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Population Biology of the Forked Hake, *Laemonema longipes* (Schmidt), off the Eastern Coast of Honshu, Japan

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Summary

Body parts of the forked hake caught by trawlers were measured to study the fish's life cycle, and fishing records of offshore trawlers were used to study the forked hake fisheries carried out off Miyagi to Fukushima. It appears that the forked hake is a long-lived and slow-growing species among marine teleosts. The forked hake feed on plankton as well as nekton. They spawn numbers of pelagic eggs from February to April and migrate as their life cycle changes. They may live near the sea bottom at night and at a layer about 50 meters above the bottom in the daytime. The forked hake are caught in abundance by trawlers off Miyagi to Fukushima at night in November-December, when they migrate to the area. The migrating biomass decreased in 1980-1983 when fishing was intensified, but it began to increase in 1984. If the forked hake stock has decreased under the influence of fishing, it may take a long time to recover. The stock seems to be fluctuating annually controlled by environmental factors.

Catches of the walleye pollock in the northern North Pacific had decreased markedly due to intensified regulation over the Japanese fisheries by the USA and the USSR, resulting in a lack of pollock for fish paste in Miyagi, which had three major landing ports for deep sea trawlers converted northern waters, Onagawa, Ishinomaki and Shiogama. Offshore trawlers in Miyagi then began to fish deep-sea gadoids which were abundantly distributed over the continental slope (500-1,500 m) on the Pacific side of northern Japan, as substitutes for the walleye pollock. Hashimoto (1) pointed out that deep-sea gadoids caught by offshore trawlers off northern Japan were decreasing, and it has been necessary to know the state of the stocks, but the life cycle of the deep-sea gadoids were only poorly known. The forked hake is a deep-sea gadoid, belonging to Moridae in Gadoidei. Some research institutions knew through experimental fishing that the forked hake were abundant in the seas on the Pacific side of northern Japan, and commercially useful.

The objective of the present study is to investigate the life history of forked hake, growth, feeding habits, reproduction, distribution, migration, *etc.*, as well as the present state of offshore trawl fishery, catches, fishing seasons, fishing times, composition by species of the catches, *etc.*, and the present state of the stock.

This paper was originally written as Yokota's master thesis for the Course of Fisheries Science, Division of Agriculture, Tohoku University, in 1987.

Materials and Methods

The forked hake were sampled from landings of offshore trawlers registered to Miyagi Prefecture at Ishinomaki Fish Market from April, 1985 to January, 1986. The sea area open to the offshore trawlers is shown in Fig. 1.

Age was determined through scale, otolith and vertebra, and body length was measured to examine growth patterns. Stomach contents were also weighed and examined to taxa, to study feeding habits. Maturity of gonads was examined with the naked eye, and gonad weight, egg numbers, and egg size by developmental stages of oocytes were measured or counted to study reproductive processes. Fishing records of the offshore trawlers were used to examine distribution and migration. Catch statistics and landing slips were checked at the fish market, and fishermen were asked to write and submit fishing records, in order to know the amount of fish caught, the fishing period and the time of day of fishing operation.

Since fishing gears and methods used by the offshore trawlers have remained unchanged throughout the year, their catchability coefficient seems to have been constant, and we could use catch per unit effort (CPUE) as a measure of abundance.

Results

Distribution

Fig. 2 shows length compositions by sex of the forked hake samples caught at intervals of 100 meters in depth, with modes at about 42 and 56 cm for male and female, respectively. As seen in the figure, fewer male and more female fish occur with increasing depth, and very few males are observed beyond the 800 m isobath.

Fig. 3 shows the distribution of average catch per hour in $5' \times 5'$ square and reveals that the fish were caught between the 300 and 1100 m isobaths, with the most abundant area around 800 m in depth. CPUE was about 50 kg in September and October, increased to about 600-1,000 kg in November and December, and decreased to about 400 kg in January and February. CPUE was highest in November and December. Fig. 4 shows the seasonal changes in CPUE off Iwate and Chiba. Off Iwate the CPUE was high in November and December as it was for the Miyagi to Fukushima area, while it was high in January off Chiba.

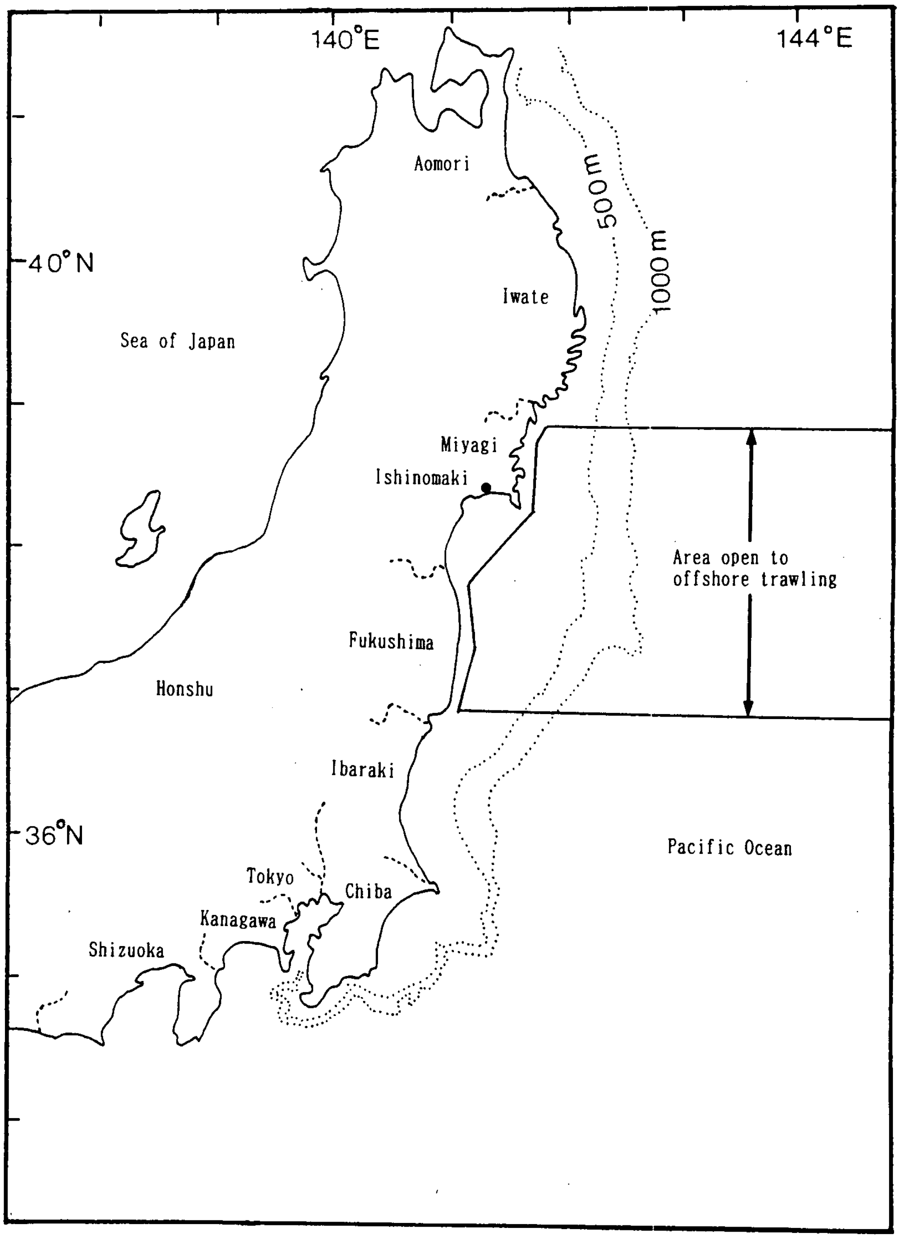

FIG. 1. Showing Ishinomaki which was the survey base, and area open to offshore trawlers registered to Miyagi Pref.

Fig. 5 shows an image of fish schools recorded by the fish finder of an offshore trawler and it can be seen that the forked hake stayed just above the bottom at night, but ascended to a layer 50 m above the bottom in the daytime.

Seasonal changes in length composition

Since no useful meaures for age determination, such as scales, otoliths and vertebrae were available, we estimated the growth pattern of the forked hake by

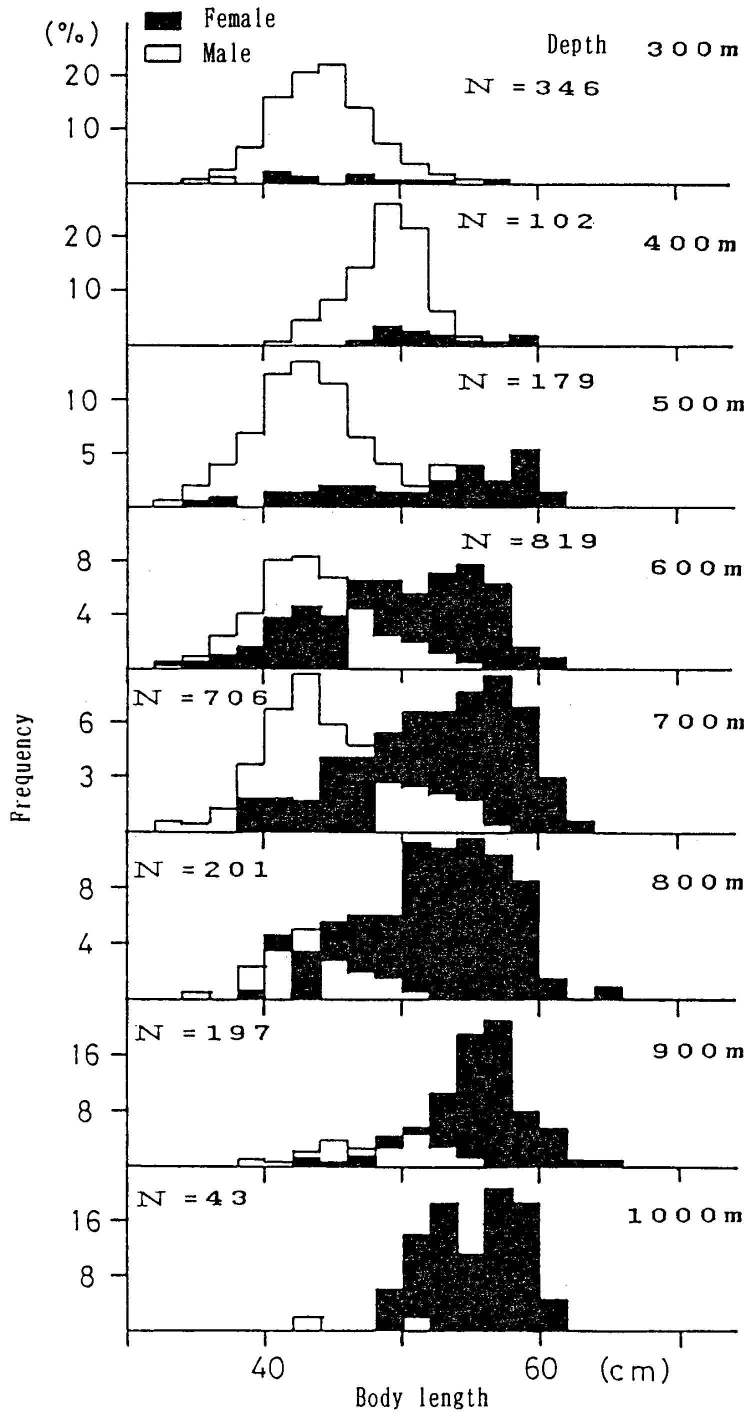

FIG. 2. Body length composition by sex of the forked hake caught in respective depth zone.

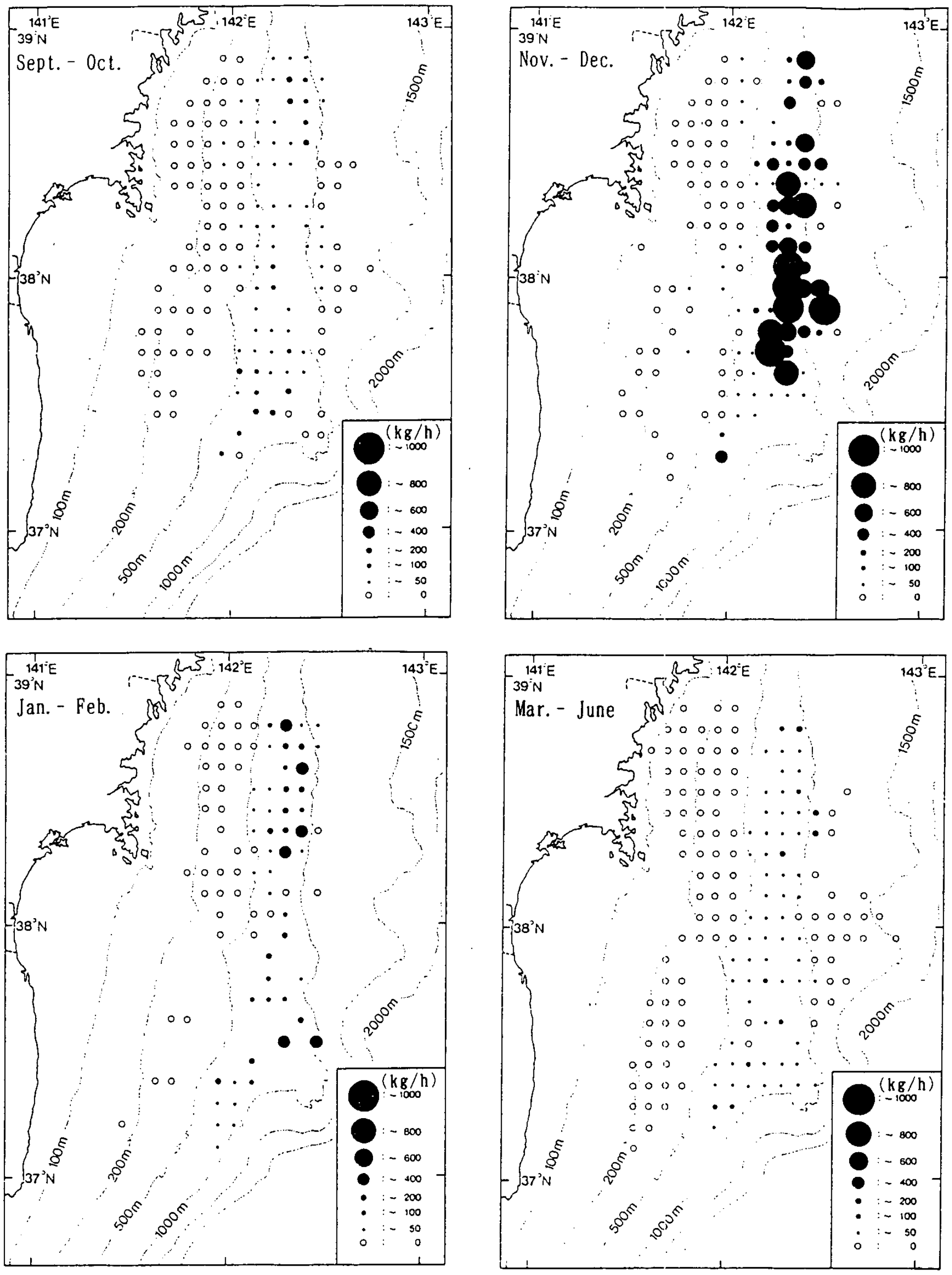

FIG. 3. Catch per one-hour tow in 5′×5′ squares.

connecting modes of body length.

Seasonal changes in length composition by sex of the fish caught off Miyagi to Fukushima are shown in Fig. 6. Modes of length were 42 cm in male and 56 cm in female, which remained unchanged throughout the year. Few males over 55 cm, and females over 60 cm, occurred in this area.

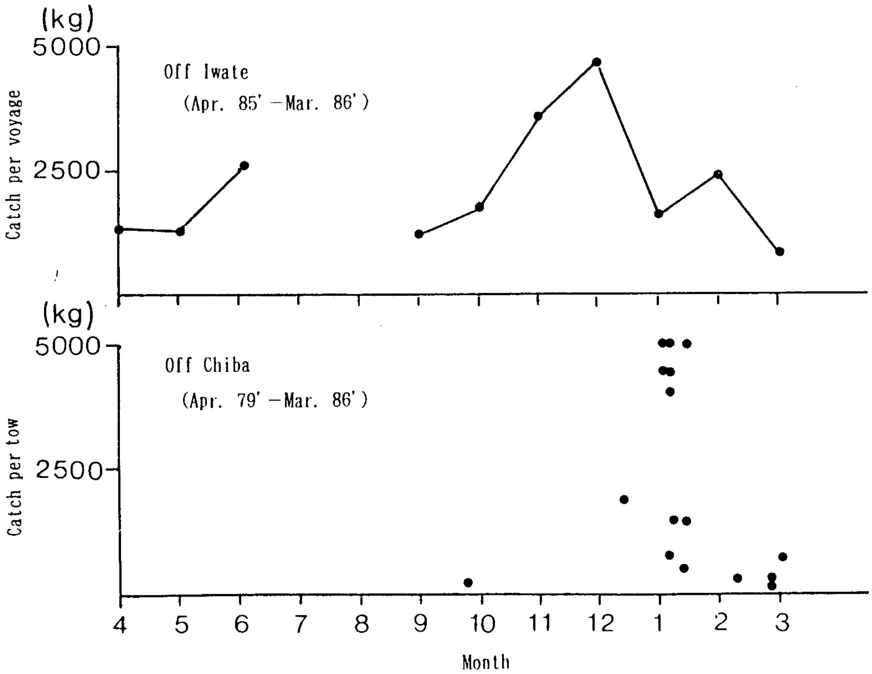

FIG. 4. Seasonal change in CPUE off Iwate and Chiba.

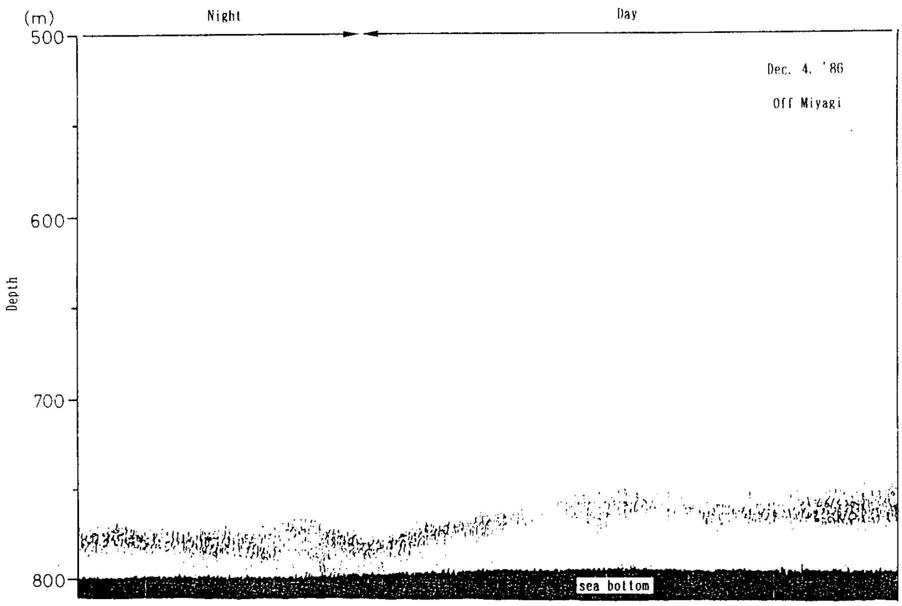

FIG. 5. Fish school of the forked hake recorded by the fish finder of an offshore trawler.

Feeding habits

Taxon compositions in terms of weight observed in stomachs of the forked hake by sex are shown in Fig. 7. Both male and female feed on the plankton (copepods, euphausiids) or nekton (lantern fishes, squids, *etc.*), but fish under

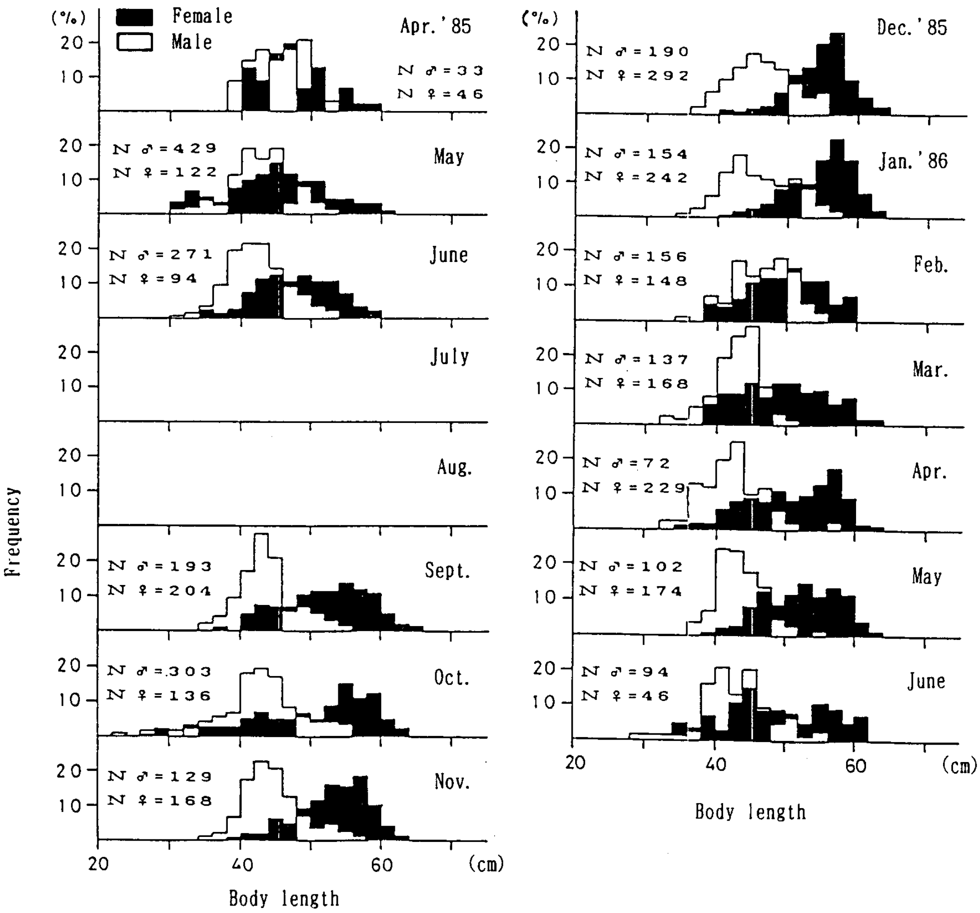

FIG. 6. Seasonal change in body length composition by sex of forked hake caught off Miyagi to Fukushima.

about 35 cm prefer plankton, while those over about 35 cm primarily take nekton, especially lantern fishes. Tyler (2) and Omori (3) classified feeding habits of the demersal fish into three categories, nekton, epi-fauna and in-fauna feeders. The forked hake is a nekton feeder according to their criteria.

Reproduction

The relation between body length and the gonadosomatic index (GSI) for the different sexes are shown in Fig. 8. The fish seem to start muturing when their length exceeds 33 cm for males and 41 cm for females. They appear to spawn in Feberuary-April, since males with low GSI increased and females with transparent eggs just prior to spawning were observed.

Compositions of oocyte diamter for each developmental stage are shown in Fig. 9. When GSI exceeds 2%, the yolk begins to accumulate in some oocytes as they enter the growth phase. When GSI becomes 12-14%, some oocytes begin to absorb water, and completely ripe eggs are formed. At this stage, we can see two

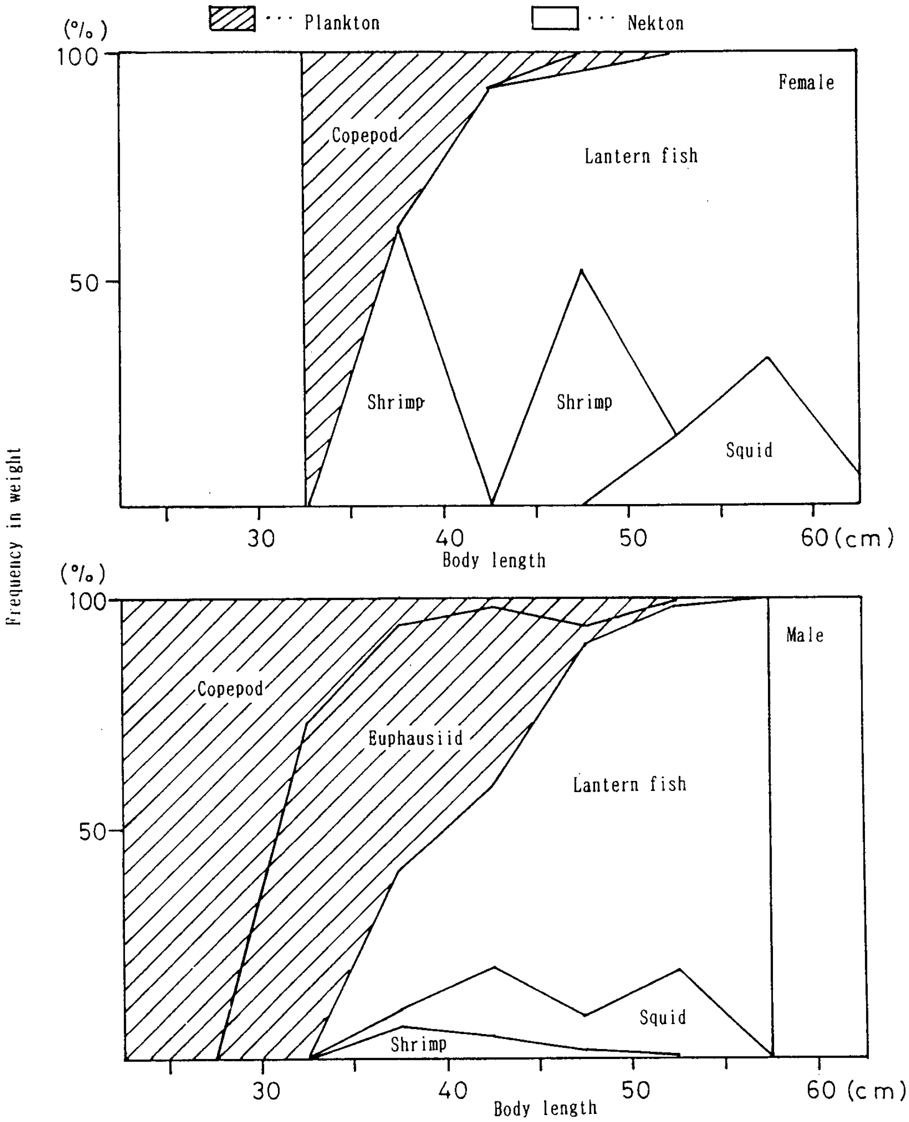

FIG. 7. Stomach content composition in weight by sex.

modes of oocyte diameter. After ripe eggs are released, some oocytes remaining in the growth phase begin to develop into ripe eggs and will be spawned. The pattern of maturation and oviposition in the forked hake is bimode-split-batch spawning, according to Kawasaki (4). Since mode of oocytes just prior to ovulation is 1.0-1.1 mm, the size of spawned eggs is estimated to be the same.

The regression of fecundity (F) on body length (L) is $F = 1.23 \times 10 \cdot L^{2.74}$ (Fig. 10). Here, fecundity is oocyte number in the growth phase, and gonads with 3-10% GSI are used. Very few fish (only one in February) with unreleased ripe eggs in their gonads were observed, showing that the fertility of the forked hake is almost equal to the fecundity, 300,000-900,000.

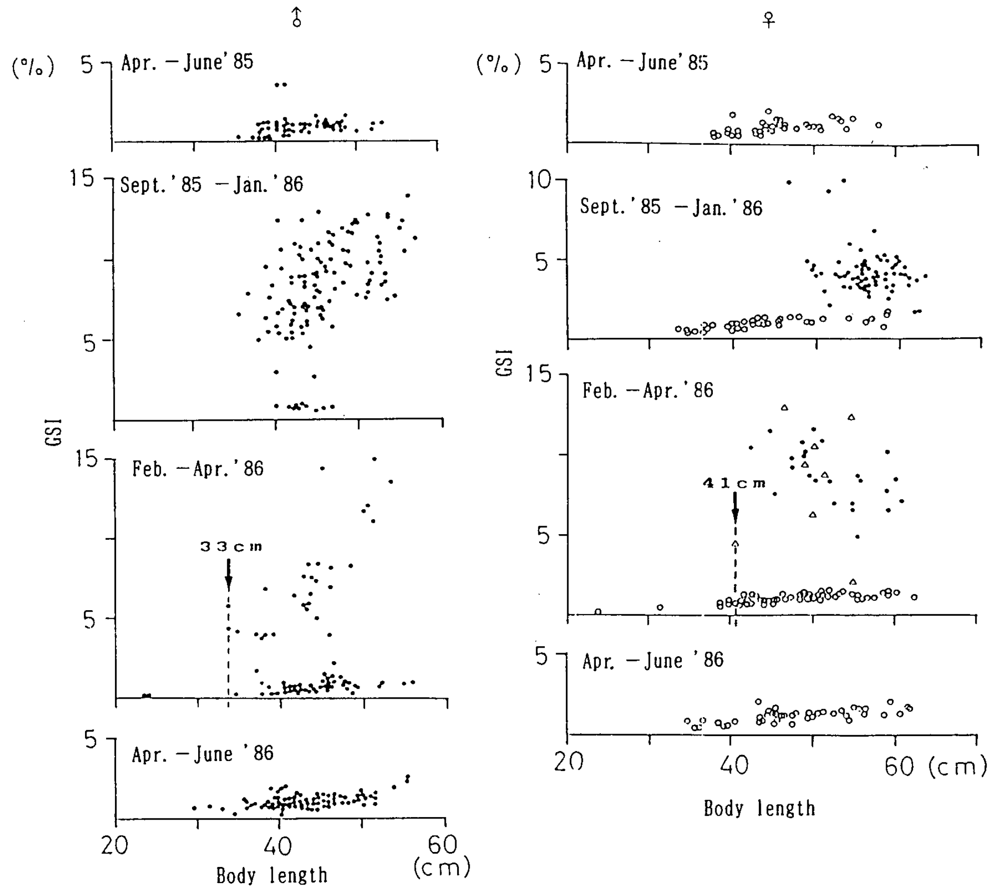

FIG. 8. Change in regression of GSI on length by sex.
* GSI = 100 × G/W (G : Gonad weight, W : Body weight)
** ●—Oocyte at growing phase
△—Ooyte at growing and maturing phases
○—Immature oocyte
×—Degeneration after ovulation

Forked hake catch by offshore trawlers

Fig. 11 shows seasonal changes in catch of the forked hake caught by offshore trawlers registered to Miyagi Prefecture. Catch was abundant in November and December but less in other months.

Fig. 12 shows year-to-year changes in catch per tow in the November-December season, which was decreasing from 1980 to 1983, but increasing after 1984.

Fig. 13 shows catch per one-hour tow in the daytime and at night for each month, with high catch at night but decreasing to one-half to one-third in the daytime.

Off Miyagi to Fukushima, adult hake seem to be distributed more abundantly than young fish since, as shown in Fig. 6, most fish caught there were 40-60 cm in

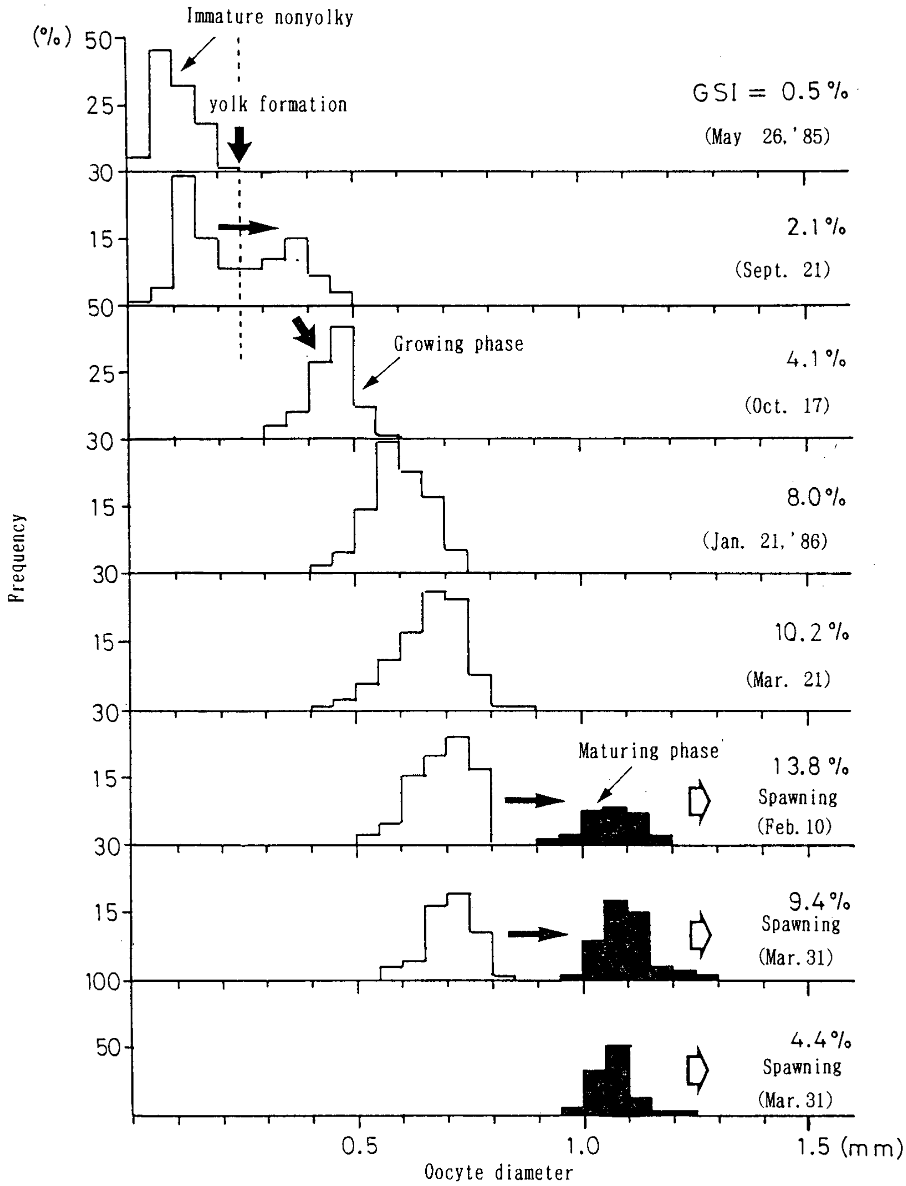

FIG. 9. Oocyte diameter compositions arranged by developmental stages.

length.

Discussion

Characteristics of life cycle

The growth rate and life span of the forked hake are not yet clearly known. Кодолов И Паутов wrote that the forked hake is long-lived (5). According to Kawasaki (4), demersal fishes, characteristics of which are larger size and sexual dimorphism (the female is lager than the male), like the forked hake, are long-

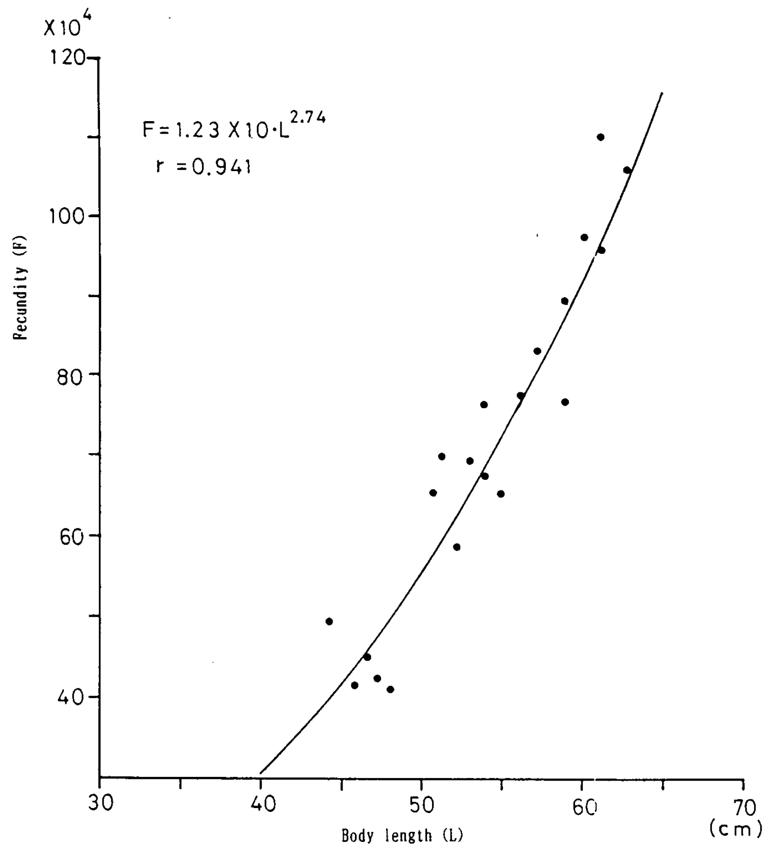

FIG. 10. Regression of fecundity on body length.

lived and slow in growth. In the case of Gadidae, it takes five years for the Pacific cod to reach 40 cm, and 10 years to reach 90 cm in length (6), and for the walleye pollock in the Sea of Japan the length of five-year-old fish is 40 cm (7). In the case of Macrouroidei, lengths are 60 cm and 90 cm for five-year and ten-year-old hoki (8), 40 cm, 60 cm, 80 cm and 90 cm for five years, ten years, twenty years and twenty five years, respectively, in *Coryphaenoides rupestris* (9). It takes five years, ten years and twenty five years for *Macrourus berglax* to grow to 30 cm, 50 cm, 90 cm, respectively (9). These facts indicate that most gadiforms are long-lived and slow-growing. Modes of body length remained unchanged throughout the year, as seen in Fig. 6, indicating that growth was extremely slow because of old age.

Okamura (10) examined the stomach contents of 25 species of Macrouroidae caught on the Pacific coast of Japan and wrote that although a small amount of zooplankton such as euphausiids was observed in their stomachs, their major food was benthic animals. Pearcy and Ambler (11), upon examining the stomach contents of five species of Macrouridae off Oregon, stated that they were fundamentally omnivores, because they took various kinds of animals like polychaetes, pelecypods, cephalopods, planktonic, benthic and pelagic crustaceans, and fishes.

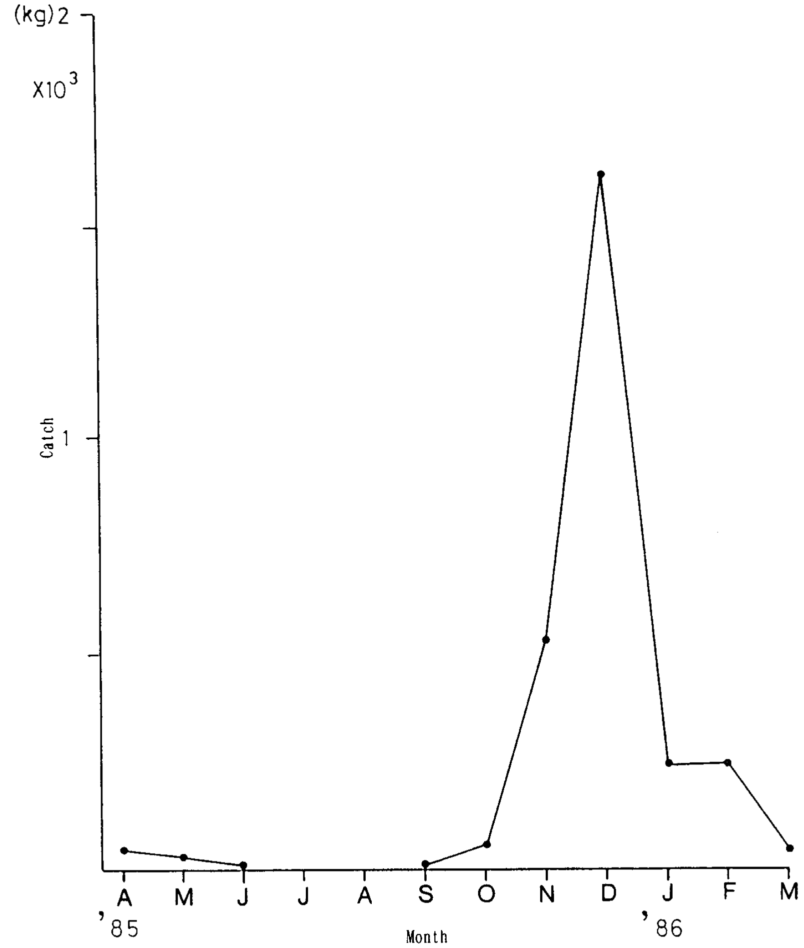

FIG. 11. Seasonal change in catch of forked hake by the offshore trawlers registered to Miyagi Pref.

This shows that many fishes that live on the continental slope feed primarily on the demersal animal community, though they also take a small amount of plankton. On the contrary, the forked hake took nekton exclusively, and epi- or in-fauna was never observed in their stomachs in the present study. This indicates that the forked hake is a nekton feeder, among the three feeding categories assigned by Tyler (2) or Omori (3).

This study made clear that the CPUE of forked hake became higher off Iwate and off Miyagi to Fukushima in November-December, off Chiba in January. Hashimoto (12) reported that the CPUE increased after September off the Pacific coast of Aomori and was highest in October-November. According to a fishing survey by the Fisheries Agency, the CPUE was higher off Ibaraki in January (13). These facts show that the CPUE of forked hake was higher of Aomori in October-November, off Iwate to Fukushima in November-December, and off Ibaraki to Chiba in January. It seems, therefore, that the forked hake make a

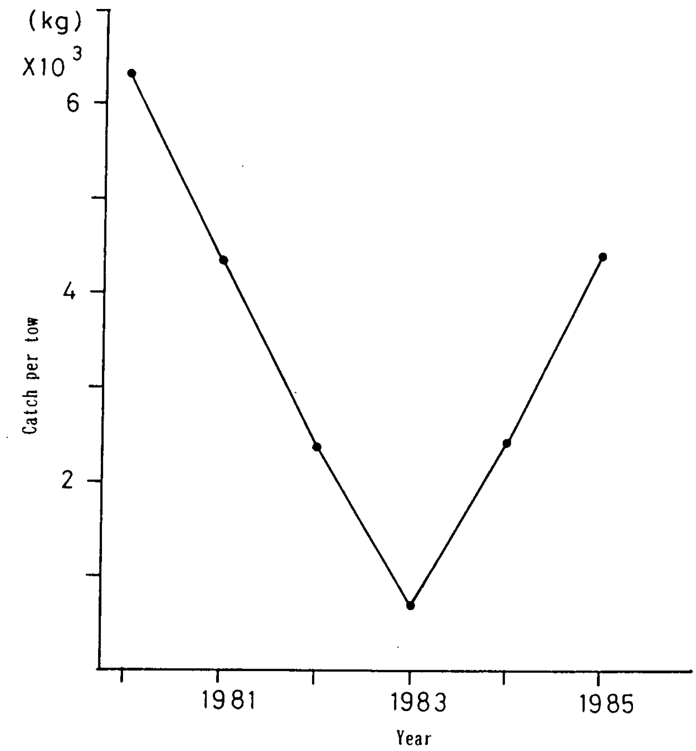

FIG. 12. Interannual change in catch per tow of forked hake during November-December.

south-bound migration along the Pacific coast of Japan. The present study shows that they reproduce in February-April. In egg and larva surveys their eggs near the surface were sampled off Kanto District in February-April (13, 14). It appears that a migration pattern of the forked hake, as illustrated in Fig. 14, can be presumed, based on their life cycle.

Immatures under 30 cm were scarcely caught by fishing surveys carried out on the Pacific coast of northern Japan (13, 15). In the present study, only a very small number of fish under 30 cm were caught off Miyagi to Fukushima. It has been reported, however, that immature fish of 20-30 cm long were caught in the Sea of Okhotsk (15). Eggs and larvae were sampled off Kanto (16). From the above facts, we can say that the life cycle of the forked hake is as follows : Mature fish migrate to the area near Kanto along the Pacific coast of Japan from the north to reproduce in late winter to spring, followed by a north-bound return after reproduction. Young fish born near the Kanto area migrate northward. Our view of the life cycle of forked hake echoes that of Кодолов И Паутов (5).

Diel change in catch of the forked hake well reflects their ecology. Catch per one-hour tow in the daytime was one-half to one-third that at night, showing a diel vertical migration.

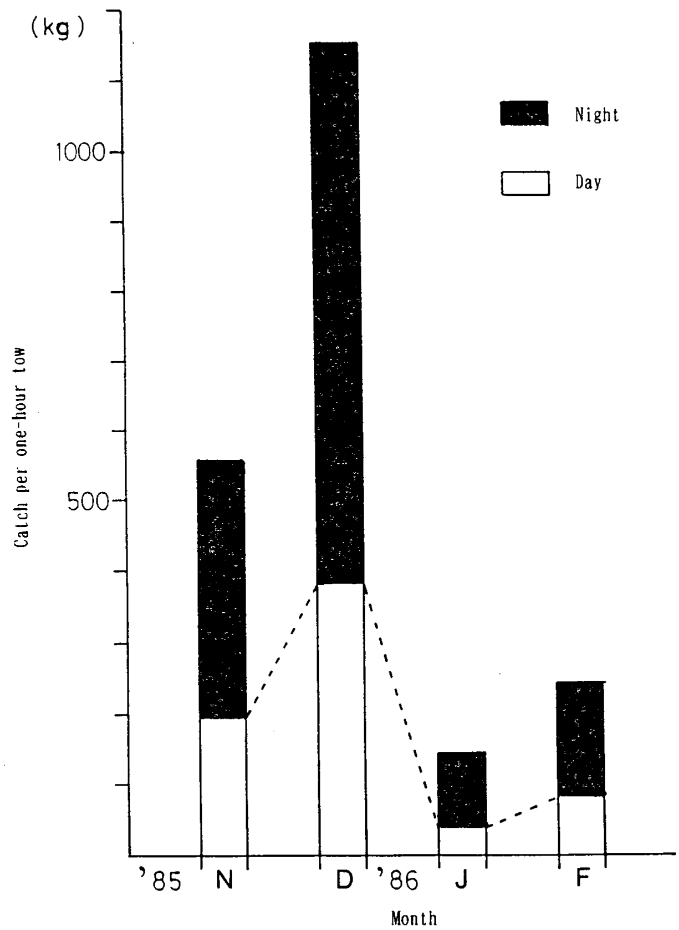

FIG. 13. Month-to-month change in catch per one-hour tow of forked hake at night and in the daytime.

Present state of the forked hake resources

Catch per one-hour tow off Miyagi and Fukushima had decreased between 1980 and 1983, which is possibly a result of decrease in the migrating biomass. The result of experimental fishing by the Aomori Prefectural Fisheries Experimental Station, shows that catch per tow had also declined from 1979 to 1982 (17).

Offshore trawlers registered to Miyagi Prefecture started fishing the forked hake in 1978. Russian boats were permitted to take the forked hake within Japan's 200-mile area in 1977 under the Japan-Soviet Fisheries Agreement. Intensified fishing in 1979-83, therefore, may have been responsible for a decrease in the stock. Catch per tow, however, has increased off Miyagi and Fukushima since 1984, showing a possible rise in stock. If the stock decreased due to fishing between 1979 and 1983, it would be impossible for it to recover in such a short time, strongly suggesting a natural cause for the fluctuation in stock. It is difficult to discuss the problem in grater detail, since only a short period has

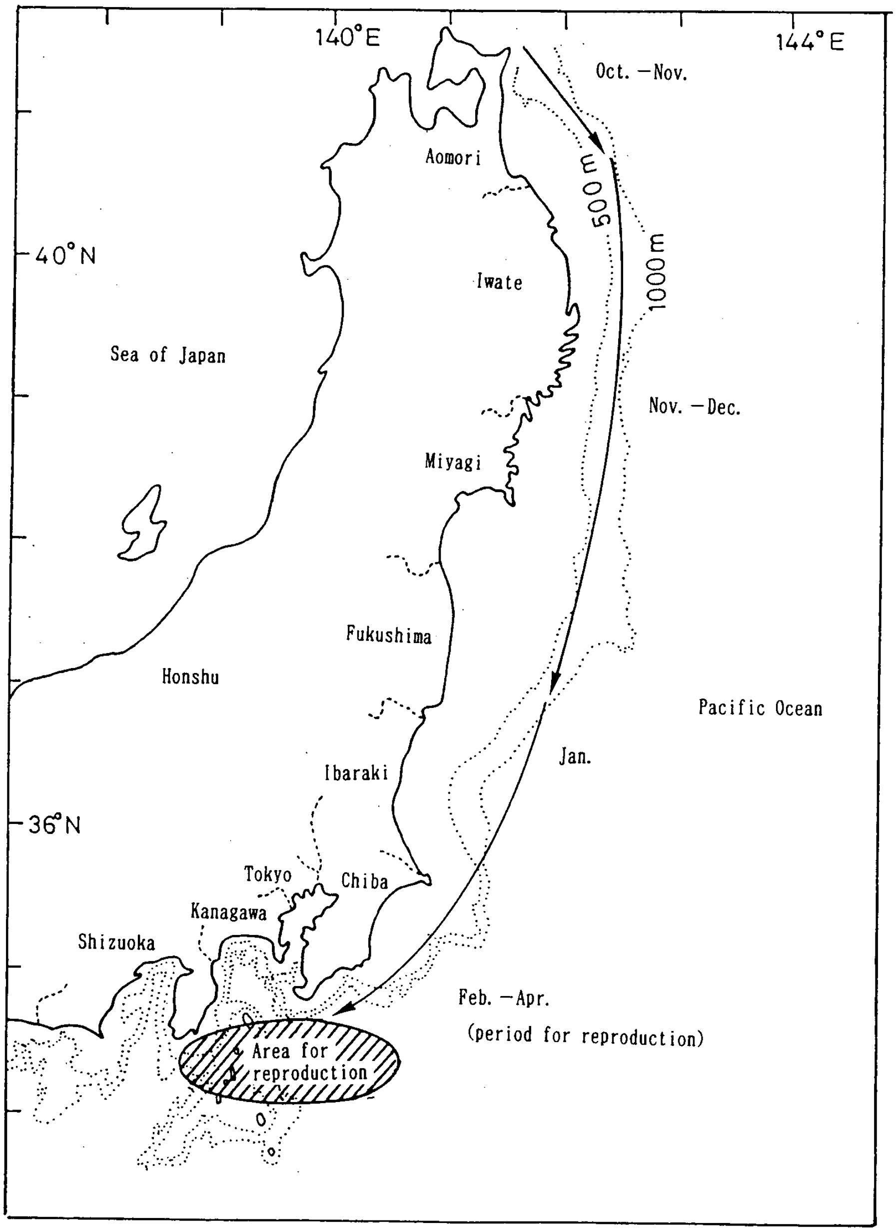

FIG. 14. A conceptual scheme of adult fish migration for reproduction.

elapsed since 1977, when the fishing for the forked hake started.

Acknowledgments

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