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Original Article

Distribution and movement of larvae, juvenile and young of the pointhead flounder *Hippoglossoides pinetorum* in Ishikari Bay and vicinity, Hokkaido

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SUMMARY: To determine the nursery grounds and process of recruitment to adult stock, pelagic larvae, post-settlement juveniles and young fish of the pointhead flounder *Hippoglossoides pinetorum*, samples were collected in Ishikari Bay and the Rumoi coast, Hokkaido from 1991 to 1994. Spawning may continue from late May to mid September with the peak between July and August. However, since pelagic larvae were caught only from late July to early September in the present study, it was assumed that the restricted cohort recruited to post-settlement juvenile stage. Newly settled juveniles occurred in Ishikari Bay in September and in the Rumoi coast in late August and were mainly distributed at depths of 30–69 m. The habitat of 1-year-old and older flounder was deeper than that of 0-year-old flounder in autumn. Post-settlement juveniles gradually migrate to shallow areas during winter and their main habitats were at a depth range of 20–30 m in May. Although 1- and 2-year-old flounder were caught in the area of 20–40 m depths in June, few 3-year-old or older flounder were sampled by beam trawl. The same phenomena were recognized from the re-analyzed data of the otter trawl surveys in 1988. The pointhead flounder mainly occurred in the shallow water of the continental shelf until 2 years old and shifted their habitat to deeper areas (the upper area of the continental shelf) by 3 years old in Ishikari Bay and the surrounding area.

KEY WORDS: ***Hippoglossoides pinetorum*, movement, newly settled juvenile, nursery grounds, pelagic larvae, recruitment.**

INTRODUCTION

The geographical distribution of pointhead flounder *Hippoglossoides pinetorum* ranges from Sakhalin, southward to coastal waters of the Sea of Japan, Korea, East China Sea and the Pacific coast from Hokkaido to Joban.[1] Pointhead flounder is one of the main components of the demersal fish community[2] and is also an important flatfish species of Danish seine and gill net fisheries in Ishikari Bay and the surrounding area. Pointhead flounder begin to recruit to the fishery resource as 3 year olds.[3] The fishing grounds of commercial trawl fisheries and gill net fisheries for pointhead flounder range from the deep continental shelf area to the upper area of the continental slope. In Ishikari Bay, pointhead flounder are caught by gill net fisheries at depths of mainly 70–80 m during spawning season. Ecological information on pointhead flounder[4–12] is mainly based on data from commercial landings. Although there are a few studies about distribution, feeding habits and morphology of planktonic larvae,[13–16] growth of post-settlement juveniles,[17] and distribution of immature fish,[10,18] little information is available about the occurrence and movement of post-settlement juvenile and young fish.

In the present study we sampled pelagic larvae, post-settlement juveniles and young fish of pointhead flounder in Ishikari Bay and Rumoi coast, Hokkaido and determined their nursery grounds and the process of recruitment to adult stocks.

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MATERIALS AND METHODS

Gonadosomatic index of adult fish

Pointhead flounder was sampled from commercial landings at the Yoichi and Furubira fisheries market from April 1991 to December 1992. Body length, body weight (*BW*) and gonad weight (*GW*) of each specimen were measured and sex was recorded. To estimate the spawning period, mean gonadosomatic index (*GSI*) of female fish was calculated by month as follows:

$$GSI = GW \times 100/(BW - GW)$$

The *GSI* was calculated only for mature fish judging from the developmental status of gonads by visual observation, or fish of 20 cm *BL* when it was difficult to determine by observation of the gonads whether fish were mature or not.[3]

Eggs and pelagic larvae collection

Sampling surveys of pelagic larvae in Ishikari Bay (Fig. 1) were made by RV *Oyashio Maru* of Hokkaido Fisheries Experimental Station between July 1991 and November 1992. Samples of eggs and larvae were collected by horizontal tows with a larval net (mouth diameter = 1.3 m, length = 4.5 m, mesh size = 0.62 mm) for 10 min at a towing speed of 2 knots on the surface layer at night. Sampling of larvae was also conducted by oblique tows from 30 m depth (or the sea bottom when water depth was shallower than 30 m) to the surface with a larval net at night. Samples were immediately preserved in 5% sea water formalin. Salinity and temperature were observed by Conductance Temperature Depth (CTD) at an interval of 1 m.

Pointhead flounder eggs and larvae were identified based on Yusa,[13] Pertseva-Ostroumova[14] and Nagasawa [15] and sorted under a binocular microscope. The number of eggs and larvae were counted and total length (*TL*) of larvae was measured to 0.1 mm.

Post-settlement juvenile and young fish collection

Samples of post-settlement juvenile and young fish were collected between June 1991 and July 1993 from Ishikari Bay (Fig. 1). In August and September 1994, samples were also collected from Rumoi coast (Fig. 1). Collections were made with a small beam trawl net (Ishikari Bay: 2.5 × 1.5 m, cod end mesh aperture, 2.5 mm with a speed of about 2.5 knots for 10–20 min; Rumoi: 1.8 × 0.33 m, cod end mesh aperture, 2.5 mm with a speed of about 3 knots for 5–10 min) at water depths between 20 m and 80 m in Ishikari Bay and between 20 m and 60 m in the Rumoi coast. Samples were immediately frozen on board.

All specimens collected were measured to the nearest millimeter (0-year-old fish 0.1 mm) in standard length (*BL*), and weighed to the nearest 0.1 g. Aging was determined by otolith assessment.[17]

RESULTS

Seasonal change in mean *GSI* of female flounder

There was a marked increase in mean gonadosomatic index (*GSI*) in late June (Fig. 2). Mean *GSI* was high from late June to August in both 1991 and 1992, and fell to a low value in October (Fig. 2). During the period between June and August, spent fish were found with the exception of June 1992, so standard deviations of *GSI* were large. In July 1991, 58.6% of mature fish were spent fish. Percentage of spent females in August 1991 (21.1%) and 1992 (29.4%) was significantly lower than that in July(χ^2 test: both P<0.001).

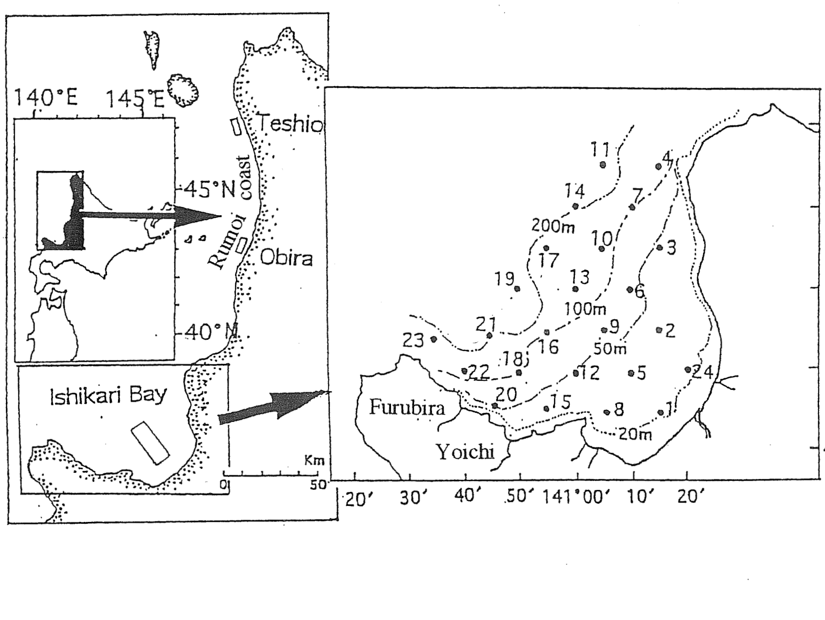

Fig. 1 Map of the coastal waters of northwestern Hokkaido showing study area and larval sampling stations. Rectangle indicates beam trawl survey area.

Occurrence and distribution of eggs and pelagic larvae

Pointhead flounder eggs collected by horizontal tow were observed from late May to early September and were most abundant in July 1992. However, no eggs of pointhead flounder were sampled in mid and late September (Fig. 3). Pelagic larvae ranging in total length from 3.5 mm to 7.1 mm were collected in late July 1991. Of 22 individuals collected, 16 larvae were sampled by an oblique tow (Table 1). As an oblique tow was not conducted in September and October, it was uncertain whether pelagic larvae existed or not in the study area during this period. From late July to mid September in 1992, pelagic larvae occurred between 3.2 mm and 14.4 mm in total length. Every specimen was caught by oblique tow (Table 1). Pelagic larvae were collected mainly in the offshore area (sea depths of 50 m or deeper) (Table 1).

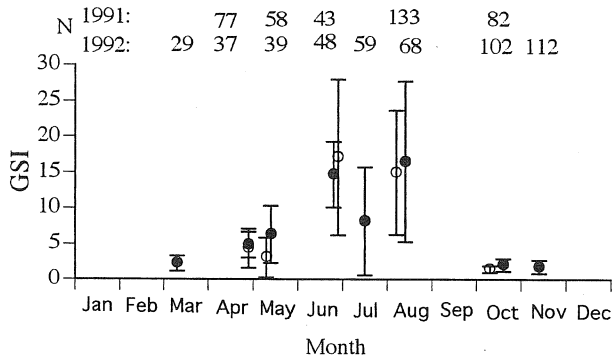

Fig. 2 Monthly change in gonadosomatic index (*GSI*) of female *Hippoglossoides pinetorum* in Ishikari Bay based on data from (●) 1991 and (○) 1992. Means and standard deviations are presented. Numerals in figure indicate number of samples analyzed.

Seasonal change in abundance of sequent three year-classes juveniles by depth in Ishikari Bay

Figure 4 shows a seasonal change in abundance of the 1990, 1991 and 1992 year-classes, expressed as the number of catch per 15 min tow at each depth in Ishikari Bay, from June 1991 to July 1993. In June 1991, pointhead flounder of the 1990 year-class was caught at all depths where the sampling surveys were conducted, and dominated at a depth of 40 m. Pointhead flounder decreased in number and was not sampled at 20 m, 30 m and 40 m depth in both September and November 1991. Pointhead flounder of the 1990 year-class occurred at depths from 20 m to 80 m again in May but was not collected at any depths in November 1992. In May 1993, this year-class was found in small numbers at depths of 30 m and 60 m.

The 1991 year-class was the most abundant of the three year-classes and occurred as a young-of-the-year at 30 m, 40 m and 50 m depths in September 1991. In November the abundance of the 1991 year class became high and the depth range of the distribution became wider. In February 1992, the pointhead flounder of this year-class was caught at all survey depths with a most

Table 1 Number of horizontal and oblique tows, number of individuals collected and number of sampling stations where *Hippoglossoides pinetorum* larvae were collected from June 1991 to November 1992 in Ishikari Bay

Date	No. of tows		No. of larvae collected (Station no. where larvae collected)	
	Horizontal	Oblique	Horizontal	Oblique
1991				
23–25 July	24	11	6 (Stns 2, 10)	16 (2, 6, 10, 16)
2–4 September	24	0	0	–
24–26 September	24	0	0	–
7–8 October	24	0	0	–
1992				
25–26 May	24	24	0	0
6–7 July	24	13	0	0
27–29 July	24	13	0	5 (16, 19, 23)
26–28 August	24	13	0	6 (16, 19)
7–9 September	24	13	0	1 (23)
16–17 September	24	13	0	5 (12, 14)
28–29 September	24	13	0	0
20–21 October	24	13	0	0
5–6 November	18	7	0	0

Oblique tows were mainly conducted at Stations 2, 4, 6, 8, 10, 12, 14, 16, 19, 20, 22, 23 and 24 presented in Fig. 1. Oblique tows were not done at Stations 14 and 19 in July 1991, and at Stations 15, 18, 20, 21, 22 and 23 in November 1992.

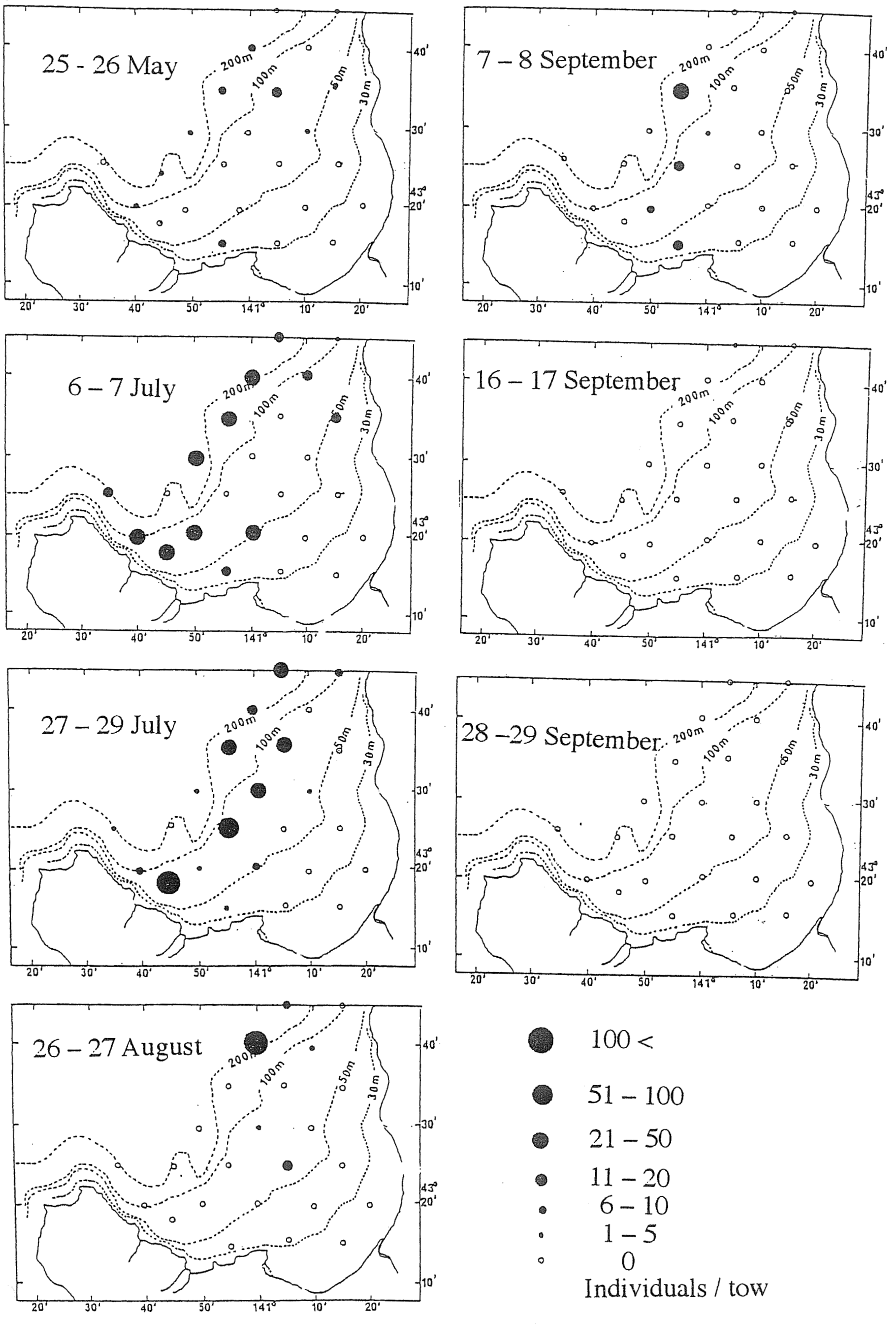

Fig. 3 Number of *Hippoglossoides pinetorum* eggs collected by horizontal tows with a larval net (mouth diameter = 1.3 m, length = 4.5 m, mesh size = 0.62 mm) for 10 min at a towing speed of 2 knots at the surface layer at night in Ishikari Bay from 25 May to 29 September 1992.

abundant depth of 40 m. The main area of the distribution moved to shallower waters from May to July, followed by movement to an offshore area and no 1991 year-class were collected at depths shallower than 50 m in September and 60 m in November 1992, respectively. In May 1993, the 1991 year-class were found in large numbers in a shallow area, especially at 30 m, but became less abundant in July.

No fish of the 1992 year-class were collected in 1992. This cohort was found in small numbers at 30 m in May 1993 and increased in number in July 1993.

Body size of the 1991 year-class by depth in Ishikari Bay from September 1991 to July 1993

Figure 5 shows the body length frequency distributions of the 1991 year-class in 9 months. The smallest juvenile (16.0 mm *BL*) of the 1991 year-class was sampled at 30 m in September 1991. In November 1991, the smallest juvenile collected was 27 mm *BL*. Significant differences in mean body length of the 1991 year-class were not seen among water depths in November 1991 (ANOVA, $P = 0.30$), May 1992 (ANOVA, $P = 0.37$) and

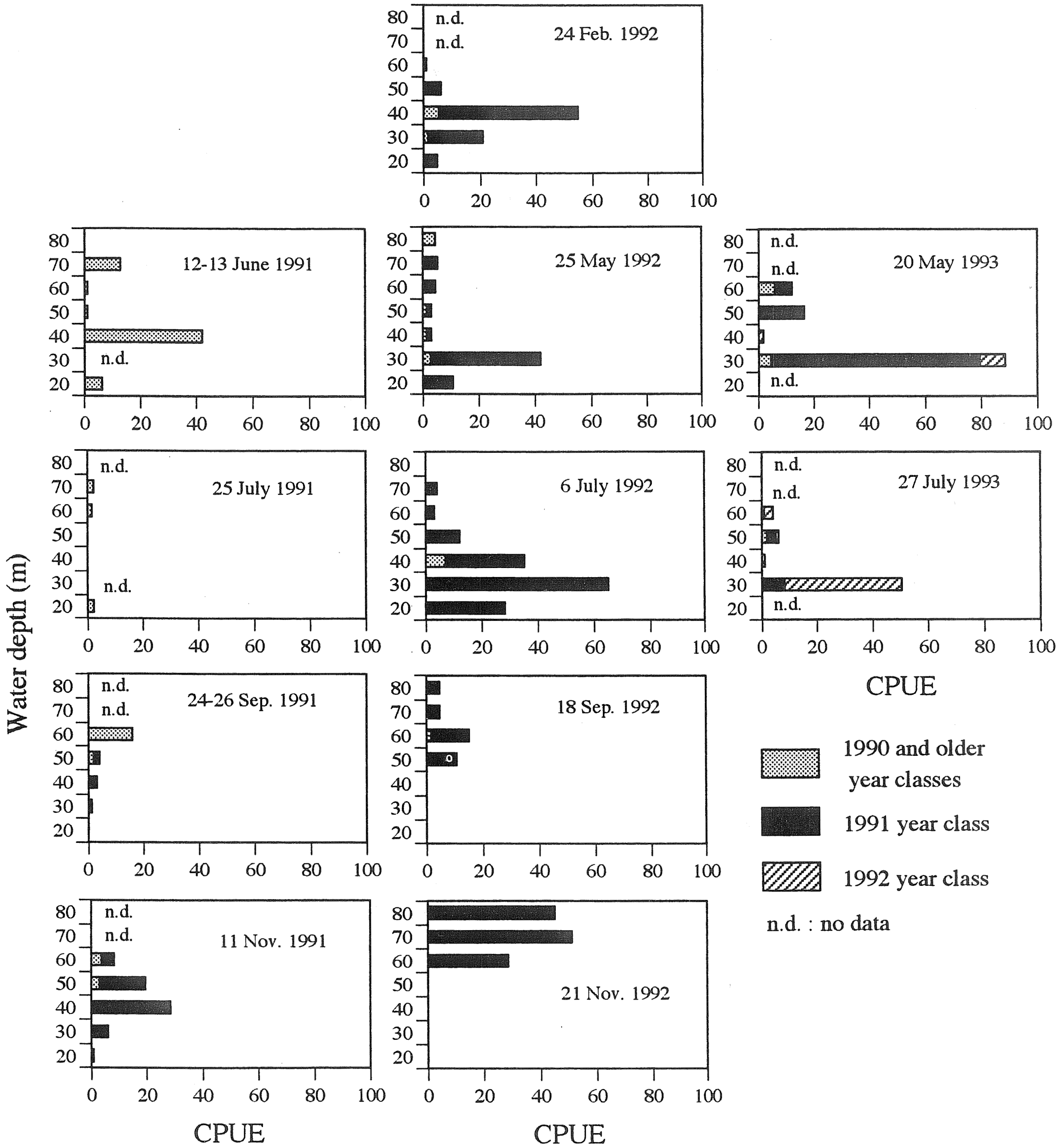

Fig. 4 Catch per unit of effort (CPUE) of 1990 and older, 1991 and 1992 year-classes of *Hippoglossoides pinetorum* collected by beam trawl net by water depth in Ishikari Bay from June 1991 to July 1993. CPUE are expressed as the number of catch per 15 min tow.

September 1992 (ANOVA, $P=0.10$). However, in the remaining 4 months (except for July 1993 because of insufficient number of samples), mean body lengths were significantly different among water depths (February, July and November 1992: ANOVA, $P<0.01$; May 1993: ANOVA, $P<0.05$).

In February 1992 when major habitat shifted to shallower waters, mean body length (51.8 mm *BL*) of juveniles caught at 20 m and 30 m was significantly larger than that in 40 m and deeper areas (45.1 mm *BL*: *t*-test, $P<0.001$). In contrast, in July, November 1992 and May 1993, mean body length of flounder in deeper areas have

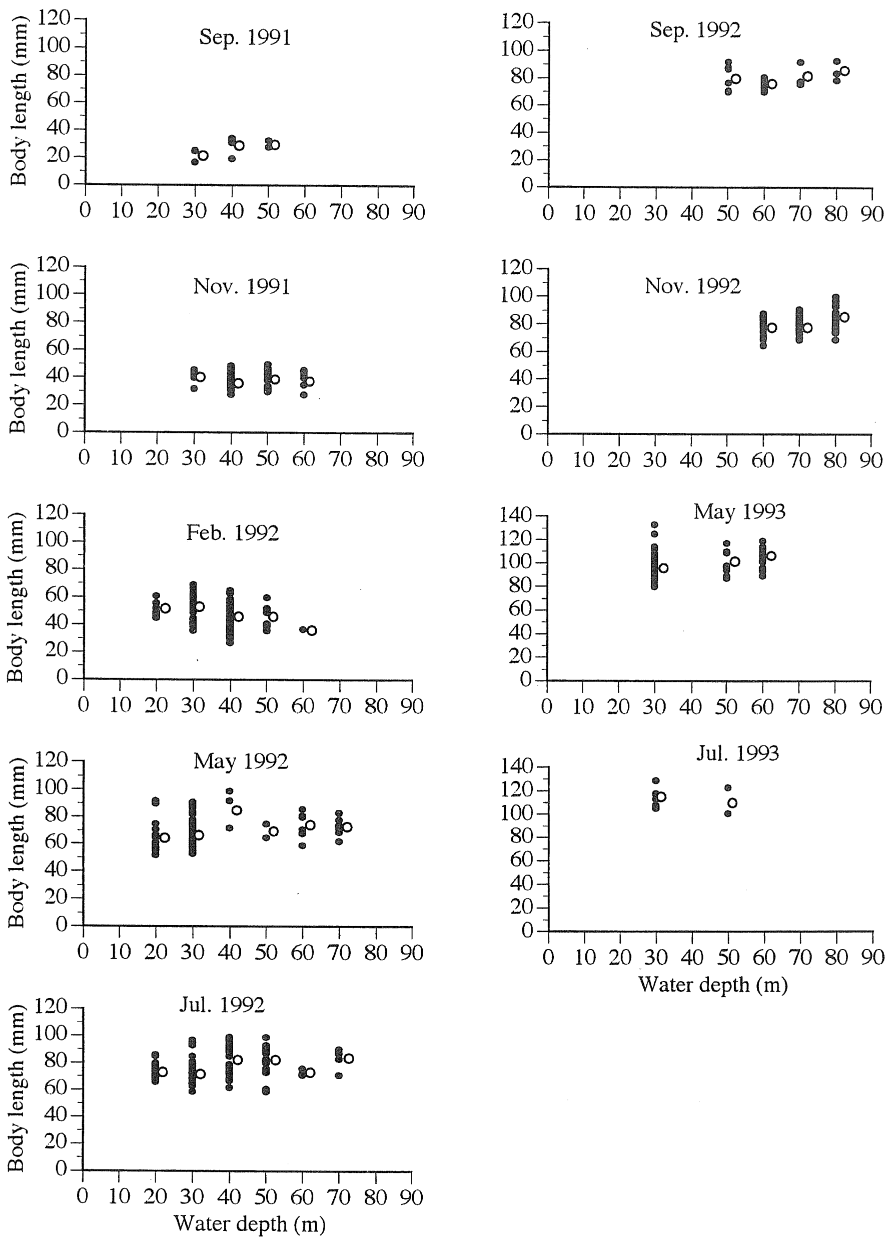

Fig. 5 Individual body length (●) and average body length (○) of the 1991 year-class of *Hippoglossoides pinetorum* by water depth from September 1991 to July 1993.

a tendency to be large. There were significant differences between <30 m depth (72.6 mm *BL*) and >40 m depth (80.1 mm *BL*) in July 1992 (t-test, $P<0.001$), <70 m depth (79.2 mm *BL*) and 80 m depth (82.7 mm *BL*) in November 1992 (t-test, $P=0.013$) and 30 m depth (94.6 mm *BL*) and >50 m depth (101.8 mm *BL*) in May 1993 (t-test, $P=0.003$), respectively.

Body size and abundance of pointhead flounder in Rumoi coast in August and September 1994

Figure 6 shows the body length frequency distributions of pointhead flounder from Obira in August 1994 and Teshio in September 1994.

No pointhead flounder was collected at depths shallower than 40 m in both areas. The post-settled juveniles whose body lengths ranged between 14.4 mm and 28.8 mm were found at two depth ranges (40–49 m, and 60–69 m) in Obira. The post-settled flounder from 10.9 mm to 28.0 mm in body length were also sampled at the deepest two ranges in Teshio. The 1-year-old flounder were more abundant at the depth ranges of 50–59 m in both Obira and Teshio.

DISCUSSION

In the present study, spent females were found in the commercial landings from late June to August and mean

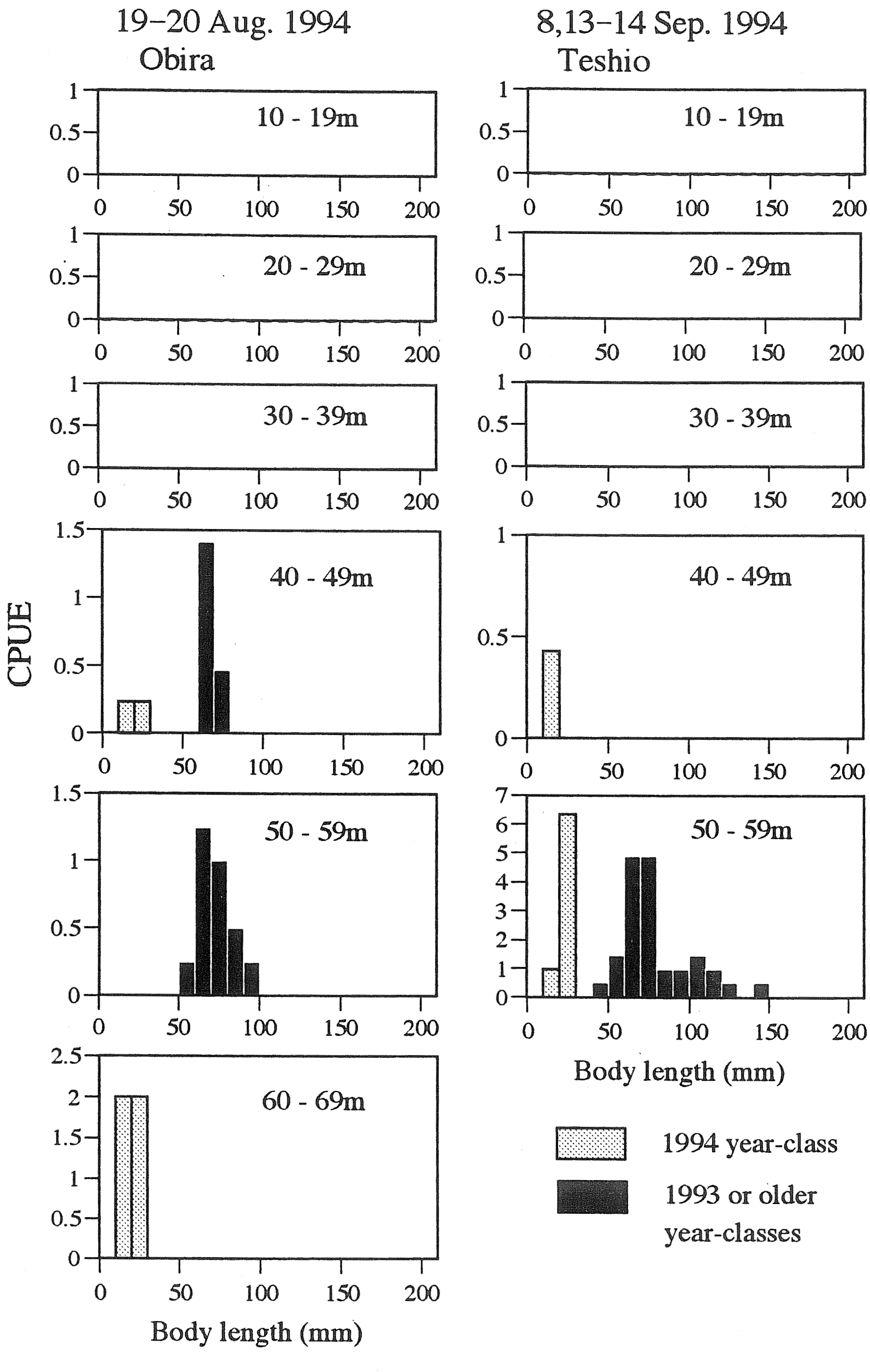

Fig. 6 Body length frequency distributions of *Hippoglossoides pinetorum* collected by small beam trawl net by depth range in Obira in August, and Teshio in September 1994. Number of individuals collected are adjusted to those per 1 km tow.

gonadosomatic indices were high from June to August. Tanaka *et al.* reported that spent females begin to occur in Ishikari Bay in June and ripening female were found in the offshore area of northwestern Hokkaido even in September.[19] In addition, Nagasawa[15] collected pointhead flounder eggs in the western offshore waters of Hokkaido from mid August to mid September. Pointhead flounder eggs which were collected in larval sampling surveys of the present study were observed from late May to early September and were most abundant in July (Fig. 3). These results suggested that pointhead flounder has a long spawning period. In the southwestern Japan Sea, spawning season of pointhead flounder is from January to April.[20] Although the spawning season is quite different from Ishikari Bay, spawning also continues for about 4 months in Ishikari Bay. Judging from these results, spawning may continue from late May to mid September with a peak between July and August.

However, pelagic larvae were caught from late July to mid September in the present study. The period of occur-

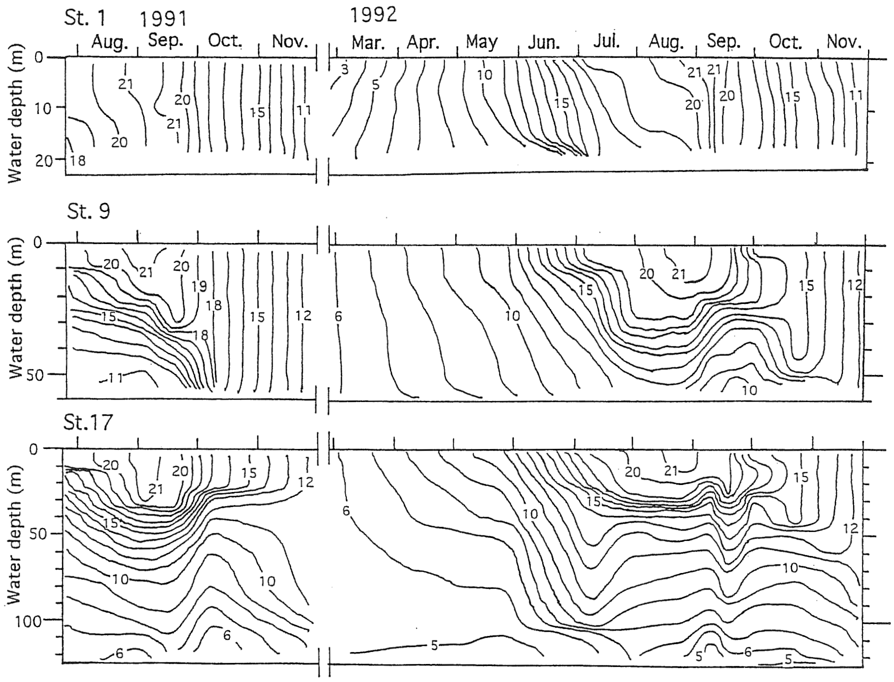

Fig. 7 Temporal changes in the vertical distribution of water temperature at Stations 1, 9, and 17 from August 1991 to November 1992. The location of stations is presented in Fig. 1.

rence of pelagic larvae was about 2 months shorter than that of eggs. Mature fish were caught by commercial fisheries mainly at 70–80 m depth from late May to September and the temperatures of these depths during this period were almost the same. However, the surface water temperature changed from about 11°C in late May to 21°C in mid September (Fig. 7). Thus, the change in surface water temperature might induce mortality during the larval stage.

Adult flounder are densely distributed during a spawning period in the offshore area where water depths are between 50 m and 80 m along the northwest coast of Hokkaido.[19] The major distribution of pelagic larvae was found in the offshore area where sea depths were 50 m or deeper. The pattern of egg distribution in Ishikari Bay was similar to that of larvae. As the distribution of pelagic larvae coincides with the route of the Tsushima Warm Current entering Ishikari Bay, the transportation of eggs and pelagic larvae is thought to be closely related to the hydrographic conditions of the Tsushima Warm Current.[21]

There have been no previous studies on the distribution of newly settled juveniles of pointhead flounder. Newly settled juveniles of pointhead flounder (16 mm *BL*) occurred in Ishikari Bay in September (Fig. 4). However, in Rumoi coast located in the north of Ishikari Bay, newly settled juveniles (10.9 mm *BL*) were caught in late August (Fig. 6). Settlement of pelagic larvae probably begins in Ishikari Bay in August. In both areas, newly settled juveniles were distributed at depths of 30–69 m. Some flatfish species migrate to shallow waters by using tide-related vertical migration[22–29] and concentrate in shallow coastal waters.[22–33] However, pointhead flounder larvae do not move into shallow areas but settle in wide depth ranges. Their nursery grounds are shallower than the adult habitats and these phenomena coincide with other flatfish species in Japan.[32]

Pointhead flounder juveniles gradually migrate to shallow areas during winter and their main habitat was at 20–30 m depth in May. Water temperature distributed uniformly in their habitat between November and the next May. Thus, water temperature is not thought to be a factor of migration. It has been reported for some flatfish species[30,34] that fast-growing larger juveniles emigrated earlier from the nursery grounds. Minami and Tanaka suggested that emigration from the nursery was closely related to the balance between food supply and the food requirements of flatfish juveniles.[32] In the present study, larger pointhead flounder juveniles occurred in the shallower area in February. It is reasonable to consider that fast-growing larger juveniles of pointhead flounder move earlier to shallow areas. Gammarids, mysids and shrimps, which comprise important diets of pointhead flounder juveniles, were abundant in 20–30 m depths from November to February.[35] Food availability might be a possible factor for migrating to shallow waters.

In November 1991, the 1991 year-class (0-year-old) mainly distributed in areas shallower than 60 m but in November 1992 they (1-year-old) occurred in deeper areas than 60 m. This fact suggests that the habitat of 1-year-old flounder are deeper than that of 0-year-old flounder in autumn. In spring, 1- and 2-year-old flounder were caught in areas of 20–40 m depth. However, few 3-year-old or older flounder were sampled by beam trawl. The beam trawl is not available for collecting 3-year-old

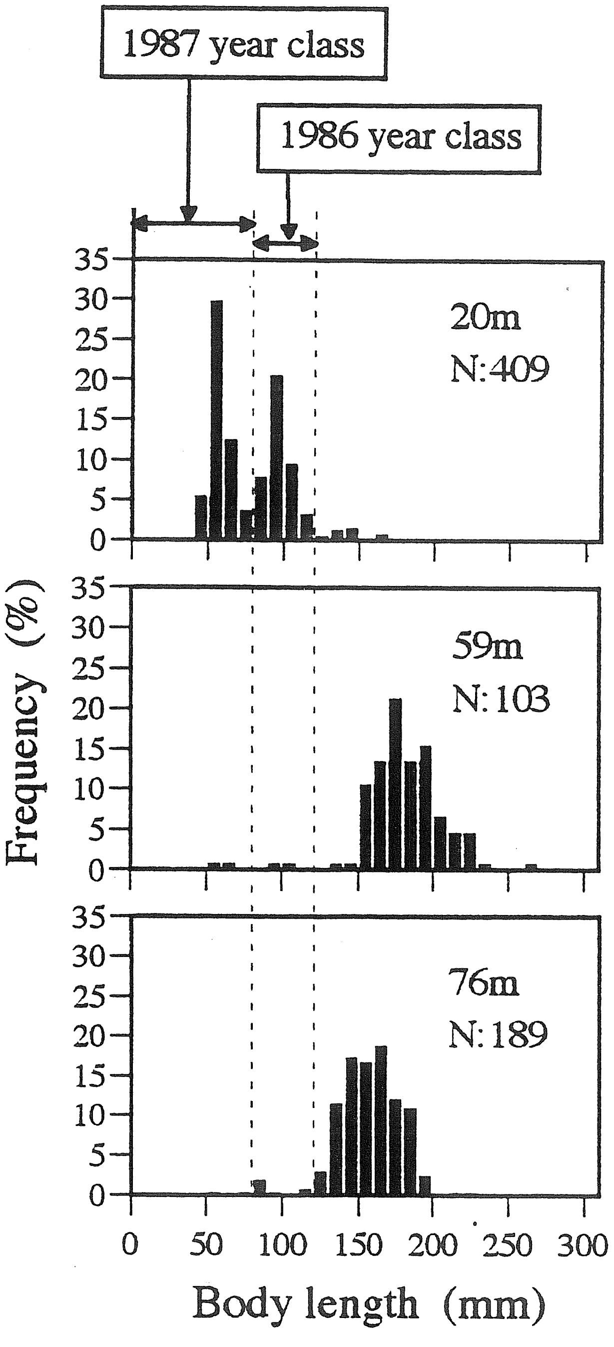

Fig. 8 Body length frequency distributions of *Hippoglossoides pinetorum* collected by otter trawl survey at depths of 20 m, 59 m, and 76 m in Ishikari Bay in June 1988. Body length of 1986 and 1987 year-classes are estimated from the age–length relationship according to Hokkaido Central Fisheries Experimental Station.[36]

or older fish because of net efficiency. Trawl surveys from 1984 to 1987 (sampled by an otter trawl net with cod end mesh aperture of 3.3 cm) showed that about 8 cm *BL* flounder were mainly distributed in 20–30 m depths and 13 cm *BL* or larger fish occurred mainly in 50 m or deeper.[18] The data from the May 1988 trawl survey (sampled by otter trawl net with cod end mesh aperture of 1.1 cm) was re-analyzed (Fig. 8).[36] The sampling area of the trawl survey was almost the same as that of beam trawl surveys. Judging from age–length relationships, the distribution of the 1987 and the 1988 year-classes were clearly separated from that of 3-year-old or older fish by sea depth.[17] This result agrees with the results from beam trawl surveys.

Pointhead flounder mainly occurred in the shallow water of the continental shelf until 2-year-old and shifted their habitat to deeper areas at 3-year-old in Ishikari Bay and the surrounding area.

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