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Distribution and Migration of Adult Walleye Pollock off Hiyama, Southwestern Hokkaido

Tatsuaki Maeda, Toshikuni Nakatani,
Toyomi Takahashi, and Syogo Takagi
Hokkaido University
Hakodate, Hokkaido, Japan

Adult pollock, Theragra chalcogramma (Pallas), which spawns off Hiyama Subprefecture in southwestern Hokkaido, have been exploited commercially since about 1902. This population is the target of the midwater longline fishery (Hokkaido Agency, 1915). The catch had three peaks of more than 17,000 tonnes in 1920, 1935, and 1952 (Maeda et al., 1988), but showed a downward trend between 1958 to 1974, reaching a low of 1,000 tonnes (Figure 1). However, the catch rapidly recovered in 1978, and had risen to 17,000 tonnes by 1982. In recent years, about 10,000 tonnes have been processed. According to tagging experiments of pollock on the east coast of the Korean Peninsula carried out by the Tyosen Fisheries Experimental Station in 1931-1936, 13 tagged individuals were recaptured off Hiyama and Shiribeshi Subprefectures. (Imp. Fish. Exp. St., 1936, 1937, 1938; Ogata, 1956). Similar yearly catch fluctuations were found between Hiyama and the east coast of Korea. Therefore, in the past, the hypothesis was that the fish shoals which migrate to the coastal waters of Hiyama were the same population as found along the east coast of the Korean Peninsula.

Tsuji (1978) stated that most of the population that migrates to Hiyama includes the northern Japan Sea stock which is distributed from Shiribeshi in southwestern Hokkaido to the

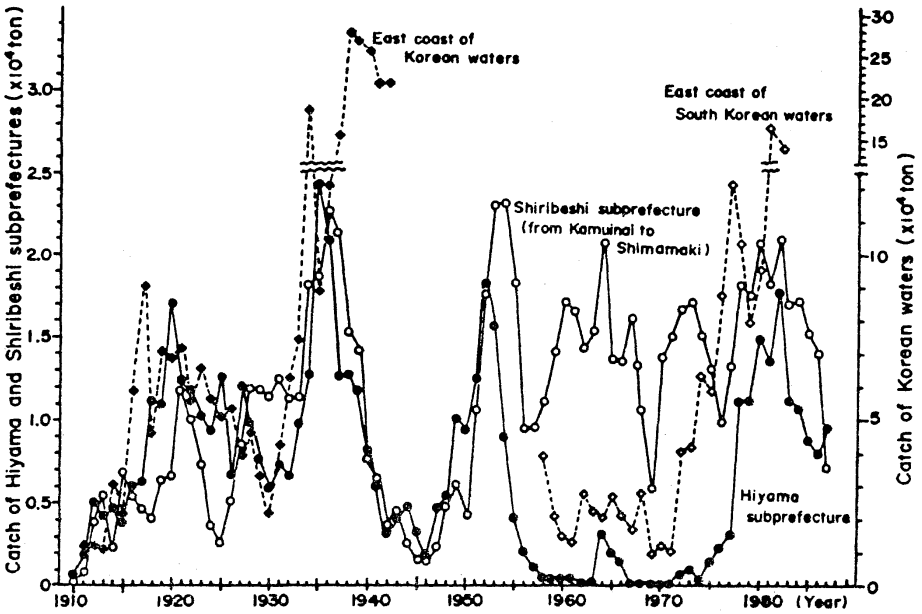


Fig. 1. Annual change of pollock catch off Hiyama and Shiribeshi Subprefectures of southwest Hokkaido, east coast of the Korean Peninsula, and east coast of southern Korea.

west coast of Sakhalin and northern Primore (Figure 2). Accordingly many researchers have assumed that fish shoals migrate to Hiyama along the continental shelf from Rishiri, Rebun Island and Masashi Bank in the northern part of the Japan Sea. Then, after the spawning season, they migrate northward for feeding.

However, researchers have not surveyed the migration and distribution of pollock in the offshore area of the Japan Sea. The cause of catch fluctuations has not been determined. Clarifying the fish behavior is an important problem for the management of the pollock populations and to forecast fishing conditions. This paper presents data on the pollock obtained in the coastal waters of southwest Hokkaido.

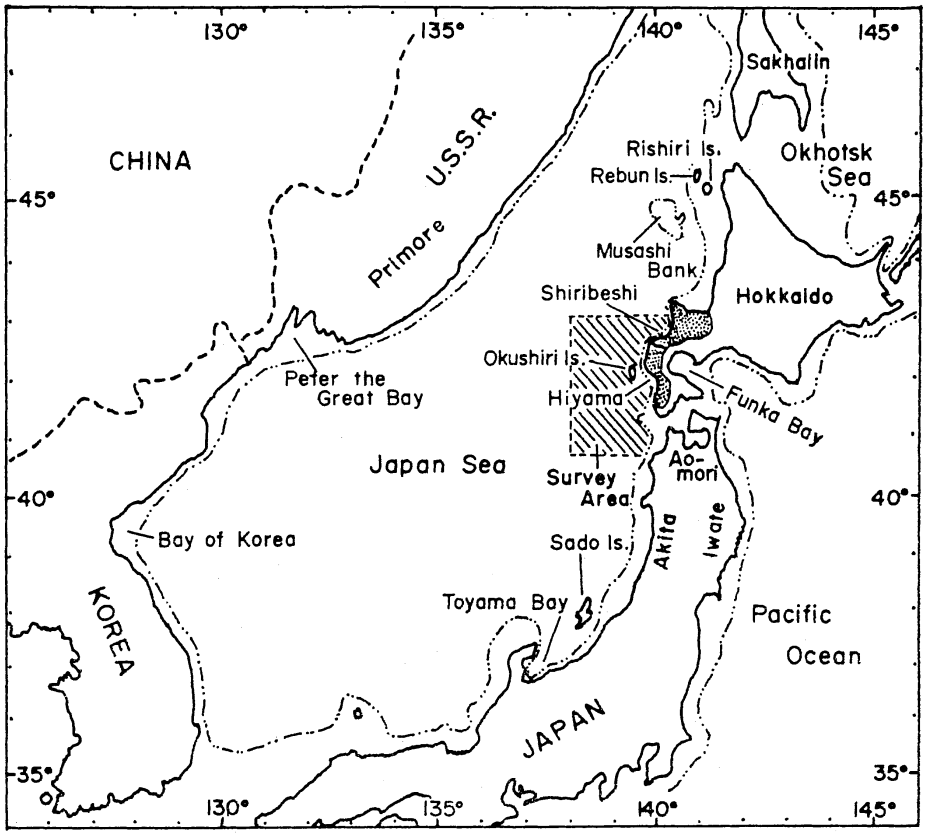


Fig. 2. Survey area off Hiyama and Shiribeshi Subprefectures of southeast Hokkaido.

Methods

The authors began research on the distribution and migration of pollock, mainly off Hiyama, in 1983 and concentrated on such problems as observing the sea temperature and salinity in October (later feeding period), January-February (spawning period) and April (early feeding period). Vertical sampling of zooplankton as food items, and horizontal sampling of pollock eggs, were conducted with a Norpac net. Fish shoals were observed with 50 KHz and 24 KHz echosounders. Sampling of fish shoals was with a midwater trawl. Biological measurements were made on adult pollock samples.

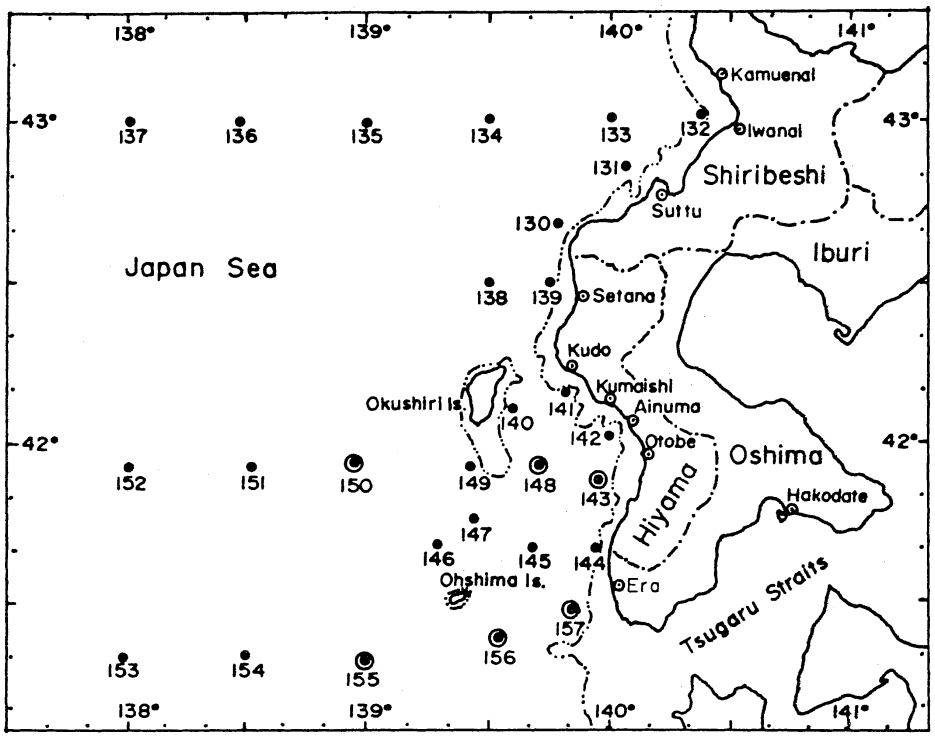


Fig. 3. Stations for hydrographic observation and sampling for pollock collected by midwater trawling off Hiyama and Shiribeshi of southwest Hokkaido during October 19-28, 1987.

• : Oceanographic observation.

◉ : Oceanographic observation and midwater trawl.

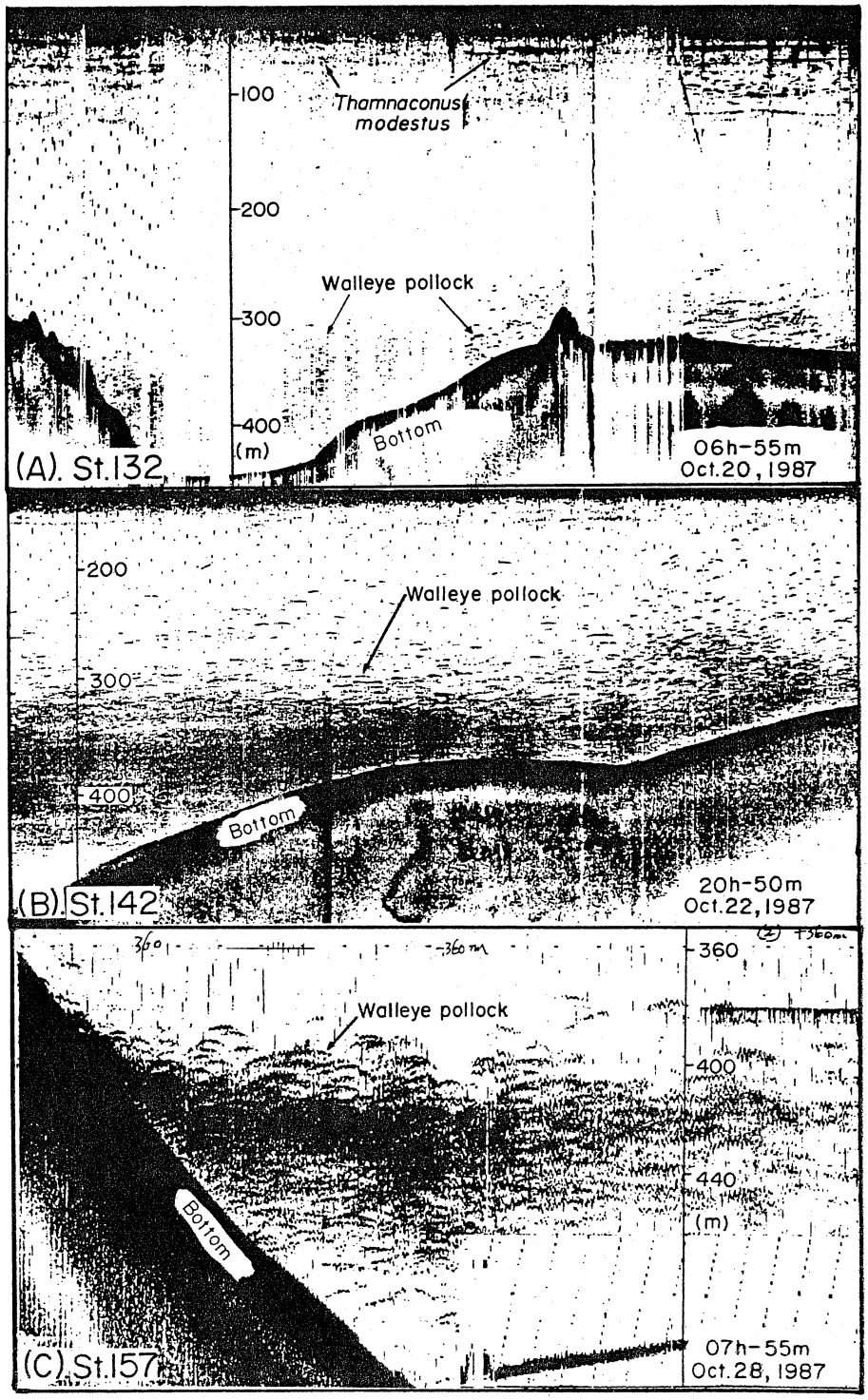
Results

Later feeding period (October)

In October 1987 and 1988, sampling was conducted by the training ship Hokusei Maru, Faculty of Fisheries, Hokkaido University (Figure 3). Echograms of fish shoals located by echosounder are shown in Figure 4 and Figure 5. Results of experimental midwater trawling (height of net mouth 40 m) at stations where fish shoals were observed on echograms are shown in Table 1. During this sampling period, pollock and

filefish, Thamnaconus modestus, were dominant. The 50-100 m layer of St. 155-B was covered by a warm water mass. The major catches at this station by the midwater trawl were filefish. It is believed that filefish caught in the midwater trawl which was fished at 400-500 m depth were actually taken, in the near-surface layer, during net shooting and haul back. Accordingly, the echoimage of echo-sounder at the 400-500 m layer were presumed to be pollock shoals. Distributions of pollock discussed here are based on the echogram results.

In the coastal area from Hiyama to Shiribeshi, fish shoals were widely dispersed off Iwanai in the northern area (St. 132), but were dense of Hiyama (off Era) at St. 157 (Figure 4). Distribution of the shoals in the coastal area were mainly on the continental shelf and the continental slope at a depth of 200-500 m. Dense fish shoals were found at St.143 and St. 157, in the coastal area, but were thin in the westward area at St. 152 and St. 155 (Figure 5). Fish shoals mainly inhabited the 400-450 m depth zone in the coastal area and 200-350 m depth off shore. The relationship between fish shoals and profile of temperature and salinity from St. 142 to St. 152 off Hiyama are shown in Figure 6. As seen in Figure 6, pollock shoals inhabited water along the 0.5°C isotherm. At St. 148 and St. 149, pollock were influenced by the Tsushima Warm Current and were found in a deeper layer from 380 to 600 m. Vertical hauls for zooplankton were made with a Norpac net from the surface to 500 m depth which is the diurnal vertical migration of zooplankton. The biomass of Euphausiacea, Copepods, and Amphipods are shown in Figure 7. Zooplankton biomass was generally low in the coastal area (Figure 6) which is influenced by the Tsushima Warm Current and high in the subarctic water of the Japan Sea which as less than 1°C west of longitude 139°E which was found from the sea bottom to 100 m (Shimomura and Miyata, 1957). Most of the pollock specimens sampled by the midwater trawl net were adults (Figure 3 and Table 1). Body length composition and sex ratios are shown in Figure 8. Near Ainuma and Otobe on the spawning grounds (St. 143), large fish were dominant and females comprised only 39.5% (Maeda et al., 1988). But southeast of Okushiri Island (St. 148) and from Oshima Island to Era (St. 155-157) which is far from the spawning grounds, fish were of a smaller size and the percentage of females


100
Thamnaconus modestus
200
Walleye pollock
300
400
(m)
Bottom
(A). St.132
06h-55m
Oct.20, 1987
200
Walleye pollock
300
400
Bottom
(B). St.142
20h-50m
Oct.22, 1987
360
Walleye pollock
400
440
(m)
Bottom
(C). St.157
07h-55m
Oct.28, 1987

greater (62.5%). Distribution patterns of the fish shoals were found to be the same during the October 1988 survey (Figure 9).

Spawning period (January-February)

The authors studied the distribution pattern of adult pollock in relation to egg distribution and sea conditions by the fishing boat Kudo in January 1983 and January-February, 1984. From the echograms (24 KHz), pollock shoals mainly inhabited the 200 m layer. According to the horizontal distribution of temperature and salinity (Figure 10), midwater longline fishing grounds formed in the 2°-3.5^{o} water mass which lies along the continental shelf, stretched in a tongue shape from southward of Okushiri Island to off Otobe-Ainuma. As seen in temperature and salinity profiles of Figure 11, pollock shoals appear in 2°-3.5^{o}C water (150-250 m depth) becoming shallower on the continental shelf and deeper offshore.

Horizontal tows of the Norpac net revealed a dense horizontal distribution of pollock eggs at the 200 m depth off Otobe, Ainuma and Kumaishi (Maeda et al., 1988). The number of eggs per 10 m^3 of surface water were classified by developmental stage (Figure 12). Stage 1 (from fertilization to blastula stage, about one day after spawning; Yusa, 1954; Hamai et al., 1971; Nakatani and Maeda, 1981) were mainly distributed off Otobe-Ainuma, and then gradually transported northward by the current as they developed.

Results of biological measurements of pollock caught by midwater longline at six stations (Figure 10-B and D) are shown in Figure 13. Body length ranged from 29 to 52 cm, with mode at 36 to 42 cm, females were dominant comprising 72.5-94.4% of the catch. According to maturation stage, adult females were at stage 30-50 and males were more than stage 40 at spawning. Near Otobe, Ainuma and Kumaishi where

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Fig. 4. Echograms of pollock obtained by echosounder of 50 KHz during October 20-28, 1987.
(A) : St. 132 on the coast of Iwanai.
(B) : St. 142 on the coast of Otobe.
(C) : St. 157 on the coast of Era.

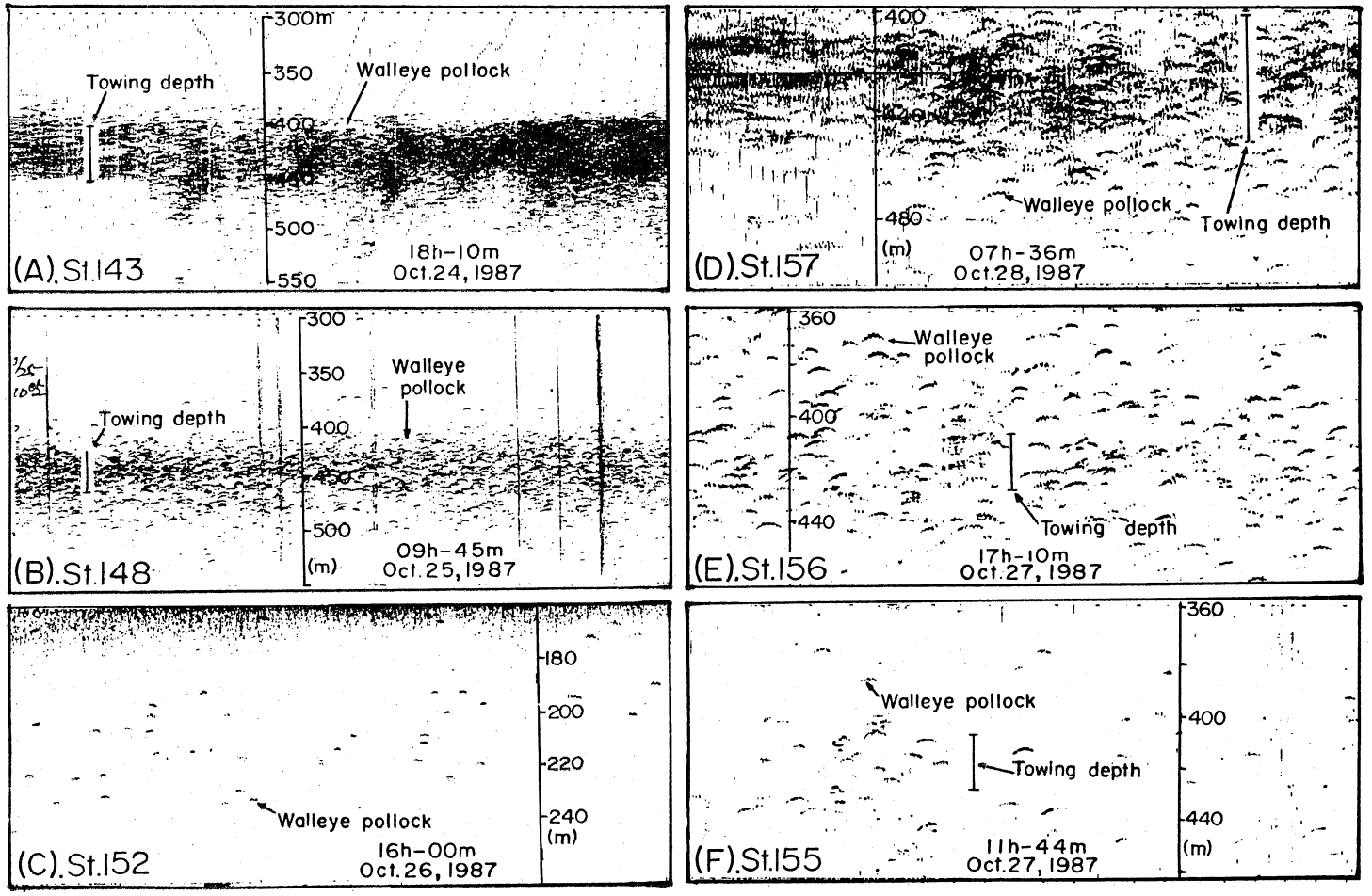
Towing depth
Walleye pollock
300m
350
400
500
550
(A).St.143
18h-10m
Oct.24, 1987
300
350
400
500
(m)
Towing depth
Walleye pollock
(B).St.148
09h-45m
Oct.25, 1987
180
200
220
240
(m)
Walleye pollock
(C).St.152
16h-00m
Oct.26, 1987
400
480
(m)
Walleye pollock
Towing depth
(D).St.157
07h-36m
Oct.28, 1987
360
400
440
Walleye pollock
Towing depth
(E).St.156
17h-10m
Oct.27, 1987
360
400
440
(m)
Walleye pollock
Towing depth
(F).St.155
11h-44m
Oct.27, 1987

Table 1. Species composition of midwater trawl samples in the coastal waters of Hiyama of Hokkaido during October 24-28, 1987.

Station	143	148	150	155-A	155-B	156	157
Date	24.Oct.	25.Oct.	25.Oct.	27.Oct.	27.Oct.	27.Oct.	28.Oct.
Time	17:55	08:51	18:02	10:50	12:48	16:58	06:42
Position N	41° 53'	41° 50'	41° 56'	41° 19'	41° 21'	41° 22'	41° 26'
E	140° 00'	139° 40'	139° 03'	139° 02'	139° 05'	139° 30'	139° 51'
Bottom (m)	800~1000	1260	3500	1720	1720	1552	800~975
Towing depth (m)	400~ 450	420~470	400~450	410~430	50~100	410~430	410~440
Species (Number)							
Theragra chalcogramma	43	168	4	125	0	45	75
Aptocyclus ventricosus	10	0	0	0	0	80	5
Thamnaconus modestus	138	148	16	5	4670	110	0
Acanthopsetta nadeshnyi	0	99	3	0	0	0	0
Others	14	0	19	5	20	0	10

stage 1 eggs were abundant (sample 3-6), females with pellucid eggs were predominantly at stage 40. But, with the exception of these points, stage 30 pre-spawning and stage 50 post-spawning fish were dominant (sample 1-2). Differences in the gonad indices (G.I. = G.W. x 100/B.W.) of males were small. Gonad indices among females close to the spawning grounds (sample 3-6) ranged from 11.14 to 15.31, but ranged from 9.13 to 10.20 in samples 1-2 offshore. The liver indices (L.I. = L.W. x 100/B.W.) of males were lower than females in all samples, although the differences by station were small.

Early feeding period (April)

In order to clarify the migration pattern of pollock shoals after the spawning period, observation of the sea temperature and salinity, echolocation of shoals (50 KHz), and fish sampling by midwater trawling (net mouth height 17 m) were carried out by the training ship Oshoro Maru, Hokkaido University in April 1988.

Pollock shoals had a broad horizontal distribution from the

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Fig. 5. Echograms of pollock obtained by echosounder (50 KHz), and towing depth of midwater trawl on 41°55'N line and 41°20'N line of latitude during October 24-28, 1987.

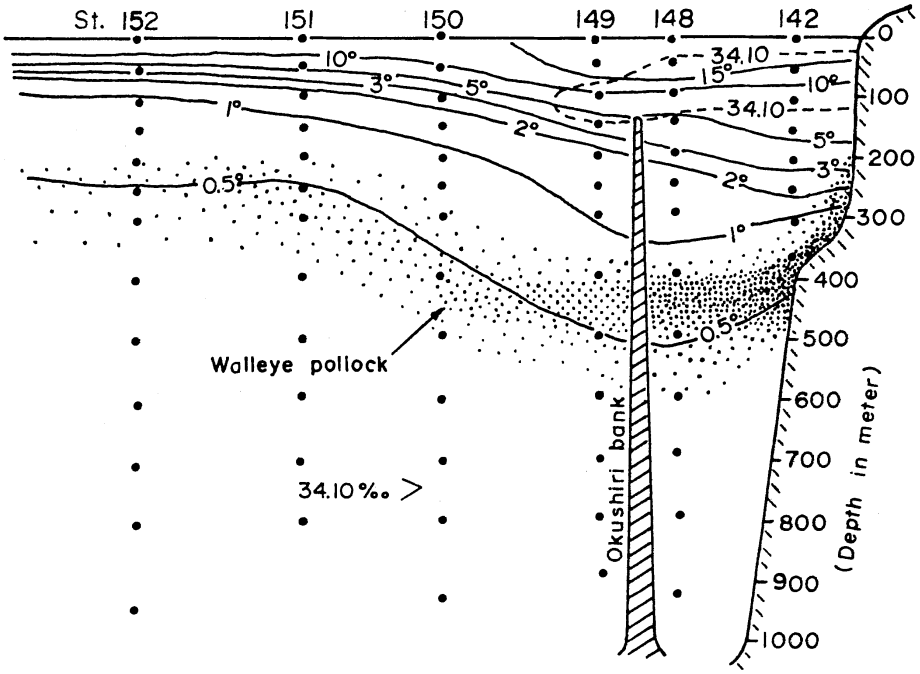

Fig. 6. Vertical distribution of temperature, salinity, and pollock on 41°55'N line of during October 24-26, 1987.

coastal area, where they were abundant, to longitude 139°E (Figure 14). But, the density in spawning grounds (St. 2 and St. 13) was lower than that of the spawning period.

Vertical distribution was in the 100-400 m layer, but they mainly inhabited the 180-280 m layer. Vertical profiles of temperature and salinity along latitude 42°N (off Otobe) show pollock shoals inhabiting 0.5°-3°C temperature zone and especially 1°-2°C as shown in Figure 15. As shown in the figure, sea temperature was not always a key factor in determining pollock shoal distribution in these areas. The shoals moved to water masses lower than 2°-3.5°C in the spawning period. It appears that pollock shoals began to move from the coastal area to the westward area and the subarctic water mass at the central part of the Japan Sea where zooplankton prey were abundant.

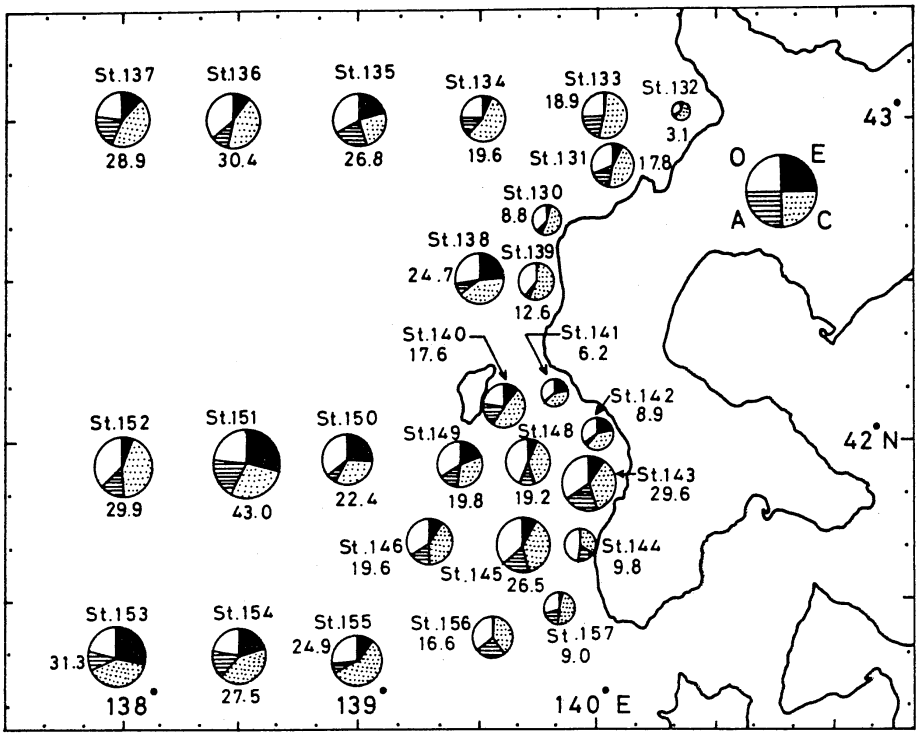

Fig. 7. Biomass of zooplankton sampled by vertical haul of Norpac net from 500 m depth to the surface during October 19-28, 1987.

Numbers : Biomass (g/m^3) of zooplankton

E : Euphausiacea C: Copepods

A : Amphipods O: Other

Discussion

According to investigations of pollock, at the end of the feeding period (October), the densities of spawning shoals coming to the southwestern coast of Hokkaido were low off hiribeshi and high off Hiyama. This difference in the density between the northern and southern coasts is reflected in the catch (November 1987-March 1988). The catch increased 47.5% off Hiyama and decreased 33.0% off Shiribeshi (Kamuinai-Shiribeshi) compared with last year's catch (November 1986-March 1987). This shows that offshore investigation of pollock shoals in October is effective not

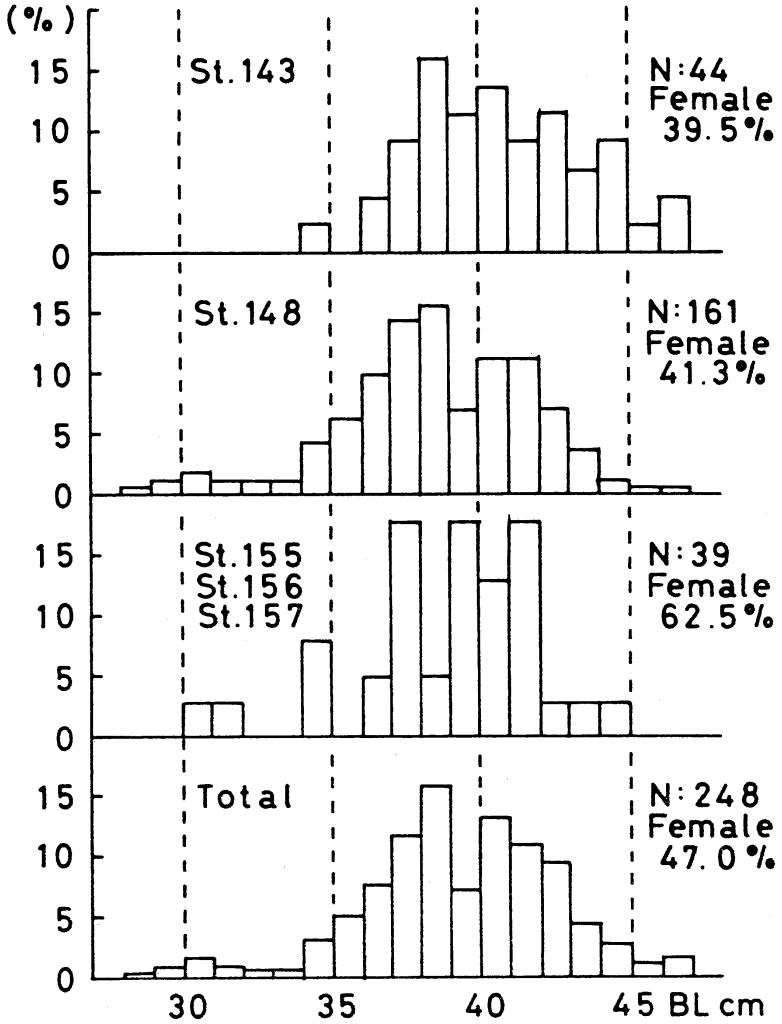

Fig. 8. Size compositions and sex ratio of walleye pollock sampled by midwater trawl during October 14-22, 1987.

only in predicting the catch of the fishing season, but also suggests that fish shoals do not migrate directly to Hiyama along the continental shelf from Rishiri, Rebun Island and Masashi Bank in the northern part of the Japan Sea. Therefore, it is assumed that the spawning migration of pollock came to the near coastal area through the front of the subarctic water (Figure 6) lying to the westward of Hokkaido and were contained in the subarctic water of the

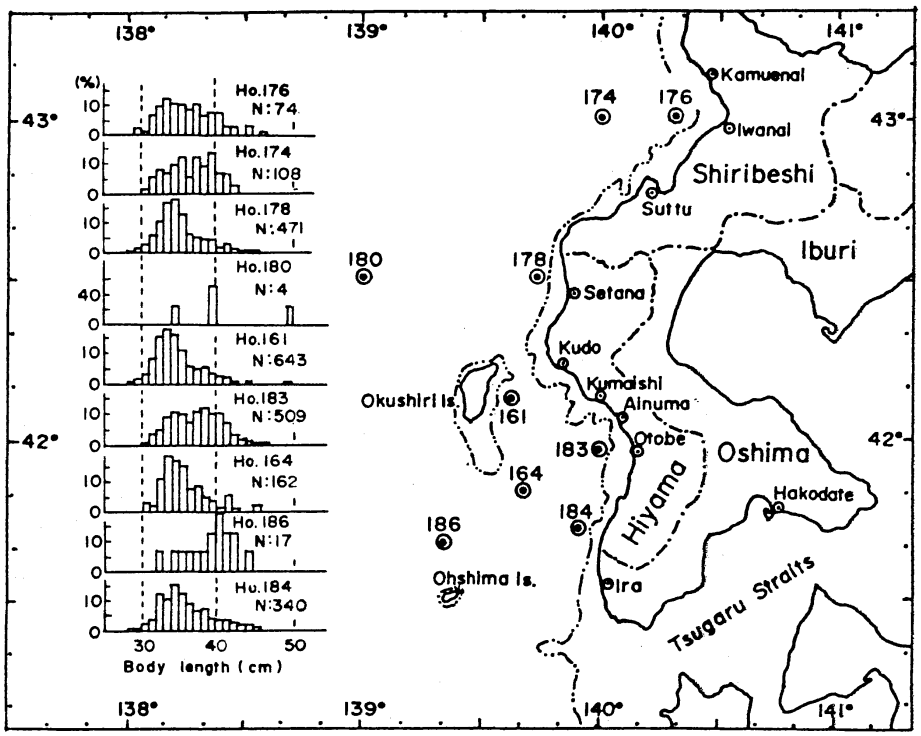

Fig. 9. Station for midwater trawl and size composition of pollock sampled by midwater trawl during October 14-22, 1988.

central Japan Sea where zooplankton prey are abundant (Figure 7). The fish shoals then migrate to the spawning grounds along the coastal area of Otobe-Ainuma.

This migration route is evident from the spatial distribution pattern of pollock off Hiyama. Large-sized and early-maturing fish migrate to the coastal area sooner than small-sized fish. Also, males migrate to the spawning grounds earlier than females. This phenomenon agrees with the migration patterns in the continental shelf of the eastern Bering Sea (Maeda and Hirakawa, 1977) and around Funka Bay in southern Hokkaido (Maeda et al., 1983; Maeda 1986).

Spawning grounds of pollock off Hiyama occur on the continental slop at 200 m depth (2°-3.5^{o} C) from off Otobe to

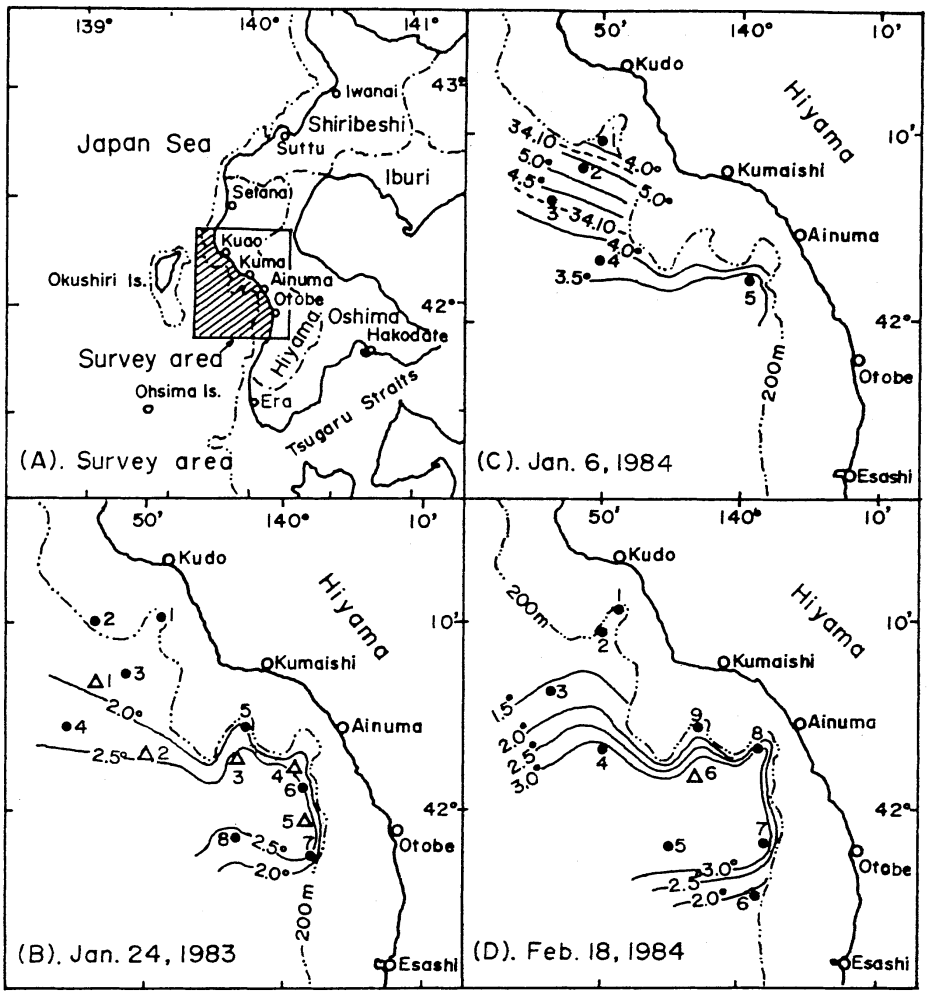

Fig. 10. Horizontal distribution of temperature (°C) and salinity (ppt) at 200 m depth in the coastal waters of Hiyama.

Ainuma. It was observed that the percentage of maturity stage 40 fish was high off Otobe-Ainuma (sample 4-6). Gonad weight indices and the ratio of empty stomachs were also higher than the offshore areas (sample 1-2).

The authors reported that male dominance on the spawning grounds is one of the typical features of pollock on the continental shelf of the eastern Bering Sea and around Funka

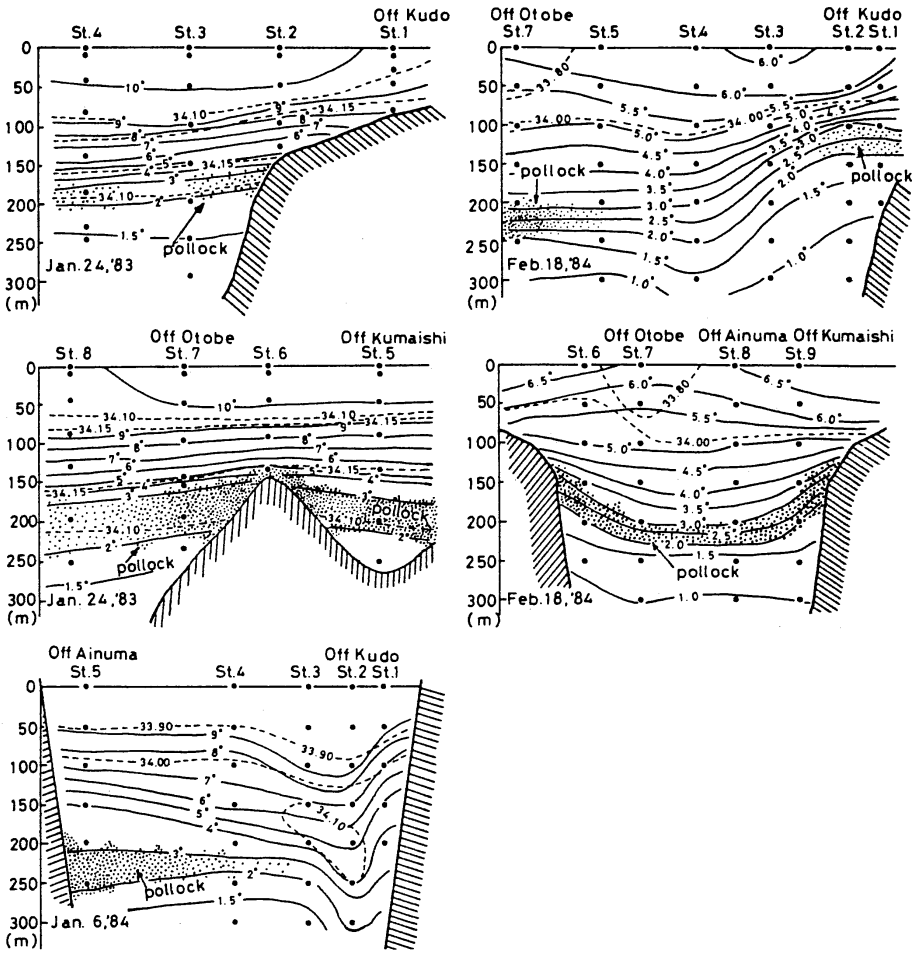

Fig. 11. Vertical distribution of temperature (°C), salinity (ppt), and pollock in the coastal waters of Hiyama.

Bay (Maeda and Hirakawa, 1977; Maeda et al., 1983; Maeda, 1986). But off Hiyama the percentage of males was low 9.6-27.5% in samples collected by midwater longline (Figure 13). This may be caused by selected fishing for females to make salt ovaries (tarako). When pollock were tagged on the spawning grounds (200 m depth) off Ainuma in February 1986-1988, each year we found the percentage of males was 90% or

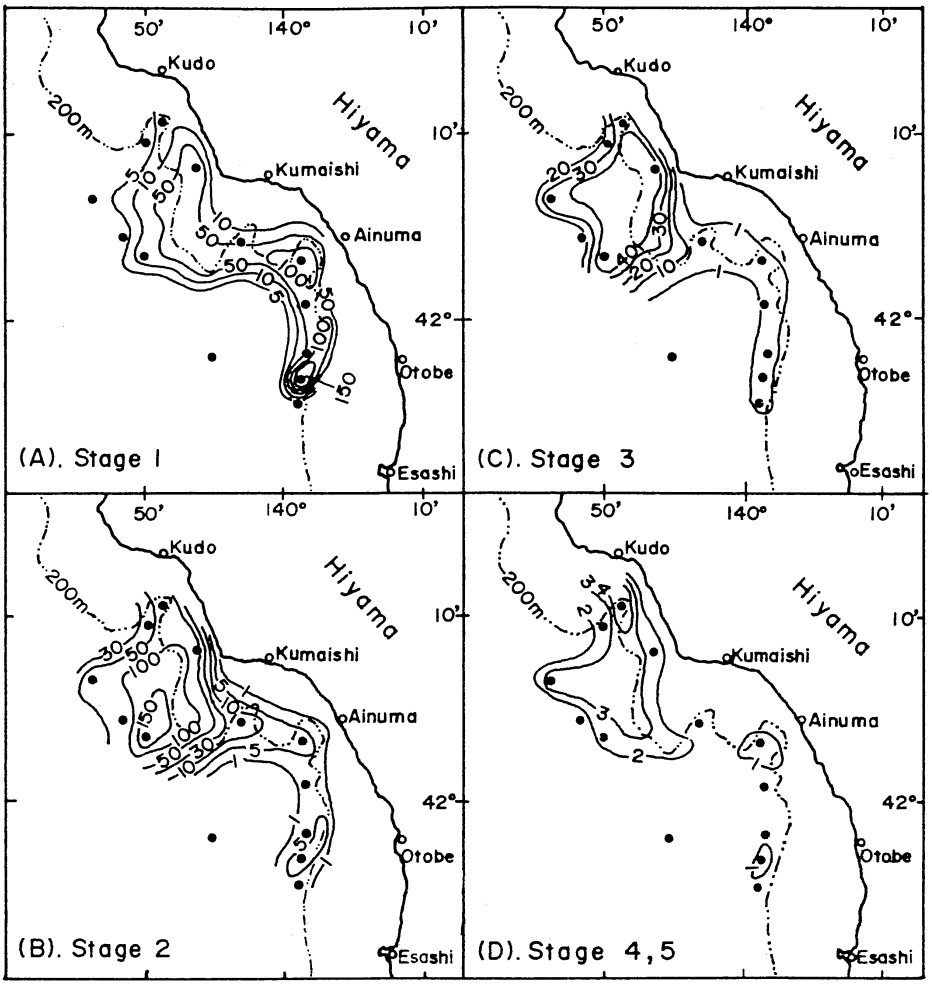

Fig. 12. Horizontal abundance (n/10 m^3) of pollock eggs by developmental stage obtained by surface tow of Norpac net on February 18, 1984.

Stage 1 : Fertilization-bastula stage.

Stage 2 : First gastrula stage-blastopore just before closing.

Stage 3 : Completely closed blastopore-embryo reaching three-fourths of the yolk circumference.

Stage 4 : Embryo reaching over three-fourths of the yolk circumference, embryo reaching full circle of the yolk circumference.

Stage 5 : Embryo reaching over full circle of the yolk circumference.

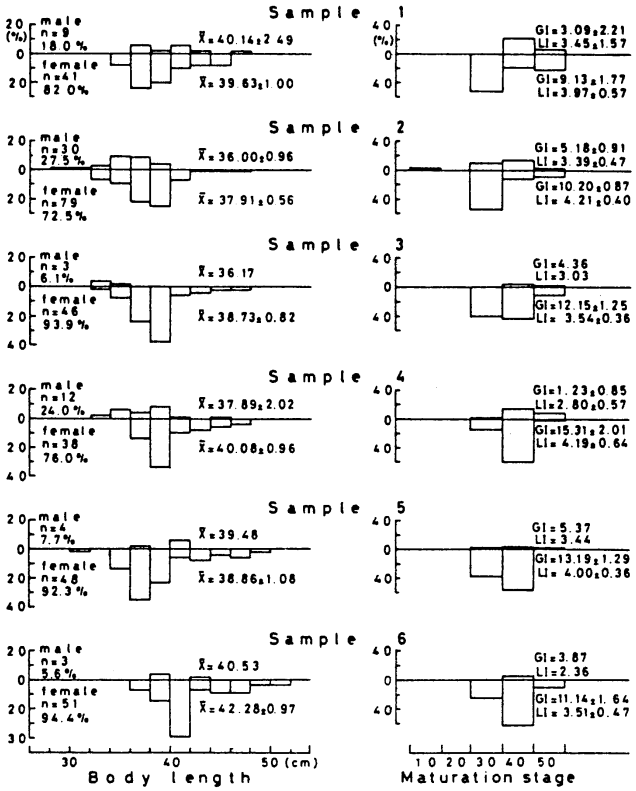

Fig. 13. Compositions of body length, sex ratio, gonad maturation, gonad indices, and liver indices of pollock in the coastal waters of Hiyama, Hokkaido.

Gonad maturation stage

Male :

Stage 10 : Immature fish, testes thread-like.

Stage 20 : Adult fish, but testes small.

Stage 30 : Testes large, milk-white and opaque.

Stage 40 : Ripe, testes large.

Stage 50 : Spent fish, testes withered.

Female :

Stage 10 : Immature fish, ovaries still small.

Stage 20 : Adult fish, but ovaries still small.

Stage 30 : Ovary large and opaque.

Stage 40 : Ripe, eggs transparent, partly or all.

Stage 50 : Spent fish.

G.I. : Gonadosomatic index (gonad weight x 100/body weight)

L.I. : Liver index (live weight x 100/body weight)

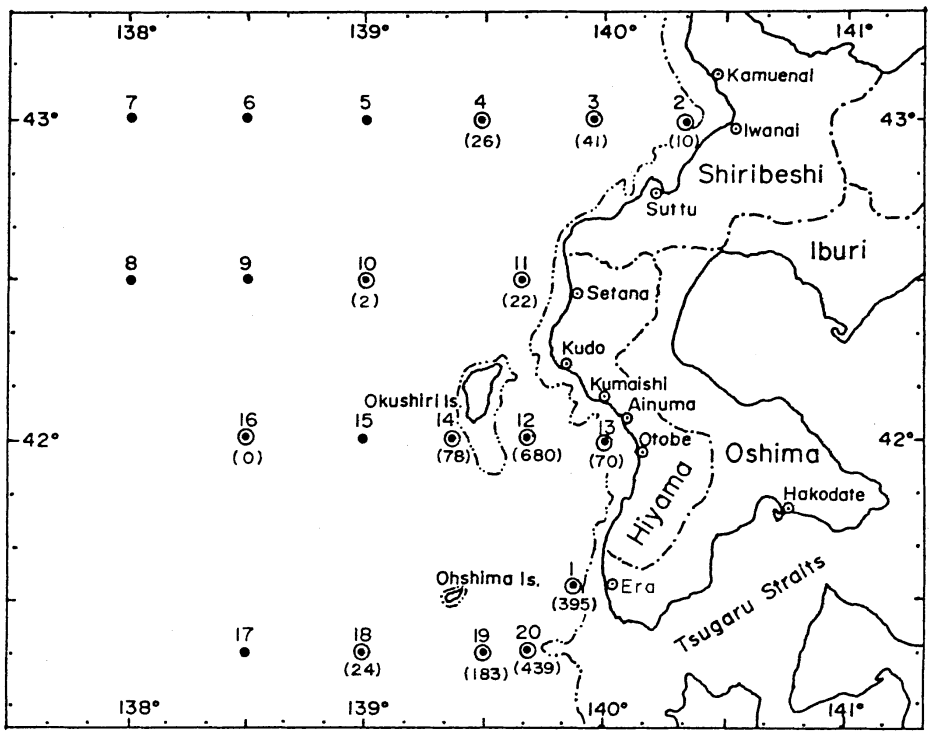

Fig. 14. Stations for hydrographic observation and sampling stations for pollock collected by midwater trawl in the coastal waters of Hiyama and Shiribeshi of Hokkaido during April 1-7, 1988.

( ) : Catch of pollock collected by midwater trawl per hour.

• : Oceanographic observation

◉ : Oceanographic observation and midwater temperature.

more in released fish. As mentioned above, in the spawning period (January-February) males migrate to the spawning grounds on the continental slope earlier than females. Therefore, it appears that females predominate in the offshore area, and after attaining maturity they approach the spawning grounds in the coastal area where males are dominant. After spawning, they move again into the offshore area.

It is believed that during the early feeding period in April,

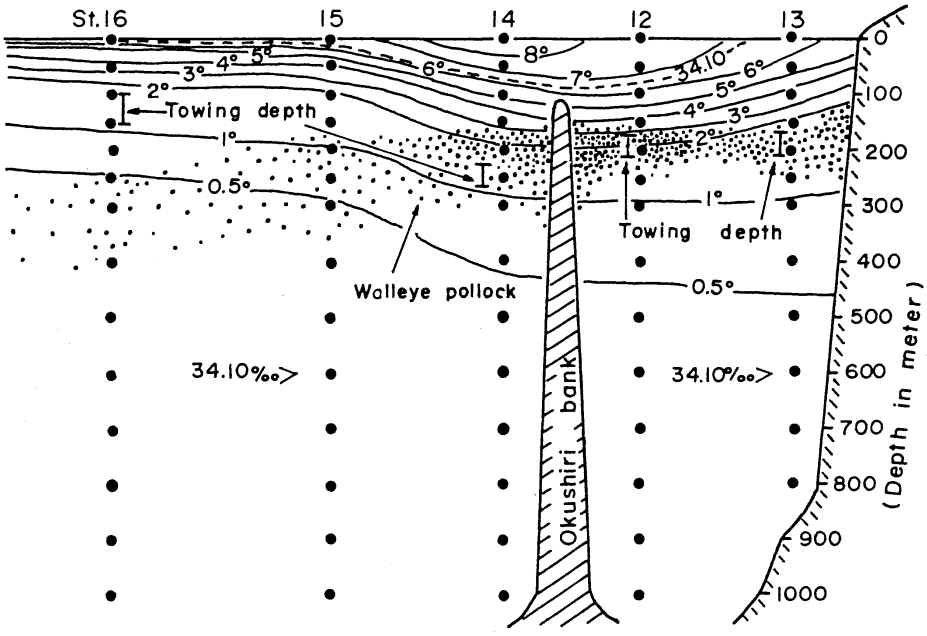

Fig. 15. Vertical distribution of temperature, salinity, and pollock on 42° N line during April 4-5, 1988.

fish shoals begin to disperse from the 2°-3.5°C water mass in the spawning grounds to the cold water (0.5°-2°C) of the deeper layer in the offshore area, and they then move to subarctic waters where prey zooplankton are abundant.

Ishigaki (1960) reported that pollock were caught by pink salmon surface longline during their feeding period from mid-April to early June in the frontal area of subarcticwater off Hiyama and Shiribeshi. Ogata (1979) noted that pollock were distributed in subarctic water from off the Korean Peninsula-Primore to the central Japan Sea in the feeding period (April-June). Tanaka (1983) reported that in subarctic water between Hiyama-Shiribeshi and Primore in July-August many echograms of fish shoals were recorded deeper than the 50 m layer and ascertained by angling that these were pollock shoals.

A large scale pollock tagging experiment was carried out

along the eastern coast of the Korean Peninsula by the Tyosen Fisheries Experimental Station, 1931-1936. About 50,000 tagged Pollock were released and 223 were recaptured along the east coast of Korea and off Primore (Ogata, 1979), but 13 were found off Hiyama and Shiribeshi in Hokkaido (Impe. Fish. Exp., 1936, 1937, 1938).

Based on these data and the author's data, the distribution and migration of pollock may be summarized as follows: A portion of the pollock shoals that finished spawning in the coastal area of the Japan Sea move to the bottom (Hamai et al., 1967; Gong and Zhang, 1986) while another part moves to midwater and migrates to the subarctic water in the central Japan Sea where zooplankton prey are abundant (Fukataki, 1974). Therefore, in the central Japan Sea, it is presumed that pollock shoals migrating from the east coast of the Korean Peninsula and Primore would combine with shoals migrating from the west coast of Hokkaido and then migrate to each spawning ground of the near area during the spawning period.

Eggs spawned off Hiyama are transported to the northern area by the Tsushima Warm Current (Figure 12), but the life cycle of young and immature fish has not yet been clarified. However, according to Yoshida (1982) and Hokkaido Regional Fisheries Laboratory data, of the 5,163 pollock tagged and released around Rebun Island in May-June 1979, tagged fish were mainly recaptured within the second year in the area of release, but then they migrated southward and were recaptured after the second year off Hiyama. The percentage of recaptured fish off Hiyama was higher than around Rebun and Rishiri Island. This information suggests recruitment to the population migrating to the spawning periods off Hiyama, but further studies must be conducted to confirm this.

References

Fukataki, F. 1974. Fisheries development of the Japan Sea. Tsushima Warm Current. Koseishya-Koseikaku, Tokyo, 115-128. (In Japanese.)

Gong, G., and C.I. Zhang. 1986. The pollock (*Theragra chalcogramma*) stock in Korean waters. Int. N. Pac. Fish. Comm. Bull. 45: 21-38.

Hamai, I., K. Kyushin, and T. Kinoshita. 1967. On the inhabit condition of fish in Shimamaki waters of Hokkaido. Hokkaido Development Agency, 158 p. (In Japanese.)

Hamai, I., K. Kyushin, and T. Kinoshita. 1971. Effect of temperature on the body form and mortality in the developmental and early larval stage of the Alaska pollock, Theragra chalcogramma (Pallas). Bull. Fac. Fish. Hokkaido Univ. 22(1): 11-29.

Hokkaido Agency. 1915. Walleye pollock. Report of industry investigation (part of Fisheries). 15: 234-256. (In Japanese.)

Imperial Fisheries Experimental Station. 1936. Tagging and recapture fish. Oceanographic investigation. 58: 200-205. Minist. Agric. For. Japan. (In Japanese.)

Imperial Fisheries Experimental Station. 1937. Tagging and recapture fish. Oceanographic investigation. 60: 205-209. Minist. Agric. For. Japan. (In Japanese.)

Imperial Fisheries Experimental Station. 1938. Tagging and recapture fish. Oceanographic investigation. 62: 172-181. Minist. Agric. For. Japan. (In Japanese.)

Ishigaki, T. 1960. Where do pollock go after spawning? Hokkaido Fish. Exp. St. Monthly Rep. 17(9): 351-363. (In Japanese.)

Maeda, T., and H. Hirakawa. 1977. Spawning grounds and distribution pattern of Alaska pollock in the eastern Bering Sea. Bull. Japan. Soc. Sci. Fish. 43: 39-45. (In Japanese with English summary.)

Maeda, T., T. Takahashi, and M. Ueno. 1983. Behavior in each life period of adult Alaska pollock in the adjacent waters of Funka Bay, Hokkaido. Bull. Japan. Soc. Sci. Fish. 49: 577-585. (In Japanese with English summary.)

Maeda, T. 1986. Life cycle and behavior of adult pollock (Theragra chalcogramma [Pallas]) in water adjacent to Funka Bay, Hokkaido Island. Int. North Pac.

Fish. Comm. Bull. 45: 39-65.

Maeda, T., T. Takahashi, and T. Nakatani, 1988. Distribution, migration and spawning grounds of adult walleye pollock, Theragra chalcogramma, in the coastal waters of Hiyama Subprefecture, Hokkaido. Bull. Fac. Fish. Hokkaido Univ. 39: 216-229. (In Japanese with English summary.)

Nakatani, T., and T. Maeda. 1981. Transport process of the Alaska pollock in Funka Bay and adjacent waters, Hokkaido. Bull. Japan. Soc. Sci. Fish. 47: 1115-1118.

Ogata, T. 1956. Bottom fisheries and resources in the Sea of Japan. Bull. Japan Sea Reg. Fish. Res. Lab. 4: 93-139. (In Japanese with English summary.)

Ogata, T. 1979. Populations in the Sea of Japan. Studies on clarification of pollock populations in the Bering Sea and the waters around Kamchatka Peninsula. Minist. Agric. For. and Fish., Technol. conf. Bur., Tokyo, Japan., 123-138. (In Japanese.)

Shimomura, T., and K. Miyata. 1957. Sea conditions and water systems in the Japan Sea. Bull. Japan Sea Reg. Fish. Res. Lab. 6: 23-95. (In Japanese with English summary.)

Tanaka, M. 1983. Calculated examples by scientific portable echofinder. Report on the Northern Japan Bottom Fish Conference, Fish. Reso. Rese. Conference, Fiscal 1982. Fisheries Agency of Japan, 62-75. (In Japanese.)

Tsuji, H. 1978. On the population of pollock in the waters around Hokkaido. Hokkaido Fish. Exp. St. Monthly Rep. 35: 1-57. (In Japanese.)

Yoshida, H. 1982. On the results of pollock tagging in the waters around Hokkaido. Report on the Northern Japan Bottom Fish Conference, Fish. Reso. Rese. Conference, Fiscal 1981. Fisheries Agency of Japan, 70-79. (In Japanese.)

Yusa, T. 1954. On the normal development of the fish, Theragra chalcogramma (Pallas), Alaska pollock. Bull. Hokkaido Reg. Fish. Res. Lab. 10: 1-5. (In Japanese with English summary.)