Population Structure of the Spuid, Loligo japonica, Distributed in Sendal Bay.

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Population Structure of the Spuid, *Loligo japonica*, Distributed in Sendai Bay.

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Summary

The population structure of the squid, *Loligo japonica*, caught by the set nets and small trawlers in Sendai Bay during the periods of May 1975 to July 1976 and October 1978 to December 1979 was studied based on the relationship between mantle length and maturity of the female. The results obtained are summarized as follows:

1. Three groups with different breeding seasons are distributed in Sendai Bay. Each is named Groups I, II and III, respectively.
2. Group I becomes mature and copulates in the offshore region. When this group approaches the coastal region, most have completed maturation and copulation. Spawning in this group occurs between May and July.
3. Group II becomes mature and copulates on the way to the coast from offshore. When this group appears in the coastal region, most have completed maturation and copulation. This group stays in the coastal region from May to July while in the pre-spawning stage.
4. Group III is found in the coastal region from June to August where it becomes mature and copulates.
5. Judging from growth patterns, the estimated life span of all three groups is one year.
6. From mantle length composition in the offshore region, the mean mantle length of the adult is estimated below:

Group I : female: 10–11 cm, male: 9–9.5 cm
Group II : female: 8–9 cm, male: 7–8.5 cm
Group III: female: 6–7 cm, male: 6–6.5 cm

The majority of squids caught by small trawlers and set nets in Sendai Bay are *Todarodes pacificus*, *Dorytheuthis bleekeri* and *Loligo japonica* (1).

Among these species, *Todarodes pacificus* is distributed close to Japan. Its population is reported to consist of three groups with different breeding seasons. These subpopulations are called "Winter", "Summer" and "Autumn" (2). While the population structure of *Dorytheuthis bleekeri* has not been studied, it is possible to distinguish between some groups with breeding season different with one another, because the spawning season of this species is long (3). In fact, it is possible to discriminate between three groups with different breeding seasons as in

case of *D. kensaki* (4). On the other hand, the study of the ecology of *Loligo japonica* and its population structure has not been emphasized and therefore is examined in the present study.

Materials and Methods

Samples of the squids were obtained from commercial catches of set nets and small trawlers during the periods of May 1975 to July 1976 and October 1978 to December 1979. Set nets were located off Orinohama, Miyatomurohama and Yuriage along northern Sendai Bay*1. Small trawlers were based on Haragama, operating mainly in Sendai Bay.

Samples collected from May 1975 to July 1976 were examined regarding the mantle length of fresh squid, and the body weight and sexual organ weight of formalin-preserved squid. Those collected from October 1978 to December 1979 were examined only for their mantle length.

Furthermore, the CPUE for every half month was calculated using the catch records of a set net located off Yuriage and those of Happo-maru, a small trawler operating in northern Sendai Bay, from January 1969 to January 1971. The monthly CPUE was calculated using the total monthly catches and number of voyages made by the small trawlers based on Haragama operating mainly in Sendai Bay from September 1974 to June 1977.

The above-mentioned set net was located in a sea area less than 20 m in depth and the small trawlers operated in a sea area deeper than 20 m. Thus the former area was called "coastal" and the latter "offshore".

Results

Change in CPUE

The set net fishery in the coastal region along the coast of northern Sendai Bay is in operation from May to November every year. In 1969, the level of CPUE of squid was high during the latter half of May and after October and low between these dates. In 1970, the level of CPUE was high in June, July and after the latter half of September (Fig. 1 upper column).

The level of CPUE of *Loligo japonica* caught by the trawlers in the offshore region of northern Sendai Bay was very low from April to September 1969, and high from October 1969 to April 1970. There was no catch made by the trawlers from July to August as it was closed season. But, the CPUE level was supposed to be very low from April through September 1970 (Fig. 1 lower column).

Futhermore, the level of CPUE of *Loligo japonica**2 caught by the trawlers

*1 Northern and southern Sendai Bay are separated by north latitude 37°50′.

*2 The data used in calculating CPUE depended upon the catch statistics of Haragama Fisheries Cooperative Association. In these statistics, the category "other squids" almost exclusively contains *Loligo japonica*.

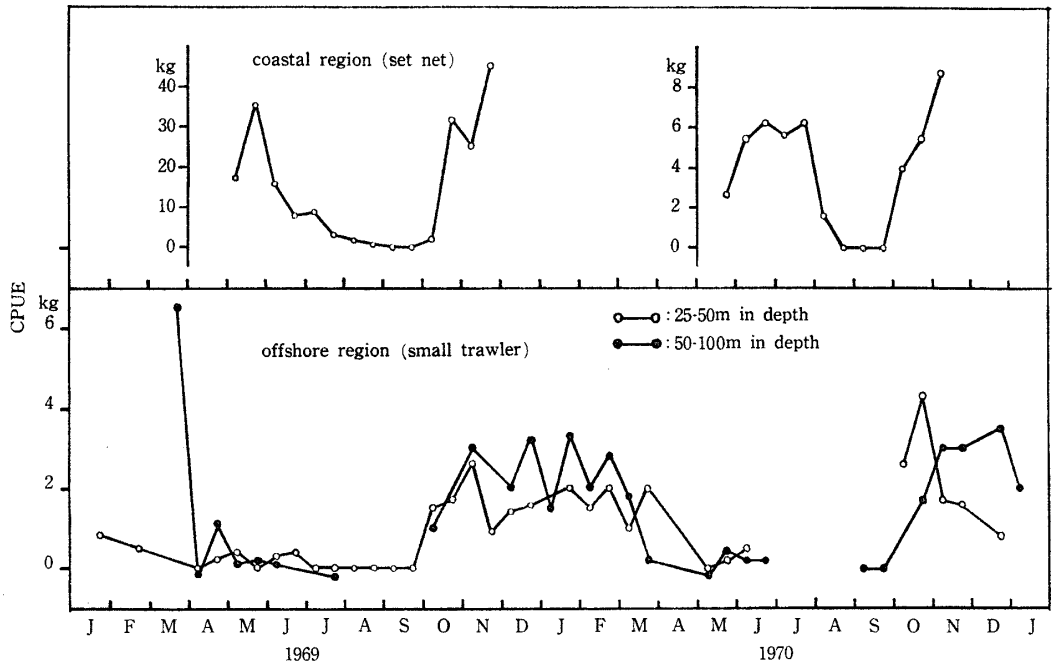

FIG. 1. Month-to-month change in CPUE of *Loligo japonica* in the coastal and offshore regions of northern Sendai Bay.

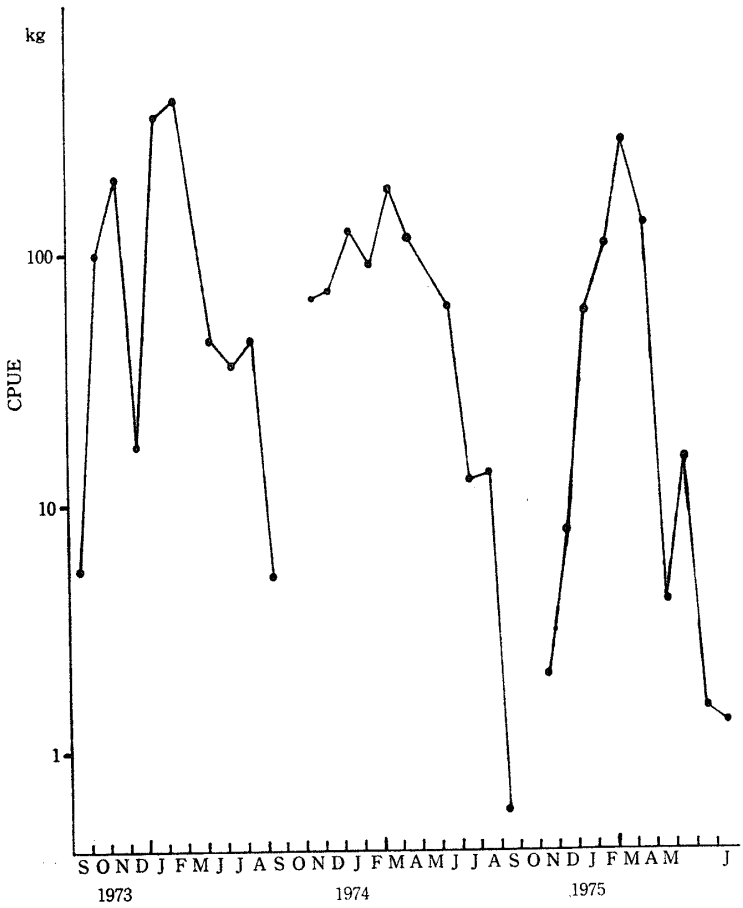

FIG. 2. Month-to-month change in CPUE of "other squid" in the offshore region of Sendai Bay.

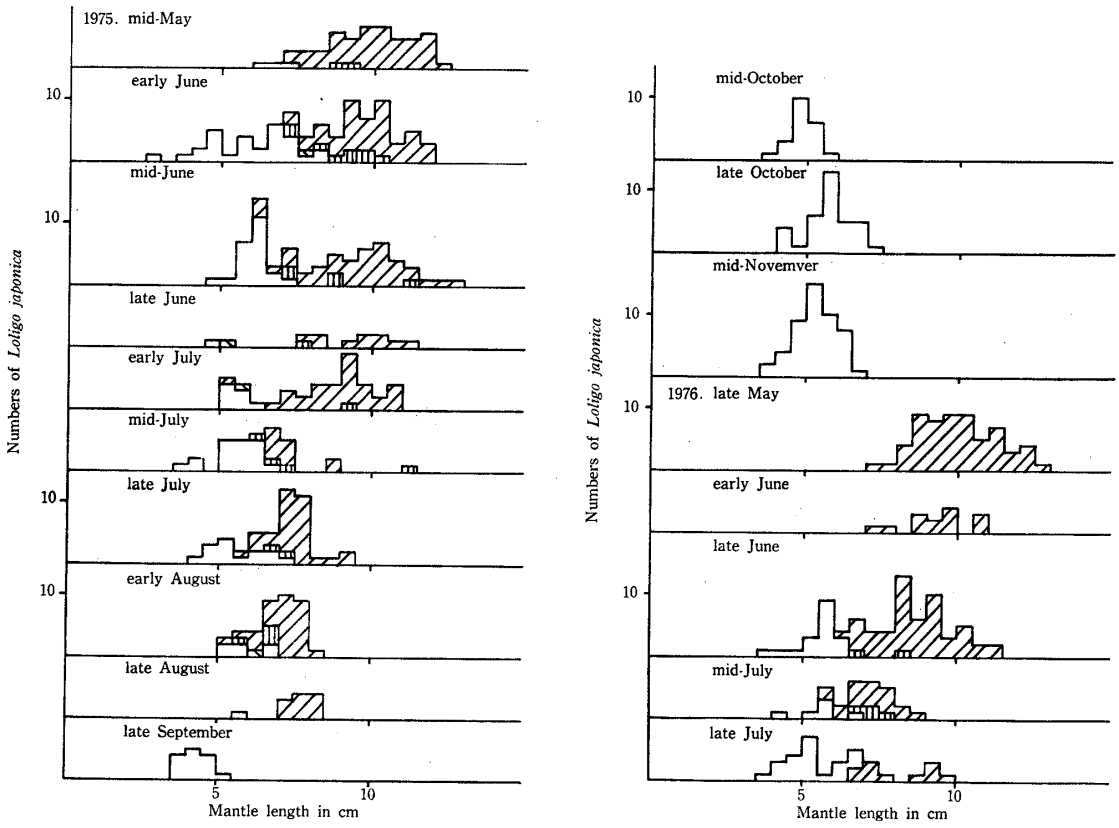

FIG. 3–A FIG. 3–B

FIG. 3. Mantle length composition of female squid by degrees of maturity in the coastal region.

▨: mature and copulated squid
▥: mature and noncopulated squid
▧: premature and copulated squid
□: premature and noncopulated squid

based on Haragama Port operating in Sendai Bay increased from autumn to winter and decreased from winter to summer (Fig. 2).

Mantle Length Composition

Coastal region (Figs. 3 and 4)

A large-sized group over 7 cm appeared during May in 1975 and 1976 and a medium-sized group appeared later during June in 1975 and 1976. This resulted in a wider range of length distribution than in May alone. While the large-sized group disappeared after mid-July 1975, the medium-sized group continued to exist until August. Most squid of the medium-sized group were 4 to 8 cm in mantle length. They disappeared after September, and a small-sized group was found during September, and remained until mid-November.

Offshore region (Figs. 5 and 6)

The mantle length composition of most squid of the large-sized group observed between mid-May and mid-June 1975 and between late April and mid-May 1976 were over 7 cm. This showed a resemblance in size to the coastal large-sized group

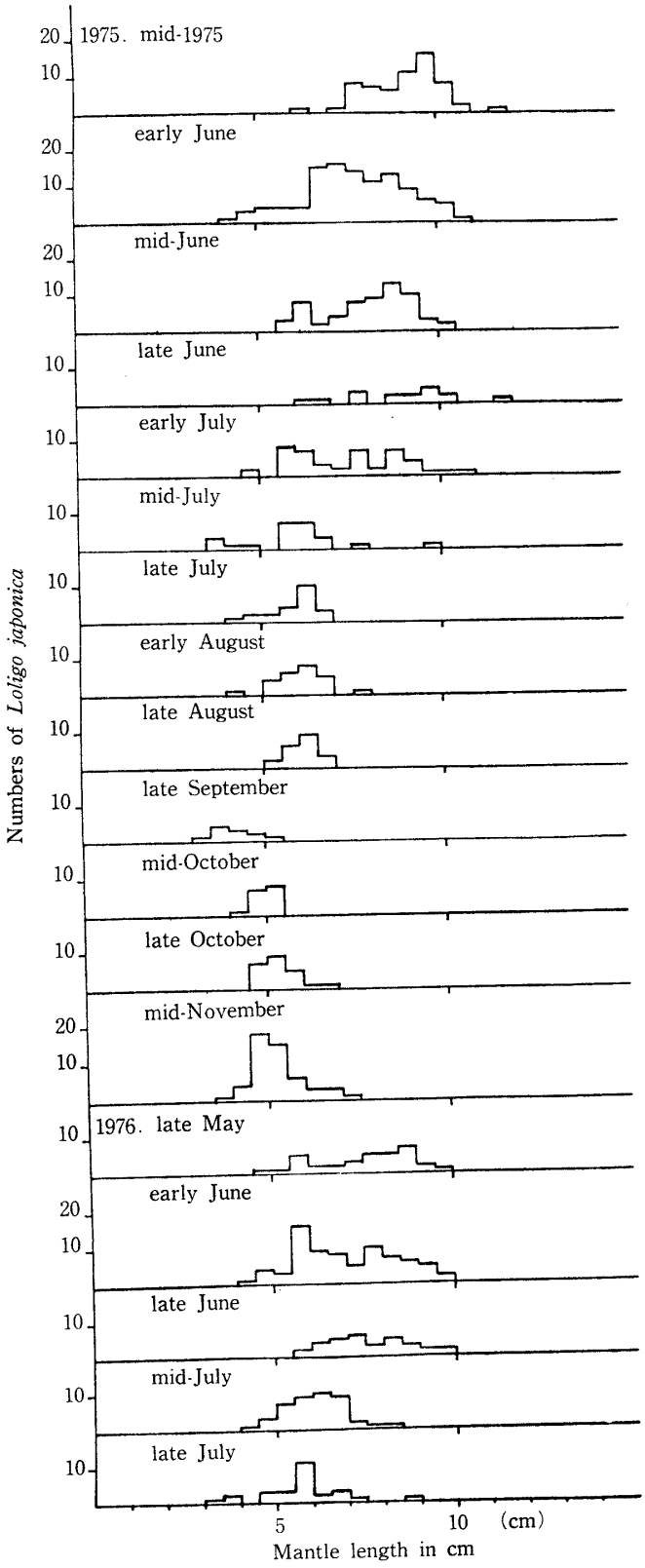

FIG. 4. Mantle length composition of male squid in the coastal region.

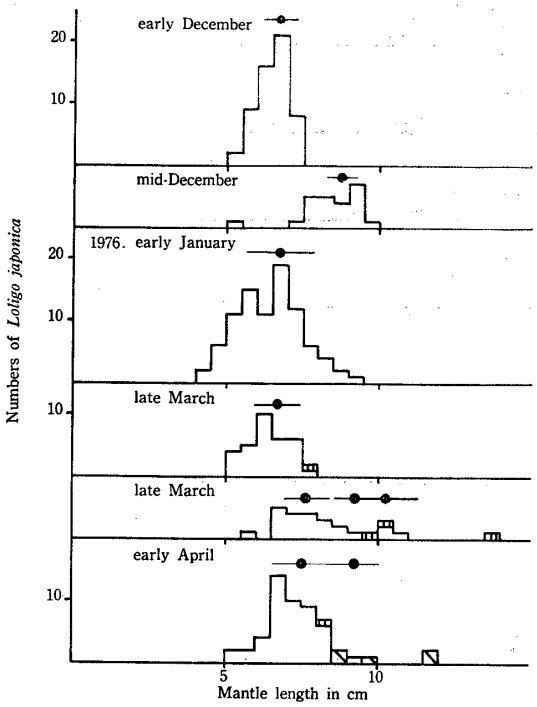

FIG. 5–A

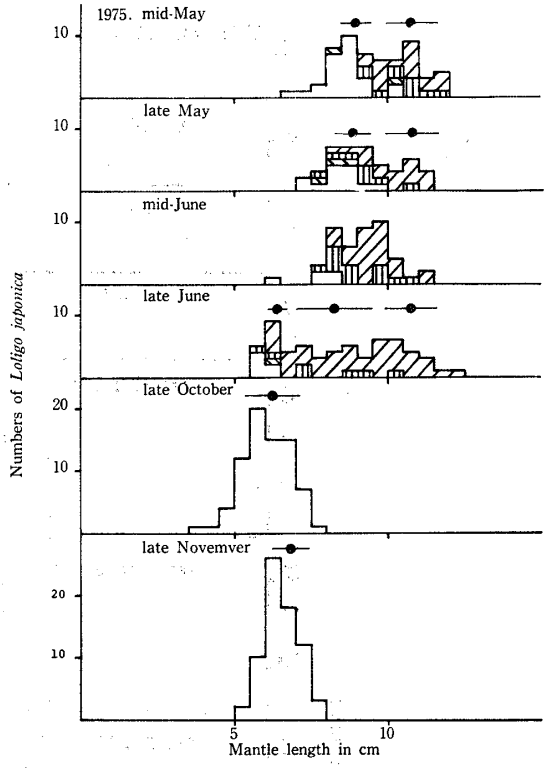

FIG. 5–B

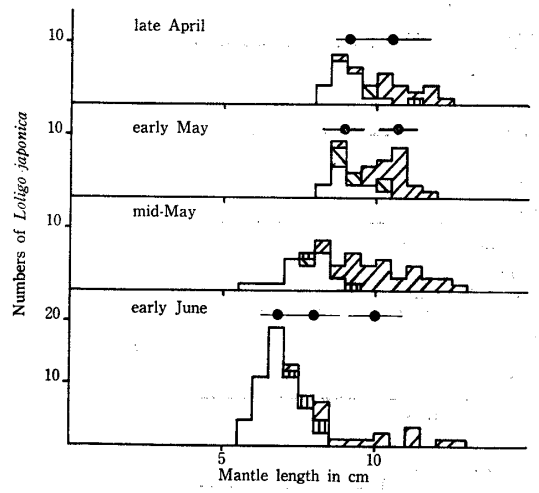

FIG. 5–C

FIG. 5 Mantle length composition of female squid by degrees of maturity in the offshore region.
▨: mature and copulated squid
▥: mature and noncopulated squid
▧: immature and copulated squid
□: immature and noncopulated squid
●: mode distinguished by Cassie's method
—: 95% Confidence limits

observed during May (Figs. 3 and 4), with the exception of male squid found to be under 7 cm in mid-May 1976. In late June 1975 and early June 1976, large-sized and small-sized groups co-appeared. Their size ranges resembled those of the coastal group observed in June. From October to December 1975, a small-sized group appeared, most of them being between 4 to 8 cm. After December the occurrence of some groups with different modes were observed.

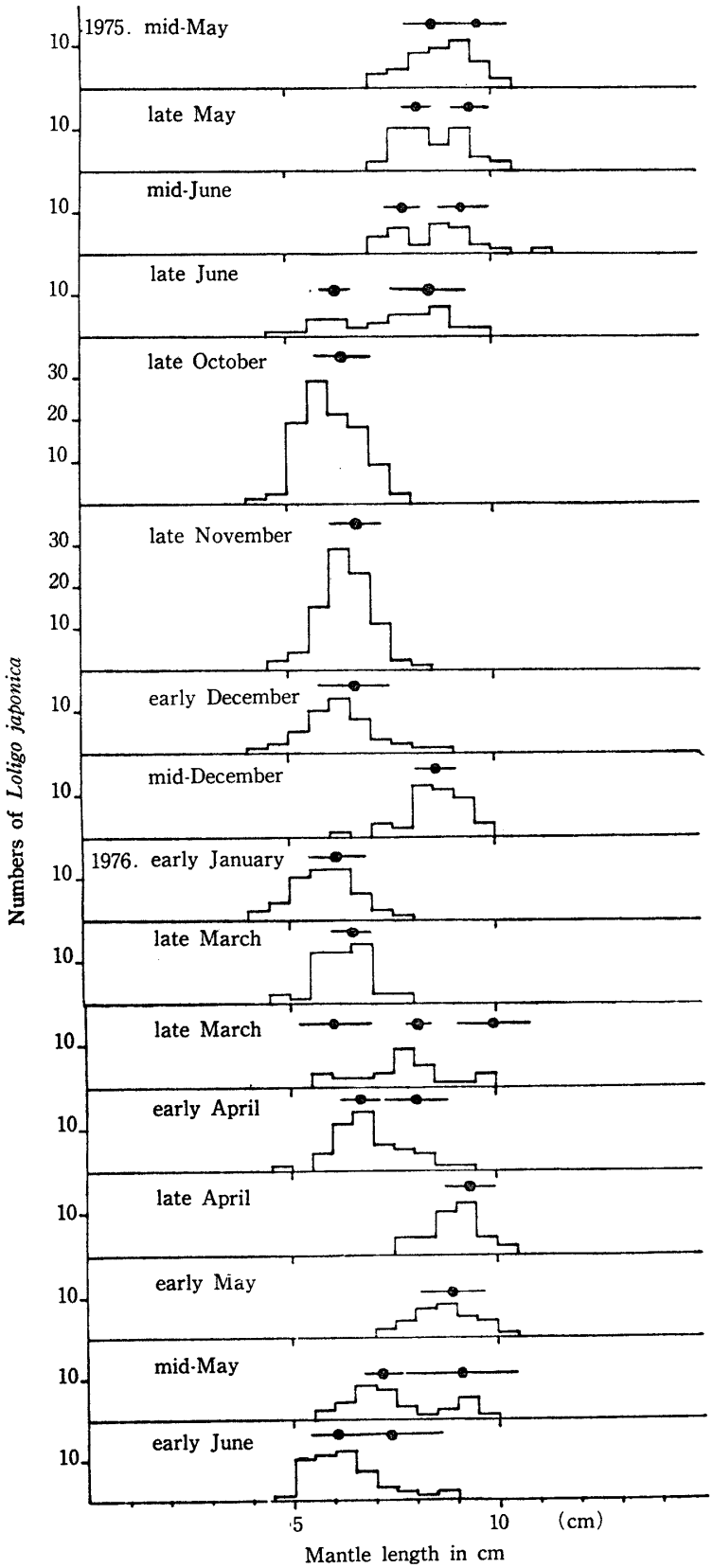

FIG. 6. Mantle length composition of male squid in the offshore region.
●: mode distinguished by Cassie's method —: 95% confidence limits

Process of Maturity

Distinction of Maturity Degrees

Female squids that hold mature eggs in their oviducts appeared prior to the spawning season. In Fig. 7, the proportion of females holding mature eggs in

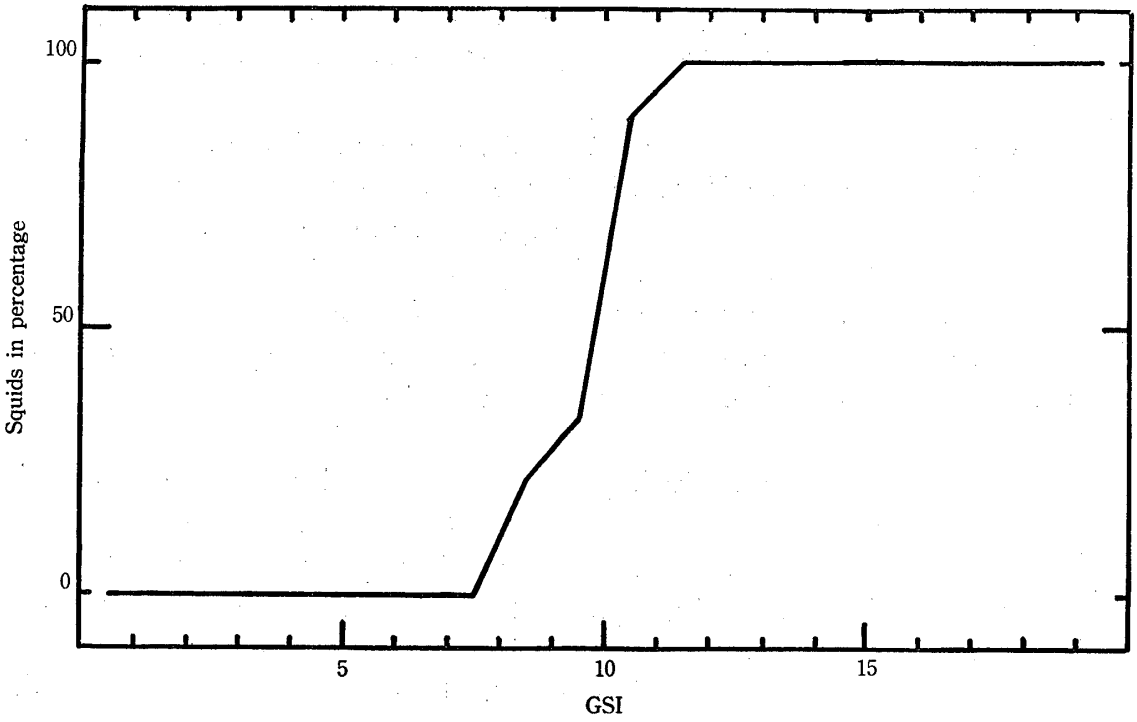

FIG. 7. Change in number of squid keeping matuse eggs in their oviducts as percentage of females with progression of GSI.

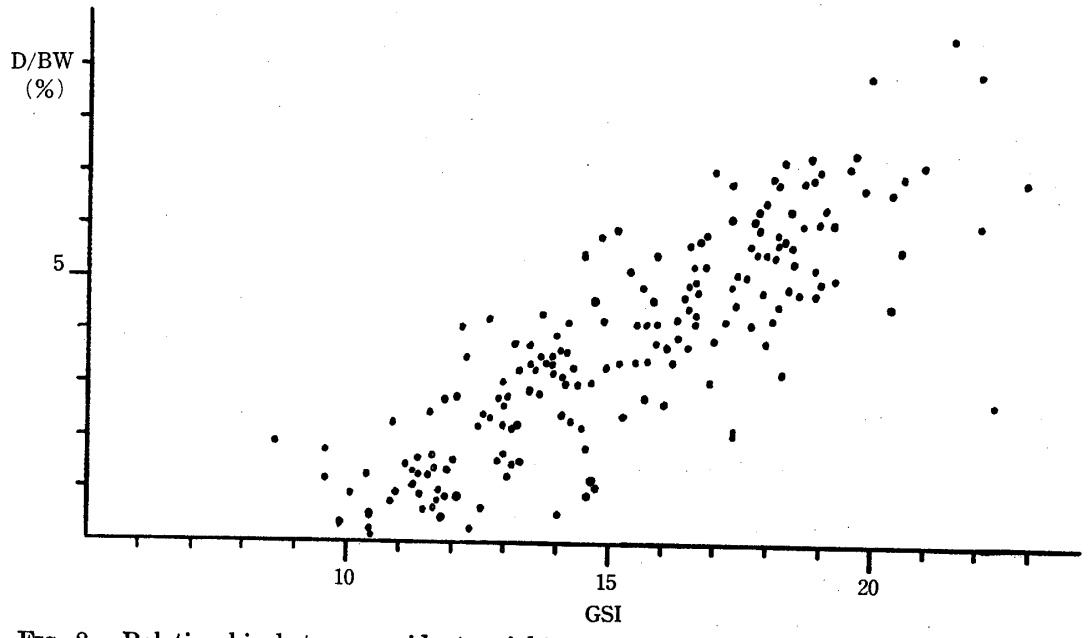

FIG. 8. Relationship between oviduct weight as a percentage of body weight and GSI.

their oviducts is shown compared to their GSI*.

As seen in Fig. 7, females holding mature eggs in their oviducts were first observed when their GSI became 8 per cent. A porportion of them exceeded 50 per cent at 8 per cent in GSI, and reached 100 per cent when the GSI exceeded 11 per cent.

As shown in Fig. 8, the proportion of oviduct weight to body weight in females holding mature eggs in their oviducts increases when the GSI reaches about 10 per cent.

Judging from the above-mentioned results, it is concluded that the criteria for discriminating mature squid from immature ones is when the squid reaches 10 per cent in GSI or whether or not mature eggs exist in the oviduct.

Mantle Length Composition by Maturity Degrees

In Figs. 3 and 5, overall mantle length compositions of female are partitioned into the following categories, "mature squid", "immature squid", "copulated squid", and "noncopulated squid" in the coastal and offshore regions.

Coastal region

As shown in Fig. 3, large-sized, mature and copulated groups had appeared during May in 1975 and 1976. These were followed by small-sized, immature and noncopulated groups in June. The large-sized groups disappeared after mid-July 1975. The small-sized group stayed until late August, while the mature and copulated squids gradually increased in number until late August. In September, the small-sized group disappeared. In late September, small-sized, immature and noncopulated groups were observed until November.

Offshore region

As seen in Fig. 5, an immature and noncopulated group was exclusively found from October 1975 through January 1976. This group resembled, in maturity, the coastal group which was observed from September to November 1975.

A number of mature and copulated squid were observed among large-sized squid in late March and early April 1976. Their overall mantle length composition was divided into three normal distributions by Cassie's method (5).

The large-sized group appearing from mid-May to mid-June 1975 and from late April to mid-May 1976 resembled the coastal large-sized group in mantle length distribution, but a difference in maturity between the two groups was observed. This showed that many squid over 9 cm were mature and copulated, while many squid between 7 and 9 cm were immature or noncopulated in 1975. In 1976, many squid over 10 cm were mature and copulated, whereas many squid

* GSI is defined as below:
$GSI = 10^2 \times (D+G+O)/\text{Body weight}$
D: oviduct weight
G: oviduct gland weight
O: ovary weight

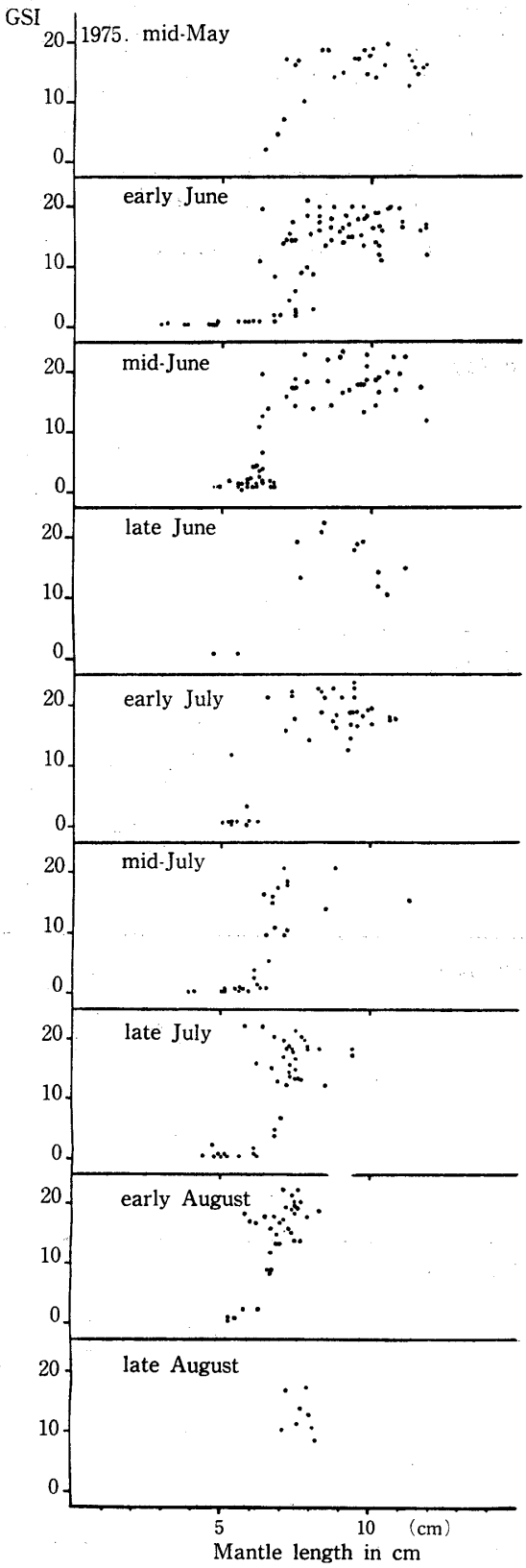

FIG. 9. Relationship between GSI and mantle length in the coastal region.

between 7 and 10 cm were immature or noncopulated. The overall mantle length composition was divided into two normal distributions having modes at over 10 cm and about 9 cm except during mid-May 1975 and mid-June 1976.

A small-sized group followed the large-sized group in late June and early June. The small-sized group in 1975 consisted of mature and immature squid, while most squid were immature in 1976. These offshore mantle length composition resembled the coastal ones of June, being divided into three normal distributions.

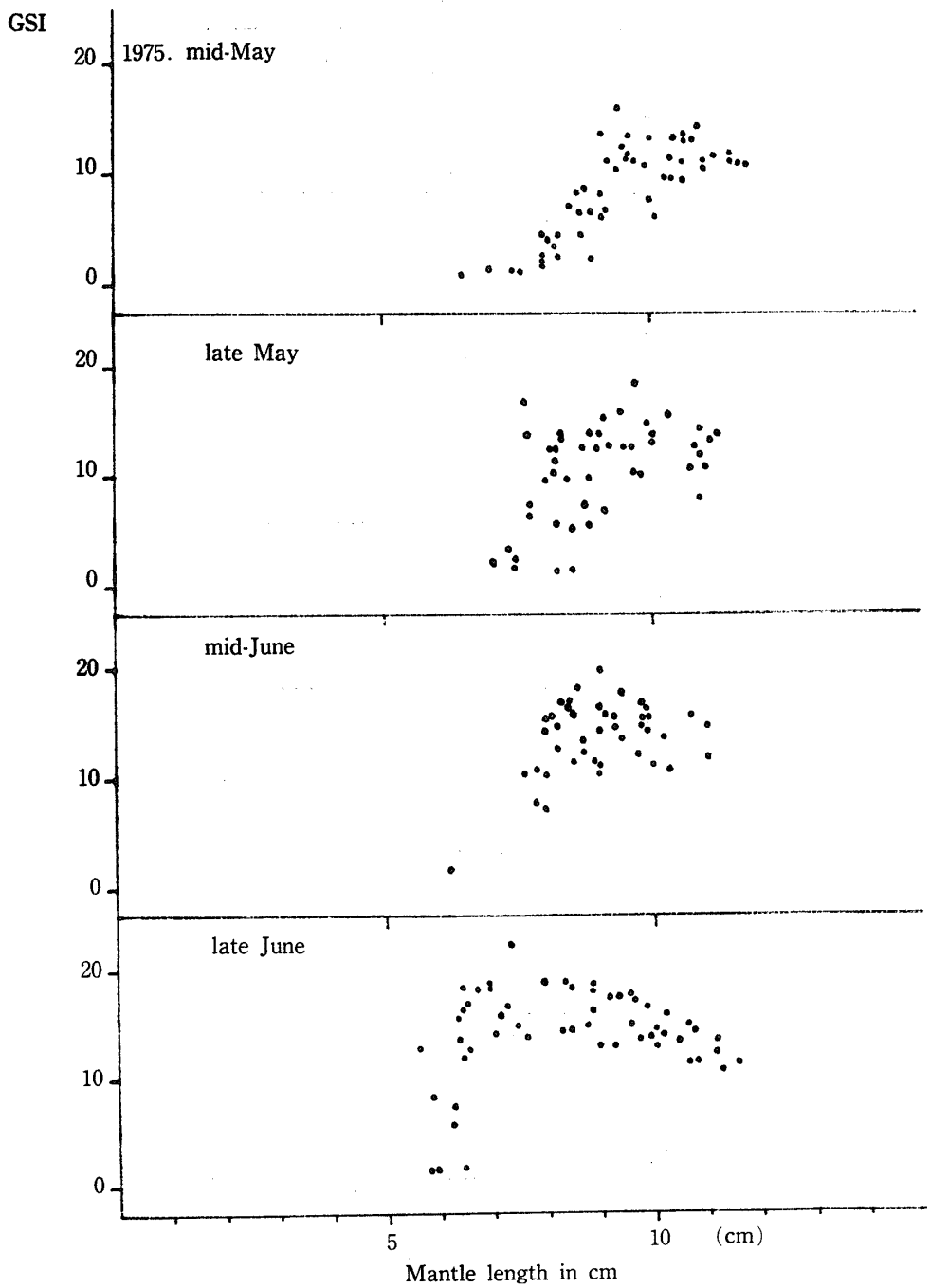

FIG. 10. Relationship between GSI and mantle length in the offshore region.

Relationship between GSI and Mantle Length

Coastal region (Fig. 9)

In May large-sized mature squid were abundant, followed by small-sized and immature ones in June. After mid-July large-sized and mature squid ended their stage and small-sized squid played the main part. This small-sized group continued to include both mature and immature squid.

Offshore region (Fig. 10)

Most squid over 9 cm were mature in May, while many squid between 7 and 9 cm were immature. Most squid were mature in mid-June and in late June squid over 7 cm became mature. Whereas squid under 7 cm consisted of both mature and immature ones.

Growth and Longevity

As shown in Fig. 11, three different modes can be recognized from May to June, i.e., the first somewhat over 10 cm, the second 8 to 9 cm and the last about 7 cm in the offshore. This shows the existence of three groups.

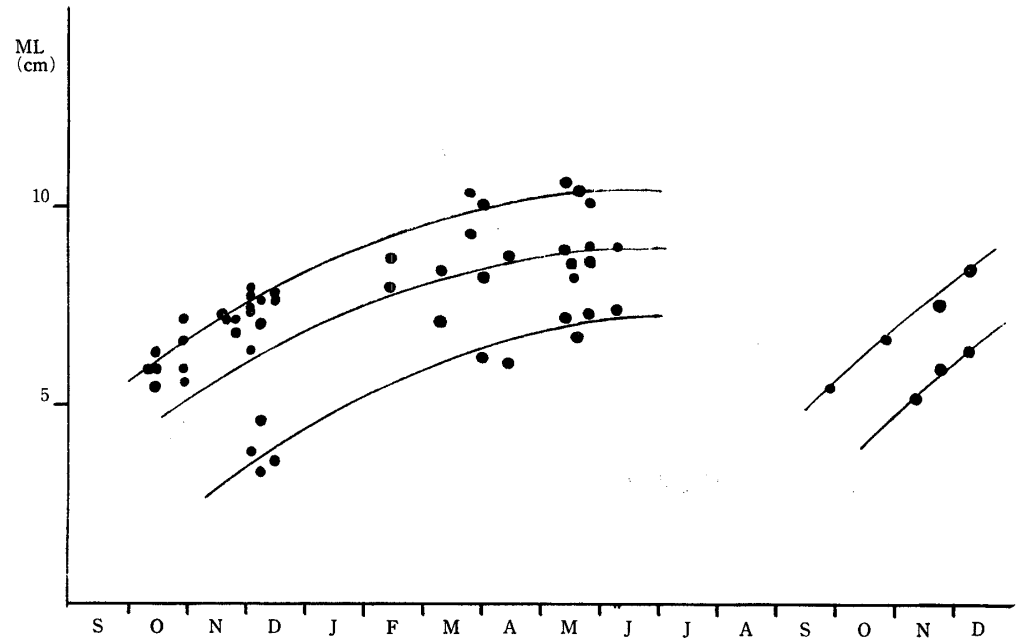

FIG. 11. Month-to-month change in the unsexed mode distinguished by Cassie's method. Each growth curve is estimated by the change in the mode.

The modes progressed toward large from October 1978 to June 1979, tended toward small in October 1979, and again continued toward large until December 1979. This process seemed to show that the longevity of *Loligo japonica* is one year.

Discussion

Three groups of female squids, large-sized mature, large-sized immature and small-sized mature, are distributed in the offshore region from late April to late

June. The groups are named Groups I, II and III in the decreasing order of size. Groups I and II co-habit from late April to mid-June, while Group III stays in June. The modes of mantle length are 10 cm, 8–9 cm and 7 cm in Groups I, II and III, respectively.

Three groups are observed in the coastal region as well. These groups are large-sized mature (from May to July), small-sized mature (from June to August) and small-sized immature (from September to November). In the coastal region, CPUE attains a minimum around September. This results from the fact that two mature groups appear before September and another immature after October. On the other hand, the level of CPUE in the offshore is high only when immature groups appear in the offshore region from October to January, while it is low when mature or copulated squids are found.

It can be stated in general that *L. japonica* approaches the coast while increasing in maturity and die after spawning, suggesting that the longevity of this species may be one year. Newly born cohorts are believed to expand their range to offshore, resulting in an increasing in CPUE in offshore as well as along the coast.

The large-sized mature group observed in the coastal region is seemingly the mixed aggregation of Groups I and II because of a similarity in size. On the other hand, the coastal small-sized mature group may correspond to Group III. Small-sized immature squid come from premature of Gropus I, II or III in the coastal region. Groups I and II become mature and couplate in the offshore region and on the way to coast, respectively, while Group III behaves similarly in the coastal region.

According to the regression of oviduct weight as a percentage of body weight on mantle length, some squid with light oviducts were observed among those over 10 cm in late June and after May near the coast, suggesting that they were spawning. Squid of 7–10 cm, however, seemed to remain in the maturation stage (Figs. 12 and 13). The former is Group I spawning after May and appearing in a somewhat offshore area in late June, while the latter is Group II.

In conclusion, three groups with different breeding seasons are thought to be distributed in Sendai Bay. In examining mantle length composition in the offshore region, mean sexed length ranges for adults of each group are listed below:

Group I: female: 10–11 cm, male: 9–9.5 cm

Group II: female: 8–9 cm, male: 7–8.5 cm

Group III: female: 6–7 cm, male: 6–6.5 cm

We would like to thank Dr. A. OKATA, chief director of Fishery Biology of Fisheries Experimental Station of Ibaraki Pref., for giving valuable suggestions. We are deeply grateful to Messrs. I. KAMEI and S. OKAWA, fishermen of set nets, the members of Haragama Fisheries Cooperative Association and those of the Section of Fishery Biology, Tohoku University, for their help in sampling.

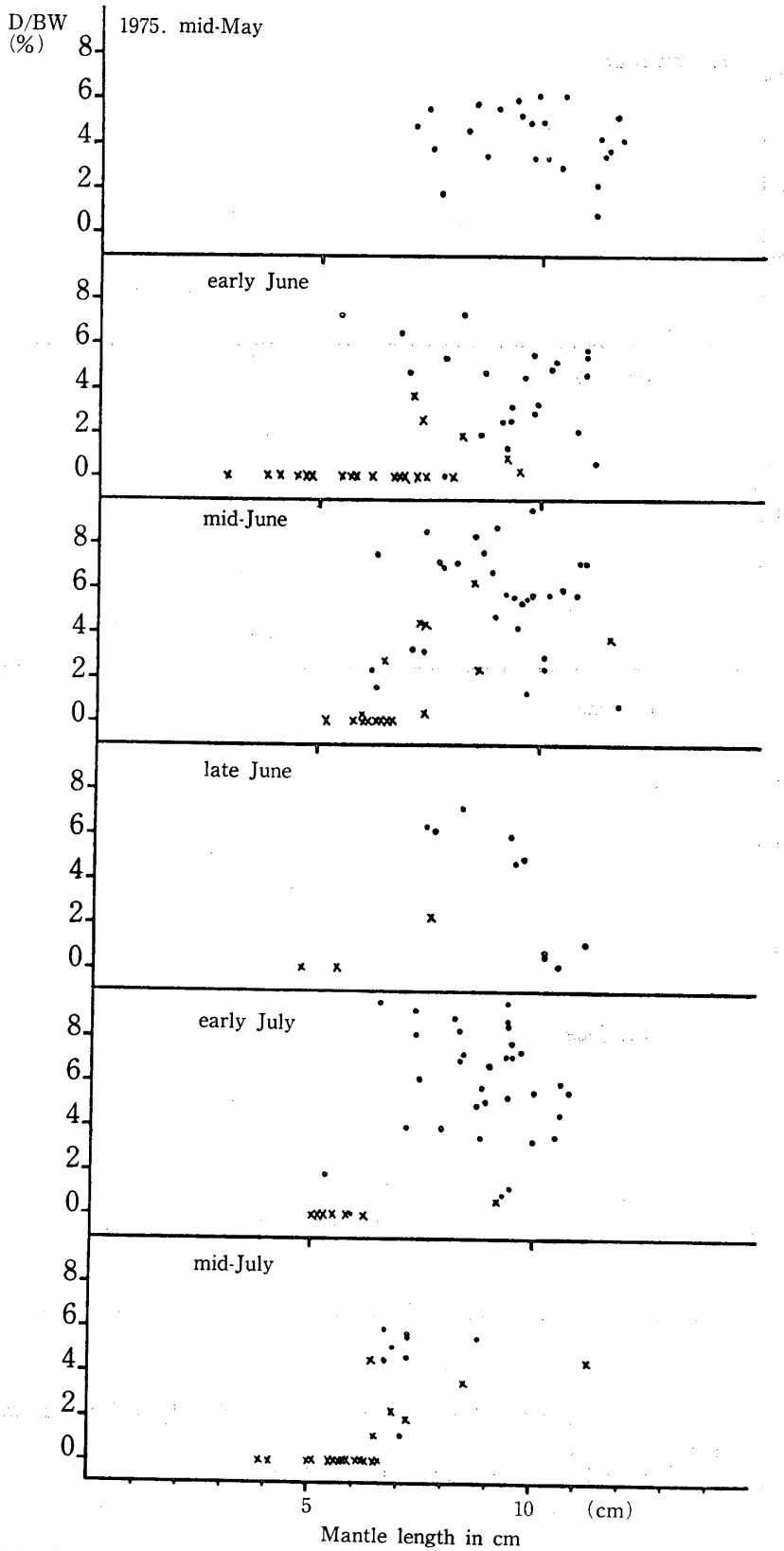

FIG. 12. Regression of oviduct weight as a percentage of body weight on mantle length in the coastal region.
● : copulated squid × : noncopulated squid

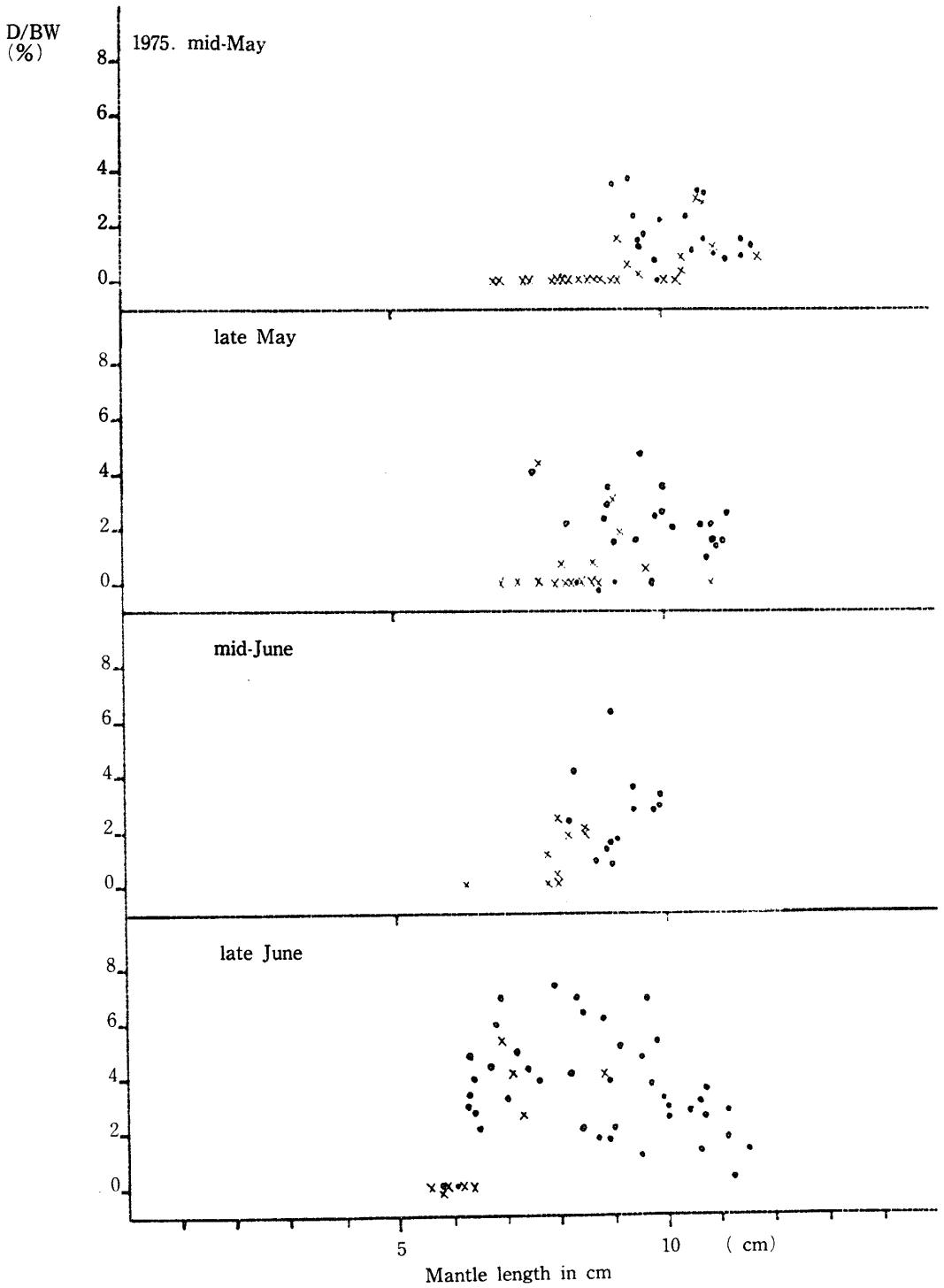

FIG. 13. Regression of oviduct weight as a percentage of body weight on mantle length in the offshore region.
● : copulated squid × : noncopulated squid

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