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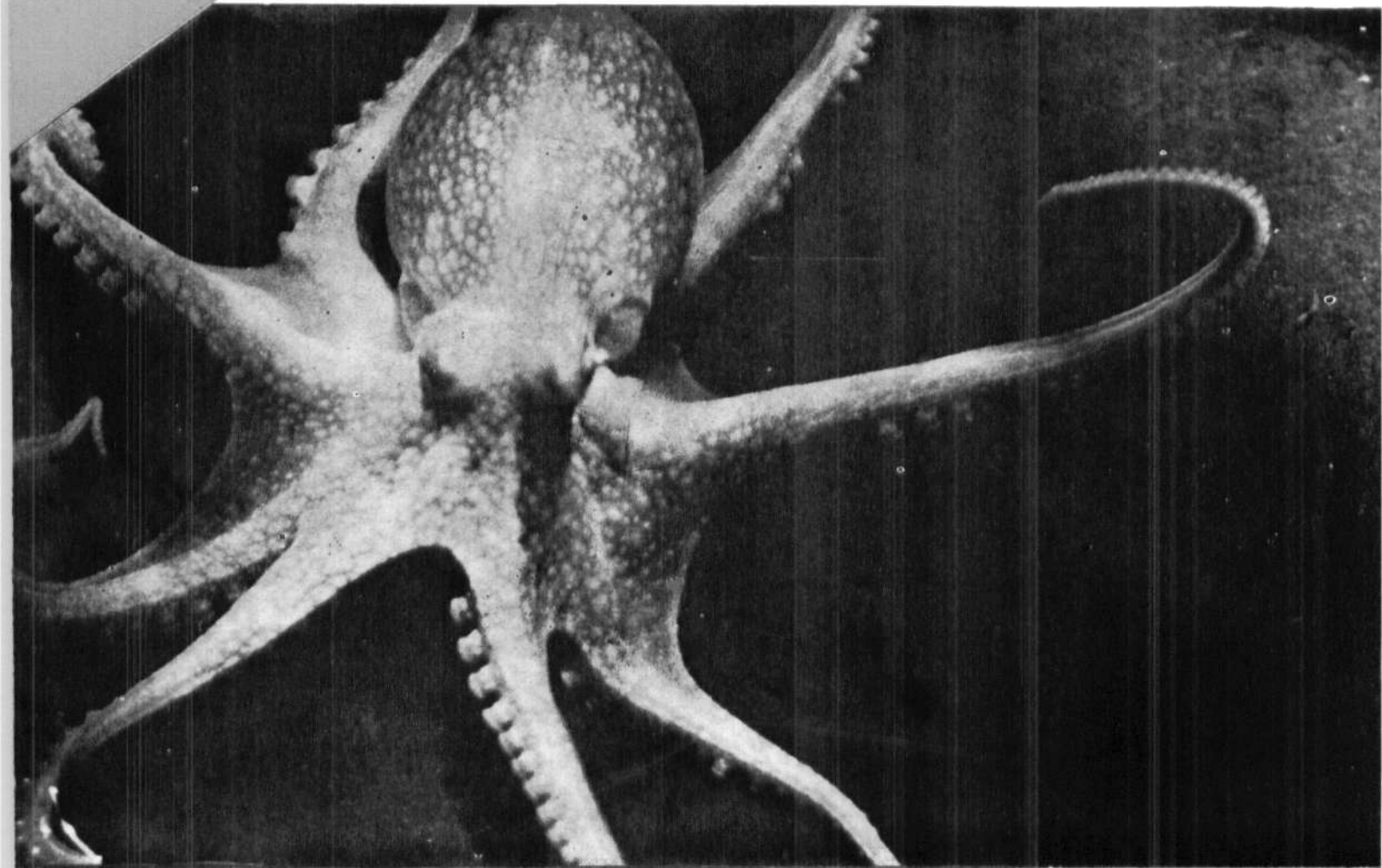
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CEPHALOPOD BIONOMICS, FISHERIES AND RESOURCES OF THE EXCLUSIVE ECONOMIC ZONE OF INDIA

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SOME ASPECTS OF THE BIOLOGY OF SQUIDS

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ABSTRACT

The results of studies on the biological aspects such as sexuality, sex ratio, size at first maturity, spawning, age and growth, distribution of adults, food, predators, life-history and distribution of juveniles of three species of squids *Loligo duvaucelii*, *Sepioteuthis lessoniana* and *Doryteuthis sibogae* are presented. The breeding period of all the three species was found to be prolonged. In *Loligo duvaucelii* the males attained sexual maturity earlier than females in the various fishing grounds investigated.

Loligo duvaucelii Orbigny

BIONOMICS AND LIFE-HISTORY

REPRODUCTION

Sexuality

This species is heterosexual and males are distinguishable by the hectocotylization of the left ventral arm. The males grow to a larger size than females.

Sex ratio

Along Waltair coast females were generally the dominant sex with the average sex ratio during 1976-80 being F 52 : M 48. However, in the various years in one to four months which differed from year to year males outnumbered females (Fig. 1). In contrast along Kakinada coast the males were the dominant sex with the average sex ratio during 1977-80 being M 54 : F 46 (Fig. 1). Only in a few months sexes were equally distributed in the two areas. As on the Kakinada coast males dominated along Madras coast also with an average sex ratio of M 56 : F 44. Females exceeded males in one to five months and only in one month, August, 1977 the two sexes were in equal ratio (Fig. 2).

At Vizhinjam on the west coast on a comparison of the average annual totals of the two sexes, females were seen to be the dominant sex (F 58 : M 42). Only in one to three months at different periods of the year males were the dominant sex (Fig. 3). Along Cochin

coast males were dominant especially during the months February-May and September-October (Fig. 3). Along Bombay coast the sex ratio did not show any well-defined seasonal changes (Fig. 2).

Unlike *Loligo duvaucelii* of Indian coasts, the ratio of males and females is 1 : 1 in squids of spawning schools as well as immature squids of *Loligo opalescens* of Monterey Bay, California (Fields, 1965).

Maturity

Along the east coast, males mature within the size range 50-150 mm at Waltair and 50-130 mm at Madras with 50% maturing at 67 mm and 85 mm in the two areas respectively (Fig. 4). All the males mature by the time they grow to 150 mm at Waltair and 130 mm at Madras. Males mature at a larger size on the west coast, the size of 50% maturity being 108 mm at Vizhinjam and 122 mm at Cochin. All the males reach the mature stage at sizes of 170 mm at Vizhinjam as well as at Cochin.

Females were found to attain maturity at a larger size as compared with males. On the east coast the size at first maturity is 108 mm at Waltair and 96 mm at Madras. The females attain maturity when they range in size between 50 mm and 170 mm at Waltair and between 70 mm and 150 mm at Madras. All females reached the mature stage at 170 mm at Waltair and at 150 mm at Madras. On the west coast the size of 50% maturity is 110 mm at Vizhinjam and it is slightly higher, 128 mm at Cochin. The size ranges in which maturity was attained by this species at Vizhin-

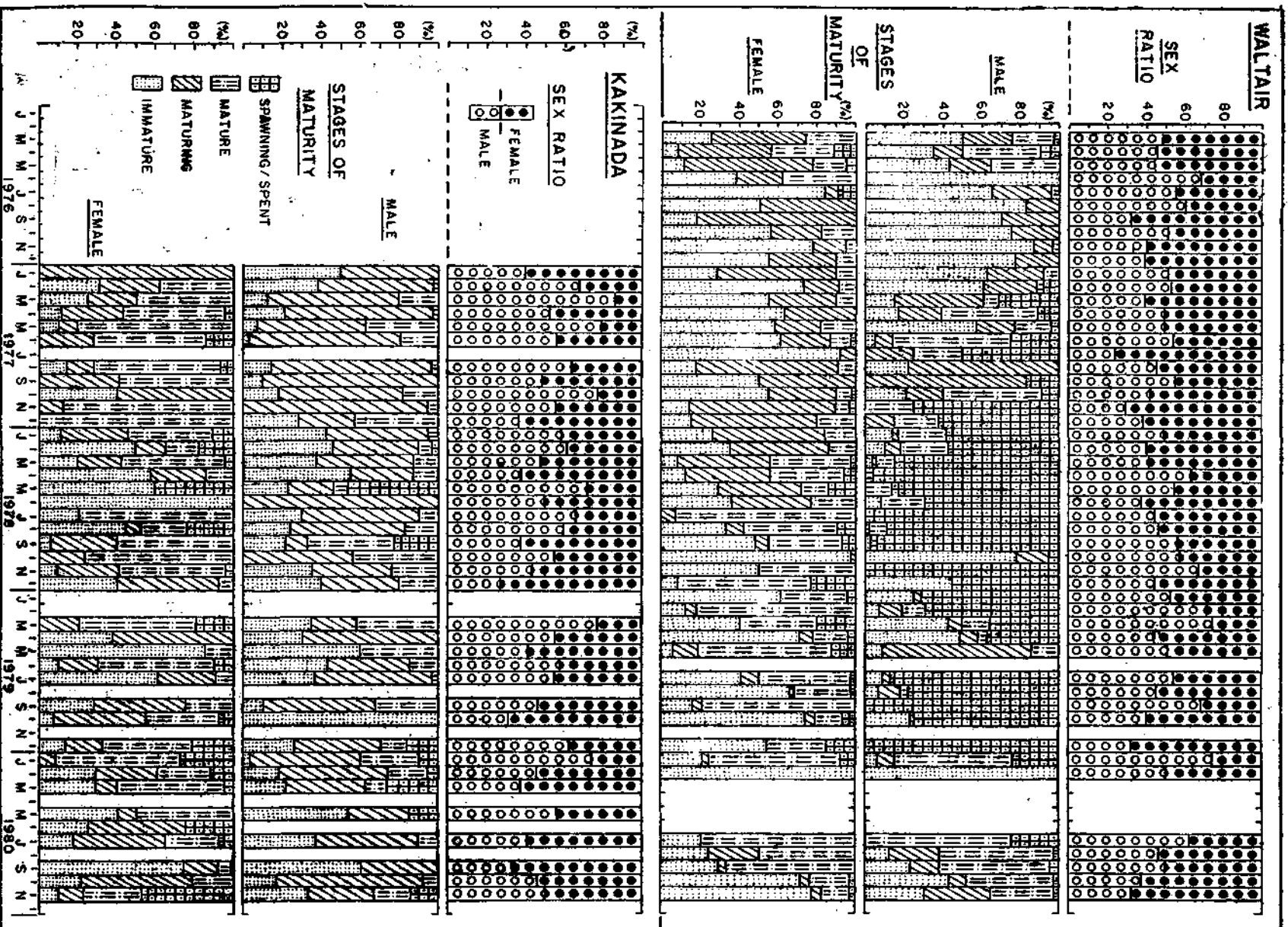


FIG. 1. Sex ratio and stages of maturity of *Loligo dinanchei* off Waltair (Visakhapatnam) and Kakinada.

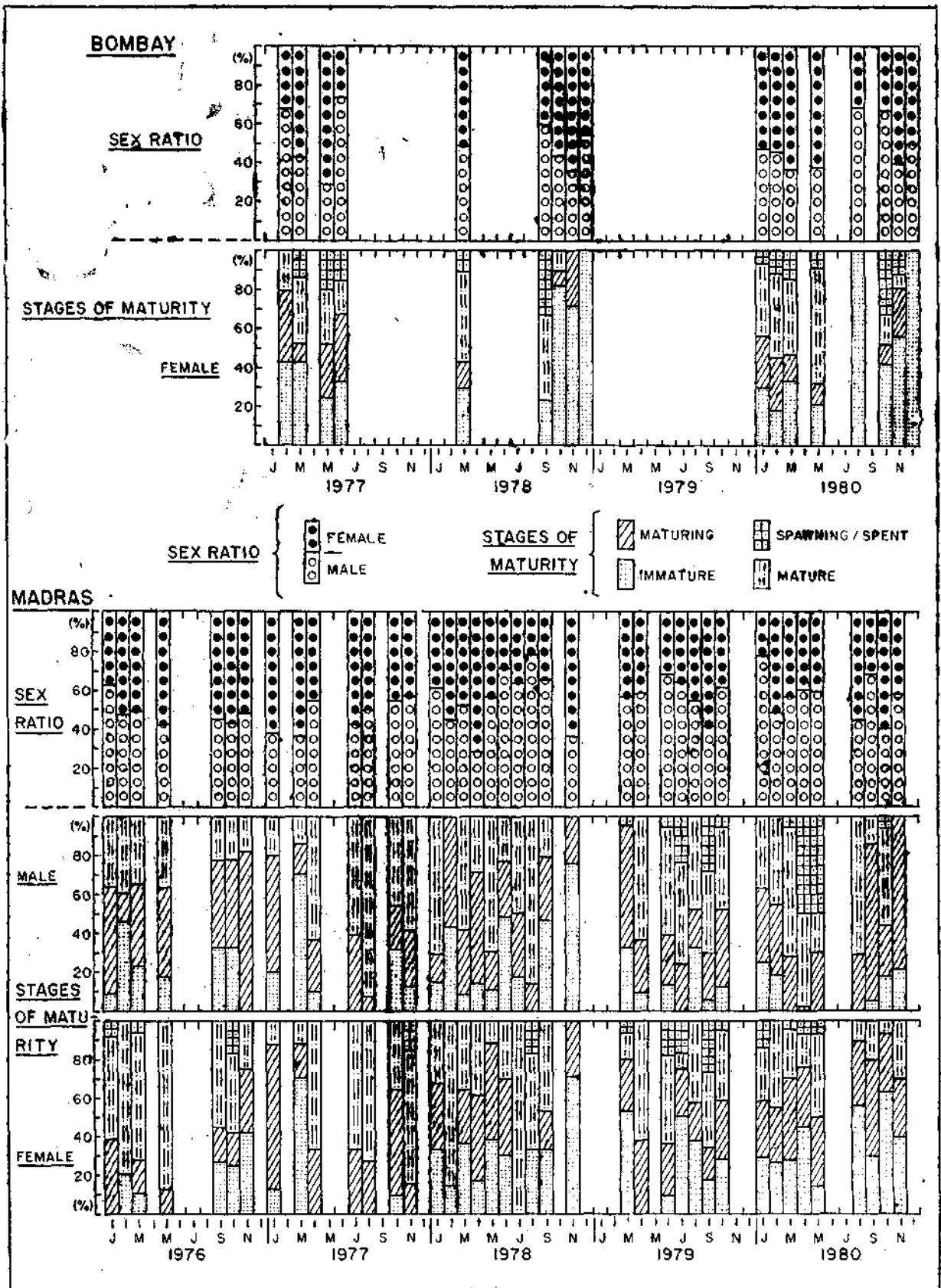


FIG. 2. Sex ratio and stages of maturity of *Loligo divaucteli* off Bombay and Madras.

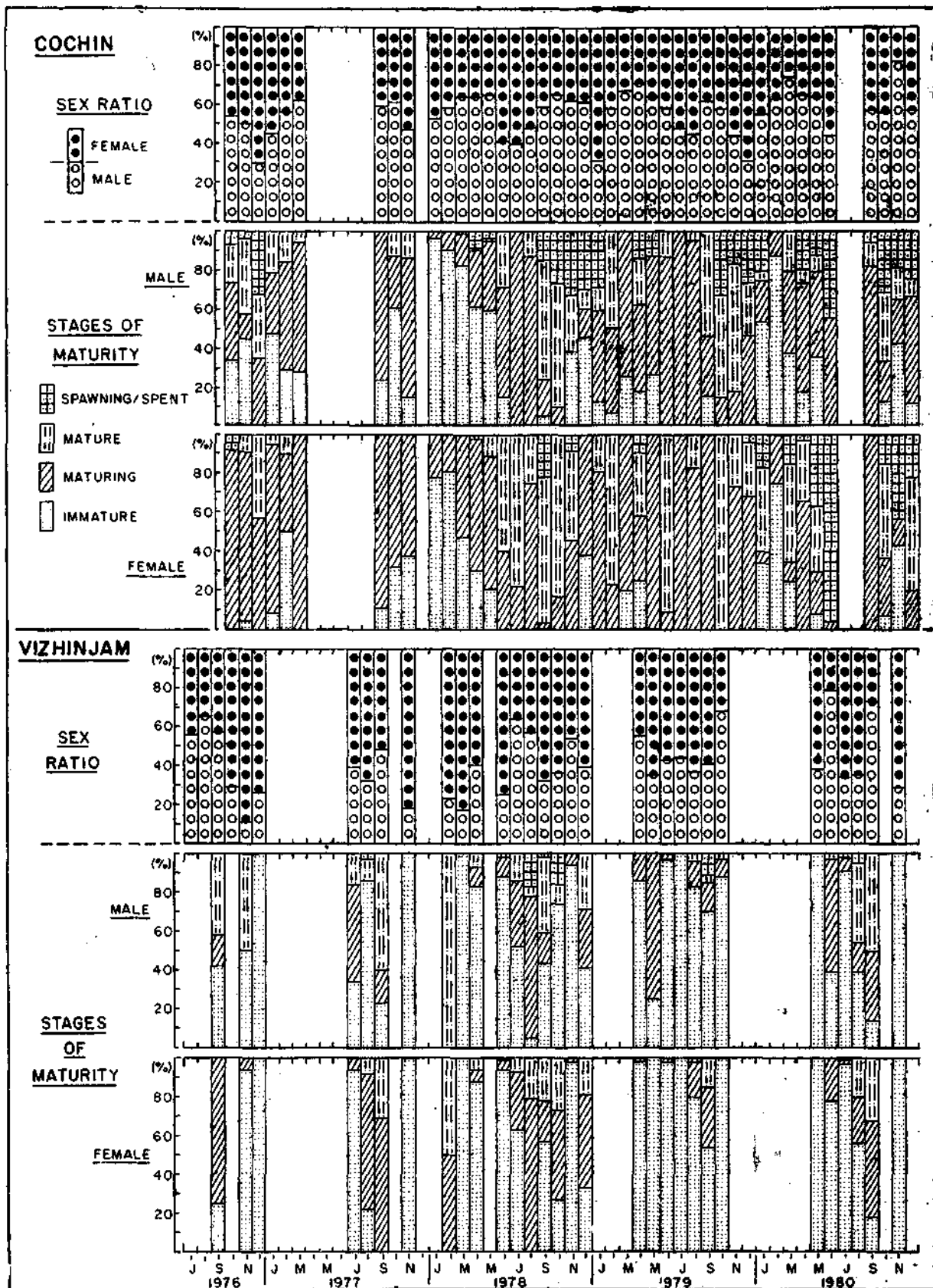


FIG. 3. Sex ratio and stages of maturity of *Loligo duvaucelii* off Cochin and Vizhinjam.

jam and Cochin were 90-190 mm and 90-170 mm respectively. All the females attained mature stage when they reached a size of 170 mm at Cochin and only at 190 mm at Vizhinjam.

The studies carried out on *Loligo duvaucelii* at different centres shows that males of the species mature at comparatively smaller size than females in all the areas. Another noteworthy feature is that squids of the two sexes become sexually mature at smaller sizes along the east coast than those along the west coast. The factors

Spawning

Maturing males and females were recorded at all centres along the east and west coasts of India in several months indicating that maturation takes place all through the year. At Waltair mature females were found all round the year with peak numbers in January-March, May, July, September and December. Spawning females occurred in small percentages in several months indicating breeding activity almost throughout the year (Fig. 1). Mature males were common or moderately so in different months. Spawning males

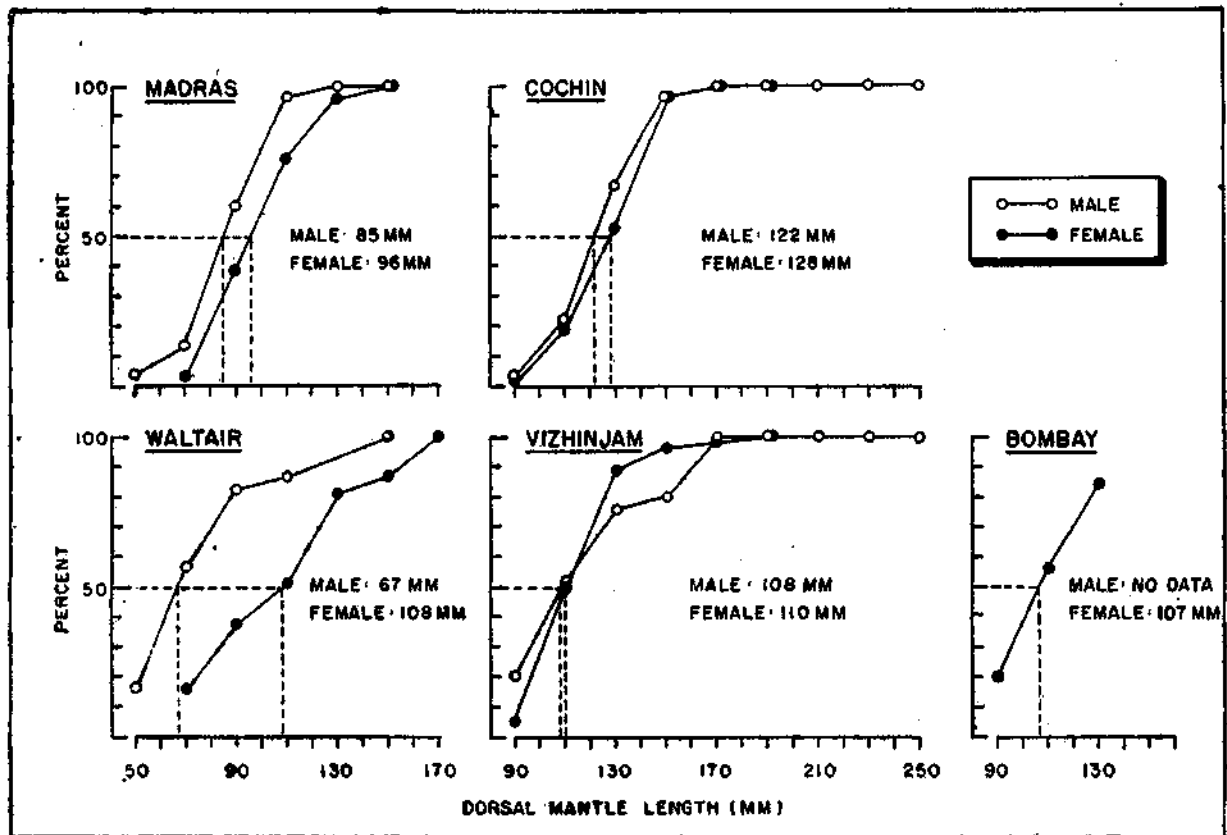


FIG. 4. Size at first maturity of *Loligo duvaucelii* off Madras, Cochin, Waltair (Visakhapatnam), Vizhinjam and Bombay.

responsible for the differences are not clear and require an in-depth study. Maturation of reproductive organs of squids is considered to be controlled by hormonal stimulation in turn influenced by environmental factors like day length and water temperature (Grieb and Beeman, 1978).

The size at which all the squids reached mature stage is higher in both sexes of *Loligo duvaucelii* along the east and west coasts of India as compared to *L. opalescens* of California coast, in which it has been observed (Fields, 1965) that males attain maturity in the size range 70-130 mm and females in the range 81-140 mm.

were very common in the months January-April, June-September and November-December.

At Kakinada mature females were common and spawners were in small percentages all round the year (Fig. 1). Mature males were found in small to moderate percentages almost throughout the year and spawners in all months except October.

At Madras mature females were common from January to November with peak numbers in six months February, April, May and July-September (Fig. 2). As at the northern centres Waltair and Kakinada,

spawning females were found at Madras only in small percentages except for February and December when they were not recorded. Like the females, mature males also were found from January to November, with peaks in January, April to August and October. Spawning males occurred in small or moderate numbers in different months except January, February, August and November-December.

At Vizhinjam mature females were found in all months except March, May and November and they occurred generally in small percentages except in February and September when they were moderately common (Fig. 3). Spawning females were not observed along Vizhinjam coast. Mature males were recorded throughout the year except in January, March and May and they were very common in two months viz., February and September while spawning males in small numbers were observed only in three months August-October.

Along Cochin coast mature females were encountered in varying abundance. They were very common in June, July and October, moderately so in February, April, August, November and December and less common in other months (Fig. 3). Generally spawning females occurred in small numbers along this coast in all months except July-August. Mature males were commonly seen from September to December and they were moderately common in the other months. Males in running condition were observed in all months except February-March and July-August and they formed fairly good percentages in June and October-December.

Along Bombay coast mature females were common from January to May and in September and they were less common in June and October (Fig. 2). Spawning females occurred along with the mature ones and were common in September and moderately so in May, June, October and November. The studies carried out show that along both the coasts the spawning season of *L. duvaucelii* is very much prolonged with peaks in varying months.

Fields (1965) has considered that in Monterey area two populations of *L. opalescens* entered spawning grounds, one a dominant one from January to June and the other which migrated from south of Point Conception from July to December.

In sexually ripe *L. duvaucelii* females the ovary and oviduct with ova are large and fill the entire posterior region of the mantle cavity while the nidamental glands are large, firm and white and the accessory nidamental glands orange red in colour. In ripe male squids the

testis is elongated, thick and milky white and the spermatophore sac is filled with fully formed spermatophores. The mantles and fins of the mature male and female squids are thick and well developed.

After spawning, the mantle of females become thin and flaccid. The ovary contains a few residual ova and there are a few or no ova in the oviduct. The nidamental glands are small in size and flabby while the accessory nidamental glands are pale pink in colour. In spent males the testis is thin and the spermatophore sac is small containing small number of spermatophores. The body and fins of spent males show a loss in size and shape but this is not as much as in the case of spent females.

It is not possible to state whether *Loligo duvaucelii* die after one spawning. Some male squids of the species *L. peali* have been considered by Summers (1969) to survive after first spawning season and may live upto three years. Fields (1965) opined that females of *L. opalescens* spawn only once and die and since the ratio of males and females is equal, males including precocious ones spawn only once in their lifetime.

ADULT HISTORY

Growth

Based on a preliminary study of the progression of modes of both males and females combined it was found that on Waltair coast this species grows to a size of 64 mm at the end of 6 months and 112.8 mm at the end of 1 year. The rate of growth of this species along Kakinada coast is higher than at Waltair with the squids attaining a size of 83 mm at the end of 6 months and 121 mm in one year.

On the west coast the growth rate of *L. duvaucelii* is more or less similar in Vizhinjam and Bombay areas upto the age of one year. In Vizhinjam area this species grows to 69 mm at the end of 6 months, 122.2 mm in one year, 167 mm in 1½ years and 209 mm in 2 years. Along Bombay coast a growth of 68.6 mm in 6 months, 124.4 mm in one year, 170.5 mm in 1½ years, 208.4 mm in 2 years, 232.8 mm in 2½ years and 262.7 mm in 3 years was noticed.

It may be seen that the growth attained by this species is more or less similar upto the end of first year along both east and west coasts. While a growth of 149 mm is reached at the end of 1½ years along east coast, a higher size of 167 to 176 mm is attained on west coast. Along the latter coast this squid grows to 209-220 mm in 2 years, 233-255 mm in 2½ years and 263 mm

in 3 years. Along both coasts of India broods originate at different periods of the year in various areas indicating that recruitment is not confined to any particular period. It is most interesting to note that the growth of *L. duvaucelii* is very fast as compared to that in *L. opalescens*. Fields (1965) has recorded a growth of 65 mm, 120 mm and 150-165 mm at the end of first, second and third years in *L. opalescens* in Monterey Bay.

Detailed studies on the growth of males and females of this species carried out at Cochin and Madras using Von Bertalanfy's formula indicated differential growth rates for males and females at Cochin. But in the same species off Madras coast the growth pattern was similar in both sexes within the size range 45-155 mm.

Relative age	Cochin		Madras
	Males (mm)	Females (mm)	Males and Females (mm)
6 months	.. 86	91.9	75.3
12 months	.. 149.3	142.6	122.3
18 months	.. 196.0	170.6	151.5
24 months	.. 130.0	186.0	169.8

Length-weight relationship

Study of the length-weight relationship of this species of the Madras and Cochin coasts showed that the rate of increase in weight in relation to length differed in males and females. The allometric growth formulae for the two sexes are as follows.

Centre	Males	Females
Madras	$W = 0.000683 L^{2.3769}$	$W = 0.000377 L^{2.5201}$
Cochin	$W = 0.00103 L^{2.2408}$	$W = 0.0005655 L^{2.2985}$

Distribution of Adults

This is a neritic species adults of which are common from the coastal shallow waters upto depths of about 80 m on the continental shelf of both the coasts of India.

The size range of adult males caught in trawl nets off Madras is 50-155 mm while it is slightly higher, 50-175 mm at Waltair. Adult females 70-155 mm and 70-170 mm in size were obtained in the above two areas. In the trawl catches off Kakinada females ranged between 80 mm and 165 mm in size while males measured a maximum of 184 mm. In Bombay area adult males with a maximum size of 285 mm were caught in trawl nets while adult females obtained in the same gear measured only 80-165 mm. On the southwest coast in the trawl catches at Cochin and boat seine and hooks and line catches at Vizhinjam,

adult males were 90-255 mm and adult females 90-190 mm.

Maximum size

The largest size of adult males found along the east coast were 184 mm (at Kakinada) and 170 mm (at Madras) and the largest sizes attained along the west coast were higher being 285 mm (at Bombay) and 190 mm (at Cochin and Vizhinjam). The largest female along east coast (Waltair) and on the west coast (at Cochin and Vizhinjam) measured 190 mm.

Food

Prawns and fishes form the chief item of food of this species. Other items like crabs, stomatopods and euphausiids also form the diet of this squid. Cannibalism has been often noticed.

Kore and Joshi (1975) reported that the food of *L. duvaucelii* of Ratnagiri coast consisted of crustaceans, fish and squids, the crustacean portion including mysids, euphausiids and ostracods. A decrease in feeding intensity was noticed in the squids in the spawning season.

Oommen (1977) studied the structure of the alimentary canal, digestive enzymes and food and feeding habits of *L. duvaucelii* of Cochin area. He found that squids with empty stomach formed as much as 54% of the total number of squids examined. Crustaceans and fishes were the important diet of the squid. The former were dominant in April-May and the latter were common from October to March. The stomach contents were identified by noting the species caught along with the squids in trawl nets and examining the skeletal remains found in stomachs of squids. Prawns, crabs and *Squilla* were the most common crustaceans and sardines, anchovies, mackerel, *Synagris* and *Lactarius* the most common fishes to form the food, (Oommen 1977). Cephalopods including *Loligo duvaucelii* and *Loliolus* sp. were found throughout the year and amounted to 16%.

In *Loligo pealei*, Vovk (1972) recorded seasonal and diurnal changes in feeding intensity. There was active feeding during day time with peak about 16.00 hrs. Fields (1965) found that crustaceans, fishes and polychaetes were the common food of *L. opalescens* of Monterey area and with increase in size the proportion of crustaceans decreased while that of fish increased. Squids above the size of 120 mm showing cannibalism. Karpov and Cailliet (1978) studied the food and feeding habits of *L. opalescens* caught in mid-water and bottom trawls along California coast and observed that euphausiids, copepods and other crustaceans formed the main

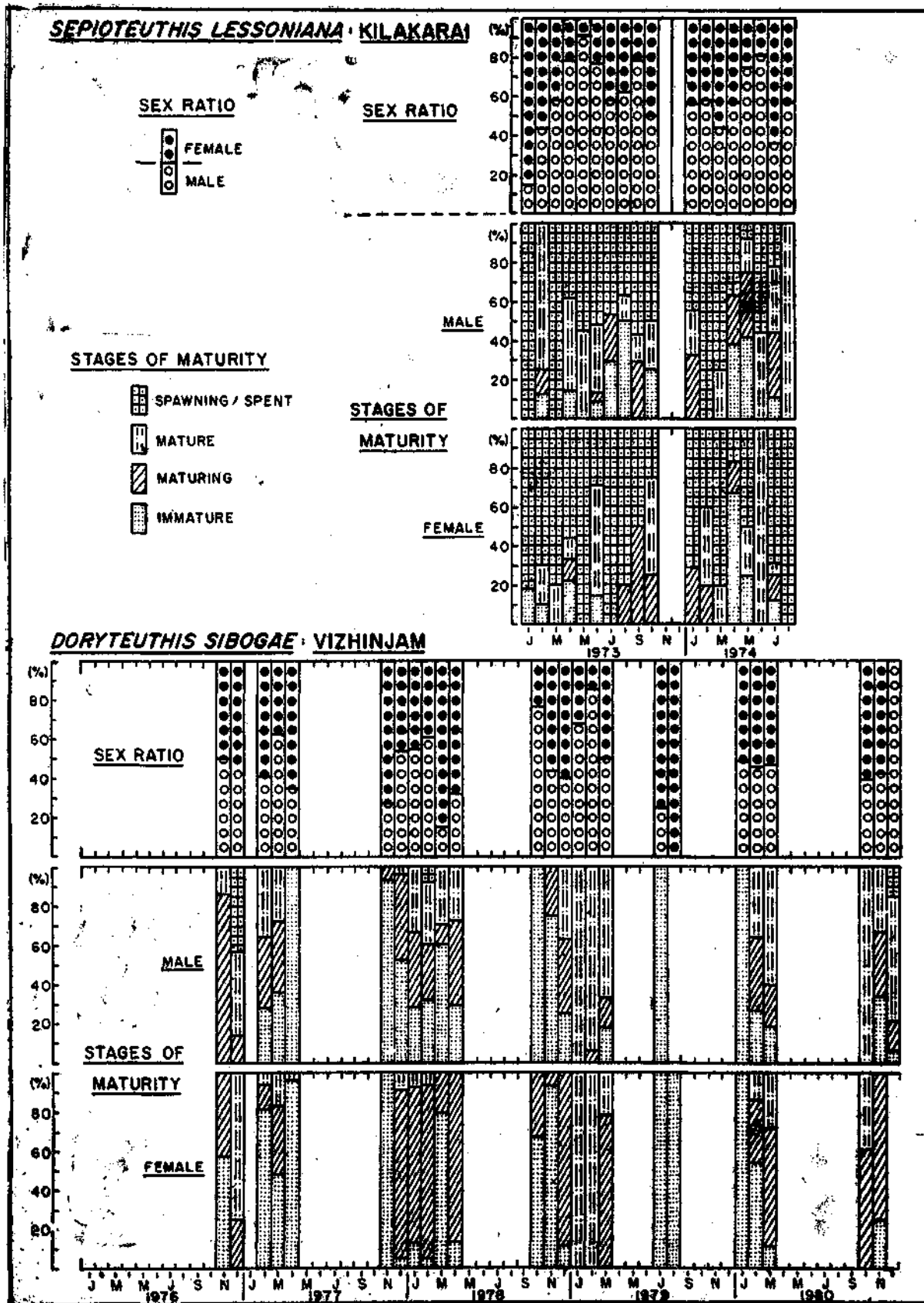


FIG. 5. Sex ratio and stages of maturity of *Sepioteuthis lessoniana* off Kilakarai and *Doryteuthis sibogae* off Vizhinjam.

food item of *L. opalescens* which was also found to be cannibalistic. The authors noted that fish, gastropods, radiolarians and polychaetes formed only minor components of the diet of the species. Few differences were noticed in the food in relation to sex or size. It was reported that squids captured in deeper waters off California fed more on euphausiids and copepods as compared to those from shallow waters. Bidder (1950) determined that in *Loligo* digestion is completed in 4 to 6 hours and the species feeds once or twice a day and also more often when food is available but it does not feed continuously.

Predators

Loligo sp. has been found to form food of *Euthynnus affinis* and large sized *Auxis thazard* and *A. thynnoides* off Vizhinjam coast. Talbot and Penrith (1963) have recorded that *Thunnus alalunga*, *T. albacares*, *T. obesus* and *Histioteuthis bonellina* of South African waters prey on *Loligo reynaudi*.

LIFE HISTORY

Distribution of Juveniles

Juveniles of this species measuring up to 45 mm have been recorded in trawl catches at Waltair, Kakinada and Madras on the east coast and at Cochin and Bombay on the west coast throughout the year. They were obtained in small quantities in shore seines and boat seines along the two coasts.

Sepioteuthis lessoniana Lesson

BIONOMICS AND LIFE-HISTORY

REPRODUCTION

Sexuality

This species is heterosexual and in males which are larger than females the left ventral arm is hectocotylized.

Sex ratio

In 1973 males of this species were dominant in Kilakarai area from March to September (M 58 : F 42—M 91 : F 9) and females were dominant (F 56 : M 44—F 85 : M 15) only in two months January-February (Fig. 5). The two sexes were in equal ratio in October, 1973. In 1974 males outnumbered females in a number of months January-February, April-June and August. Only in March and July females were dominant (F 56 : M 44—F 64 : M 36). The overall average sex ratios during 1973 and 1974 show that males were the dominant sex in the two years. The data of Rao (1954) show that among mature squids, females were dominant in four out of eight months when observations were made viz., June, October and February-March. When the overall averages were compared males were found to be the dominant sex constituting 55% as in 1973-74 data.

Maturity

The observations carried out during 1973-74 have shown that males and females mature in the size range of 90-190 mm with 50% of the two sexes attaining maturity at sizes of 112 mm and 98 mm (Fig. 6). All squids of both sexes were mature at 190 mm. Rao (1954) stated that males of this species reach sexual maturity within the size range of 67.5 mm—112.5 mm and females within 102.5—112.5 mm.

Spawning

Mature females were found to occur in seven months viz., February to July and October and were more common in February, June and October. Mature males were observed continuously from January to October with dominance in February, May, June and August. Spawning females and males were recorded from January to October. Spawning females were most common from January to May and July to September. The data indicate prolonged spawning period from January to September or October in this species. Based on observations made in two fishing seasons during 1950-51, Rao (1954) found that the gonads of the species were in fully, partially or wholly spent condition in May-June, wholly spent from July to October and in a state of fulness from December to February and from this inferred that the spawning period extends from January to June.

After spawning drastic changes take place in the structure of reproductive organs and also mantle and fins. In the sexually mature females the mantle and fins are thick and the ovary has a large number of ripe ova which occupy greater portion of the posterior part of the mantle cavity, the nidamental glands are large and glossy white and the accessory nidamental glands are of orange red colour. On copulation spermatophores are deposited on their buccal membranes. After spawning the mantle and fins become thin, the ovary has only a small number of eggs, the nidamental glands are of pale colouration and the accessory nidamental glands pinkish. In mature males the testis is large and glossy and fully developed and spermatophores are present in the spermatophore sac. After spawning the testis is thin and flabby and the spermatophore sac contains a few residual spermatophores. The mantle and fins of males also become thin after spawning as in females.

Spawning takes place in shallow coastal waters of Mandapam area at depths of 3-10 m as it is evident from the capture of gravid and partly spawned squids caught in shore seines which are operated within about 1 km from the shore (Rao, 1954).

ADULT HISTORY

Growth

Growth studies of the species of Kilakarai Coast (Mandapam area) carried out during 1973-75 and the determination of average growth, showed that the species attains a size of 69 mm at the end of 6 months, 129 mm at the end of one year, 178 mm at the end of one and half years, 217 mm at the end of two years, 246 mm at two and half years and 265 mm at the end of three years. Rao (1954) found that the species from Mandapam-Rameswaram area attained lesser sizes of 95 mm, 166 mm and 219.5 mm at the end of the first, second and third years of the life of the squid.

Distribution of Adults

Adults measuring 65-340 mm are caught in coastal waters of Palk Bay and Gulf of Mannar in shore seines

and hand jigs. Squids of moderate size 120-180 mm are caught in trawling grounds off Mandapam. Stray individuals of this species are obtained off Vizhinjam also.

Maximum size

Males grow to a much larger size than females. The highest sizes of males and females recorded in Mandapam area are 340 mm and 209 mm respectively.

Food

Rao (1954) recorded that bony fish comprised the main food of squids and prawns and crabs formed part of diet to some extent. A good number of squids were also seen to be cannibalistic. The food organisms in the stomachs were found to be broken pieces which made specific identification difficult. Observations on this species in Kilakarai area during 1973-74 indicated

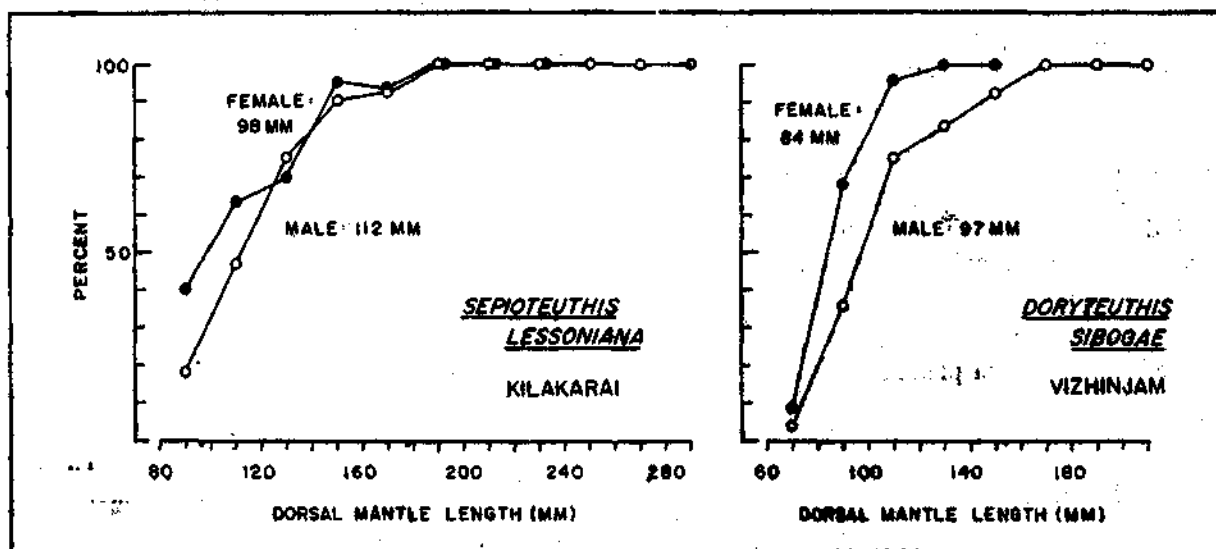


FIG. 6. Size at first maturity of *Sepioteuthis lessoniana* off Kilakarai and *Doryteuthis sibogae* off Vizhinjam.

hat fishes including *Lelognathus* sp., *Upeneus* sp., *Apogon* sp. and others were the most common items of food. Prawns were next in importance while alpheids and stomatopods were found only in a small number of squids. Only a few instances of cannibalism were noticed during 1973-74.

LIFE-HISTORY

Eggs

The eggs are present in egg capsules which consist of a central gelatinous matrix from which finger-shaped capsules numbering fifty or more radiate (Alagarwami, 1966). The egg clusters lie attached to floating or stationary algae, tree branches or other hard, submerged structures in littoral waters. The egg clusters are common in the shallow sheltered coastal waters of

Mandapam area where seaweeds abound. The egg capsules have jelly-like consistency with a firm translucent outer wall and are 62-68 mm in length and 12-13 mm in width. Six or seven eggs are present in a linear row in each capsule with spaces in between and are visible through the gelatinous capsule. The eggs of *S. lessoniana* are large, elongately oval and telolecithal. They measure 6 mm in length and 4.6 mm in breadth and are covered by a chorion with the micropyle at the animal pole of the egg and a perivitelline space surrounding the ovum.

Early development

The early development has been studied by Alagarwami (1966). The cleavages of the egg result in 64 cell stage and later the blastoderm. On the fifth day

after collecting, the shell gland is seen as a depression around which there is a ridge, the primordium of the mantle. Below this is in the depression, the primordia of ctenidia are present. The stomodaeum is formed anteriorly and rudiments of eyes anterolaterally. The primordia of the ventral arms also are formed as thickenings at the lower edge of the blastoderm. By the sixth day the eyes are more well-developed, the mantle grows and covers the primordia of various organs and more arms are budded off.

On the seventh day the ctenidia are long and plume-like, the systemic and branchial hearts are well developed and funnel cartilages formed. The primordia of fins develop by the eighth day. By the fourteenth day the developing embryo appears like a miniature adult with the eyes, mantle, arms and visceral organs well formed. At this stage the embryo moves inside the chorion.

The newly hatched squid measures 7.5 mm in total length (including arms) and 3 mm in width and resembles the adult in basic structural features. In the newly hatched young one, the mantle is transparent, the visceral organs can be seen from outside, yellow and brown chromatophores are found on the mantle, head, arms and dorsal surface of fins, the arms are well developed and funnel completely formed.

The eggs were hatched and the young ones reared by Sivalingam and Pillai (1983) for a period of ten days by feeding them with plankton.

Distribution of juveniles

Young squids 20-60 mm in size are caught in shore seines in Palk Bay and Gulf of Mannar in Mandapam area from February to October. Juveniles measuring 40-60 mm are obtained in small numbers in shore seines along Vizhinjam Coast.

Doryteuthis sibogae Adam 1954

BIONOMICS AND LIFE-HISTORY

REPRODUCTION

Sexuality

Sexes are separate. In addition to hectocotyli- zation of the left ventral arm, the males are larger and have generally slender body with ventro-medial concentration of chromatophores on the mantle.

Sex ratio

The data collected during November, 1976-December, 1980 (Fig. 5) show that females were generally the dominant sex. Males outnumbered females in March 1977, February and October 1978, January and February 1979 and December, 1980. The two sexes were in almost equal ratio in November and December, 1976

and March 1979. When the annual ratios of males and females were compared, females were dominant over males in three years, 1977-79 the ratios being F 56 : M 44, F 54 : M 46 and F 54 : M 46 respectively. In 1976 and 1980 males were proportionately more and formed 57% and 54% respectively.

Maturity

The studies made at Vizhinjam during 1976-80 (Fig. 6) indicate that males attain maturity in the size range 70-170 mm with 50% being mature at a size of 97 mm. Females reach the mature condition in the size range 70-130 mm with 50% maturity at 84 mm. All males and females become mature when they grow to sizes of 170 mm and 130 mm respectively.

Spawning

Sexually mature females were recorded in October, December and January to April with dominance in December, January and February (Fig. 5). Mature males occurred from October to April with preponderance in October, December and January-March and spawning males in December and February. The occurrence of mature squids in several months during the period October-April suggests that the breeding season of the species is protracted.

ADULT HISTORY

Growth

The study of the modal sizes has indicated that the squid grows to a size of 106-120 mm with an average size of 113 mm at the end of the first year and a size of 182 mm at the end of the second year. The longevity of the species appears to be over two years.

Distribution of Adults

Adult squids 70-205 mm in dorsal mantle length occur in the coastal waters of Vizhinjam and are captured in shore seines, boat seines and hooks and lines. The larger individuals are frequently caught in the last mentioned gear.

Maximum size

Males grow to a maximum size of 205 mm and the largest size of females recorded is 165 mm.

Food

The stomach contents of this species include fish, cephalopods and crustaceans.

LIFE HISTORY

Distribution of Juveniles

Juveniles measuring 20-60 mm are caught in shore seines along Vizhinjam Coast during January-February and in some years upto June.

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