タイ湾で漁獲されるアジアジンドウイカの成熟と外套長組成

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Maturity and Length Frequency Distribution of the Indian Squid *Loligo duvauceli* Caught in the Gulf of Thailand*1

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Samples of the Indian squid *Loligo duvauceli*, 5,303 males and 6,149 females, were collected by otter boad trawlers and light-luring fishing boats off the west coast of the Gulf of Thailand from 1986-1989.

The speciments were classified into five stages of maturity for both sexes. The group maturity curves showed that sizes at 50% maturation approximated 17 cm ML for males and 10 cm ML for females. Two substantial recruitments of catchable stock were found in December-March and July-October, based on the appearance of larger sized squids rather than the 50% mature sizes.

Assuming that the successive shift observed in the length frequency distributions are expressed by the von Bertalanffy growth equation and the time from birth to recruitment was 4 months, the growth parameters K were estimated at 0.083 month^{-1} for male squid and 0.095 month^{-1} for female squid.

For aging commercially important tropical squids, growth is usually estimated using mantle length frequency data. To investigate the growth patterns of tropical species in an attempt based upon for mantle length distribution of squids appearing in the catch, it is necessary to consider the recruitment frequency of a catchable-size group. It is often impossible, however, to distinctively define the successive shift of modes and the recruitment of the youngest catchable-size group. This is mainly due to the relatively long spawning period and rapid growth in tropical squids.

The growth of the Indian squid *Loligo duvauceli* was studied using data collected from Indian waters.[1] According to the study, the growth parameters of the von Bertalanffy equation were K=1.1 and 1.7 year^{-1} whereas the l_∞ were 37.2 and 23.8 cm for males and females, respectively. Based on data from the Gulf of Thailand,[2] the growth parameter K was estimated at 0.86 year^{-1} for mixed males and females, assuming that the spawning took place mainly in October-December.

The objective of this paper is to present some preliminary results from the analysis of the group maturity curve and the mantle length frequency distribution of Indian squid sampled off the west coast of the Gulf of Thailand. In this study, the authors paid attention to the differences in squid sizes between two successive modes at once, probably due to two separate spawning periods. It was also considered desirable to base growth estimation on the von Bertalanffy equation.

Materials and Methods

Squids were caught commercially by otter trawlers[3] and light-luring fishing boats[4] with stick-held cast nets, dip nets, or box nets in the area off the west coast of the Gulf of Thailand at depths of between 10 and 50 m (Fig. 1). The catches were landed mainly at Prachuap Kirikhan (Pran Buri), Chumporn (Lang Suan) and Surat Thani (Pha-ngan Island) provinces on the west Gulf coast.

At fish markets from January to December 1986, the squids landed were randomly sampled as the opportunity arose. The mantle lengths of fresh samples (ML: length of mantle from

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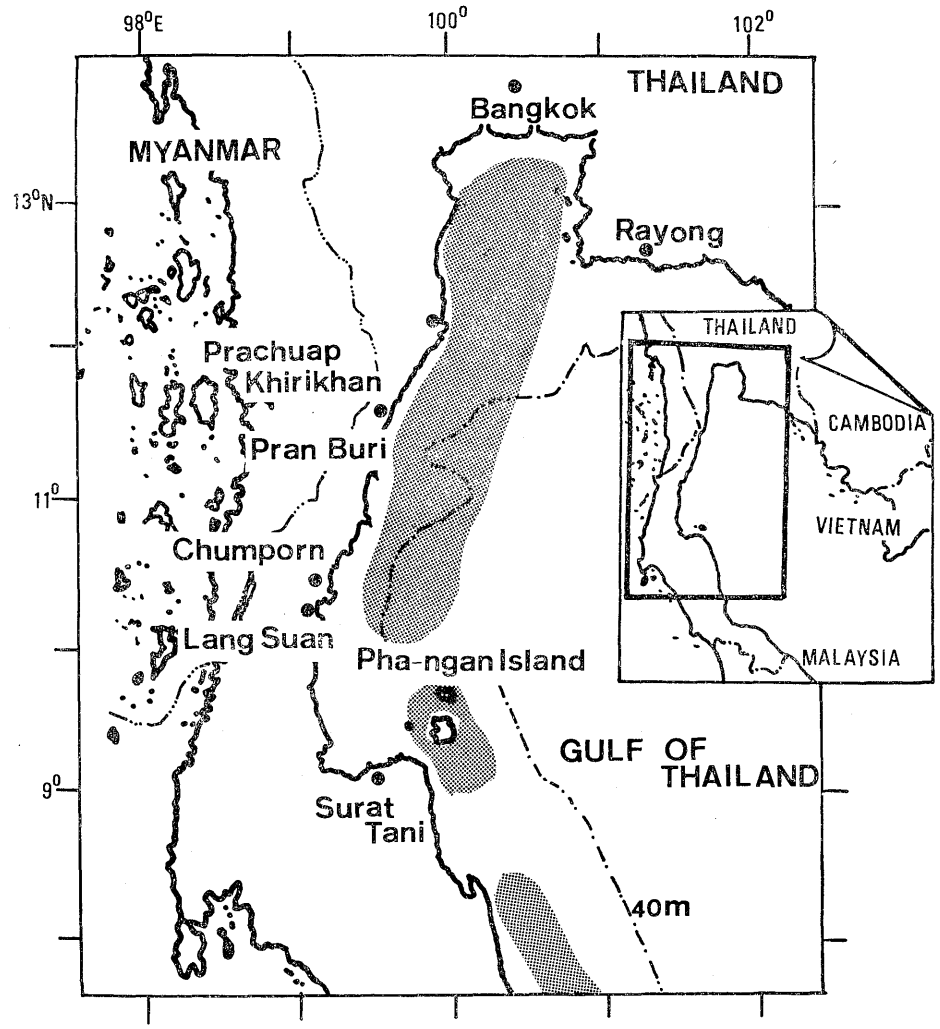

Fig. 1. Geographic locations of sampling sites and the fishing area (shaded part) on the west coast of the Gulf of Thailand.

most anterior-point on the dorsal side to the posterior body tip) were measured to the nearest millimeter and grouped into 10 mm length classes. The ranges of squid size (ML) measured were 60–219 mm for males and 60–169 mm for females. Sex was determined by the existence of hectocotylized arms and by observation of the reproductive system.

A total of 1,921 fresh males and 1,979 fresh females sampled were separated and categorized into five stages (I–V) of maturity with reference to proposed categories.[5-7] The following stages were distinguished by a visual inspection of the gonads and accessory reproductive glands. Female

I–*Immature*: Small ovary, transparent membranous, not granulate structure. Nidamental gland noticeable.

II–*Maturing*: Nidamental gland and accessory nidamental gland small to large, ovary with granulate structure, whitish opaque. Eggs small, 0.2 mm in maximum diameter.

III–*Mature*: Nidamental gland and accessory nidamental gland large. Two different stage eggs (oval or polygonal, whitish opaque, and round, reticulated pale-yellowish) eggs 1.0 mm in maximum diameter.

IV–*Fully Mature*: Nidamental gland and accessory nidamental gland very large, accessory nidamental gland bright red color. Ovary enlarged to fill dorsal portion of mantle cavity with reticulated pale-yellowish eggs. Eggs in oviduct 1.0 mm in diameter. Oviduct gland filled with fully mature eggs.

V–*Spent*: Gonad small, nidamental gland relatively large and soft. A small number of large eggs in ovary.

Male

I–*Immature*: Testis membranous, no sperm in spermatophoric sac.

II–*Maturing*: Testis clearly visible. Seminal vesicle and spermatophoric sac well developed. Spermatophoric sac with few sperm, soft, whitish and structureless particles.

III–*Mature*: Testis compact and voluminous. Sperm developed in spermatophoric sac, but not full.

IV–*Fully Mature*: Testis rigid. Sperm densely packed in spermatophoric sac and noticeable in base and tip ofpenis.

V–*Spent*: Testis long and thin, few sperm in spermatophoric sac.

During the period between January 1988 and December 1989, the mantle lengths of a total of 3,382 males and 4,170 females were measured to the nearest millimenter at the Pran Buri fish market. The measurements collected monthly were classified into centimenter classes to analyze size frequency distributions separately by sex.

Results

Estimations of Mature Squid Size

In a five-stage development scale for arbitrary categorization of maturity (Table 1), the three stages III–V were easily separable by sex, possessing clear ripe eggs for females or several spermatophores or a spermatophoric sac for males. A total of 691 male (35.9%) and 1,186 female (59.9%) squids were categorized as mature-spent (stages III–V), while the other stages I–II (1,230 males, 793 females) were immature-maturing squids with incomplete gonad development. The smallest size classes of squids with mature gonads were 7–8 cm ML for both sexes. The percentage of mature to total squids classed by the 1 cm ML interval, group maturity, is shown in Fig. 2 by sex.

As a convenient index of the mantle length ML at group maturation, the length at 50% maturity is usually used, approximated at about 17 cm for males and about 10 cm for females. It is clear that there is a difference of about 7 cm in ML between sexes at 50% maturation, and that males become mature more gradually than females.

Monthly Variation in Length Frequency Distribution

The length frequency distribution of male and female Indian squid is given in Figs. 3 and 4, showing the effects on average size of apparent variation in recruitment. The months in which small squid groups of 6–7 cm in ML came into prominence varied during the sampling period from January 1988 to December 1989. The following trends in monthly figures showing ML of less than 10 cm are conspicuous in the length distribution of both male and female squid.

Table 1. Number of specimens by five maturity stages at one-centimeter intervals

Mantle length (mm)	Male					Total	Female					Total
	I	II	III	IV	V		I	II	III	IV	V	
60- 69	10	9				19	22	15				37
70- 79	15	9	4	2		30	19	15	5	2		41
80- 89	9	12	3	2		26	24	23	12	12		71
90- 99	52	32	15	2		101	57	52	49	62	11	231
100-109	54	53	19	6	2	134	98	102	90	118	31	439
110-119	80	59	30	13	1	183	75	112	103	205	66	561
120-129	79	88	36	9	5	217	36	54	58	111	57	316
130-139	75	82	55	12	2	226	16	28	25	40	34	143
140-149	51	94	39	16	7	207	6	23	17	15	11	72
150-159	51	107	46	15	8	227	4	8	12	10	8	42
160-169	22	77	61	18	7	185	1	3	8	7	7	26
170-179	14	32	46	28	6	126						
180-189	4	31	36	25	10	106						
190-199	2	20	15	13	6	66						
200-209		7	22	17	4	50						
210-219			7	9	2	18						
Total	518	712	434	197	60	1921	358	435	379	582	225	1979

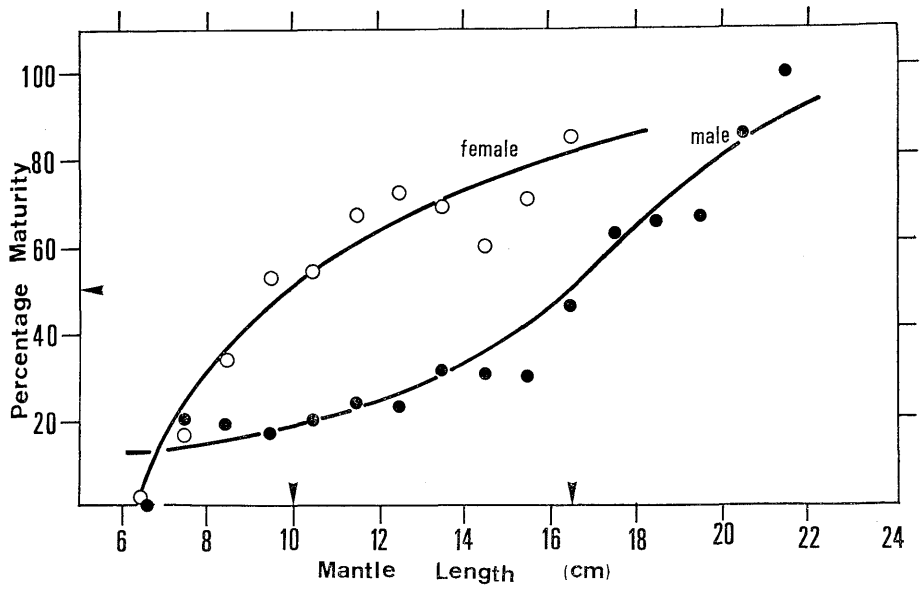

Fig. 2. Maturity percentage of males and females in relation to mantle length. Points for both sexes represent percentage occurrences of mature squids (stages III-V in Table 1) in each class of mantle length per one-centimeter interval. The two curves were fitted by eye.

During July-October and December-March, there appears to be relatively substantial recruitment. This implies that there are two spawning periods, because the small squid group (mean ML of 6–7 cm) appeared in the catchable stock every July-October and December-March.

The two groups recruited in the early half (December-following March) and in the late half (July-October) of the year are called Groups A and B. It was observed that males larger than 17 cm in ML (50% maturity length) appeared during June-October and February-April, respectively, as shown in Fig. 3. On the other hand, females larger than 10 cm ML (50% maturity length) in Groups A and B appeared in July-September and December-April, respectively, as shown in Fig. 4.

The larger male and female squids mentioned above were composed of two or three groups in terms of size. The largest sized group comprised a much lower fraction of the total number of samples, the largest sizes of males and females being 26 cm (October 1989, Fig. 3) and 18 cm ML (June 1988, Fig. 4), respectively. Namely, it seems that there appears to be sexual differences in the Indian squid ML, probably in 8 cm ML in the final stage of life.

During the period from July-September, a prominent small-length group (mean ML of 6–7 cm for Group B) and a relatively large-length group (mean ML of 11–14 cm for Group A) was found in the females frequency distribution. It happened, however, that these groups appeared or disappeared in the catch. It is probable that two distinctive groups at least are distributed with different mean sizes, due to the two spawning periods in one year.

Estimation of Growth Parameter K

As mentioned in Figs. 3 and 4, there are two substantial recruitments per year. Assuming that each main spawning month is in the middle of the spawning period, this suggests that the spawning period interval between Groups A (December-March) and B (July-October) may be about 7 months, although there is no direct evidence to prove this. It is implied, simultaneously, that the interspawning period may be about 3 months, from April to June. Due mainly to this time lag, the difference in squid size between Groups A and B occurred. For example, a prominent small group and a relatively large group can be rather clearly found for both sexes in July 1988, as shown in Figs. 3 and 4. The normal distribution curves were fitted to these distinguishable groups by Cassie's method, and size differences in ML between the two groups were estimated as 7.5 cm ML for males and

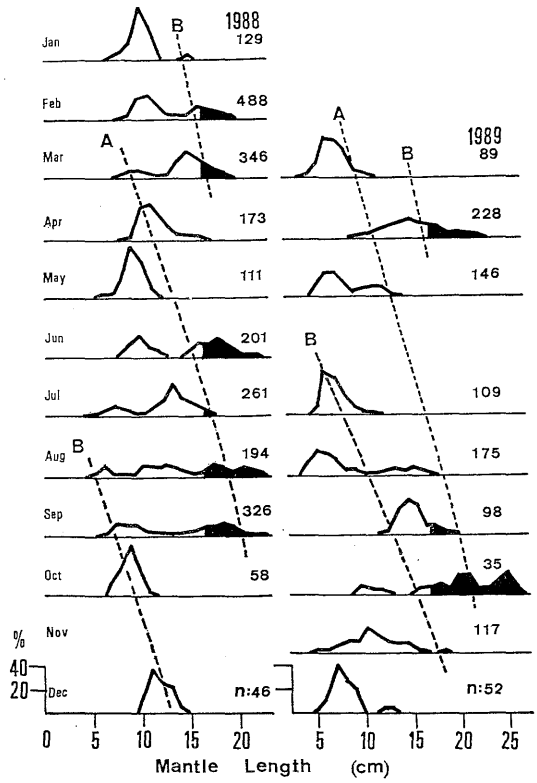

Fig. 3. Monthly length frequency distribution of male squid landed at markets.

The shaded area represents the group size larger than 17 cm ML evaluated in Fig. 2. Brokenlines show the estimated growth curves for Group A (recruiting in the early half of the year) and Group B (recruiting in the late half of the year), respectively.

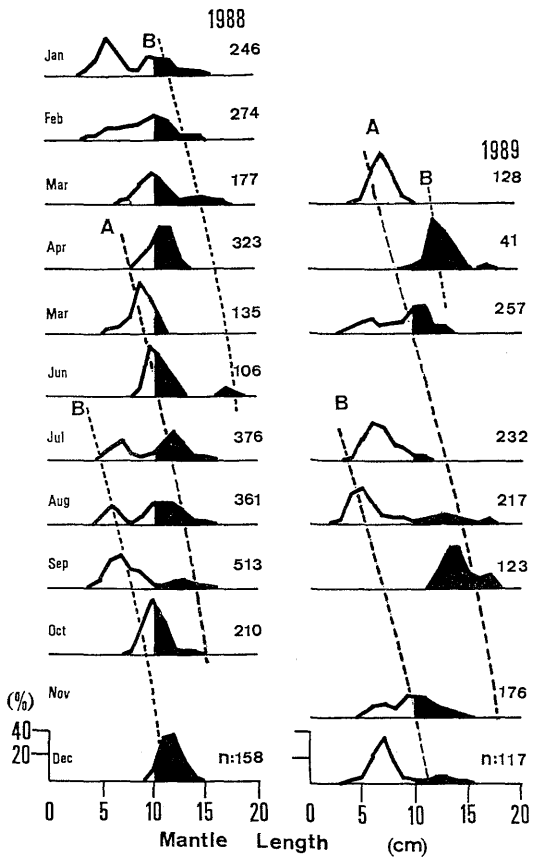

Fig. 4. Length frequency distribution of female squid landed at markets in monthly periods.

The shaded area represents the group size larger than 10 cm ML evaluated in Fig. 2. Broken lines show the same as in Fig. 3.

5.2 cm ML for females.

Assuming the Indian squid growth is depicted using the von Bertalanffy growth model, the difference in squid size between two spawning groups at intervals of a given time[8,9] t is

$$l_t - l_{t-\Delta t'} = l_\infty \exp\{-k(t+t_0)\}\{\exp(k\Delta t') - 1\}$$

where l_t and $l_{t-\Delta t'}$ are the squid lengths of Groups A and B, respectively, $\Delta t'$ the time interval of interspawning, K and t_0 the constants of the von Bertalanffy growth equation, and l_∞ the asymptotic length, or the maximum attainable size. The asymptotic length was calculated on the basis of the ratio of the largest size of squids in catches to the estimated l_∞ in Indian waters,[1] the rations being 0.69 for males and 0.78 females. As the largest squids appearing in catches were 26 cm for males and 18 cm for females, as shown in Figs. 3 and 4, the two values of l_∞ for males and females, therefore, are estimated to be 37.6 cm and 23.0 cm, respectively. When $t=4$ months, $t_0=0$, $\Delta t'=3$ to 6 months, and $l_\infty=37.6$ cm for males and 23.0 cm for females, as a first approach to the problem of growth in the Indian squid, the relationships of squid size differences in successive months ranging from 3 to 6 months and with the growth parameter K of dimension month^{-1} are shown in Fig. 5. In this figure, the values of $l_{t-\Delta t'}$ can have a slight influence positively or negatively on t_0. Using the difference in male squid size of ML 5.2 cm and female squid size (ML 7.5 cm) in July 1988, the values of K ranged from approximately 0.039 to 0.095 month^{-1} for females, and from 0.035 to 0.083 month^{-1} for males through the values of $\Delta t'=3$ to 6 months. The time interval of interspawning between Groups A and B, $\Delta t'=3$ months, was chosen as the first approximation. Therefore, the growth parameters K were estimated to be 0.083 month^{-1} for

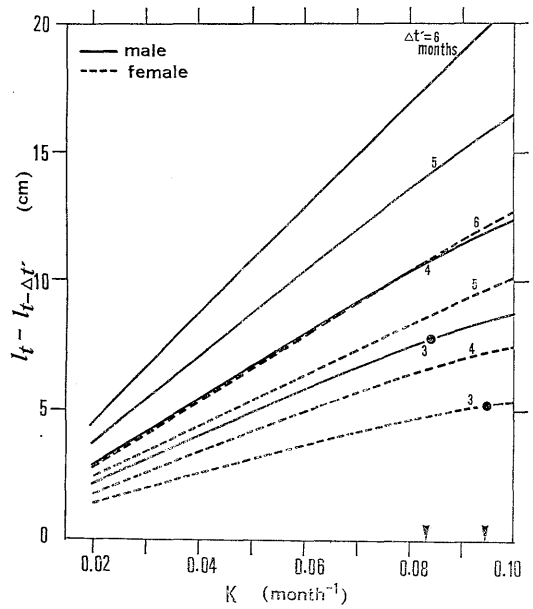

Fig. 5. The difference in squid size (ML) which results from different spawning times at intervals of $\Delta t'=3-6$ months in a given population, plotted against K of the von Bertalanffy growth equation.

$K=0.095$ month^{-1} for females and 0.083 month^{-1} for males are estimated.

males and 0.095 month^{-1} for females. Considering the growth parameters estimated above and properly adjusting the spawning month ($t=0$), the growth lines for both Groups A and B were fitted to the length frequency distribution (dotted lines in Figs. 3 and 4). Since the months in which many squid groups became prominent in length frequency distribution varied in 1988 and 1989, it is difficult to show a prominent peaked trend accurately along the growth lines.

Discussion

The estimation that the 50% maturity size of females is 10 cm ML and that the equivalent for males is 17 cm ML is suggested to be significant. Namely, based upon the appearance and disappearance of squids larger than 50% maturity size in successive modes during transitional months, it seems that there are two spawning periods: the early half of the year and the late half of the year at an interval of about 3 months. This supports earlier studies on the Indian squid in the Gulf of Thailand.[10] Chotiyaputta[10] reported that a higher percentage of mature squids were found separately during the period from January to May and from September to November.

Throught a series of sampling work on this species, there still remain some questions in evaluating the size of 17 cm ML for males to be a 50% mature size. It is probably due to a small number of mature and spent male squids (stage IV and V in Table 1) and presumably due to improper categories in the development scale of male maturity. The spent category may not be reliable in males, because some ripe spermatophores always remain intact. It also varis depending on each person's subjective point of view in identification work.

Growth rates of both sexes estimated in the present study are slightly different from those previously evaluated for the combined sexes in the Gulf of Thailand,[2] and both sexes on the coast of Kerala, India.[1] Even though there are some differences in estimated growth rates, the growth curves fitted to size frequency distribution in catches seem to be of possible significance and will be close enough for practical needs.

Since no previous studies on the growth components of young Indian squid have been found in the literature, it was assumed that the rather small-size squids sampled in July 1988 and 1989, with ML of 6–7 cm for males and females, corresponded to the 4-month age group. Consequently, it follows that Indian squid may have had recruits into catchable stock after the elapse of 4 months after birth. According to the growth estimations of other Loliginid squid, *L. opalescens*,[11] *L. pealei*,[7] *L. vulgaris*,[12] *Sepioteuthis lessoniana*,[13] and *Photololigo edulis*,[14] which inhabit quite different areas characterized by oceanic conditions, squid size at 4–6 months is 5–7 cm ML for both sexes, roughly estimated from the figures or tables in the literature. Generally, it may be natural that the Indian squid inhabiting tropical waters shows a rapid growth rate as compared with high latitude waters. Therefore, in the resulting 4 months, $K=0.083$ month^{-1} for males and 0.095 month^{-1} for females, as shown in Fig. 5, is probably significant in comparison with the results from other species.

In order to obtain conclusive evidence on the periodical appearance and disappearance of mature squid in the monthly length distribution, the number of specimens leaves much to be desired; only in 1988 was it possible to obtain a reasonable sample. In reality, the age structure and the distribution of maturity stages in commercial landings may not be representative of that

within the squid population, nor even between successive hauls by light-luring nets.[15] This may be occur because squids in different maturity stages or age classes are not equally available or vulnerable to fishery. Therefore, the present findings require some justifications from further samplings, based upon aging from microstructure in statoliths,[14,16,17] In categorizing squid maturity, the present approach cannot be relied upon for designations of mature stages by spawning group, because the maturity was categorized for each length class. In view of squid population structure by cohort, further analyses will be required.

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