	-	-	-	-	-	-	-	0.01	-	-	0.02	-	0.81	0.02	-	-	-	-	-	-	-
Saurida isarankurai	0.02	0.67	1.55	0.31	0.62	-	0.02	0.02	2.04	3.40	2.88-	8.81	-	-	2.14	0.63	0.70	0.27	2.57	-	0.03
Saurida undosquamis	-	0.03	-	-	0.91	-	*	0.05	0.02	0.02	-	-	-	-	-	-	-	-	-	-	-

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Contd. 3.5

Food items	*S. tumbil*							*S. undosquamis*							*S. isarankurai*						
	Jan.	Feb.	Mar.	Apr.	May	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Nov.	Dec.
Saurida spp.	0.04	0.42	0.65	0.36	0.04	0.13	0.52	0.06	0.23	0.06	-	-	-	0.21	-	0.42	1.74	0.05	-	-	*
Nemipterus spp.	4.11	0.18	1.85	3.00	0.55	1.51	1.67	9.65	0.35	0.21	0.09	0.45	3.15	0.14	0.03	-	-	-	-	-	-
Platycephalus spp.	0.09	0.01	0.14	1.67	2.77	0.03	0.23	0.23	0.02	2.27	0.12	0.52	-	0.09	-	0.02	-	-	-	-	-
Cynoglossus spp.	0.17	0.30	-	0.50	1.24	-	0.22	0.11	0.19	0.01	0.01	-	-	0.25	0.03	-	*	-	-	-	-
Leiognathus spp.	0.02	0.12	-	0.72	0.61	-	-	0.18	0.61	0.16	1.69	3.78	-	-	*	-	-	0.04	-	-	-
Upeneus spp.	-	0.09	0.34	0.01	-	1.25	-	0.02	-	-	-	-	-	-	-	-	-	-	-	-	-
Apogon sp.	-	*	0.02	0.48	0.92	-	-	-	-	0.12	0.18	0.62	-	-	-	-	-	-	-	-	-
Epinephelus sp.	0.06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lactarius lactarius	-	-	-	-	-	-	0.66	-	-	0.01	-	-	-	-	-	-	-	-	-	-	-
Therapon sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gobius sp.	-	-	0.15	1.08	0.26	-	-	-	-	-	0.01	0.20	-	-	-	-	-	-	0.06	-	-
Fish remains	24.04	34.70	53.25	25.43	23.97	58.31	10.81	28.12	53.30	13.83	25.09	24.79	3.30	42.55	39.61	86.03	88.11	74.21	95.75	100	46.89
Loligo duvauceli	21.51	6.42	13.69	39.51	66.95	19.93	42.26	37.68	24.04	57.21	3.35	6.51	-	16.64	0.05	*	0.09	*	0.38	-	0.01
Sepia sp.	-	-	-	0.01	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	*
Crab	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Squilla sp.	0.03	-	*	-	-	0.01	*	0.01	-	-	-	-	-	0.09	-	*	-	-	-	-	-
Parapenaeopsis stylifera	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Acetes sp.	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-	0.01	-	-	-	-	-
Soleneocera crassicornis	-	-	-	-	-	-	-	-	-	-	0.08	-	-	-	-	-	-	-	-	-	-
Prawns	*	0.01	*	*	0.03	-	0.01	0.05	0.12	0.04	0.16	0.36	-	0.01	*	0.09	0.08	0.05	0.01	-	0.01
Mud	-	-	0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

* in fractions only

Table - 3.6: Monthwise distribution of Index of Preponderance of different food items of males and females of *S. isarankurai*

Food items	Males							Females						
	Jan.	Feb	Mar	Apr	May	Nov	Dec	Jan	Feb	Mar	Apr	May	Nov	Dec
Stolephorus devisi	0.23	0.16	0.05	0.29	-	-	-	62.42	16.83	1.80	0.83	-	-	9.93
Stolephorus spp.	0.90	0.04	-	-	-	-	0.05	6.89	0.15	0.08	0.10	1.98	-	2.16
Bregmaceros sp.	32.56	2.99	7.79	38.59	2.52	-	61.13	9.05	7.85	9.20	16.30	0.53	-	38.30
Saurida isarankurai	0.34	0.29	-	-	21.14	-	0.04	3.01	0.92	1.74	0.57	2.74	-	0.01
Saurida spp.	-	-	0.29	0.09	-	-	0.01	-	0.57	3.21	0.05	-	-	-
Nemipterus spp.	-	0.15	-	-	-	-	-	0.05	-	-	-	-	-	-
Platycephalus sp.	-	0.11	-	-	-	-	-	-	-	-	-	-	-	-
Cynoglossus sp.	-	-	0.02	-	-	-	-	-	-	-	-	-	-	-
Leiognathus sp.	0.02	-	-	-	-	-	-	0.05	-	-	0.08	-	-	-
Gobius sp.	-	-	-	-	2.52	-	-	-	-	-	-	-	-	-
Fish remains	65.93	96.08	91.64	61.03	70.46	100	38.76	18.43	73.62	83.81	81.99	94.34	100	49.57
Loligo duvauceli	-	-	0.08	-	3.36	-	*	0.10	-	0.12	*	0.38	-	0.02
Sepia sp.	-	-	-	-	-	-	0.01	-	0.01	-	-	-	-	-
Squilla sp.	-	0.02	-	-	-	-	-	-	-	-	-	-	-	-
Acetes sp.	-	0.03	-	-	-	-	-	-	-	-	-	-	-	-
Prawns	0.02	0.13	0.13	*	-	-	*	-	0.05	0.04	0.08	0.03	-	0.01

* in fractions only

Table - 3.7: Monthwise distribution of Index of Preponderance of different food items of males and females of *S. tumbil*

Food items	Males							Females						
	Jan	Feb	Mar	Apr	May	Nov	Dec	Jan	Feb	Mar	Apr	May	Nov	Dec
Stolephorus devisi	29.17	67.14	40.84	45.27	1.38	7.55	89.04	7.89	50.02	19.33	12.45	-	6.96	6.19
Stolephorus bataviensis	-	1.24	-	0.14	0.09	-	-	0.08	-	0.10	0.06	1.08	0.06	0.10
Stolephorus indicus	-	-	-	-	-	-	-	-	0.07	-	0.36	-	-	-
Stolephorus macrops	-	-	0.12	-	-	-	-	-	-	0.75	-	-	-	-
Stolephorus spp.	0.63	1.10	-	-	0.47	7.08	0.02	0.27	0.07	0.41	0.17	-	6.20	0.01
Sardinella spp.	-	-	0.53	-	-	-	-	0.04	-	0.10	-	-	-	-
Nematosa sp.	-	-	-	-	-	-	0.18	-	-	-	-	-	-	-
Decapterus sp.	-	-	-	-	-	17.93	-	0.09	-	-	-	0.68	3.86	0.72
Carangids	-	-	-	-	-	-	0.45	-	-	-	-	-	-	0.63
Rastrelliger kanagurta	-	-	-	-	-	-		0.02	0.26	0.10	0.15	-	-	-
Bregmaceros sp.	-	-	-	-	-	-	-	-	*	-	-	0.01	-	-
Saurida isarankurai	-	-	1.97	0.90	2.03	-	-	0.09	1.99	1.26	0.07	-	-	0.01
Saurida undosquamis	-	0.16	-	-	0.27	-	-	-	-	-	-	2.16	-	-
Saurida spp.	0.63	0.08	1.18	0.14	0.12	-	0.14	0.02	1.03	0.35	0.42	-	0.16	0.25
Nemipterus spp.	30.23	2.47	-	1.11	0.06	-	0.54	5.13	1.77	5.35	4.46	1.62	1.88	3.20

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Contd. 3.7

Food items	Males							Females						
	Jan	Feb	Mar	Apr	May	Nov	Dec	Jan	Feb	Mar	Apr	May	Nov	Dec
Platycephalus sp.	0.21	0.7	0.79	0.51	1.26	2.36	1.17	0.21	0.06	-	2.39	4.86	-	0.21
Cynoglossus sp.	0.26	0.44	-	0.68	1.14	-	0.03	0.03	0.07	-	0.36	1.17	-	*
Leiognathus sp.	-	0.33	-	1.27	1.20	-	-	0.07	0.05	-	0.37	0.14	-	-
Upeneus sp.	-	0.06	1.97	0.06	-	-	-	-	0.13	-	-	-	1.55	-
Apogon sp.	-	-	-	0.15	1.89	-	-	-	0.01	0.06	0.73	0.18	-	-
Epinephelus sp.	-	-	-	-	-	-	-	0.26	-	-	-	-	-	-
Lactarius lactarius	-	-	-	-	-	-	-	-	-	-	-	-	-	1.51
Gobius sp.	-	-	0.87	1.49	0.84	-	5.59	-	-	-	0.76	-	-	-
Fish remains	35.54	25.14	45.55	34.05	20.84	65.08	2.84	17.20	30.77	52.21	18.71	24.89	54.52	7.34
Loligo duvauceli	3.33	1.84	6.12	14.23	68.41	-	-	68.47	13.69	19.98	58.51	63.07	24.80	79.83
Sepia sp.	-	-	-	-	-	-		-	-	-	0.02	-	-	-
Crab	-	-	-	-	-	-	-	0.01	-	-	-	-	-	-
Squilla sp.	-	-	0.01	-	-	-	-	0.11	-	-	-	-	0.01	*
Parapenaeopsis stylifera	-	-	-	-	-	-	-	-	-	-	-	-	-	*
Acetes sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Prawns	-	*	0.01	-	-	-	-	0.01	0.01	-	0.01	0.14	-	-
Mud	-	-	0.04	-	-	-	-	-	-	-	-	-	-	-

* in fractions only

Table - 3.8: Monthwise distribution of Index of Preponderance of different food items of males and females of *S. undosquamis*

Food items	Males							Females						
	Jan.	Feb.	Mar.	Apr.	May	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Nov.	Dec.
Stolephorus devisi	46.78	24.81	43.74	59.91	53.75	64.83	36.20	15.92	13.35	14.14	70.82	52.37	17.40	41.31
Stolephorus bataviensis	-	2.00	-	0.11	-	-	1.13	0.17	0.07	0.02	0.05	-	-	-
Stolephorus indicus	-	-	-	-	-	-	-	-	-	-	-	0.52	-	-
Stolephorus spp.	1.95	0.67	0.21	-	-	1.96	3.28	0.18	-	0.06	-	*	1.02	0.26
Sardinella spp.	0.19	-	0.78	-	-	-	-	0.04	2.94	0.13	-	-	-	0.41
Decapterus sp.	-	-	-	-	-	-	5.82	-	0.19	-	-	-	73.71	1.63
Rastrelliger kanagurta	-	-	0.04	-	-	-	-	-	0.12	-	0.08	-	-	-
Carangids	0.25	-	-	-	-	3.93	-	0.14	-	-	-	-	-	0.01
Bregmaceros sp.	-	0.05	-	-	-	1.96	0.12	-	0.01	-	-	0.08	0.29	-
Barracuda	-	-	0.41	-	-	-	-	-	-	-	0.04	-	-	-
Fistularia sp.	-	-	-	-	-	-	-	-	0.03	-	-	-	-	-
Lagocephalus sp.	-	0.01	0.10	-	-	-	-	0.01	0.19	-	-	-	-	-
Triacanthus sp.	-	-	0.08	-	-	-	-	-	-	-	-	-	-	-
Leptocephalus	-	-	-	-	-	15.72	-	-	-	-	-	-	0.21	-
Eel	-	-	-	-	-	10.61	0.37	0.01	-	-	0.05	-	-	-
Saurida isarankurai	0.04	10.15	7.66	1.78	5.86	-	-	0.01	0.62	2.28	3.62	10.16	-	-

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Contd. 3.8

Food items	Males							Females						
	Jan.	Feb.	Mar.	Apr.	May	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Nov.	Dec.
Saurida undosquamis	0.63	0.04	-	-	-	-	-	*	0.02	0.04	-	-	-	-
Saurida spp.	-	0.37	0.50	-	-	-	0.12	0.10	0.04	-	-	-	-	0.03
Nemipterus spp.	31.04	1.33	0.33	0.22	-	-	0.63	5.73	0.15	0.16	-	0.98	4.30	0.08
Platycephalus spp.	3.08	-	2.01	-	0.68	-	0.81	0.02	0.05	1.80	0.10	0.44	-	0.02
Cynoglossus spp.	0.03	1.67	0.16	0.03	-	-	2.50	0.09	0.01	-	0.01	-	-	0.03
Leiognathus spp.	0.63	1.02	0.87	0.27	2.54	-	-	0.08	0.52	0.03	2.92	3.56	-	-
Upeneus spp.	0.08	-	-	-	-	-	-	0.01	-	-	-	-	-	-
Apogon sp.	-	-	0.21	0.38	-	-	-	-	-	0.09	0.10	1.36	-	-
Lactarius lactarius	-	-	-	-	-	-	-	-	-	0.01	-	-	-	-
Gobius sp.	-	-	-	-	0.56	-	-	-	-	-	0.02	0.08	-	-
Fish remains	12.37	56.21	17.20	31.23	36.05	0.99	46.18	24.40	39.93	11.29	19.65	18.51	3.07	30.12
Loligo duvauceli	2.93	1.48	25.48	5.81	0.56	-	2.56	53.05	41.71	69.94	2.33	11.51	-	26.03
Sepia sp.	-	-	-	-	-	-	-	-	*	-	-	-	-	-
Crab	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Squilla sp.	-	-	-	-	-	-	0.25	0.02	-	-	-	-	-	0.07
Acetes sp.	-	-	0.01	-	-	-	-	-	-	-	-	-	-	-
Solenocera crassicornis	-	-	-	0.08	-	-	-	-	-	-	0.07	-	-	-
Prawns	-	0.19	0.21	0.21	-	-	0.03	0.02	0.05	0.01	0.14	0.43	-	-

* in fractions only

Table - 3.9: Index of Preponderance of food items in relation to different size groups of *S. tumbil*

Size-group (mm) / Food items	80-99	100	120	140	160	180	200	220	240	260	280	300	320	340	360	380	420	440
Stolephorus spp.	-	13.03	51.42	87.49	87.71	78.26	57.97	73.12	54.03	17.57	18.59	1.87	1.16	0.12	8.78	-	0.71	-
Decapterus spp.	-	-	-	-	-	-	-	-	0.03	1.88	0.20	0.51	-	1.21	-	-	-	-
Saurida spp.	0.13	1.54	1.60	0.12	0.05	0.16	2.30	2.96	4.01	2.18	0.35	0.13	0.26	0.17	1.61	8.48	-	-
Nemipterus spp.	-	-	-	-	-	0.01	1.92	0.29	1.39	1.93	2.78	5.32	15.69	1.75	18.05	0.21	34.04	-
Platycephalus sp.	-	-	-	-	-	-	0.03	0.03	0.91	0.07	1.79	0.02	-	0.12	1.18	5.65	63.83	-
Cynoglossus sp.	4.02	10.49	6.69	1.00	0.23	0.39	0.17	-	0.02	-	-	-	-	-	-	-	-	-
Leiognathus spp.	-	-	-	-	0.01	0.02	0.78	0.04	0.16	0.32	1.21	0.03	-	-	-	-	-	-
Gobius sp.	-	-	-	-	-	0.01	-	0.26	0.16	-	0.32	0.04	-	-	-	-	-	-
Lactarius lactarius	-	-	-	-	-	-	-	-	-	-	-	0.16	0.46	3.21	-	-	-	-
Other teleostean fishes	3.35	0.15	0.07	0.01	0.01	-	1.24	0.02	2.94	0.66	0.89	0.61	1.08	0.68	7.09	2.69	-	95.83
Fish remains	91.16	74.02	37.64	11.28	11.94	20.93	34.59	19.14	28.98	33.76	12.77	2.92	11.96	52.06	14.51	12.59	1.42	4.17
Cephalopods	1.34	0.77	2.09	0.05	0.05	0.22	0.96	4.14	7.30	41.63	61.09	88.36	69.35	40.68	47.71	70.36	-	-
Crustaceans	-	-	0.49	0.05	-	-	0.04	-	0.07	-	0.01	0.03	0.04	-	1.07	0.02	-	-

Table - 3.10: Index of Preponderance of food items in relation to different size groups of *S. undosquamis*

Size group (mm) / Food items	60-79	80	100	120	140	160	180	200	220	240	260	280	300
Stolephorus spp.	-	-	6.69	70.63	73.34	78.58	75.81	51.68	14.03	1.95	1.27	-	-
Sardinella spp.	-	-	-	-	0.28	0.13	-	0.14	1.02	2.04	0.16	-	-
Rastrelliger kanagurta	-	-	-	-	-	0.01	0.02	-	0.06	-	-	-	-
Decapterus sp.	-	-	-	-	-	0.05	-	1.47	0.02	1.19	0.24	-	-
Carangids	-	-	-	-	-	0.01	-	0.02	0.03	0.22	-	-	-
Saurida spp.	22.22	10.09	0.96	0.06	0.92	1.22	5.29	3.05	0.21	0.12	0.10	2.14	
Nemipterus spp.	-	-	-	-	0.11	0.01	0.16	1.79	3.82	0.49	2.22	-	12.95
Platycephalus sp.	-	-	-	-	0.03	0.65	0.42	0.61	0.16	0.19	0.44	-	-
Cynoglossus sp.	-	-	0.03	0.08	-	0.06	0.20	0.03	0.43	-	0.01	-	-
Leiognath us sp.	-	-	0.14	1.79	1.34	1.80	2.44	0.20	0.07	-	0.08	-	-
Upeneus spp.	-	-	-	-	0.05	-	-	0.01	-	-	-	-	-
Apogon sp.	-	-	-	0.03	0.14	0.12	0.13	0.04	-	-	-	-	-
Gobius sp.	-	-	-	-	-	0.03	0.01	-	0.01	-	-	-	-
Eel	-	-	-	-	0.09	0.02	-	0.07	-	-	0.04	-	-
Other teleostean fishes	-	5.88	0.01	0.01	0.01	0.07	0.01	0.11	0.06	0.05	0.04	0.11	-
Fish remains	77.78	82.12	91.65	25.96	23.69	16.26	12.26	27.13	26.35	29.54	21.82	2.24	3.37
Cephalopods	-	-	-	0.02	-	0.97	3.12	13.63	53.61	64.17	73.56	95.51	82.90
Crustaceans	-	1.91	0.52	1.42	-	0.01	0.13	0.02	0.12	0.04	0.02	-	0.78

Table - 3.11: Index of Preponderance of food items in relation to different size groups of *S. isarankurai*

Size group (mm) / Food items	50-59	60	70	80	90	100	110	120	130
Stolephorus spp.	-	-	0.03	0.01	0.05	0.57	13.60	63.75	52.63
Bregmaceros sp.	-	10.17	19.44	16.81	7.66	19.83	32.22	9.26	0.13
Saurida spp.	-	0.18	0.13	0.50	0.44	0.28	0.32	2.62	46.04
Other teleostean fishes	-	-	-	-	0.01	0.02	0.03	0.01	-
Fish remains	100	89.64	80.33	82.64	91.74	79.24	53.73	24.28	1.20
Cephalopods	-	-	0.03	0.01	0.05	0.04	0.01	0.07	-
Crustaceans	-	0.01	0.04	0.03	0.05	0.02	0.09	0.01	-

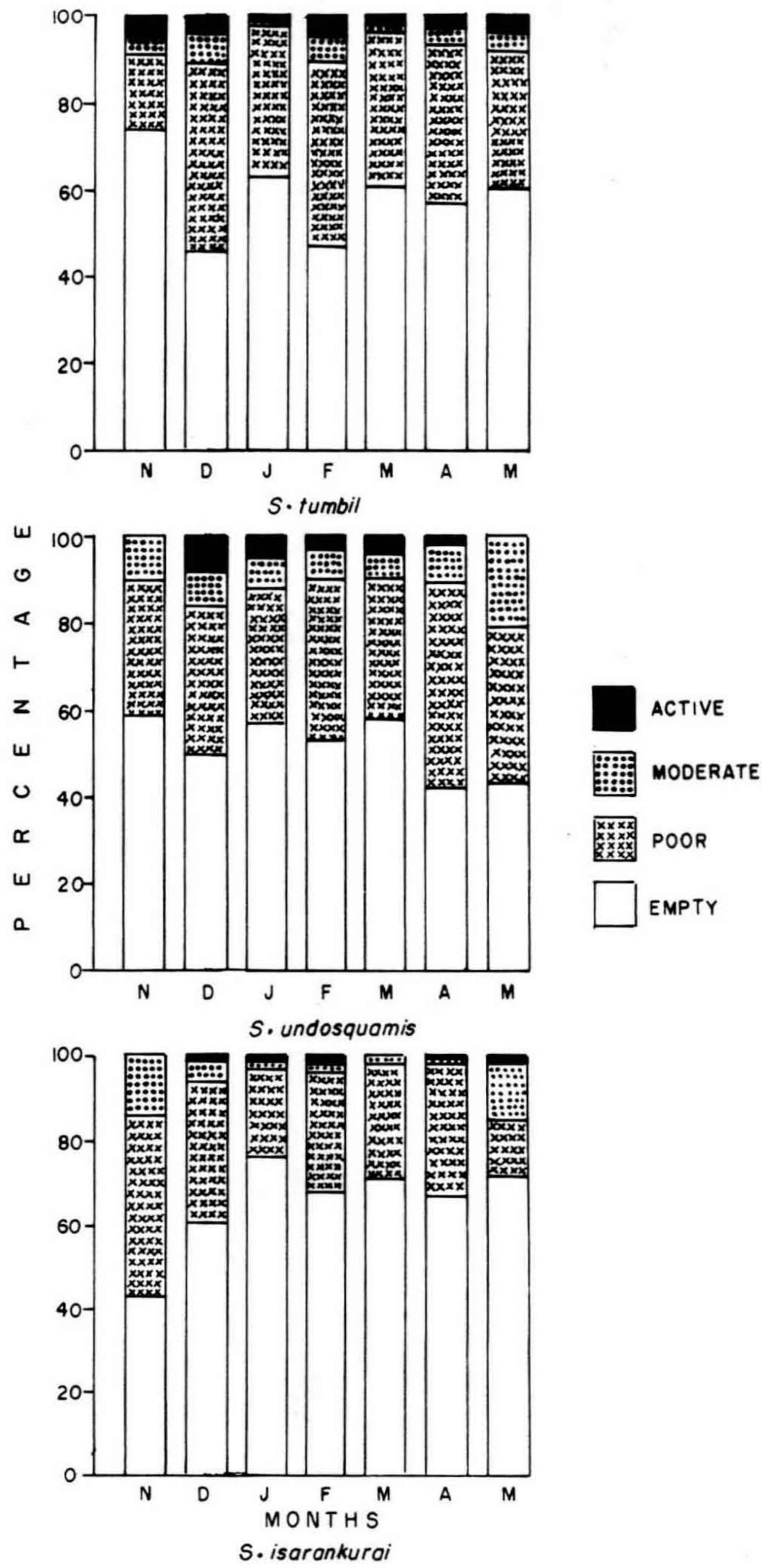

Fig. 3.1 Feeding intensity in males in relation to months.

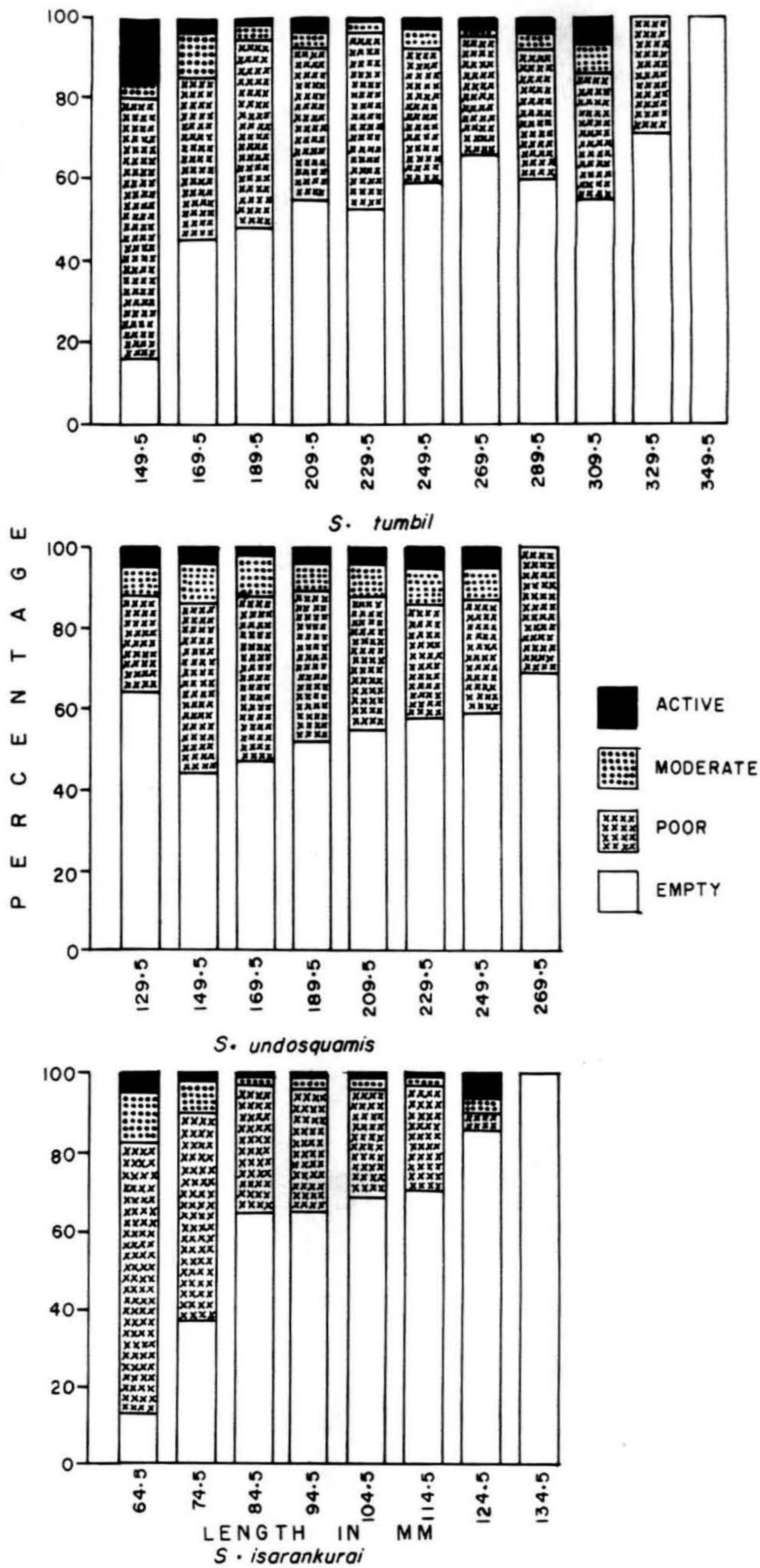

Fig. 3.2 Feeding intensity in males in relation to length.

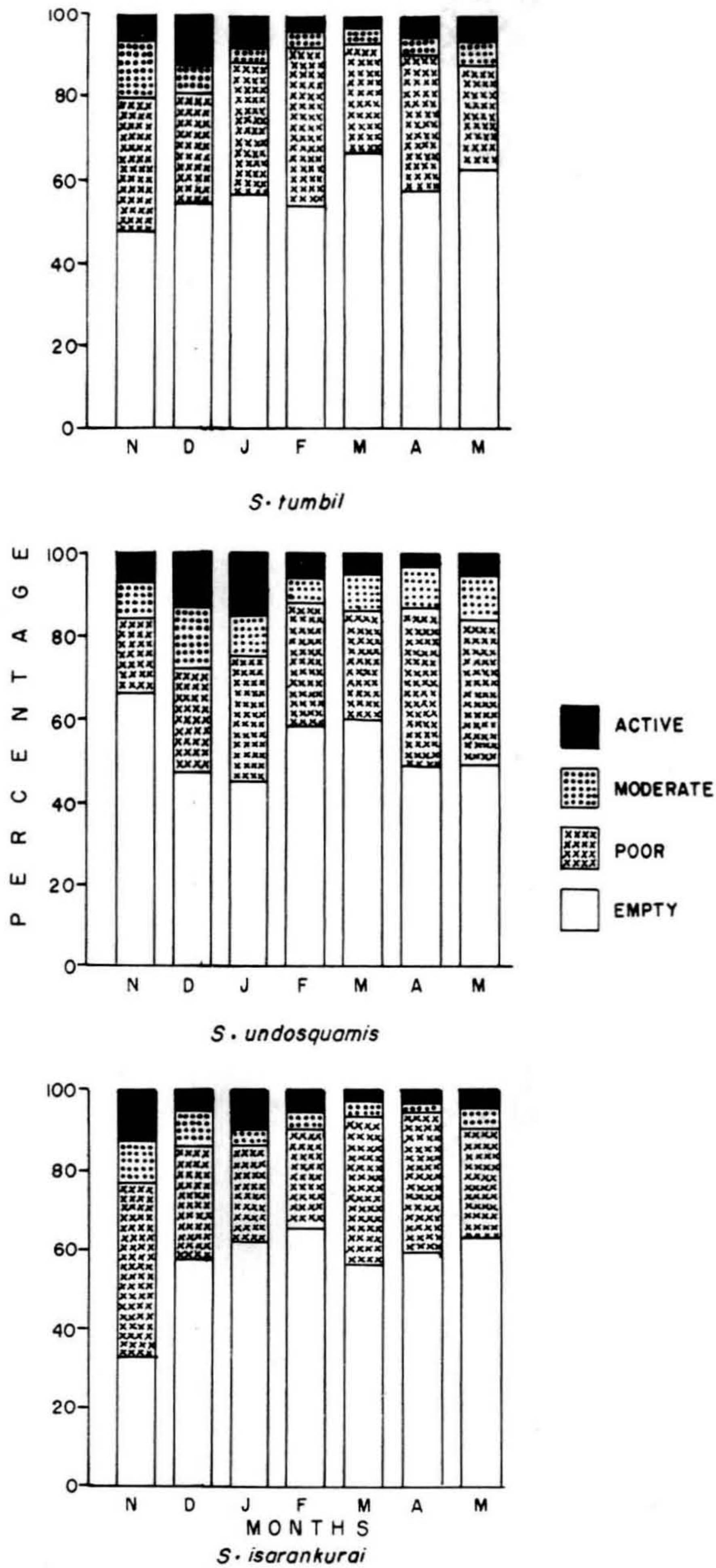

Fig. 3.3 Feeding intensity in fe males in relation to months.

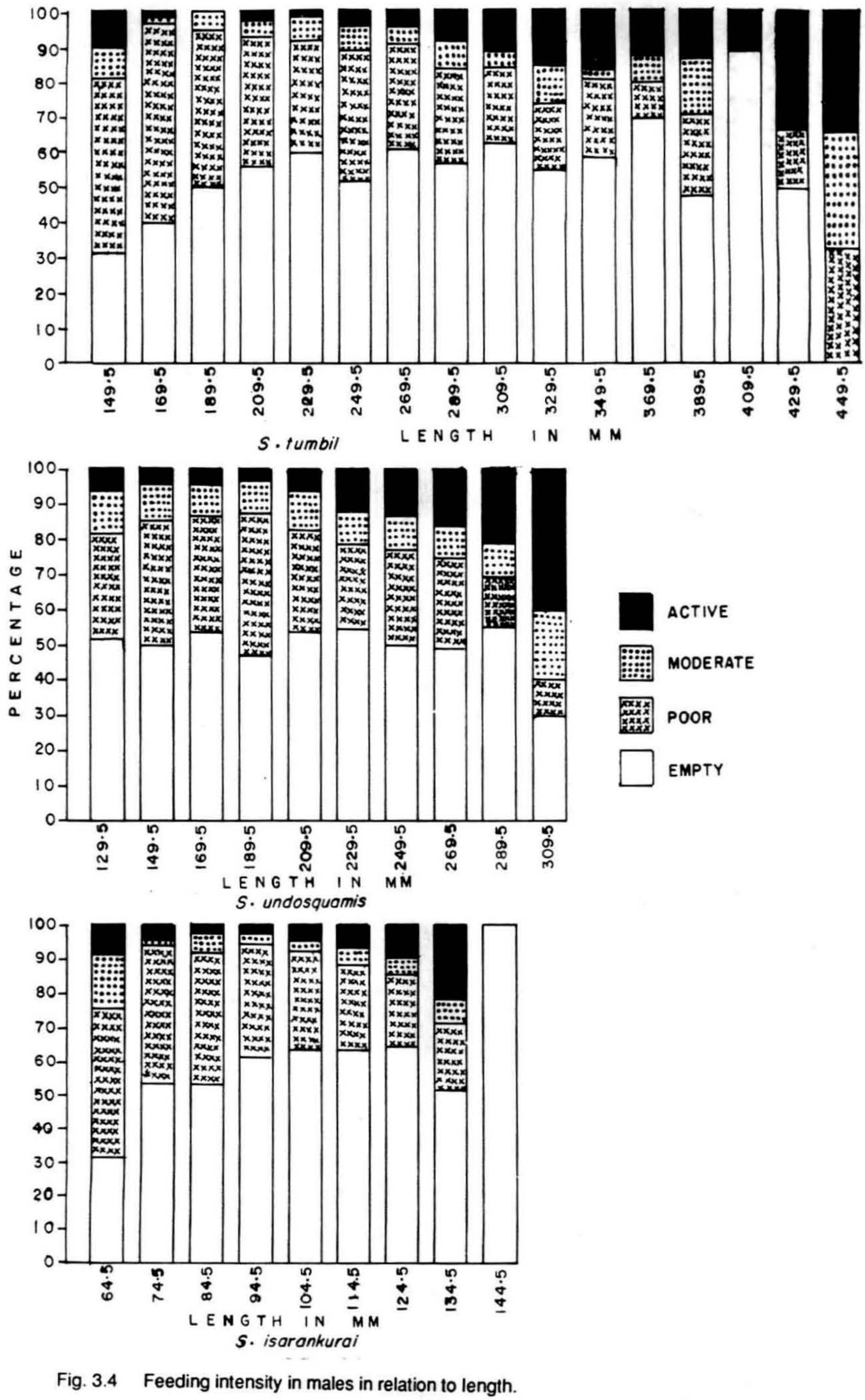

Fig. 3.4 Feeding intensity in males in relation to length.

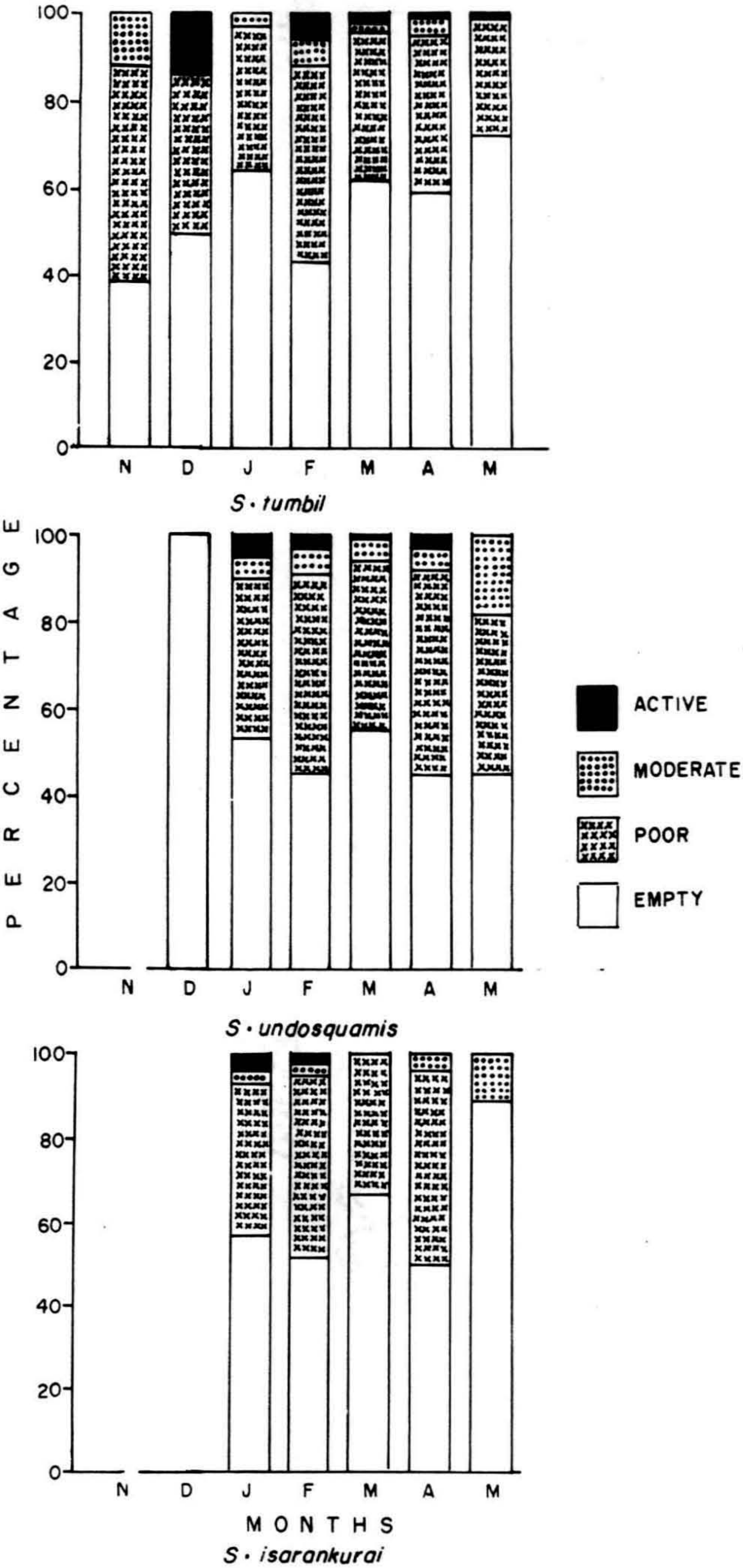

Fig. 3.5 Feeding intensity in immature males (stages I and II).

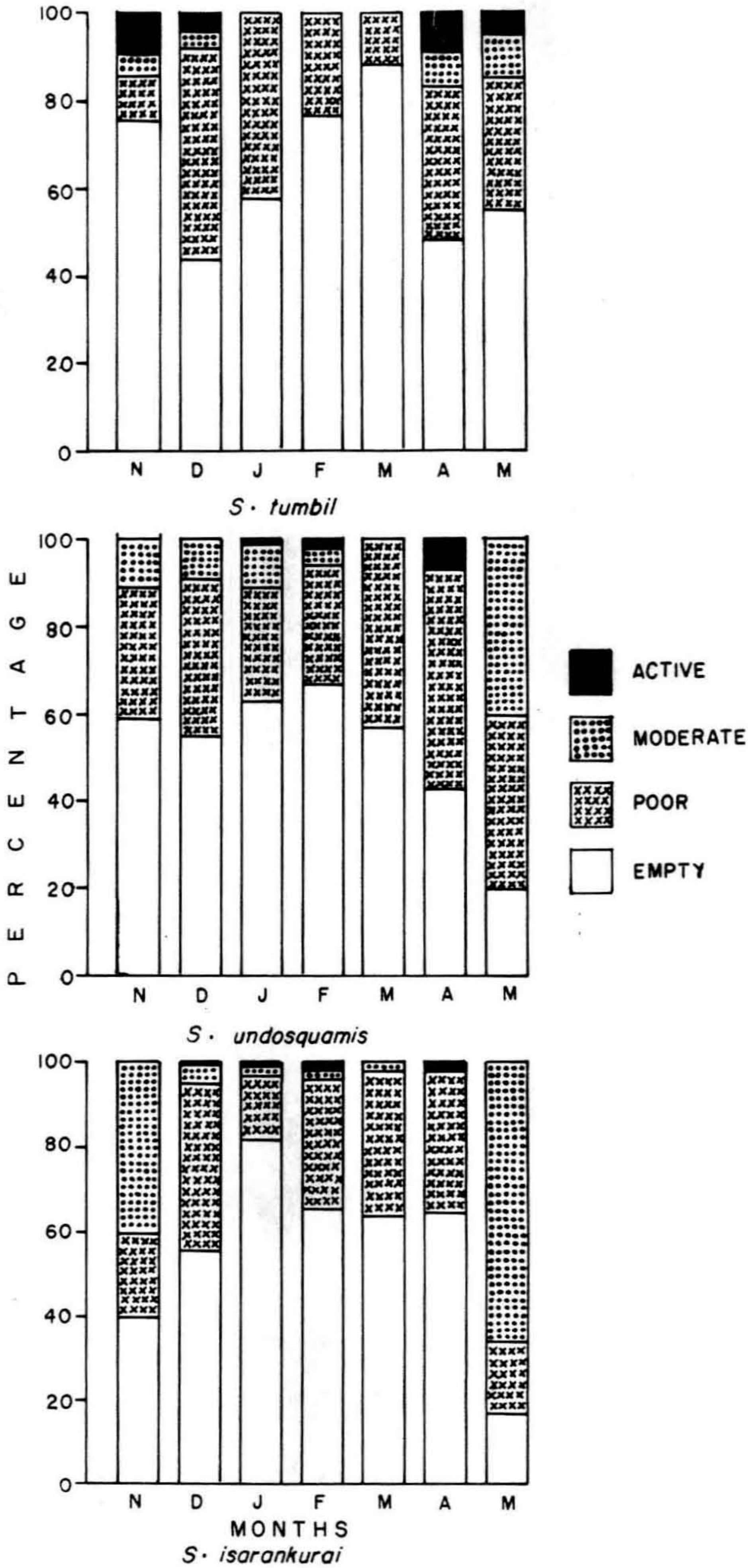

Fig. 3.6 Feeding intensity in maturing and mature males (stages III and IV).

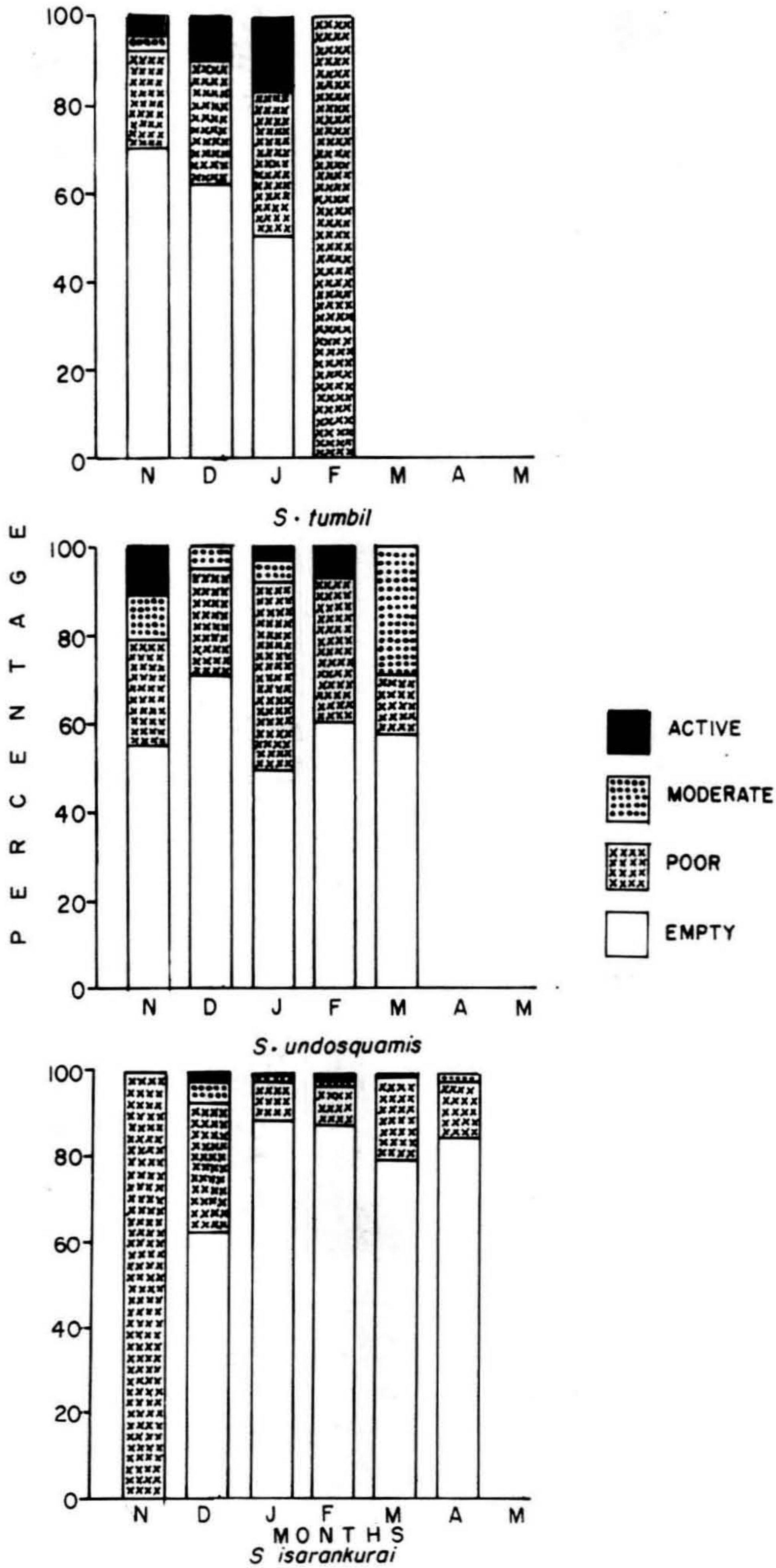

Fig. 3.7 Feeding intensity in gravid/ripe males (stages V and VI).

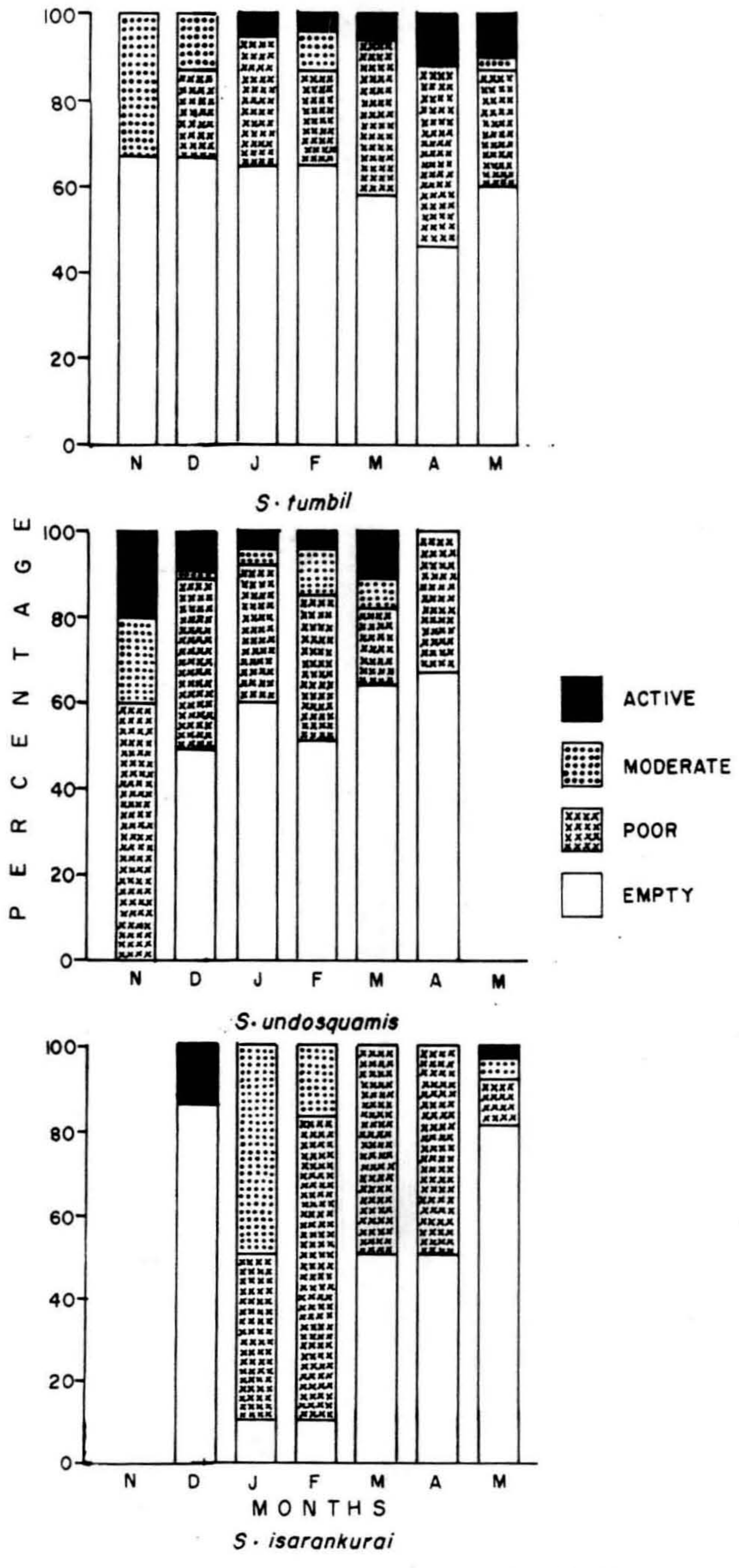

Fig. 3.8 Feeding intensity in spent males (stages VIIa and VIIb).

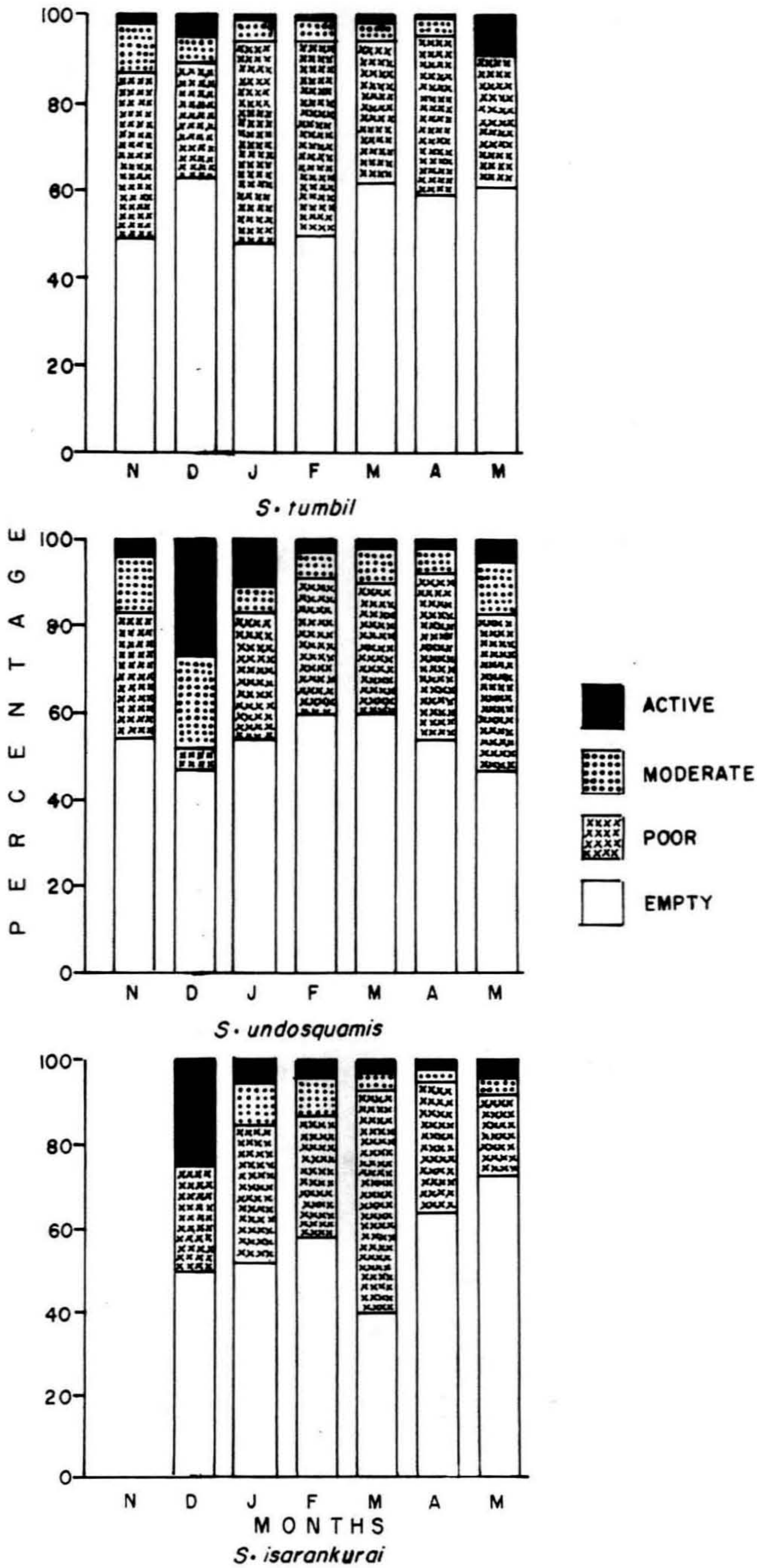

Fig. 3.9 Feeding intensity in immature females (stages I and II).

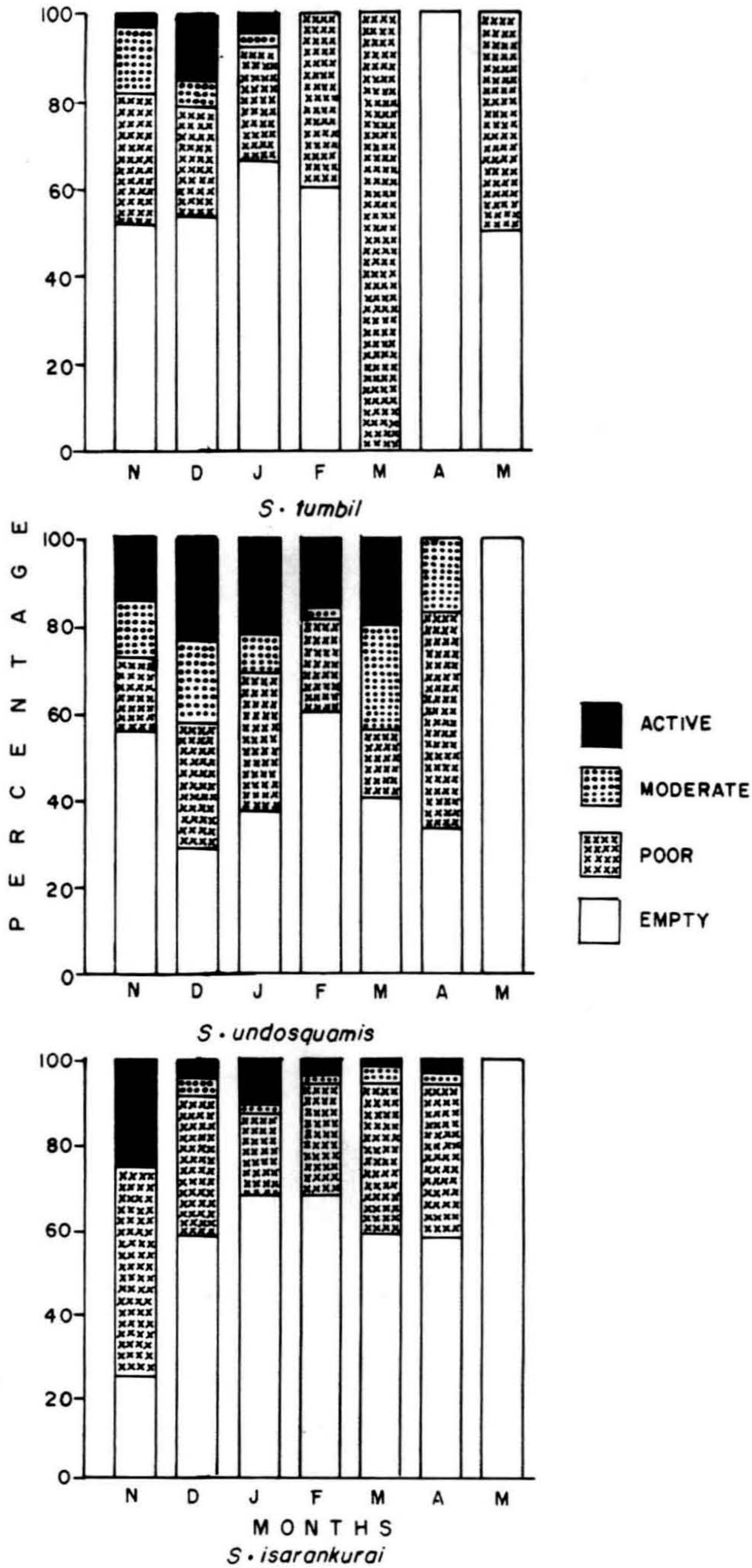

Fig. 3.10 Feeding intensity in maturing and mature females (stages III and IV).

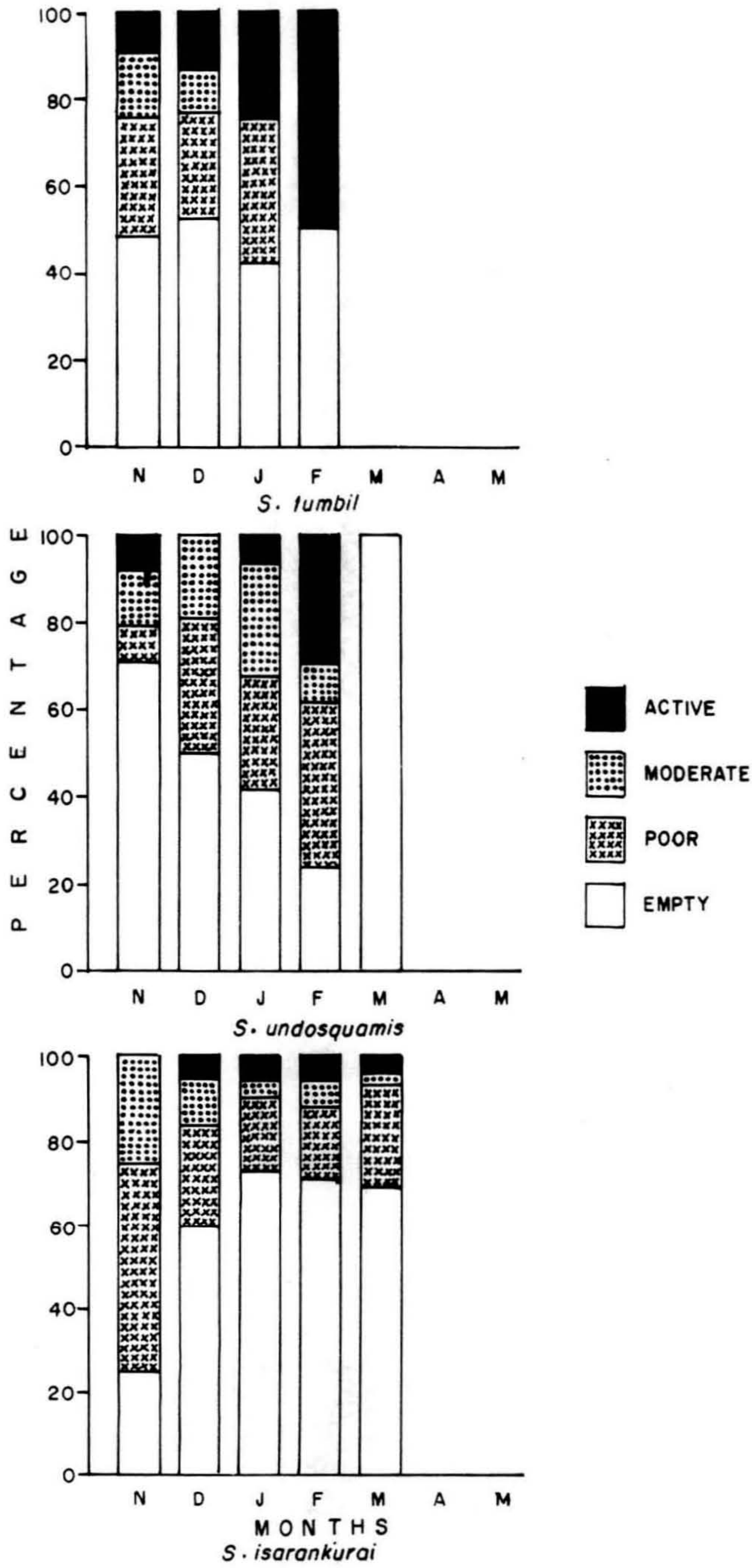

Fig. 3.11 Feeding intensity in gravid/ripe females (stages V and VI).

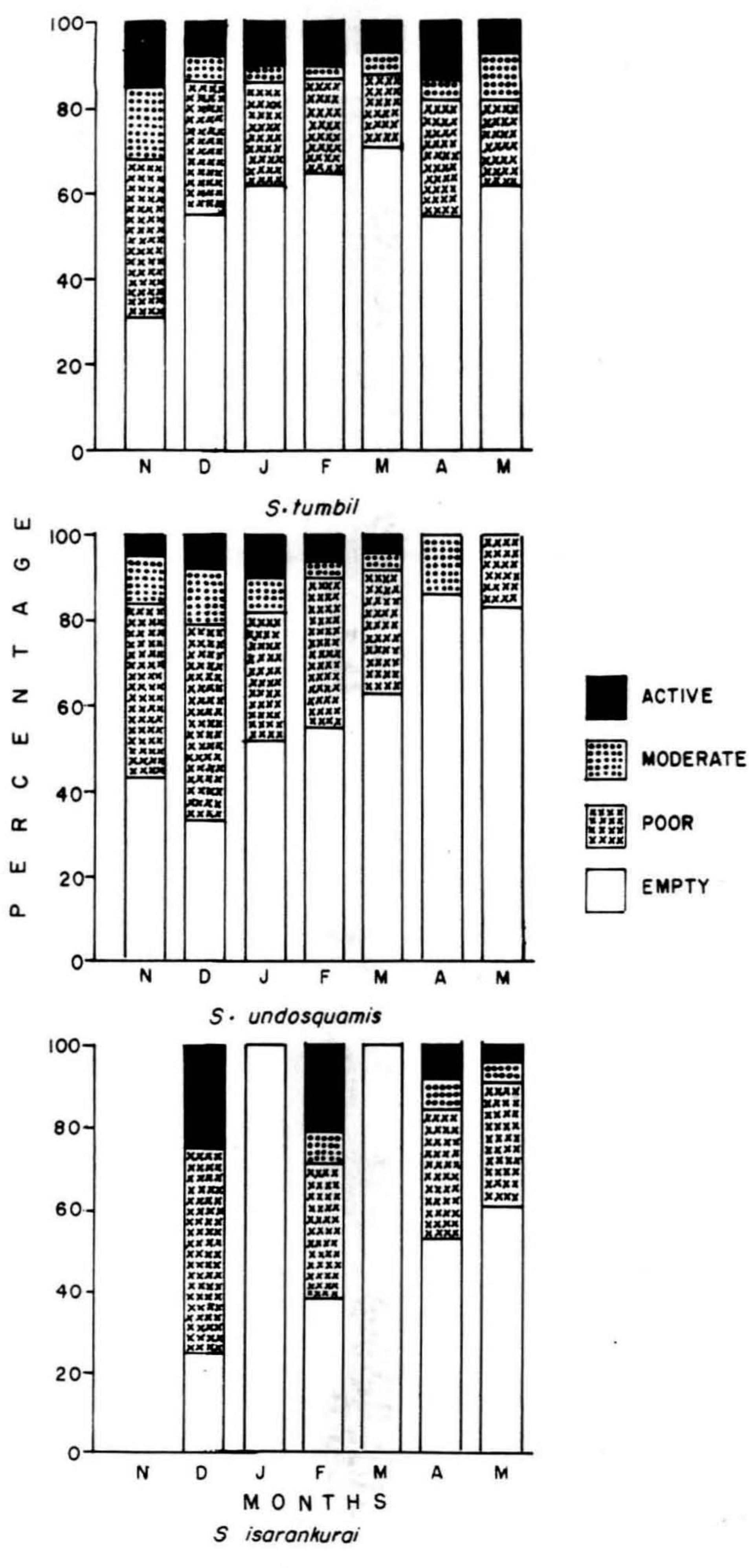

Fig. 3.12 Feeding intensity in spent females (stages VIIa and VIIb).

Chapter IV

AGE AND GROWTH

INTRODUCTION

In the studies of biological profile of a species, age and growth form the most fundamental and important aspect. A knowledge of these parameters is essential to understand the dynamic features of the population and forms the basic key to determine the quantity of fish that could be produced in a fish population against time. Once the addition (weight) in a fish stock in relation to time is determined, the optimum size at age can be fixed for rational exploitation of a fishery. Further, the loss in a given fish stock due to natural and fishing mortality is to be estimated for arriving at Maximum Sustainable Yield and biomass estimation. Thus, a knowledge on the size (age) structure and growth rate and other akin growth parameters is essential pre-requisite for successful fishery management.

In fishes, age and growth rate can be determined by:

a) tagging and recapture;

b) culturing the fish in cages/ponds providing congenial environment and suitable food and studying their growth in captivity;

c) markings (annual/seasonal) found on the hard parts such as scales, otoliths, finrays and skeletal parts;

d) length distribution method.

Of these, the first two methods are preferable as they offer direct evidence (result), but are difficult to implement, as appropriate infrastructure facilities are required to carry out the programme. The other methods are indirect. Growth determination from marking on the hard parts has been successfully used in temperate waters. During summer and autumn, fish in their ecosystem tend to register maximum growth due to optimum food supply and environmental condition, particularly the temperature. The growth becomes slow during winter and spring when both the food availability and environmental factors are relatively at low levels. Corresponding to the seasonal changes the annual markings in the hard parts are seen as widely spaced or opaque zones due to fast growth followed by narrower and more transparent spaced zones owing to slow growth.

A lot of literature is available from temperate waters on the use of hard parts in the study of fish growth. Instances of age determination in fishes using hard parts is two centuries old. A Swedish clergyman determined the age of pike (*Esox lucius*) and other species by counting the rings on the vertebrae and his findings were similar to modern readings (Hederstörm, 1959, original version, 1759). Maier (1906) reviewed the history of age determination from the 17th to end of 19th centuries. Hoffbauer's (1898) grouping of circuli in carp and interpreting as yearly marks made Thompson (1902) to extend this procedure to marine fishes. The earlier reviews on this aspect are given by Thompson (1902) and Graham (1929) and the recent ones may be referred to in the works of Chugunova (1959), Bagenal (1974) and Pauly (1978).

In tropical waters, the markings on hard parts, though less pronounced, are found in marine and fresh water fishes, but no authentic evidences are available as to their annual nature. As there is generally no marked variation in environmental factors like temperature, various workers attribute the causative factors for such markings to spawning, fluctuations in food supply, monsoon etc. Nevertheless, there have been certain studies on age determination of fishes from Indian waters using the hard parts (Menon, 1950; Seshappa and Bhimachar, 1951 and 1954; Radhakrishnan, 1954 and 1957; Kutty, 1961; Pantulu, 1961 and 1962; Qasim and Bhatt, 1964 and 1966; Rao, 1966 and Muthiah, 1982).

Consequent upon doubtful authenticity of marking as to its depicting the annual nature of growth pattern as noted above, in the tropics, the method of length frequency distribution has found wider application for age determination. Moreover, it is generally found easier to analyse the length frequency data as it requires less equipment and facilities. In the present study, the length frequency distribution method was used for age and growth rate estimation of the species.

Length frequency method has been the most popular technique for age estimation of fishes all over the world since 18th century. It was first introduced by Petersen (1892) and commonly known as "Petersen Method", inwhich peaks in the length frequency of a given sample is assumed to represent different year classes (age groups). In another method, known as "Modal Progression Analysis", the peaks in the length frequency samples arranged sequentially in time, are connected to follow the progression of modes (peaks) and the growth estimated (George and Banerji, 1964 and Brothers, 1980). The application of the first method is however, beset with certain short comings, as the modes representing the older fishes may overlap as normally the growth rate slows down considerably with increasing age and thus making the fixation of age difficult. Nevertheless, it is possible to separate the year classes by graphical methods, as described by Harding (1949). Cassie (1954), Tanaka (1956) and Bhattacharya (1967) or by computer based methods as demonstrated by Hasselblad (1966), Abrahamson (1971) and Yong and Skillman (1971). In the second method, the problem posing is, the difficulty in interconnecting the several modes available in the length frequency. The peaks in the length distribution may be the outcome of several broods arising from prolonged or fractional spawning of fish as it happens in the tropical waters and hence, the various modes occurring in any single length frequency sample cannot be fixed to a definite age group. Due to the same reason the peaks in the time series length frequency cannot be interconnected with certainty. Thus, both the methods are highly subjective and often lead to doubtful results (Pauly, 1981 and 1982, Josse *et al.*, 1979 and Ricker, 1975).

Recently, Pauly (1980 and 1983) has proposed an 'integrated method' by combining the above two methods. In this, a growth curve joining majority of the peaks is drawn directly upon length frequency distribution arranged sequentially in time or on to the same sample repeated over and over along the time axis with a concept that length-growth in fishes is fast in early part of life and then slows smoothly. Such a smooth curve is likely to represent the average growth of fishes in a population. Devaraj (1982) introduced the 'scatter diagram technique' of modal progression analysis in which the modal lengths in the length frequency distribution are plotted in the form of a scatter diagram against sequence of time and the trend of progression of modes through time is marked by eye fitted line. By these two methods, some of the doubts encountered in the Petersen's methods can be overcome and certain extent of reliability can also be achieved.

Pauly and David (1981) have attempted a new approach for a rapid, reliable and objective method of computer based length frequency analysis called ELEFAN (Electronic Length - Frequency Analysis). The principle involved in this programme is to split the composite length frequency into peaks and troughs and the best growth curve passing through maximum number of peaks avoiding troughs is selected using a goodness of fit by a ratio of ESP/ASP. Here the peaks are assumed to represent individual cohorts. The procedure in this method involves the following steps:

The length frequency samples are restructured for identifying 'peaks' and 'troughs' objectively and are allotted certain positive and negative points respectively. A growth curve is fitted for an arbitrary "seed" input values of L_∞ and K, starting from base of a certain peak by projecting forwards and backwards against time to meet all other samples of sample-set arranged sequentially in time. Whenever, the curve hits a peak (positive) or trough (negative) it scores 'points' and the total sum of points is called ESP (Explained Sum of Points). The sum of scores from the positive peaks in the curve is called ASP (Available Sum of Points). The ratio between ESP/ASP = R_n is a measure of goodness of fit. The "seeded" values of L_∞ and K are increased or decreased until a growth curve with the highest value of R_n is obtained. The corresponding "seed" values of L_∞ and K are taken as final estimates of the von Bertalanffy growth parameters.

A number of mathematical models of growth described by Gompertz (1825), von Bertalanffy (1938), Bagenal (1955), Rafail (1973) and Udupa (1976) and some known as logistic (Pearl and Read, 1923) and exponential (Ricker, 1958) are now available for deriving growth information of fish stocks and for further use in the yield models. Beverton and Holt (1957), Ursin (1968) and Ricker (1975) have described the theory of various growth models. Of the available models, the most widely used one is that of von Bertalanffy for which methods of fitting the formula have been given by Beverton & Holt (1957) and Ricker (1958). The model expresses the length 'L' at time 't' as:

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

Where L_{∞} = the maximum length that the fish can theoretically attain, K = growth co-efficient or curvature parameter or the rate at which the fish approaches asymptotic length, 't_0' = theoretical age of fish at (birth) length zero, provided the fish grows conforming to von Bertalanffy's growth equation and 'e' = the base of natural logarithm.

The growth of different species of *Saurida* from various parts of the world has been studied by a number of workers. Tiews *et al.* (1972) determined the growth rate of *S. tumbil*, using Petersen method from Philippine waters. The age and growth of this species were studied employing scales by Okada and Kyushin (1955) from East China - Yellow Seas; Shindo (1972) from East China; Xucai and Qiyong (1988, 1989) from South-Fujian and Taiwan Bank and Yeh *et al.* (1977) from East China and the Gulf of Tonkin. Lee *et al.* (1986) estimated the age and growth of *S. undosquamis* from the reading on the vertebrae from the southern part of the Taiwan Strait. Kühlmorgen-Hille (1970) calculated the growth rate of this species by length frequency method from the east-west coast of Gulf of Thailand, while Sinoda and Intong (1978) reported it from the inner Gulf of Thailand. Lee and Yeh (1989) studied the age of this species by using scale method from the southern Taiwan Strait and Budnichenko and Nor (1978) from the Arabian coast. Sanders *et al.* (1984) estimated the growth parameters of *S. undosquamis* from the Gulf of

Suez by the Bhattacharya programme. Boonwanich and Amornchairojkul (1982) determined the growth parameters of *S. elongata* and *S. undosquamis* from the upper and southern Gulf of Thailand. Hamada (1986) studied the age and growth of *S. wanieso* by scale method. Boonwanich (1991) computed the growth parameters of *S. elongata* and *S. undosquamis* from southern Gulf of Thailand by employing ELEFAN programme.

Age and growth studies on *Saurida* spp. from Indian waters are very limited. Rao (1984) studied the age and growth of *S. tumbil* and *S. undosquamis* from the northwestern Bay of Bengal. Dighe (1977) determined the age of *S. tumbil* from Bombay waters. Both the authors followed the Petersen method for their studies. There is no published information on the age and growth of *S. tumbil* from the southwest coast of India. Similarly, there is no information on this aspect in respect of *S. undosquamis* from the west coast of India. In the case of *S. isarankurai* no study is available from any part of the world. Hence, the present investigations were undertaken to study the growth parameters of these three species, which form a significant proportion of the demersal fish catch in the Karnataka waters of the west coast of India.

MATERIAL AND METHODS

The material for the study was collected during 1989-91, from the commercial trawl catches landed at Mangalore, Malpe, Bhatkal and Karwar, the four important trawl fishing centers of Karnataka coast. The former two centers are located in the Dakshina Kannada District and the latter in the Uttara Kannada District. Length and weight measurements of random samples, each consisting 100-300 fish, were taken in the field itself, once in a fortnight for two or three consecutive days. No data could be collected during June - October due to cessation of trawl fishing in the monsoon months of June - August and later due to non-commencement of night trawl fishing during September - October, as *Saurida* spp. are exclusively caught by night fishing trawlers.

A total of 14,780 *S. tumbil*, 8,733 *S. undosquamis* and 10,030 *S. isarankurai* was measured for length distribution studies. Total length was measured in mm from tip of snout to end of longest caudal ray of upper lobe. Length measurements were grouped into 20 mm for the larger species, *S. tumbil*, 10 mm for the medium growing *S. undosquamis* and 4 mm for the smaller species, *S. isarankurai* and the numbers in each size interval was totalled. This data were then raised to the total individual species catch of the fortnight, based on sample weight. Pooling of the two fortnight's length distribution gave monthly estimated numbers, in each size class. The monthly estimated numbers, thus obtained for the fishing season, November - May, 1989-90 and 1990- 91, formed the data base for further analysis. As the trawlers of different sizes (6.75 m - 15 m OAL) operate in 20-60 m depth area along the Karnataka coast, using trawl nets of 15-40 mm mesh size and since the initial observations did not show much variations in the component of their catch, the entire coastal area of the state has been treated as a single unit area, and the estimated numbers of fish in each size group obtained from all the four centres were pooled together (corresponding to each calendar month) monthwise and final length distribution was prepared for the estimation of growth parameters of the three species. Pooled data of two season's total estimated numbers in each size class were used for growth estimation and mortality studies.

Length data were analysed by computer based ELEFAN method ("COMPLEAT ELEFAN" package) as described by Gayanilo *et al.* (1988) to obtain the growth parameters. In this, ELEFAN 'O', 'I' and 'II' programmes were made use of. The grouped data set were first entered into ELEFAN 'O' and stored in files, so that they could be used as and when required for analysis. This was then put to automatic search routine by ELEFAN I. As this programme requires arbitrary values of L_∞ and K as seeded input, the same was done with variable starting points and lengths. Through this, the starting sample and length was fixed alongwith the acceptable values of L_∞ and K at reasonable values of R_n. Further higher values of R_n were obtained by putting it through response surface analysis in ELEFAN I by "refining".

Growth parameters, L_∞ and K were also estimated using the Bhattacharya (1967) method in combination with Gulland and Holt Plot (1959). The Bhattacharya method splits the composite length frequency distribution into normal distribution representing various cohorts. In this method, the length frequency distribution is transformed into a straight line by plotting the differences between consecutive logarithmic values of the number of fish against the lower limit of length groups. From the plot, the first group (cohort) was separated by visual examination and followed by regression analysis. The numbers constituting the first cohort was calculated and substracted from the total distribution and the process was repeated with left over distribution until all the cohorts are identified. The mean lengths of cohorts thus obtained were plotted against time and following the trend, probable progression of cohorts were connected.

Gulland and Holt plot (1959) as described by Sparre *et al.* (1989) was used to get the growth parameters of L_∞ and K. In this plot, the differences in length between consecutive means over difference in time ($\Delta L/\Delta t$) against the mean length between the two corresponding mean lengths were computed and plotted. Further, regression analysis of all the available data pairs i.e.,

$Y = \Delta L/\Delta t$ and $X = \bar{L}$ gave

$K = -b$ and $L_\infty = -a/b$

Computations for the Bhattacharya method and Gulland and Holt plot, LFSA programme by Sparre *et al.* (1989) were carried out using LFSA programme by Sparre (1987) with the help of a computer. For this, the ELEFAN files were converted to LFSA files.

The modified version of the Wetherall formula (Wetherall *et al.*, 1987 and Pauly, 1986) was used as a collateral for the confirmation of values of L_∞ arrived at by ELEFAN and Bhattacharya-Gulland and Holt plot methods. The Wetherall formula is based on linear regression i.e.,

$\bar{L} = L' = a + b L'$ where

$L_\infty = a/-b$, L' = the lower limit of the first length used in calculating $\bar{L}$, and $\bar{L}$ = the mean length of fully recruited fish computed upward L'.

$\bar{L}$ is calculated from cumulative numbers of length frequency sample as follows:

$$= \frac{\text{group midlength x nos. in each length group}}{\text{total number of fish}}$$

t_o was estimated using the equation

$$\text{Log}_e = \frac{L_\infty - L_t}{L_\infty} = Kt_o - Kt \text{ which is of the linear form,}$$

$y = a - b\,x$ where,

$a = Kt_o$, hence 't_o' = a/K which is the same as the point of intersection of the regression line with time axis.

Taking the length attained at the end of each quarter as obtained by ELEFAN, the 't_o' was calculated by regression of age 't' as 'X' against -

$$\text{Log}_e = \frac{L_\infty - L_t}{L_\infty} \text{ as 'Y'}$$

The length attained at quarterly interval was taken for *S. tumbil* and *S. undosquamis*. As *S. isarankurai* grows to smaller size, length attained at the end of each month was taken for the calculation of 't_o' for this species.

RESULTS

S. tumbil

Monthly length frequency data (estimated numbers of fish) grouped into 20 mm interval for the two seasons (Table 4.1) was utilised for ELEFAN I, the step by step work programme of which has been described in the material and methods section. The resultant growth curve in the restructured length frequency distribution is given in Fig. 4.1. The highest value got for R_n was 0.2 and the corresponding values of L_∞ and K are 575 mm and 0.57/year respectively. The maximum length recorded for the species in the fishery was 483 mm. The length attained at the end of each month as obtained by ELEFAN is presented in Table 4.2.

The mean lengths of cohorts identified from the Bhattacharya analysis of monthly length frequency distribution through LFSA are given in Table 4.3. The same were plotted against month and the most probable progression of cohorts interjoined. The regression analysis of $\bar{L}$ and $\Delta L/\Delta t$ (Table 4.4) gave estimate of slope = -0.4556 and intercept = 267.35748.

Using the equation, $K = -(b) = K = 0.4556$ per year and

$$L_\infty = -(a/b) = \frac{267.35748}{0.4556} = 586.76655 \text{ mm were obtained.}$$

The length frequency distribution (estimated numbers of fish) with a class interval of 20 mm, pooled for the two seasons, 1989- 90 and 1990-91 (Table 4.1) were used for modified Wetherall *et al.* (1987) plot method through the ELEFAN II programme. Fig. 4.2 gives the point of selection of full recruitment (Table 4.5). The points used above 339.5 mm (L') was selected for regression analysis against $\bar{L} - L'$ at 29.795 mm which gave values for 'a', 'b' and 'r' as 76.66, -0.139 and 0.888 respectively. Substituting the values to the equation,

$$L_\infty = a/(1-b) = L_\infty = -a/b$$

$$L_\infty = \frac{-76.66}{-0.139} = 551.51 \text{ mm was obtained}$$

't_0' was estimated (Table 4.6) by taking the lengths attained at the end of every quarter and by regressing

$$\log_e = \left(\frac{L_\infty - Lt}{L_\infty}\right) = y \quad \text{and 't'} = x.$$

The 'a' and 'b' values obtained were 0.012315 and -0.57088 respectively.

Since b = K and a = $K_{\bullet}t_0$

$$t_0 = a/K = \frac{0.012315}{0.57} = 0.021605 \text{ years}$$

which is same as the (Fig. 4.3) point of intersection of the regression line with time axis.

The von Bertalanffy growth equation based on the length growth parameters estimated by ELEFAN can be expressed as:

$$L(t) = 575\ [1\text{-}\exp\ (-0.57\ (t\text{-}(+\ 0.021605))]$$

S. undosquamis

Computation through ELEFAN I programme using the monthly length frequency samples for the two fishing seasons grouped into 10 mm class interval (Table 4.7) gave the best fitting growth curve (Fig. 4.4) in the restructured length frequency distribution with the highest R_n value of 0.2 in the response surface. The values of L_∞ and K for this R_n value were 360 mm and 0.64 per year respectively. The maximum length recorded in the fishery was 340 mm. The length attained at the completion of each month is given in Table 4.8.

The Bhattacharya analysis for separation of various cohorts (Table 4.9) and using the growth rate of the assumed cohorts for Gulland and Holt plot (Table 4.10) gave values of L_∞ = 356 and K = 0.66 with correlation coefficient of 0.836.

Size-distribution data of estimated numbers of fish for the two fishing seasons, 1989-90 and 1990-91 were pooled and grouped into 10 mm interval (Table 4.7) for analysis by the modified Wetherall *et al.* (1987) plot method, through ELEFAN II. Table 4.11 gives the data used for the estimation of L_∞. Fig . 4.5 shows the point of selection of full recruitment group. For regression, points above 239.5 mm of the L' values and the corresponding values of

$\bar{L} - L'$ = 21.982 were selected. The value obtained for 'a' was 70.56, 'b' = -0.201 and 'r' = 0.951.

L_∞ estimated using the formula, L_∞ = -a/b was 350.629 mm.

't_0' was calculated (Table 4.12) as done for *S. tumbil* and was found to be 0.0006578 years, and is shown graphically in Fig. 4.6.

The von Bertalanffy growth function by taking the growth parameters as obtained by ELEFAN could be written as:

$$L(t) = 360\ [1\text{-}\exp\ (-0.64\ (t\text{-}\ (+\ 0.0006578))]$$

S. isarankurai

The monthly length frequency data (Table 4.13) analysed by ELEFAN I programme, gave the best fitting growth curve in the restructured length distribution (Fig. 4.7) with the highest R_n value of 0.2. The corresponding value for L_∞ was 158 mm and for K = 1.52. The estimated L_∞ was found nearer to the largest fish measuring 140 mm recorded in the fishery. The length attained at the end of each month is shown in Table 4.14.

The values of L_∞ and K estimated by the method of Bhattacharya (Table 4.15) and Gulland and Holt plot (Table 4.16) are 155.87 mm and 1.543/year respectively.

The pooled length frequency data (estimated numbers of fish) for the two fishing seasons, 1989-90 and 1990-91, grouped into 4 mm size interval (Table 4.13) were made use for modified Wetherall *et al* (1987) method through ELEFAN II. Table 4.17 shows the data utilised for estimation of L_∞. Fig . 4.8 depicts the plots of the cut off length from the point of fully recruited group. Regressing between the points upward of cut off length of 121 mm against $\bar{L} - L'$ of 3.879 mm gave:

'a' = 15.47

'b' = -0.096 and

'r' = 0.978

L_∞ (-a/b) was found out as 161.71 mm. 't_0' was computed by taking the lengths attained at the completion of every month (Table 4.18) and by regression as done in other species.

't_0' (a/k) was 0.033602 years and it is graphically shown in Fig. 4.9.

Using the length growth parameters as obtained by ELEFAN, i.e., L_∞ = 158 mm and K = 1.5, the von Bertalanffy growth function could be expressed as:

$$L(t) = 158\,[1-\exp(-1.5\,(t-(+\,0.033602))]$$

COMPARISON OF GROWTH PARAMETERS

Growth parameters of a given species can be tested for their reliability by comparing them with the available growth studies or with the related species in the same family. But, such comparison cannot be made by using L_∞ and K separately, as the growth in fishes is not linear and comparison of growth character individually may be misleading (Pauly, 1979 and Sparre *et al.* 1989).

Pauly and Munro (1984) proposed an emprically derived growth performance index (Munro's phi prime test), ϕ' (phi prime) which is expressed by the equation:

$$\phi' = \log K + 2 \log L_\infty \text{ where}$$

K is expressed in annual basis and L_∞ in cm. The equation has proved that the quantity of ϕ' approximately normally distributed within the family members and generally, its values is around 3. In the present study the ϕ' value is found to be 3.27 for *S. tumbil*, 2.97 for *S. undosquamis* and 2.58 for *S. isarankurai*.

DISCUSSION

S. tumbil

For *S. tumbil*, the L_∞ estimates derived through the ELEFAN, Bhattacharya and the modified Wetherall *et al.* (1987) plot methods are 57.5, 58.7 and 55.2 cm respectively, which are comparable. The growth parameters available for this species from other regions of the world are shown in Table 4.19. It is seen that, the L_∞ values for the East China Sea and Gulf of Tonkin are quite high ranging from 68.7 to 79.5 cm. Pauly (1978) based on the data in Tiews *et al.* (1972) from Manila Bay and East China Sea has estimated the L_∞ at 43.6 cm. Rao (1984) calculated L_∞ for this species from the north western Bay of Bengal at 63.7 cm and Chakraborty *et al.* (MS) at 60 cm for the species from Bombay waters. The L_∞ estimates obtained in the present study is close to those got from India by Rao (1984) and Chakraborty *et al.* (MS). The difference in the L_∞ values for the species from different regions may be due to differences in the environmental parameters and ecosystem characteristics in different tropical waters, difference in size structure at different localities and the methodology adopted for the study of growth parameters.

The K values obtained in the present study are 0.57/year and 0.46/year by ELEFAN and Bhattacharya analysis respectively. The values obtained in the East China Sea and the Gulf of Tonkin range from 0.08 to 0.12 (Table 4.19). Pauly (1978) calculated K value at 0.43 using the data of Tiews *et al.* (1972), for the species from Manila Bay and East China Sea. Rao (1984) computed 'K' value at 0.25 for the species from the north-western Bay of Bengal of India and Chakraborty *et al.* (MS) worked out at 0.51 for the species of Bombay area. The growth coefficient obtained for the species of East China Sea and Gulf of Tonkin, appear to be low (0.08 - 0.12), whereas, Pauly's estimation of 0.43 for the species of the same area seem to be reasonable. The value of 0.57 derived at in the present study through the ELEFAN is closer to the value of 0.51, obtained by Chakraborty *et al.* (MS) for the species of north west coast of India.

The growth performance index ϕ' values vary from 2.69 to 2.91 for the species of East China and the Gulf of Tonkin (Table 4.19). For the Indian species, the values worked out to 3.0 and 3.26 from the growth parameters obtained by Rao (1984) for species of north-western Bay of Bengal and Chakraborty *et al.* (MS) for the species of Bombay waters respectively. The value of 3.27 estimated in the present study is almost same as that of Chakraborty *et al.* (MS). Both the studies are from the west coast of India and the higher ϕ' values in these observations may perhaps be due to the higher growth-coefficient values than those from other regions.

S. undosquamis

The ELEFAN, the Bhattacharya and Wetherall *et al.* methods gave L_∞ values at 36.0, 35.6 and 35.5 cm respectively, showing the results obtained through these three methods are similar. There have been good number of studies on the growth characteristics of this species from the Gulf of Thailand (Pauly, 1978 - based on Kühlmorgen-Hille, 1970 and Ben Yami and Glaser, 1974; Boonwanich and Amornchairojkul, 1982; Sommani, 1989; Siripakhavanich, 1990 and Boonwanich, 1991). Sanders *et al.* (1984) estimated the growth parameters of the species from the Gulf of Aden and Chakraborty *et al.* (MS) from the north-west coast of India. The estimates of growth parameters and ϕ' available from the above studies are given in Table 4.19. It can be seen that the L_∞ values range from 30.30 to 46.10 and the values obtained in the present study is well comparable with most of these estimates.

The 'K' values available for the species from various regions as given in Table 4.19, vary widely from 0.25 to 2.34. The value of 0.64 obtained in the present studies through the ELEFAN method is close to the estimates worked out by Pauly (1978) based on the data presented by Ben Yami and Glaser (1974); Boonwanich (1991) for the species from the Gulf of Thailand and Chakraborty *et al.* (MS) for the species from the north- west coast of India.

The growth performance index ϕ' values available for *S. undosquamis* (Table 4.19) vary from 2.51 to 3.42. The value of 2.92 obtained in the present observation is closer to those obtained by Pauly (1978), Boonwanich (1991) and Chakraborty *et al.* (MS).

S. isarankurai

The growth parameters deduced through the ELEFAN, the Bhattacharya and Wetherall *et al.* methods, in the present study, seem reasonable and comparable with the result obtained for other species of *Saurida* spp. from different regions (Table 4.19). First, the ELEFAN method gave L_∞ value as 15.8 cm and subsequent analysis by Bhattacharya and Wetherall *et al.* plot gave almost similar values at 15.6 and 16.2 cm respectively. The ϕ' value of 2.58 appears to be a little low, as compared to all the available ϕ' values for different species of *Saurida* from various regions. However, the value is comparable with that obtained for *S. undosquamis* from the Gulf of Aden (Sanders *et al.*, 1984).

The determination of the number of components in the Gulland and Holt (1959) plot of the Bhattacharya (1967) programme and their identification to form a cohort is almost subjective, sometimes, the number of points are difficult to be connected.

Similarly in the Wetherall *et al.* (1987) plot, the selection of points of full recruitment in the growth is more or less subjective. On the otherhand, the ELEFAN programme offers a more objective method, using goodness of fit. Because of these facts, though the estimates of growth parameters of L_∞ through the above three methods (Table 4.20) and K by the ELEFAN and the Bhattacharya methods gave more or less similar results with minor variations for all the three species, the values arrived at through the ELEFAN method were considered for estimates for von Bertalanffy growth equation for all the three species and were used in the subsequent analysis of mortality, stock assessment, etc.

The study indicated that, of the three species, *S. tumbil* grows faster and to a larger size, attaining 246, 389 and 470 mm at the end of 1,2,3 year of its life respectively, whereas, *S. undosquamis* grows at a slow pace and reaches 170, 260, 307 and 332 mm at the completion of 1,2,3 & 4 year respectively. The third species, *S. isarankurai* is smaller growing and short lived and attains a size of 121 mm on the completion of a year. The minimum size at maturity was found to be 249 mm and 260 mm respectively for males and females of *S. tumbil*, 170 mm and 210 mm for males and females of *S. undosquamis* and 83 mm for both sexes of *S. isarankurai*. Hence, it is evident that the first two species starts spawning when they are about 1-year old, whereas, *S. isarankurai* after the end of 0.5-year. The growth rate appears to be very fast during the 1st year of their life in *S. tumbil* and *S. undosquamis* and during the first 6 months in the case of *S. isarankurai* and it slows down in the subsequent periods, indicating that these species have comparatively less growth rate after attaining maturity as in most of the other tropical fishes.

The maximum size recorded in the fishery was 483 mm for *S. tumbil*, 340 mm for *S. undosquamis* and 140 mm for *S. isarankurai* and the longevity of these species is worked out to be 3.33, 4.83 and 1.5 years respectively.

From the length frequency data it is observed that the fishery of *S. tumbil* composed of 0-3 year classes, of which the 0-year class and 1-year class were found to be the main stay of the fishery forming each about 45% of the catch. In the case of *S. undosquamis*, the fishery was constituted by 0-4 year classes, the dominant age groups were found to be 0-year and 1-year classes, forming about 34% and 61% respectively of the catch. The fishery of *S. isarankurai* was composed almost entirely by 0-year class, forming as high as 96% of the catch.

LENGTH-WEIGHT RELATIONSHIP

The study of length-weight relationship assumes great importance in fishery biological research, as it provides a mathematical relationship between them, enabling the derivations of one variable from the other. For example, collection of data on length in the field or on board a fishing/research vessel can be accomplished rather more easily and quickly than the collection of weight data, and once a relationship is established between these variables, the length data can be transformed into weight data. It further aids in obtaining information on the general well being of the fish, minimum size at maturity, spawning season, variations in weight due to feeding, maturation and growth, by estimating the condition factor (K) and relative condition factor (K_n). It is also useful in the estimation of weight-growth parameter 'W_∞' corresponding to the length-growth parameter 'L_∞', which forms one of the important parameters in the yield per recruit studies. Sometimes, the length-weight relationship is utilised for the identification of different stocks of the same species (David, 1963).

As the weight of fish is a function of length, the former being a measure of volume and the latter linear, it has been shown that their functional relationship can be described by the hypothetical cube law $W = cL^3$ where, W = weight, L = length and C = a constant. However, this equation is found valid only in cases where specific gravity and body form remain constant, obeying isometric growth pattern, in which the exponent of length (L) is found to be equal to 3 (Allen, 1938). But in actuality, fish do not keep constancy in growth and body form, as they, in the course of development, pass through several stages or stanzas (Vaznetsov, 1953). In such cases, each of the stages may have its own length-weight relationship, often resulting in allometric form of growth, deviating from the exponential value of 3. Hence, a generalised parabolic equation, $W = aL^b$, where, W = weight, L = length, 'a' = a constant equal to 'c' and 'b' another constant to be derived emprically has been found to explain the relationship between length and weight better than the cube formula (Le Cren, 1951). The exponential value of 'b' in the parabolic equation is found to vary from 2.5 to 4 (Hile, 1936 and Martin, 1949).

The equation $W = aL^b$ can be transformed into linear function by taking logarithmic values of the length and weight data, and the values of 'a' and 'b' can be estimated by regression analysis. Then the equation takes the form of

$$\text{Log } W = \log a + b \log L \text{ or } y = a + bx$$

where, $y = \log W$; $x = \log L$; $a = \log a$, the intercept of the line on the 'y' axis and b = an exponent.

Exhaustive data on length and weight representing wide ranging sizes can be grouped into short length classes and the average length and weight of each classes can form the input data for linear regression analysis. The length-weight relationship borne out of such exercise would form a representative relationship for the population. However, if the sampling consists of only of older age group fishes or of individuals, belonging to a particular size group, the relationship so established would then become a biased one.

Studies on the length-weight relationship have been made on a large number of marine fishes in India. Some of them include *Trichiurus haumela* (Prabhu, 1955), *Coilia dussumieri* (Bal and Joshi, 1956), Mackerel (Pradhan, 1956), *Thrissocles mystax* (Venkataraman, 1956), *Sillago sihama* (Radhakrishnan, 1957), *Pseudosciaena diacanthus* (Rao, 1963), *Sardinella longiceps* (Antony Raja, 1967), *Trichiurus lepturus lepturus* (James, 1967), *Sardinella albella* and *S. gibbosa* (Sekharan, 1968), *Nemipterus japonicus* (Krishnamoorthi, 1971), *Polynemus heptadactylus* (Kagwade, 1971), *Tachysurus thalassinus* (Mojumder, 1971), *Cynoglossus semifasciatus, C. dubius* and *C. bilineatus* (Seshappa, 1981), *Decapterus dayi* (Srinivasan, 1981). *Leiognagthus bindus* (Murthy, 1983), *Jopnieops vogleri* (Muthiah, 1982), *Stolephorus devisi* and *S. bataviensis* (Rao, 1988 and 1988a) and *Euthynnus affinis* (Muthiah, 1986).

The length-weight relationship study on *Saurida tumbil* was carried out by Tiews *et al.* (1972) from the Philippine waters, Yeh *et al.* (1977) from East China Sea and Gulf of Tonkin and Xucai and Qiyong (1988) from south Fujian and Taiwan Banks. Sanders *et al.* (1984) studied the length-weight relationship of *S. undosquamis* from Gulf of Suez, Edwards *et al.* (1985) from the Gulf of Aden, Lee *et al.* (1986) from southern part of Taiwan Strait and Van der Elst (1981) from southern Africa. Hamada (1986) determined the length-weight equations of *S. wanieso* from East China Sea. From the Indian waters, the published information on the length-weight relationship of *Saurida* spp. was that of Rao (1983a) who studied the relationship in *S. tumbil* and *S. undosquamis* from the north-east coast of India. Dighe (1977) studied the length-weight relationship of *S. tumbil* from Bombay waters.

The following account gives a detailed study on the length-weight relationship of three species of *Saurida*, *viz.*, *S. tumbil, S. undosquamis* and *S. isarankurai*. In respect of *S. undosquamis* the present contribution forms the first report from the west coast of India and in the case of *S. isarankurai*, the original one for the species, as no other information is available from any part of the world.

MATERIAL AND METHODS

Random samples of *S. tumbil, S. undosquamis* and *S. isarankurai* were collected from the commercial fish landings at Karwar, Bhatkal, Malpe and Mangalore. Data on length and weight were recorded from fresh samples. The total length was measured in mm from tip of the snout to tip of upper caudal lobe. Weight was taken upto 1 g for *S. tumbil* and *S. undosquamis* whereas in the case of *S. isarankurai* and juveniles of the former two species, weights were recorded upto 0.001 g. The length data were grouped into 10 mm interval for *S. tumbil* and *S. undosquamis* and 1 mm interval for *S. isarankurai* and the average length and weight were determined by adding up the actual lengths and weights of all individuals falling in the respective groups and dividing the total by the number of fish in each group. Length-weight relationship were calculated separately for males, females and juveniles. Scatter diagrams of length against weight and logarithms of lengths and weights were plotted for these three groups separately.

For adopting the general exponential equation $W = aL^b$, least square computations were made using log L(X) and log W(Y) for obtaining values of ΣX, ΣX^2, $\overline{X}$, ΣY, ΣY^2, $\overline{Y}$ and ΣXY where Σ denotes summation and $\overline{X}$ and $\overline{Y}$ mean values of X and Y respectively. The regression co-efficient or slope of the regression line (b) was computed using the equation.

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

where N = number of samples. The intercept (a) was determined by the formula-

$a = \overline{Y} - b\overline{X}$. Using these values, linear equation of length-weight relationship -

$\text{Log } W = \log a + b \log L$ or $y = a + bx$, was obtained. Further, converting these logarithmic values into antilogarithms, the exponential form of $W = aL^b$ was obtained.

The significance of variation between the regression co- efficients of both sexes was tested by subjecting to analysis of co-variance following Snedcor and Cochran (1967).

The estimates of regression co-efficient of males and females were tested for finding the significance of variation from the expected value of 3 by employing the 't' test using the formula -

$t = \frac{b - \beta}{S_b}$ where β is equal to 3.

The 95% confidence limits of 'b' was calculated using the formula

$$S_b \times t(n-2).$$

RESULTS

S. tumbil

A total of 959 males (total length ranging from 150 to 273 mm and weight from 25.8 to 350 g), 1558 females (length range from 150 to 480 mm and weight from 23.4 to 1050 g) and 302 juveniles (length range from 101 to 149 mm and weight from 5 to 30.6 g) was used for the study.

The length - weight relationships for these three categories separately and pooled are:

Males	$W = 0.00001635$	$L^{2.8618}$
Females	$W = 0.000006998$	$L^{3.0179}$
Juveniles	$W = 0.000000468$	$L^{3.5493}$
Pooled	$W = 0.000003432$	$L^{3.1421}$

The same in the logarithmic form is given as:

Males	$\text{Log } W = -4.7865 + 2.8618 \text{ Log}$	$L, (r = 0.9998)$
Females	$\text{Log } W = -5.1550 + 3.0179 \text{ Log}$	$L, (r = 0.9991)$
Juveniles	$\text{Log } W = -6.3294 + 3.5493 \text{ Log}$	$L, (r = 0.9945)$
Pooled	$\text{Log } W = -5.4645 + 3.1421 \text{ Log}$	$L, (r = 0.9984)$

Scatter diagrams of lengths against weights are presented separately for males, females and juveniles in Figs. 4.10, 4.11 and 4.12. The logarithmic form of relationships are shown in Figs. 4.13, 4.14 and 4.12.

Application of analysis of co-variance to the regression co- efficients of males and females showed that values of slope differed significantly at 5% level. But, the values of elevation did not show significant difference at 5% level. Hence, separate equations are required to express the relationship in this species (Table 4.21 and 4.22).

The values of 't' were calculated as for:

Males = -10.85

Females = 0.80

which did not show significant difference (at 5% level) from the expected value of 3 indicating weight-growth in the species is isometric.

The 95% confidence intervals for variation in the estimation of 'b' are for:

Males = 0.0250

Females = 0.0459, hence 'b' becomes for

Males = 2.8368, 2.8868

Females = 2.9720, 3.0638

S. undosquamis

The study in this species is based on 857 males ranging in length from 130 to 273 mm and weight from 11 to 141 g, 1584 females (length range from 130 to 316 mm and weight from 11 to 232 g) and 333 juveniles (length range from 72 to 129 mm and weight from 1.33 to 13.2 g).

The exponential form of relationship for these three groups separately and pooled are as follows:

Males $W = 0.000006533 \; L^{3.0125}$

Females $W = 0.000004282 \; L^{3.0926}$

Juveniles $W = 0.000000378 \; L^{3.5612}$

Pooled $W = 0.00000134 \; L^{3.3066}$

The straight line equations derived are:

Males $\text{Log } W = -5.1849 + 3.0125 \; \text{Log } L, (r = 0.9980)$

Females $\text{Log } W = -5.3684 + 3.0926 \; \text{Log } L, (r = 0.9995)$

Juveniles $\text{Log } W = -6.4220 + 3.5612 \; \text{Log } L, (r = 0.9994)$

Pooled $\text{Log } W = -5.8728 + 3.3066 \; \text{Log } L, (r = 0.9979)$

Scatter plots of length against corresponding weight (Figs. 4.15, 4.16 and 4.17) and logarithmic values of length against logarithmic values of weight (Figs. 4.18, 4.19 and 4.17) have been plotted separately for males, females and juveniles.

Analysis of co-variance (Table 4.23 and 4.24) showed that the regressions of the length-weight relationship of males and females were not significant at 5% level in slope and elevation. Hence, the data for both sexes were pooled and a common equation was fitted as given below:

$$W = 0.000004967\ L^{3.0647}$$

or

$$\text{Log } W = -5.3039 + 3.0647 \text{ Log } L$$

The 't' values estimated were for

Males = 0.2397

Females = 3.8934

and it was found insignificant for males, whereas, significant for females at 5% probability. When the 'b' value of common equation to both sexes was tested for 't', it was found significant at 1% level but insignificant at 5% level.

The 95% confidence limits of 'b' was calculated as for:

Males	= 0.1123 then 'b' can be	2.9803,	3.2049
Females	= 0.0506 then 'b' becomes	3.0420,	3.1432
Pooled	= 0.0511 then 'b' becomes	3.0136,	3.1158

S. isarankurai

For the purpose of length-weight relationship study in this species, a total of 1155 males in the length range of 75 to 134 mm and weight range of 1.4 to 12.1 g, 1806 females with length range from 75 to 140 mm and weight from 1.62 to 19.3 g and 280 juveniles varying in length from 63 to 74 mm and weight from 0.7 g to 2.6 g were utilised.

The exponential form of relationship computed for males, females and juveniles separately and pooled are:

Males	$W = 0.000003745$	$L^{3.0602}$
Females	$W = 0.000001714$	$L^{3.2232}$

Juveniles $W = 0.000000159 \quad L^{3.7868}$

Pooled $W = 0.000002061 \quad L^{3.1860}$

The logarithmic form of relationship corresponding to the above are:

Males $\text{Log } W = -5.4265 + 3.0602 \quad \text{Log } L, (r = 0.9964)$

Females $\text{Log } W = -5.7660 + 3.2232 \quad \text{Log } L, (r = 0.9988)$

Juveniles $\text{Log } W = -6.7979 + 3.7868 \quad \text{Log } L, (r = 0.9871)$

Pooled $\text{Log } W = -5.6860 + 3.1860 \quad \text{Log } L, (r = 0.9979)$

Scatter diagrams of exponential relationship of length against weight (Figs. 4.20, 4.21 and 4.22) and straight line relationship based on logarithms of length and logarithms of weight are shown separately for males, females and juveniles in Figs. 4.23, 4.24 and 4.22 respectively.

The regressions between the sexes showed significant difference at 5% and 1% level at both, slope and elevation. Hence separate length-weight equations for males and females would express the relationship adequately (Table 4.25 and 4.26).

The calculated values for 't' for the two sexes are:

Males = 1.6355

Females = 10.7040

It was found to be insignificant in males, whereas, significant in females at 5% and 1% level.

The 95% confidence limits of 'b' was computed as for:

Males = 0.074 then 'b' = 2.9862, 3.1342

Females = 0.042 then 'b' = 3.1812, 3.2652

DISCUSSION

The study of length-weight relationship in the three species of *Saurida* spp. shows an exponential relationship when lengths were plotted against weight. Similarly, logarithms of length plotted against logarithms of weight gave linear form of relationship. In the juveniles of all the three species, the regression co-efficients are well above the expected value of 3 and much higher than males and females of the respective species. This shows higher rate of weight increase in juveniles and the weight-growth at this stage follows the allometric pattern to certain extent.

In *S. tumbil*, the slope of the relationship between the two sexes showed significant difference at 5% and 1% level, whereas the value of elevation did not show difference at 5% and 1% level, therefore, a separate equation for males and females would explain the relationship better. Rao (1983a) while studying the length-weight relationship of *S. tumbil* in the size range of 140-450 mm, from the north-east coast of India, observed significant difference in slope of the relationship at 5% level but not at 1% level. However, in respect of elevation, it was significant both at 5% and 1% level. Tiews *et al.* (1972) have roughly fitted the length-weight relationship for both sexes of *S. tumbil* and found no difference between the sexes. Yeh *et al.* (1977) in their observation on the length-weight relationship of *S. tumbil* from East China Sea and the Gulf of Tonkin, have recorded no significant difference at 1% level between males and females in each region. However, with the pooled data they found significant difference at 1% level in the regression co-efficient and adjusted mean.

Rao (1983a) carried out 't' test to find out variation in the 'b' values from the expected value of 3 for males as well as females of *S. tumbil* and found significant difference at 5% and 1% level, whereas, in the present study, the 't' values have shown insignificant difference in both sexes at 5% and 1% level.

Testing the regressions of males and females of *S. undosquamis* from north-east coast of India, Rao (1983a) found no significance in slope and elevation and put forward a common equation for both the sexes. The present observations confirm his findings and a general equation for both the sexes has been formulated. Rao (1983a) observed the value of 't' in males, significant at 5% level but not at 1%, whereas, for females it was insignificant at 5% and 1% level. But the present results show variations from that of Rao's observations, as significant difference at 5% and 1% level is found in the case of females, and no significance in the case of males at 5% and 1% level.

In *S. isarankurai*, the smallest species among the three species studied, significant differences were found in slope and elevation of the relationship between the sexes, hence separate length-weight equation for the sexes was proposed. The 't' test in both the sexes gave similar results to those obtained for *S. undosquamis*, the 't' values showing significant difference at 5% and 1% level in females and no difference in males.

The length-weight relationship ($W = aL^b$) parameters of *Saurida* spp. available in the literature are given in Table 4.27. It can be seen that, in all cases, the regression co-efficient varies from 2.99 to 3.43 and in general, the females show higher values than males indicating that the former is heavier than the latter. The results of the present study on the length-weight relationship of three species of *Saurida* are in general agreement with the published results on the *Saurida* spp.

In conclusion, it can be said that, the correlation coefficients (r) in all cases were found to be highly significant. Since, the regression co-efficients were found to be significant between sexes of *S. tumbil* and *S. isarankurai* and insignificant in *S. undosquamis*, separate equations for sexes in the first two species and a common one in *S. undosquamis* would represent the relationships better. The regression co-efficients of both sexes in *S. tumbil* did not differ significantly from 3 indicating isometric growth. In case of *S. undosquamis* and *S. isarankurai* males obey isometric growth, whereas, females depart significantly from isometric growth.

Table 4.1: Monthwise length frequency distribution (estimated numbers) of *S. tumbil* in the Karnataka coast during 1989/90 - 1990/91

Length in mm	Nov. 1989	Dec. 1989	Jan. 1990	Feb. 1990	Mar. 1990	Apr. 1990	May 1990	Total 1989-90	Nov. 1990	Dec. 1990	Jan. 1991	Feb. 1991	Mar. 1991	Apr. 1991	May 1991	Total 1990-91	Grand Total 1989-91
40-59	-	771	-	266	-	-	-	1037	-	-	-	-	-	-	-	-	1037
60-79	-	-	2528	26612	8712	-	-	37852	-	49	-	-	-	-	-	49	37901
80-99	-	11562	7068	77000	17424	326	-	113380	-	3688	3181	-	-	-	-	6869	120249
100-119	-	9316	43686	28665	14172	652	-	96491	-	18642	11599	-	-	-	-	30241	126732
120-139	-	9250	129621	26087	8712	10532	-	184202	-	28990	57803	7575	320	-	-	94688	278890
140-159	-	7065	201588	124802	2208	8332	-	343995	-	12887	195749	26871	10740	5100	-	251347	595342
160-179	-	512	161111	231921	15658	21722	-	430924	-	10984	309634	28847	8375	32300	32	390172	821096
180-199	-	1027	87130	260207	62424	20922	11212	442922	-	2488	251008	44321	109868	14192	1575	423452	866374
200-219	898	833	9892	240775	330128	77272	22994	682792	2210	318	118062	260069	152773	22279	10524	566235	1249027
220-239	2246	1055	383	125256	443510	283537	63274	919261	11268	5825	22008	378235	298729	100359	23702	840126	1759387
240-259	5390	8739	747	18714	201182	478739	274976	988487	13771	31525	46319	185923	314076	190220	81676	863510	1851997
260-279	5839	4046	12309	9610	47656	229144	209408	518012	4849	65420	99797	51143	185980	210326	251745	869260	1387272
280-299	2695	5586	34228	32189	12735	119208	83715	290356	442	45767	189257	51473	90204	131354	211374	719871	1010227
300-319	1796	6489	22972	21269	12986	13877	54388	133777	442	13970	159148	93392	41322	69660	110151	488085	621862
320-339	449	225	19546	36156	4950	5907	47226	114459	526	4834	47232	125861	69797	37621	51239	337110	451569
340-359	-	158	13048	46821	20395	3482	6148	90052	221	2996	40155	40664	75813	48955	28531	237335	327387
360-379	-	-	612	15039	11225	4928	18535	50339	-	4105	118245	20004	33107	31598	15666	116305	166644
380-399	-	-	-	5902	18528	6435	24839	55704	-	1040	6415	20257	25799	31783	3991	89285	144989
400-419	-	-	2528	131	-	866	6748	10273	-	1354	344	2937	8867	4917	3318	21737	32010
420-439	-	-	-	425	819	-	6178	7422	-	86	3962	2628	1458	4307	-	12441	19863
440-459	-	-	-	425	-	-	-	425	-	1182	2387	-	2442	2152	191	8354	8779
460-479	-	-	-	-	-	433	-	433	-	-	-	-	1023	-	-	1023	1456
480-499	-	-	258	-	-	-	-	258	-	-	62	508	512	-	191	1273	1531
Total	19313	66634	749255	1328272	1233424	1286314	829641	5512853	33729	256150	1575947	1340708	1431205	937123	793906	6368768	11881621

Table 4.2: Length at age of *S. tumbil* as obtained by ELEFAN method

Age (Month)	1	2	3	4	5	6	7	8	9	10	11	12	13	114	15	16	17	18	19	20
Length (mm)	20	46	70	94	117	138	158	177	196	214	230	246	261	276	289	303	316	328	339	350
Age (Month)	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Length (mm)	361	371	380	389	397	406	414	421	428	435	442	448	454	460	465	470	475	479	484	488

TABLE 4.3 Mean lengths of cohorts of S.tumbil obtained by Bhattacharya method

Sample date	Mean lengths of cohorts found			
1989 NOV 15	258.868			
1989 DEC 15	124.721	198.269	253.426	291.198
1990 JAN 15	149.271	307.366		
1990 FEB 15	89.862	187.999	296.550	348.065
1990 MAR 15	98.904	231.251	353.588	
1990 APR 15	246.829	371.732		
1990 MAY 15	261.064	319.730	390.941	
1990 NOV 15	243.457	329.965		
1990 DEC 15	126.309	171.985	274.006	347.250
1991 JAN 15	172.746	290.037	347.359	
1991 FEB 15	160.687	231.235	318.295	
1991 MAR 15	158.177	262.302	337.826	381.622
1991 APR 15	173.335	248.267	205.879	
1991 MAY 15	228.063	291.312		

TABLE 4.4 Input data obtained from Bhattacharya analysis for S.tumbil for Gulland & Holt regression analysis

t1	Dates	t2		dt	L(t1)	L(t2)	mean-L	dL/dt
DEC 15	1989	MAR 15	1990	0.247	198.270	231.251	214.760	133.557
MAR 15	1990	APR 15	1990	0.085	231.251	246.829	239.040	183.351
APR 15	1990	MAY 15	1990	0.082	246.829	261.064	253.947	173.535
MAY 15	1990	NOV 15	1990	0.504	261.064	329.965	295.515	136.701
NOV 15	1990	DEC 15	1990	0.082	329.965	347.251	338.608	210.718
DEC 15	1990	JAN 15	1991	0.085	347.251	347.359	347.305	1.278
DEC 15	1989	MAR 15	1991	1.247	124.721	337.826	231.274	170.901
MAR 15	1990	MAY 15	1991	1.167	98.904	291.312	195.108	164.875

L8	586.7665		
Confidence interval	-23.06257	-	1196.596
K	.4556459		
Confidence interval	-.5746268	-	1.485919

TABLE 4.5 Data for estimation of L_∞ and Z/K for S.tumbil using the method of Wetherall

L(mean)-L'	L'	N (cumulative)	
200.400	39.500	11881621	
180.416	59.500	11880584	
160.962	79.500	11842683	
142.510	99.500	11722434	
123.959	119.500	11595702	
106.767	139.500	11316812	
92.140	159.500	10721470	
78.953	179.500	9900374	
65.565	199.500	9034000	
54.480	219.500	7784973	
47.468	239.500	6025586	
44.094	259.500	4173589	
41.069	279.500	2786317	
38.741	299.500	1776090	
34.226	319.500	1154228	
29.795	339.500	702659	***
27.064	359.500	375272	
20.694	379.500	208628	
25.058	399.500	63639	
20.297	419.500	31629	
17.680	439.500	11766	
20.251	459.500	2987	
10.000	479.500	1531	

*** regression line is fitted from this point
$Y = 76.66 + (-0.139) * X$, $r = -.888$

Estimate of Loo = 551.968 mm
Estimate of Z/K = 6.200

Table 4.6: Data for estimation of t_0 for *S. tumbil* by Gulland & Holt plot

L_t (mm)	$L_\infty - L_t$ (mm)	$\frac{L_\infty - L_t}{L_\infty}$	$\log_e \frac{L_\infty - L_t}{L_\infty}$ (Y)	t(year) (X)
70	505	0.8782	-0.1298	0.25
138	437	0.76	-0.2744	0.5
196	379	0.6591	-0.4168	0.75
246	329	0.5721	-0.5583	1.0
289	286	0.4974	-0.6983	1.25
328	247	0.4296	-0.8450	1.50
361	214	0.3722	-0.9883	1.75
389	186	0.3234	-1.1286	2.0
414	140	0.2435	-1.4127	2.50
454	121	0.2104	-1.5586	2.75
470	105	0.1826	-1.7004	3.00
484	91	0.1582	-1.8435	3.25

Table 4.7 Monthwise length frequency distribution (estimated numbers) of *S. undosquamis* in the Karnataka coast during 1989/90 - 1990/91

Length in mm	Nov. 1989	Dec. 1989	Jan. 1990	Feb. 1990	Mar. 1990	Apr. 1990	May 1990	Total 1989-90	Nov. 1990	Dec. 1990	Jan. 1991	Feb. 1991	Mar. 1991	Apr. 1991	May 1991	Total 1990-91	Grand Total 1989-91
60-69	-	-	-	-	-	-	-	-	-	-	166	-	-	-	-	166	166
70-79	-	1497	10752	1285	-	-	-	13534	-	-	166	2193	221	-	-	2580	16114
80-89	-	17212	13487	28713	-	-	-	59412	-	-	6961	2193	-	-	-	9154	68566
90-99	-	12722	43294	49669	3767	-	-	109452	-	-	13921	2193	442	1407	2268	20231	129683
100-109	-	6735	85072	74742	5750	120	570	172989	-	-	34969	4387	-	7434	2268	49058	222047
110-119	-	2245	63376	92048	8924	205	-	166798	-	28	37171	10784	4577	18258	19936	90754	257552
120-129	-	2245	63471	101397	19224	4765	-	191102	-	-	41986	11324	5507	23288	40338	122443	313545
130-139	-	-	74257	160880	15173	6942	-	257252	-	-	28497	18477	12502	19740	51002	130218	387470
140-149	-	2372	48331	136901	27727	29718	-	245049	-	55	15665	25013	55224	26663	52864	175484	420533
150-159	-	13926	32598	119881	34952	45437	5707	252501	78	57	436	27825	81013	26112	95675	231196	483697
160-169	440	17683	16677	160069	54373	58314	14822	322378	320	206	872	38771	144694	40154	129721	354738	677116
170-179	440	53180	9378	80687	40118	71338	30684	285825	882	3672	1661	18830	173821	45624	216991	461481	747306
180-189	1320	72887	6405	94251	21312	59256	26979	282410	843	6634	26469	20784	180077	44590	320993	600390	882800
190-199	3080	76296	21467	31184	11207	44999	20505	208738	398	9293	58659	73445	129454	47393	343646	662288	871026
200-209	1320	71665	34020	10085	14578	14814	19460	165942	406	10867	118366	102134	104295	25870	239419	601357	767299
210-219	2640	50897	13041	10975	11602	4947	10635	104737	203	7398	76940	116603	126899	20082	152398	500523	605260
220-229	880	46906	13976	12194	8328	3112	5600	90996	812	8250	55654	99311	76577	8705	74170	323479	414475
230-239	1320	39726	14880	9156	6243	573	3325	75223	-	2866	116296	113166	47816	3689	37601	321432	396655
240-249	880	26216	14129	18344	4759	205	1140	65673	-	3364	79946	141801	64864	470	25227	315672	381345
250-259	-	9811	8136	23795	3569	-	570	45881	-	1419	32034	136159	87727	1543	18613	277495	323376
260-269	-	3282	2866	9460	5650	-	-	21258	-	1073	20847	65545	30431	2480	2268	122644	143902
270-279	-	1037	1427	9006	1783	-	570	13823	-	1853	12329	56007	44628	470	-	115287	129110
280-289	-	693	716	2979	-	-	-	4388	-	320	11540	41844	17492	607	-	71803	76191
290-299	-	-	762	454	-	-	-	1216	-	291	19626	15344	31291	-	10866	77418	78634
300-309	-	-	-	-	-	-	-	-	-	1741	7968	25424	7824	-	-	42957	42957
310-319	-	-	-	-	-	-	-	-	-	-	1845	-	-	-	-	1845	1845
320-329	-	-	-	-	-	-	-	-	-	-	502	-	4131	-	-	4633	4633
330-339	-	-	-	-	-	-	-	-	-	-	166	-	-	-	-	166	166
340-349	-	-	-	-	-	-	-	-	-	-	-	-	221	-	-	221	221
Total	12320	529233	592518	1238155	299039	344745	140567	3156577	3942	59387	821658	1169557	1431728	364577	1836264	5687113	8843690

Table 4.8 Length at age of *S. undosquomis* as obtained by ELEFAN method

Age (Month)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Length (mm)	18	36	53	69	85	99	113	125	138	149	160	170	180	189	198	207	215	222	230	236	243	249	254	260	265	270	275	279	283	287
Age (Month)	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Length (mm)	291	295	298	301	304	307	310	313	315	317	320	322	324	326	327	329	331	332	334	335	336	338	339	340	341	342	343	344		

Table 4.9: Mean lengths of cohorts of *S. undosquamis* obtained by Bhattacharya method

Sample Date	Mean lengths (mm) of cohorts found						
1989 Nov. 15	193.263	234.656	-	-	-	-	-
1989 Dec. 15	100.072	161.059	212.109	219.954	-	-	-
1990 Jan. 15	106.562	138.8	202.081	235.828	278.911	-	-
1990 Feb. 15	122.358	139.343	170.874	194.212	225.973	250.736	269.841
1990 Mar. 15	127.143	164.845	190.734	-	-	-	-
1990 Apr. 15	130.858	180.796	215.751	-	-	-	-
1990 May 15	181.538	201.43	-	-	-	-	-
1990 Nov. 15	180.324	208.859	-	-	-	-	-
1990 Dec. 15	199.78	225.811	255.551	272.615	-	-	-
1991 Jan. 15	110.21	131.917	173.003	208.69	235.822	294.013	-
1991 Feb. 15	110.274	142.748	203.247	240.619	271.221	297.877	-
1991 Mar. 15	145.687	179.409	249.208	-	-	-	-
1991 Apr. 15	125.246	177.293	214.694	263.337	-	-	-
1991 May 15	188.72	191.07	-	-	-	-	-

TABLE 4.10 Input data obtained from Bhattacharya analysis for *S. undosquamis* for Gulland & Holt regression analysis

t1	Dates	t2		dt	L(t1)	L(t2)	mean-L	dL/dt
NOV 15	1989	FEB 15	1990	0.252	234.656	250.736	242.697	63.821
FEB 15	1990	FEB 15	1991	1.000	250.736	297.877	274.307	47.141
NOV 15	1989	FEB 15	1990	0.252	193.264	225.974	209.619	129.827
DEC 15	1989	NOV 15	1990	0.918	100.072	208.859	154.466	118.509

L8	356.0733		
Confidence interval	-91.83832	-	803.9848
K	.661441		
Confidence interval	-.6571076	-	1.97999

TABLE 4.11 Data for estimation of L_∞ and Z/K for *S. undosquamis* using the method of Wetherall

L(mean)-L'	L'	N (cumulative)	
127.601	59.500	8843688	
117.603	69.500	8843522	
107.809	79.500	8827408	
98.613	89.500	8758842	
90.020	99.500	8629159	
82.266	109.500	8407112	
74.708	119.500	8149560	
67.497	129.500	7836015	
60.748	139.500	7448545	
54.084	149.500	7028014	
47.712	159.500	6544317	
42.641	169.500	5867201	
38.135	179.500	5119895	
35.039	189.500	4237096	
32.812	199.500	3366070	
31.023	209.500	2598772	
28.924	219.500	1993512	
25.204	229.500	1579037	
21.982	239.500	1182380	***
20.066	249.500	801035	
20.266	259.500	477659	
16.848	269.500	333757	
14.322	279.500	204647	
9.851	289.500	128456	
7.508	299.500	49822	
13.198	309.500	6865	
6.211	319.500	5020	
10.711	329.500	387	
5.000	339.500	221	

*** regression line is fitted from this point

Y = 70.56 + (-0.201)*X , r= -.951

Estimate of Loo = 350.629 mm

Estimate of Z/K = 3.969

Table 4.12: Data for estimation of t_o for *S. undosquamis* by Gulland and Holt plot

L_t (mm)	$L_\infty - L_t$ (mm)	$\frac{L_\infty - L_t}{L_\infty}$	$\text{Log}_e \frac{L_\infty - L_t}{L_\infty}$ (Y)	t (X) (year)
53	307	0.8527	-0.1593	0.25
99	261	0.725	-0.3215	0.5
138	222	0.6166	-0.4835	0.75
170	190	0.5278	-0.6390	1.00
198	162	0.45	-0.7985	1.25
222	138	0.3833	-0.9589	1.50
243	117	0.325	-1.1239	1.75
260	100	0.2777	-1.2812	2.00
275	85	0.2361	-1.4435	2.25
287	73	0.2028	-1.5955	2.50
298	62	0.1722	-1.7591	2.75
307	53	0.1472	-1.9159	3.00
315	45	0.125	-2.0794	3.25
322	38	0.1055	-2.2490	3.50
327	33	0.0916	-2.3903	3.75
332	28	0.0777	-2.5549	4.00
336	24	0.0666	-2.7090	4.25
340	20	0.0555	-2.8913	4.50
343	17	0.0472	-3.0528	4.75

Table 4.13 Monthwise length frequency distribution (estimated numbers) of *S. isarankurai* in the Karnataka waters during 1989/90 - 1990/91

Length in mm	Nov. 1989	Dec. 1989	Jan. 1990	Feb. 1991	Mar. 1991	Apr. 1991	May 1991	Total 1989-90	Nov. 1990	Dec. 1990	Jan. 1990	Feb. 1990	Mar. 1990	Apr. 1990	May 1990	Total 1990-91	Grand Total 1989-91
34-37		-	-	-	-	-	-	-	-	-	-	-	49206	8195	-	57401	57401
38-41		5914	-	1102	1240	-	-	8256	-	-	-	-	-	-	-	-	8256
42-45		-	-	44291	-	-	-	44291	-	-	6300	-	-	-	-	6300	50591
46-49		-	-	12715	1240	267118	-	281073	-	-	20013	5112	36268	-	30093	91486	372559
50-53		5914	-	4408	2480	308431	-	321233	-	49	38912	10224	20139	-	30093	99417	420650
54-57		5914	-	9960	179406	340122	-	535402	-	-	134519	15336	20139	-	30093	200087	735489
58-61		23657	-	87627	412926	594792	-	1119002	-	2491	157489	46007	20139	39015	120371	385512	1504514
62-65		5914	-	81338	312907	677416	13344	1090919	-	-	160295	46006	34541	59744	319551	620137	1711056
66-69		23658	-	92222	405644	993162	26688	1541374	-	-	182124	122105	123206	114335	699287	1241057	2782431
70-73		11828	287240	96266	1177229	712505	13344	2298412	-	-	206218	194359	70809	158427	979164	1608977	3907389
74-77		-	-	174119	1013309	625912	13344	1826684	-	-	150184	241510	364701	418294	865946	2040635	3867319
78-81		-	37296	285346	1314158	794559	26687	2458046	-	-	86838	276458	796641	863270	737477	2760684	5218730
82-85		-	180916	305974	1703840	1239376	66718	3496824	-	49	80532	275514	1716488	1353274	1046502	4472359	7969183
86-89		11828	37296	587608	1134908	991501	93405	2856546	-	245	28828	229491	2737841	1544074	582697	5123176	7979722
90-93		5914	37296	708837	1668014	1290879	40031	3750971	-	2450	24056	176524	2351219	1613087	1085639	5253065	9004036
94-97		11829	-	669389	1997833	1640052	66718	4385821	487	124476	21353	159573	1269995	1450528	1192112	4218524	8604345
98-101		5914	-	374864	1188706	1405195	80062	3054741	1459	493988	27688	95811	761837	463676	945161	2789620	5844361
102-105		11829	-	136149	1723684	649592	66718	2587972	2627	1064658	150659	180631	346463	264421	701584	2711043	5299015
106-109		53229	574480	215269	651117	267638	13344	1775077	973	2218646	288301	538876	834745	286294	458007	4625842	6400919
110-113		76889	218213	131459	416488	102388	40031	985466	681	3148036	377689	807286	1124475	222150	255992	5936309	6921775
114-117		65058	74592	91161	49152	82626	-	362589	486	2912600	349583	745340	737534	188288	61131	4994962	5357551
118-121		47315	287240	114358	175687	25467	-	650107	195	2055296	248298	499937	597588	90764	24830	3516908	4167015
122-125		41401	-	65106	95825	25467	-	227799	97	1024214	205556	251287	550281	40919	6208	2078562	2306361
126-129		11829	-	11801	1240	25467	-	50337	-	265033	62753	137897	291783	6105	6208	769779	820116
130-133		-	-	551	-	-	-	551	-	33402	20555	93870	99876	11044	-	258747	259298
134-139		-	-	-	-	-	-	-	-	11085	5632	5924	46015	16797	-	85453	85453
138-141		-	-	-	-	-	-	-	-	-	1368	-	-	8602	-	9970	9970
Total		425832	1734569	4301960	15627033	13059665	560434	35709493	7005	13356808	3035743	5155078	15001930	9221303	10178146	55956012	91665505

Table 4.14: Length at age of *S. isarankurai* as obtained by ELEFAN method

Age (Month)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Length (mm)	11	28	44	57	69	80	88	97	104	110	116	121	125	129	133	135	138

Table 4.15: Mean lengths of cohorts of *S. isarankurai* obtained by Bhattacharya method

Sample date	Mean lengths (mm) of cohorts found			
1989 Dec. 15	57.00	95.00	115.095	-
1990 Jan. 15	49.229	83.000	72.279	-
1990 Feb. 15	82.898	93.177	-	-
1990 Mar. 15	81.453	95.127	119.254	-
1990 Apr. 15	62.213	88.15	77.819	-
1990 May 15	59.847	85.613	98.93	-
1990 Nov. 15	80.012	102.387	107.271	-
1990 Dec. 15	113.029	-	-	-
1991 Jan. 15	67.069	112.658	126.151	-
1991 Feb. 15	81.112	114.657	-	-
1991 Mar. 15	67.786	87.7	110.95	124.545
1991 Apr. 15	73.04	88.037	112.634	135.028
1991 May 15	73.502	84.651	108.544	-

TABLE 4.16 Input data obtained from Bhattacharya analysis for <u>S.isarankurai</u> for Gulland & Holt plot regression analysis

t1	Dates	t2		dt	L(t1)	L(t2)	mean-L	dL/dt
DEC 15	1989	MAR 15	1990	0.247	95.000	119.254	107.127	98.216
DEC 15	1989	MAY 15	1990	0.414	57.000	98.930	77.965	101.296
MAY 15	1990	JAN 15	1991	0.671	98.930	126.151	112.541	40.567
JAN 15	1991	APR 15	1991	0.247	126.151	135.028	130.590	35.946
JAN 15	1990	MAY 15	1990	0.329	49.229	85.613	67.421	110.598
MAY 15	1990	MAR 15	1991	0.833	85.613	124.545	105.079	46.737
JAN 15	1991	APR 15	1991	0.247	67.069	112.634	89.852	184.514

L8	155.8704		
Confidence interval	13.68403	-	298.0569
K	1.542683		
Confidence interval	-.6363062	-	3.721672

TABLE 4.17 Data for estimation of L_∞ and Z/K for *S. isarankurai* using the method of Wetherall

L(mean)-L'	L'	N (cumulative)	
60.421	33.000	9166550	
56.457	37.000	9160810	
52.462	41.000	9159984	
48.490	45.000	9154925	
44.680	49.000	9117669	
40.878	53.000	9075604	
37.195	57.000	9002055	
33.794	61.000	8851604	
30.420	65.000	8680498	
27.361	69.000	8402255	
24.598	73.000	8011516	
21.745	77.000	7624784	
19.195	81.000	7102911	
17.368	85.000	6305993	
15.595	89.000	5508021	
14.251	93.000	4607618	
13.065	97.000	3747183	
11.109	101.000	3162747	
8.943	105.000	2632846	
7.173	109.000	1992754	
5.926	113.000	1300577	
4.676	117.000	764821	
3.879	121.000	348120	***
3.567	125.000	117484	
3.188	129.000	35472	
2.418	133.000	9542	
2.000	137.000	997	

*** regression line is fitted from this point
Y = 15.47 + (-0.096)*X , r= -.978

Estimate of Loo = 161.710 mm
Estimate of Z/K = 9.456

Table 4.19: Estimation of growth parameters of *Saurida* spp. in the Karnataka waters and those available in the literature

Species	Sex	L ∞ cm	K/Year	ϕ'	Region	Reference
S. tumbil	-	43.60	0.43	2.91	Manila Bay, East China Sea	Pauly (1978) based on Tiews *et al.* (1972)
	-	37.5	1.03	3.16	Manila Bay, Philippines	Ingles and Pauly (1984)
	-	41.0	0.70	3.07	Visayan Sea, Philippines	"
	M	68.70	0.12	2.75	East China Sea, Taiwan	Yeh *et al.* (1977)
	F	74.20	0.10	2.74	"	"
	M	78.30	0.08	2.69	Gulf of Tonkin, Vietnam	"
	F	79.50	0.10	2.80	"	"
	-	63.70	0.25	3.00	North east coast of India	Rao (1984)
	-	60.00	0.51	3.26	North west coast of India	Chakraborty *et al.* (MS)
	-	57.50	0.57	3.27	Mid-west coast of India	Present study
S. undosquamis	-	37.90	0.89	3.11	Inner Gulf of Thailand	Pauly (1978), based on Kuhlmorgen - Hille (1970)
	-	41.30	1.13	3.28	Gulf of Thailand, off Prachuap - Khirikhan	"
	-	31.50	0.70	2.84	Mediteranean, Israel coast	Pauly (1978), based on Ben Yami and Glaser (1974)
	M	31.00	1.89	3.26	Upper part of the Gulf, Thailand	Boonwanich and Amornchairojkul (1982)
	F	36.00	1.64	3.33	"	"
	M	32.50	1.60	3.23	Inner Gulf of Thailand	Sommani (1989)
	F	42.30	1.02	3.26	"	"
	M	31.80	1.62	3.21	Gulf of Thailand	Sommani (1989)
	F	43.00	0.96	3.25	"	"
	M	30.30	2.34	3.33	Upper part of the Gulf Thailand	Siripakhavanich (1990)
	F	35.20	2.13	3.42	"	"
	-	40.60	0.60	3.00	Southern Gulf of Thailand	Boonwanich (1991)
	M	36.00	0.25	2.51	Gulf of Aden	Sanders *et al.* (1984)
	F	37.00	0.39	2.72	"	"
	-	42.10	0.51	2.96	North west coast of India	Chakraborty *et al.* (MS)
	-	36.00	0.64	2.92	Mid-west coast of India	Present study
	-	30.5	0.80	2.87	Visayan Sea, Philippines	Ingles and Pauly (1984)
S. elongata	M	37.70	1.24	3.25	Upper part of the Gulf, Thailand	Boonwanich and Amornchairojkul (1982)
	F	41.60	1.19	3.31	"	"
S. isarankurai	-	15.8	1.52	2.58	Mid-west coast of India	Present study

Table 4.20: Estimates of growth parameters by different methods of *Saurida* spp. in the Karnataka waters

Method	Wetherall plot	ELEFAN			Bhattacharya analysis - Gulland & Holt plot		
Growth parameters/species	L_∞ (cm)	L_∞ (cm)	K/Year	ϕ'	L_∞ (cm)	K/Year	ϕ'
S. tumbil	55.20	57.5	0.57	3.27	58.7	0.46	3.20
S. undosquamis	35.5	36.0	0.64	2.92	35.6	0.66	2.92
S. isarankurai	16.2	15.8	1.52	2.58	15.6	1.54	2.57

Table 4.21: Statistics of the length - weight relationship of juveniles, males and females of *S. tumbil*

Group	N	ΣX	ΣY	ΣXY	ΣX^2	ΣY^2	b	a	r
Males	19	45.159014	38.294177	91.570558	107.526851	78.765342	2.861842	-4.786514	0.999834
Females	33	81.697440	76.441680	191.255122	202.922730	183.147087	3.017940	-5.155039	0.999139
	8	16.259602	7.074058	14.612256	33.112926	7.097073	3.549263	-6.329443	0.994531

N = Number of observations, ΣX, ΣY = Sum of logarithmic values of length and weight respectively, ΣX^2, ΣY^2, ΣXY = Sum of squares and products
b = Regression co-efficient, a = Intercept, r = Correlation co-efficient

Table 4.22: Comparison of regression lines of length-weight relationship of males and females of *S. tumbil*

	d.f.	Σx^2	Σxy	Σy^2	Regression co-efficient (b)	Deviation from Regression		
						d.f.	S.S.	M.S.
Within Males	18	0.193349	0.553333	1.584079	2.861842	17	0.000531069	0.000031269
Females	32	0.666012	2.009984	6.076468	3.017940	31	0.010457657	0.000337344
						48	0.010988726	0.000228932
Pooled	50	0.859361	2.563317	7.660547	2.982817	49	0.014640283	0.000298781
			Difference between slopes			1	0.003651557	0.003651557
Between		0.117914	0.358825	1.091942	-	-	-	-
Total	51	0.977275	2.922142	8.752489	-	50	0.015013363	-
			Between adjusted means			1	0.00037308	0.00037308

Comparison of slopes : F = 15.95, d.f. 1, 48; Significant at 5% and 1% level
Comparison of elevation : F = 1.25, d.f. 1, 49; Not significant at 5% and 1% level
d.f = degrees of freedom; Σx^2, Σxy, Σy^2 = Corrected sum of squares and products;
S.S. = Sum of squares
M.S. = Mean square

Table 4.23: Statistics of the length - weight relationship of juveniles, males and females of *S. undosquamis*

Group	N	ΣX	ΣY	ΣXY	ΣX^2	ΣY^2	b	a	r
Males	15	34.496985	26.149601	60.543356	79.470414	46.810211	3.012533	-5.184913	0.998046
Females	19	44.410452	35.345512	83.330409	104.035544	67.963527	3.092627	-5.368392	0.999497
Juveniles	6	11.953718	4.037448	8.160089	23.847897	3.131617	3.561191	-6.422003	0.999416

N = Number of observations, ΣX, ΣY= Sum of logarithmic values of length and weight respectively, ΣX^2, ΣY^2, ΣXY = Sum of squares and products
b = Regression co-efficient, a = Intercept, r = Correlation co-efficient

Table 4.24: Comparison of regression lines of length - weight relationship of males and females of *S. undosquamis*

	d.f.	Σx^2	Σxy	Σy^2	Regression co-efficient (b)	Deviation from Regression		
						d.f.	S.S.	M.S.
Within Males	14	0.134282	0.404530	1.223436	3.012533	13	0.004772881	0.000367145
Females	18	0.230899	0.714085	2.210621	3.092627	17	0.002220846	0.000130638
	-	-	-	-	-	30	0.006993727	0.000233124
Pooled	32	0.365181	1.118615	3.434057	3.063180	31	0.00753832	0.000243172
		Difference between slopes				1	0.000544593	0.000544593
Between	1	0.011847	0.036863	0.114713	-	-	-	-
Total	33	0.377028	1.155478	3.548770	-	32	0.007576508	-
		Between adjusted means				1	0.000038188	0.000038188

Comparison of slopes : F = 2.33, d.f. 1, 30; Not Significant at 5% and 1% level
Comparison of elevation : F = 0.16, d.f. 1, 31; Not significant at 5% and 1% level
d.f = degrees of freedom; Σx^2, Σxy, Σy^2 = Corrected sum of squares and products;
S.S. = Sum of squares, M.S. = Mean square

Table 4.25: Statistics of the length - weight relationship of juveniles, males and females of *S. isarankurai*

Group	N	ΣX	ΣY	ΣXY	ΣX^2	ΣY^2	b	a	r
Males	52	104.018800	36.137200	73.025203	208.316285	27.387318	3.060163	-5.426486	0.996407
Females	60	120.829163	43.502511	88.682791	243.662117	35.019705	3.223249	-5.766000	0.998786
Juveniles	12	22.021654	1.817084	3.356446	40.418539	0.360047	3.786791	-6.79786	0.987122

N = Number of observations, ΣX, ΣY = Sum of logarithmic values of length and weight respectively

ΣX^2, ΣY^2, ΣXY = Sum of squares and products, b = Regression co-efficient

a = Intercept, r = Correlation co-efficient

Table 4.26: Comparison of regression line of length - weight relationship of males and females of *S. isarankurai*

	d.f.	Σx^2	Σxy	Σy^2	Regression co-efficient (b)	Deviation from Regression d.f.	S.S.	M.S.
Within Males	51	0.241078	0.737738	2.273910	3.060163	50	0.016311394	0.000326228
Females	59	0.334006	1.076591	3.478564	3.223249	58	0.008422202	0.00014521
	-	-	-	-	-	108	0.024733596	0.000229015
Pooled	110	0.575084	1.814329	5.752474	3.154894	109	0.028458517	0.000261087
	-	-	Difference between slopes			1	0.003724921	0.003724921
Between	1	0.005046	0.011283	0.025231	-	-	-	-
Total	111	0.580130	1.825612	5.777705	-	110	0.032683756	-
			Between adjusted means			1	0.004225239	0.004225239

Comparison of slopes : F = 16.26, d.f. 1, 108; Significant at 5% and 1% level

Comparison of elevation : F = 16.18, d.f. 1, 109; Significant at 5% and 1% level

d.f = degrees of freedom; Σx^2, Σxy, Σy^2 = Corrected sum of squares and products;

S.S. = Sum of squares, M.S. = Mean square

Table 4.27: Length - weight relationship ($W = {}_aL^b$) parameters of *Saurida* spp. in the Karnataka waters with those available in the literature

Species	Group	a	b	Type of length	Region of study	Reference
S. tumbil	Males	3.8019×10^{-6}	3.2271	FL	East China Sea	Yeh *et al.* (1977)
	Females	4.6903×10^{-6}	3.2024	FL	"	"
	Pooled	4.3053×10^{-6}	3.2124	FL	"	"
	Males	1.3219×10^{-6}	3.3426	FL	Gulf of Tonkin	"
	Females	6.0870×10^{-7}	3.4312	FL	"	"
	Pooled	8.4625×10^{-7}	3.3941	FL	"	"
		2.488×10^{-6}	3.2180	-	South-Fujian and Taiwan Bank	Xucai and Qiyong (1988)
		2.196×10^{-6}	3.2573	-	"	"
	Males	3.642×10^{-3}	3.2018	TL	North-east coast of India	Rao, (1983a)
	Females	2.614×10^{-3}	3.2957	TL	"	"
	Males	5.563×10^{-6}	3.1496	SL	North-west coast of India	Dighe (1977)
	Female	4.363×10^{-6}	3.1989	SL	"	"
	Males	1.6349×10^{-5}	2.8618	TL	Mid-west coast of India	Present study
	Females	6.9984×10^{-6}	3.0179	TL	"	"
	Juveniles	4.68×10^{-7}	3.5493	TL	"	"
	Pooled	3.432×10^{-6}	3.1426	TL	"	"

Contd...

Contd. 4.27

Species	Group	a	b	Type of Length	Region of study	Reference
S. undosquamis		0.010	3.03	FL	Gulf of Aden	Edwards *et al.* (1985)
	Males	5.4535×10^{-3}	3.1158	FL	Southern part of Taiwan strait	Lee *et al.* (1986)
	Females	5.3428×10^{-3}	3.1167	FL	"	"
		9.06×10^{-6}	2.99	FL	South Africa	Torres,1991
	Males	8.279×10^{-3}	2.991	TL	Gulf of Suez	Sanders *et al.* (1984)
	Females	6.793×10^{-3}	3.033	TL	"	"
	Pooled	5.343×10^{-3}	3.084	TL	"	"
	Males	5.128×10^{-3}	3.0753	TL	North-east coast of India	Rao, (1983a)
	Females	5.852×10^{-3}	3.0271	TL	"	"
	Males	6.533×10^{-6}	3.0125	TL	Mid-west coast of India	Present Study
	Females	4.282×10^{-6}	3.0926	TL	"	"
	Juveniles	3.78×10^{-7}	3.5612	TL	"	"
	Pooled	1.34×10^{-6}	3.3066	TL	"	"
S. isarankurai	Males	3.745×10^{-6}	3.0602	TL	"	"
	Females	1.714×10^{-6}	3.2232	TL	"	"
	Juveniles	1.59×10^{-7}	3.7868	TL	"	"
	Pooled	2.061×10^{-6}	3.1860	TL	"	"
S. wanieso	(Jan-Apr)	2.642×10^{-3}	3.372	FL	East China Sea	Hamada,(1986)
	(May-Jul)	4.058×10^{-3}	3.216	FL	"	"
	(Aug-Sep)	4.316×10^{-3}	3.232	FL	"	"

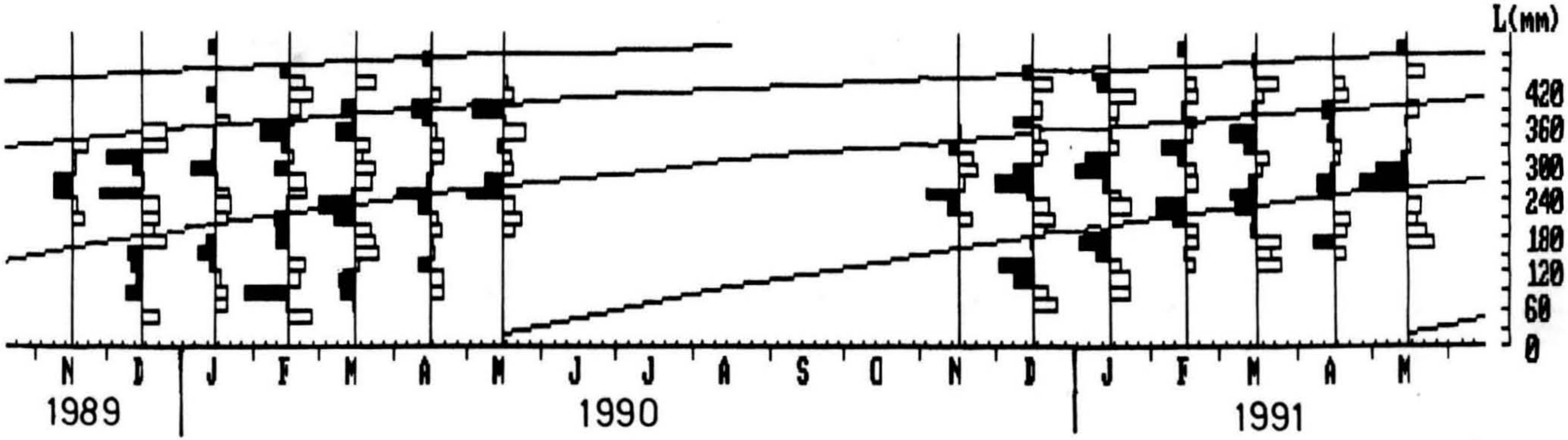

Fig. 4.1 Restructured length frequency distribution with superimposed growth curve of *S. tumbil* as estimated using the ELEFAN I programme.

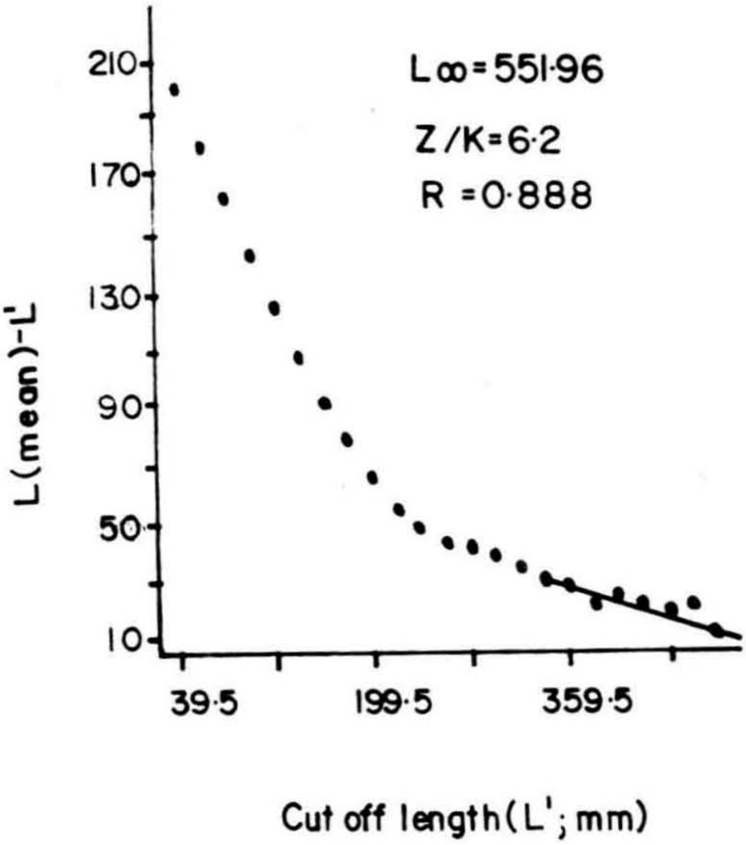

Fig. 4.2 Wetherall plot to estimate L_∞ and Z/K for *S. tumbil*.

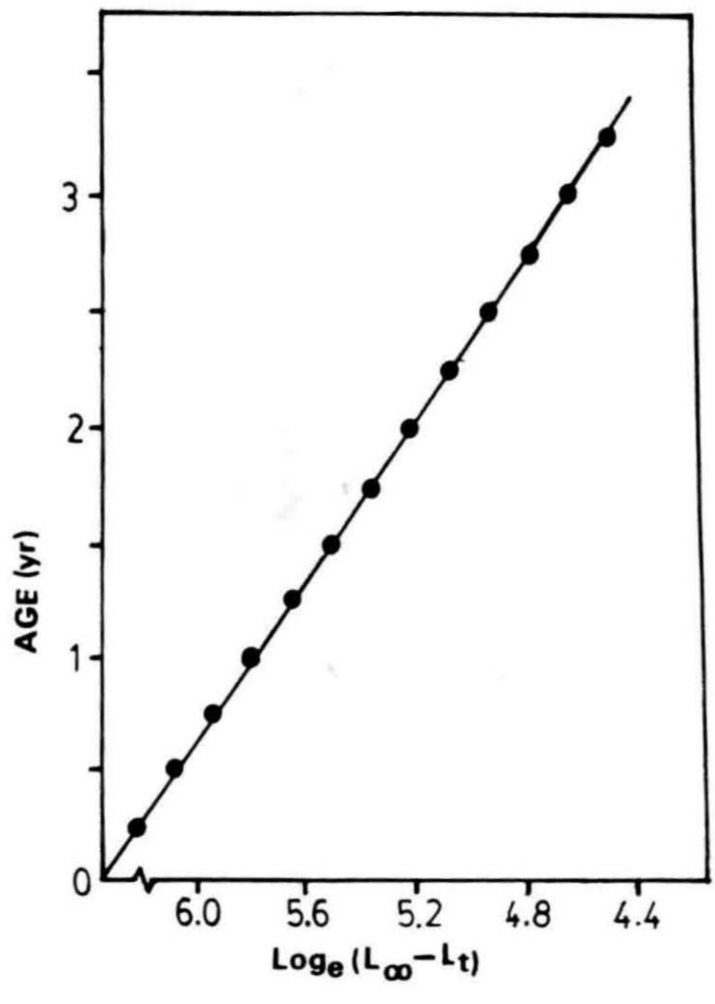

Fig. 4.3 $Log_e(L_\infty - L_t)$ plotted against age to determine t_0 for *S. tumbil*.

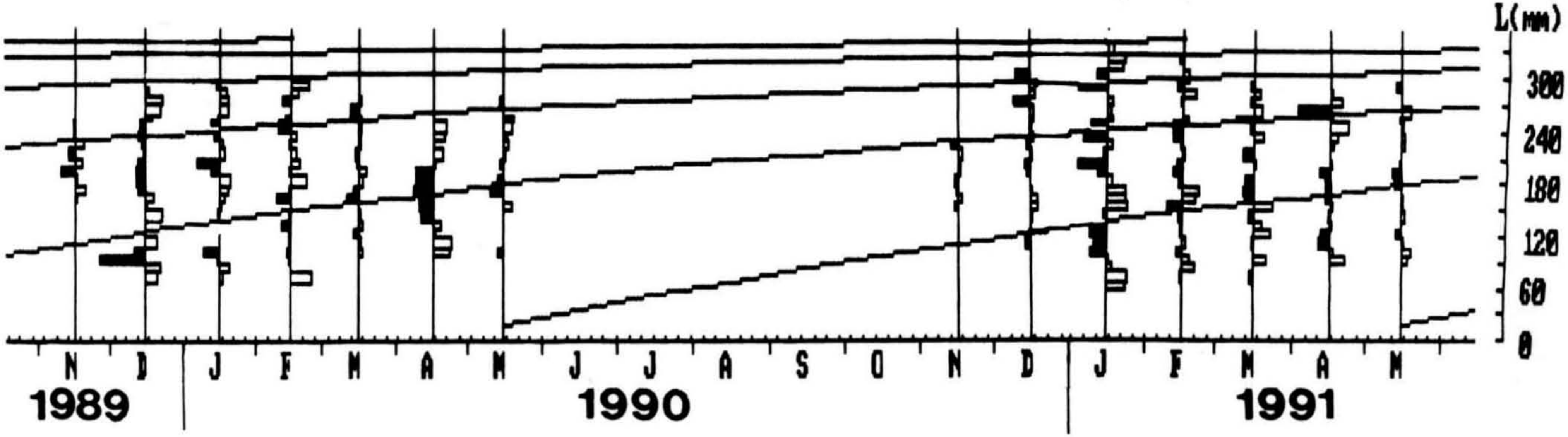

Fig. 4.4 Restructured length frequency distribution with superimposed growth curve of *S. undosquamis* as estimated using the ELEFAN I programme.

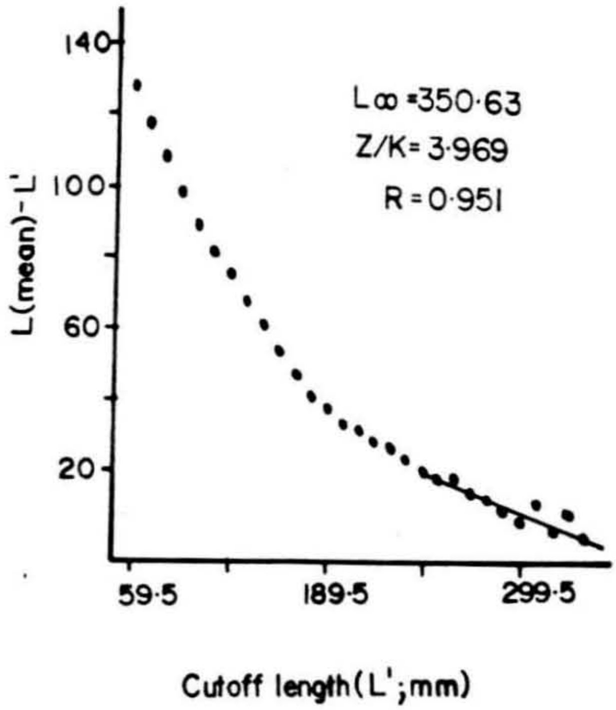

Fig. 4.5 Wetherall plot to estimate L_∞ and Z/K for *S. undosquamis*.

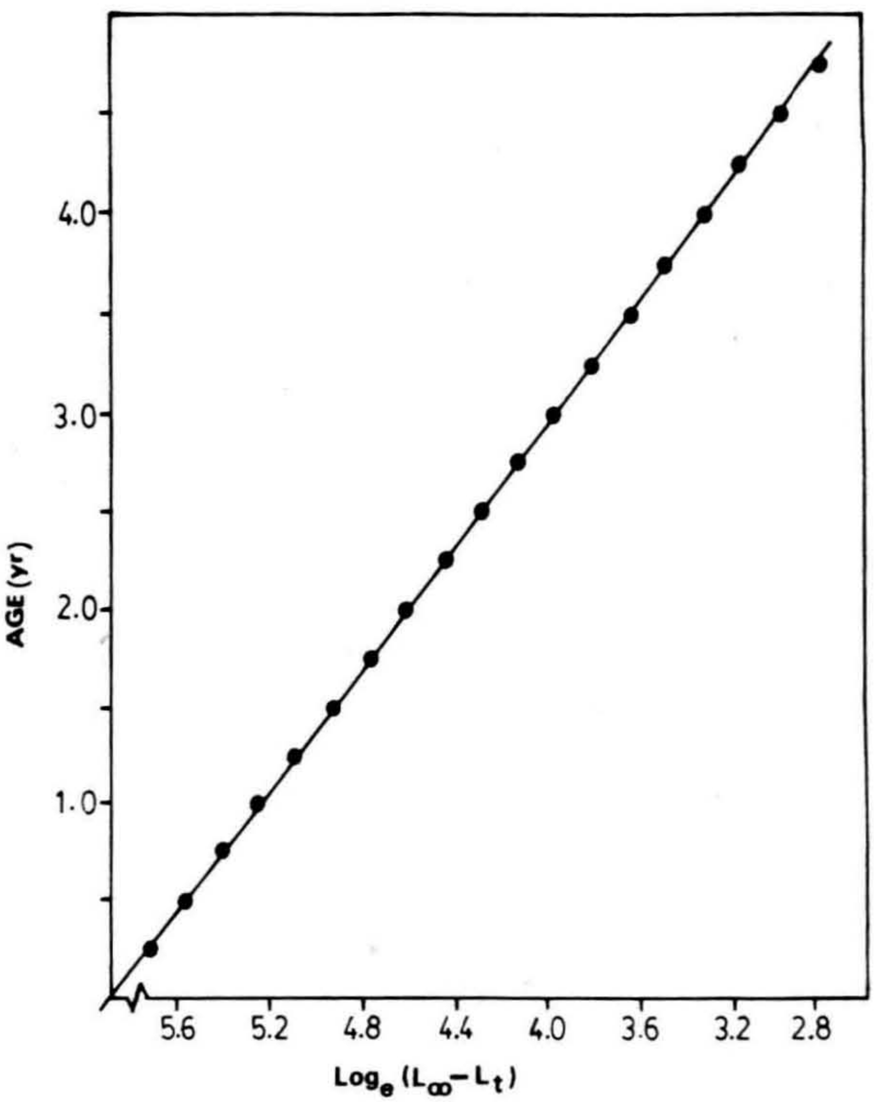

Fig. 4.6 Loge (L_∞-L_t) plotted against age to determine t_0 for *S. undosquamis*.

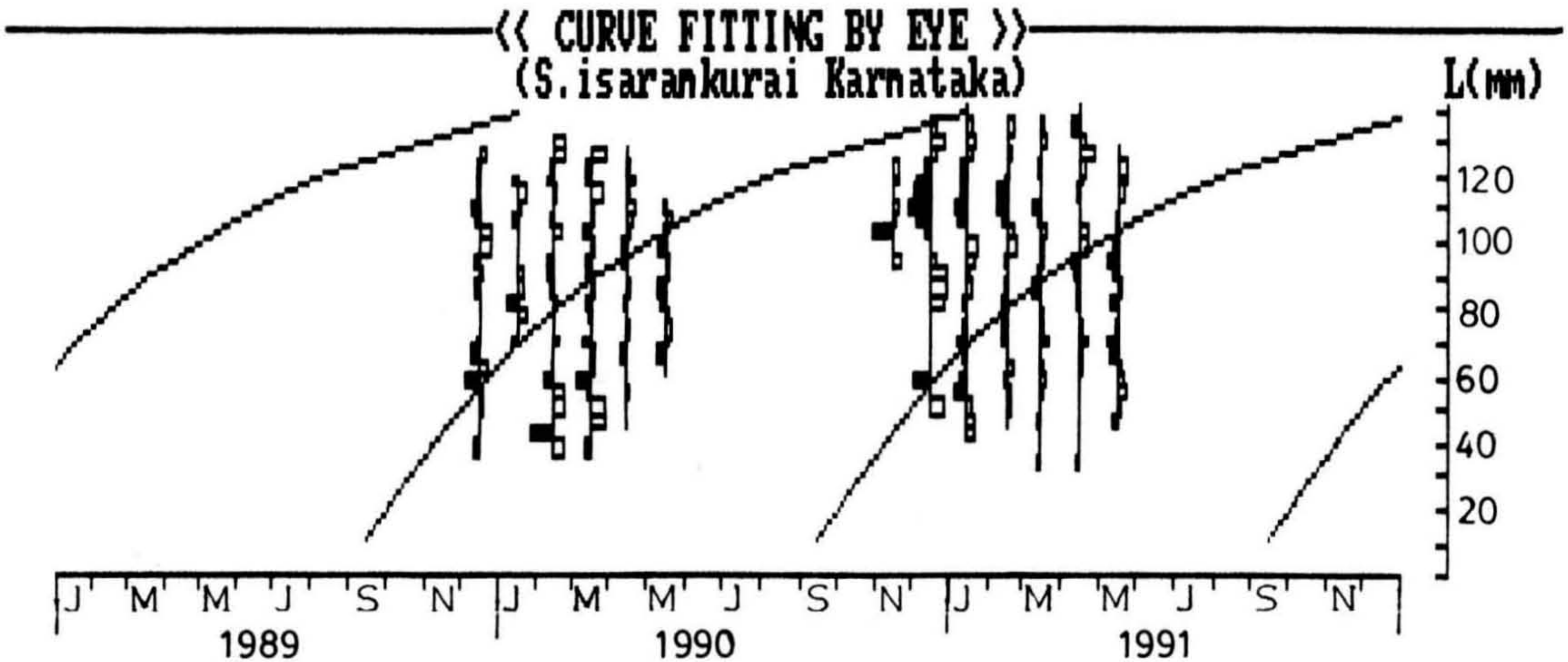

Fig. 4.7 Restructured length frequency distribution with superimposed growth curve of *S. isarankurai* as estimated using the ELEFAN I programme.

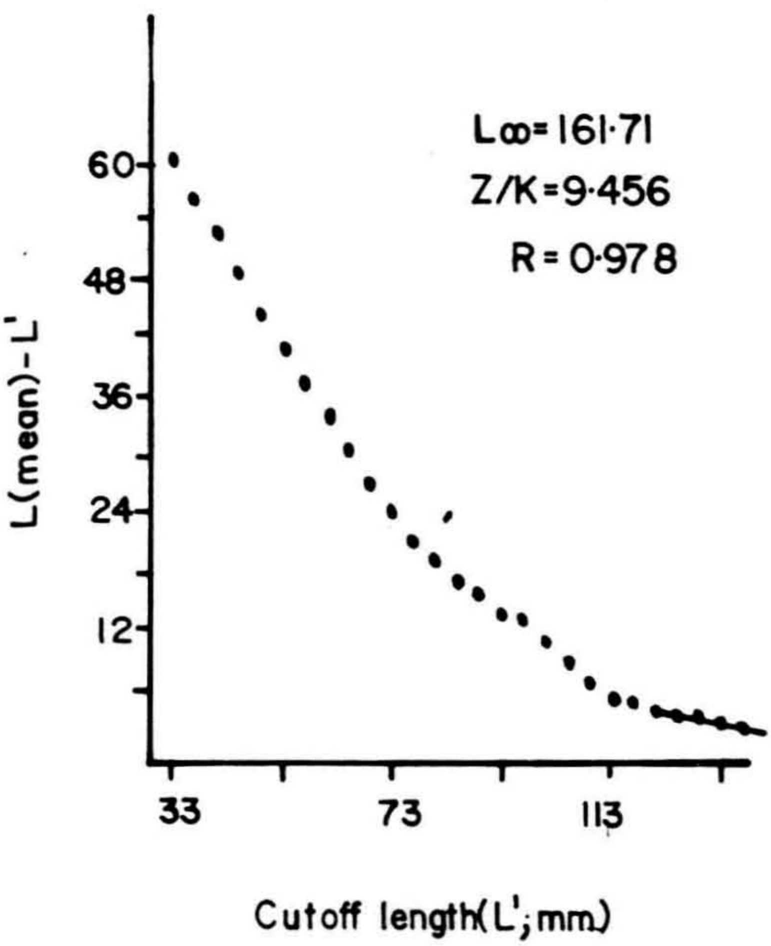

Fig. 4.8 Wetherall plot to estimate L_∞ and Z/K for *S. isarankurai.*

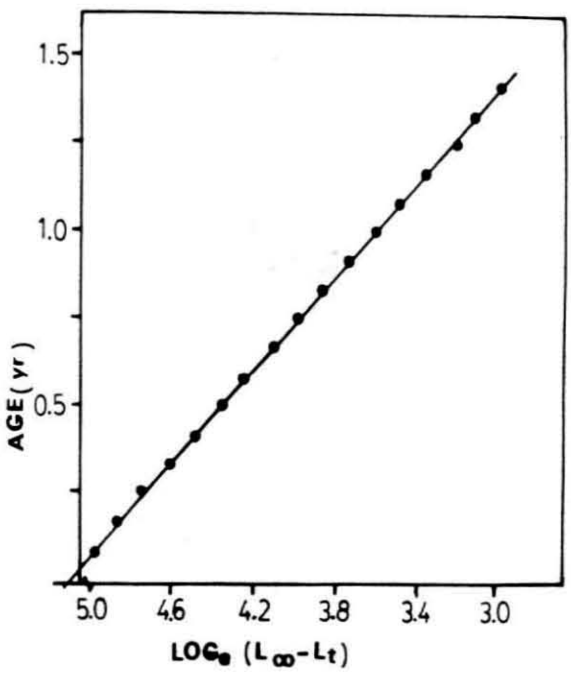

Fig. 4.9 $Log_e (L_\infty - L_t)$ plotted against age to determine t_0 for *S. isarankurai*.

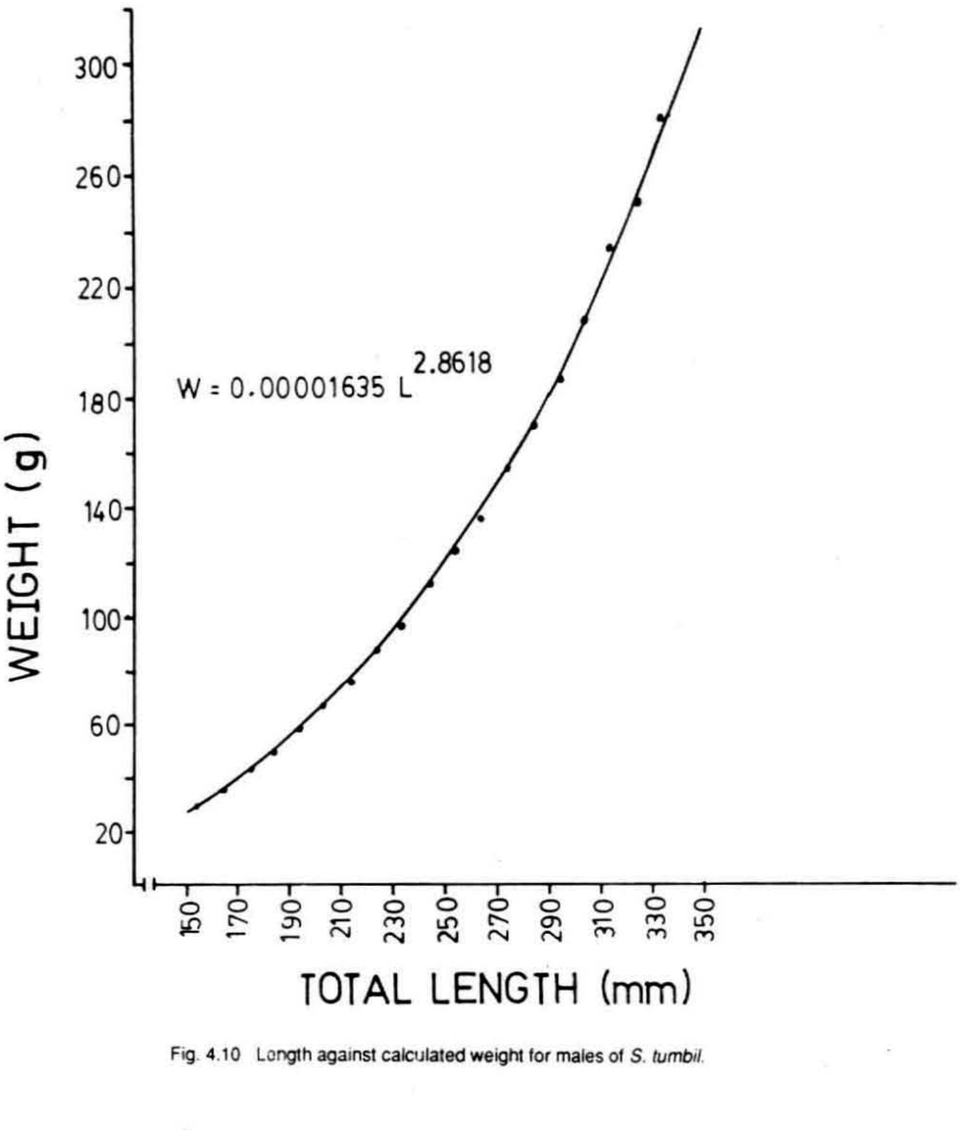

Fig. 4.10 Length against calculated weight for males of *S. tumbil*.

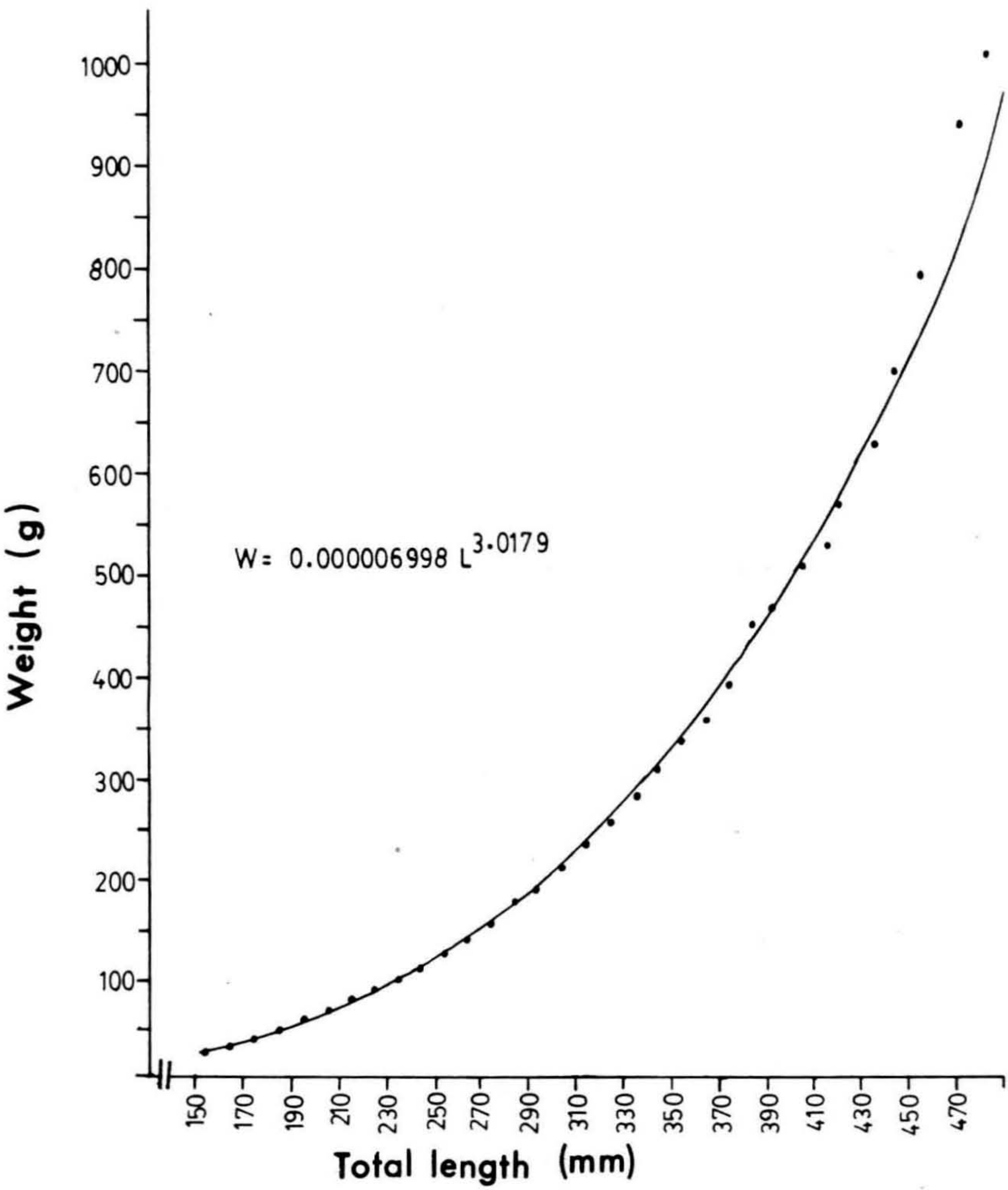

Fig. 4.11 Length against calculated weight for females of *S. tumbil.*

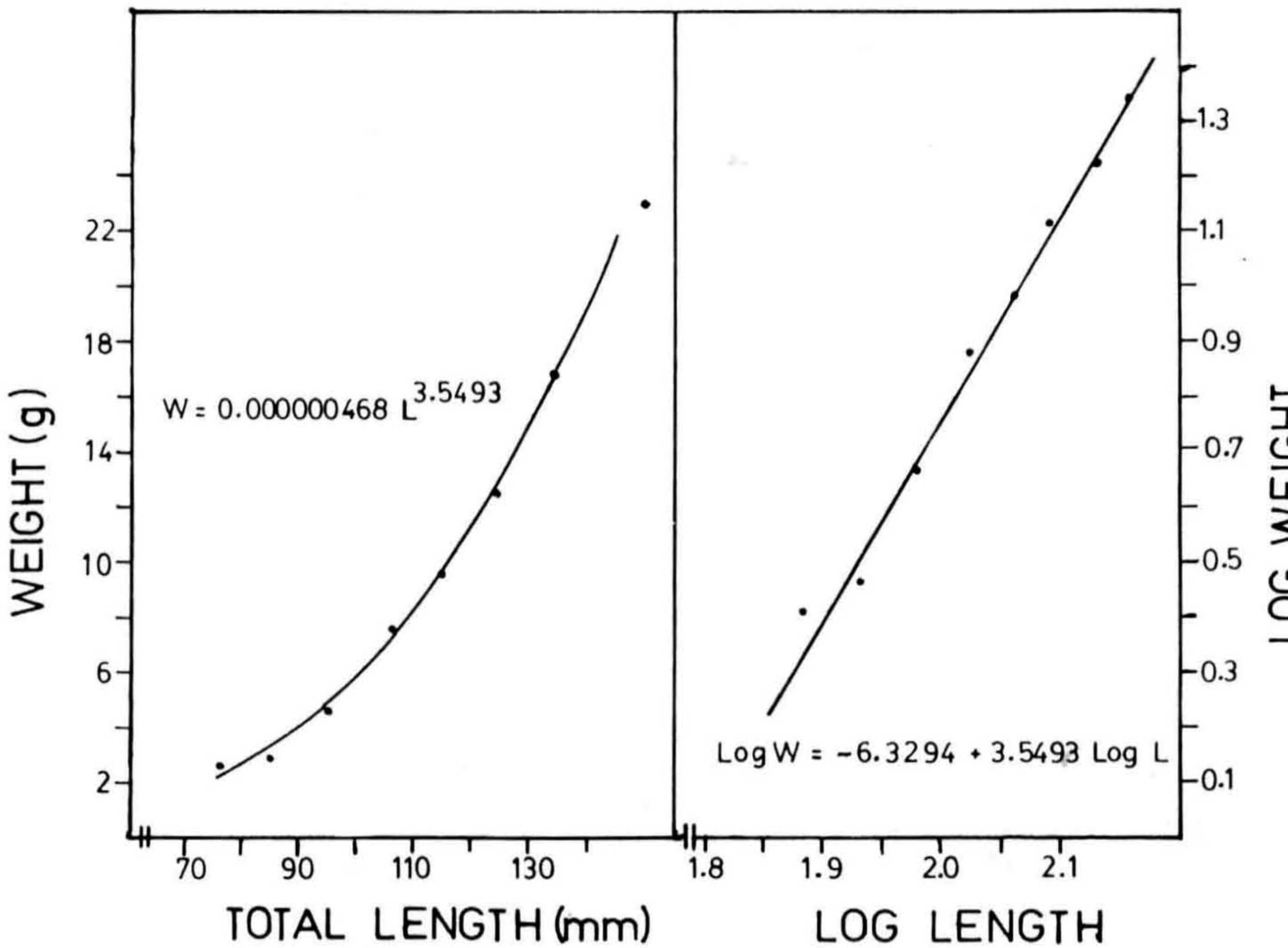

Fig. 4.12 **Length against calculated weight and logarithmic relationship between length and weight for juveniles of *S. tumbil*.**

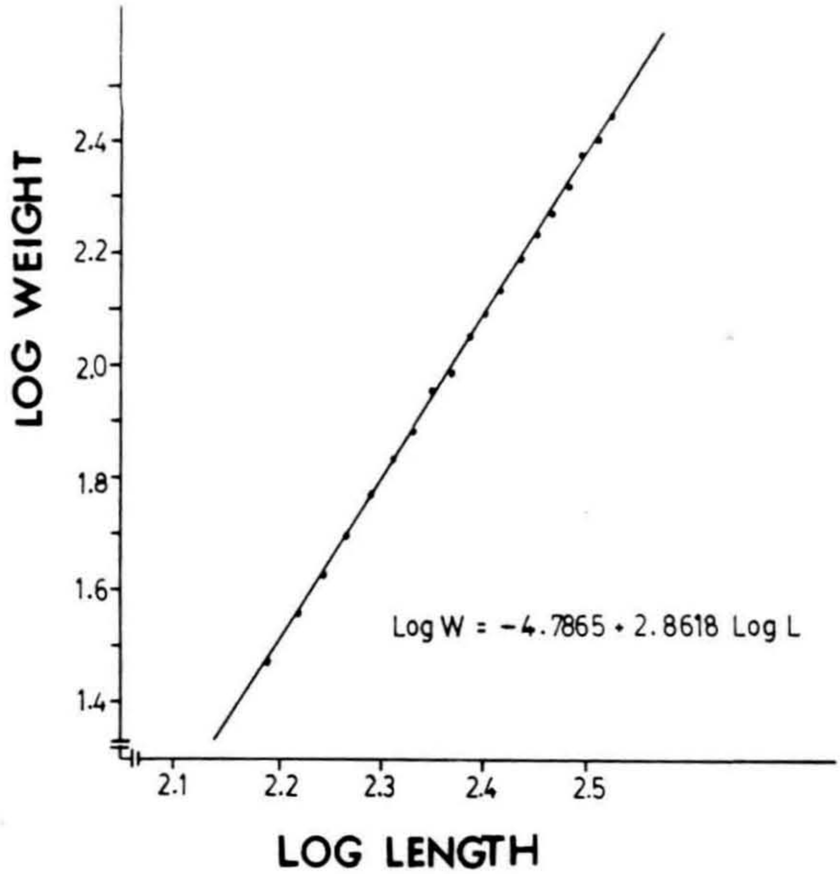

Fig. 4.13 Logarithmic relationship between length and weight for males of *S. tumbil.*

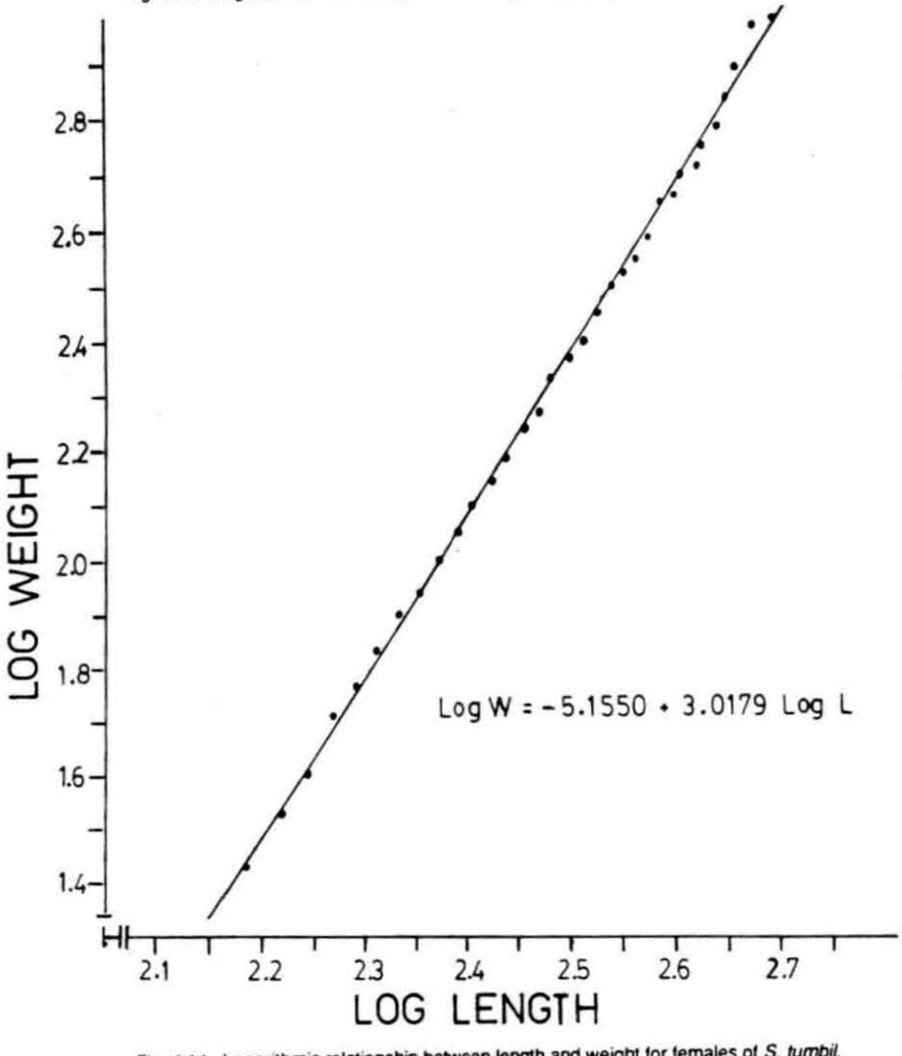

Fig. 4.14 Logarithmic relationship between length and weight for females of *S. tumbil.*

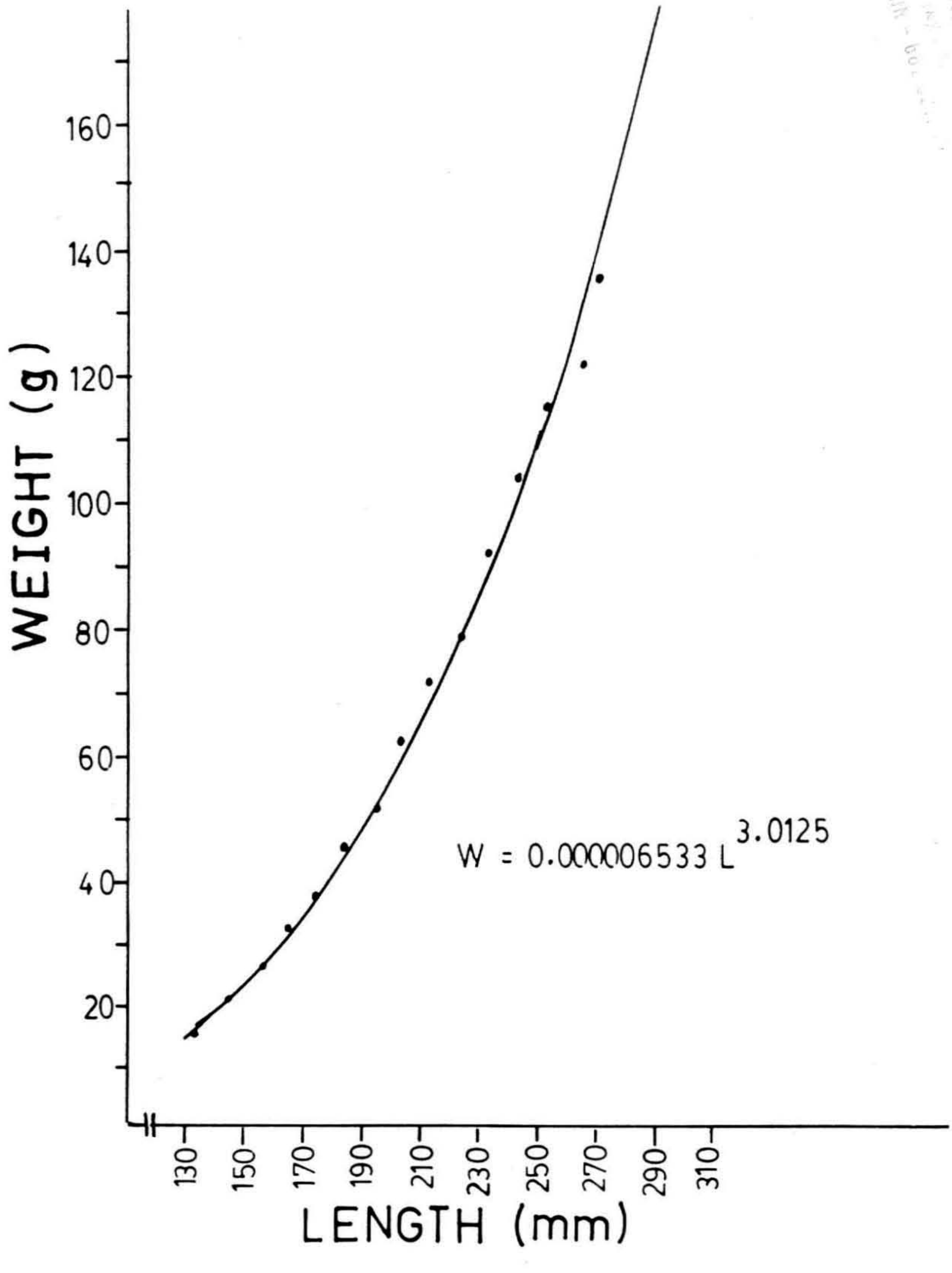

Fig. 4.15 Length against calculated weight for males of *S. undosquamis*.

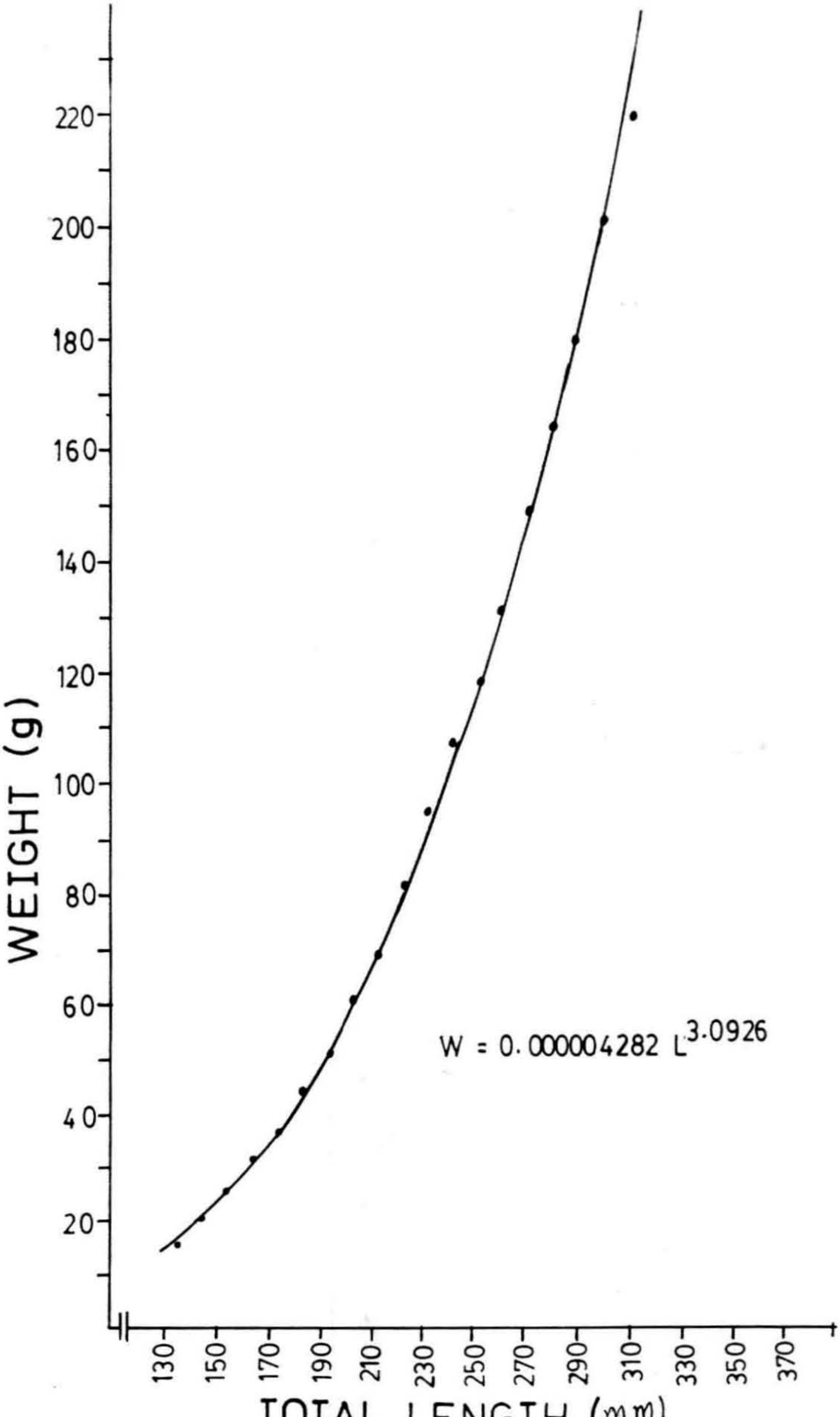

Fig. 4.16 Length against calculated weight for females of *S. undosquamis.*

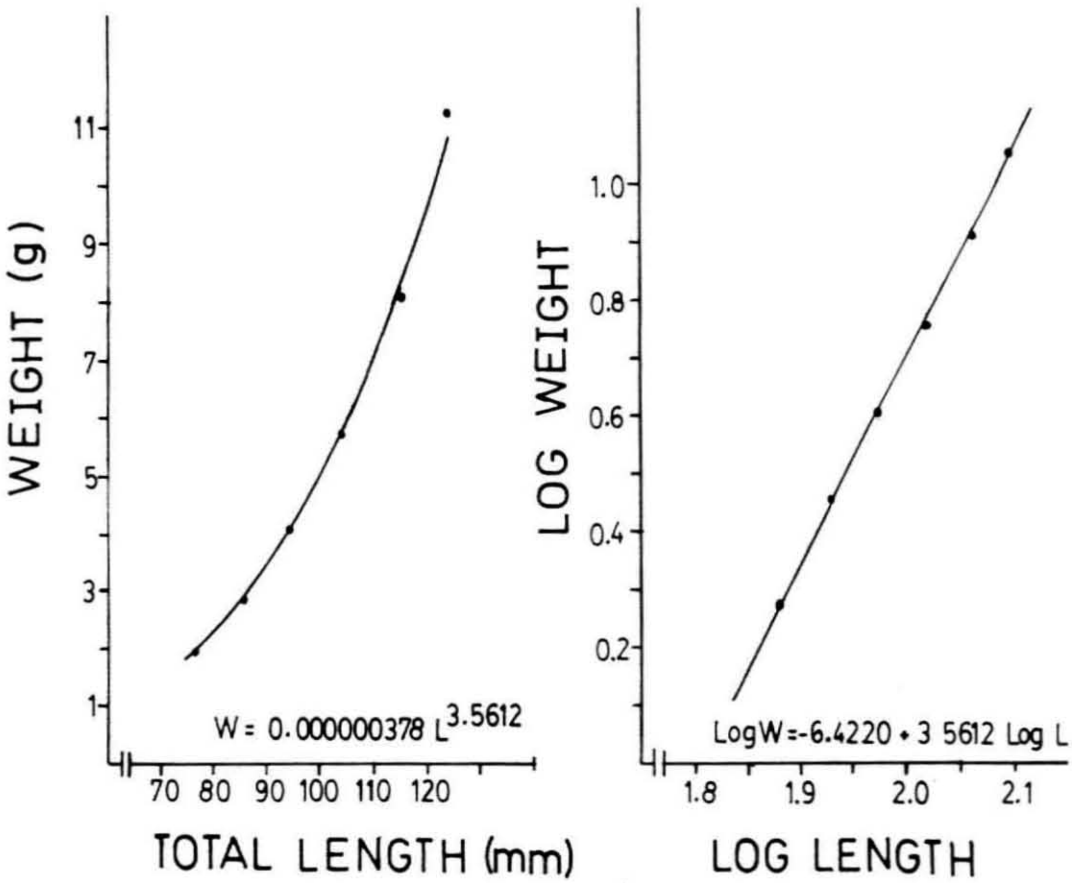

Fig. 4.17 Length against calculated weight and logarithmic relationship between length and weight for juveniles of *S. undosquamis*.

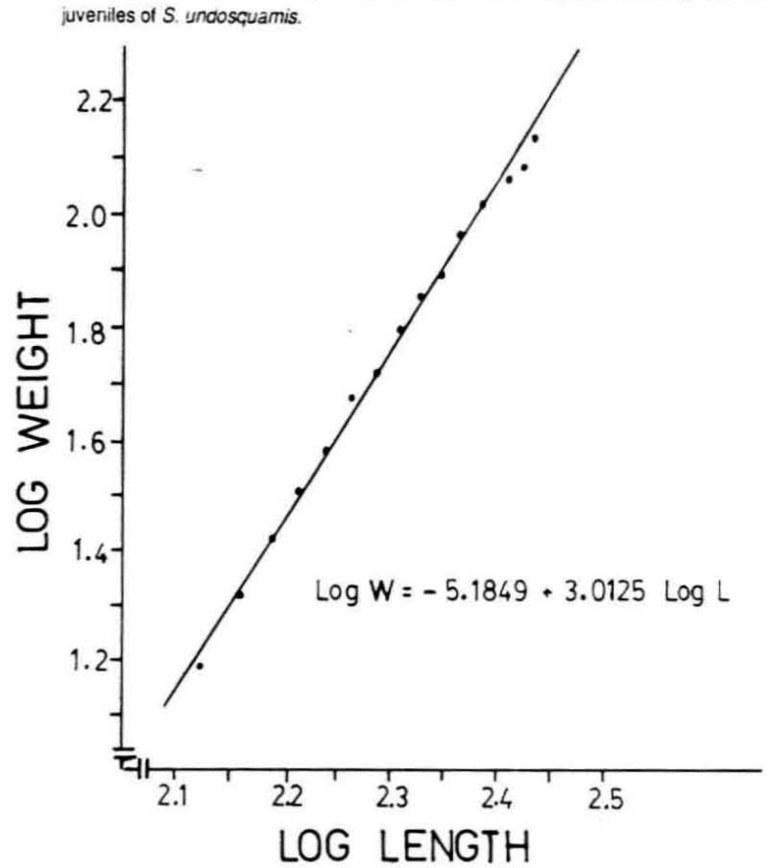

Fig. 4.18 Logarithmic relationship between length and weight for males of *S. undosquamis*.

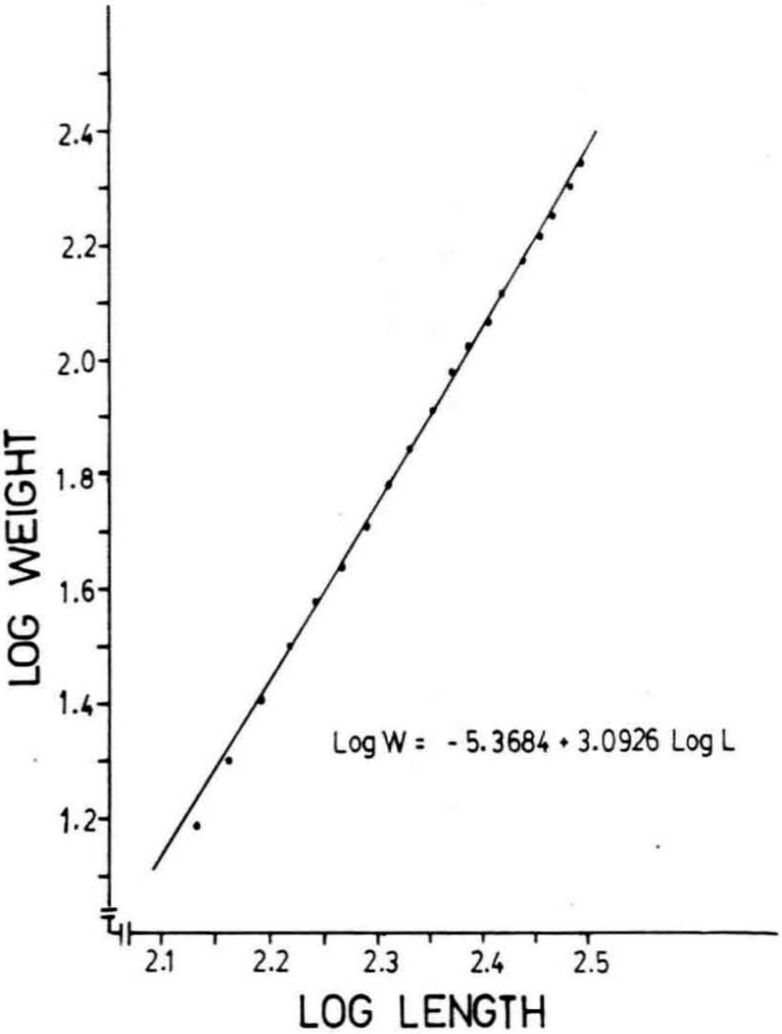

Fig. 4.19 Logarithmic relationship between length and weight for females of *S. undosquamis*.

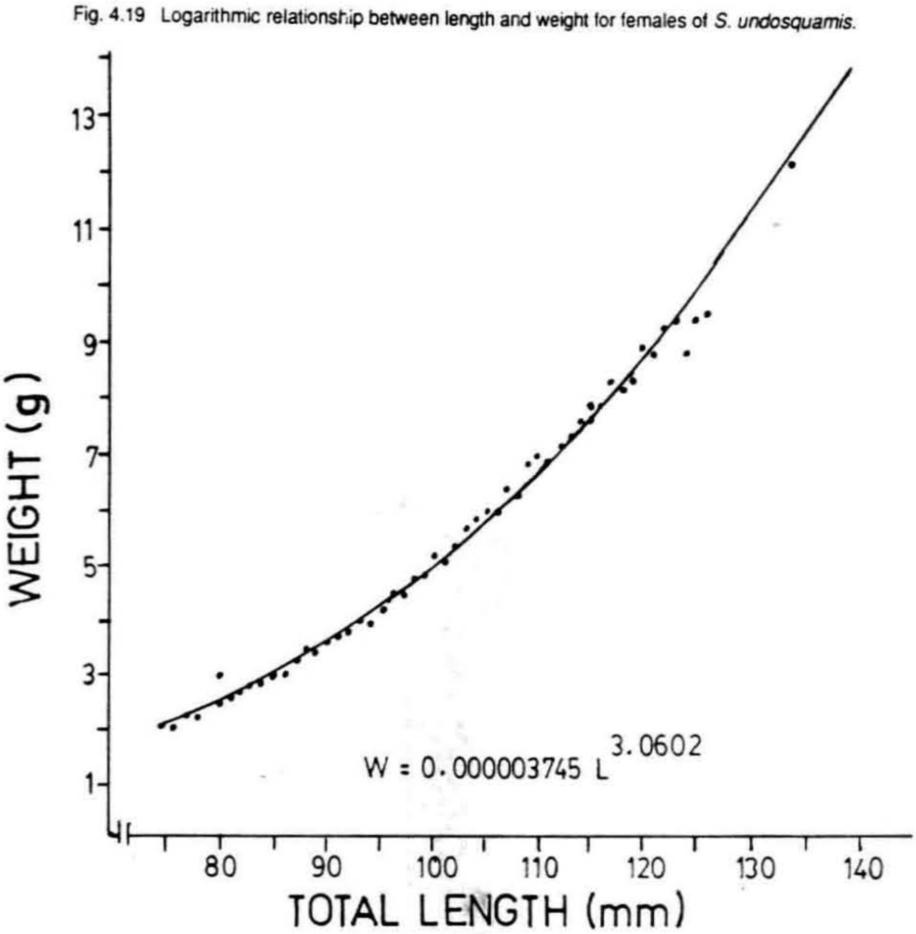

Fig. 4.20 Length against calculated weight for males of *S. isarankurai*.

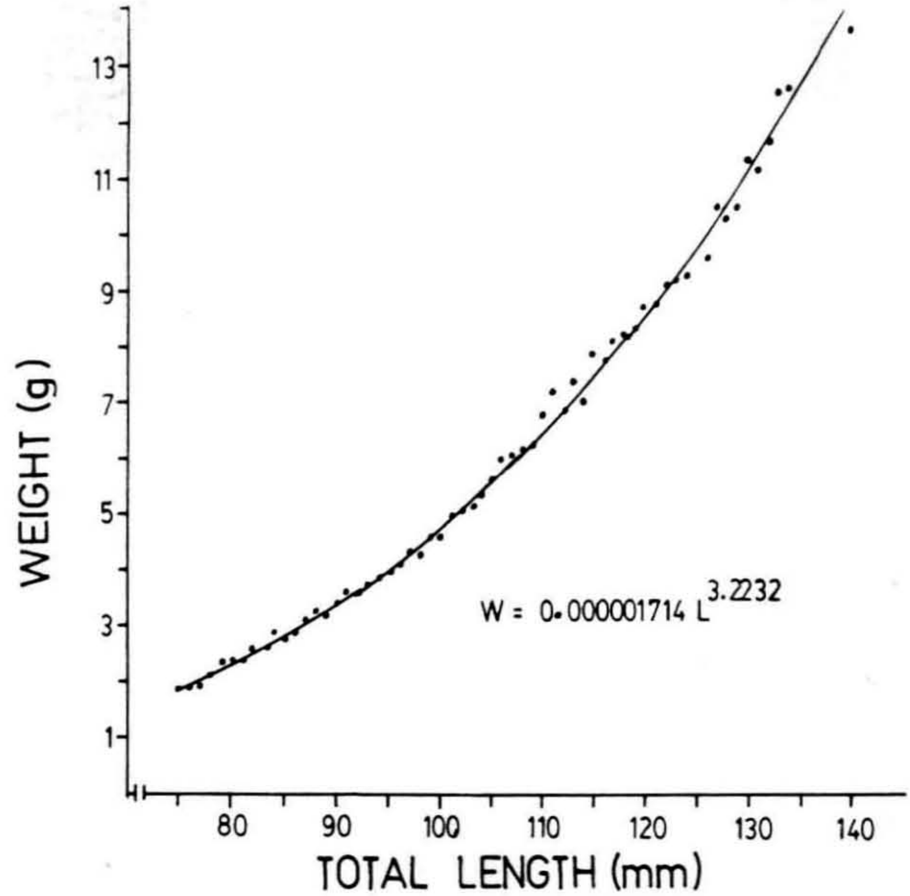

Fig. 4.21 Length against calculated weight for females of *S. isarankurai.*

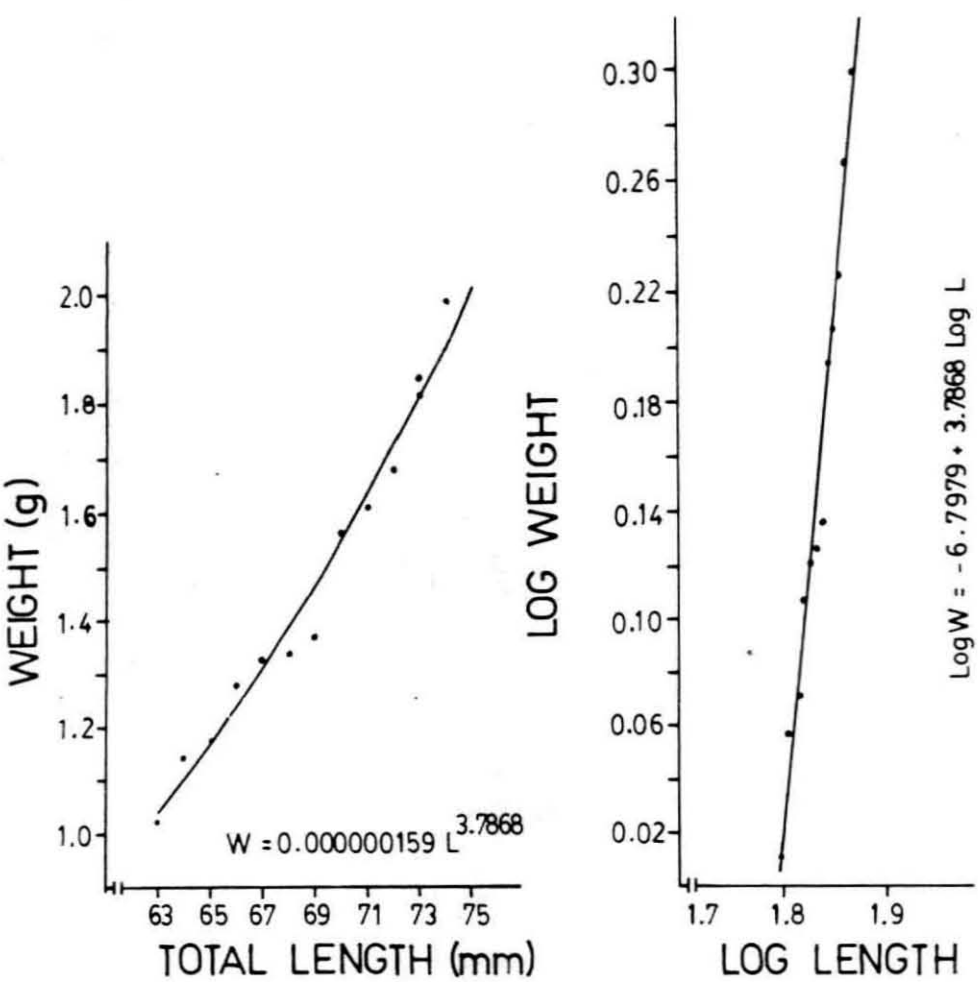

Fig. 4.22 Length against calculated weight and logarithmic relationship between length and weight for juveniles of *S. isarankurai.*

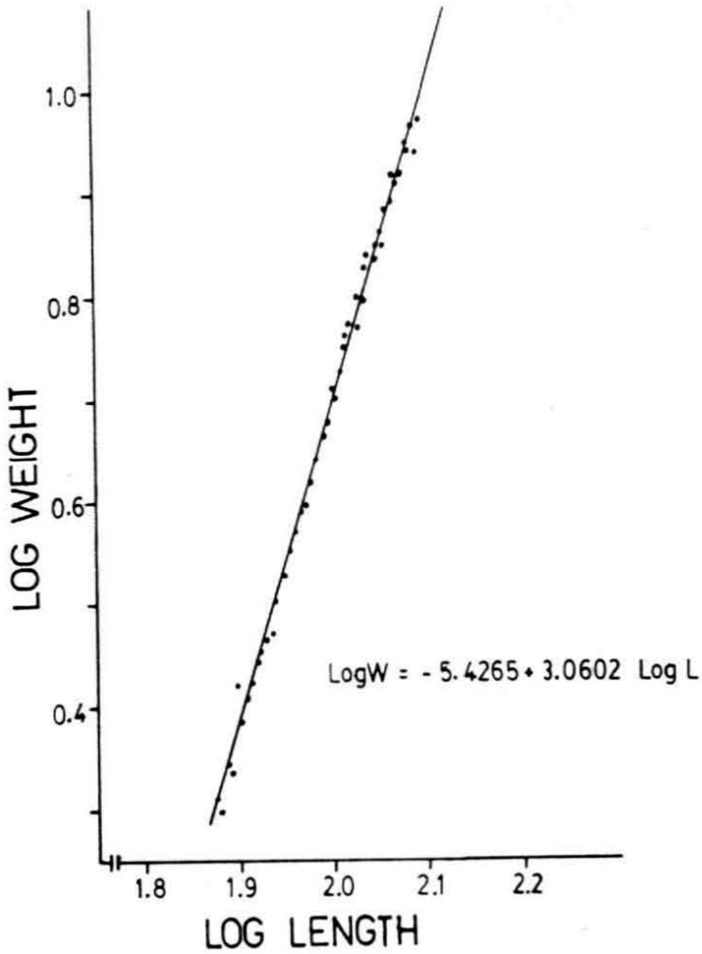

Fig. 4.23 Logarithmic relationship between length and weight for males of *S. isarankurai*.

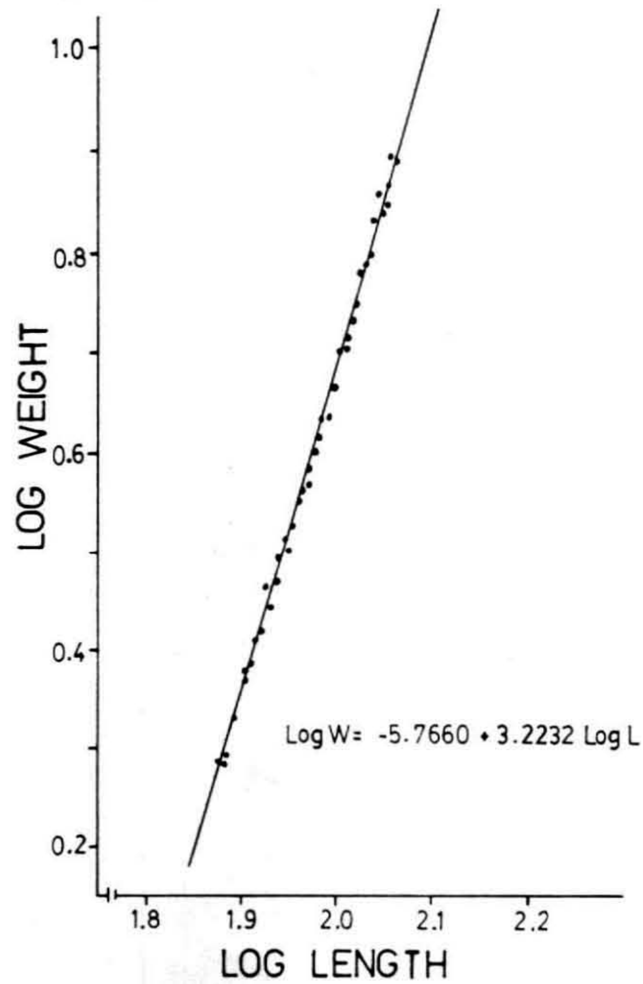

Fig. 4.24 Logarithmic relationship between length and weight for females of *S. isarankurai*.

Chapter V

REPRODUCTION

INTRODUCTION

Generation of species continues by means of reproduction which is an integral link of the life history of fish. Fishes exhibit a complexity of reproductive strategies, tactics and traits so as to leave some offspring for maintaining the existence of subsequent generations. The reproductive strategy relates to the general reproductive behaviour of the individuals, while the reproductive tactics are the variation in the general pattern which the fish adapts in response to fluctuations in the environment. The reproductive traits include aspects such as size/age at first reproduction (maturity), size/age dependent fecundity, sex-ratio, nature of gametes and timing of spawning season (Wootton, 1984). A study on these reproductive characteristics is essential in the determination of population stock size from egg numbers, periodicity of strength of broods (years class recruitment), spawning time and place and sex composition of exploited stock. A knowledge on these aspects is necessary for successful fishery management and for the rational exploitation of fish stocks.

Many studies on the various aspects of reproductive characteristics of fishes have been made from different parts of the world. Some of the important contributions are by Fulton (1899), Clark (1934), Hickling and Rutenberg (1936). Dejong (1939), June (1953), Bagenal (1957), MacGregor (1957), Otsu and Uchida (1959), Yoshida (1966), Macer (1974), Crossland (1977), Fox (1978), Hunter and Goldberg (1980), William and Clarke (1982), and Davis (1985).

Some of the Indian contributors on the subject include Hornell (1910), Panikkar and Aiyar (1939), Pradhan and Palekar (1956), Prabhu (1956), Qasim and Qayyum (1961), Rao (1963), Raju (1964), Rao (1964), Antony Raja (1967), James (1967), Parulekar and Bal (1971), Qasim (1973), Devaraj (1977), James and Baragi (1978) and Muthiah (1986a).

Studies on the reproductive biology of *Saurida* spp. have been made from different regions of the world and most of these relate to *S. tumbil*.

Delsman (1938) and later Mito (1961) described the eggs and larvae of *S. tumbil* (?) from the Java Sea and Japanese waters respectively. Okada and Kyushin (1955) referred to the subject while studying the stocks of *S. tumbil* from the East China and Yellow Seas. Yamada *et al.* (1965), Yamada (1968) and Liu and Yeh (1974) studied the maturity and spawning of *S. tumbil* from the East China Sea. Liu and Tung (1959) investigated the spawning ecology of the species from Taiwan Straits. Tiews *et al.* (1972), mentioned about the reproduction of the species from the Philippine waters. Naumov (1968) gave an account on the fecundity of *S. tumbil* from the Indian Ocean. Latif and Shenouda (1973) made detailed observations on the gonads of *S. undosquamis* from the Gulf of Suez. Zuyev and Salekhova (1970) and Oven (1976) reported on the reproduction of *S. gracilis* and *Trachinocephalus myops* respectively and Budnichenko and Dimitrova (1981) studied the sexual cycle and fecundity of *S. undosquamis* and *S. tumbil* from the Arabian Sea.

Investigations on the reproductive biology of *Saurida* spp. from the Indian waters are very limited. Gopinath (1946) described the post larvae of *S. tumbil* from the Trivandrum Coast. Later, Nair (1952) dealt with the eggs of this species from the Madras Coast. Vijayaraghavan (1957) and Kuthalingam (1959) reared the eggs of the species upto larval stages, while, Raju (1963) reported on the eggs of the species from Waltair and Dileep (1977) on the larval development and distribution from the southwest coast of India. Annigeri (1963) made notes on the intraovarian eggs and spawning periodicities of the species by making observations on a limited number of specimens from the Mangalore area in the mid-west Coast of India. Rao (1983) gave a comprehensive account on the maturation and spawning of *S. tumbil* and briefly on the same aspects of *S. undosquamis* from the north western part of Bay of Bengal. Dighe (1977) carried out similar studies on *S. tumbil* from the Bombay waters.

Since detailed studies on the reproductive biology of *S. tumbil* from the Karnataka waters, of *S. undosquamis* from the west coast of India and of *S. isarankurai* from any part of the world, are not available, the present investigation on the reproductive characteristics of these species was taken up and the results presented.

MATERIAL AND METHODS

Fortnightly fish samples were collected from the trawler landings at Mangalore, Malpe, Bhatkal and Karwar during the trawl fishing season, November-May of 1989-90 and 1990-91. Samples were not available during June-August due to the suspension of fishing by trawl units. Similarly, during September-October, *Saurida* spp. were not represented in the trawl catch, as during this period, trawl was generally operated in the nearshore waters. The fish samples were cleaned in the laboratory and after removing the moisture by blotting, total length and weight were noted. Fish were dissected to record sex and stage of maturity. The gonads were removed and weighed. Ovaries were preserved in 5% formalin.

For classification of maturity stages, the International Council for the Exploration of the Sea (ICES) Scale (Wood, 1930 and Loven and Wood, 1937) was adopted. Accordingly, the ovaries and testes were categorised into seven stages. The fresh ovaries were examined macroscopically for studying the general external characteristics and the organisation of the ovary. The preserved material was used for microscopic study. The testes were subjected to only macroscopic examination. For the purpose of studying the duration and frequency of spawning, measurements of ova diameter were recorded following the procedures described by Clark (1934), Hickling and Rutenberg (1936), June (1953), Prabhu (1956), Rao (1963) and James (1967). A stage ocular micrometer which gave a value of 0.0137 mm for each micrometer division (md) was used to measure the diameter of eggs. As the preliminary examination of distribution of ova diameter frequency from different parts of the ovary revealed that there was no difference in the size of ova from different parts of the gonad, eggs were sampled from the middle portion of the ovary for further studies. Ova measuring less than 5 md were not measured as they were present in large numbers in all the ovaries. However, ova below 5 md were measured from the immature ovaries (stages I and II) for studying the progressive growth of ova. The ova diameter frequency from the ovaries of identical stage of maturity were pooled for plotting graph.

Gonado-somatic-index (GSI) was estimated applying the method of June (1953) -

$$GSI = \frac{\text{Weight of the gonad}}{\text{Weight of the fish}} \times 100$$

The monthly mean index values were calculated separately for males and females.

Relative condition (K_n) was calculated using Le Cren's (1951) formula -

$$K_n = \frac{W}{\hat{W}}$$

where W represents the observed weight and $\hat{W}$, the calculated weight derived from the length-weight relationship. The mean K_n values for both sexes were computed separately for various months and in relation to different size groups.

The average size at first maturity was determined by plotting the percentages of fishes from stage IV onwards, against their length groups. Maturity curves were drawn to the scatter plots so as to estimate the length at which 50% of fish mature.

The sex-ratio distribution was studied by employing the Chi- square test (X^2), using the equation of Fisher (1970) as followed by Dhulkhed (1971). For the purpose of testing the significance of the variations in the proportion of males in the monthly samples of each season, the following Chi-square test was used -

$$\text{Chi-square test} = 1/\bar{p}\,\bar{q}\ \{\Sigma(ap) - n.\bar{p}\}$$

where

p = proportion of males in the monthly samples

a = number of males in the monthly samples

$\overline{p}$ = proportion of males in one year

n = number of males in one year

$\overline{q} = 1-\overline{p}$

To test whether the observed sex-ratio in each month and individual length group differs significantly from the expected ratio, the following Chi-square equation was followed -

$$\text{Chi} - \text{square} = \Sigma \frac{(O - E)^2}{E}$$

where

O = observed number of males and females in each month/ length group.

E = expected number of males and females in each month/length group.

For the purpose of fecundity estimation, ovaries in stages IV and V only were considered. After removing the moisture from the ovaries with blotting paper, they were weighed in a monopan electronic balance to the nearest 0.001 g. A small portion of the ovary was separated and weighed to the nearest 0.001 g. The sampled portion was placed on a microslide and ova were teased out. All mature ova were counted and the fecundity was estimated employing the formula -

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

The relationship between fecundity and different variables like fish length, fish weight and ovary weight was worked out by the least square method.

$F = aX^b$

where F = fecundity, X = fish length or fish weight or ovary weight, a = constant and b = regression co-efficient. The exponential relationship was transformed into a straight line relationship based on logarithms by the following equation -

Log fecundity = log a + b log X

REPRODUCTIVE ORGANS

The male and female reproductive organs lie in the posterior part of the abdominal cavity and are attached to the dorsal wall of the abdominal cavity by a thin membranous mesorchium or mesovarium. The two lobes of the gonad lie free in the anterior end and are interconnected before opening into the exterior by a common genital aperture. In view of the fact that the shape and external appearance of the reproductive organs are similar in all the three species, a general description of the same is given below.

Testes

Testes, the male reproductive organs are paired and symmetrical. In the early stages, they are long and thread-like. With growth, they become flattened and ribbon like and increase in length anteriorly. On maturity, they become thick, broad, milky-white and soft. They extend to almost the entire body cavity. Veination is prominent and horizontal ridges are seen. Milt oozes out on slight pressure. The vasa deferentia of the two testes meet at the posterior end and open to the exterior by a common aperture.

Ovaries

The female reproductive organs consist of a pair of ovaries lying lengthwise in the body cavity. The right and left ovaries in most cases are symmetrical, however, sometimes the right and left lobes are unequal in length, the former being little longer than the latter. In the posterior end they are inter connected before opening into the exterior through the common genital aperture. On attainment of maturity the ovary occupies almost the entire body cavity. Each ovary is cylindrical in shape with conspicuous veination. The inner wall of the ovary is lined with germinal epithelium which proliferates the ova.

MATURITY

On the basis of macroscopic examination the external features such as shape, size and girth of the ovary and microscopic structure of ova, seven maturity stages corresponding to the standard maturity stages by ICES (Wood, 1930) could be recognised in females. In males also, the maturity stages could be assigned to seven stages based on external macroscopic examination. As the macro- and microscopic structure of the gonads in the three species are similar, a general description common for these species is given below:

MALES

Stage I: Immature

Testes narrow, thread-like and transparent; pale pinkish or light reddish; less than 0.5 mm in width; extend more than 1/2 length of body cavity.

Stage II: Immature

Little broader than stage I; reddish or pale white or light pinkish in colour and transparent with veination; occupy more than 1/2 length of body cavity.

Stage III: Maturing

Broader and band-like; pale white or pinkish white or reddish white; veination clear; extend more than 2/3 of length of body cavity; milt oozes on hard pressure.

Stage IV: Mature

Thicker and broad; pinkish white or creamy white or reddish white with prominent veination; occupying more than 2/3 of length of body cavity; milt oozes on pressure.

Stage V: Gravid (Ripening)

Thicker than stage IV; creamy white or pinkish white with veination; occupying more than 2/3 length of body cavity; milt extrudes on pressure.

Stage VI: Ripe (Running/oozing)

Testes thicker and broad; creamy white with clear veination; transverse marking of blood vessels and transverse striations; occupy more than 3/4 length of body cavity; soft, milt flows out on slight pressure.

Stage VIIa: Partially spent

Pale white, loose and shrunken appearance; vasa deferentia thick and creamy white containing milt to be extruded.

Stage VIIb: Fully spent

Reddish white or pale white with veination; transparent; occupy 2/3 length of body cavity; no milt oozes out on pressure.

FEMALES

Stage I: Immature

Ovaries ribbon-like band; occupy more than 1/2 length of body cavity; glassy transparent; pale white or reddish or light pinkish; broader than testes. Ova not visible to the naked eye; under microscope ova appear small, transparent, yolkless and not easily separable; majority ova with mode at 0.04 mm in all the three species.

Stage II: Immature

Ovaries club shaped; occupying more than 1/2 length of body cavity; transparent; reddish or pale white or light pinkish or flesh coloured with veination; microscopically ova appear transparent; double walled; yolk formation just commenced around the nucleus; majority ova with mode at 0.11 mm in all the three species.

Stage III: Maturing

Ovaries broader and thicker; occupying nearly 3/4 of body cavity; reddish white or pinkish white with veination; microscopically ova round, transparent, double walled the outer one thicker. Yolk concentration around the nucleus visible faintly. Majority ova with mode at 0.25 mm.

Stage IV: Mature

Occupy more than 3/4 of body cavity; pinkish or reddish or combination of both; veination clear. Ova discernible by the granulated appearance. Yolk formation complete giving opaque appearance. Vacuolation processes just set in and periphery getting transparent. Majority ova with mode at 0.52 mm in *S. tumbil* and *S. undosquamis* and at 0.32 mm in *S. isarankurai*.

Stage V: Gravid (Ripening)

Ovaries extending more than 3/4 length of the body cavity; light pinkish or pinkish or reddish-pink with clear veination; granulated appearance. Most of the ova opaque followed by ripening ova. Vacuolation process completed. Majority ova with mode at 0.66 mm in *S. tumbil* and 0.59 mm in *S. undosquamis* and *S. isarankurai*.

Stage VI: Ripe (Running/oozing)

Ovaries long, round and occupy almost the full length of body cavity; translucent; reddish pink or dark pinkish or pale pinkish with conspicuous veination; granulated appearance. Ripe ova pale white with reticulate pattern without oil-globules. Majority ova with mode at 1.06 mm in *S. tumbil*, 0.79 mm in *S. undosquamis* and 0.73 mm in *S. isarankurai*.

Stage VIIa: Partially spent

Ovaries loose, shrunken and resemble much like stage V or IV or III with few left over ripe eggs. Posterior portion of the ovaries dark blood shot with prominent veination while the upper part is pinkish.

Stage VIIb: Fully spent/spent recovering

Ovaries flat, flaccid, shrunken and deep reddish giving blood shot appearance. Length much reduced almost like stage II. Sometimes few disintegrated ripe eggs seen.

SIZE AT FIRST MATURITY

All fish do not mature at the same length. The earliest length at which maturity is attained is taken as the minimum size at maturity by some workers. But this representing only a small or insignificant percentage of the population may not give the true picture of a population and hence, for population studies the minimum size at first maturity is considered at 50% level.

For the purpose of determining the minimum size at first maturity, 937 males and 1669 females of *S. tumbil*, 883 males and 1759 females of *S. undosquamis* and 2596 males and 3455 females of S. *isarankurai*. were used. Fishes in maturity stages IV and above were considered as 'mature' and their percentages in each length group were plotted against the mid- length of the size groups. Maturity curves were drawn to the scatter plots so as to estimate the length at which 50% fish mature.

The maturity curve shows that 50% of males and females of *S. tumbil* (Fig. 5.1) mature at 250 mm and 264 mm length respectively. The age at these lengths were 1.00 year for males and 1.07 years for females. From the maturity curve (Fig. 5.2) for *S. undosquamis*, it is seen that 50% males mature at 167 mm length and females at 207 mm. The age at these lengths were 0.97 years and 1.34 years respectively. Fig. 5.3 shows the maturity curve for *S. isarankurai* and the size at maturity at 50% level for both males and females was at 83 mm and the corresponding age was 0.50 year.

Okada and Kyushin (1955) determined the size at first maturity in females of *S. tumbil* at 34-35 (FL) and males at 28 cm, from the East China and Yellow

Seas. Yamada *et al.* (1965) reported that the minimum size at first maturity in *S. tumbil* from the East China as 35 cm (FL) for females and 28 cm for males. However, a review of the same in 1963 showed that the minimum size at first maturity was 31 cm and 25 cm in females and males respectively. The reason attributed by them for this variation was the reduction in stock size in 1963 as compared to that of 1951 findings. Tiews *et al.* (1972) have observed that the females in Philippine waters attain maturity at a total length of 19-21 cm and males at 17-19 cm. Liu and Yeh (1974) determined the biological minimum size of females of *S. tumbil* at about 27 cm (FL) in East China Sea and Taiwan Strait, 28 cm in the northern part of South China Sea and 29 cm in the Gulf of Tonkin. However, in respect of males a common length at 25 cm was reported in all regions. Dighe (1977) estimated the minimum size at maturity for the species in the Bombay waters at 208 mm (SL). Rao (1983) determined the minimum size at maturity for the species from the northwestern part of Bay of Bengal as 26 cm (TL) and the size at 50% maturity as 30 cm. Budnichenko and Dimitrova (1981) recorded that females attain maturity at 20-21 cm (FL) and males 18-19 cm in the Arabian Sea.

For *S. undosquamis* of the Gulf of Suez, Latif and Shenouda (1973) have observed both mature and immature females in the range of 14-15.9 cm (SL) and all the males above 14 cm were mature (fish below 14 cm were not sampled). From the same region, Sanders *et al.* (1984) estimated the minimum size at maturity at 17 cm (TL) for females and 16.6 cm for males. For the Arabian Sea population of the species, Budnichenko and Dimitrova (1981) determined the sexual maturity at a fork-length of 15-16 cm for females and at 11-12 cm for males.

From the above, it is observed that in all cases, females attain maturity at a higher length than males. The present observation also showed such a differential size at maturity in *S. tumbil* (250 mm for males and 264 mm for females) and *S. undosquamis* (167 mm for males and 207 mm for females). On the other hand in *S. isarankurai* both males and females mature at a common length of 83 mm.

SPAWNING SEASON

The percentage occurrence of gonads in different stages of maturity based on the pooled data for two years, 1989-90 and 1990-91 for both males and females of the three species is presented in Tables 5.1 - 5.6. It is observed that in *S. tumbil* (Tables 5.1 and 5.2) mature fishes (stages IV and V) and spent fishes (stages VIIa and b) occurred during November- February. Ripe (stage VI) specimens were encountered during October-January. Their percentage was high during November - December. In other months (March - May and August), fish were found either in immature or maturing stage. This shows that the species spawns for a longer period, extending from October - February with an intensive spawning during November - December. As data are not available from June - September, it is not possible to determine the full extent of spawning months. However, since all the adult fish sampled during April - May have been either in immature or resting condition, it is possible that fish may not be ready for next spawning in the subsequent months; for the development from immature to mature condition may take atleast 2-3 months.

In *S. undosquamis*, mature (stage IV), early ripe (stage V) and ripe (stage VI) fishes were encountered during November - March and their percentage being high in November-December (Tables 5.3 and 5.4). Spent fishes occurred during December-March with high percentage in November-January. All the adult fishes in April - May and August were immature or in spent-recovering condition. This indicates that spawning in this species too takes place for a longer duration from November - December. In the absence of data during June - July, September-October, the full duration of the spawning season could not be ascertained. Since all adult fishes were in spent-recovering stage during April - May, it is probable that the species may not be ready for spawning till September - October as observed in the case of *S. tumbil*.

In *S. isarankurai*, fully ripe fishes occurred during November-April and spent fishes from December to April (Tables 5.5 and 5.6). The percentage of ripe individuals showed a major peak in December and a secondary peak in February. Similarly, the occurrence of spent fishes also showed two peaks, a major one during December-January and another minor one in April. All the adult fishes observed during May were in spent- recovering condition. It is concluded that spawning in this species is also a protracted one extending from November to April with a major spawning peak during December, followed by a minor peak in February. Due to the non-availability of data during June-October it is not possible to study the maturity condition of the fish during this period. In view of the fact that all adult fish were found in spent-recovering condition in May, it is presumed that in this species also spawning cycle would commence again from September-October, after completing the maturation process during May - August.

According to Annigeri (1963) ripe fishes of *S. tumbil* were available in the trawl catches at Mangalore from November to January. Spent fishes first appear in December and their percentage increased subsequently. Dileep (1977) while studying the larval development and distribution of *S. tumbil* off the southwest coast of India reported that though the larvae were present in the early part of the year, the peak period of their availability was from September-December. This led him to infer that spawning in this species takes place during this period. Dighe (1977) observed that *S. tumbil* in the Bombay waters spawns during October - January. The present study shows that spawning in the species occurs during October - February with a peak during November - December, thus supporting the above observations. Further, the findings of Dileep (1977) on the availability of larvae from September onwards shows that spawning in the species may start from September onwards. All the adult fishes observed during March - May were in spent- recovering condition and it is likely that further development of the gonads may take sometime and the fish may be ready for next spawning from September - October. It may therefore be inferred that the spawning activity of the species during March-August is lean. This is in agreement with the observations of Rao (1983) who reported that the species in the northwestern part of Bay of Bengal has a protracted spawning period from October to March with a peak in November-December; fishes encountered during April-July are either in immature or spent recovering state and those during August - September are in the active process of maturation.

Yamada *et al.* (1965) have reported that spawning occurs in *S. tumbil* during April-June in the shallow waters near the coast of the Chinese Mainland. According to Liu and Yeh (1974) spawning season of the species extends from March to June in the East China Sea and Taiwan Strait and from February to May in the northern part of the South China Sea and Gulf of Tonkin. On the other hand, Tiews *et al.* (1972) have observed mature and ripe fishes in the Philippine waters throughout the year. According to Budnichenko and Dimitrova (1981), *S. tumbil* in the Arabian Sea spawns intermittently throughout the year.

In the case of *S. undosquamis* the present study shows that the spawning occurs during November-March and the April-May period coincides with the resting period of the gonads. Rao (1983), based on the occurrence of fish in stages III and IV of maturity, assumed that the species in the northwestern part of Bay of Bengal spawns from October to March. Latif and Shenouda (1973) and Sanders *et al.* (1984) observed that the species in the Gulf of Suez spawns over a protracted period during April-June. Budnichenko and Dimitrova (1981) reported that the species in the Arabian Sea spawns throughout the year with a peak in October - March.

The results of the present investigation revealed that spawning in the three species studied is protracted, extending over 5-6 months; during October-February in *S. tumbil*, November-March in *S. undosquamis* and

November - April in *S. isarankurai*. From this, it is inferred that spawning activity ceases for the season first in *S. tumbil* in February, followed by *S. undosquamis* in March and later in *S. isarankurai* in April. All the three species have a resting period after these months. It is also known that there is a single peak period of spawning during November-December in both *S. tumbil* and *S. undosquamis* whereas, *S. isarankurai* has a major peak month of spawning in December followed by another minor peak in February.

RECRUITMENT PATTERN

An important aspect of study of recruitment in fishes, is to know its structure in a given year so as to determine whether, the recruitment is discrete or continuous in conjunction with the spawning/birth period of fishes. Recruitment, even in tropical fishes generally oscillates seasonally and is often normally distributed in one or two peaks per year (Pauly, 1982). Recruitment pattern is described in the form of a graph, the peaks and troughs on it will reflect the seasonality of the recruitment of stock (Samb, 1988). The annual recruitment pattern is calculated from the length frequency data and the corresponding growth parameters by projecting each length frequency sample backward on to a time axis (Ingles and Pauly, 1984). The ELEFAN programme includes a procedure for obtaining such recruitment pattern. The position of the modes in the size distribution when adjusted to real time by means of a value of 't_0' would indicate the time of the year when recruitment is most intense and this should generally correspond to the peak spawning season (Pauly, 1982). In the ELEFAN programme, the 't_0' used in the calculation is zero and the monthly values of the recruitment pattern are based on relative ages pertaining to only an arbitrary year and hence, the exact time of recruitment cannot be determined and only the shape of the recruitment can be indicated, not its position on the time axis (Pauly, 1982; Ahamed, 1988).

The computation procedure involved in ELEFAN II, as described by Samb (1988) are,

a) each length class of each sample is divided into 10 intervals of equal size

b) the value added to the recruitment pattern memory is length class Ni/10 divided by the time required to grow the length interval in question

c) the lowest monthly recruitment value is substracted from all 12 values resulting in atleast one zero value corresponding to the month of lowest recruitment and

d) the resulting distribution is converted into relative frequency.

Recruitment pattern in *S. tumbil* shows a single pulse covering a period of 3-5 months with a peak in two months (Fig. 5.4). Studies on the maturation and spawning indicate that the species spawns during October-February with a peak in November-December and the occurrence of juveniles of the length range of 40-119 mm over an extended period of December-April further supports the view that spawning in the species is a prolonged one.

Similarly, in *S. undosquamis* also, the recruitment curve indicates that recruitment to the fishery takes place in a single pulse extending over a longer duration of 4-6 months with an intense recruitment in two months (Fig. 5.5). Observations on the maturation and spawning testify that the species spawns during November-March with a peak in November-December. Young fish between 60 and 99 mm were caught during December-May. These observations lend further support that the species spawns during an extended period.

In *S. isarankurai*, the recruitment pattern shows two pulses (Fig. 5.6), one prominent peak covering 3 months and the other a minor one occurring for a short duration of 2 months. The time interval between the two modes is only two months. From the spawning studies it is evident that the species spawns during November - April with a major peak in December and a secondary peak in February. Small fish measuring 34-69 mm length were caught during December - May. From these observations, it is evident that spawning in this species also is extended over a longer duration with two peaks.

Ingles and Pauly (1974) reported that in *S. tumbil* and *S. undosquamis* from the Philippine waters, annual recruitment occurs in two pulses of unequal strength.

DEVELOPMENT OF OVA TO MATURITY AND FREQUENCY OF SPAWNING

Ova diameter studies in fishes are undertaken to determine the duration and frequency of spawning. For the purpose of studying the development of ova to maturity, ova diameter measurements from ovaries in stages I-VII were made. The measurements were grouped into size classes of 5 micrometer divisions (1 md = 0.0137 mm) and the frequency polygons were drawn.

The ova diameter frequency polygons of *S. tumbil* depicting the development of ova from ovaries of stages I to VII are shown in Fig. 5.7. In stage I, a unimodal ('a') distribution of ova is seen. All the ova are immature and yolkless with a round nucleus. The size of ova ranged from 2 to 10 md with majority of ova measuring 3 md. In stage II, the ova are immature and transparent but commencement of yolk deposition around the nucleus and towards the periphery is seen. Majority of the ova measure 8 md ('a') and form the general egg stock. Some of the ova measure upto 23 md. In the next stage (III), differentiation of ova from the immature stock takes place. A batch of developing ova gets separated and forms a minor mode at 33 md ('b'). The major mode 'a' at 18 md has progressed from 8 md seen in the previous stage. This mode represents the maturing group of ova. In these ova, 3/4 of the ovum area is layered with yolk granules with more concentration around the central portion giving semiopaque appearance, while, the area nearer to the periphery is somewhat semitransparent. The mode at 33 md constitutes the mature group of ova in which the yolk formation is almost complete.

In stage IV, mode 'b' is shifted to 38 md while mode 'a' is found stationary at 18 md. Mode 'b' forms the majority group which is distinctly separated from the maturing group of ova under mode 'a'. The size range of the mature ova is from 38 to 53 md. These ova are with perivitteline space and transparent. These two modes progress further to 28 md ('a') and 48 md ('b') in stage V. The majority of ova at mode 'b' are ripening wherein the whole ovum area is becoming transparent. In the ripe ovary (stage VI) modes 'a' and 'b' are shifted to 33 md and 78 md respectively. Though ova of all stages (maturing, mature and ripe) are seen, the ripe ova group with a size range of 53-88 md is distinctly separated from the maturing and mature group of ova. The maximum size of ova measures 90 md. They are fully transparent with reticulate markings, sometimes with a patchy area of diffused yolk and devoid of oil globule. Although the mode 'a' representing the mature and maturing group of ova is not distinctly demarcated from each other, this group is clearly separated from the ripe group of ova ('b').

The size distribution of ova in different stages of maturity of *S. undosquamis* is shown in Fig. 5.8. It is seen that in stages I and II representing immature ovaries, the ova show a single mode 'a' at 3 md and 8 md respectively. The ova at 3 md are yolkless and with round nucleus. In the ova of 8 md, yolk formation has commenced around the nucleus. In stage III, the mode 'a' has progressed to 18 md which constitutes the maturing group of ova. From this group, one batch of ova grows faster and gets separated and forms a mode 'b' at 38 md in stage IV. The original mode 'a' at 18 md seen in stage III has shifted to 23 md. The ova at mode 'b' are mature, whereas, those at mode 'a' represent early mature group. Both these modes are demarcated distinctly. In stage V, the mode 'a' is shifted further to 28 md and mode 'b' to 43 md. The former mode represents early mature group of ova and the latter mode ripening stage. In the ripe ovary (stage VI), ova of all stages are seen as in *S. tumbil*. Mode 'a' seen at 28 md in the previous stage remains stationary and mode 'b' shifts to 58 md which constitutes the ripe ova ranging from 43 to 78 md. Both the groups are clearly separated. In mode 'a', the early mature group is not clearly distinguishable from the maturing group of ova. The ripe ova are transparent, devoid of oil globule and show reticulate pattern as observed in the ripe ova of

S. tumbil. Here also, sometimes, a small opaque area of irregular shape is formed by the diffused yolk. The maximum size of ripe ova is 77 md.

Ova diameter frequency polygons for various stages of maturity in respect of *S. isarankurai* are presented in Fig. 5.9. In stages I and II. all ova are immature forming a single mode 'a' at 3 md and 8 md respectively. The maximum size of ova measures 8 md and 13 md respectively. In stage III, the first group of developing ova gets separated and forms a mode 'b' at 18 md. This group of ova represents the maturing eggs with the maximum size of 28 md. The mode 'a' at 8 md seen in the previous stage remains stationary in stage III also. In stage IV, mode 'b' develops to 28 md constituting mature group of ova. The mode 'a' moves to 13 md. The ova under this mode also are in maturing stage as the ova of mode 'b' (18 md) in stage III. The biggest ova measure upto 43 md. In the penultimate stage (V), mode 'b' has progressed to 43 md indicating faster growth and mode 'a' to 18 md. Both the groups of ova at mode 'a' and 'b' are markedly separated. The group of ova at mode 'b' is in ripening stage with transparent peripheral area. The size of mature and ripening ova ranges from 33 to 58 md. In the ripe stage of maturity, (VI) the modes 'a' and 'b' at 18 md and 43 md further advance to 28 md and 53 md respectively. The ova under mode 'b' form the majority group of ova with size ranging from 43 to 63 md. The mode 'a' constitutes the minor group of mature ova which is not clearly separated from the maturing group of ova. But the wide gap seen between mode 'a' and 'b' in the penultimate stage is narrowed. The maximum size of ripe ova measures 64 md. The general structure of ripe ova is similar to that of *S. tumbil* and *S. undosquamis*, i.e., without an oil globule and with reticulate pattern.

The ova diameter frequency distribution of mature (stage IV) ovaries in all three species showed the presence of three distinct groups of ova *viz.*, immature stock (<8 md), maturing group (13-18 md) and mature group (23-33 md). In the penultimate stage (V), in addition to the above groups, ripening eggs (38-43 md) are seen. In the final stage of maturity (VI), besides all these four groups, fully ripe eggs (43-88 md in *S. tumbil*, 45-78 md in

S. undosquamis and 43-68 md in *S. isarankurai*) are present. The presence of different groups of yolked ova in the mature ovaries of any species of fish is an indication of multiple spawning (Mac Gregor, 1957; Clark, 1934 and Hickling and Rutenberg, 1936).

It has been shown that in fishes which spawn simultaneously and only once a year, the batch of eggs to be spawned will be withdrawn from the general egg stock in a single group, sharply distinguishable atleast in the later stages of maturation (James and Baragi, 1978 and De Silva, 1973). Walford (1932) and Prabhu (1956) have reported that fishes which breed only once in a restricted and short definite period, their mature ovaries will have two types of ova, the immature group and the mature group. Prabhu (1956) has stated that in fishes which spawn only once a year, but for a longer duration, "the size range of mature ova irrespective of the number of modes representing them, has been found to be nearly half the total range in size of the intra- ovarian eggs in the whole ovary". James (1967) has expressed similar view. In the present study, the total range of ova is 3- 88 md in *S. tumbil*, 3-78 md in *S. undosquamis* and 3-63 md in *S. isarankurai* and the mature ova measure 33- 88 md in *S. tumbil*, 28-78 md in *S. undosquamis* and 28-63 md in *S. isarankurai* which are nearly half of the total range. The presence of such a wide range of mature and ripe ova suggests that these ova may be shed over a prolonged period.

It is observed that after the ripe ova are released, the ovary resembles stage V or IV or III. Such ovaries appear as loose, somewhat shrunken, the upper part pinkish and lower part reddish. Microscopic examination of these ovaries, shows the presence of few healthy ripe eggs and sometimes they are in a disintegrated state, in addition to the normal distribution of ova in different stages. These observations clearly indicate that a batch of ripe eggs have been just spawned out. After the release of ripe ova, the resemblance of the partially spent ovary as stage V or IV or III may be dependent on the maturity state of the next lower mode closer to the spawned out ripe ova. Since, the mode 'a' representing early mature and mature group of ova is found nearer to the ripe group of ova in all the three species, these groups of ova activate their growth as soon as the ripe ova are extruded and get ready for their release in the same spawning season. This cycle is repeated till the entire quota of eggs destined to be released in the current spawning season are exhausted and finally the ovary reverts to spent recovering stage similar to stage II, in which some of the residual ova in stages III-IV are in a disintegrated state. In such a stage, the ovary appears loose, hollow, flaccid and dark-red in colour. Fish with this type of ovaries occur only at the end of the spawning season.

The second group of ova under mode 'a' is likely to be released in the same spawning season as they have already attained 3/4 process of maturation and need not wait till the next spawning season. This is further confirmed by the absence of fishes in stages III-VI after the end of the spawning season in the respective species, i.e., February for *S. tumbil*, April for *S. undosquamis* and May for *S. isarankurai*. Thereafter, in the subsequent months, all fish above the minimum size at first maturity length in respect of the three species are found in stage II only, with transparent immature gonads. From the foregoing, it is evident that spawning in these three species studied is prolonged and in multiple batches.

Annigeri (1963) studied the spawning periodicity of *S. tumbil* from the Mangalore coast (west coast of India) which forms part of the present area under investigation. Rao (1983) while studying the maturation and spawning of lizardfishes from Visakhapatnam (north-western part of Bay of Bengal) has discussed in detail the differences found between his studies and that of Annigeri. Both workers have used the same magnification for their ova diameter measurements. Annigeri (1963) reported the size range of intra-ovarian eggs to be between 1 and 48 md, whereas, Rao (1983) has observed the same to be between 1 and 90 md, which is nearly double that of Annigeri's observation. According to the latter, the fully ripe ova had mode at 35-38 md and were semitransparent and each ovum had a pinkish-yellow oil globule of 3 to 7 md. Rao (1983) has found the ripe ova to be completely transparent and showed characteristic hexagonal markings on the egg membrane and the eggs were devoid of oil globule. He concluded that the frequency curve for stage VI given by Annigeri (1963) resembles that of a stage IV of Visakhapatnam. Further, according to Rao (1983), Annigeri (1963) would have considered a partly spent ovary as stage VI and the semitransparent ova with mode at 35-38 md may represent ripening eggs differentiated from the mature eggs after one or two batches of fully ripe and transparent ova were shed. In the light of this, Rao (1983) desired the need for examining more specimens from Mangalore regarding the size of intra ovarian eggs, the ripe eggs and about the presence of oil globule and other characteristics before confirming the differences noted above in specimens from Mangalore and Visakhapatnam.

The area of present investigation also covers the Mangalore region, some of the doubts raised by Rao (1983) is cleared in this study. The same magnification as used by Annigeri (1963) and Rao (1983) was used in the present study. It showed that the size of intraovarian eggs of *S. tumbil* ranged from 1-88 md and the fully ripe ova ranged from 43-88 md. These ripe ova were completely transparent with reticulate pattern (irregular pattern of hexagonal markings) and also an yellowish patchy area of the diffused yolk. Vijayaraghavan (1957), Kuthalingam (1959) and Raju (1963) have observed hexagonal markings on the ripe eggs of the species. Kuthalingam (1959) reported that the eggs of the species are pelagic and have an average diameter of 1.12 mm. According to Okada and Kyushin (1955) the diameter of fully ripe ova of *S. tumbil* from the East China and Yellow Seas varied from 0.96 to 1.50 mm. Budnichenko and Dimitrova (1981) reported that the eggs of *S. tumbil* and *S. undosquamis* in the Arabian sea are pelagic and contain no fat droplet. According to them, the size of oocytes ranged from 0.25 to 1.6 mm in diameter in *S. undosquamis* and from 0.2 to 1.3 mm in *S. tumbil*.

Number of batches of eggs released in a season:

For estimating the number of batches of eggs spawned, the method followed by De Silva (1973) was adopted. In that, ratio of the total number of yolked eggs in the ovary to the number of ova in the most advanced state of maturity is considered as the number of batches of eggs shed per season. The number of yolked oocytes and the number of ova from 3 specimens of *S. tumbil*, 9 of *S. undosquamis* and 17 of *S. isarankurai* were estimated and the results are given in Tables 5.7, 5.8 and 5.9. It is observed that the number of batches of eggs released varied from 2.8 to 4.8 with an average of 3.83 in *S. tumbil*, from 2.5 to 5.95 (average 4.29) in *S. undosquamis* and from 2.05 to 4.99 (average 2.94) in *S. isarankurai*.

The ova diameter frequency distributions in the three species, show two groups of ova in the ripe ovaries which are released on an average of 4 batches in *S. tumbil* and *S. undosquamis* and in 3 batches in *S. isarankurai*. Rao (1983) observed three groups of ova in the ripe ovaries of *S. tumbil*, which are released in five or six batches. Annigeri (1963) reported two groups of ova which are shed in two batches, in case if the second batch is not resorbed. Tiews *et al.* (1972) have shown that *S. tumbil* spawns 2-3 batch of eggs in the Philippine waters. According to Naumov (1968), *S. tumbil* in the Bay of Bengal release their eggs in 3 batches. Budnichenko and Dimitrova (1981) reported that *S. tumbil* and *S. undosquamis* in the Arabian Sea spawn intermittently, throughout the year in 3-6 batches and 4-9 batches respectively. Latif and Shenouda (1973) reported that *S. undosquamis* in the Gulf of Suez, is a fractional or portional spawner, releasing their eggs 3-4 times during a spawning season. Zuyev and Salekhova (1970) reported that it is very difficult to establish the spawning frequency of *S. gracilis* from the Arabian Sea, as fish in different maturity stages were encountered over a fairly long period (February - May).

GONADO - SOMATIC INDEX (GSI)

Gonado-somatic index or the relative ovary weight (ovary weight/wt. of fish x 100) is useful to explain the state of maturity and intensity of spawning (June, 1953; Yuen, 1955 and James, 1967). The index for each individual was calculated for both males and females separately and monthly averages were drawn. For this study a total of 404 males (length range: 140- 349 mm) and 1123 females (140-449 mm) of *S. tumbil*; 454 males (140-279 mm) and 867 females (140-319 mm) of *S. undosquamis* and 487 males (70-134 mm) and 980 females (70-140 mm) of *S. isarankurai* was used.

In males of *S. tumbil* (Fig. 5.10), high GSI values are seen in October-November and it begins to decrease from December to January. Thereafter the values are low upto May and it increases again in August. For females (Fig. 5.10) high values are noticed during November-December and decreases from January with the lowest value during March-May. Higher values in both sexes during October-December indicate full development of gonads and low values during March-May indicate resting gonads after the spawning activity is complete. This lends further support that the species spawns for a prolonged period during October-January with an intensive spawning during November-December and does not breed during March-May period.

In both sexes of *S. undosquamis*, the index values are high during November-February, thereafter it shows decreasing trend reaching the lowest in April-May (Fig. 5.11). Highest value is recorded in January for males and December for females. The higher values during November-March are due to the availability of fish with mature gonads and the lower values during April-May correspond to fish with resting gonads. This suggests that the species spawns for a longer period, from November-March with a possibility of a peak breeding during November-December.

For *S. isarankurai*, the GSI values are high during November-March for both sexes (Fig. 5.12) with two peaks. In males, the major peak is recorded in January and a minor one in March. In females, they are noticed in December and March respectively. The values in both sexes show a decrease in April and reaches the lowest in May. Evidently, the higher values during November-March and low values from April onwards relate to the attainment of full maturity of gonads in the former period and to the spent gonads in the latter period. This indicates that in this species also, the spawning season is prolonged

(November-March) with a major peak in December-January and a minor one in March and the spawning activity begins to cease from April.

As expected, in all the three species, the average value of GSI is far higher in females than males owing to the heaviness of ovaries in females. The high values of GSI in all the three species appear to coincide with the spawning period as already inferred from the monthly distribution of different maturity stages of gonads.

RELATIVE CONDITION FACTOR ('K_n')

Variation from the expected weight for length of individual fish or groups of individuals is an indication of 'condition' (Le cren, 1951) of the fish due to several factors like fatness, general well being or gonad development. The variations in specific gravity of fish flesh (Tester, 1940) and their importance in the study of condition have been discussed by Kesteven (1947). It is known that the variations of weight against length are not due to changes in specific gravity but due to changes in volume or form, since the fish always maintain the same density as that of surrounding water. Such changes are determined by the study of "condition factor or "co-efficient of condition" or "ponderal index", so as to express the condition of the fish in numerical terms such as degree of well being, relative robustness and plumpness or fatness (Hile, 1936; Thompson, 1943; Lagler, 1956). The condition factor is computed based on the cube law using the expression,

$$K = W\,L^3 \times 100$$

where K = the condition factor, W = weight of fish and L = length of fish.

As this formula does not function adequately independent of length and other variable factors in fish, Le Cren (1951) has formulated a relative condition factor, 'K_n' expressed as:

$$K_n = W/a\ L^n \text{ or } K_n = \frac{W}{\hat{W}}$$

where 'K_n' = the relative condition factor, W = observed weight and $\hat{W}$ = calculated weight got from the length - weight relationship.

The monthly average relative condition factor was calculated separately for males and females and in relation to size.

For *S. tumbil* the mean 'K_n' values for males ranging in size from 140 to 339 mm and for females from 140 to 480 mm are represented in Fig. 5.13. It can be seen that in males the condition was high in the immature fishes (149.5-189.5 mm). It decreased in the next size group (209.5 mm) after which there was an increase in the 229.5 mm length range and it dropped again in 249.5 mm size group. The increase in 229.5 mm may be due to the onset of maturation process and the drop in the condition factor at 249.5 mm indicates spawning and this length corresponds to the 50% of maturity length. Thereafter, the condition increased in 269.5 mm and fell in 289.5 mm and again showed an increase in the next size group.

The 'K_n' value in females was higher above unity level in the 189.5-229.5 mm size group and the fish were in the process of attaining maturity (Fig. 5.13). Thereafter, it decreased progressively and reached to a low at 269.5 mm. It is observed that the fish attains 50% maturity level at 263.5 which is close to the low condition at 269.5 mm. The condition above this length showed rise and fall alternatively, the low value being noticed at 349.5 mm, 403.5 mm and 429.5 mm.

Mean 'K_n' values for different months in respect of males and females are shown in Fig. 5.14. It can be seen that in both sexes the Kn values were low during November-December and high in January followed by a decrease in February. Thereafter, in males the values increased in March and declined in April and there was a slight recovery in May. The low 'K_n' values observed in November-December may be attributed to the loss of weight by the spawning individuals as feeding rate was better in both sexes during this period.

Fig. 5.15 shows the mean 'K_n' values for *S. undosquamis* for different size groups of males ranging from 100 to 280 mm and females 100 to 310 mm. It may be seen that in males the 'K_n' values showed a gradual rise from 104.5 mm onwards reaching a peak in 154.5 mm. A decreasing trend in the values was noticed from the next size group and attaining the lowest in 174.5 mm. Since the fish upto 144.5 mm are immature, the high values in 154.5 mm might be due to the accumulation of fat prior to spawning and the drop in the 174.5 mm size group could be due to the spawning activity of the fish. It has been observed that 50% of males mature at 166.5 mm which is closer to 174.5 mm at which the condition showed a fall. The rise in the values in 184.5 mm, 214.5 mm, and 244.5 mm and the subsequent fall in 204.5 mm and 224.5 and 264.5 mm appear to be associated with subsequent spawning of the fish.

Similar to the observations made in males, the 'K_n' values in females (Fig. 5.15) showed an increasing trend from 104.5 mm size group onwards and attained a peak in 154.5 mm size group. Thenceforth, the values declined gradually reaching a low in 204.5 mm. As fish upto 164.5 mm were found to be immature, the rise in the 'K_n' values upto this length might be due to the building up of gonad and the subsequent decreasing trend and fall in 204.5 mm could be due to the spawning stress on the fish. This length is very close to the 50% attainment of maturity length at 206.5 mm. The 'K_n' values showed fluctuating trend at higher lengths. The values showed peaks at 214.5 mm, 234.5 mm and 284.5 mm and troughs at 224.5 mm 274.5 mm and 294.5 mm. This may be associated with subsequent maturation and spawning cycle.

The monthly trends in the mean 'K_n' values in both sexes presented a similar pattern of ups and downs (Fig. 5.16). 'K_n' values were low in November-December and increased in January and dropped again in February. It showed an increase again in March followed by a decline in April and an increase in May. The peak spawning period for the species is found to be November-February and hence the low 'K_n' values obtained during November-December and February could be associated with the spawning activities of the species.

Mean 'K_n' values for *S. isarankurai* in relation to different size groups of males ranging in length from 72 to 127 mm and females from 72 to 132 mm are plotted in Fig. 5.17. It is seen that in both sexes the values were low in 72 and 77 mm size groups. It showed an increase in 82 mm and dropped in the next size group (87 mm). Fish in the 72 and 77 mm size groups were found immature and the gradual increase in the 82 mm might be due to building up of fat before maturation and the dip in the value in 87 mm could be due to spawning stress of the fish. This length is close to 83 mm, the length at which the species attains 50% sexual maturity. Above 87 mm, the values fluctuated in both sexes. In males, peak values were noticed at 102, 117 and 127 mm and low values at 112 mm and 122 mm. Similarly, females showed high values at 92, 107, 117 and 132 mm and low values at 97, 112, and 127 mm. These peaks and troughs in the larger size groups might be related to later maturation and breeding cycle of the species.

Monthly distribution of mean 'K_n' values for males and females are presented in Fig. 5.18. It can be seen that, in males the values were high in November-December, which fell in January. It showed an increase in February-March and dropped to the lowest in April and attained another peak in May. In females, the value was highest in November and showed a decline in December-January, followed by a slight increase in February. Thereafter it showed a gradual decrease reaching the lowest in April and again a rise in May.

The rise in 'K_n' values in both sexes in November-December and again in February-March might be due to the preponderance of fish with ripe gonads and the fall in the values in the subsequent months might be due to loss in weight of gonads as a result of spawning.

The variations in condition of fish are mainly due to reproductive cycle, food intake or other unknown factors. Thompson (1943) reported that the high and low condition in the plaice, *Pleuronectes platessa* are observed before and after spawning. Qasim (1957) was of the view that the increase and decrease in the condition of shanny, *Blennius pholis* may be due to general building up and loss of reserves respectively. In the present observation also the high and low condition in all the three species correspond to spawning cycle of the species. Hickling (1930) and Hart (1946) have shown that the variation in 'K' is related to the attainment of first maturity. Hart (1946) observed that the fall in the condition factor is due to the onset of maturity and stated that the point of inflexion on the curve showing diminution of 'K' indicates the length at which sexual maturity is attained. In the present study the inflexion in the 'Kn' values in the three species relates to attainment of sexual maturity. The observations on the 'Kn' values of the three species corroborate the inference drawn from the study on the length at maturity and spawning season of the respective species.

SEX RATIO

A study on the sex-ratio distribution of fish in different months or seasons may help in estimating stock size by fecundity method. A knowledge on this is also useful in determining whether there is sexual segregation and consequently to know whether the fishing removes one sex or the other selectively.

In the three species of *Saurida* studied, the sex of adults cannot be determined by the external morphological characters. However, in *S. tumbil* from the East-China and Yellow Seas, Matsubara and Iwai (1951), Okada and Kyushin (1955) and Liu and Tung (1959) have observed that the second dorsal fin ray in males above 150 mm in standard length is prolonged and this character is related to size and maturity of the fish. But in the present observation no such differentiation in the length of second dorsal fin ray has been noticed. Rao (1983) has also not observed any difference in the second dorsal fin ray of *S. tumbil* from Visakhapatnam. Nevertheless, females can be differentiated from males during the spawning season by the bulging belly due to the fully developed ovaries.

The sexes were determined by opening the body cavity and inspecting the gonads. Monthwise data for the two fishing seasons, November-May of 1989-90 and1990-91 were used. For length-wise sex ratio study, data were distributed at 10 mm class intervals for the larger species of *S. tumbil* and *S. undosquamis* and at 5 mm class interval for the smaller growing *S. isarankurai*. The observed ratios were tested against the expected 1:1 ratio by the method of Chi-square.

In *S. tumbil* sexes could be differentiated from 120 mm onwards. Out of 2714 fishes examined, 1004 were males and 1700 females. The male to female ratios for 1989-90 and 1990-91 seasons were 1:1.54 and 1: 1.80 respectively.

The results of homogenity (Chi-square) show that the observed proportion of males in different months of 1989-90, 1990-91 and for the pooled data for two seasons is significant at 5% and 1% levels (Table 5.10).

The analysis of sex ratio in each month during the two seasons separately and for the pooled data of the corresponding months of two seasons are given in Table 5.11. The results indicated a significant departure from 1:1 ratio in November, December and January of 1989-90 season and in all months excepting May in 1990-91. The pooled data for the two seasons showed significant departure in all months except in May. The number of specimens analysed in August and October being insignificant, the results obtained in these months were not taken into consideration. In all cases the significant departure was due to the dominance of females.

The sex ratio analysis in relation to length for the pooled data for the two seasons showed no significant deviation from 1:1 ratio at 5% level upto 259 mm length group (Table 5.12). Significant departure was noticed at 5% in fish of 260 mm and above, upto 360 mm due to predominance of females. Beyond 360 mm all fish observed were females.

In *S. undosquamis* the sex could be differentiated in fish above 80 mm. A total of 2708 fishes was examined for sex ratio analyses, of which, 919 were males and 1789 females. The male to female ratio was 1:1.84 in 1989-90 and 1:2.01 in 1990-91.

The Chi-square test for the proportion of males in the monthly samples during the two seasons separately and the combined data for the two seasons (Table 5.13) indicated that the observed proportion of males was statistically significant at 5% and 1% levels in 1989-90, 1990-91 and for the pooled data for two years. The significant departure was due to the dominance of females.

The month-wise analysis indicated a significant deviation from 1:1 ratio at 5% level in all months of observations except in December and March in 1989-90 and in all months in 1990-91 as well as for the pooled data of two seasons (Table 5.14) owing to the dominance of females.

The data on sex ratio in relation to length for the pooled data for the two seasons (Table 5.15) showed that there is no significant variation from the 1:1 ratio in 90-99 mm, 110-119 mm, 160-169 mm and 190-199 mm. Significant departure at 5% level was noticed in size groups 200 mm and above due to preponderance of females. In the larger size groups of 290-299 mm, 300-309 mm and 310-319 mm, only females were represented.

Differentiation of sex in *S. isarankurai* could be made from 55 mm size onwards. Out of 6427 fish examined, 2853 were males and 3574 females (1:1.25). The male to female ratio was 1:2.15 and 1:1.09 in 1989-90 and 1990-91 respectively.

The homogenity test for the proportion of males in the monthly samples during 1989-90 and 1990-91 and for the combined data for two seasons (Table 5.16) indicated that the observed proportion of males was significant at 5% and 1% levels due to the dominance of females.

The analysis of sex ratio in each month showed a significant departure from the expected ratio of 1:1 in all months of the fishery (November-December and February-May) except in January in 1989-90 (Table 5.17). The variations were due to the dominance of males in November and the predominance of females in the other months. In the second season (Table 5.17) it was significant in December and March-May. The departure was due to the dominance of females in December, April-May and males in March. However, the pooled data (Table 5.17) gave results of significant deviation in all months except January. In all cases the departure at 5% level was due to dominance of females except in November, when males outnumbered females.

Sex ratio analysed for lengthwise distribution (Table 5.18) showed no significant departure in 55-59 mm, 60-64 mm, 70-74 mm, 75-79 mm and 85-89 mm size groups. In the size groups above 90 mm and upto 130 mm significant deviation was noticed. While the variation in 80-84 mm, 105-109 mm and 110-114 mm was due to the preponderance of males, in all other groups the deviation was due to the dominance of females. All specimens observed above 130 mm size were found to be females.

Yamada (1968) reported a very large female:male ratio in *S. tumbil* collected from the coast of Chinese Mainland indicating female dominance. However, he observed that the ratio was almost 1:1 when the population consisted of fish measuring less than 20 cm. Liu and Tung (1959) recorded excess of males in Taiwan Strait except during the spawning season, when females predominated. Tiews *et al.* (1972) observed dominance of males during most of the time in the fishing grounds off Manila Bay and San Miguel Bay. Liu and Yeh (1974) have found unequal sex ratio in *S. tumbil* with females predominating in the larger size groups in the East and South China Seas. One of the reasons attributed for the differential distribution was the slower growth of males. Dighe (1977) observed females to be slightly more than males in the Bombay waters. Budnichenko and Dimitrova (1981) reported the dominance of males over females in the Arabian Sea, the sex ratio approximately being 2:1.

According to Latif and Shenouda (1973) in the Gulf of Suez, the percentage of males of *S. undosquamis* showed decreasing tendency during the spawning season (January - May) of 1965. But in 1966, the percentage showed increasing trend from January to April but dropped to the lowest in May. Out of 19 months of sampling covering the two years, 1965-'66, males were found to be more only in 4 months. Budnichenko and Dimitrova (1981) recorded male dominancy in the spawning population (2:1).

In the present observation, the sex ratios based on the pooled data for the two fishing seasons (1989-90and1990-91) showed a general preponderance of females (6 months out of 7 months of fishery in *S. tumbil*); in all 7 months in *S. undosquamis* and 5 months in *S. isarankurai*). The sex ratio in relation to length showed that females outnumbered males above the size at first maturity length group of 260 mm in *S. tumbil* and 200 mm in *S. undosquamis*. In the case of *S. isarankurai*, males were more in the minimum size at first maturity length group of 80-84 mm. Above this length, females were found to be dominant upto 130 mm except in size groups, 105-109 mm and 110-114 mm.

In the sizes of above 370 mm in *S. tumbil*, 290 mm in *S. undosquamis* and 135 mm in *S. isarankurai* all fish were found to be invariably females.

FECUNDITY

Knowledge on the fecundity is important in the determination of spawning potential of fish stocks and fishery management. The fecundity study helps in comparing different stocks, and the relationship between fecundity and length or weight of fish is useful in estimating the fecundity of known length or weight of fish. For purpose of estimating stock size from fecundity it is more convenient to use data for average fecundity at each length groups (Holt, 1958). Fecundity is defined as the number of ripening eggs in the ovary just before the next spawning. Accordingly, in the present study fecundity was estimated by counting all mature ova and the relationship between fecundity and body length, body weight and ovary-weight was studied.

A total of 117 mature fishes of *S. tumbil* ranging from 223 mm to 458 mm in total length (TL), 75-795 g body weight, 3.054-52.080 g ovary weight was utilised for the fecundity study. Fecundity varied between 33,998 ova (237 mm) to 3,07,923 ova (458 mm) (Table 5.19). The smallest fish of 223 mm had 40,211 ova. It is observed that generally the fecundity increased with growth in length and weight of fish and ovary weight.

The relationship between fecundity and these parameters is worked out and the equations are given below:

Relation between fish length (L) and fecundity (F), (Fig. 5.19).

$$\text{Log } F = -2.15653 + 2.840726 \log L, (r^2 = 0.894697)$$

Relation between fish weight (W) and fecundity, (Fig. 5.20)

$$\text{Log } F = 2.799168 + 0.903263 \log W, (r^2 = 0.869873)$$

Relation between ovary weight (OW) and fecundity, (Fig. 5.21).

$$\text{Log } F = 4.133336 + 0.783762 \log OW, (r^2 = 0.832301)$$

The fecundity of 83 specimens of *S. undosquamis* ranging in size between 178 mm and 316 mm (TL); 45-232 g body weight and 2.465-12.413 g ovary weight were used. Fecundity varied from 32,529 (178 mm) to 1,91,924 ova (316 mm) (Table 5.20). Generally, the fecundity showed increasing tendency with increment in length, weight and ovary weight of fish. The regression between fecundity and length, weight and ovary weight of fish was calculated and graphically represented.

The regression equation for the relationship of length of fish (L) and fecundity (F) can be expressed as: (Fig. 5.22).

$$\text{Log } F = -1.93548 + 2.874139 \log L, (r^2 = 0.9244178)$$

The relationship between weight of fish (W) and fecundity (F) is: (Fig. 5.23)

$$\text{Log } F = 2.918659 + 0.979487 \log W, (r^2 = 0.918269)$$

The regression between ovary weight (OW) and fecundity (F) is : (Fig. 5.24).

$$\text{Log } F = 4.077133 + 1.098949 \log OW, (r^2 = 0.772786)$$

For *S. isarankurai*, the fecundity was estimated from 197 specimens of the size ranging between 80 mm and 136 mm (TL). The minimum body weight was 2.3 g and the maximum body weight being 16.87 g. The gonad weight ranged from 0.176 g to 0.909 g. The fecundity varied from 3,003 ova (84.3 mm) to 15,069 ova (136 mm) (Table 5.21). The fecundity generally increased with increase in size of fish. Regression between fecundity and fish length, fish weight and ovary weight is presented in Fig. 5.25, 5.26 and 5.27 respectively.

The equation derived for fish length (L) and fecundity (F) is:

$$\text{Log } F = -1.87594 + 2.786928 \log L, (r^2 = 0.941881)$$

The expression for weight of fish (W) and fecundity is:

$$\text{Log } F = 3.138745 + 0.814420 \log W, (r^2 = 0.947419)$$

The relationship between ovary weight (OW) and fecundity (F) can be expressed as:

$$\text{Log } F = 1.833804 + 0.753637 \log OW, (r^2 = 0.850633)$$

In fish, which spawns in batches, the estimation of fecundity is difficult (Qasim and Qayyam, 1963). Fecundity varies in the same species in different periods or under different environmental conditions (Hickling, 1940 and Nikolskii, 1965). Fecundity has been shown to increase as square of length of fish (Clark, 1934) or as cube of length (Simpson, 1951; Bagenal, 1957; Sarojini, 1957; Pillay, 1958 and Varghese, 1961 and 1976) or a fourth power of length (Farran, 1938) or more than the fourth power of length (Varghese, 1976 and 1980). In the present study the exponential values in the length-fecundity relation (2.84 in *S. tumbil*, 2.87 in *S. undosquamis* and 2.79 in *S. isarankurai*) showed that fecundity in all the three species increased at a rate closer to the cube of their length. These exponential values were found to be lower than that values from length-weight relation (3.0179 in *S. tumbil*, 3.0926 in *S. undosquamis* and 3.2232 in *S. isarankurai*). This suggests that in these species, the fecundity increased at a lower rate than the rate of increase of body weight in relation to length.

The regression co-efficient for the fecundity and body weight relationship was 0.903,0.98 and 0.81 for *S. tumbil, S. undosquamis* and *S. isarankurai* respectively. This shows that the rate of egg production in relation to weight of fish is much lower than that of length of fish. Also, it is evident that the relationship between the fecundity and body weight in these three species is similar.

The exponential values of the ovary weight and fecundity relation for the three species (0.78 for *S. tumbil*, 1.1 for *S. undosquamis* and 0.75 for *S. isarankurai*) show that the relationship among them is almost similar.

It is seen that in all three species, the fecundity of the oldest fishes is apparently large indicating that these species do not become senile, a condition associated with reduced production of eggs (Nikolskii, 1963 and 1965).

Based on a limited fecundity study of 25 ovaries of *S. tumbil* from the Philippine waters, Tiews *et al.* (1972) reported that fish from 22 to 36 cm in fork length (FL) had on an average 28,000 eggs and a clear relationship between fecundity and length could not be possible. Liu and Yeh (1974) showed that the fecundity of *S. tumbil* in the East China Sea and Taiwan Strait, increased as the fourth power of length and as cube of length in the northern part of the South China Sea and Gulf of Tonkin. According to Budnichenko and Dimitrova (1981), *S. tumbil* from the Arabian Sea, having a FL of 26-38 cm and weight of 155-455 g had vitelline oocytes ranging from 92,900 to 1,90,900. Rao (1983) estimated 37,569 to 2,14,981 eggs for fish in the size range of 290 to 430 mm TL in the western part of Bay of Bengal.

Latif and Shenouda (1973) have found wide range of fecundity for a given length of *S. undosquamis* from the Gulf of Suez and the average fecundity showed a straight line relationship showing increase of fecundity with increase in length and weight of fish. According to Budinchenko and Dimitrova (1981) for the Arabian Sea population of *S. undosquamis*, the number of oocytes varied from 1,99,000 to 4,72,000 in fish measuring 26-42 cm in FL and weighing

229-729 and the fecundity showed an increase with corresponding increase in body length and weight. Rao (1981) estimated 16,542 to 78,942 ova in *S. undosquamis* of size ranging between 25.7 to 32.0 cm in TL from the northwestern part of Bay of Bengal.

Table 5.1: Monthly percentage occurrence of males of *S. tumbli* in different stages of maturity

Stages of maturity		I		II		III		IV		V		VI		VIIa		VIIb	
Month	No. of fish	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No/	%	No.	%
Nov.	53	2	3.77	6	11.32	4	7.55	14	26.32	21	39.62	3	5.66	1	1.89	2	3.77
Dec.	90	15	16.67	1	1.11	4	4.44	23	25.56	28	31.11	4	4.44	1	1.11	14	15.56
Jan.	102	26	25.49	2	1.96	2	1.96	32	31.37	7	6.86	-	-	13	12.75	20	19.61
Feb.	244	158	64.75	42	17.21	8	3.28	3	1.23	1	0.41	-	-	1	0.41	31	12.70
Mar.	151	78	51.65	30	19.87	4	2.65	-	-	-	-	-	-	2	1.32	37	24.50
Apr.	153	59	38.56	21	13.73	10	6.53	-	-	-	-	-	-	-	-	63	41.18
May	140	25	17.86	15	10.71	6	4.29	-	-	-	-	-	-	2	1.43	92	65.71
Aug.	2	-	-	-	-	1	50.00	1	50.00	-	-	-	-	-	-	-	-
Oct.	2	-	-	-	-	-	-	-	-	-	-	2	100	-	-	-	-

Table 5.2: Monthly percentage occurrence of females of *S. tumbli* in different stages of maturity

Stages of maturity		I		II		III		IV		V		VI		VIIa		VIIb	
Month	No. of fish	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No/	%	No.	%
Nov.	213	-	-	45	21.13	17	7.98	34	15.96	62	29.11	19	8.92	11	5.16	25	11.74
Dec.	360	27	7.50	15	4.17	26	7.22	170	47.22	41	11.39	9	2.50	10	2.78	62	17.22
Jan.	224	50	22.32	3	1.33	6	2.68	40	17.86	6	2.68	1	0.45	10	4.46	108	48.21
Feb.	338	167	49.41	75	22.19	1	0.30	2	0.59	3	0.88	-	-	1	0.30	89	26.33
Mar.	200	-	-	29	14.50	85	42.50	-	-	-	-	-	-	-	-	86	43.00
Apr.	204	39	19.12	94	46.08	3	1.47	-	-	-	-	-	-	-	-	68	33.33
May	129	13	10.08	42	32.56	1	0.77	-	-	-	-	-	-	-	-	73	56.59
Aug.	1	-	-	1	(100)	-	-	-	-	-	-	-	-	-	-	-	-

Table 5.3: Monthly percentage occurrence of males of *S. undosquamis* in different stages of maturity

Stages of maturity		I		II		III		IV		V		VI		VIIa		VIIb	
Month	No. of fish	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Nov.	29	-	-	-	-	1	3.45	21	72.41	4	13.79	1	3.45	-	-	2	6.90
Dec.	123	-	-	2	1.63	-	-	26	21.14	39	31.71	5	4.06	13	10.57	38	30.89
Jan.	197	20	10.15	1	0.51	7	3.55	59	29.95	27	13.71	4	2.03	30	15.23	49	24.87
Feb.	202	50	24.75	15	7.43	12	5.94	45	22.28	10	4.95	2	0.99	6	2.97	62	30.69
Mar.	146	37	25.34	5	3.42	8	5.48	12	8.22	10	6.85	1	0.68	12	8.22	61	41.78
Apr.	132	43	32.58	16	12.12	11	8.33	4	3.03	-	-	-	-	-	-	58	43.94
May	54	33	61.11	2	3.70	7	12.96	-	-	-	-	-	-	-	-	12	22.22
Aug.	1	1	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 5.4: Monthly percentage occurrence of females of *S. undosquamis* in different stages of maturity

Stages of maturity		I		II		III		IV		V		VI		VIIa		VIIb	
Month	No. of fish	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Nov.	78	2	2.56	9	11.54	9	11.54	30	38.46	8	10.26	-	-	15	19.23	5	6.41
Dec.	205	5	2.44	13	6.34	8	3.90	90	43.90	23	11.22	14	6.83	6	2.93	46	22.44
Jan.	405	43	10.62	23	5.68	3	0.74	136	33.58	41	10.12	5	1.23	26	6.42	128	31.60
Feb.	346	122	35.26	68	19.65	7	2.02	85	24.57	14	4.04	1	0.29	6	1.73	43	12.43
Mar.	274	54	19.71	132	48.18	4	1.46	41	14.96	8	2.92	1	0.36	-	-	34	12.41
Apr.	292	108	36.98	170	58.22	3	1.03	3	1.03	-	-	-	-	-	-	8	2.74
May	159	101	63.52	49	30.82	-	-	1	0.63	-	-	-	-	-	-	8	5.03
Aug.	1	1	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 5.5: Monthly percentage occurrence of males of *S. isarankurai* in different stages of maturity

Stages of maturity		I		II		III		IV		V		VI		VIIa		VIIb	
Month	No. of fish	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Nov.	14	-	-	-	-	2	14.28	3	21.43	9	64.29	-	-	-	-	-	-
Dec.	441	-	-	1	0.23	-	-	147	33.33	254	57.60	16	3.63	17	3.85	6	1.36
Jan.	448	24	5.36	9	2.01	8	1.79	216	48.21	166	37.05	1	0.22	9	2.01	15	3.35
Feb.	713	22	3.08	28	3.93	68	9.54	314	44.04	232	32.54	12	1.68	-	-	37	5.19
Mar.	516	6	1.16	6	1.16	69	13.37	243	47.09	178	34.50	3	0.58	-	-	11	2.13
Apr.	362	22	6.08	31	8.56	47	12.98	103	28.45	77	21.27	-	-	9	2.49	73	20.17
May	80	-	-	1	1.25	-	-	1	1.25	-	-	-	-	-	-	78	97.50

Table 5.6: Monthly percentage occurrence of females of *S. isarankurai* in different stages of maturity

Stages of maturity		I		II		III		IV		V		VI		VIIa		VIIb	
Month	No. of fish	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Nov.	9	-	-	-	-	1	1.11	3	33.33	5	55.56	-	-	-	-	-	-
Dec.	623	-	-	5	0.80	1	0.16	191	30.66	354	56.82	49	7.87	10	1.61	13	2.09
Jan.	449	36	8.02	16	3.56	6	1.34	203	45.21	155	34.52	4	0.89	19	4.23	10	2.23
Feb.	836	35	4.19	51	6.10	52	6.22	379	45.33	256	30.62	13	1.56	2	0.24	48	5.74
Mar.	640	27	4.22	38	5.94	49	7.66	288	45.00	216	33.75	5	0.78	3	0.47	14	2.19
Apr.	661	47	7.11	20	3.02	15	2.27	178	26.93	122	18.46	5	0.76	12	1.82	262	39.64
May	197	1	0.51	1	0.51	1	0.51	-	-	1	0.51	-	-	-	-	193	97.97

Table 5.7: Ratio of the number of ripe eggs to the total number of eggs of *S. tumbil*

Length (mm)	Fecundity	No. of ripe eggs	No. of times of spawning
266	68,553	24,523	2.80
283	70,358	14,658	4.80
364	1,90,870	49,163	3.88

Table 5.8: Ratio of the number of ripe eggs to the total number of eggs of *S. undosquamis*

Length (mm)	Fecundity	No. of ripe eggs	No. of times of spawning
178	32,529	13,035	2.50
188	50,119	9,954	5.04
192	38,423	12,430	3.09
212	59,138	19,536	3.03
214	55,714	9,371	5.95
220	74,215	12,707	5.84
221	78,864	14,931	5.28
235	86,558	17,737	4.88
245	56.133	18,978	2.96

Table 5.9: Ratio of the number of ripe eggs to the total number of eggs of *S. isarankurai*

Length (mm)	Fecundity	No. of ripe eggs	No. of times of spawning
90	3,806	1.530	2.49
92	6,155	3,006	2.05
107	5,067	1,953	2.59
110	6,981	3,239	2.16
112	8,318	2,377	3.50
112	8,146	3,122	2.61
114	7,150	2,834	2.52
117	8,379	3,436	2.44
118	9,402	2,515	3.74
120	8,000	2,167	3.69
120	8,715	3,011	2.89
121	9,787	4,677	2.09
123	10,603	3,627	2.92
124	11,660	3,848	3.03
126	14,189	4,080	3.48
128	10,082	2,022	4.99

Table 5.10: Chi-square test for proportion of males in the monthly samples of *S. tumbil* during 1989-90 and 1990-91

Year	D.F.	Chi-square value	Significant at 5%	Significant at 1%
1989-90	7	97.44	S	S
1990-91	7	82.56	S	S
1989-91 (pooled)	8	153.44	S	S

Table 5.11: Monthly distribution of sex-ratio and chi-square test in *S. tumbil* during 1989-90; 1990-91 and pooled for 1989-91

Month	No. of specimens	Males	Females	Sex-ratio	Proportion of males	Chi-square	Significant or not at 5% level	D.F.
1989-90								
Nov.	167	18	149	1 : 8.28	0.1078	102.7605	S	1
Dec.	53	16	37	1 : 2.31	0.3019	8.3208	S	1
Jan.	115	32	83	1 : 2.59	0.2783	22.6174	S	1
Feb.	290	140	150	1 : 1.07	0.4828	0.3448	NS	1
Mar.	125	64	61	1 : 0.95	0.5120	0.1072	NS	1
Apr.	142	66	76	1 : 1.15	0.4648	0.7042	NS	1
May	78	45	33	1 : 0.73	0.5769	1.8462	NS	1
Aug	3	2	1	1 : 0.50	0.6667	0.3333	NS	1
	973	383	590	1 : 1.54	0.3936	44.0380		
1990-91								
Nov.	102	37	65	1 : 1.76	0.3627	7.6863	S	1
Dec.	409	77	332	1 : 4.31	0.1883	158.9853	S	1
Jan.	232	78	154	1 : 1.97	0.3362	24.8966	S	1
Feb.	332	137	195	1 : 1.42	0.4127	10.1325	S	1
Mar.	234	92	142	1 : 1.54	0.3932	10.6838	S	1
Apr.	235	100	135	1 : 1.35	0.4255	5.2128	S	1
May	198	99	99	1 : 1	0.5	0.0	NS	1
Oct	2	2	0	1 : 0	1.0000	1.0000	-	-
	1744	622	1122	1 : 1.80	0.3567	143.3486		
1989-90 and 1990-91 (Pooled)								
Nov.	269	55	214	1 : 3.89	0.2045	93.9814	S	1
Dec.	462	93	369	1 : 3.97	0.2013	164.8831	S	1
Jan.	347	110	237	1 : 2.15	0.3170	46.4813	S	1
Feb.	622	277	345	1 : 1.25	0.4453	7.4341	S	1
Mar.	359	156	203	1 : 1.30	0.4345	6.1532	S	1
Apr.	377	166	211	1 : 1.27	0.4403	5.3714	S	1
May	276	144	132	1 : 0.92	0.5217	0.5217	NS	1
Aug.	3	2	1	1 : 0.50	0.6667	0.333	NS	1
Oct.	2	2	0	1 : 0	1.0000	0.0	-	-
	2717	1005	1712	1 : 1.70	0.3699	183.9709		

NS = Not significant; S = Significant

Table 5.12: Length-wise distribution of sex-ratio and chi-square test in *S. turnbii*

Size group (mm)	No. of specimens	Males	Females	Sex-ratio	Chi-square	Significant or not at 5% level	D.F.
120-129	6	5	1	1 : 0.2	2.6667	NS	1
130-139	8	2	6	1: 3.0	2.0000	NS	1
140-149	24	8	16	1: 2.0	2.6667	NS	1
150-159	34	18	16	1: 0.88	0.1176	NS	1
160-169	60	32	28	1: 0.88	0.2667	NS	1
170-179	76	36	40	1: 1.11	0.2105	NS	1
180-189	85	45	40	1: 0.89	0.2941	NS	1
190-199	98	55	43	1: 0.78	0.7347	NS	1
200-209	100	53	47	1: 0.89	0.3600	NS	1
210-219	99	54	45	1: 0.83	0.8182	NS	1
220-229	132	63	69	1: 1.10	0.2727	NS	1
230-239	183	86	97	1: 1.13	0.6612	NS	1
240-249	248	118	130	1: 1.10	0.5806	NS	1
250-259	235	109	126	1 : 1.16	1.2298	NS	1
260-269	245	100	145	1 : 1.45	8.2653	S	1
270-279	225	64	161	1 : 2.52	41.8178	S	1
280-289	195	60	135	1 : 2.25	28.8462	S	1
290-299	130	33	97	1 : 2.94	31.5077	S	1
300-309	103	28	75	1 : 2.68	21.4466	S	1
310-319	109	22	87	1 : 3.95	38.7615	S	1
320-329	65	4	61	1 : 15.25	49.9846	S	1
330-339	57	4	53	1 : 13.25	42.1228	S	1
340-349	62	2	60	1 : 30.00	54.2581	S	1
350-359	30	1	29	1 : 29.00	26.1333	S	1
360-369	25	1	24	1 : 24.00	21.16000	S	1
370-379	28	-	28				
380-389	17	-	17				
390-399	15	-	15				
400-409	5	-	5				
410-419	5	-	5				
420-429	4	-	4				
430-439	3	-	3				
440-449	1	-	1				
450-459	2	-	2				

NS = not significant; S = significant

Table 5.14: Monthly distribution of sex-ratio and chi-square test in *S. undosquamis* during 1989-90; 1990-91 and pooled for 1989-91

Month	No. of specimens	Males	Females	Sex-ratio	Proportion of males	Chi-square	Significant or not at 5% level	D.F.
1989-90								
Nov.	38	4	34	1 : 8.50	0.1053	23.6842	S	1
Dec.	137	63	74	1 : 1.17	0.4599	0.8832	NS	1
Jan.	307	81	226	1 : 2.79	0.2638	68.4853	S	1
Feb.	186	73	113	1 : 1.55	0.3925	8.6022	S	1
Mar.	138	60	78	1 : 1.30	0.4348	2.3478	NS	1
Apr.	168	65	103	1 : 1.58	0.3869	8.5952	S	1
May	13	2	11	1 : 5.50	0.1538	6.2308	S	1
	987	348	639	1 : 1.84	0.3526	85.7964		
1990-91								
Nov.	70	25	45	1 : 1.80	0.3571	5.7143	S	1
Dec.	195	62	133	1 : 2.15	0.3179	25.8513	S	1
Jan.	312	125	187	1 : 1.50	0.4006	12.3205	S	1
Feb.	384	143	241	1 : 1.69	0.3724	25.0104	S	1
Mar.	289	90	199	1 : 2.21	0.3114	41.1107	S	1
Apr.	266	71	195	1 : 2.75	0.2669	57.8045	S	1
May	203	54	149	1 : 2.76	0.2660	44.4581	S	1
Aug	2	1	1	1 : 1	0.5000	0.0	-	-
	1721	571	1150	1 : 2.01	0.3318	194.7943		
1989-90 and 1990-91 (Pooled)								
Nov.	108	29	79	1 : 2.72	0.2685	23.1481	S	1
Dec.	332	125	207	1 : 1.66	0.3765	20.2530	S	1
Jan.	619	206	413	1 : 2.01	0.3328	69.2229	S	1
Feb.	570	216	354	1 : 1.64	0.3789	33.4105	S	1
Mar.	427	150	277	1 : 1.85	0.3513	37.7728	S	1
Apr.	434	136	298	1 : 2.19	0.3134	60.4700	S	1
May	216	56	160	1 : 2.86	0.2593	50.0741	S	1
Aug.	2	1	1	1 : 1	0.5000	0.0	NS	1
	2708	919	1789	1 : 1.95	0.3394	279.5052		

Table 5.13: Chi-square test for proportion of males in the monthly samples of *S. undosquamis* during 1989-90 and 1990-91

Year	D.F.	Chi-square value	Significant at 5%	Significant at 1%
1989-90	6	12.59	S	S
1990-91	7	19.61	S	S
1989-91 (pooled)	7	16.40	S	S

Table 5.15: Length-wise distribution of sex-ratio and chi-square test in *S. undosquamis*

Size group (mm)	No. of specimens	Males	Females	Sex-ratio	Chi-square	Significant or not at 5% level	D.F.
90-99	10	2	8	1 : 4.0	3.6	NS	1
100-109	25	6	19	1 : 3.17	6.76	S	1
110-119	44	18	26	1 : 1.44	1.4545	NS	1
120-129	67	22	45	1 : 2.05	7.8955	S	1
130-139	97	27	70	1 : 2.59	19.0619	S	1
140-149	124	50	74	1 : 1.48	4.6452	S	1
150-159	148	53	95	1 : 1.79	11.9189	S	1
160-169	170	74	96	1 : 1.30	2.8471	NS	1
170-179	201	86	115	1 : 1.34	4.1841	S	1
180-189	267	106	161	1 : 1.52	11.3296	S	1
190-199	269	119	150	1 : 1.26	3.5725	NS	1
200-209	267	114	153	1 : 1.34	5.6966	S	1
210-219	247	101	146	1 : 1.45	8.1984	S	1
220-229	197	58	139	1 : 2.40	33.3046	S	1
230-239	173	38	135	1 : 3.55	54.3873	S	1
240-249	122	18	104	1 : 5.78	60.6230	S	1
250-259	116	11	105	1 : 9.55	38.0862	S	1
260-269	78	9	69	1 : 7.67	46.1538	S	1
270-279	39	4	35	1 : 8.75	24.6410	S	1
280-289	24	1	23	1 : 23.00	20.1667	S	1
290-299	11	-	11				
300-309	8	-	8				
310-319	2	-	2				

NS = not significant; S = significant

Table 5.16: Chi-square test for proportion of males in the monthly samples of *S. isarankurai* during 1989-90 and 1990-91

Year	D.F.	Chi-square value	Significant at 5%	Significant at 1%
1989-90	6	149.46	S	S
1990-91	6	65.57	S	S
1989-91 (pooled)	6	91.79	S	S

Table 5.17: Monthly distribution of sex-ratio and chi-square test in *S. isarankurai* during 1989-90, 1990-91 and pooled for 1989-91

Month	No. of specimens	Males	Females	Sex-ratio	Proportion of Males	Chi-Square	Significant or not at 5% level	D.F.
1989-90								
Nov.	73	52	21	1 : 0.40	0.7123	13.1644	S	1
Dec.	56	19	37	1 : 1.95	0.3393	5.7857	S	1
Jan.	14	4	10	1 : 2.50	0.2857	2.5714	NS	1
Feb.	630	266	364	1 : 1.37	0.4222	15.2444	S	1
Mar.	395	89	306	1 : 3.44	0.2253	119.2127	S	1
Apr.	303	44	259	1 : 5.89	0.1452	152.5578	S	1
May	28	2	26	1 : 13.00	0.0714	20.5714	S	1
	1499	476	1023	1 : 2.15	0.3175	199.6057		
1990-91								
Nov.	10	5	5	1 : 1	0.5000	0.	NS	1
Dec.	1089	474	615	1 : 1.30	0.4353	18.2562	S	1
Jan.	890	446	444	1 : 0.99	0.5011	0.0045	NS	1
Feb.	985	491	494	1 : 1.01	0.4985	0.0091	NS	1
Mar.	848	480	368	1 : 0.77	0.5660	14.7925	S	1
Apr.	734	328	406	1 : 1.24	0.4469	8.2888	S	1
May	252	81	171	1 : 2.11	0.3214	32.1429	S	1
	4808	2305	2503	1 : 1.09	0.4794	8.1539		
1989 - 90 & 1990-91 (Pooled)								
Nov.	83	57	26	1 : 0.46	0.6867	11.5783	S	1
Dec.	1145	493	652	1 : 1.32	0.4306	22.0795	S	1
Jan.	904	450	454	1 : 1.01	0.4978	0.0177	NS	1
Feb.	1615	757	858	1 : 1.13	0.4687	6.3164	S	1
Mar.	1243	569	674	1 : 1.18	0.4578	8.8697	S	1
Apr.	1037	372	665	1 : 1.79	0.3587	82.7859	S	1
May	280	83	197	1 : 2.37	0.2964	46.4143	S	1
	6307	2781	3526	1 : 1.27	0.4409	88.0014		

NS = Not significant; S = Significant

Table 5.18: Length-wise distribution of sex-ratio and chi-square test in *S. isarankurai*

Size group	No. of specimens	Males	Females	Sex-ratio	Chi-square	Significant or not at 5% level	D.F.
55	4	1	3	1 : 3.00	1.0000	NS	1
60	17	8	9	1 : 1.13	0.0588	NS	1
65	27	6	21	1 : 3. 5	8.3333	S	1
70	63	29	34	1 : 1.17	0.3968	NS	1
75	186	82	104	1 : 1.27	2.6022	NS	1
80	436	243	193	1 : 0.79	5.7339	S	1
85	644	344	300	1 : 0.87	3.0062	NS	1
90	709	314	395	1 : 1.26	9.2539	S	1
95	629	196	433	1 : 2.21	89.2989	S	1
100	515	217	298	1 : 1.37	12.7398	S	1
105	784	493	291	1 : 0.59	52.0459	S	1
110	934	576	358	1 : 0.62	50.8822	S	1
115	770	269	501	1. : 1.86	69.9013	S	1
120	450	64	386	1 : 6.03	230.4089	S	1
125	199	8	191	1 : 23.88	168.2864	S	1
130	52	3	49	1 : 16.33	40.6923	S	1
135	5	-	5	-	-	-	-
140	3	-	3	-	-	-	-

NS = not significant; S = significant

Table 5.19: Number of mature ova in relation to average length, weight and ovary-weight of *S. tumbil*

Average length (mm)	Average weight (g)	Average ovary-weight (g)	No. of specimens	No. of mature ova
223	75.0	3.054	1	40,211
237	101.5	4.478	2	33,998
241	107.0	6.963	4	42,880
247	114.6	4.941	7	41,931
253	113.0	6.744	2	55,332
257	121.3	5.137	4	39,296
262	135.7	4.448	3	38,327
266	143.8	4.453	4	54,921
271	137.4	6.007	9	68,043
277	156.2	7.959	5	63,477
281	165.5	7.684	6	71,884
287	172.5	8.755	8	75,818
292	185.6	8.614	7	61,517
295	190.0	9.181	1	57,381
302	205.3	7.583	4	66,466
305	219.0	9.452	2	88,772
312	217.5	12.845	6	85,020
317	250.8	9.719	4	82,692
322	252..5	11.917	4	117,322
328	273.0	18.701	2	83,178
332	342.0	13.459	3	87,326
337	305.0	21.053	3	134,745
343	320.5	12.182	4	102,698
346	319.5	14.992	2	132,898
352	310.0	20.260	1	141,820
356	339.0	11.699	3	110,873
364	360.0	46.850	1	190,870
372	368.7	14.413	3	118,916
377	429.0	13.093	1	100,609
385	394.5	22.213	2	193,079
394	425.5	17.175	2	154,986
398	463.5	17.691	2	165,327
416	540.0	10.40	1	158,292
420	580.0	21.066	3	185,353
458	795.0	52.080	1	307,923

Table 5.20: Number of mature ova in relation to average length, weight and ovary-weight of *S. undosquamis*

Average length (mm)	Average weight (g)	Average ovary-weight (g)	No. of specimens	No. of mature ova
178	45.0	4.100	1	32,529
188	58.0	4.778	1	50,119
192	50.0	5.061	1	38,423
195	58.0	2.465	1	41,751
203	63.0	3.884	1	59,647
206	66.3	3.258	3	46,879
212	73.2	4.312	5	51,375
218	80.0	3.644	4	55,914
221	83.2	5.257	6	70,128
227	91.5	4.396	4	65,526
232	94.3	4.973	4	79,171
237	115.0	5.708	5	65,405
242	113.2	5.472	7	85,914
247	120.3	5.955	6	88,177
253	124.6	5.584	3	88,383
256	139.9	6.508	8	105,796
261	129.2	6.856	6	103,804
266	146.0	8.340	2	129,645
272	152.5	4.614	2	85,812
279	160.5	7.823	2	131,905
282	174.8	8.796	5	136,574
287	168.0	10.515	3	150,968
292	188.5	6.678	2	114,667
316	232.0	12.413	1	191,924

Table 5.21: Number of mature ova in relation to average length, weight and ovary-weight of *S. isarankurai*

Average length (mm)	Average weight (g)	Average ovary-weight (g)	No. of specimens	No. of mature ova
80	2.30	0.176	1	3,520
82	2.30	0.108	1	3,284
84	2.77	0.187	6	3,003
87	3.17	0.270	3	3,233
88	3.08	0.152	2	3,530
91	3.79	0.236	6	3,765
92	3.67	0.202	6	4,025
94	4.01	0.308	2	3,697
97	4.42	0.237	7	4,269
98	4.35	0.277	5	4,766
101	4.81	0.303	5	5,530
102	4.71	0.291	4	4,032
104	5.25	0.261	3	5,288
107	6.74	0.455	10	5,595
109	6.61	0.393	6	5,263
110	7.78	0.560	7	7,378
113	7.46	0.530	9	6,455
115	7.88	0.570	12	6.949
117	7.70	0.471	9	7,160
119	8.21	0.591	10	8,535
120	9.21	0.637	20	8,359
123	9.82	0.624	11	8,684
125	9.97	0.576	18	9,101
127	10.55	0.666	10	9,978
128	10.70	0.625	10	10,343
130	11.68	0.804	8	10,785
133	13.03	0.909	3	11,918
134	11.76	0.511	2	10,435
136	16.87	0.851	1	15,069

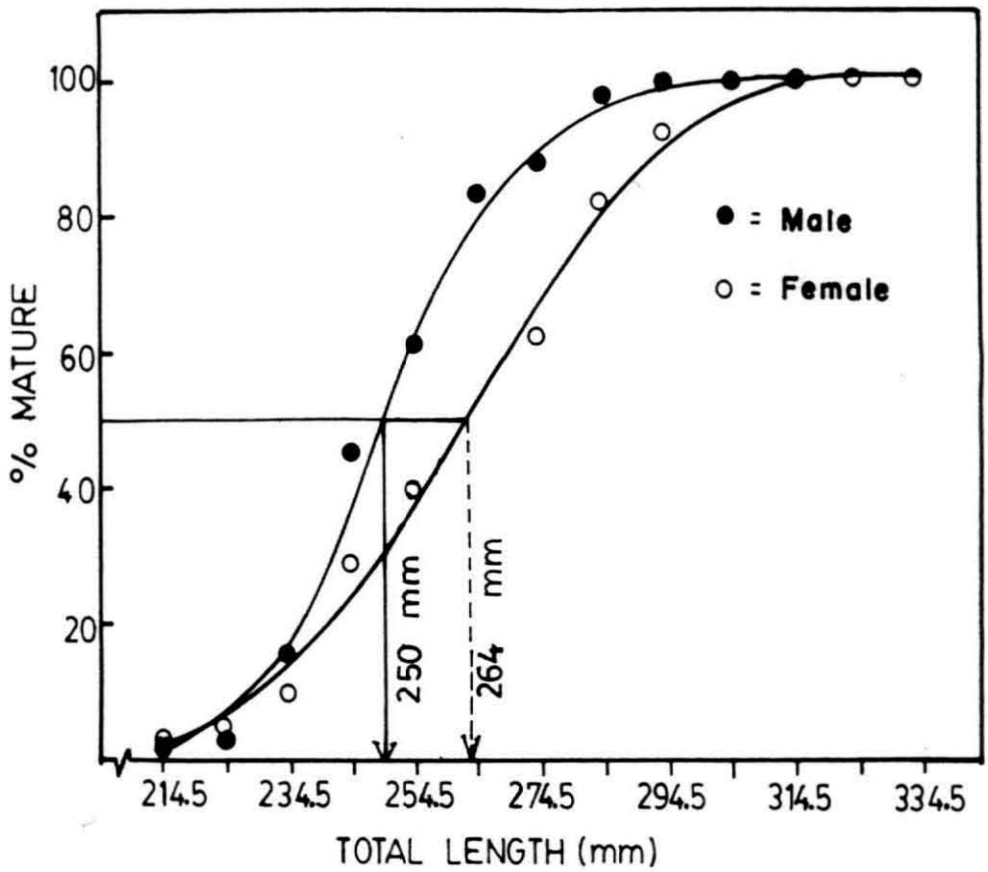

Fig. 5.1 Maturity curve of *S. tumbil.*

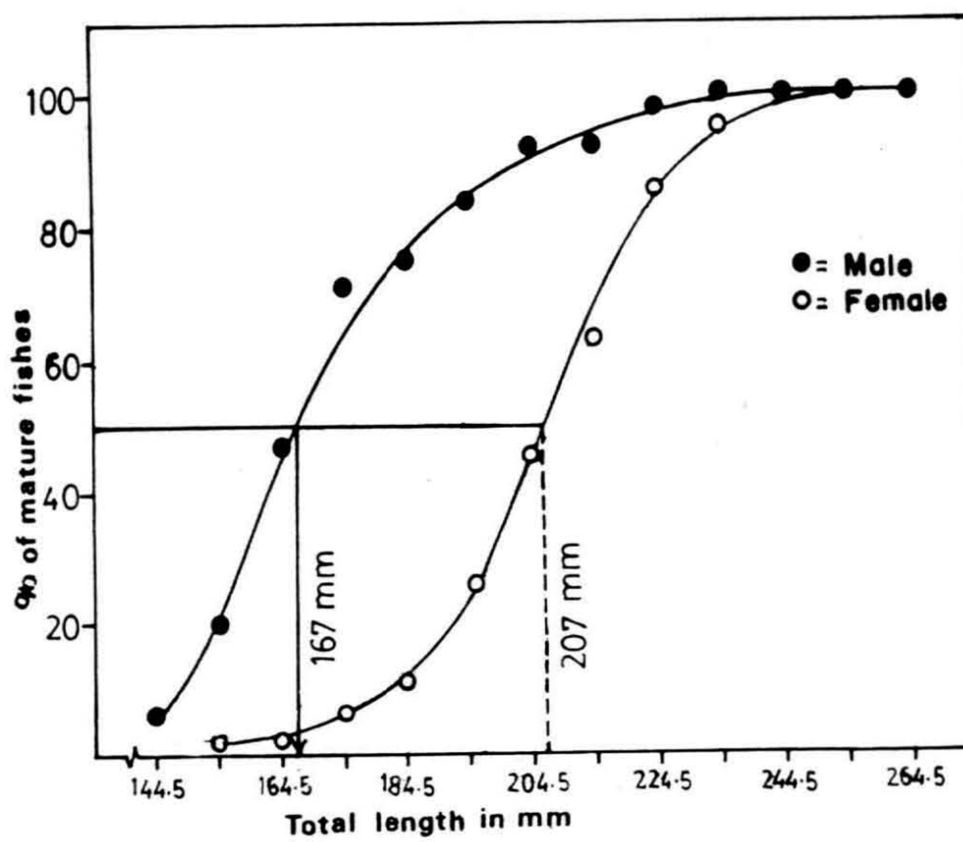

Fig. 5.2 Maturity curve of *S. undosquamis.*

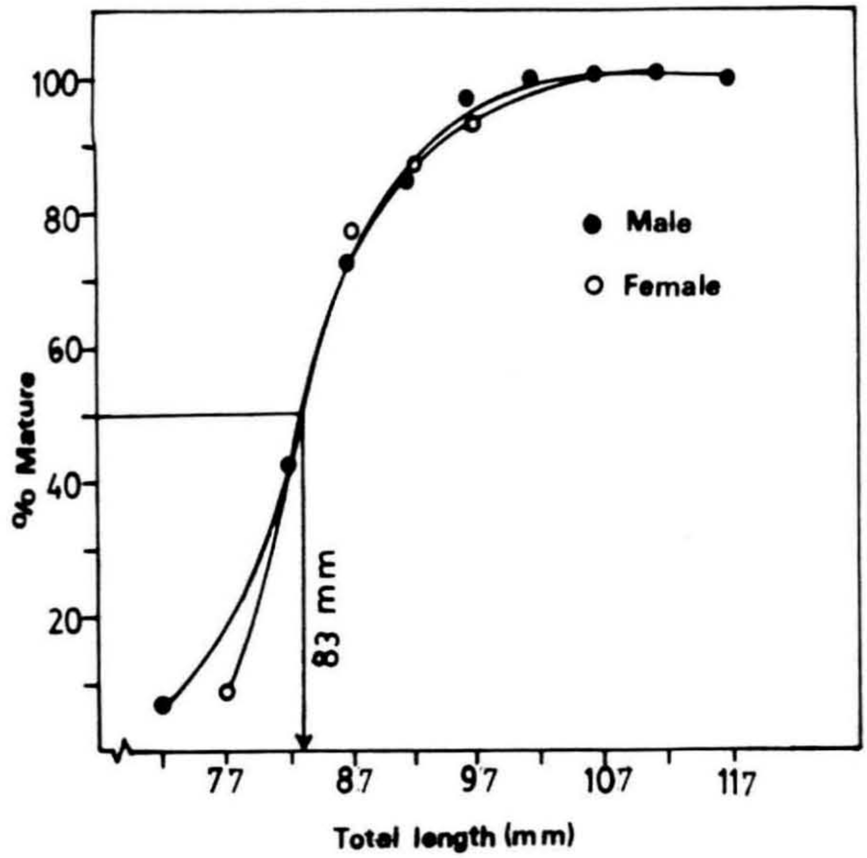

Fig. 5.3 Maturity curve of *S. isarankurai.*

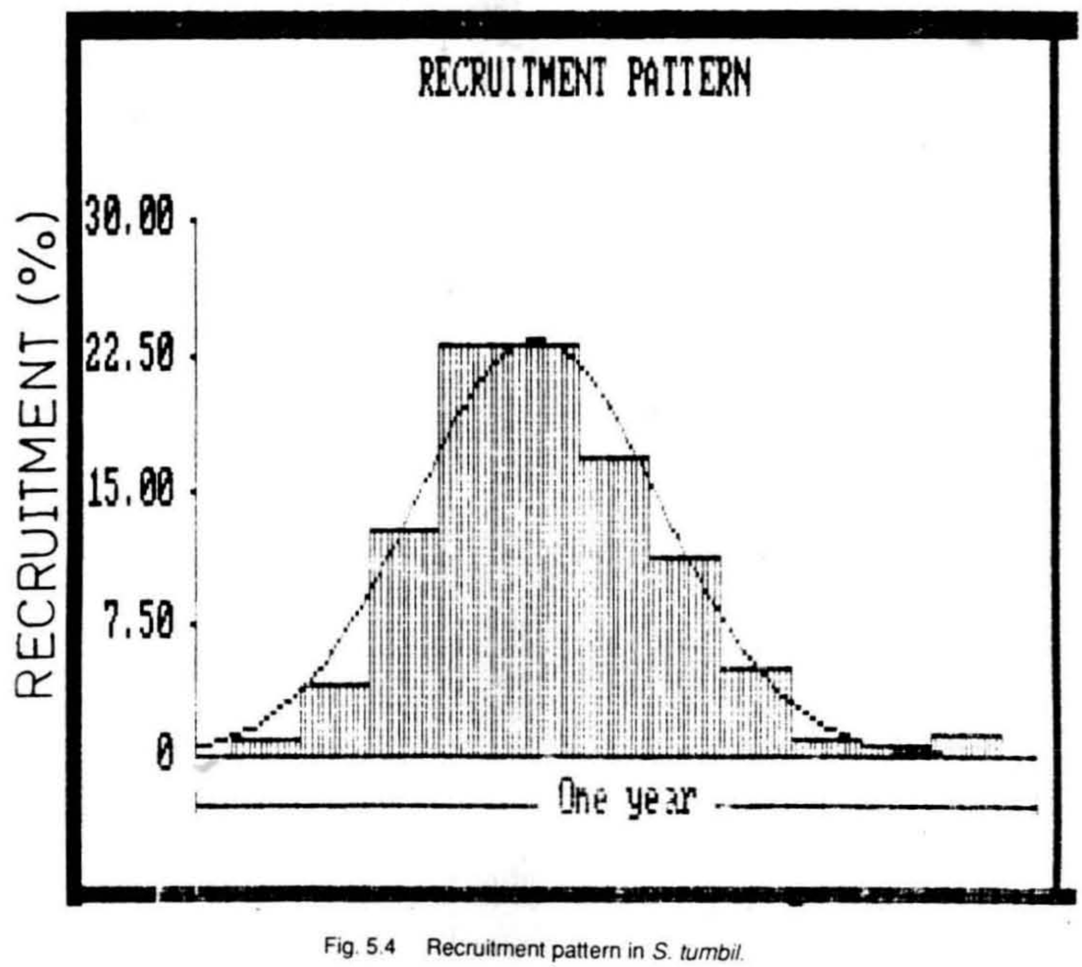

Fig. 5.4 Recruitment pattern in *S. tumbil.*

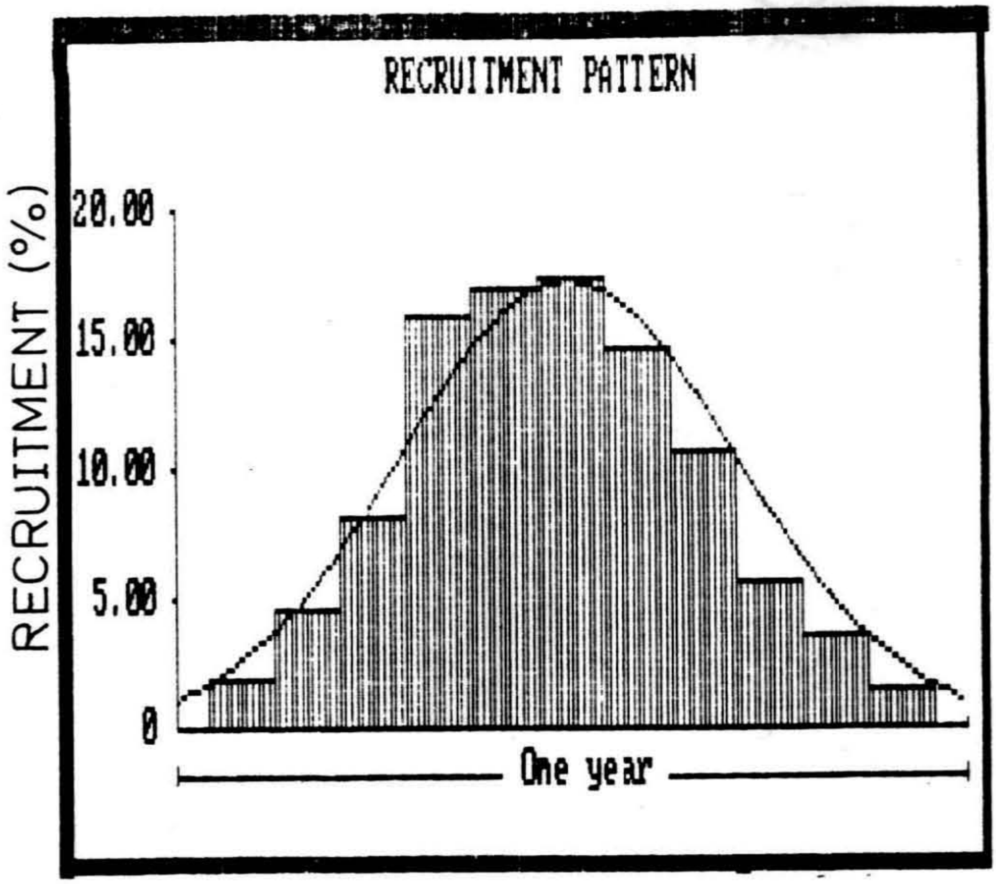

Fig. 5.5 Recruitment pattern in *S. undosquamis.*

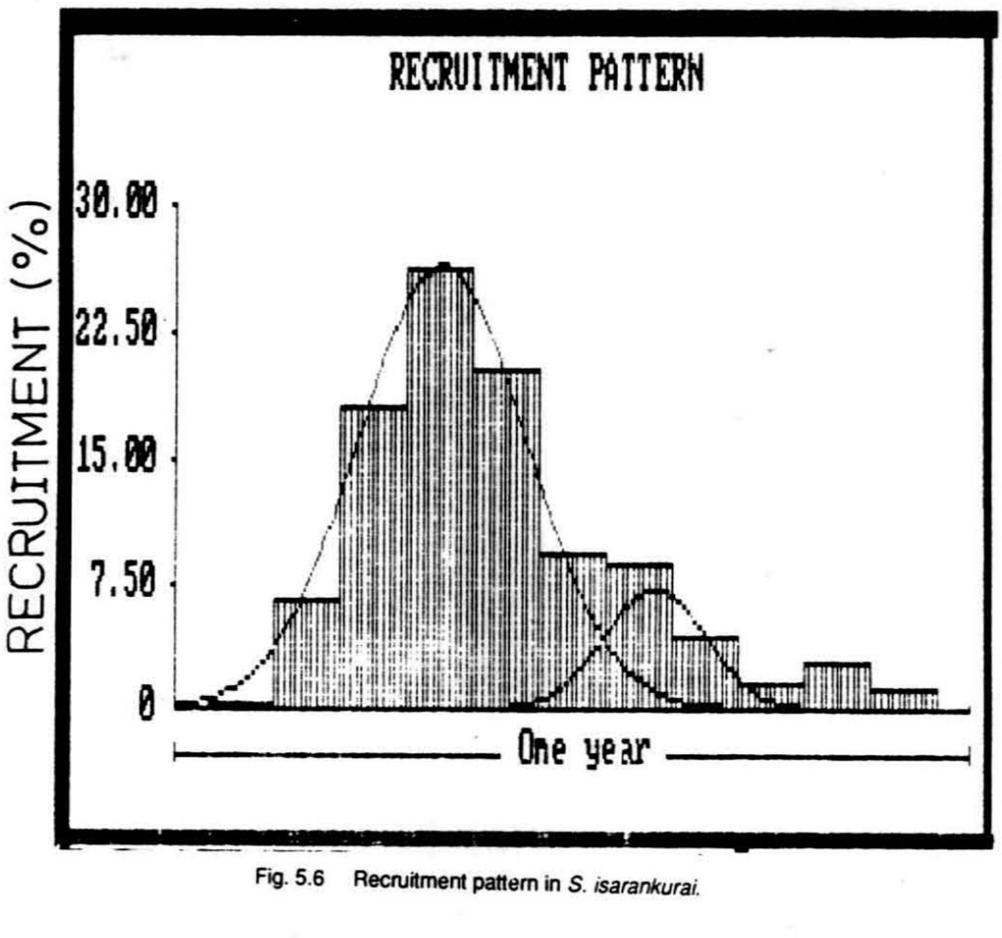

Fig. 5.6 Recruitment pattern in *S. isarankurai.*

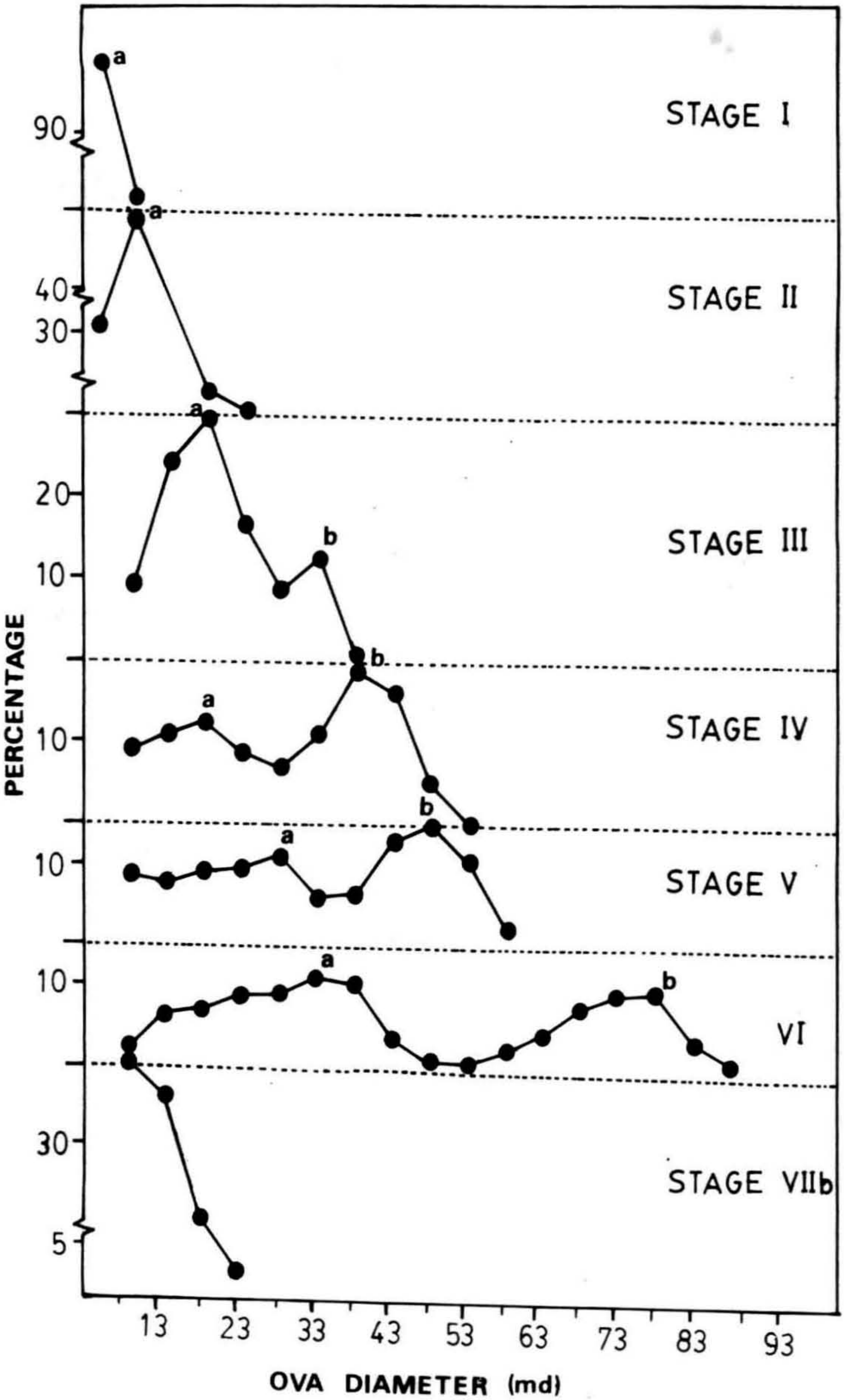

Fig. 5.7 Ova diameter frequency polygons of *S. tumbil* in various stages of maturity (1 md = 0.0137 mm).

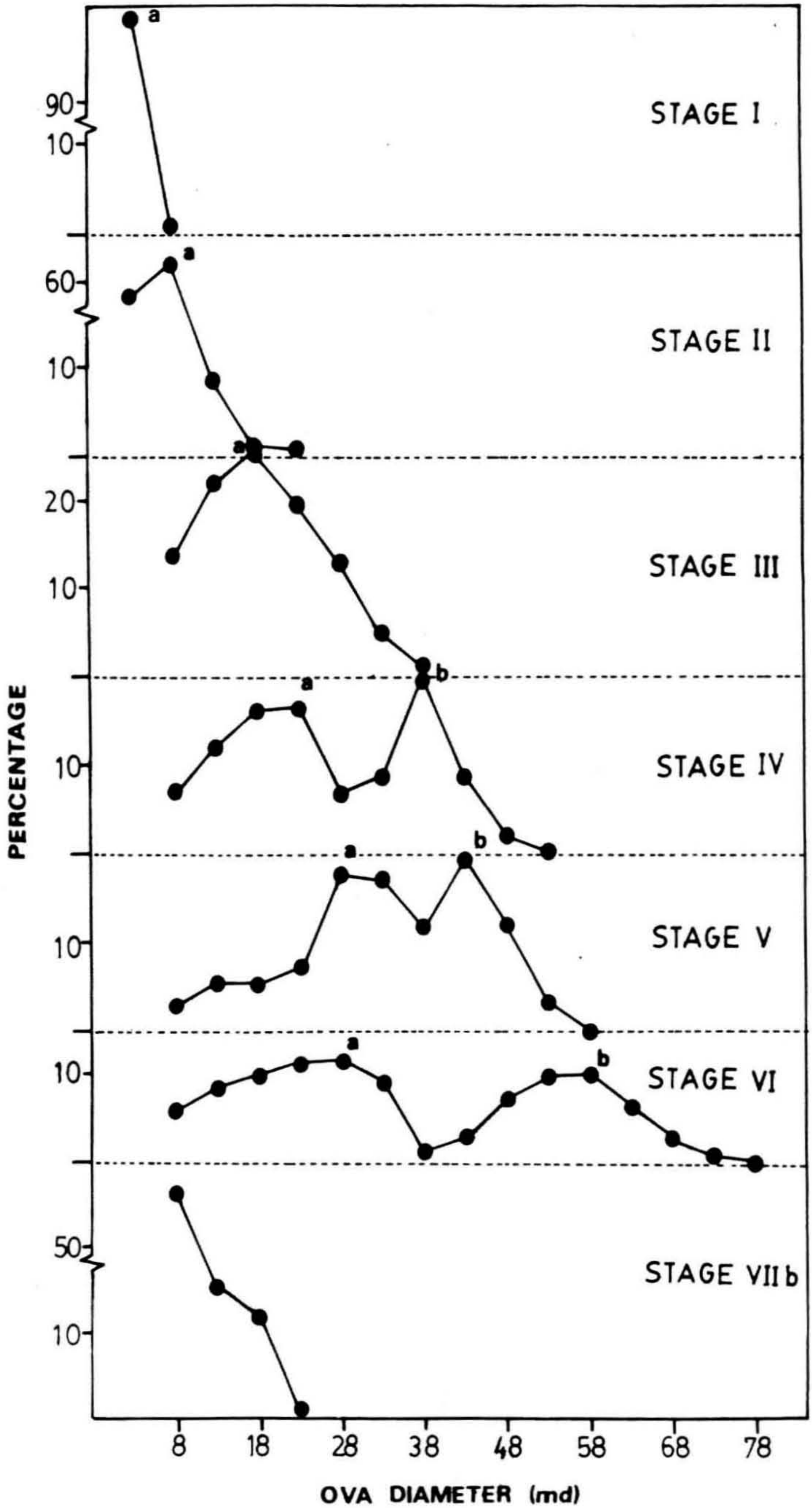

Fig. 5.8 Ova diameter frequency polygons of *S. undosquamis* in various stages of maturity (1 md = 0.0137 mm).

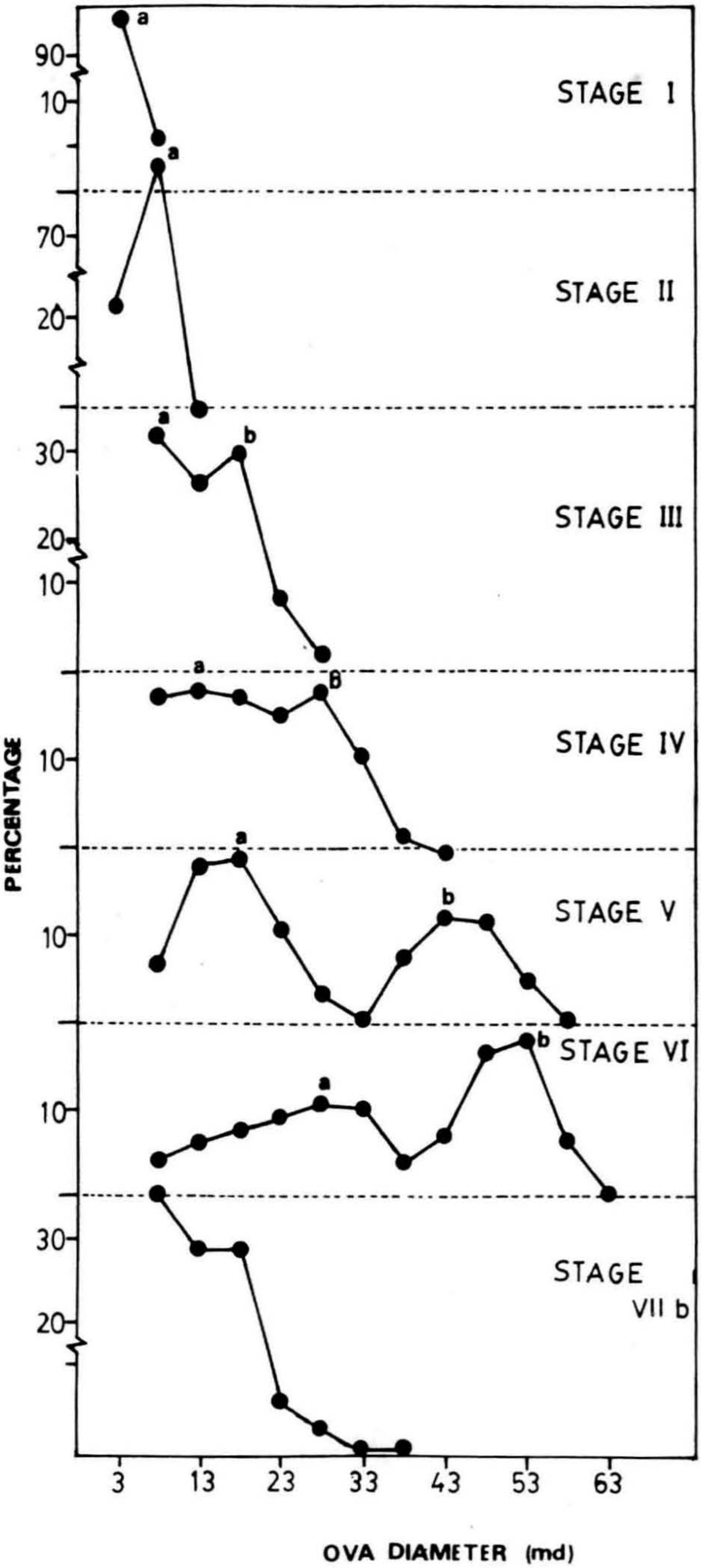

Fig. 5.9 Ova diameter frequency polygons of *S. isarankurai* in various stages of maturity (1 md = 0.0137 mm).

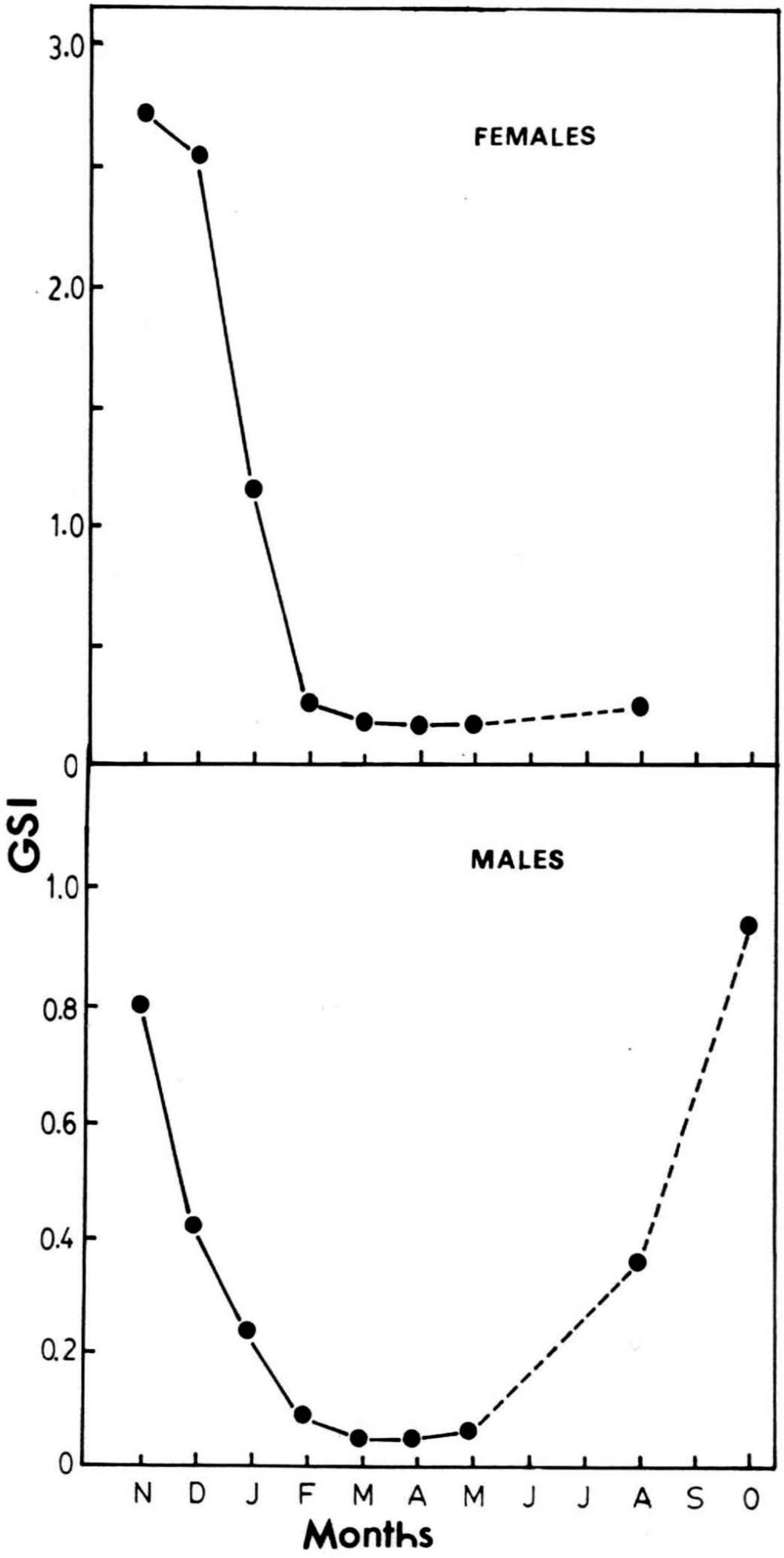

Fig. 5.10 Monthly gonado-somatic indices (GSI) in males and females of *S. tumbil*.

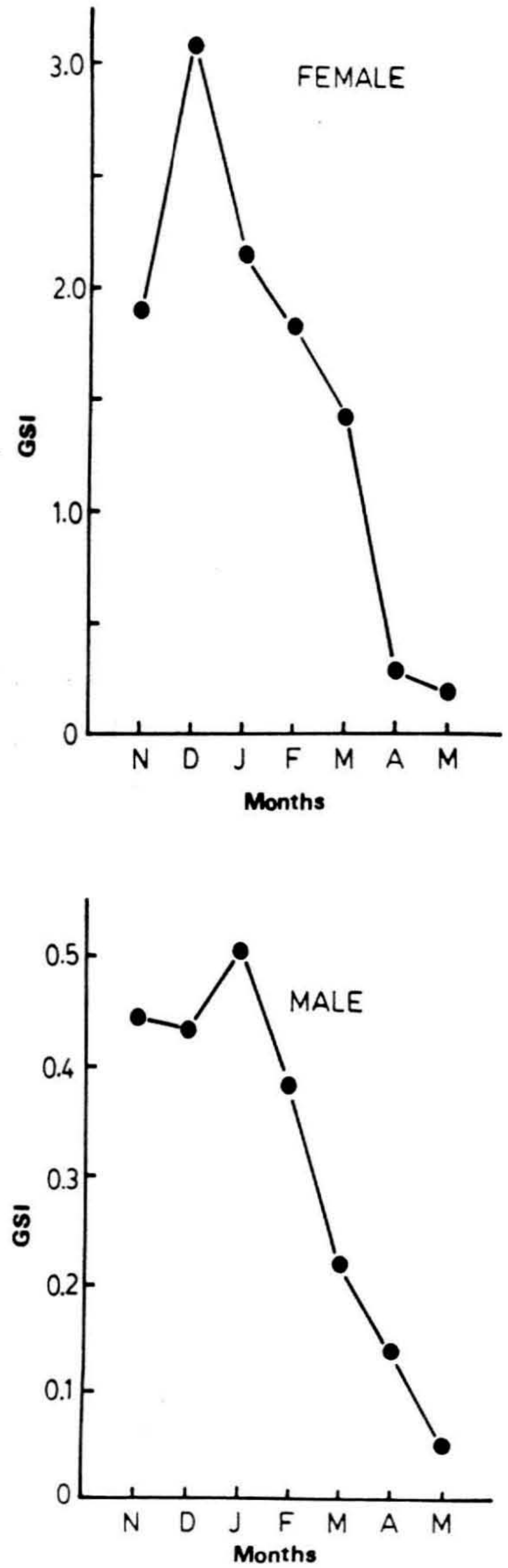

Fig. 5.11 Monthly gonado-somatic indices (GSI) in males and females of *S. undosquamis*.

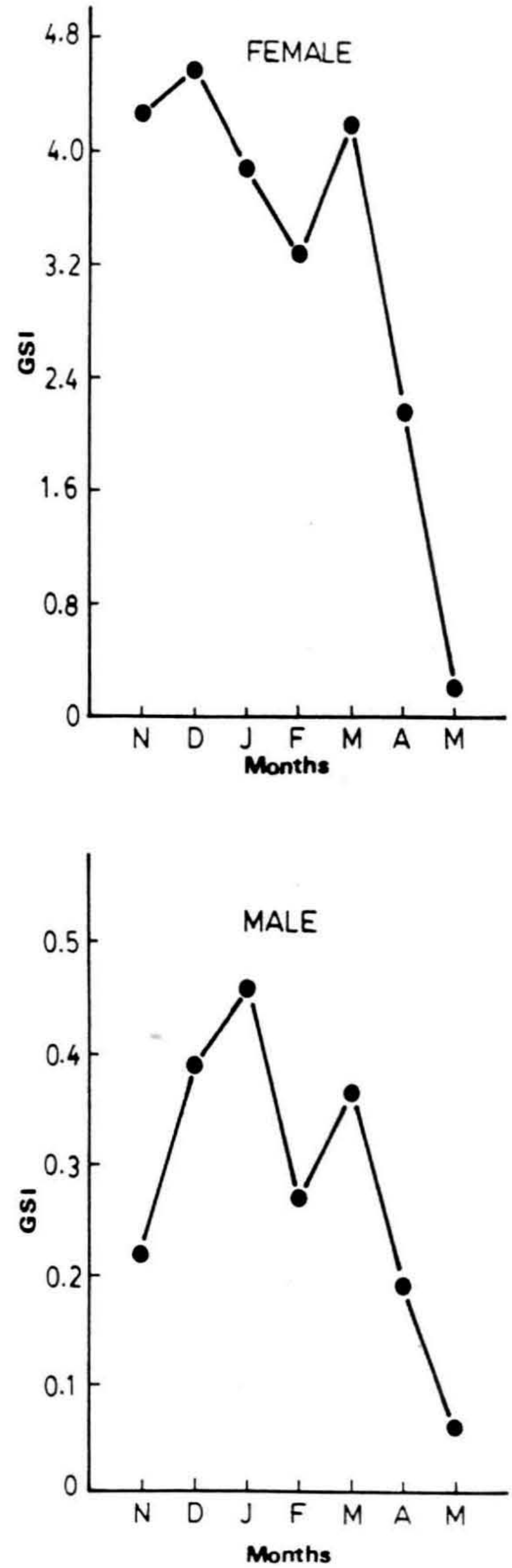

Fig. 5.12 Monthly gonado-somatic indices (GSI) in males and females of *S. isarankurai*.

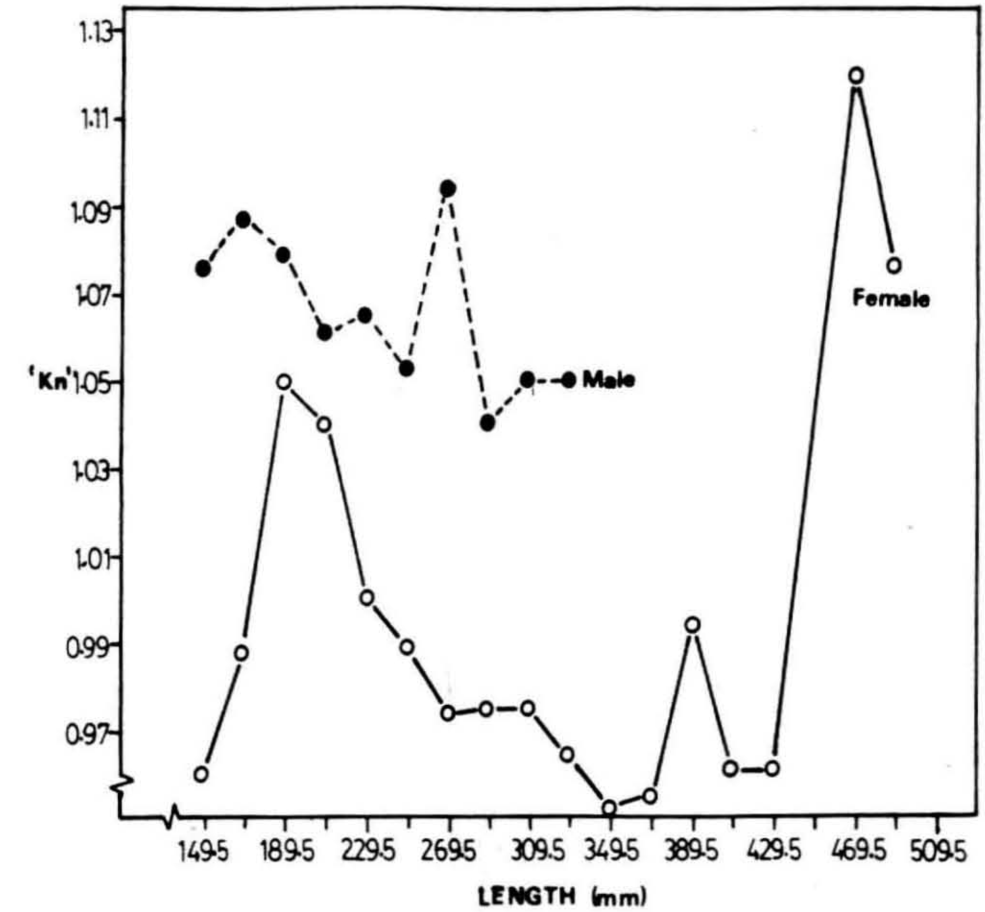

Fig. 5.13 Mean 'Kn' values for males and females of *S. tumbil* at different lengths.

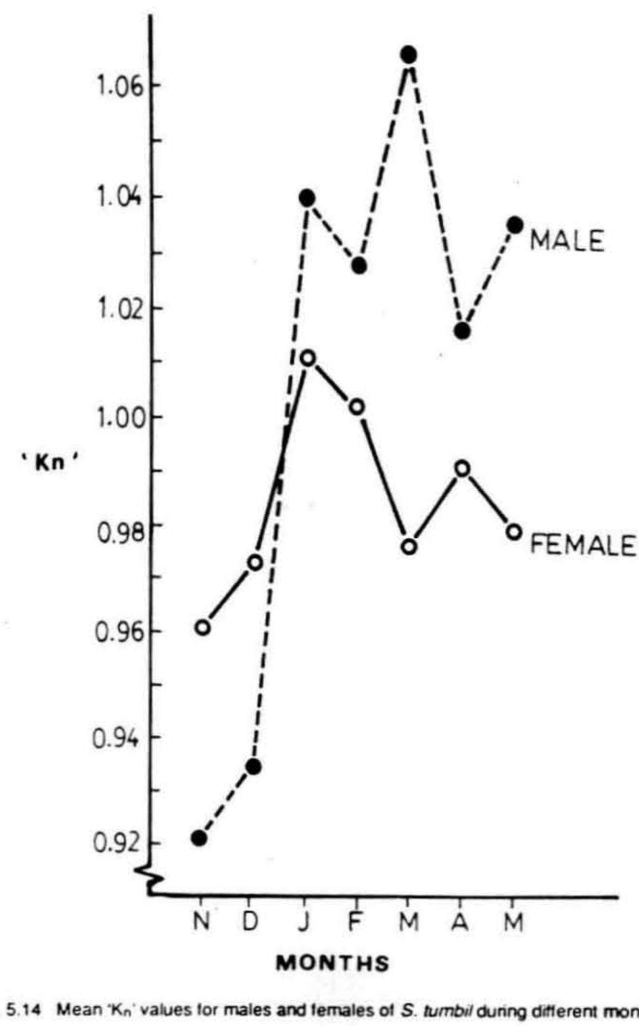

Fig 5.14 Mean 'Kn' values for males and females of *S. tumbil* during different months

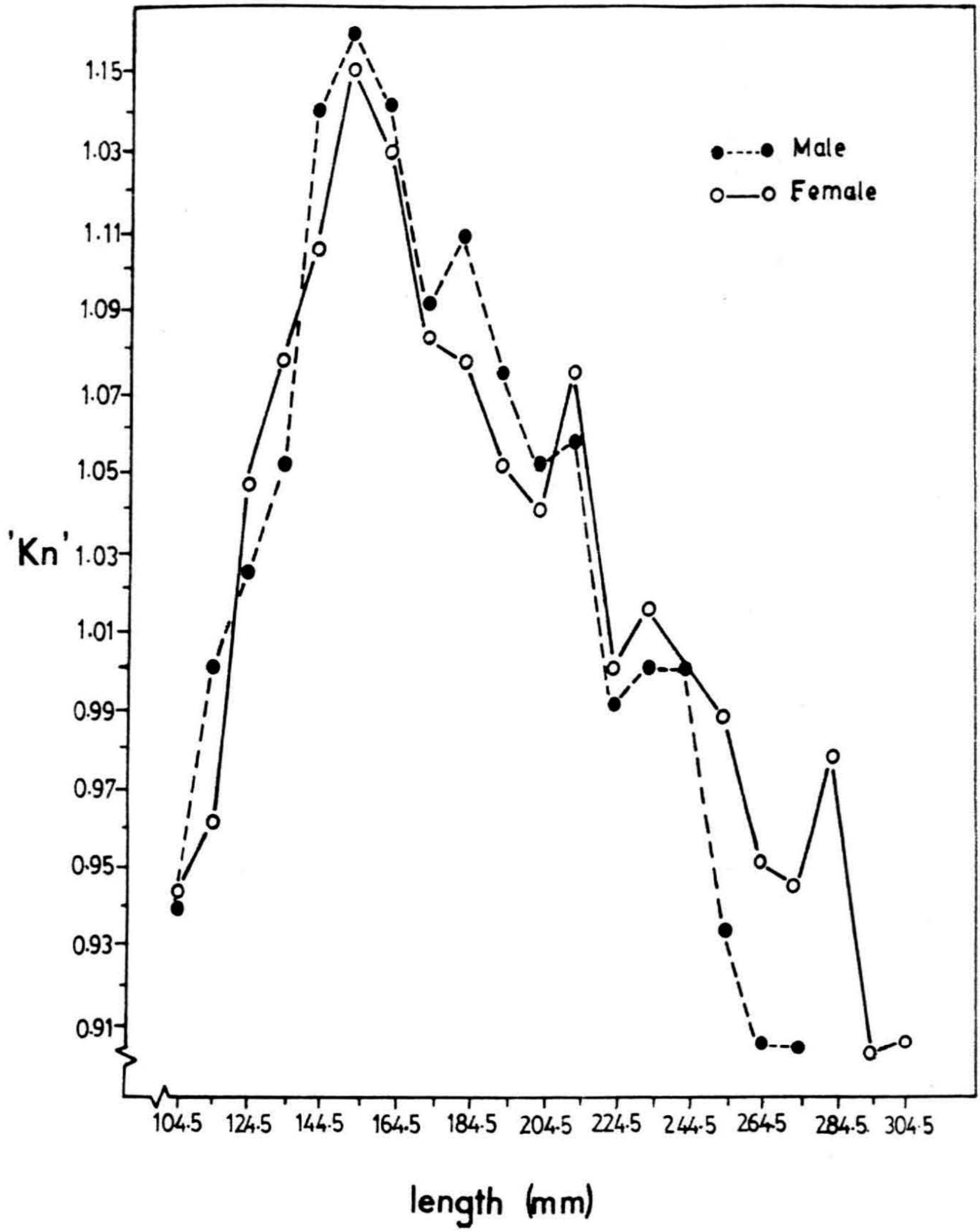

Fig. 5.15 Mean 'K_n' values for males and females of *S. undosquamis* at different lengths.

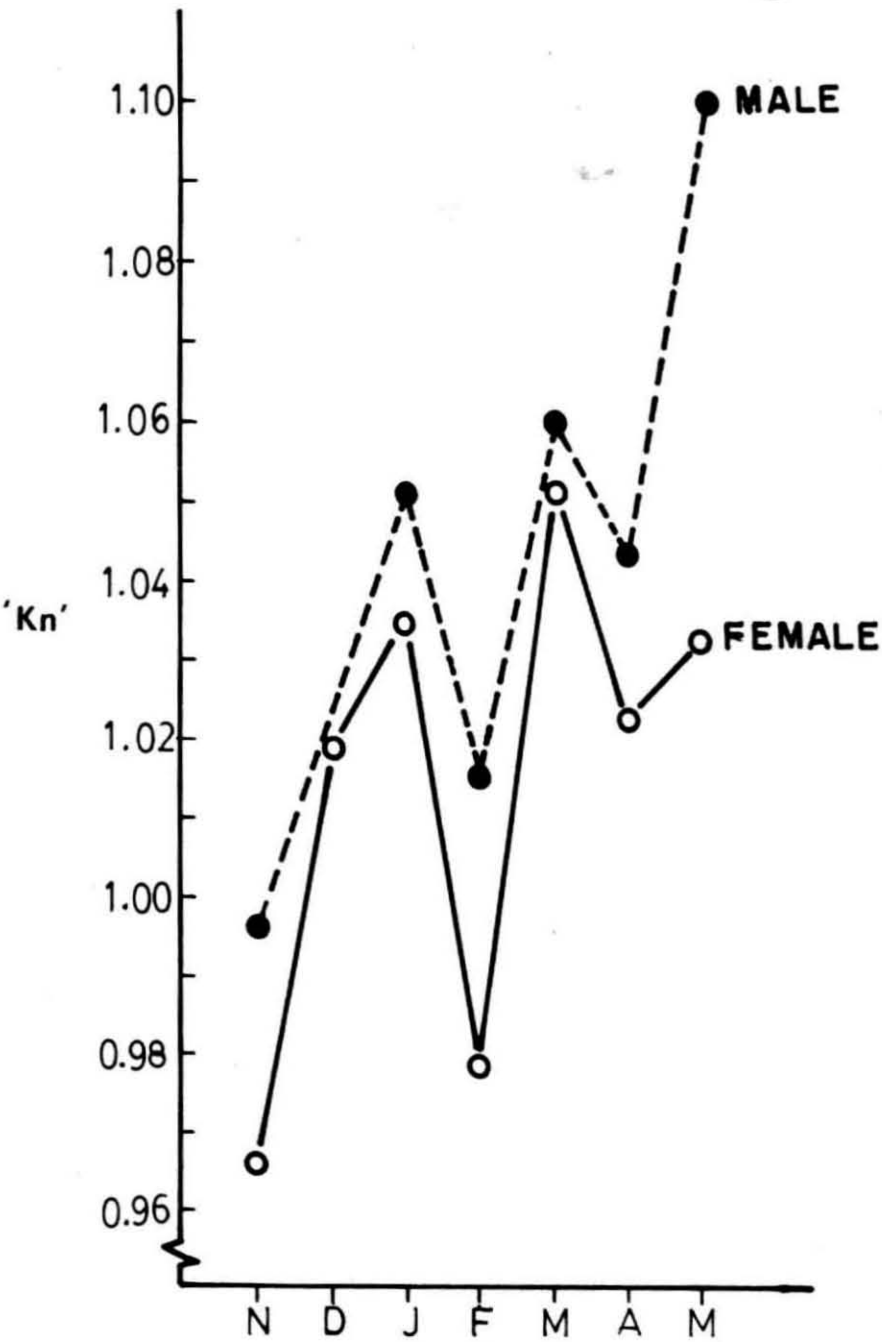

Fig. 5.16 Mean 'K_n' for males and females of *S. undosquamis* during different months.

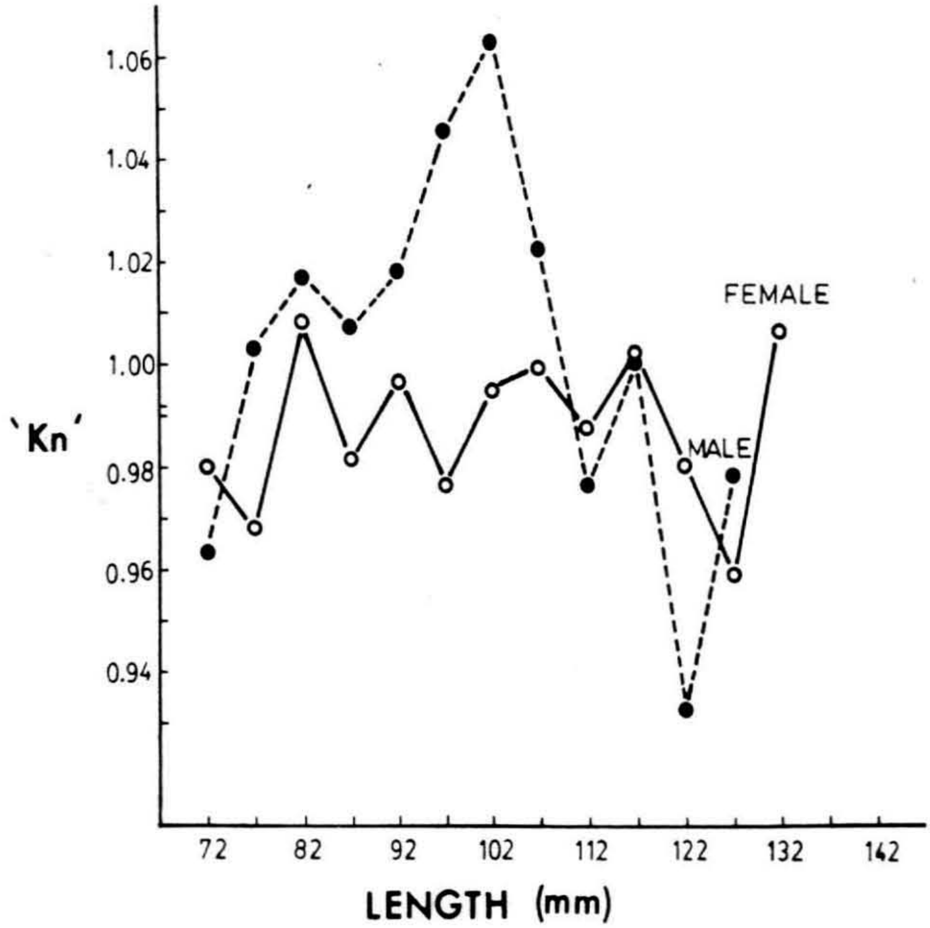

Fig. 5.17 Mean 'K_n' values for males and females of *S. isarankurai* at different lengths.

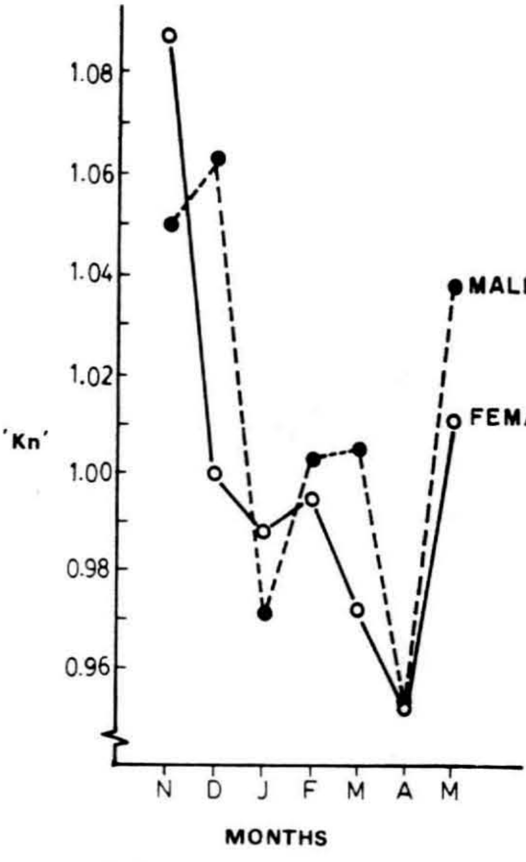

Fig. 5.18 Mean 'K_n' values for males and females of *S. isarankurai* during different months.

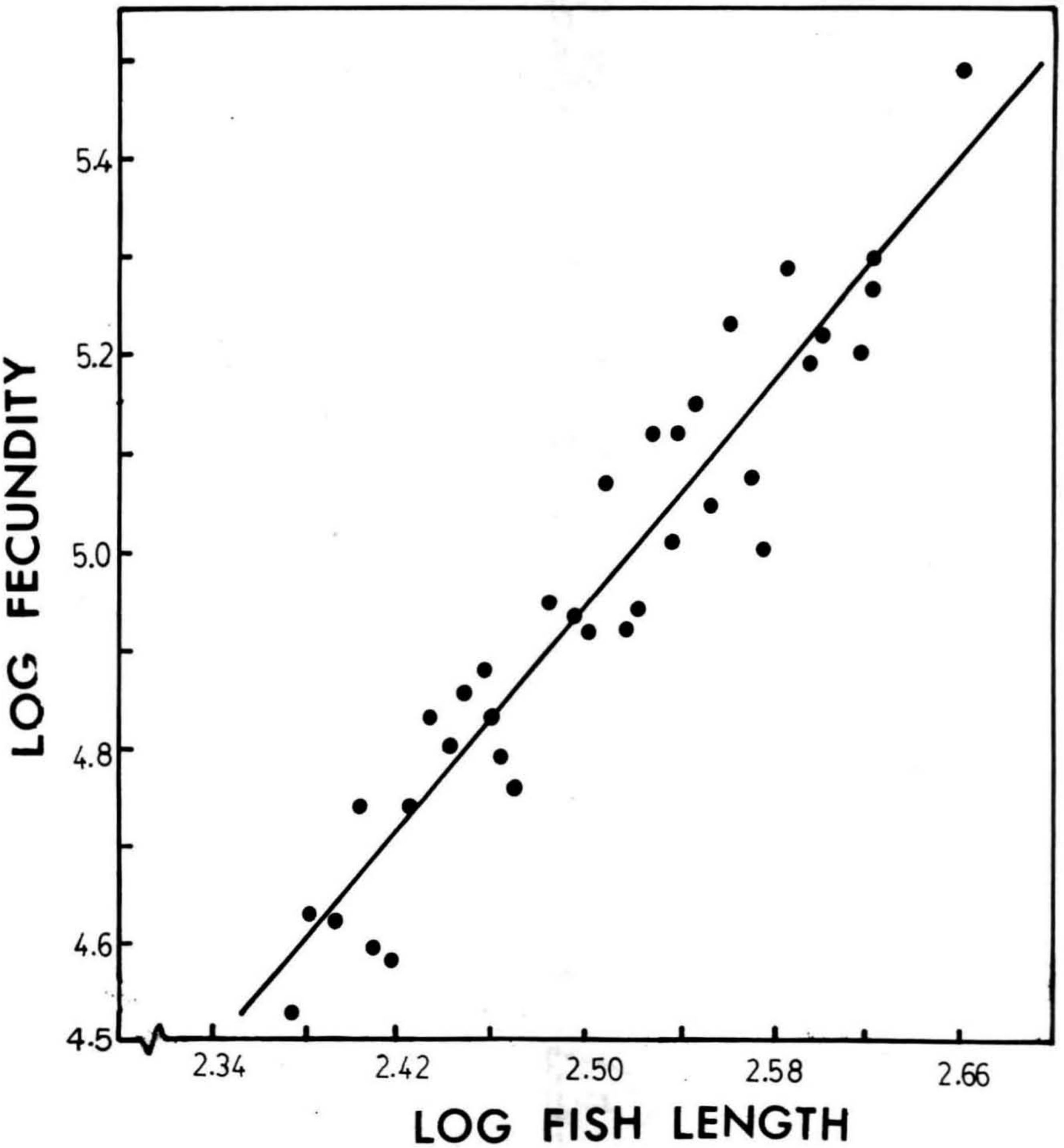

Fig. 5.19 Scattergram of log of fish length against log of fecundity for *S. tumbil*.

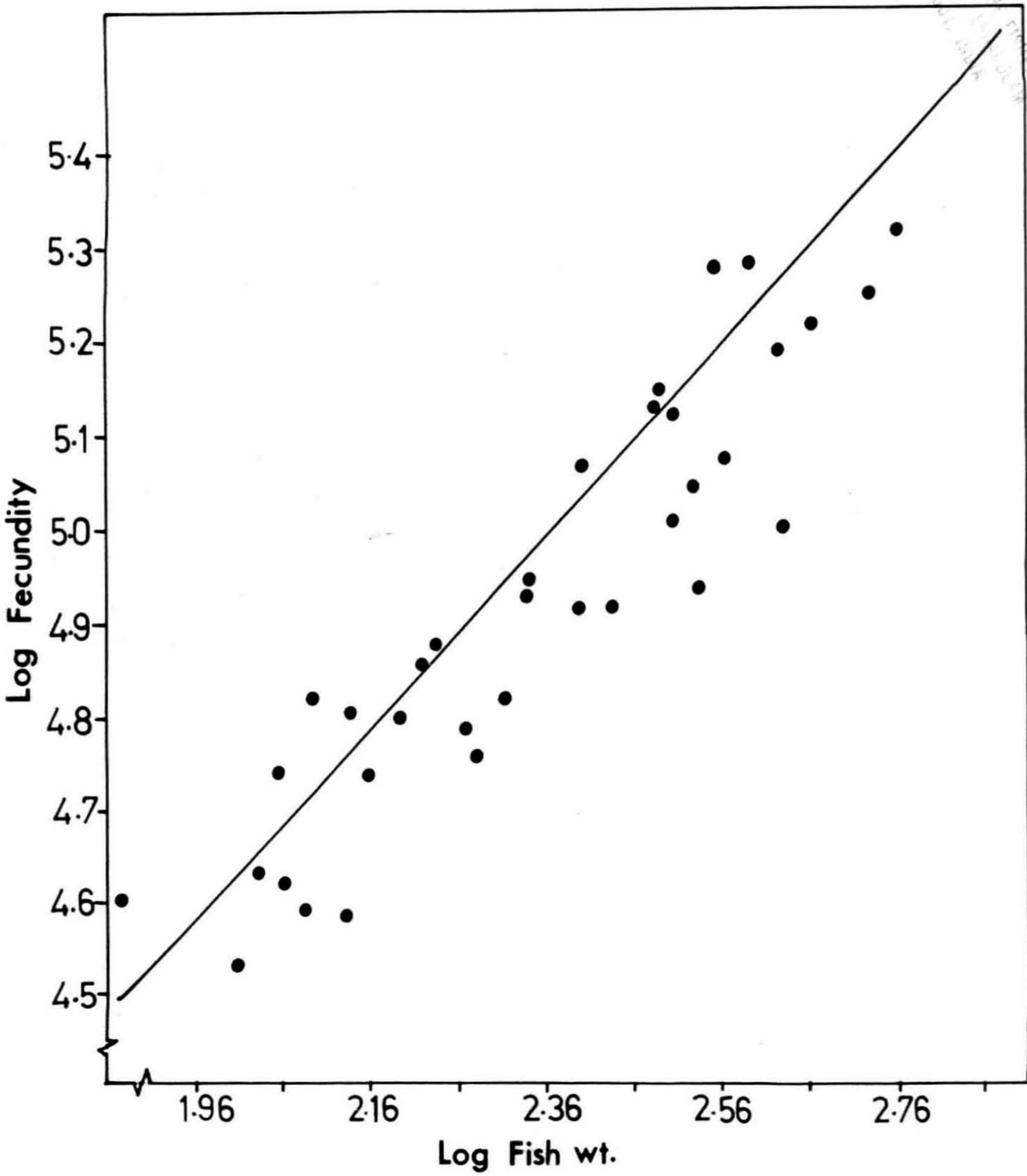

Fig. 5.20 Scattergram of log of fish weight against log of fecundity for *S. tumbil*.

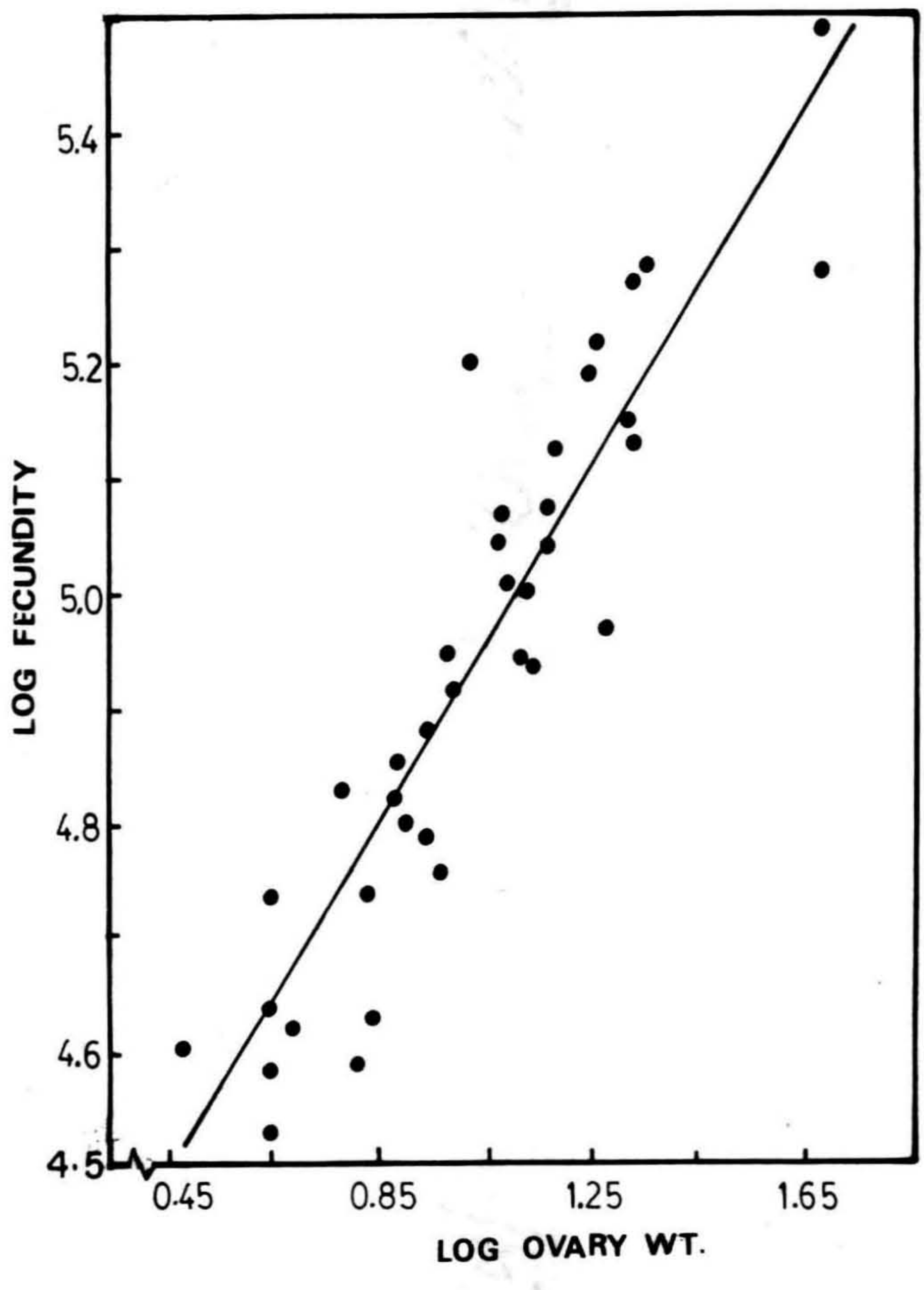

Fig. 5.21 Scattergram of log of ovary weight against log of fecundity for *S. tumbil.*

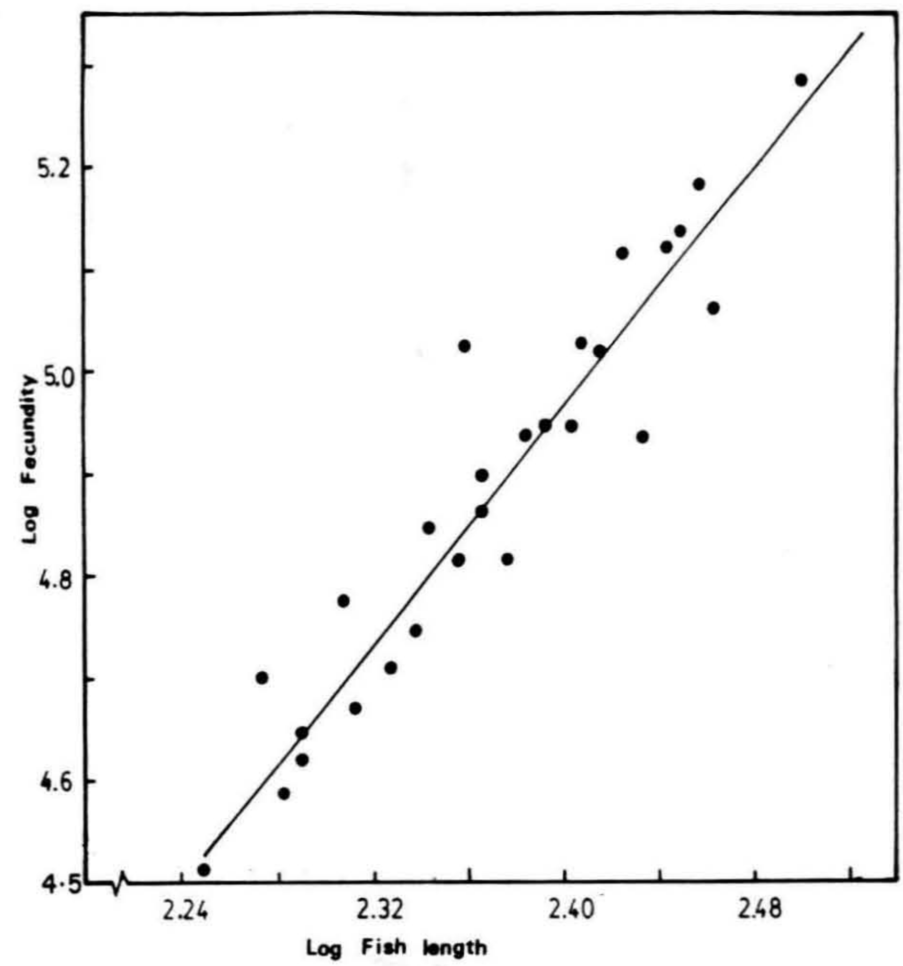

Fig. 5.22 Scattergram of log of fish length against log of fecundity for *S. undosquamis*.

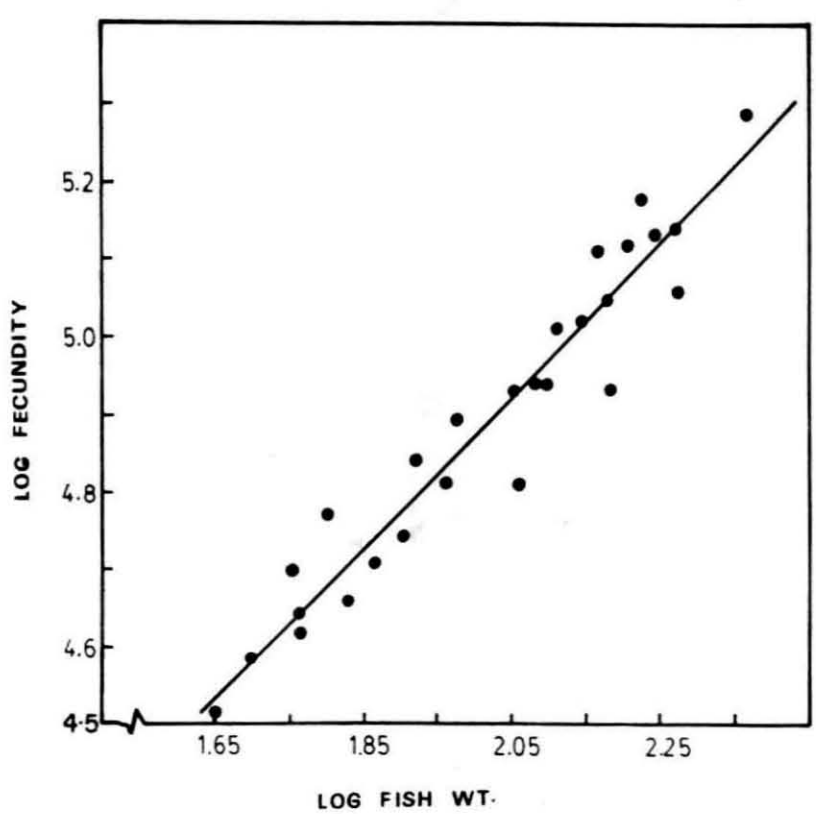

Fig. 5.23 Scattergram of log of fish weight against log of fecundity for *S. undosquamis*.

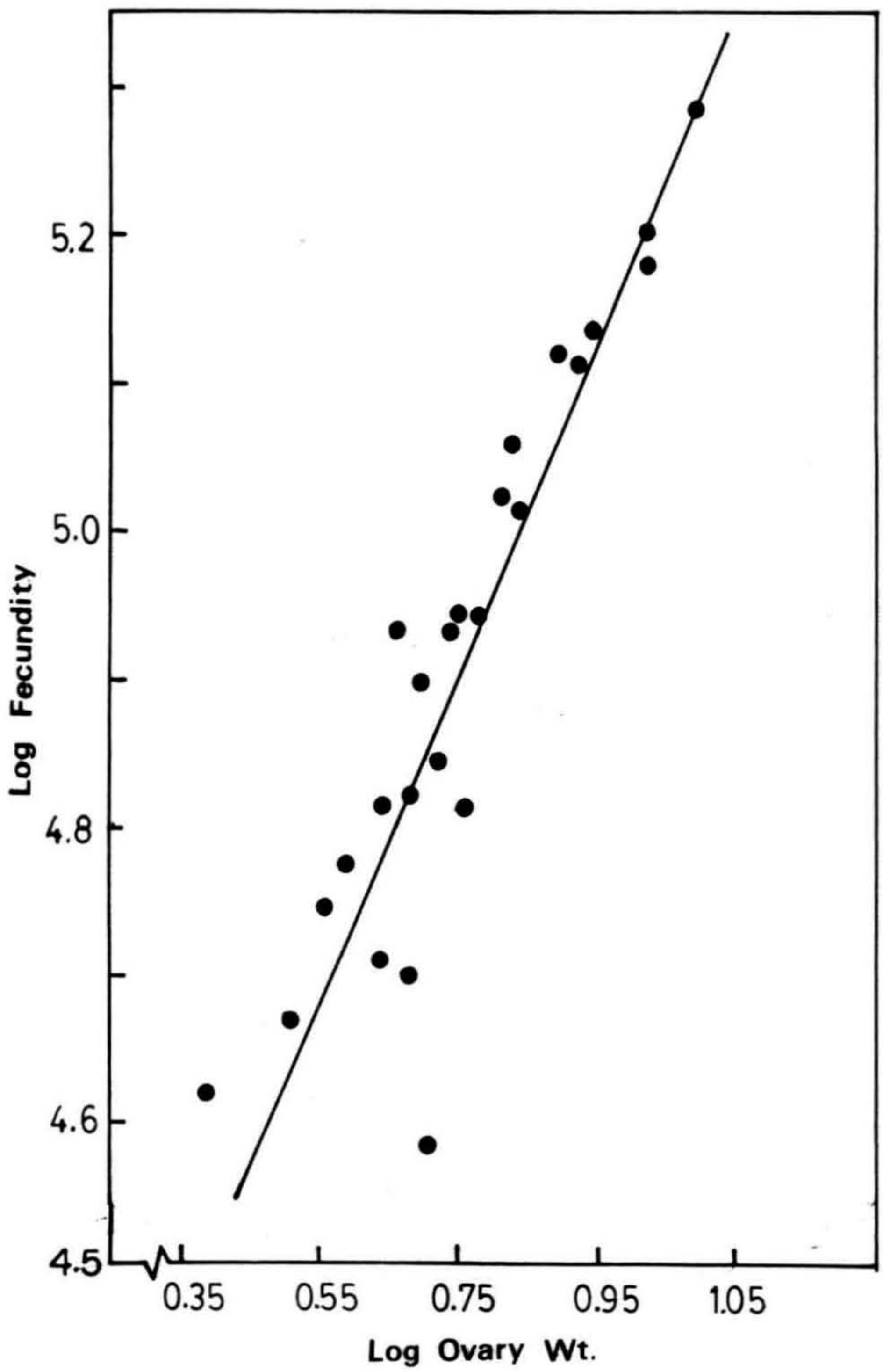

Fig. 5.24 Scattergram of log of ovary weight against log of fecundity for *S. undosquamis*.

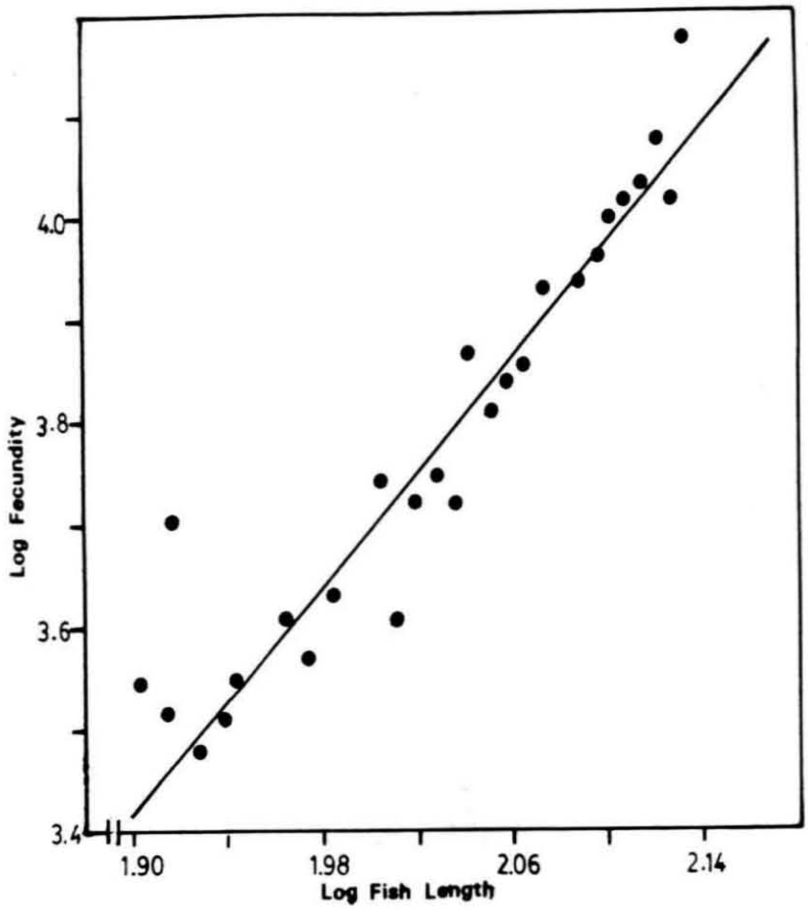

Fig. 5.25 Scattergram of log of fish weight log of fecundity for *S. isarankurai*.

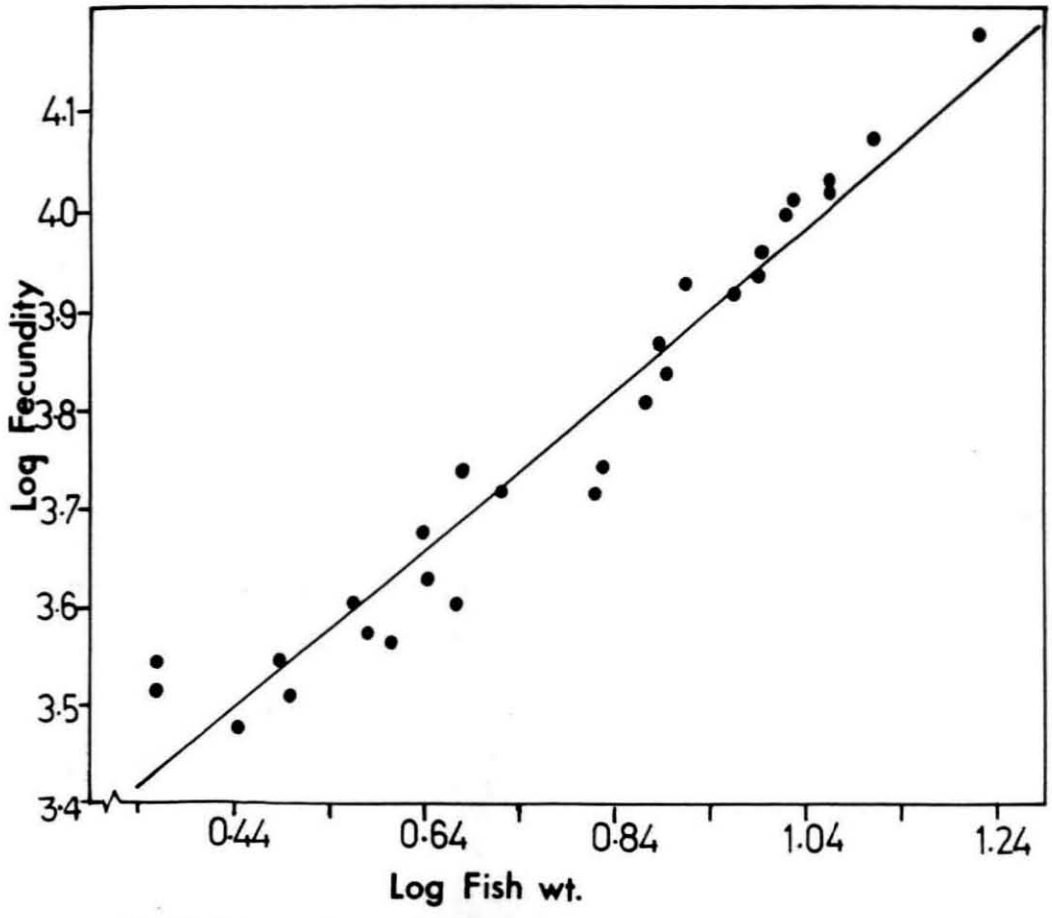

Fig. 5.26 Scattergram of log of fish weight against log of fecundity for *S. isarankurai*.

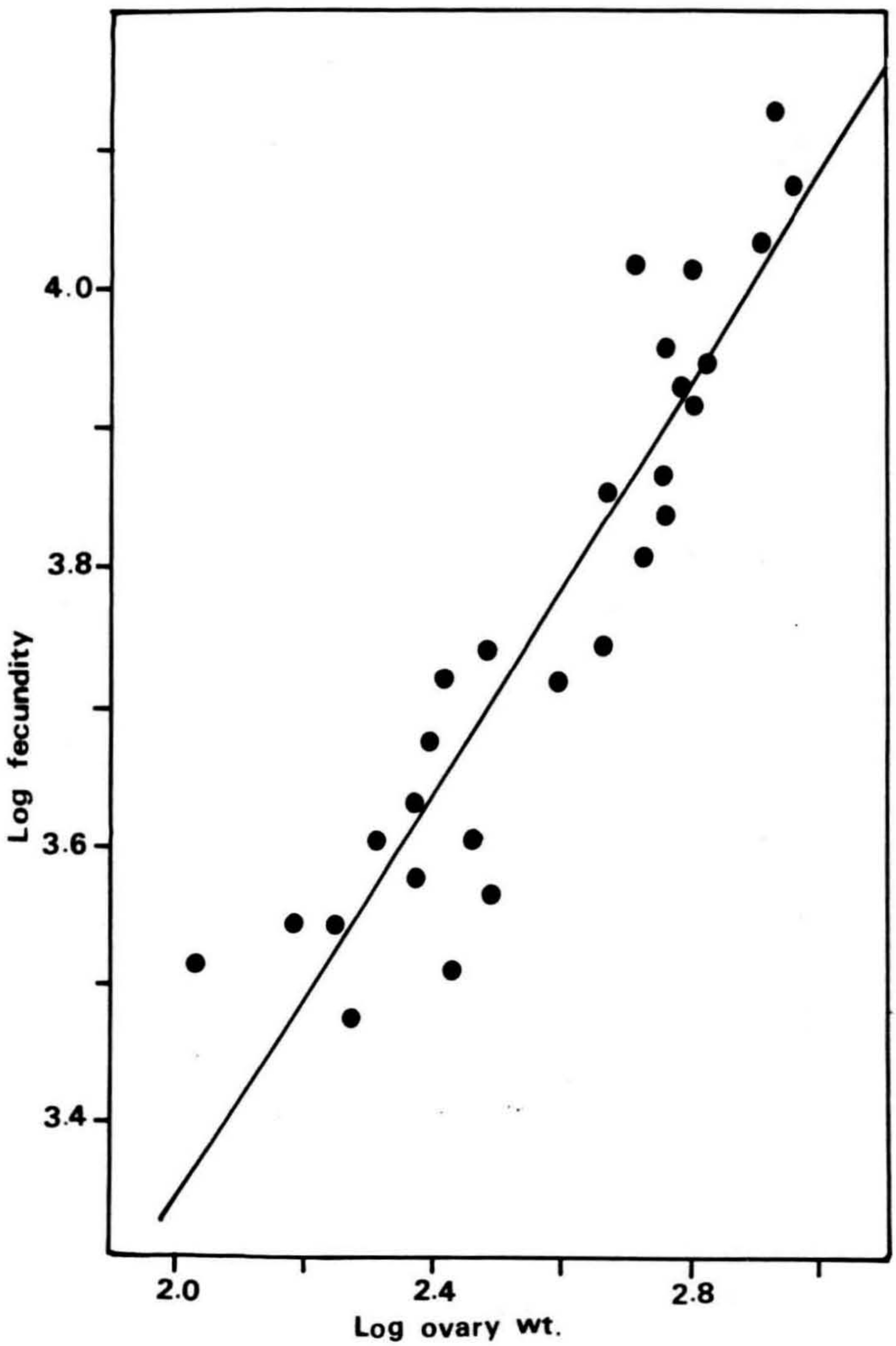

Fig. 5.27 Scattergram of log of ovary weight against log of fecundity for *S. isarankurai.*

Chapter VI

POPULATION DYNAMICS

INTRODUCTION

Fish form a part of man's food, particularly in meeting his much needed protein demand. The ever increasing human population of the world demands more and more food supply not only from land, but also from aquatic resources. With the advanced technology, the quantum of output of living resources for human consumption from the oceans has increased the production level on one hand and at the same time, certain fish stocks are over exploited due to unrestricted fishing. In such a context, a need arises for the management of the fishery resources for optimal exploitation in order to get renewable yield on a continuing basis. For successful management practice, a knowledge on the dynamics of fish population is essential to understand and quantify the stock, that could be produced in consideration of losses due to fishing as well as natural causes. These informations are useful to regulate the exploitation level and for proposing conservatory measures. Further, it would also help to understand the status of the stock under a given environmental and fishing conditions.

The earliest reference on the theoretical concept on population dynamics and productivity of waters dates back to the era of the epic, Indian Mahabharata in the 2nd century B.C., where mention has been made about the flow of Ganges in providing the basic fish food and fish supply of Bay of Bengal (Nikolskii, 1956). Attempts to conserve and allow the fish to reproduce and replenish the stock were an age old practice, as reflected from the civil and religious laws of many countries such as India and China (Nikolskii, 1956).

Various views on fish population dynamics were recorded as early as the 18th century. The modern theory on population dynamics was formulated first by Ber (1854, 1860), followed by Buckland (1861, 1864 as cited by Graham 1948), Danilevskii (1862, 1871 and 1875), Hensen and Apstein (1897), Heincke (1898) and Petersen (1895, 1900 and 1903). The ill effect of fishing on the stocks of marine fish in the form of fall in output was felt in the early 19th century in the North Sea and later it paved the way for the establishment of the

International Council for the Exploration of the Seas (I.C.E.S.) in 1902 for formulating facts and theories relating to fish population dynamics. Some of the notable contributions to the subject during the early 20th century were by Baranov (1918), Russell (1931 and 1939), Chugunov (1935), Graham (1935 and 1939), Thompson (1937) and Ricker (1940 and 1944). The theory of population dynamics became popular world-wide during the second half of 20th century, when critical reviews were made on the subject by Nikolskii (1950, 1953 and 1965), Shefer (1958), Beverton and Holt (1957), Thompson (1959) Lapin (1961), Paloheimo (1961), Gulland (1965 and 1969), Ricker (1958), Holden (1974) and Powell (1979).

In recent years our knowledge on the population dynamics is enriched by a large number of contributions, the most important among them being those of Caddy (1980), Pope (1980), Jones and Zalinge (1981), Gulland (1983 and 1988), Jones (1984), Garcia (1985) and Cushing (1988).

Stock assessment of tropical fish resources gained momentum in the last decade mainly through the works of Pauly (1979, 1980, 1980a, 1981, 1982, 1982a, 1983, 1983a, 1984, 1984a and 1987), Pauly and David (1981), Garcia and Le Reste (1981), Devaraj (1982a and 1983), Sanders *et al.* (1984a and 1984b), Alagaraja (1984), Pauly and Morgan (1987), Sparre (1987, 1987a and 1991) and Sparre and Venema (1992).

The dynamics of fish population are concerned with natality, growth and mortality of fish stocks and these processes are governed by their adaptations in relation to environment. Understanding these processes forms the essential information required for obtaining maximum yield. Fishing not only reduces the population, but also interferes with the adaptive relation of the fish species to its environment. To determine the quantitative effects of fishing and suggest ways and means so as to maintain and get optimum yield, two types of models are available. The first one is called 'Surplus Production' model and the other as analytic prediction models. The first model, also known as logistic model, was proposed by Hjort *et al.* (1933) and later developed into sigmoid curve theory by

Graham (1939 and 1943) and into surplus production model by Schaefer (1954). This model assumes trends in the population as a whole for estimating the relation between its growth and size. The input data needed are the catch and effort for a number of years. Though this model is simple to work out, the results obtained have proved to be not realistic wherein information on fish population (biological characteristics) and the environment cannot be incorporated (Gulland, 1977).

The analytic prediction models have the basis from works of Baranov (1918), Russell (1931 and 1939), Thompson and Bell (1934), Ricker (1948) and Beverton and Holt (1957). These models consider the parameters of populations constituting a particular resource separately and the yield information is obtained from a unit number or weight of recruits under a series of different fishing conditions. These models are used for estimation of stock and for predicting future yields of a fishery employing mathematical models like, 1. Virtual Population Analysis (VPA) or cohort analysis, 2. Thompson and Bell and 3. Beverton and Holt. The first model analyses the effect of fishing on a particular year class or length group. Based on the findings of the first model, the second model can be worked out. The second model describes the effect of different fishing levels in the future (Thompson andBell). The basis of the first model is on past historic data. As these models are based on variable parameters describing changes in the stock and yield on a year to year basis with regard to change in the fishing pattern on individual species length or age groups, these are called non- steady models. The third popularly used model, is 'the yield per recruit model' of Beverton and Holt (1957). This model assumes a steady state situation describing the state of stock and yield when the fishing pattern remaining the same over a long period of time and all recruits during the life are exposed to it (Sparre *et al.* 1989).

The death process effected by natural causes and fishing constitutes mortality. It is expressed as total mortality coefficient or instantaneous total mortality coefficient and the symbol used to denote this is 'Z'.

Natural mortality is due mainly to predation including cannibalism and other factors such as disease, parasitic infection, starvation, old age and environmental condition acting independently. It is expressed as instantaneous rate of natural mortality co-efficient and denoted by the sign 'M'.

Fishing mortality depends on the fishing activity and the term used to express is instantaneous rate of fishing mortality co- efficient (F) and is directly proportional to the fishing intensity (f).

Studies on the population dynamics of lizardfish are available in the works of Shindo (1972) on *Saurida tumbil* from the East China Sea; Okada and Kyushin (1955) on *S. tumbil* from the East China Sea and Yellow Sea; Sanders *et al.* (1984) and Edwards *et al.* (1985) on *S. undosquamis* from the Gulf of Aden; Xucai and Qiyong (1986 and 1988) on *Trachinocephalus myops* and *S. tumbil* from the south Fujian and Taiwan Bank, Siripakhavanich (1990) on *S. undosquamis* from upper western coast of Gulf of Thailand and Boonwanich (1991) on *S. undosquamis* from the southern Gulf of Thailand.

Studies on the dynamics of population of marine fin fishes of Indian waters are very limited. Till 1980, very few attempts were made which included the works on *Pseudosciaena diacanthus* (Rao, 1971), *Sardinella longiceps* (Annigeri, 1972), *Rastrelliger kanagurta* and *S. longiceps* (Banerji, 1973 and Sekharan, 1976), *Nemipterus japonicus* (Krishnamoorthi, 1976) and seerfish (Devaraj, 1977). After 1980, quite a number of studies are available, the most important among them are on silverbelly (Venkataraman *et al.*, 1981), mackerel (Yohannan, 1983), *N. japonicus* (Murty, 1983a and 1987), tunas (Silas *et al.* 1986), *Johnius (Johnius) carutta* (Murty, 1986), *Harpodon nehereus* (Khan, 1986), *N. japonicus* (Vivekanandan and James, 1986), catfish (Alagaraja and Srinath, 1987), *Scombermorus commerson* (Kasim and Ameer Hamsa, 1989), *Otolithes cuvieri* (Chakraborty, 1989), *Sardinella gibbosa* (Annigeri, 1989), *Secutor insidiator* (Murty, 1990) and *Trichiurus lepturus* (Chakraborty, 1990). Murty (1985) studied the dynamics of multispecies demersal fishery.

As there is no study on the population dynamics of lizardfishes, from Indian wasters, an attempt is made here to estimate the mortality parameters, yield and stock assessment of three species of *Saurida* viz., *S. tumbil*, *S. undosquamis* and *S. isarankurai*.

MATERIAL AND METHODS

The monthly and annual estimated numbers of fish in different size groups for the fishing seasons, 1989-90 and 1990-1991 in respect of *S. tumbil*, *S. undosquamis* and *S. isarankurai* obtained as detailed under the material and methods section in the Age and Growth chapter formed the data basis for estimation of total mortality 'Z'.

For the estimation of total instantaneous mortality coefficient, a number of methods are available. In the present study, four methods namely, Beverton and Holt (1956), Alagaraja (1984), length converted catch curve (Pauly, 1982) and modified Wetherall *et al.* (1987) methods were used.

The natural mortality co-efficient was determined by employing Cushing's (1968) formula, Srinath's (MS) method, as followed by Chakraborty (1990), Pauly's (1989a) and Srinath's (1990) empirical formulae.

The fishing mortality co-efficient was obtained by the subtraction of M from Z. Also, independent estimate of 'F' was derived from Allen's (1953) equation.

Total mortality co-efficient estimation

The computing procedures and the principles involved in the derivations of 'Z' by the four methods are given below:

1. Beverton & Holt method (1956)

In this method 'Z' is obtained from the mean length ($\bar{L}$), L_∞ and K of the von Bertalanffy growth parameters. The number of fish in the fully exploited length group are used under the assumption that mortality is constant for all the length groups. It further considers that the size of the fish is related to mortality, the larger the mortality the fewer the large sized fish in the fishery. It implies that the higher the mean length, the lesser is the mortality and *vice versa*. Then the relation between Z and $\bar{L}$ is

$$Z = K \frac{L_\infty - \bar{L}}{\bar{L} - L'}$$

where $\bar{L}$ is the mean length of fish of length L' and larger. L' is the lower limit of the size group from which length upwards, all lengths are under full exploitation. An example of the method of tabulation and calculation is presented in Table 6.1.

2. Alagaraja's method (1984)

The formula followed in this method is

$$\text{Log }(N_t + \Delta_t/N_t) = \frac{Z}{K} \text{ log}\left[\frac{L_\infty - L_t + \Delta_t}{L_\infty - L_t}\right]$$

where L_∞ and K represent von Bertalanffy growth parameters, L_t and $L_t + \Delta_t$ are the successive mid-point of length classes and N_t and $N_t + \Delta_t$ are their corresponding frequencies. Since Z is considered constant for the entire size range of fish, catch in number at successive ages C_t and $C_t + \Delta_t$ are proportional to N_t and $N_t + \Delta_t$.

Hence,

$N_t + \Delta_t/N_t = C_t + \Delta_t/C_t$

Z is computed as follows -

The deviations of L_t from L_∞ (= L_∞ - L_t) are converted to log values and their successive differences log (L_∞ - L_t) - log(L_∞ - L_t + Δ_t) are computed. Likewise, the successive differences log(C_t) are found out and tabulated as follows:

1	2	3	4
L_t	$L_\infty - L_t$	$\log(L_\infty - L_t)$	$\Delta\log(L_\infty - L_t)$ (A)
5	6	7	8
C_t	$\log C_t$	$\Delta\log C_t$ (B)	Z/K (B/A)

where $\Delta\log(L_\infty - L_t)$ and $\Delta\log C_t$ are the respective successive differences. Thus for each row of successive differences of the descending right limb, an estimate of $\overline{Z}/K$ is available. Z is estimated by multiplying $\overline{Z}/K$ with the growth coefficient. An example of computational procedures and tabulation is given in Table 6.2.

3. Length converted catch curve method

The method as described by Pauly (1983a, 1984 and 1984a) is also known as linearised length converted catch curve method. Here, the time taken for average fish to grow from length L_1 (lower limit) to L_2 (upper limit) and the age interval mid-points are derived from the inverse von Bertalanffy equation -

$$t(L) = t_o - \frac{1}{K} \ln \left(1 - \frac{L}{L_\infty}\right)$$ for making use of the equation -

$$\ln \frac{C(L_1, L_2)}{\Delta_t (L_1, L_2)} = C - Z \left[\frac{t(L_1) + t(L_2)}{2}\right]$$

where C = numbers caught in each length class, Δ_t = time taken to grow from lower limit (L_1) to upper limit (L_2) in each length class. Then the equation becomes linear as -

$$Y = \ln \frac{C(L_1, L_2)}{\Delta_t (L_1, L_2)} \text{ and } X = \frac{t(L_1) + t(L_2)}{2}$$

which is the form of, Y = a + bx where the slope (b) = -Z with the sign changed Z is obtained.

Scatter plot of the values of $t(L_1 + L_2)/2$ against $\ln C(L_1, L_2)/\Delta_t(L_1, L_2)$ are used to identify the straight portion of the catch curve as the first few length groups representing the ascending limb consist of fish not yet fully recruited to the fishery. An example of the calculation procedures and tabulation is given in Table 6.3.

4.Wetherall *et al.* method (1987)

This method in principle is based on Beverton and Holt (1956) formula $Z = K \dfrac{L_\infty - \bar{L}}{\bar{L} - L'}$. It estimates L_∞ and the ratio of coefficient of mortality and growth (Z/K) using the length frequency sample raised to the annual catch. The selection of L' can be at any length equal to and above the smallest length under full exploitation. With the corresponding mean lengths ($\bar{L}$) of size groups exceeding only the selection length (L') when plotted gives a linear relationship equivalent to

$$\bar{L} - L' = a + b * L'$$

where Z/K = -(1 + b)/ b or b/1-b.

Thus, this method also like Beverton and Holt's method shows that the selected mean length ($\bar{L}$) is a linear function of the selection length (L') and it functions under the notion that annual recruitment is constant, growth obeys von Bertalanffy equation and mortality rate occurring uniform. This method is useful when there is no information available about a particular stock. In the present study computation for this method was carried out by COMPLEAT ELEFAN programme (Gayanilo *et al.*, 1988) and the results dealt in the age and growth chapter. The estimated 'Z' values for the three species of *Saurida* using all the four methods are given in Tables 6.4, 6.5 and 6.6.

The modified Wetherall *et al.* method, using the two seasons' (1989-90 and 1990-91) pooled length frequency gave Z estimate as 3.53 for *S. tumbil* (Table 4.5 and Fig. 4.2). The annual average Z estimates by the other three methods, viz., Beverton and Holt method Alagaraja method and length converted catch curve method (Fig. 6.1) were 3.75, 3.6 3.90 respectively. While, the estimates by Alagaraja's and Beverton and Holt's methods are comparable the estimates by the length converted catch curve shows a little higher value and that of Wetherall *et al.* method, a little lower. Nevertheless, the average estimates of Z by all the four methods for the two seasons was 3.70 and this is taken for all further use in stock assessment studies.

The estimates of mortality coefficient obtained by the four methods for *S. undosquamis* are given in Table 6.5. The annual average estimates derived by Wetherall *et al.* method, (Table 4.11 and Fig. 4.5). Beverton and Holt method, Alagaraja method and length converted catch curve method (Fig. 6.2) were 2.54, 2.79, 2.21 and 2.95 respectively. The estimates by the first and third method are not compatible, whereas, by the second and fourth method are more or less similar. The average estimate by all the four methods is 2.62 and this value is considered for further studies.

The 'Z' calculated from the four methods in respect of *S. isarankurai* are presented in Table 6.6. The annual average estimates were 14.8, 7.15, 6.75 and 9.71 by the Wetherall *et al.* method (Table 4.17 and Fig. 4.8), Beverton and Holt method, Alagaraja method and length converted catch curve method (Fig. 6.3) respectively. The estimates by the last three methods are more or less compatible, however, the one derived from the first method (Wetherall *et al.* plot) appears very high, almost double of the values got by the second and third methods. Hence, the estimate obtained by the first method is rejected. The average estimate computed from the other three methods for the two seasons, 1989-90 and 1990-91 is 7.87 which has been used in the subsequent studies.

It is evident that the total mortality co-efficient rate was higher in 1989-90 than 1990-91 in all three species.

Natural mortality estimates

Natural mortality co-efficient rate 'M' is generally difficult to measure. Mortality is linked directly to longevity (Tanaka, 1960; Holt, 1965; Cushing, 1968; Sekharan, 1976; Saville, 1977; Pauly, 1980 and Alagaraja, 1984) and indirectly through growth co-efficient 'K' (Beverton and Holt, 1959 and Srinath, 1990). It is also related to other growth parameters like L_∞ (Srinath, MS and Sparre *et al.* 1989), W_∞ (Sparre *et al.* 1989) and maturity (Rikhter and Efanov, 1976), gonad weight (Gunderson and Dygert, 1988) and environmental temperature (Pauly, 1980a). Several simple methods are available to estimate mortality based on the above principles. The best and perhaps the most reliable method for the estimation of natural morality is that of regressing Z against effort. But in tropical multispecies multigear system apportionment of effort for a particular species is difficult. Moreover, in the present study data is available for only two years. As this method requires time series data for a number of years, it has not been attempted in the present investigations.

Pauly's empirical formula

This formula as given below uses growth parameters of a particular stock and the mean sea surface water temperature of the actual fishing area/ground.

$\text{Log } M = -0.0066 - 0.279 \log L_\infty + 0.6543 \log K + 0.4634 \log T$ where M = the instantaneous rate of mortality per year, L_∞ = asymptotic length in cm, K = annual growth co-efficient and T = average annual sea surface water temperature in degree centigrade.

Cushing's (1968) Method

In this method, it is assumed that, in the unexploited state if the number of one year olds is taken as 100 and the number surviving to maximum age (T_{max}) as 1, then the M can be estimated using the formula,

$$M = \frac{1}{T_{max-1}} \log_e \frac{100}{1}$$

The formula was applied using the T_{max} derived from Pauly's (1980) formula -

$$T_{max} = \frac{3}{K} + t_0$$

Srinath's empirical formula

Srinath (1990) proposed the following empirical formula to estimate the natural mortality:

$$M = 0.4603 + 1.4753\ K$$

where 'K' is the growth coefficient.

Srinath's formula (MS)

The formula proposed by Srinath(MS) and as followed by Chakraborty (1990) is:

$$N_L = R\,(L_\infty - L)/(L_\infty - L_r)^{M/K-1}$$

where R = the number of recruits and Lr = the length at recruitment.

The calculations were done using the formula with the assumption that 95% of the recruits die before they reach their asymptotic length.

The natural mortality coefficient estimated for the three species by the above four methods are given in Table 6.7.

For *S. tumbil*, the estimates of M ranged from 1.06 (Pauly's method) to 1.30 (Srinath's empirical formula). For Pauly's method, the parameters used were L_∞ = 57.5 cm, K = 0.57/year and the mean sea surface water temperature of 29.525°C was taken from Ramana (1989). The average estimate by all the three methods works out to 1.15 which is taken as the value for further analyses (Table 6.7).

The 'M' estimates obtained for *S. undosquamis* by the four methods (Table 6.7) varied from 1.25 (Cushing's method) to 1.40 (Srinath's empirical formula). The values arrived at by the three methods (Pauly's method - the input parameters were L_∞ = 36 cm, K = 0.64/year and temperature = 29.525°C; Cushing' formula and Srinath's method) are compatible. The average from these four methods works out to 1.31 which has been used for further studies.

The natural mortality rates obtained for *S. isarankurai* by the four methods are presented in Table 6.7.

The parameters used for Pauly's method were $L_\infty = 15.8$ cm, K = 1.5/year and annual mean sea surface water temperature = 29.525°C. The M ranged from 2.67 (Srinath's empirical formula) to 4.45 (Cushing's method). The average M value obtained by all the four methods is 3.26 which has been taken for further use in the stock assessment studies.

Fishing mortality estimates

Instantaneous rate of fishing mortality rate (F) was estimated by two methods. In the first method, F is computed by the subtraction of M from Z as -

$$F = Z - M$$

In the second method, F is estimated independently using Allen's (1953) formula -

$$F = \frac{U \times Z}{1 - e^{-Z}} \text{ in which}$$

$$U = L_c/\bar{L} = \frac{F.A}{Z} = F/Z\ (1 - e^{-Z}) \text{ where}$$

U = exploitation rate, L_c = length at first capture, $\bar{L}$ = mean size of the fish above L_c and A = annual mortality rate.

The annual average estimate of 'F' for *S. tumbil* was 2.55 obtained by subtracting 'M' 1.15 from the annual average 'Z' 3.70. The 'F' values obtained by Allen's method were 2.86 for 1989-90 and 2.51 for 1990-91, the annual average being 2.68 (Table 6.8). Since the annual yield of the species shows increasing trend the lower 'F' obtained by the first method (2.55) would be reasonable as the 'E' value works out to 0.69 which is lower than the one obtained for F at 2.68 by the second method. Hence, the F of 2.55 is taken for further use in the studies.

For *S. undosquamis* the annual average 'F' obtained by subtracting M from Z was 1.31 (F = 2.62 - 1.31 = 1.31) and 1.92 by the Allen's method (Table 6.9). In this species also, the annual catch shows improving trend and hence, 'E' at 0.50 seems reasonable.

The annual average 'F' value for *S. isarankurai* derived by subtracting M (3.26) from 'Z' (7.87) was 4.61 and by the second method it was 5.26 (Table 6.10). The E works out to 0.59 for 'F' from the first method and 0.67 by the second method. Since the catch trend of this species is also on the increasing side, the 'F' which gives the low 'E' is preferred. Hence, 'F' of 4.61 obtained from the first method is taken into account for further studies.

Mortality and Survival rate

The annual survival rate and mortality rate in the population are estimated using the expression -

$S = e^{-Z}$

$1 - e^{-Z} = 1\text{-}S = A$ where S = the annual survival rate and A = annual mortality rate.

The annual survival rate and mortality rate, thus obtained for 1989-90 and 1990-91 and the average values for the two years in respect of the three species are given in Tables 6.8, 6.9 and 6.10.

The average annual survival and mortality rates for *S. tumbil* were 2.38% and 97.62% respectively.

For *S. undosquamis*, the average annual survival rate was 7.07% and mortality 92.93%.

The average annual survival rate for *S. isarankurai* was 0.04% and mortality rate, 99.96%.

Stock assessment

For the purpose of stock assessment studies, the following parameters are considered:

(a) Exploitation rate (U): The rate of exploitation (U) is defined as the fraction of fish present at the start of a year that is caught during the year (Ricker, 1975). It is estimated by the equation given by Beverton and Holt (1957) and Ricker (1975) as -

$$U = \frac{F}{Z}(1 - e^{-Z})$$

(b) Exploitation ratio (E): It refers to the ratio between fish caught and the total mortality (Ricker, 1975) or the exploitation rate or the fraction of deaths caused by fishing (Sparre and Venema, 1992). It is estimated by the equation -

$$E = \frac{F}{Z} = \frac{F}{M+F}$$

The ratio gives an indication whether a stock is overfished or not, under the assumption that the optimal value of E equals to 0.5 or $E \approx 0.5$ which in turn is under the assumption that the sustainable yield is optimised when $F \approx M$ (Gulland, 1971).

(c) Yield: Yield is the fraction of fish population by weight taken by the fishery and is denoted by 'Y'.

(d) Standing stock (Y/F): The standing stock is a concentration of fish population for a given area at a given time. It is measured in terms of numbers, weight and is estimated from the relation: Y/F where 'Y' is the yield and 'F' is the co-efficient of fishing mortality.

(e) Total stock or annual stock or biomass (Y/U): It refers to the total weight or number of fish population available for a given area at a particular time. It is estimated from the relation Y/U where Y is the yield and U is the exploitation rate.

For the purpose of study on the stock and yield of the three species, the yield per recruit model of Beverton and Holt (1957) was used.

The yield from biomass (stock) per recruit is expressed as yield per recruit 'Y/R' (grams per recruit) because the yield is relative to the recruitment. It is a function of age at capture (t_c) which is related to estimated optimum mesh size. Y/R is measured as a function between different values of F (which is proportional to effort) and constant values of t_c and also as a function of different values of t_c and keeping constant values of F.

This model helps to find out Y/R with different inputs of F and t_c in order to assess their effect on the Y/R of the stock under study. Since the parameters of F and t_c play a vital role in the management of any fishery, the model is important for fishery biologists and resource managers.

The yield per recruit model (Beverton and Holt, 1957) assumes -

(a) recruitment is constant and takes place at same time

(b) the age at capture (t_c) corresponds to 50% point of selection ogive

(c) no fishing mortality from age t_r to age t_c

(d) all fish belonging to a brood is of same age

(e) mortality is uniform and constant from entry to the end of life span.

(f) there is complete mixing within the stock.

Thus this model has its base on the mathematical treatment of the definition of yield which assumes as a function of growth mortality and gear selection parameters in the form of an equation as suggested by Gulland (1969) and described by Sparre and Venema (1992) as -

$$Y/R = F * \exp\,[-M * (t_c - t_r)] * W_\infty * \left[\frac{1}{Z} - \frac{3S}{Z+K} + \frac{3S^2}{Z+2K} - \frac{S^3}{Z+3K}\right]$$

where

Y = yield

R = yearly number of recruits to the fishery at age t_r.

F = co-efficient of fishing mortality above the age t_c.

M = co-efficient of natural mortality above the age t_c.

t_c = age at first capture.

t_r = age at recruitment.

t_o = arbitrary age at which the fish would have had length zero.

W_∞ = the average asymptotic weight of fish corresponding to the average asymptotic length (L_∞).

K = growth co-efficient of the VBGF.

Z = F + M, the total instantaneous rate of mortality.

S = $\exp[-K * (t_c - t_o)]$

Estimates of parameters for the yield equation were derived as given below:

t_r was estimated from the smallest size of fish encountered in trawl by converting it into age using the inverse von Bertalanffy growth equation.

t_c was computed by plotting cumulative (length frequency upto the first mode) percentage of number of fish against size - interval and selecting the length corresponding to 50% cumulative frequency since the mesh selection operates in fishes whose size is lower than the first mode (Beverton and Holt, 1957).

W_∞ was obtained by converting the corresponding value of L_∞ into weight using the length - weight relationship -

$$\text{Log } W_\infty = \log a + \log L_\infty \times b$$

The yield curve was plotted by taking effort as expressed by the fishing mortality coefficient-F values in the X-axis and the dependable variable - the annual yield in grams per recruit, Y/R values in the Y-axis. The characteristics of the yield curve are that -

(a) it originates at a point where the yield is zero when the fishing mortality is also zero;

(b) as F increases, Y/R also increases rapidly at first, though at a continually decreasing rate;

(c) a maximum value of the yield $(Y/R)_{max}$ which corresponds to MSY/R is reached at a certain value of fishing mortality, F_{max} which is the optimum mortality; and

(d) thereafter, the curve descends comparatively slowly, with the slope decreasing to asymptotic yield as F approaches infinitive (∞).

Biomass per recruit

Sometimes the Y/R curve may not show a maximum. In such cases, as common in tropical fisheries, for understanding the behaviour of the exploited stock, it is advisable to consider the biomass per recruit curve (B/R). However, the Y/R and B/R curves are not alternatives and hence recommended to plot them together (Sparre *et al.* 1989).

The B/R model considers that the catch per unit effort (fishing intensity) is proportional to the yield per unit per fishing mortality Y/R/F, which in turn is equal to annual average biomass per recruit of the exploited part of the population (the biomass of fish of age t_c and above). Also, since a constant parameter system is assumed (Beverton and Holt, 1957) the yield from a stock during a year is equal to the yield from a single cohort during its life span, the relationship being expressed by the formula -

$$\bar{B}/R = Y/R \frac{1}{F} \text{ or } \bar{B}/R = \frac{1}{F} Y/R \text{ and}$$

$Y/R = F(\bar{B}/R)$ and B/R is derived using the above equation.

The biomass per recruit curve decreases continuously from a finite value, $F = 0$ (its corresponding B/R value is known as virgin biomass per recruit, B_v/R, the biomass of the unexploited stock) at first rapidly and then flattens to an asymptotic at zero as F reaches ∞. Since the average biomass is related to the cpue, the average biomass curve will have the same shape and hence, can be interpreted as the cpue curve.

Maximum sustainable yield

The greatest average catch or yield that can be obtained for a given cost of fishing from a stock under existing condition is called as maximum equilibrium catch (MEC) or simply as sustainable yield or sustainable catch.

In the present investigation, MSY was estimated by the following two methods:

1. Corten's (1974) formula -

$Y_1 = \frac{X_2 Y_1}{X_1}$ where X_1 is the Y/R which corresponds to catch in tonnes and X_2 is the Y/R at F_{max}.

2. Gulland's (1979) formula -

$P_y = Z_t \times 0.5 \times B_t$ where Z_t is the exponential rate of total mortality in the year t and B_t being the standing stock size in that year.

Optimum age of exploitation and potential yield per recruit

The optimum age of exploitation (t_y) is defined as the age when the brood attains its maximum weight (Beverton and Holt, 1957) and the potential yield (Y') is the quantity corresponding to this weight as a function of infinite fishing intensity. The optimum catch' as referred to by Herrington (1943), Nesbit (1943) and Ricker (1945) corresponds to potential yield (Devaraj, 1983) and it is that which could be obtained by allowing a year class to grow to its greatest total weight before catching them. Since the potential yield is a theoretical estimate of asymptote fishing under ideal fishing conditions involving the optimum use of gear selectivity, the amount by which the actual catch falls short of potential yield is a measure of efficiency (Holt, 1958). It is therefore important that both t_y and Y' are known in order to increase the efficiency of fishing so as to bring the actual catch as near to the potential yield as possible (Kutty and Qasim, 1968) and/or to evolve appropriate measures for the rational management of the stock.

The potential yield (Y') and the optimum age of exploitation (t_y) were estimated from the equation formulated by Kutty and Qasim (1968).

$Y' = a\ e^{-M}\ (t_y - t_r)\ \{L_\infty - (L_\infty - lo)\ e^{-Kty}\}^b$ where t_y is calculated from the relationship

$$e^{Kt_y} = \frac{(L_\infty - l_0)\ (bK + M)}{M\ L_\infty}$$

and lo from,

$lo = L_\infty\ (1 - e^{-K\ (t-to)})$ where Y' = optimum yield per recruit, a and b = exponent and constant respectively from the length-weight relationship; M = natural mortality co-efficient; t_y = optimum age of exploitation in years; t_r = age at recruitment in years; L_∞ = Length infinity in cm; lo = length in cm when t is zero and K = growth co-efficient.

S. tumbil

For fitting the yield per recruit curve the parameters used were W_∞ = 1610 g, K = 0.57 (annual), t_o = 0.0216 year, M = 1.15/year, t_c = 0.7853 years, t_r = 0.1683 years (Table 6.11). Of these, the parameters K, t_o have already been calculated (Chapter 4) and M in the early part of this chapter.

The mean length at first capture (l_c) for the two year period was derived by taking 50% of the length of selection curve (Beverton and Holt, 1957). The l_c was estimated to be 205.5 mm (Fig. 6.4) and its corresponding age (t_c) was calculated as 0.7853 years by the inverse von Bertalanffy equation.

The smallest fish of length 52 mm recorded in the two year period was taken as the length at recruitment and the age was estimated as 0.1683 years.

W_∞ was estimated by converting L_∞ (575 mm) using the length- weight relationship formula -

$$\text{Log } W_\infty = -5.4645 + 3.1421 \log L_\infty.$$

$$= \text{Log } W_\infty = -5.4645 + 3.1421 \times 2.759668$$

$$= 1610 \text{ g.}$$

The yield per recruit curve was constructed for different values of F ranging from 0 to 5.2 keeping the present age at first capture (t_c) at 0.7853 years constant (Table 6.12 & Fig. 6.5). It can be seen that F = 1.63 gives the maximum value of Y/R = 52.07 and this is taken as the maximum sustainable yield/recruit, MSY/R. The present F is 2.55 and the corresponding Y/R value is 50.794.

The average biomass of survivors, $\bar{B}$/R corresponding to Y/R values are given in Table 6.12 and the biomass per recruit curve in Fig. 6.5. Since the average biomass is related to the cpue it is expected that the biomass curve declines with increasing F. The biomass for biologically optimum fishing mortality F, (FMSY) is 19 which is 13% of virgin biomass (B_v).

Maximum sustainable yield derived from Corten's formula (1974) and Gulland's (1979) method was 781.419 t and 551.809 t respectively. According to Gulland the equation can be applied to lightly exploited stocks. In the present, the exploitation ratio (E) for *S. tumbil* is well above 0.5 level (0.69) indicating heavy exploitation. Hence the MSY derived from Corten's formula of 781.419 is considered for the study (Table 6.13).

The parameters used to derive the optimum age of exploitation (t_y) and the potential yield per recruit (Y') are given in the Table 6.14. They were found to be 1.67 years and 56.0062 g respectively.

S. undosquamis

The yield per recruit was estimated using the parameters W_{∞}=380 g, M = 1.31, K = 0.64 (annual), t_0 = 0.000657 years, t_c = 0.8763 years and t_r = 0.3326 years. The values of K and t_0 have been already computed (Chapter 4) and M in this chapter (Table 6.11).

W_{∞} was estimated from the L_{∞} (360 mm) using the length-weight formula-

$$\text{Log } W_{\infty} = -5.8728 + 3.3066 \log L_{\infty}$$
$$= -5.8728 + 3.3066 \times 2.5563$$
$$= 380 \text{ g.}$$

Age at first capture (t_c) was computed from l_c by converting the latter to age using the inverse von Bertalanffy equation. The mean length at capture (l_c) during the period was 154.5 mm (Fig. 6.6). The corresponding age was computed as 0.8763 years.

The smallest fish in the fishery was 69 mm which was considered as the l_r and its corresponding age t_r was worked out to 0.3326 years.

The yield per recruit curve was prepared using different values of F (0 to 5.2) keeping the age at first capture, t_c constant (Table 6.15 & Fig. 6.7). Maximum sustainable yield/recruit (MSY/R) of 17.36995 g was obtained at F_{max} of 2.87713. The present MSY/R was estimated to be 16.0705 g for F value of 1.31.

The mean biomass per recruit, B/R values relating to Y/R values obtained for different F values are given in Table 6.15 and the curve in Fig. 6.7. The biomass corresponding to the biologically optimum F level, MSY is around 6.0 g which is 15.7% of virgin biomass (Bv).

The maximum sustainable yield estimated by Corten's method was 232.757 t and by Gulland method 215.346 t. The exploitation ratio (E) was found to be 0.5 indicating exploitation in this species is not light. Therefore, the MSY obtained by Corten's formula of 232.757 t can be taken as a reasonable one (Table 6.13).

The optimum age of exploitation (t_y) and the potential yield (Y') were estimated to be 1.51 years and 16.56 g respectively (Table 6.14).

S. isarankurai

For the yield per recruit analysis, the parameters used were W_∞ = 21 g, K = 1.51 (annual), t_0 = 0.033602 years, M = 3.26, t_c = 0.3689 years and t_r = 0.1754 years, of which the values of K and t_0 have already been worked out (Chapter 4) and that of M in the earlier part of this chapter.

W_∞ was computed using L_∞ value (158 mm) and employing the length-weight formula -

$$\text{Log } W_\infty = -5.6860 + 3.1860 \log L_\infty$$
$$= -5.6860 + 3.1860 \times 2.19866$$
$$= 21 \text{ g.}$$

The mean length at first capture (l_c) during the period was estimated to be 64.7 mm (Fig. 6.8). By converting this into age using von Bertalanffy equation t_c = 0.3689 years was obtained.

The smallest size recorded in the fishery during the period was 35 mm. This was taken as the length at recruitment (l_r). Its corresponding age of 0.1754 years was taken as age at first recruitment (t_r).

Yield per recruit curve was made for different values of F, ranging from 0 to 5.2, keeping the age at first capture (t_c) constant. The maximum value of Y/R of 0.870 (MSY/R) was obtained for F_{max} at 6.1654 (MSY/F). For the present F of 4.6 the Y/R is 0.861 g (Table 6.16 and Fig. 6.9).

The maximum sustainable yield (MSY) was 203.977 t by Corten's method and 172.310 t by the Gulland's method (Table 6.13). In *S. isarankurai* also the value of 'E' is well above 0.5, hence the MSY derived from the first method is taken as reasonable.

The optimum age of exploitation (t_y) and the potential yield (Y') were estimated to be 0.64 years and 2.0048 g respectively (Table 6.14).

Selection length for different mesh sizes

As mesh selection experiments are difficult to perform for obtaining selection length for different mesh sizes, calculations were done by considering an increase in the cod-end mesh size by 10, 20 and 30 precents of the present average cod-end mesh size of trawl of 28 mm in the area.

The selection factor (SF) for different mesh sizes can be obtained by the relation l_c/mesh size. The l_c was 205.5 mm for *S. tumbil*, 154.5 mm for *S. undosquamis* and 64.7 mm for *S. isarankurai*. The selection factor (SF) is calculated as 7.33 for *S. tumbil*, 5.51 for *S. undosquamis* and 2.31 for *S. isarankurai*. Then the size at capture for the different new mesh sizes can be derived by the relation-

$$t_c 1 = \text{SF x mesh size.}$$

The l_c obtained for 30.8, 33.6 and 36.4 mm mesh size for *S. tumbil* is 226.05 mm, 246.59 mm and 267.14 mm respectively and their corresponding t_c would be 0.887, 0.9947 and 1.1095 years respectively. Similarly for *S. undosquamis* the values of l_c are 169.95, 185.4 and 201 mm representing t_c values of 0.9985, 1.1311 and 1.2759 years respectively. For *S. isarankurai* the l_c for new mesh sizes are 71.17, 77.64 and 84.11 mm corresponding to t_c estimates of 0.3843, 0.4734 and 0.5322 years respectively.

S. tumbil

The yield per recruit with the present M = 1.15 and three values of t_c, 0.8870, 0.9947 and 1.1095 corresponding to l_c values of 226, 246 and 267 mm showed that the Y/R increased with increase in t_c (Tables 6.17, 6.18 & 6.19 and Fig. 6.10). With t_c value of 0.887, the maximum yield was 54.84 g for F_{max} at 1.965 and thereafter Y/R showed gradual decrease with further increase in F values. For t_c of 0.9947, the MSY/R was 57.48 g with F_{max} at 2.434 and with further increase in F the yield showed decreasing trend. With t_c at 1.1095, the maximum yield was 59.911 g for F_{max} at 3.158 and the yield decreased slowly with increase in F values. For 10%, 20% and 30% increase in the mesh size with the present F at 2.55, the Y/R would be 54.46, 57.47 and 59.7 respectively as against 50.79 g for the present mesh size (28 mm) thereby showing an increase of 7.23%, 10% and 17.45% respectively. The increase in mesh size by 10% and 20% would not result in enhancing the F, above the present level. Only, if the mesh size is increased by 30%, then the F can be maintained at the present level (2.55) or increased marginally to 3.158 for getting the maximum Y/R of 59.911 g.

S. undosquamis

With the present value of M = 1.31 and t_c values of 0.9985, 1.13112 and 1.2759 representing lc of 170, 185 and 201 mm, the MSY/R shows an increase with increase in t_c (Tables 6.20, 6.21 & 6.22 and Fig. 6.10). When t_c of 0.9985 is considered, the Y/R reaches a maximum of 18.20555 g at F = 3.99394 and thereafter the Y/R shows gradual decrease. With t_c of 1.13112, the maximum yield is 18.8766 g for F_{max} of 6.312579 g. For t_c of 1.2759 the maximum yield attained is 19.31167 g with F_{max} at 14.02576. If the mesh size is increased by 10%, 20% and 30% and keeping the present level of F (1.31), the Y/R would be 16.13, 15.88 and 15.3 g respectively as compared to 16.07 g obtained for the present mesh size. The increase in mesh size by 10%, 20% and 30% would enable the stepping up of F by 3, 4.82 and 10.71 times but the MSY/R would increase marginally by 4.8%, 8.67% and 11.18% respectively. By doubling the fishing effort (F = 2.62) from the present and keeping the present age at first capture, the Y/R would go up by 1.282 g the present, registering an increase of 7.98%. However, this is not advisable as the E goes upto 0.67.

S. isarankurai

The yield per recruit for the present M = 3.26 and three values of t_c, 0.3843, 0.4734 and 0.5322 years relating to l_c values of 71.17, 77.64 and 84.11 mm indicates that the Y/R increases with increase in t_c values (Tables 6.23, 6.24 & 6.25 and Fig. 6.10). It is known that with t_c of 0.3843, the maximum yield is 0.8737 g for F_{max} = 6.6859. For t_c of 0.4734, the MSY/R of 0.9452 g is reached at

F_{max} of 12.3893. With t_c of 0.5322, the maximum yield per recruit is 0.9736 g at F_{max} = 23.1363. With 10%, 20% and 30% increase in the mesh size and keeping the present level of F (4.61) the Y/R would be 0.860, 0.884 and 0.870 g respectively as against 0.849 g got with the present mesh size indicating very insignificant increase of 1.3%, 4.1% and 2.47% respectively. Hence, the change of mesh size does not result in higher remunerative yields. From the above it is evident that the MSY/R can be increased if the mesh size is increased by 10%, 20% and 30% from the present mesh size and in that event F can be stepped up by 1.45, 2.69 and 5.02 times respectively.

DISCUSSION

Exhaustive studies on the assessment of fish stocks have been made from temperate waters whereas, the same are limited from tropical waters. However, in recent years, the need for population studies from the tropical region has been felt and gained momentum all over the world. In India, the studies on population dynamics picked up only from the later part of eighties. This delayed initiative is due to the well known problems faced in all tropical countries in the determination of ages of fishes from their hard parts owing to the absence of clear cut annual markings on them and also due to the existence of large number of species supporting a multispecies system. However, recently formulated new approaches and advanced models using the easily obtainable length frequency distribution have helped in the assessment of stocks and yields of tropical water resources. Though the fishery in India is supported by a number of species, more emphasis is laid to study individual specie s'sstock assessment using analytical models.

In the present study, the total instantaneous rate of mortality, 'Z' was studied by length frequency distribution using four methods *viz.,* Beverton and Holt method, Alagaraja's method, length-converted catch curve method and Wetherall *et al.* plot method. For the first three methods the length distribution for 1989 - 90 & 1990 - 91 were used separately, whereas, the pooled length frequency of the two years was utilized in the last method. Among the first three methods, the 'Z' derived from Alagaraja's method gave somewhat lower values in all three species as compared to those from the other two methods, the next higher values were obtained by Beverton and Holt method, followed by length-converted catch curve method. However, the results from these three methods are comparable. It is also observed that the value of 'Z' calculated by all three methods were higher for all the three species in the first year of study. The 'Z' value derived by Wetherall *et al.* plot for *S. isarankurai* is found to be 14.18 which is almost double of the values obtained by the other three methods. So this value has not been considered for computing the average value of Z which was computed from the rest of three methods. In the case of *S. tumbil* and *S. undosquamis*, the average value of 'Z' by all the four methods is comparable and taken as the final value.

The study showed that the total mortality rate was highest in the smaller species, *S. isarankurai* (7.87) and lowest in the medium size *S. undosquamis* (2.62). The larger *S. tumbil* had a moderate value (3.70).

Estimation of the natural mortality coefficient, 'M' in exploited population is difficult (Cushing, 1981) and this problem has been discussed by many workers. It is more problematic in the tropical waters where multispecies and multigear system prevails with the result, estimation of effective effort i.e., apportioning of fishing effort with reference to individual species are not available. Using time series multispecies effort for a particular species and regressing against 'Z' to arrive at the conventionally obtained 'M' is likely to result in unrealistic values of 'M' including negative ones (Ricker, 1975 and Pauly, 1982). In the absence of availability of effective effort, a number of methods are to be tried in order to get a reasonable estimate of M. It should be reasonable in the sense that they cannot be very different from the true values e.g., to estimates based on a plot of Z on effort (Ricker, 1975). Hence, in the present study four methods were used for 'M' estimation in order to minimize the error and the average value from these methods were used for stock assessment and yield studies.

Fishing mortality was easily derived from subtracting 'M' from 'Z' and also from the independent estimate of Allen (1953) method for comparison.

The average 'Z' for *S. tumbil* was 3.70, 'M' = 1.15 and 'F' = 2.55 by the method of subtraction. The independent estimate of 'F' was 3.87. The average total stock (Y/U) was estimated at 1131.509 t and standing stock (Y/F) at 298.275 t as against the yield of 760.6 t. The maximum sustainable yield (MSY) was 781.419 t. The Y/R curve shows that the F_{max} = 1.635 and the corresponding MSY/R = 52.072 g. For this, the yield would be 781.419 t with an exploitation rate of 0.44. The potential yield per recruit (Y') is found to be 56 g. The present yield of 760.6 t is realised at F = 2.55, t_c = 0.7853 years and Y/R = 50.685 g at an exploitation rate of 0.69. This shows that the population of the species is heavily exploited at present. Hence, there is a need to bring down the present level of exploitation in order to conserve the stock for future judicious exploitation.

With the present cod-end mesh size of trawl, any increase in fishing mortality (F) would result in reduced yield. The maximum yield can be possible by decreasing the present F by 58% or by increasing the cod-end by 30% so as to increase the minimum size at capture (l_c = 267 mm; t_c = 1.1095 years), in that case not only the Y/R could be increased to a maximum of 59.91 g but also the F level could be enhanced to 3.158 from the present F of 2.55.

For *S. undosquamis*, the 'Z' was computed as 2.62, M = 1.31 and F = 1.31. The independent estimate of 'F' was 1.92. The average total stock and standing stock was 464.506 t and 164.386 t respectively, whereas, the present yield is 215.345 t. The MSY yield is 232.757 t. The potential yield per recruit (Y') is estimated to be 16.56g at an optimum age of exploitation of 1.51 years.

The yield per recruit analysis indicated that the F_{max} at 2.877, MSY/R = 17.37 g as compared to the present F of 1.31 at Y/R = 16.07 g. This shows that by increasing F by 2.2 times the present level, the yield would increase by 8.1% only, which is not a desirable proposition for advocating increase of the effort level. Hence, the present exploitation rate of 0.5 is optimal for the fishery.

However, the yield per recruit analysis at three values of t_c by increasing the mesh size by 10%, 20% and 30% showed that this would enable stepping up of F (from the present level of 1.31) by 3, 4.8 and 10.7 times and the MSY/R would increase by 4.8%, 8.67% and 11.18% respectively.

'Z', 'M' and 'F' estimated for *S. isarankurai* was much higher than that of *S. tumbil* and *S. undosquamis*. Being much smaller in size and with shorter life span than the other two species, *S. isarankurai* seem to be exposed to heavy mortality on account of both fishing mortality to gear and natural mortality due to high rate of predation by larger fishes, especially as forage item of the other two *Saurida* spp. It is also found that this species tends to be cannibalistic. Young ones of this species are caught mainly as one of the varieties of 'trash fish' by trawl in all months in appreciable quantities. Because of these reasons, the high value of mortality parameters obtained are not surprising. The 'Z' was 7.87, M = 3.26 and F = 4.61. Independent estimate of F was 4.71. The potential yield per recruit is estimated at 2.005 g at an optimum age of exploitation of 0.64 years.

The yield per recruit at F_{max} of 6.165 was 0.87 g (MSY/R), whereas, the present Y/R is 0.86 g for F of 4.61. The MSY was estimated at 203.977 t as against the present yield of 201.867. The average total stock was 344.718 t and standing stock of 43.789 t. The current exploitation rate is 0.58 as compared to 0.78 at MSY/R level. However, this indicates that the F can be increased by 1.33 times (29%), but the yield increase would be just 2.11 t.

Nevertheless, in this case also, the Y/R studies with different t_c values as a consequent of 10%, 20% and 30% increase in the mesh size showed that the Y/R maxima could be reached to 6.68 g, 12.39 g and 23.14 g respectively and in that event the F also can be increased further by 1.45, 2.69 and 5.02 times **respectively from the present level.**

It is well known that the natural mortality (M) is related to age and size as the larger fishes generally would have less rate of predation. Since 'M' is linked to longevity and the latter to the von Bertalanffy curvature parameter, 'K', the M/K ratio is found constant among closely related species and sometimes within the similar taxonomic groups (Beverton and Holt, 1959 and Banerji, 1973). Hence it is possible if a given constant of M/K for one species and that K of the closely related species, the M of the latter can be worked out. The M/K ratio is known to range from 1 to 2.5 (Beverton and Holt, 1959). The estimated annual K value in the present study in the three species were 0.57 for *S. tumbil* 0.64 for *S. undosquamis* and 1.51 for *S. isarankurai*. The M values in these species were 1.15, 1.31 and 3.26 respectively. The M/K ratio in these species is worked out to 2.02, 2.05 and 2.17 respectively. The M/K ratio got from the M values obtained from all four methods in the three species fall within the known limit except by the method of Cushing for *S. isarankurai* where the value is little higher (2.96).

The M/K ratio available for some species of saurids is given in Table 6.26. It is seen that the ratio ranged from 1.65 to 2.18 except in males of *S. undosquamis* from Gulf of Suez where the value is 3.40. The M/K ratio in the present study is in conformity with the Beverton and Holt's view that M/K ratio is constant for closely related species.

The age at first capture (t_c) in respect of *S. tumbil* was 0.78 years as against the optimum age of exploitation (t_y) of 1.67 years. For *S. undosquamis* the t_c was 0.8763 years as compared to the 't_y' of 1.51 years. In *S. isarankurai* the t_c was 0.37 years as against the 't_y' of 0.64 years. It shows that in all the three species 't_y' are higher than the present values of t_c. From this it is inferred that one way of judicious exploitation might be to increase the size of the mesh in order to increase the age of exploitation from the present age of 0.78, 0.87 and 0.37 years in *S. tumbil*, *S. undosquamis* and *S. isarankurai* respectively to 1.67, 1.51 and 0.64 years respectively. This would allow the stock to grow and reach the maximum marketable age as well as to Y', and thus, averting the stock **depletion from growth overfishing.**

The present size at capture is 205.5 mm, 154.5 mm and 64.7 mm for *S. tumbil*, *S. undosquamis* and *S. isarankurai* respectively. The studies on maturation and spawning of these species have shown that the minimum size at maturity is 250 mm (males) - 264 mm (females) for *S. tumbil*, 167 mm (males) - 207 mm females for *S. undosquamis* and 83 mm for both males and females of *S. isarankurai* which sizes are well above the present length at capture. This points out that these species at present are being exploited before their attainment of maturity and without getting a chance for breeding atleast for a single time during their life span. If this situation is allowed to persist there is a fear of damage to the fishery in the form of recruitment overfishing.

The present study shows that the stock of the principal species, *S. tumbil*, which contributes significantly to the lizardfish fishery of Karnataka is overexpoloited (E = 0.69). The next important species, *S. undosquamis* is however, harvested at present at the optimum level (E = 0.5) of the stock. The third species, *S. isarankurai* which supports only a minor fishery is exploited around the maximum sustainable yield level. Although by increasing the fishing effort, it may be possible to enhance the production of the latter two species, the quantum of the resource would be only marginal and may not commensurate with the effort expended. Moreover, increase in fishing effort for *S. undosquamis* and *S. isarankurai* would result in further over exploitation of *S. tumbil* and other similarly overfished stocks of demersal fishes which coexist in the same fishing ground. Closed seasons, catch quota system and mesh size regulation of the gear are the other regulatory and managerial measures often considered in the rational management of the overexploited resources. Due to the multispecies nature of the fishery and in consideration of the social and political aspects, these regulatory measures are also found to be difficult in their proper implementation. Nevertheless, the stock assessment studies of the various individual components of demersal fish resources inhabiting in the same fishing ground would be of immense use in the context of formulation of overall strategy of management and conservation of the resources. From this point of view, the present investigations, it is envisaged, would be of great help for developing viable measures for sustainable harvest of multispecies resources exploited by the trawlers in this region.

Table 6.1: An example of calculation of 'Z' by Beverton and Holt's method for *S. tumbil* for the year 1989 - 90.

L_∞ = 575 mm K = 0.57/year.

Length - group (mm)	Mid - length	Numbers caught	Number X mid - length
60 - 79	69.5	50756	
80 - 99	89.5	82574	
100 - 119	109.5	131358	
120 - 139	129.5	208229	
140 - 159	149.5	319707	
160 - 179	169.5	405947	
180 - 199	189.5	518879	
200 - 219	209.5	681658	
220 - 239	229.5	863513	
240 - 259	249.5	808587	2o1742457
260 - 279	269.5	598952	161417564
280 - 299	289.5	314048	90916896
300 - 319	309.5	179531	55564845
320 - 339	329.5	112763	37155409
340 - 359	349.5	84950	29690025
360 - 379	369.5	65365	24152368
380 - 399	389.5	38772	15101694
400 - 419	409.5	24466	10018827
420 - 439	429.5	6040	2594180
440 - 459	449.5	2760	1240620
460 - 479	469.5	372	174654
480 - 499	489.5		

Total numbers of fully exploited group = 2236606

Σ Number X mid length of fully exploited group = 629769539

$$\bar{L} = \frac{\Sigma \text{ Number X mid length}}{\text{Total number}} = \frac{629769539}{2236606} = 281.574$$

L ' = lower limit that length and longer are under full exploitation = 240 mm

$$Z/K = L_\infty - \bar{L} / \bar{L} - L'$$

$$= (575 - 281.574) / (281.574 - 240)$$

$$= \frac{293.426}{41.574} = 7.058$$

$$Z = 7.058 \times 0.57 = 4.023$$

Table 6.2: An example of 'Z' estimation by Alagaraja's method for *S. tumbil* for the year 1989 - 90.

L_∞ = 575 mm K = 0.57(annual)

Length - group (mm)	Mid - length l_t	$l_\infty - l_t$	$\log(l_\infty - l_t)$	$\Delta \log(l_\infty - l_t)$ (A)	Number caught C_t	$\log C_t$	$\Delta \log C_t$ (B)	$\frac{\Delta \log C_t}{\Delta \log (l_\infty - l_t)}$ (B/A) = Z/K
40 - 59	49.5	525.5	2.7206					
60 - 79	69.5	505.5	2.7037	0.0169	50756	4.7055		
80 - 99	89.5	485.5	2.6862	0.0175	82574	4.9168	0.2113	
100 - 119	109.5	465.5	2.6679	0.0183	131358	5.1185	0.2017	
120 - 139	129.5	445.5	2.6488	0.0191	208229	5.3185	0.2000	
140 - 159	149.5	425.5	2.6289	0.0199	319707	5.5048	0.1863	
160 - 179	169.5	405.5	2.6080	0.0209	405947	5.6085	0.1037	
180 - 199	189.5	385.5	2.5860	0.0220	518879	5.7151	0.1066	
200 - 219	209.5	365.5	2.5629	0.0231	681658	5.8336	0.1185	
220 - 239	229.5	345.5	2.5384	0.0245	863513	5.9363	0.1027	
240 - 259	249.5	325.5	2.5126	0.0258	808587	5.9077	0.0286	1.1085
260 - 279	269.5	305.5	2.4850	0.0276	598952	5.7774	0.1303	4.7210
280 - 299	289.5	285.5	2.4556	0.0294	314048	5.4970	0.2804	9.5374
300 - 319	309.5	265.5	2.4241	0.0315	179531	5.2541	0.2429	7.7111
320 - 339	329.5	245.5	2.3901	0.0340	112763	5.0522	0.2019	5.9382
340 - 359	349.5	222.5	2.3531	0.0370	84950	4.9292	0.1230	3.3243
360 - 379	369.5	205.5	2.3128	0.0403	65365	4.8153	0.1139	2.8263
380 - 399	389.5	185.5	2.2683	0.0443	38772	4.5885	0.2268	5.1196
400 - 419	409.5	165.5	2.2188	0.0495	24466	4.3886	0.1999	4.0384
420 - 439	429.5	145.5	2.1629	0.0559	6040	3.7810	0.6076	10.8694
440 - 459	449.5	125.5	2.0986	0.0643	2760	3.4409	0.3401	5.2893
460 - 479	469.5	105.5	2.0233	0.0753	372	2.5705	0.8704	11.5591
480 - 499	489.5	85.5	1.9320	0.0913				

Value of Z/K = 6.0036

The Value of Z = 6.0036 x 0.57 = 3.4220

Table 6.3: An example of estimation of 'Z' by length - converted catch curve method for *S. tumbil* for the year 1989 - 90.

Lower Limit (mm)	Upper limit	Numbers	t_1C	t_2C	Δt	$N / \Delta t$	$\log_e N / \Delta t$	Mean relative age in year
							(Y)	(X)
60	79	50756	0.1933	0.2593	0.066	769030	13.5529	0.2263
80	99	82574	0.2628	0.3315	0.0687	1201950	13.9995	0.2972
100	119	131358	0.3352	0.4068	0.0716	1834609	14.4223	0.3710
120	139	208229	0.4107	0.4855	0.0748	2783810	14.8393	0.4481
140	159	319707	0.4895	0.5679	0.0784	4077895	15.2211	0.5287
160	179	405947	0.5721	0.6543	0.0822	4938528	15.4126	0.6132
180	199	518879	0.6587	0.7452	0.0865	5998601	15.6070	0.7020
200	219	681658	0.7499	0.8411	0.0912	7474320	15.8270	0.7955
220	239	863513	0.8461	0.9426	0.0965	8948321	16.0070	0.8944
240	259	808587	0.9478	1.0502	0.1024	7896357	15.8819*	0.9990*
260	279	598952	1.0558	1.1649	0.1091	5489936	15.5184	1.1104
280	299	314048	1.1709	1.2877	0.1168	2688767	14.8046	1.2293
300	319	179531	1.2940	1.4196	0.1256	1429387	14.1728	1.3568
320	339	112763	1.4265	1.5623	0.1358	830361	13.6296	1.4944
340	359	84950	1.5698	1.7177	0.1479	574375	13.2610	1.6438
360	379	65365	1.7258	1.8882	0.1624	402494	12.9054	1.8070
380	399	38772	1.8971	2.0770	0.1799	215520	12.2808	1.9871
400	419	24466	2.0870	2.2886	0.2016	121359	11.7065	2.1878
420	439	6040	2.2999	2.5293	0.2294	26330	10.1785	2.4146
440	459	2760	2.5423	2.8084	0.2661	10372	9.2469	2.6754
460	479	372	2.8236	3.1404	0.3168	1174	7.0682	2.9820

Table 6.4: Instantaneous rate of total mortality (Z) for *S. tumbil* for the years 1989 - 90 and 1990 - 91.

Year	Beverton & Holt's method	Alagaraja's method	Length-converted catch curve method	Modified Wetherall plot method	Average
1989 - 90	4.02	3.42	4.10		3.84
1990 - 91	3.49	3.77	3.70		3.65
1989 - 91				3.53	
Average	3.75	3.60	3.90	3.53	3.70

Table 6.5: Instantaneous rate of total mortality (Z) for *S. undosquamis* for the years 1989-90 and 1990-91

Year	Beverton & Holt's method	Alagaraja's method	Length-converfed catch curve method	Modified Wetherall plot method	Average
1989 - 90	3.23	2.57	3.15		2.98
1990 - 91	2.36	1.85	2.76		2.32
1989 - 91				2.54	
Average	2.79	2.21	2.95	2.54	2.62

Table 6.6: Instantaneous rate of total mortality (Z) for *S. isarankurai* for the years 1989 - 90 and 1990 - 91.

Year	Beverton & Holt's method	Alagaraja's method	Length-converfed catch curve method	Modified Wetherall plot method	Average
1989 - 90	9.78	7.30	9.02		8.70
1990 - 91	4.51	6.19	10.40		7.03
1989 - 91				14.18	
Average	7.15	6.75	9.71		7.87

Table 6.7: Estimation of natural mortality co-efficient (M) for *S. tumbil*, *S. undosquamis* and *S. isarankurai*

Species	Pauly's empirical formula	Cushing's method	Srinath's empirical formula	Srinath's method	Average of four methods
S. tumbil	1.06	1.07	1.30	1.15	1.15
S. undosquamis	1.30	1.25	1.40	1.31	1.31
S. isarankurai	2.85	4.45	2.67	3.09	3.26

Table 6.8: Independent estimate of fishing mortality co-efficient and survival and mortality rates of *S. tumbil*

Year	Total mortality coefficient 'Z'	Fishing mortality coefficient 'F'	Survival rate (%) 'S'	Mortality rate (%) 'M'
1989 - 90	3.83	2.86	2.17	97.83
1990 - 91	3.65	2.51	2.60	97.40
Annual average	3.74	2.68	2.38	97.62

Table 6.9: Independent estimate of fishing mortality co-efficient and survival and mortality rates of *S. undosquamis*

Year	Total mortality coefficient 'Z'	Fishing mortality coefficient 'F'	Survival rate (%) 'S'	Mortality rate (%) 'M'
1989 - 90	2.98	1.97	5.08	94.92
1990 - 91	2.32	1.87	9.83	90.17
Annual average	2.65	1.92	7.07	92.93

Table 6.10: Independent estimate of fishing mortality co-efficient and survival and mortality rates of *S. isarankurai*

Year	Total mortality coefficient 'Z'	Fishing mortality coefficient 'F'	Survival rate (%) 'S'	Mortality rate (%) 'M'
1989 - 90	8.7	5.28	0.02	99.98
1990 - 91	7.03	5.24	0.09	99.91
Annual average	7.87	5.26	0.04	99.96

Table 6.11: Parameters used for fitting the yield equation

Parameters/Species	M/year	K (annual)	t_c (years)	t_r (years)	t_o (years)	W_∞ (grams)
S. tumbil	1.15	0.57	0.7853	0.1683	0.0216	1610
S. undosquamis	1.31	0.64	0.8763	0.3326	0.000657	380
S. isarankurai	3.26	1.51	0.3689	0.1754	0.033602	21

Table 6.12: Y/R and B/R of *S. tumbil* with different values of 'F'.

F	Y/R	B/R
0.000	0.000	154.216
0.200	23.062	115.313
0.400	35.902	89.756
0.600	43.254	72.091
0.800	47.502	59.377
1.000	49.923	49.923
1.200	51.237	42.697
1.400	51.867	37.047
1.600	52.068	32.542
1.800	51.998	28.888
2.000	51.760	25.880
2.200	51.417	23.371
2.400	51.013	21.255
2.600	50.575	19.452
2.800	50.121	17.900
3.000	49.665	16.555
3.200	49.214	15.379
3.400	48.772	14.345
3.600	48.344	13.429
3.800	47.932	12.613
4.000	47.535	11.883
4.200	47.155	11.227
4.400	46.792	10.634
4.600	46.445	10.096
4.800	46.114	9.607
4.000	45.798	9.159
5.200	45.496	8.749

Parameters
W_∞ = 1610 g
K= 0.57 (annual)
t_0= 0.0216 years
M= 1.15
t_c= 0.7853 years
t_r= 0.1683 years

F_{max} : 1.635451 MSY/R : 52.07181
F0.1 = 0.8107628 Y/R for F = F0.1 : 47.67074

Table 6.13: Estimation of length at first capture (l_c) exploitation rate (U) and ratio (E), yield, total and standing stock and MSY of *S. tumbil, S. undosquamis* and *S. isarankurai* (average for 1989-90 and 1990-91).

Species	lc (mm)	Z	M	F	U	E	Yield (Y) in tonnes	Total stock (Y/U) in tonnes	Standing stock (Y/F) in tonnes	Gulland's MSY in tonnes	Present Y/R (g)	Y/R at Fmax (g)	Corten's MSY in tonnes
S. tumbil	205.5	3.70	1.15	2.55	0.6722	0.6892	760.600	1131.509	298.275	551.809	50.6845	52.0718	781.419
S. undosquamis	154.5	2.62	1.31	1.31	0.4636	0.5000	215.345	464.506	164.386	215.346	16.6705	17.3699	232.757
S. isarankurai	64.7	7.87	3.26	4.61	0.5856	0.5858	201.867	344.718	43.789	172.310	0.861	0.870	203.977

Table 6.14: Parameters used for the estimation of optimum age of exploitation (t_y) and potential yield per recruit (Y') in respect of *S. tumbil, S. undosquamis* and *S. isarankurai*.

Species/Parameters	L_∞ (cm)	l_0 (cm)	M	b	a	K (annual)	t_r (years)	t_y (years)	Y' (g)
S. tumbil	57.5	-0.7123	1.15	3.1421	0.004420	0.57	0.1683	1.67	56.0062
S. undosquam's	36.0	-0.0151	1.31	3.3419	0.002416	0.64	0.3326	1.51	16.5562
S. isarankurai	15.8	-0.8168	3.26	3.2562	0.002694	1.5	0.1754	0.64	2.0048

Table 6.15: Y/R and B/R of *S. undosquamis* with different values of 'F'.

F	Y/R	B/R
0.000	0.000	38.199
0.200	6.033	30.164
0.400	9.821	24.552
0.600	12.282	20.470
0.800	13.923	17.404
1.000	15.038	15.038
1.200	15.805	13.171
1.400	16.336	11.669
1.600	16.705	10.440
1.800	16.959	9.421
2.000	17.131	8.565
2.200	17.244	7.838
2.400	17.314	7.214
2.600	17.353	6.674
2.800	17.368	6.203
3.000	17.367	5.789
3.200	17.353	5.422
3.400	17.329	5.097
3.600	17.299	4.805
3.800	17.264	4.543
4.000	17.226	4.306
4.200	17.186	4.092
4.400	17.144	3.896
4.600	17.101	3.717
4.800	17.057	3.553
5.000	17.014	3.403
5.200	16.971	3.263

Parameters

W_∞ = 380 g

K= 0.64 (annual)

t_o= 0.000657 years

M= 1.31

t_c= 0.8763 years

t_r= 0.3326 years

F_{max} : 2.87713 MSY/R : 17.36995

F0.1 = 1.098922 Y/R for F = F0.1 : 15.45317

Table 6.16: Y/R and B/R of *S. Isarankurai* with different values of 'F'.

F	Y/R	B/R
0.000	0.000	0.808
0.200	0.146	0.729
0.400	0.265	0.662
0.600	0.362	0.604
0.800	0.443	0.554
1.000	0.510	0.510
1.200	0.566	0.471
1.400	0.612	0.437
1.600	0.652	0.407
1.800	0.685	0.380
2.000	0.713	0.356
2.200	0.736	0.334
2.400	0.756	0.315
2.600	0.773	0.297
2.800	0.788	0.281
3.000	0.800	0.266
3.200	0.811	0.253
3.400	0.819	0.241
3.600	0.827	0.229
3.800	0.833	0.219
4.000	0.838	0.209
4.200	0.843	0.200
4.400	0.846	0.192
4.600	0.849	0.184
4.800	0.852	0.177
5.000	0.854	0.170
5.200	0.855	0.164

Parameters

W_∞ = 21 g

K= 1.5 (annual)

t_o= 0.033602 years

M= 3.26

t_c= 0.3689 years

t_r= 0.1754 years

F_{max} : 6.127132 MSY/R : 0.8582584

F0.1 = 2.562087 Y/R for F = F0.1 : 0.7708245

Table 6.17: Y/R and B/R of *S. tumbil* with different values of 'F'.

F	Y/R	B/R
0.000	0.000	150.327
0.200	22.750	113.753
0.400	35.806	89.515
0.600	43.571	72.619
0.800	48.290	60.363
1.000	51.179	51.179
1.200	52.932	44.110
1.400	53.963	38.545
1.600	54.526	34.078
1.800	54.781	30.434
2.000	54.834	27.417
2.200	54.751	24.887
2.400	54.580	22.741
2.600	54.351	20.904
2.800	54.086	19.316
3.000	53.800	17.933
3.200	53.502	16.719
3.400	53.200	15.647
3.600	52.899	14.694
3.800	52.603	13.843
4.000	52.312	13.078
4.200	52.030	12.388
4.400	51.756	11.762
4.600	51.492	11.194
4.800	51.237	10.674
5.000	50.992	10.198
5.200	50.756	9.760

Parameters
W_∞ = 1610 g
K= 0.57 (annual)
t_o= 0.0216 years
M= 1.15
t_c = 0.887 years
t_r = 0.1683 years

F_{max} : 1.96467
F0.1 = .8797456
MSY/R : 54.83624
Y/R for F = F0.1 : 49.61436

Table 6.18: Y/R and B/R of *S. tumbil* for different values of 'F'

F	Y/R	B/R
0.000	0.000	145.493
0.200	22.269	111.345
0.400	35.407	88.518
0.600	43.486	72.477
0.800	48.601	60.751
1.000	51.901	51.901
1.200	54.052	45.043
1.400	55.454	39.610
1.600	56.357	35.223
1.800	56.921	31.623
2.000	57.253	28.626
2.200	57.423	26.101
2.400	57.481	23.950
2.600	57.459	22.099
2.800	57.382	20.493
3.000	57.266	19.089
3.200	57.125	17.851
3.400	56.965	16.754
3.600	56.795	15.776
3.800	56.617	14.899
4.000	56.437	14.109
4.200	56.256	13.394
4.400	56.077	12.744
4.600	55.899	12.152
4.800	55.725	11.609
5.000	55.555	11.111
5.200	55.389	10.651

Parameters

W_∞ = 1610 g

K = 0.57 (annual)

t_O = 0.0216 years

M = 1.15

t_c = 0.9947 years

t_r = 0.1683 years

F_{max} : 2.434714

F0.1 : .9547356

MSY/R : 57.48241

Y/R for F = F0.1 : .51.27361

Table 6.19: Y/R and B/R of *S. tumbil* for different values of 'F'

F	Y/R	B/R
0.000	0.000	139.635
0.200	21.601	108.007
0.400	34.674	86.686
0.600	42.951	71.585
0.800	48.372	60.465
1.000	52.014	52.014
1.200	54.508	45.424
1.400	56.239	40.171
1.600	57.449	35.906
1.800	58.297	32.387
2.000	58.889	29.444
2.200	59.296	26.953
2.400	59.571	24.821
2.600	59.747	22.979
2.800	59.850	21.375
3.000	59.900	19.966
3.200	59.910	18.722
3.400	59.891	17.615
3.600	59.849	16.624
3.800	59.790	15.734
4.000	59.720	14.930
4.200	59.641	14.200
4.400	59.555	13.535
4.600	59.466	12.927
4.800	59.374	12.369
5.000	59.281	11.856
5.200	59.187	11.382

Parameters

W_∞ = 1610 g

K = 0.57 (annual)

t_O = 0.0216 years

M = 1.15

t_c = 1.1095 years

tr = 0.1683 years

F_{max} : 3.158227

F0.1 : 1.035995

MSY/R : 59.91146

Y/R for F = F0.1 : .52.53456

Table 6.20: Y/R and B/R of *S. undosquamis* with different values of 'F'

F	Y/R	B/R
0.000	0.000	36.274
0.200	5.792	28.962
0.400	9.524	23.810
0.600	12.019	20.032
0.800	13.737	17.171
1.000	14.948	14.948
1.200	15.817	13.181
1.400	16.450	11.750
1.600	16.917	10.573
1.800	17.264	9.591
2.000	17.523	8.761
2.200	17.717	8.053
2.400	17.862	7.442
2.600	17.970	6.911
2.800	18.050	6.446
3.000	18.108	6.036
3.200	18.149	5.671
3.400	18.176	5.346
3.600	18.194	5.053
3.800	18.203	4.790
4.000	18.205	4.551
4.200	18.203	4.334
4.400	18.196	4.135
4.600	18.187	3.953
4.800	18.175	3.786
5.000	18.161	3.632
5.200	18.145	3.489

Parameters

W_∞ = 380 g

K = 0.64 (annual)

t_O = 0.000657 years

M = 1.31

t_c = 0.9985 years

t_r = 0.3326 years

F_{max} : 3.993947

F0.1 : 1.210332

MSY/R : 18.20555

Y/R for F = F0.1 : 15.85523

Table 6.21: Y/R and B/R of *S. undosquamis* with different values of 'F'

F	Y/R	B/R
0.000	0.000	33.951
0.200	5.477	27.387
0.400	9.089	22.722
0.600	11.564	19.274
0.800	13.315	16.644
1.000	14.585	14.585
1.200	15.527	12.939
1.400	16.237	11.598
1.600	16.782	10.488
1.800	17.204	9.557
2.000	17.535	8.767
2.200	17.797	8.089
2.400	18.007	7.502
2.600	18.175	6.990
2.800	18.311	6.539
3.000	18.421	6.140
3.200	18.511	5.784
3.400	18.584	5.466
3.600	18.644	5.179
3.800	18.693	4.919
4.000	18.733	4.683
4.200	18.766	4.468
4.400	18.792	4.271
4.600	18.813	4.090
4.800	18.831	3.923
5.000	18.844	3.769
5.200	18.855	3.626

Parameters

W_∞ = 380 g

K = 0.64 (annual)

t_0 = 0.000657 years

M = 1.31

t_c = 1.13112 years

t_r = 0.3326 years

F_{max} : 6.312579

F0.1 : 1.330431

MSY/R : 18.87668

Y/R for F = F0.1 : 16.01236

Table 6.22: Y/R and B/R of *S. undosquamis* with different values of 'F'

F	Y/R	B/R
0.000	0.000	31.234
0.200	5.087	25.436
0.400	8.512	21.281
0.600	10.912	18.186
0.800	12.647	15.809
1.000	13.937	13.937
1.200	14.916	12.430
1.400	15.674	11.195
1.600	16.270	10.169
1.800	16.746	9.303
2.000	17.130	8.565
2.200	17.445	7.929
2.400	17.704	7.376
2.600	17.920	6.892
2.800	18.101	6.464
3.000	18.254	6.084
3.200	18.384	5.745
3.400	18.495	5.440
3.600	18.591	5.164
3.800	18.674	4.914
4.000	18.746	4.686
4.200	18.809	4.478
4.400	18.863	4.287
4.600	18.912	4.111
4.800	18.954	3.948
5.000	18.992	3.798
5.200	19.025	3.658

Parameters

W_∞ = 380 g

K = 0.64 (annual)

t_O = 0.000657 years

M = 0.31

t_c = 1.2759 years

tr = .3326

F_{max} : 14.02576

F0.1 : 1.457748

MSY/R : 19.31167

Y/R for F = F0.1 : 15.86079

Table 6.23 Y/R and B/R of *S. isarankurai* with different values of 'F'

F	Y/R	B/R
0.000	0.000	0.797
0.200	0.144	0.721
0.400	0.262	0.655
0.600	0.359	0.598
0.800	0.439	0.549
1.000	0.507	0.507
1.200	0.563	0.469
1.400	0.610	0.436
1.600	0.650	0.406
1.800	0.684	0.380
2.000	0.713	0.356
2.200	0.737	0.335
2.400	0.758	0.316
2.600	0.776	0.298
2.800	0.791	0.282
3.000	0.805	0.268
3.200	0.816	0.255
3.400	0.825	0.242
3.600	0.834	0.231
3.800	0.841	0.221
4.000	0.847	0.211
4.200	0.852	0.202
4.400	0.856	0.194
4.600	0.860	0.187
4.800	0.863	0.179
5.000	0.865	0.173
5.200	0.867	0.166

Parameters

F_{max} : .6.685908 MSY/R : .8737258

F0.1 : 2.64544 Y/R for F = F0.1 : .7801888

W_∞ = 21 g

K = 1.5 (annual)

t_O = 0.033602 years

M = 3.26

t_c = 0.3843 years

t_r = 0.1754 years

Table 6.24: Y/R and B/R of *S. Isarankurai* with different values of 'F'

F	Y/R	B/R
0.000	0.000	0.724
0.200	0.132	0.660
0.400	0.242	0.605
0.600	0.334	0.557
0.800	0.412	0.515
1.000	0.478	0.478
1.200	0.534	0.445
1.400	0.583	0.416
1.600	0.625	0.390
1.800	0.661	0.367
2.000	0.693	0.346
2.200	0.720	0.327
2.400	0.745	0.310
2.600	0.766	0.294
2.800	0.785	0.280
3.000	0.801	0.267
3.200	0.816	0.255
3.400	0.829	0.244
3.600	0.841	0.233
3.800	0.852	0.224
4.000	0.861	0.215
4.200	0.869	0.207
4.400	0.877	0.199
4.600	0.884	0.192
4.800	0.890	0.185
5.000	0.895	0.179
5.200	0.900	0.173

Parameters

W_∞ = 21 g

K = 1.5 (annual)

t_O = 0.033602 years

M = 3.26

t_c = 0.4734 years

t_r = 0.1754 years

F_{max} : .12.3893

F0.1 : 3.132432

MSY/R : .9452488

Y/R for F = F0.1 : .8118202

Table 6.25: Y/R and B/R of *S. isarankurai* with different values of 'F'

F	Y/R	B/R
0.000	0.000	0.670
0.200	0.122	0.613
0.400	0.225	0.564
0.600	0.312	0.521
0.800	0.387	0.483
1.000	0.450	0.450
1.200	0.505	0.421
1.400	0.553	0.395
1.600	0.595	0.371
1.800	0.631	0.350
2.000	0.663	0.331
2.200	0.691	0.314
2.400	0.717	0.298
2.600	0.739	0.284
2.800	0.759	0.271
3.000	0.777	0.259
3.200	0.793	0.248
3.400	0.807	0.237
3.600	0820	0.228
3.800	0832	0.219
4.000	0.843	0.210
4.200	0.853	0.203
4.400	0.862	0.196
4.600	0.870	0.189
4.800	0.877	0.182
5.000	0.884	0.176
5.200	0.890	0.171

Parameters

W_∞ = 21 g

K = 1.5 (annual)

t_O = 0.033602 years

M = 3.26

t_c = 0.5322 years

t_r = 0.1754 years

F_{max} : 23.13632

F0.1 : 3.448079

MSY/R : 0.9736154

Y/R for F = F0.1 : .8110363

Table 6.26: M/K ratio for *Saurida* spp. available from literature

Sl. No.	Name of the species	Study area	L∞ in cm	K	M	M/K	References
1.	*S. tumbil*	Manila Bay (Philippines)	37.5	1.03	1.71	1.66	Ingles and Pauly (1984)
2.	*S. tumbil*	Visayan Sea (Philippines)	41	0.70	1.30	1.86	Ingles and Pauly (1984)
3.	*S. undosquamis*	Visayan Sea (Philippines)	30.5	0.80	1.54	1.93	Ingles and Pauly (1984)
4.	*S. undosquamis*	South Yemen	56.2	0.21	0.24	2.0	Edwards *et al.* (1985)
5.	*S. undosquamis* (males)	Gulf of Suez	36.0	0.25	0.85	3.40	Sanders *et al.* (1984)
6.	*S. undosquamis (females)*	Gulf of Suez	37.0	0.39	0.85	2.18	Sanders et *al.* (1984)
7.	*S. undosquamis*	Southern Gulf of Thailand	40.6	0.60	1.19	1.98	Boonwanich (1990)
8.	*S. elongata*	Southern Gulf of Thailand	46.1	0.94	1.55	1.65	Boonwanich (1990)
9.	*S. tumbil*	Mid-west coast of India	57.5	0.57	1.15	2.02	Present study
10.	*S. undosquamis*	Mid-west coast of India	36.0	0.64	1.31	2.05	Present study
11	*S. isarankurai*	Mid-west coast of India	15.8	1.50	3.26	2.17	Present study

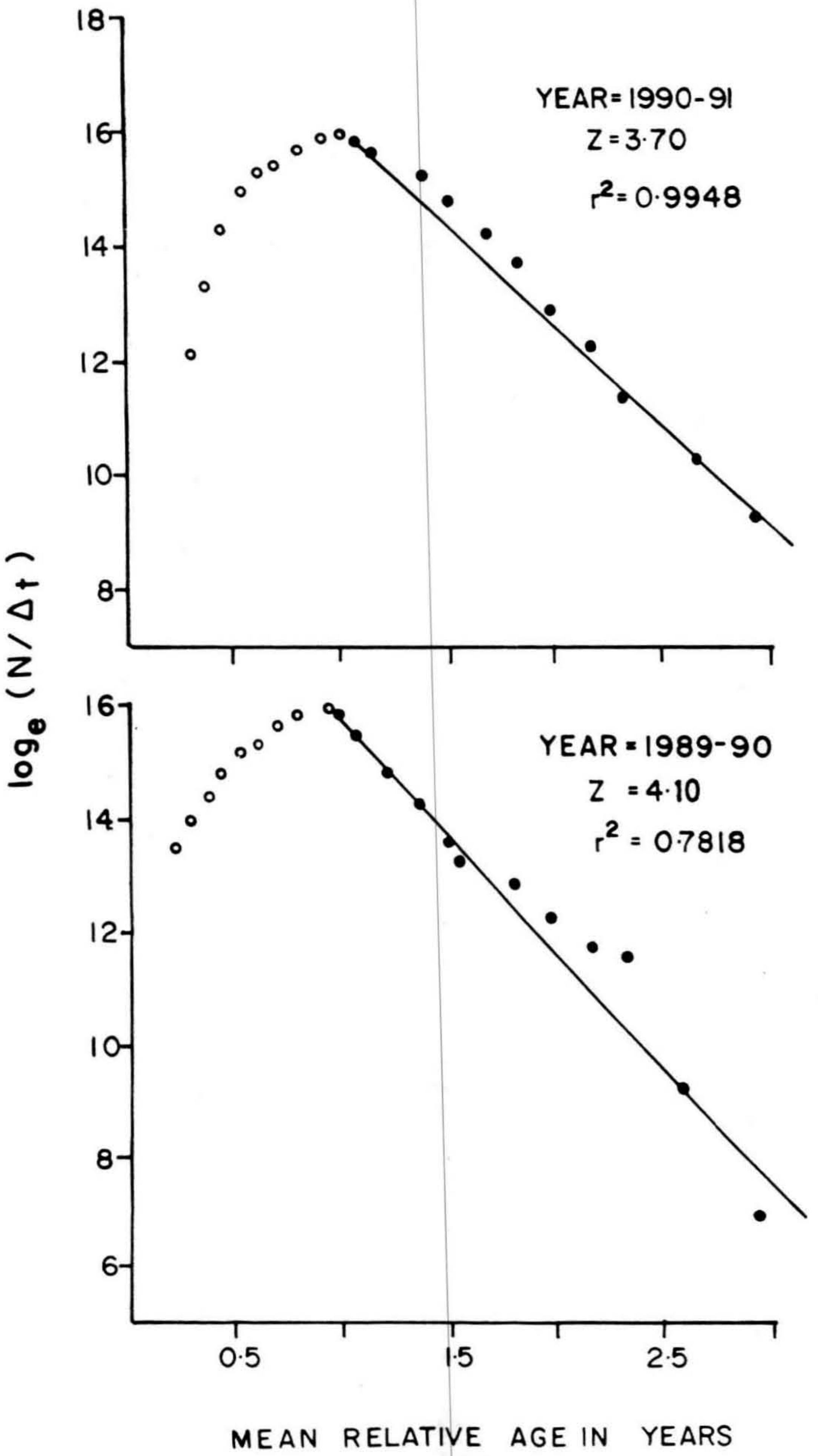

Fig. 6.1 Estimation of 'Z' by length converted catch curve method for *S. tumbil*.

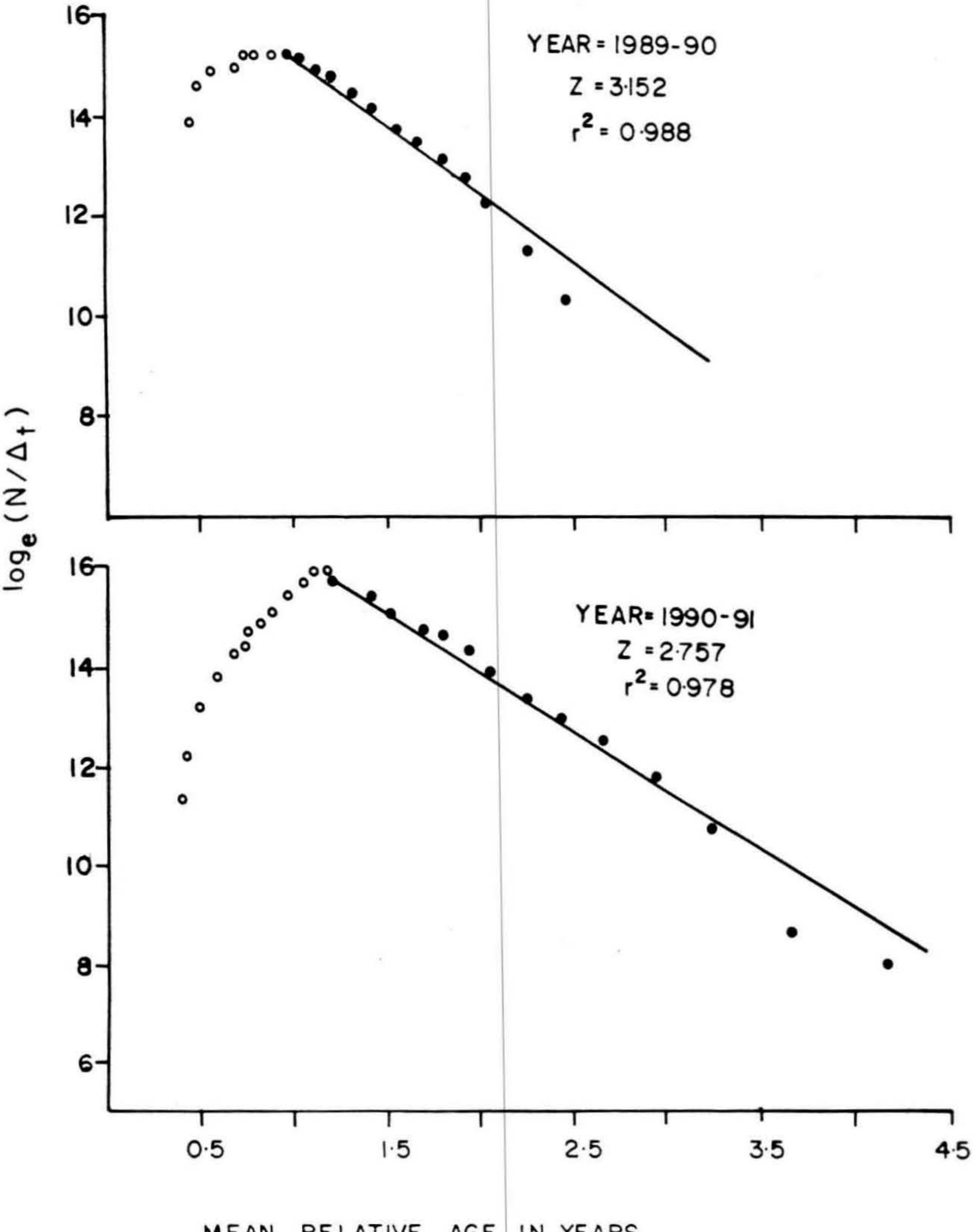

Fig. 6.2 Estimation of 'Z' by length converted catch curve method for *S. undosquamis*.

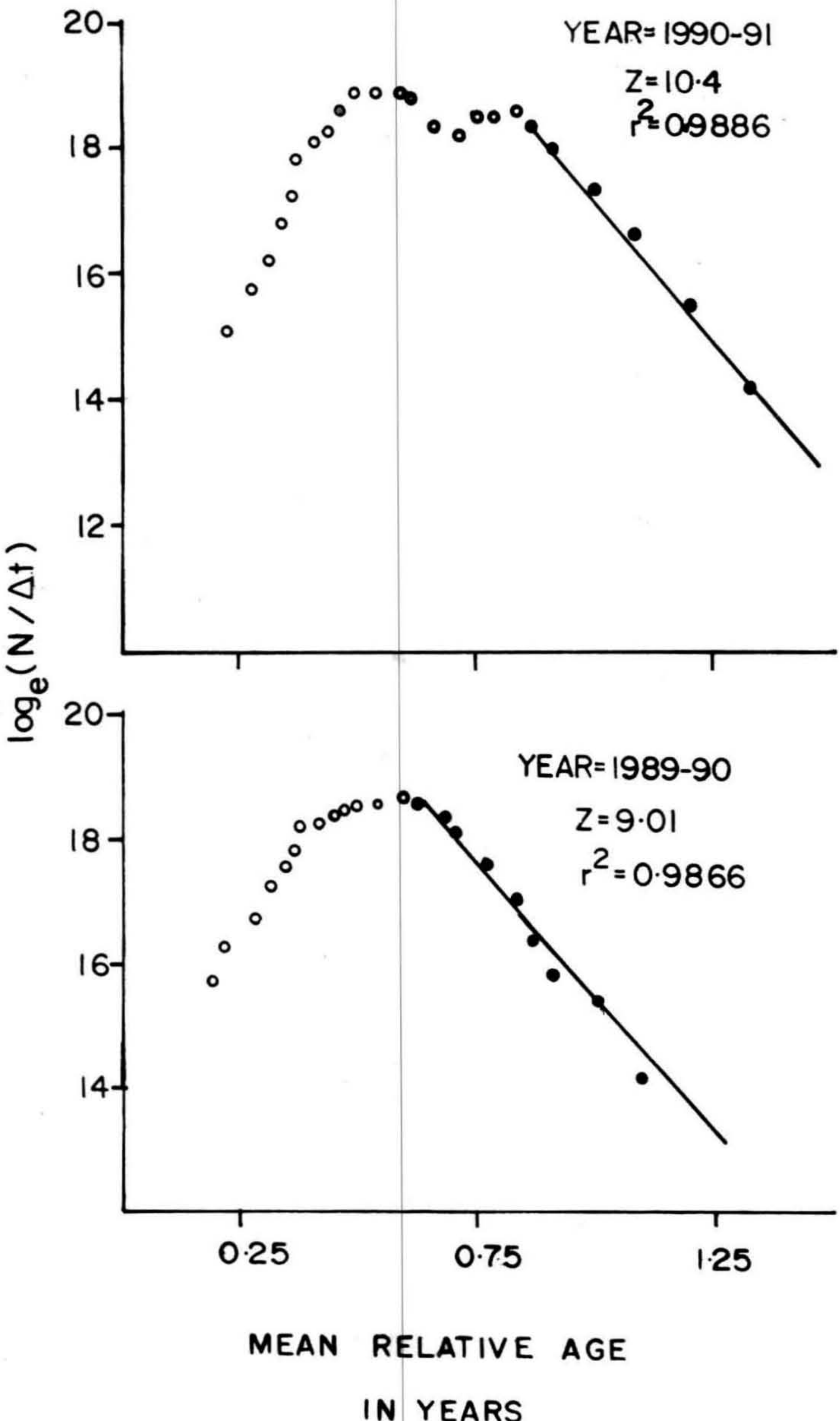

Fig. 6.3 Estimation of 'Z' by length converted catch curve method for *S. isarankurai*.

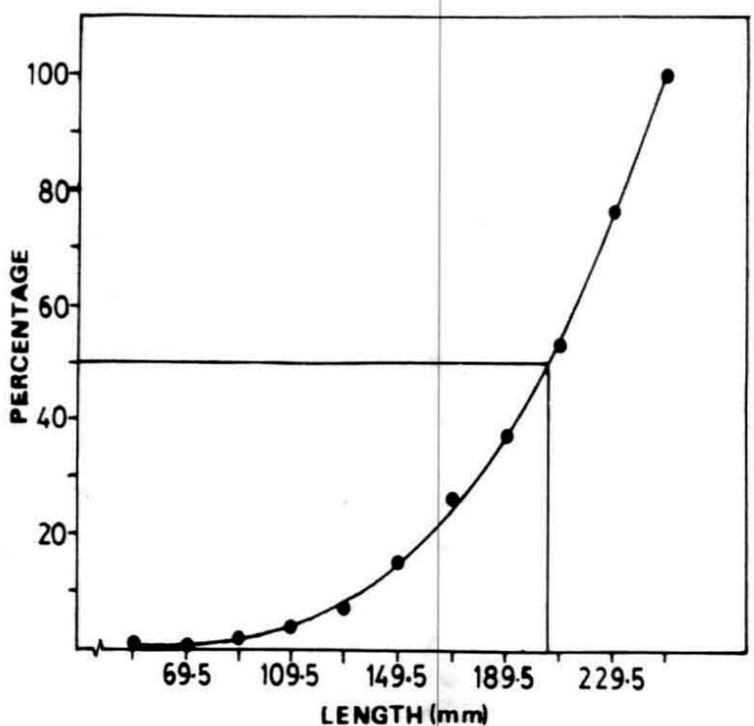

Fig. 6.4 Selection curve to determine the size/age at fish capture for *S. tumbil.*

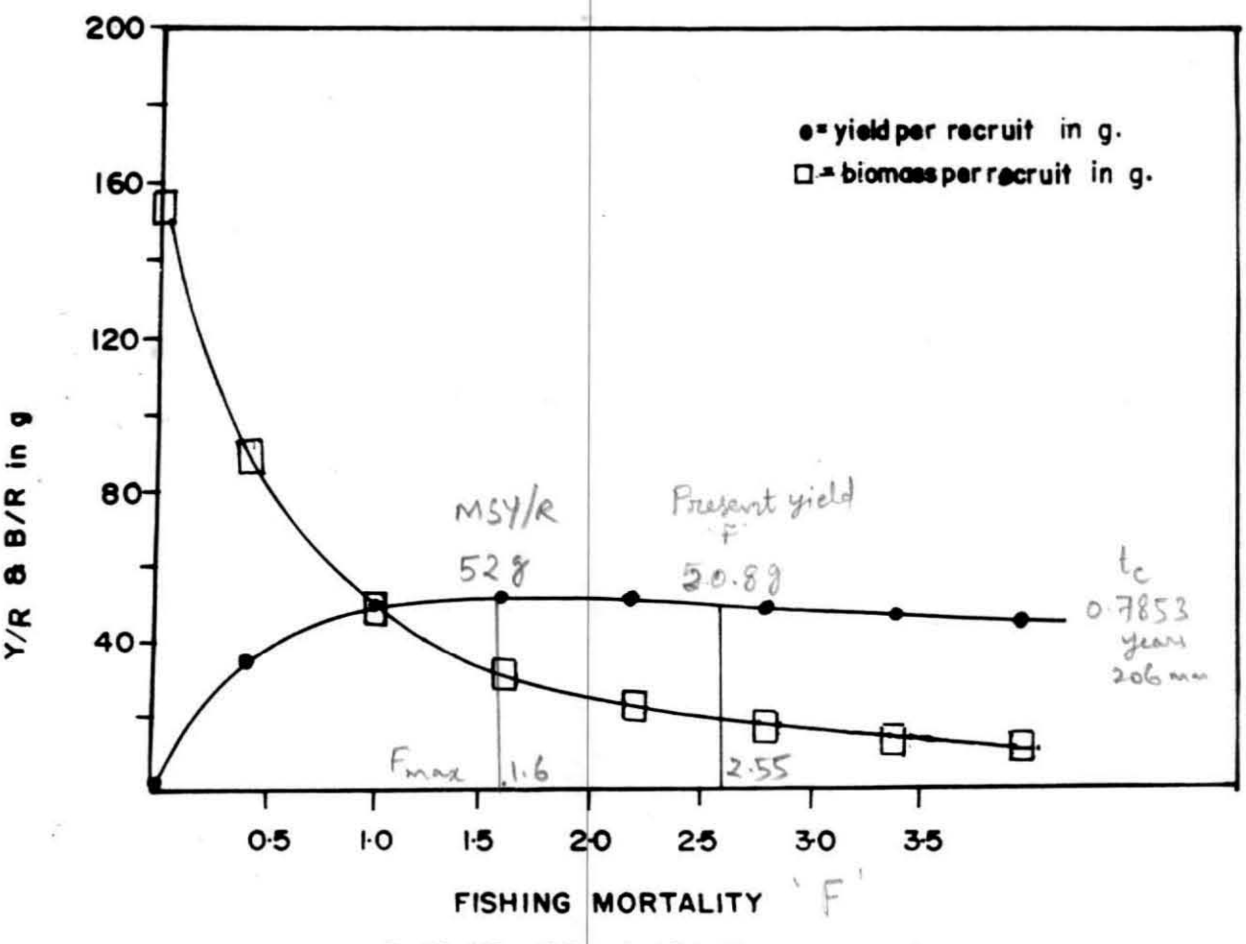

Fig. 6.5 Y/R and B/R curves of *S. tumbil.*

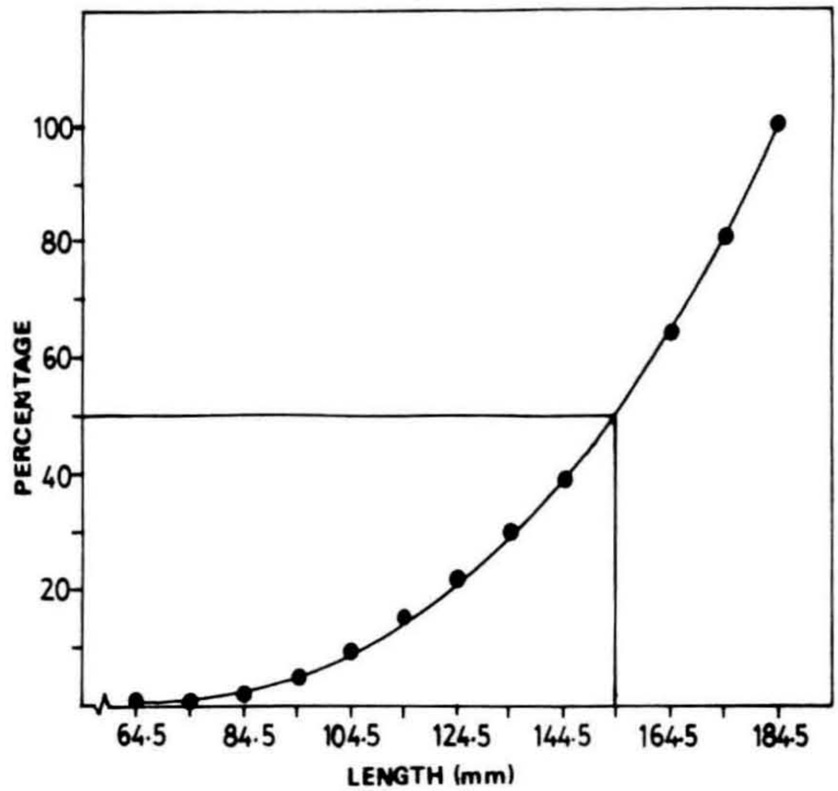

Fig. 6.6 Selection curve to determine the size/age at first capture for *S. undosquamis*.

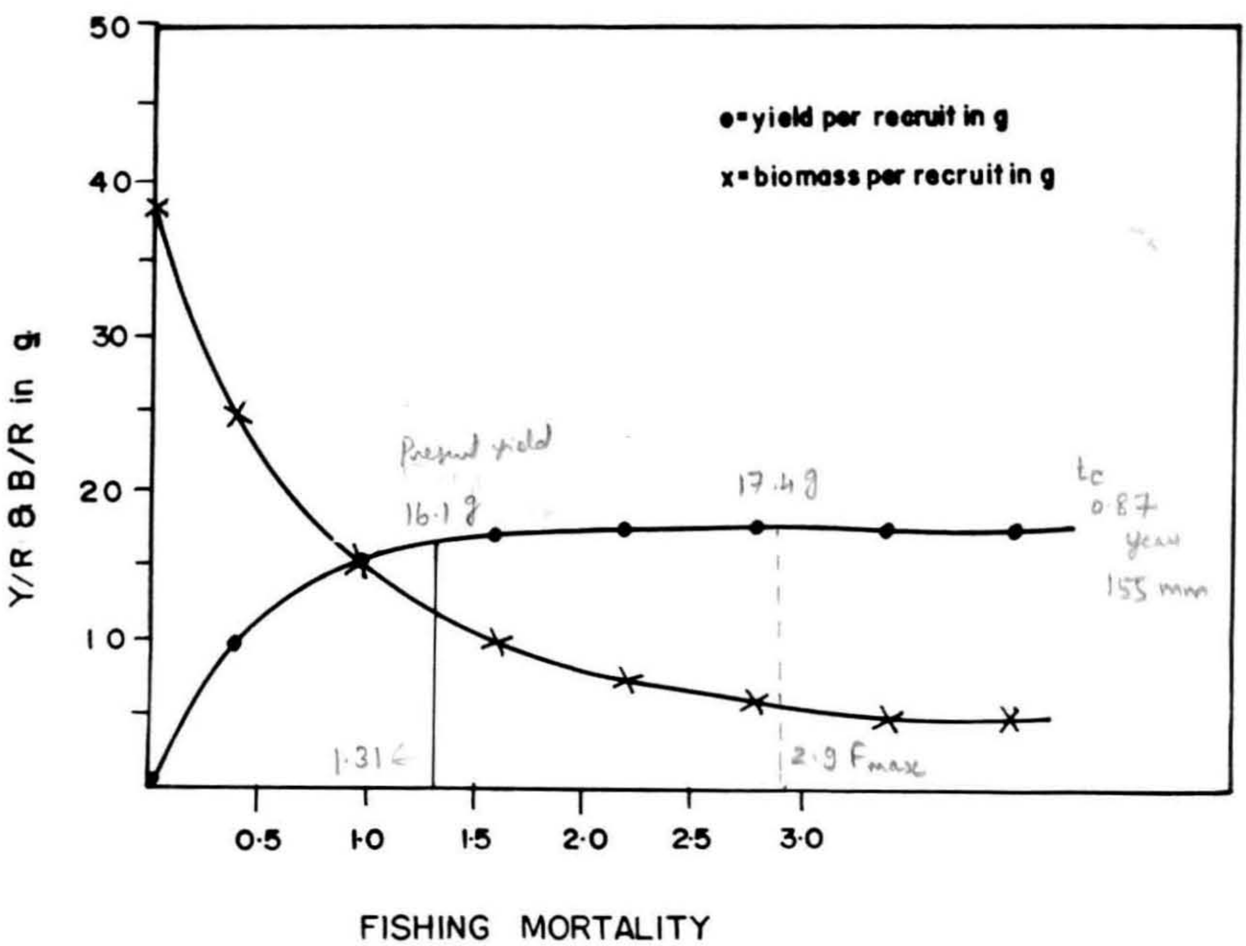

Fig. 6.7 Y/R and B/R curves of *S. undosquamis*.

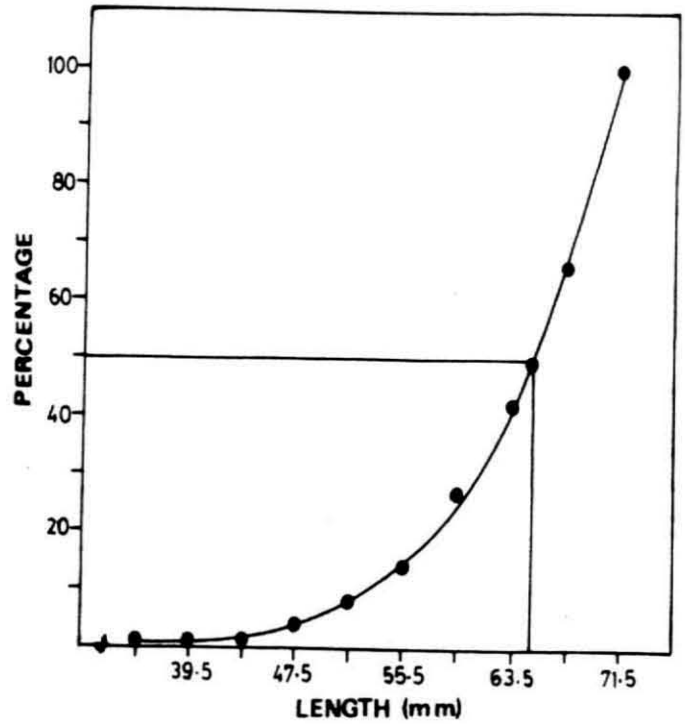

Fig. 6.8 Selection curve to determine the size/age at first capture for *S. isarankurai.*

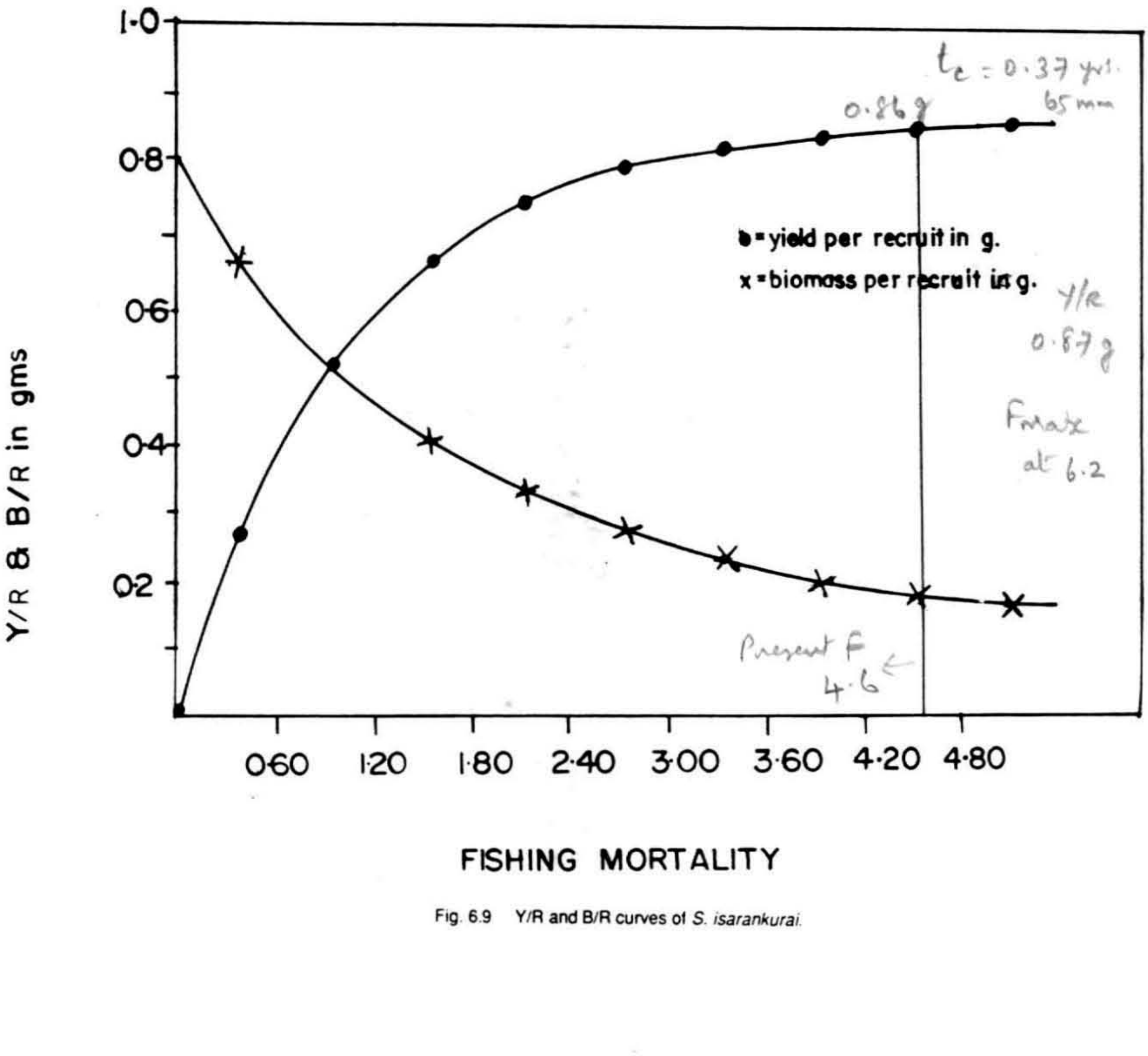

Fig. 6.9 Y/R and B/R curves of *S. isarankurai.*

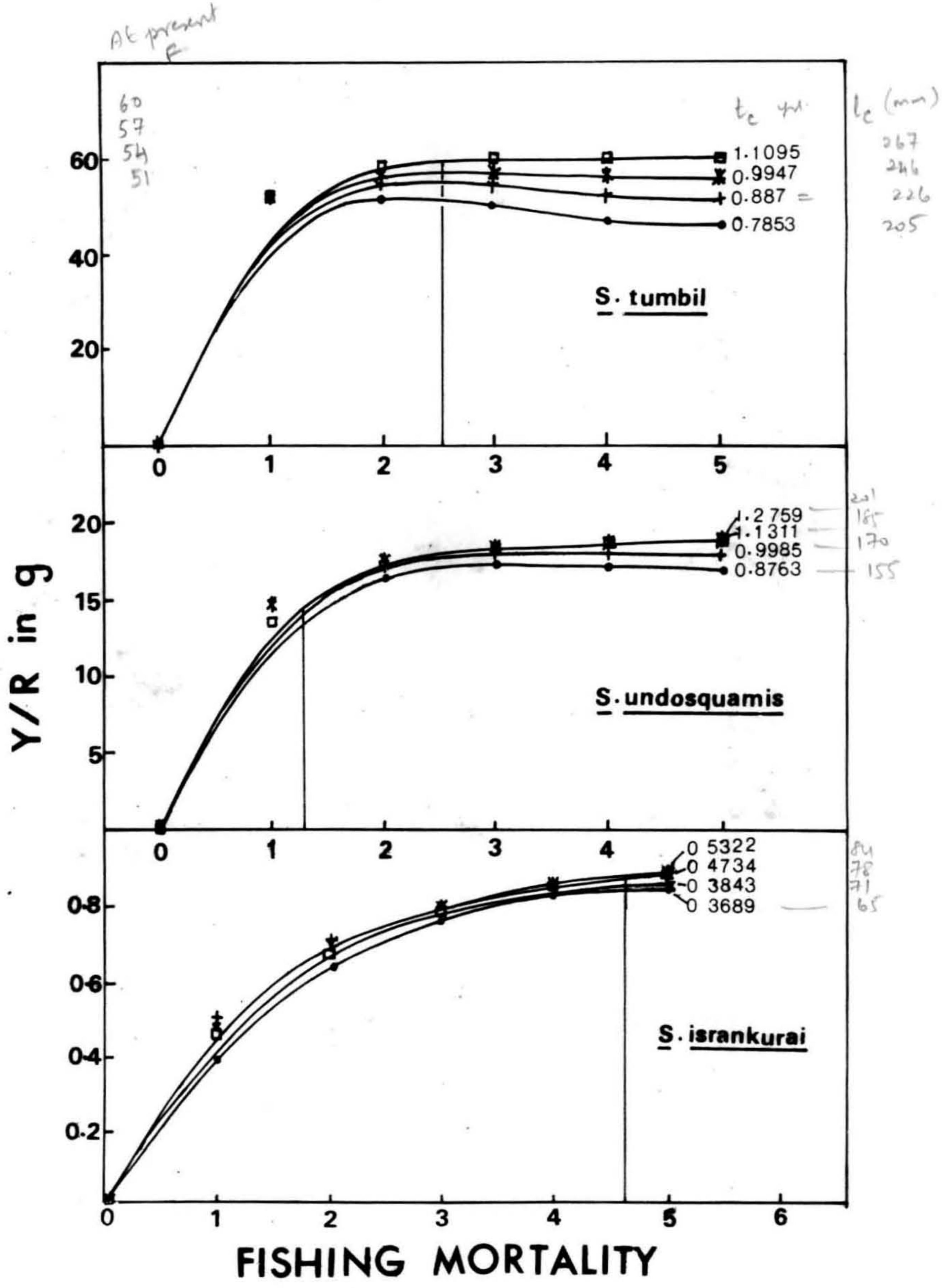

Fig. 6.10 Y/R as a function of fishing mortality in *S. tumbil S. undosquamis* and *S. isarankurai.* Numerals indicate the 't_c' values and the vertical line the present 'F'.

SUMMARY

SUMMARY

The present investigation deals with the fishery, biology and population characteristics of lizardfishes of the genus *Saurida* spp. from the Karnataka coast (lat.12° 44'-14° 53'N; long. 74° 52'-74° 02' E), south-west coast of India, based on the work carried out during November 1989 to October 1991. The data were collected from the major fish landing centres at Mangalore, Malpe, Bhatkal and Karwar along the coast.

Four species of *Saurida*, namely, *S. tumbil, S. undosquamis, S. isarankurai* and *S. longimanus* have been recorded in the fishery during the study period. While the first two species are common and known earlier, the present report of *S. isarankurai* forms the first record of the species from the Western Indian Ocean and of *S. longimanus* from the west coast of India.

Key characters of the family Synodontidae and of the genera, *Saurida spp., Synodus* and *Trachinocephalus* are presented. On the basis of the morphological, morphometric and meristic characters, the four species of *Saurida* spp. are described briefly along with their geographical distribution.

The lizardfish fishery along the Karnataka coast is supported by *S. tumbil, S. undosquamis* and *S. isarankurai*, which are caught exclusively by trawlers (6.75 - 15 m OAL) operating bottom trawl in relatively deeper waters of 20-60 m depth area during the fishing season, November-May.

The estimated landing of *Saurida* spp. at four fish landing centres at Mangalore, Malpe, Bhatkal and Karwar combined together, amounted to 840 t and 1516 t during 1989-90 and 1990-91 respectively, indicating an increasing trend in their production. Centre-wise also, the fishery exhibited an increasing trend, except at Malpe where the catch and catch rate showed a decline in the second year. Mangalore ranked foremost in the production of *Saurida* spp. with an average annual catch of 617 t, followed by Malpe, 450 t; Karwar 88 t and Bhatkal 23 t, showing an overall gradual reduction in the production from south to north. However, the contribution of *Saurida* spp. in the total marine fish

catch by trawlers was highest at Karwar (8.22%) followed by Mangalore (6.55%), Malpe (5.41%) and Bhatkal (3.18%). Similarly, the annual catch per unit effort (cpue) of *Saurida* spp. was highest at Karwar, 16.2 kg and lowest at Bhatkal, 10.10 kg. At Mangalore and Malpe centres, the cpue was more or less same, being around 14 kg. The peak period of the fishery was February-March at Mangalore, April-May at Malpe and March at Bhatkal and Karwar.

The species-wise composition in general and centre-wise, showed that *S. tumbil* was the major species forming over 50% of the total lizardfish catch and its percentage contribution increased from south to north. *S. undosquamis* and *S. isarankurai* contributed to about 18% and 17% respectively of the lizardfish catch. The fishery importance of the latter species from the Karnataka coast was reported here for the first time.

Studies made on the food and feeding habits revealed that all the three species are predatory carnivores feeding on fishes, cephalopods and crustaceans. The most common fishes encountered in the stomach contents of *S. tumbil* and *S. undosquamis* belonged to the genera, *Stolephorus, Saurida*, *Nemipterus, Platycephalus, Leiognathus* and *Cynoglossus*. In the case of *S. isarankurai*, the food consisted mainly of the genera, *Bregmaceros, Stolephorus* and *Saurida* spp.. The cephalopod food was represented by *Loligo duvauceli* and that of crustacean food by prawns, *Squilla* sp. and crabs. Species-wise, season-wise, size-wise and sex-wise qualitative and quantitative analysis of stomach contents were carried out to study the similarities and disparities of food and feeding regimes of all the three species and the results discussed. In general, all the three species showed preference to *Stolephorus, L. duvauceli* and *Saurida* spp., *S. tumbil* exhibited greater inclination for bottom feeding than *S. undosquamis; S. isarankurai* had more diet restriction than the other two species and fed mainly on juvenile fishes; feeding intensity was relatively better during spawning season of the species and differential feeding intensity in the smaller and larger sizes and in different maturity stages was observed.

The age and growth of the species were estimated by three methods namely, ELEFAN Programme I, Bhattacharya analysis in combination with Gulland and Holt plot and modified Wetherall plot using the length frequency distribution. All three methods gave comparable results in all three species. However, the von Bertalanffy growth equation (VBGE) is expressed based on the growth parameters obtained by ELEFAN.

S. tumbil grows faster and to a larger size, attaining 246 mm, 389 mm and 470 mm respectively at the end of 1,2 and 3 year of its life. The von Bertalanffy growth equation described for this species was:

$$L(t) = 575 [1\text{-}\exp(-0.57 (t\text{-}(+0.021605))]$$

The maximum size recorded was 483 mm and the longevity of the species was estimated as 3.3 years. The fishery was composed of 0-3 year classes, of which the 0-year and 1-year class fishes were found to be the mainstay of the fishery, each group contributing about 49% of the catch.

S. undosquamis grows at a slower pace and reaches to 170 mm, 260 mm, 307 mm and 332 mm respectively at the end of first, second, third and fourth year of its life. The VBGE derived was:

$$L(t) = 360 [1\text{-}\exp(-0.64 (t\text{-} (+0.0006578))]$$

The largest size recorded in the fishery was 340 mm and the longevity was found to be 4.83 years. The fishery was constituted by 0-4 year classes, of which 0-year class formed 33.66% and 1-year class 62.57% of the exploited catch.

S. isarankurai is a smaller growing and short-lived species. It attains a size of 121 mm at the completion of a year. The VGBE derivated for this species was:

$$L(t) = 158 [1\text{-}\exp(-1.5 (t\text{-}(+0.033602))]$$

The maximum size recorded for the species was 140 mm and the longevity as 1.5 years. The fishery was composed of 0-year and 1-year classes. Of this, the 0-year class constituted as high as 96% of the fishery.

S. tumbil and *S. undosquamis* attain first maturity at the end of 1 year and *S. isarankurai* at 0.5 year. The growth rate showed that the former two species grow faster during the fist year and the latter during the first 6 months of its life, indicating faster growth before attaining maturity, as observed in most of the tropical fishes.

Studies on the length-weight relationship showed that the regression co-efficients of both sexes in *S. tumbil* did not differ significantly from 3 indicating isometric growth. In the case of *S. undosquamis* and *S. isarankurai*, males obeyed isometric growth whereas females departed significantly from the isometric growth. Further, juveniles of all three species were found to deviate from the cube law.

The average size at fist maturity was 250 mm for males and 264 mm for females of *S. tumbil*, 167 mm for males and 207 mm for females of *S. undosquamis* and 83 mm for both the sexes of *S. isarankurai*.

The monthly distribution of maturity stages, gonado-somatic index (GSI) and relative condition ('Kn') indicated that spawning in these species was a prolonged one; extending from October to February in *S. tumbil* and November-March in *S. undosquamis* with a peak in November-December in both the species. In *S. isarankurai* spawning occurred during November-April with a major peak in December followed by a minor peak in February. Since all the adult fishes were either immature or spent-recovering condition after February, March and April respectively in *S. tumbil*, *S. undosquamis* and *S. isarankurai*, it was inferred that the spawning activities ceased after this period.

Recruitment pattern in *S. tumbil* and *S. undosquamis* suggested a single pulse. However, in *S. isarankurai*, it showed two pulses of unequal strength.

The maturation process of ova and distribution pattern of ova diameter in the ovaries of these fishes indicated multiple spawning behaviour during the breeding season. *S. tumbil* and *S. undosquamis* were found to release on an average of 4 batches and *S. isarankurai* 3 batches of eggs during the spawning season.

The sex ratio studies showed a general preponderance of females in all the three species. Females outnumbered males above the length group of 260 mm in *S. tumbil* and 200 mm in *S. undosquamis*. In *S. isarankurai*, males were more in the length group of 80-84 mm. Above this length, females were found to be dominant upto 130 mm except in 105-114 mm size groups. Above 370 mm in *S. tumbil*, 290 mm in *S. undosquamis* and 135 mm in *S. isarankurai* all fish were found to be invariably females.

Generally, the fecundity showed a linear relationship with length and weight of fish and ovary weight. The fecundity varied from 33,998 ova (237 mm) to 3,07,923 ova (458 mm) in *S. tumbil*, 32,529 ova (178 mm) to 1,91,924 ova (316 mm) in *S. undosquamis* and 3,003 ova (84 mm) to 15,069 ova (136 mm) in *S. isarankurai*.

The total instantaneous rate of total mortality (Z), the natural mortality co-efficient (M) and the fishing mortality co-efficient (F) were estimated for the three species. The maximum sustainable yield (MSY) was computed employing Gulland's (1979) formula and Corten's (1974) method. The total stock and standing stock, exploitation rate (U) and exploitation ratio (E) were also computed. The yield per recruit (Y/R) model of Beverton and Holt (1957) was employed for the study of stock and yield status. The potential yield per recruit (Y') and the optimum age of exploitation (t_y) were estimated using the equation formulated by Kutty and Qasim (1968).

The total, natural and fishing mortalities were estimated as 3.70, 1.15 and 2.55 respectively for *S. tumbil*. The exploitation rate was 0.67 and the exploitation ratio 0.69. The total stock was estimated at 1132 t and the standing stock at 298 t. The MSY was 781 t as against the present yield of 761 t. The Y/R at F max of 1.64 was 52.07 g as compared to the Y/R of 50.69 g at the present F of 2.55 indicating already a declining trend in the yield. The potential yield per recruit was found to be 56 g at an optimum age of 1.67 years. The present age at capture was 0.78 years.

The Z, M and F estimated for *S. undosquamis* were 2.62, 1.31 and 1.31 respectively. The total stock, the standing stock and the MSY were 465 t, 164 t and 233 t respectively as compared to the present yield of 263 t. The Y/R at F max of 2.88 was 17.37 g as against 16.07 g at the present F of 1.31. The present exploitation rate was 0.46 and the exploitation ratio, 0.50. The Y' was found to be 16.55 g. The optimum age of exploitation was 1.51 years as against the present age of capture of 0.87 years.

For *S. isarankurai*, the Z, M, F were estimated at 7.87, 3.26 and 4.61 respectively. The exploitation rate was computed at 0.58 and the exploitation ratio at 0.58. The MSY was 204 t as against the present yield of 202 t. The average total stock was 345 t and the standing stock, 44 t. The maximum Y/R was 0.87 g at F max of 6.17 as compared to the present Y/R of 0.86 g for F of 4.61. The potential yield per recruit was 2.0 g. The optimum age of exploitation was 0.64 years as against the current age at capture of 0.37 years.

The Y/R with 10%, 20% and 30% increase of cod-end mesh from the present and keeping the present F constant, the Y/R would be 54.46 g, 57.47 g and 59.7 g respectively for *S. tumbil*, 16.13 g, 15.88 g and 15.30 g for *S. undosquamis* and 0.86 g, 0.88 g and 0.87 g for *S. isarankurai*. The study shows that with 10% and 20% increase in cod-end mesh size, F cannot be increased for further exploitation of *S. tumbil*; however, only at 30% increase, the present F of 2.55 can be maintained. Whereas, in the cases of *S. undosquamis* and *S. isarankurai*, F can be increased in the event of cod-end mesh size increase by over 10%.

The M/K ratios of 2.02, 2.05 and 2.17 respectively for *S. tumbil*, *S. undosquamis* and *S. isarankurai* compared well with that of *Saurida* spp. from other parts of the world thereby giving further credence to the constancy of M/K ratio among the closely related species.

The present size at capture is 206 mm, 155 mm and 65 mm for *S. tumbil*, *S. undosquamis* and *S. isarankurai* respectively, which are less than the average size at first maturity of these species indicating that atleast a segment of the population of these species are captured at present without allowing them a chance for breeding even once during their life span.

The study indicated the stocks of the main species, *S. tumbil* which contributes significantly to the lizardfish fishery is over-exploited (E = 0.69). The next important species, *S. undosquamis* is harvested at present at an optimum level (E = 0.50). The third species *S. isarankurai* which supports a minor fishery is exploited around the MSY level (E = 0.58). It is possible to enhance the effort to get increased yield for the latter two species, but the quantum of output may not commensurate with the effort expended. Moreover, it would result in further over exploitation of *S. tumbil* and other similarly over fished stocks of demersal varieties of fishes which co-exist in the same fishing ground. Regulatory measures, in the context of prevailing multispecies nature of the demersal fishery and in consideration of the socio-political aspects are discussed.

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*·Not referred to in original.

APPENDIX