Bull. Fac. Fish. Hokkaido Univ.
50(3), 155-169, 1999.

Occurrence Periods and Food Habits of Cresthead Flounder *Pleuronectes schrenki* Juveniles in Lake Notoro, Hokkaido

Tetsuya TAKATSU[1], Shigeo TAKAGI[1,2], Shin-ichi YOKOYAMA[3] and Toyomi TAKAHASHI[1]

Abstract

To elucidate the occurrence periods, the food habits and somatic growth conditions of cresthead flounder *Pleuronectes schrenki* juveniles, sampling was conducted with an epibenthic sledge net for juveniles and with a Van Dorn bottle for their food organisms in Lake Notoro in June-July 1992 and May-August 1993. Lake Notoro is a subarctic, brackish lake that opens into the Sea of Okhotsk. Juveniles were found in nearshore areas (1.0-6.0 m depth) in July 1992, June, July and August 1993, but not in June 1992 or May 1993. Almost all juveniles were distributed in areas with sandy bottom or sandy bottom with scattered seaweed beds. Juveniles fed mainly on *Eurytemora* spp. in July 1992 and August 1993, and harpacticoid copepods other than *Microsetella* spp. in July 1993. Large food organisms, such as gastropods, polychaetes, mysids, cumaceans, gammarids and caprellids, were subsidiary prey for juveniles and composed a small portion of the stomach contents. *Eurytemora* spp. and harpacticoids other than *Microsetella* spp. were smaller (0.23-0.33 mm width and 0.08-0.28 mm width, respectively) than the other food organisms, and were distributed near the lake bottom during daylight. These coastal and demersal copepods could sustain the growth of cresthead flounder juveniles in Lake Notoro at their nursery ground. Two allometric growth curves between standard length and body weight indicated that juveniles were significantly heavier in July 1992 than in July 1993. It is possible that *Eurytemora* spp. are a more effective food source for juvenile somatic growth than demersal harpacticoids in July.

Key words: Cresthead flounder, *Pleuronectes schrenki*, Juvenile, Occurrence, Food habits, Lake Notoro, Demersal copepods, Somatic growth, *Eurytemora* spp., Harpacticoida

Introduction

The cresthead flounder *Pleuronectes schrenki* is distributed on the continental shelf from the northern part of Honshu Island to Sakhalin and the southern part of the Sea of Okhotsk (Nakabo, 1993). In Lake Notoro, cresthead flounder are caught by bottom gill nets, set nets and beam trawl nets. Cresthead flounder have been studied on the spatial distribution (Morita et al., 1963; Morita, 1964; Morita and Ohara, 1965a, 1967; Morita et al., 1966; Yokoyama and Shimoyama, 1995), stock identification (Ishida, 1948, 1949; Morita and Ohara, 1965b; Yokoyama and

[1] *Laboratory of Marine Resources Ecology, Department of Marine Biological Science, Faculty of Fisheries, Hokkaido University*
(北海道大学水産学部資源生態学講座)
[2] *Present Address: NICHIREI Corporation, Tsukiji, Chuuou-ku, Tokyo 104-8402, Japan*
((株)ニチレイ)
[3] *Hokkaido Institute Mariculture, Shikabe, Hokkaido 041-1404, Japan*
(北海道栽培漁業総合センター)

Shimoyama, 1995; Yokoyama, 1998), food habits (Okubo, 1951), growth (Okubo, 1951, 1952) and fecundity (Yamamoto and Ishida, 1947; Ishida, 1950; Ito, 1953; Minagawa, 1956). In addition, we have several investigations on the laboratory-reared larvae, such as the development of eggs and larvae (Yamamoto and Ishida, 1947; Yamamoto, 1951; Hikita, 1952; Yusa, 1960; Yokoyama and Tanaka, 1996), the abundance of albinism and reversal larvae (Sugiyama et al., 1985) and the protein, DNA and RNA contents of larvae (Fukuda et al., 1986). However, the early life history of this species in the field is still unclear.

Predation may be a potent regulator of year-class strength of fishes (Hunter, 1981). Predation by the brown shrimp *Crangon crangon* causes significant mortality in 0-group plaice *Pleuronectes platessa* during and shortly after settling on tidal flats in the western Wadden Sea (van der Veer and Bergman, 1987). Feeding and somatic growth conditions are presumably important factors affecting subsequent year-class strength in late larval and early juvenile stages, because fast-growing individuals will be exposed to predators for a shorter period than slow-growing individuals (Houde, 1987; Anderson, 1988; Campana, 1996; Meekan and Fortier, 1996). In this study, we examined the occurrence and food of cresthead flounder juveniles shortly after settling and compared somatic growth conditions in two years in Lake Notoro.

Materials and Methods

Lake Notoro is a brackish lake situated in Abashiri City, Hokkaido and opens into the Sea of Okhotsk (Fig. 1). The lake has a circumference of 31 km and a surface area of 59 km^2. The narrow mouth of the lake measures 200 m in width and 6-7 m in depth. The lake's deepest point (22 m depth) is located 1.9 km northwest of Futamigaoka, water temperature near the surface ranges from $-1.5°C$ to 21.4°C during the year, and the lake surface is frozen from the beginning of January to the middle of April (Kurata and Nishihama, 1987). High-salinity water from the Soya Warm Current (Aota, 1975) enters the lake in May and remains until October (Kurata and Nishihama, 1987). At depths shallower than 10 m, sand is the most common sediment type, while at depths greater than 10 m, silt is most common.[*1] Seaweed beds (*Zostera marina* and *Z. caespitosu*) are found in some areas shallower than 5 m depth.[*2,*3]

Surveys were conducted in Lake Notoro from June to July 1992 and from May to August 1993 (Fig. 1, Table 1). Juveniles of Pleuronectiformes distributed on the bottom were collected with an epibenthic sledge net (1.40 m wide, 0.55 m tall and 3.0 mm mesh). Except in June 1992, tows were made in nearshore areas (1.0-6.0 m depth) because intermediate breeding nets of the scallop *Patinopecten yessoensis* were set up in the center of the lake. Two towing methods were used. In one method, the net was towed using an outboard motor for 10 min at a speed of about 0.8 m ·

[*1] Nishihama, Y. (1987). Survey of scallop's distribution. "*S61 Jigyo Hokokusho*", *Hokkaido Abashiri Fish. Exp. Sta.*, 201-205 (in Japanese).

[*2] Tada, M. and Sawazaki, T. (1986). Survey of *Zostera* beds' distribution in Lake Notoro. "*S60 Jigyo Hokokusho*", *Hokkaido Abashiri Fish. Exp. Sta.*, 205-210 (in Japanese).

[*3] Tada, M. and Tomita, K. (1987). Survey of *Zostera* beds in Lake Notoro. "*S61 Jigyo Hokokusho*", *Hokkaido Abashiri Fish. Exp. Sta.*, 225-229 (in Japanese).

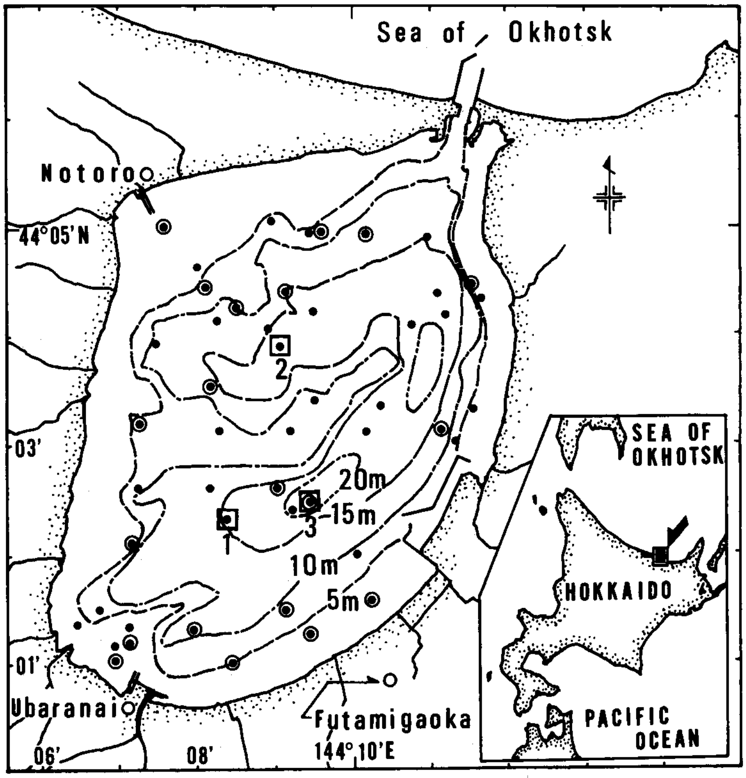

Fig. 1. Location of sampling and observation stations in June-July 1992 and May-August 1993, and bottom contours in Lake Notoro. Numerals indicate copepods sampling stations.
●: STD observation,
○: Epibenthic sled net sampling,
□: Van Dorn bottle sampling station.

sec^{-1}. This method was adopted in July 1992, May 1993 and June 1993. In the other method, the net was lowered to the bottom, the boat moved ahead about 100 m as the net remained at the lowered point, and then the net was retrieved using a net hauler from the anchored boat at a speed of about 0.4 m • sec^{-1}. This method was adopted in June 1992, July 1993 and August 1993. One to three tows were conducted at each station. On board, all Pleuronectiformes collected were immediately fixed in 10% buffered formalin in lake water, and after 24 hours, they were transferred into a 70% ethanol solution to prevent decalcification. Length shrinkage and weight loss of Pleuronectiformes due to fixation and preservation were not taken into consideration in this study. During each sampling except for June 1992, four bottom sediment types were identified by visual observations on the distribution of seaweed beds and examining sediment that adhered to a sounding lead that touched the bottom. Water temperatures were measured with an STD.

To determine the vertical distribution patterns of copepods, sampling was conducted with a 6-liter Van Dorn bottle at subsurface (2 m depth), mid-water (7-8 m depth) and near-bottom (1-2 m above the bottom) levels at Stns. 1-3 from May

Table 1. Number of STD stations and water temperatures (minimum-median-maximum) on the bottom, and number of tows, number of sampling stations, range of towing depth, and total number of *Pleuronectes schrenki* juveniles collected with an epibenthic sledge net.

Date	STD			Epibenthic sledge net			
	Number of stations	Temperature range on the bottom (°C)	Temperatures on the bottom at 1.0–6.0m depth stations (°C)	Number of tows	Number of stations	Range of towing depth (m)	Total number of juveniles collected
June 23–26, 1992	19	9.4–12.2–16.7	12.7–13.6–16.7	14	11	1.7–20.9	0
July 29–30, 1992	26	14.4–17.7–20.7	16.5–18.2–20.7	7	6	2.0–4.2	47
May 19–20, 1993	14	2.3–6.5–8.6	5.7–7.4–8.6	8	7	1.4–5.1	0
June 23–25, 1993	13	8.3–12.2–13.3	12.1–12.6–13.3	10	6	1.0–4.6	6
July 28–29, 1993	17	13.6–17.2–19.1	15.7–18.2–19.1	8	7	1.0–6.0	80
August 30–31, 1993	17	15.3–19.5–20.9	19.5–20.3–20.9	7	7	1.3–5.4	64

to August 1993 (at Stn. 3 in July 1993, the near-bottom sampling depth was 15 m). Water samples of 5 liters were filtered with a 40 μm mesh sieve (DIN130), and the collected plankton were immediately preserved in 5% buffered formalin in lake water. Copepod densities were expressed as the number of individuals per 1 liter. All sampling was carried out during daylight.

Cresthead flounder *Pleuronectes schrenki* and black plaice *Pleuronectes obscurus* were found together in Lake Notoro. Both are morphologically similar. In the laboratory, juveniles of the two species were distinguished by the characters of their lower pharyngeal teeth (Hubbs, 1915; Yamamoto and Ishida, 1947). Cresthead flounder juveniles were counted for each tow, measured in standard length (SL) to the nearest 0.1 mm with an electric slide caliper, and then weighed to the nearest 1 mg. The total number of juveniles collected at each station was used to determine station density (inds. • 100 m^{-2}). The surface area sampled was calculated by multiplying the mouth width of the sledge net by the total distance the net was towed. It was assumed that the filtered efficiency of the sledge net for juveniles was 100% and that there was no difference in the catch efficiency between the two towing methods.

Stomach contents of the juveniles and wild copepods were identified to the lowest possible taxa and counted. The stomach contents were weighed to the nearest 0.1 mg after drying for five minutes on a filter paper. Harpacticoid copepods were distinguished into two groups: *Microsetella* spp. and other harpacticoids. Maximum widths of prey were measured to the nearest 12.5 μm under a binocular dissection microscope with a micrometer. Data on stomach contents were expressed as percent frequency of occurrence (F%), percent by number (N%) and percent by weight (W%) of food items. To compare the feeding intensity among samples, stomach contents indices (*SCI*) were calculated by the following formula:

$$SCI = Stomach\ content\ weight\ [g] \times 10^2 / Body\ weight\ [g]$$

Body weight of juveniles included the stomach content weight.

The Mann-Whitney test (U-test) and Kruskal-Wallis test (KW-test) were used to compare water temperatures, juveniles densities, length-frequency distributions, numbers of food organisms and *SCIs* between two samples and among three or more samples, respectively. Three-way analysis of variance (ANOVA) without replication was used to compare copepod densities at three depth levels at three stations during four sampling periods in 1993. Analysis of covariance (ANCOVA) between log-transformed standard length and log-transformed body weight (excluding stomach-content weight) in July 1992 and 1993 was used to compare the allometric growth curves. Significance levels were set at 0.05.

Results

Water Temperatures

Surface temperatures of lake water increased from 13.8-17.9°C in June to 19.4-22.7°C in July 1992, and from 6.4-9.4°C in May to 20.2-21.4°C in August 1993. Bottom temperatures increased from 9.4-16.7°C in June to 14.4-20.7°C in July 1992, and from 2.3-8.6°C in May to 15.3-20.9°C in August 1993 (Table 1). Median temperatures on the bottom at stations with bottom depths of 1-6 m were 18.2°C in both July 1992 and July 1993, and were not significantly different (U-test: $Us=21$, $n=7, 5$, $P>0.20$).

Distribution of Cresthead Flounder Juveniles

A total of 197 cresthead flounder juveniles were collected from 54 tows (Table 1). Although no juveniles were collected in June 1992 or May 1993, some were collected at the eastern part of the lake in June 1993 (Fig. 2). Juveniles were widely distributed in the nearshore areas of the lake in July 1992, and in July and August 1993. The maximum density recorded was 18.8 inds. • 100 m^{-2} at the sandy-bottom station off Ubaranai in July 1993. No juveniles were distributed at the seaweed-bed stations (Wd). One juvenile occurred at a muddy-bottom station (M, 0.4 inds. • 100 m^{-2}) off Ubaranai. Almost all juveniles were distributed in areas with sandy bottom (S) or sandy bottom with scattered seaweed beds (S.Wd). The median density in S and S.Wd areas in July 1992 was 4.5 inds. • 100 m^{-2}. In June, July and August 1993, the median densities were 0.7, 7.1 and 5.7 inds. • 100 m^{-2}, respectively. In July and August 1993, juveniles were collected at the same stations, and the median densities in July and August 1993 were not significantly different (U-test: $Us=28$, $n=7, 7$, $P>0.20$).

Length Frequency Distribution of Cresthead Flounder Juveniles

The smallest juvenile (14.2 mm SL) was collected at a station of the southern part of the lake in June 1993 (Fig. 2). The median SL in July 1992 was 25.5 mm (Fig. 3). In June, July and August 1993, the median SLs were 25.6 mm, 21.5 mm and 33.9 mm, respectively. A significant difference was found among SLs in these four sampling periods (KW-test: $KW=128.7$, $df=3$, $P=1.1 \cdot 10^{-27}$). In August 1993, all juveniles were 28.5 mm SL and larger, except for a single 19.4mm SL individual.

Diet of Cresthead Flounder Juveniles

Juveniles fed mainly on copepods, particularly *Eurytemora* spp. (*E. pacifica* and *E. herdmani*) and harpacticoid copepods other than *Microsetella* spp. (Other Harpacticoida, Table 2). In June 1993, *Eurytemora* spp. were consumed by all juve-

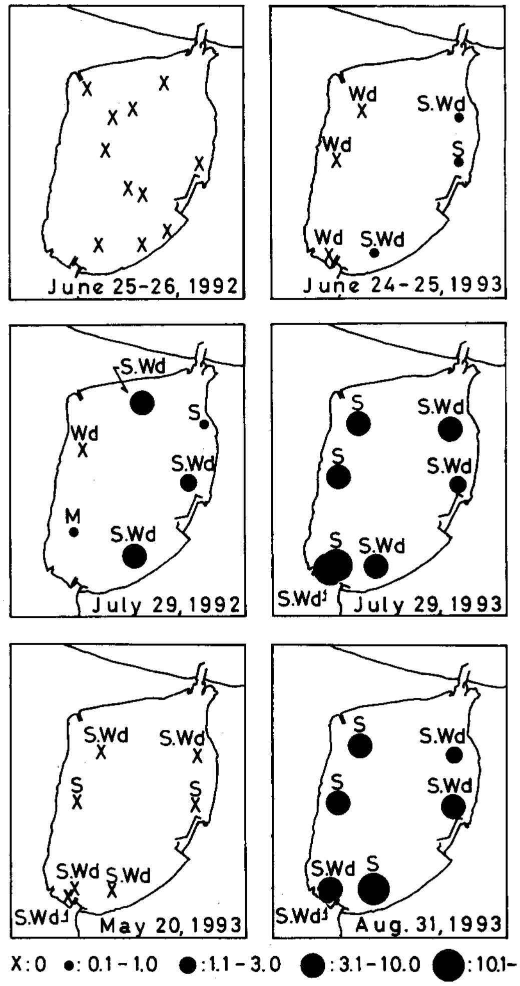

Fig. 2. Density distribution of cresthead flounder juveniles collected with an epibenthic sledge net in Lake Notoro. The densities of juveniles are expressed as number of individuals per 100 m^2 (inds. • 100 m^{-2}). Except for June 1992, bottom sediment types at each sampling station were shown as follows:

Wd : mainly seaweed beds,
S.Wd : sand with scattered seaweed beds,
S : sand,
M : mud.

niles (F%=100, N%=10.5, W%=8.8), and harpacticoid copepods other than *Microsetella* spp. were also abundant in the stomachs (F%=66.7, N%=72.3, W%=40.8). Harpacticoid copepods other than *Microsetella* spp. were the most common prey in July 1993 (F%=100, N%=74.5, W%=46.2). *Eurytemora* spp. were the most common prey item in July 1992 (F%=87.2, N%=59.0, W%=60.6) and August 1993 (F%=85.9, N%=74.5, W%=56.3). Benthic gastropods were often found in the stomachs in July 1992 (F%=57.4, N%=3.9, W%=1.2) and July 1993

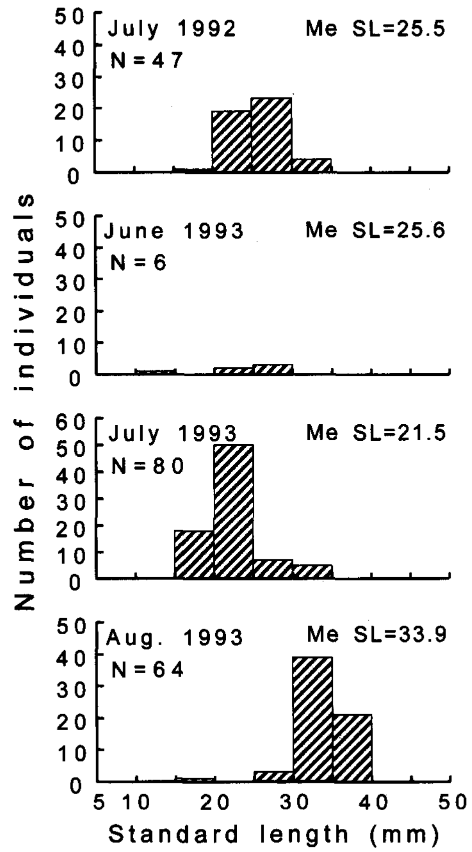

Fig. 3. Size frequency distribution of cresthead flounder juveniles collected with an epibenthic sledge net on the bottom in Lake Notoro. N: sample size, Me SL: median standard length.

(F%=68.8, N%=9.5, W%=13.0). Gammarid amphipods were also found frequently in the stomachs (F%=59.6, 50.0 and 64.1 in July 1992, July 1993 and August 1993, respectively). Polychaetes found in the stomachs included phyllodocids, aphroditids, glycerids, syllids, spionids and sabellids. In June 1993, polychaetes were commonly fed on (F%=83.3, N%=12.3, W%=40.1). Cumaceans and caprellid amphipods were frequent prey in July 1992 (F%=76.6 and F%=51.1, respectively). Cresthead flounder juveniles rarely fed on parasitic copepods; two taeniacanthid copepod individuals were preyed upon by two juveniles (27.5 mm SL and 21.1 mm SL) in July 1992. In addition, six caligoid copepods were found in juveniles (23.2-37.5 mm SL) in July and August 1993. These caligoid copepods were chalimus-stage larvae.

Median *SCIs* (stomach contents indices) ranged from 0.76 in July 1992 to 1.4 in June 1993 (Table 2). The median *SCI* in July 1992 (0.76) did not differ significantly from that in July 1993 (0.81, U-test: $Us=2{,}040$, $n=80, 47$, $P=0.42$). The median number of food organisms in July 1992 (53 individuals) did not differ

Table 2. Frequency of occurrence (F%), numerical composition (N%), and gravimetric composition (W%) of food items in stomachs of *Pleuronectes schrenki* juveniles collected in Lake Notoro in July 1992 and June-August 1993.

Food organism	July 1992			June 1993			July 1993			Aug. 1993		
	F%	N%	W%	F%	N%	W%	F%	N%	W%	F%	N%	W%
TURBELLARIA	0	0	0	0	0	0	0	0	0	1.6	0.2	0.1
GASTROPODA	57.4	3.9	1.2	16.7	0.9	<0.1	68.8	9.5	13.0	23.4	0.2	0.8
BIVALVIA	14.9	0.3	<0.1	0	0	0	23.8	3.3	5.3	9.4	<0.1	0.1
POLYCHAETA	38.3	1.7	2.2	83.3	12.3	40.1	38.8	0.6	3.6	23.4	0.2	10.5
ARACHNIDA												
Acarina	0	0	0	0	0	0	1.3	<0.1	<0.1	1.6	<0.1	<0.1
CRUSTACEA												
Cladocera												
Evadne nordmanni	0	0	0	0	0	0	0	0	0	1.6	<0.1	<0.1
Copepoda												
Calanoida												
Paracalanus parvus	0	0	0	0	0	0	2.5	0.1	0.1	0	0	0
Pseudocalanus newmani	0	0	0	0	0	0	1.3	<0.1	<0.1	0	0	0
Clausocalanus sp.	0	0	0	0	0	0	2.5	<0.1	<0.1	0	0	0
Eurytemora spp.	87.2	59.0	60.6	100.0	10.5	8.8	70.0	8.4	10.2	85.9	74.5	56.3
Centropages abdominalis	0	0	0	0	0	0	1.3	0.3	0.4	0	0	0
Acartia longiremis	0	0	0	0	0	0	1.3	<0.1	<0.1	0	0	0
Cyclopoida												
Oithona spp.	0	0	0	0	0	0	3.8	0.3	0.1	1.6	0.3	<0.1
Harpacticoida												
Microsetella spp.	0	0	0	0	0	0	0	0	0	1.6	<0.1	<0.1
Other Harpacticoida	74.5	20.6	6.5	66.7	72.3	40.8	100.0	74.5	46.2	81.3	21.3	9.1
Poecilostomatoida												
Corycaeidae	0	0	0	0	0	0	0	0	0	1.6	<0.1	<0.1
Taeniacanthidae	4.3	<0.1	0.1	0	0	0	0	0	0	0	0	0
Shiphonostomatoida												
Caligidae	0	0	0	0	0	0	2.5	<0.1	1.2	6.3	<0.1	0.4
Mysidacea	4.3	<0.1	<0.1	16.7	0.3	0.7	6.3	<0.1	5.0	18.8	0.2	10.8
Cumacea	76.6	6.3	10.7	0	0	0	22.5	0.5	2.2	20.3	0.2	0.5
Amphipoda												
Gammaridea	59.6	4.3	10.7	33.3	3.4	1.4	50.0	1.9	8.4	64.1	2.3	9.7
Caprellidea	51.1	3.8	7.3	0	0	0	17.5	0.4	1.3	29.7	0.3	0.2
Decapoda												
Natantia	4.3	<0.1	0.2	16.7	0.3	5.4	2.5	<0.1	0.7	0	0	0
UROCHORDATA												
Appendicularia	0	0	0	0	0	0	1.3	<0.1	<0.1	1.6	<0.1	<0.1
Unidentified food			0.5			2.7			2.3			1.6
Minimum-Median-Maximum number of food organisms	5-53-169			11-33-185			4-61.5-423			1-101.5-774		
Minimum-Median-Maximum weight of food organisms (mg)	0-1.8-7.9			0.4-2.2-4.3			0-1.1-10.4			0.1-5.4-49.5		
Minimum-Median-Maximum of *SCI*	0-0.76-2.7			0.26-1.4-3.7			0-0.81-3.33			0.02-1.0-6.2		
Number of fish examined	47			6			80			64		
Number of empty stomachs	0			0			0			0		
Minimum-Median-Maximum of SL (mm)	19.9-25.5-32.8			14.2-25.6-29.9			15.2-21.5-33.4			19.4-33.9-38.5		

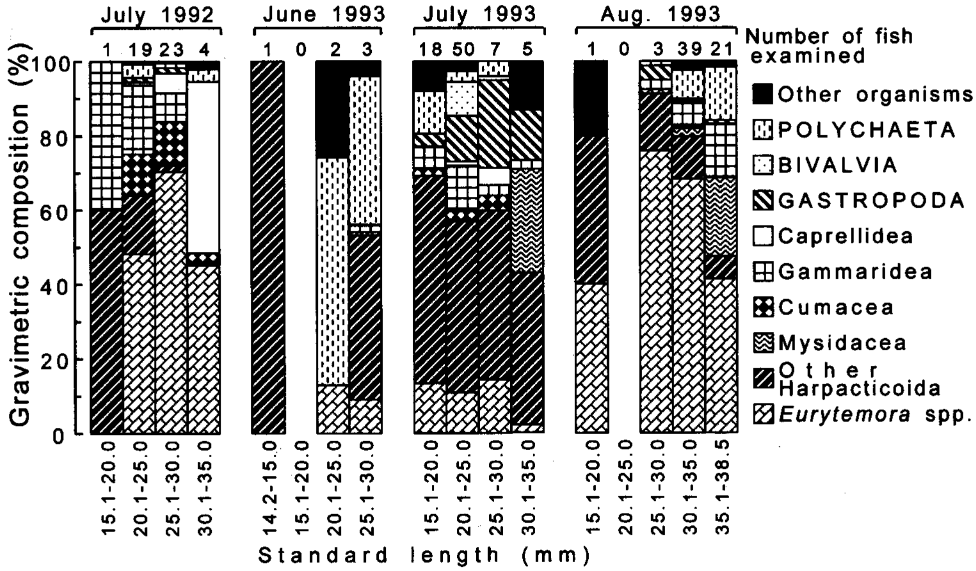

Fig. 4. Diet compositions (percent by weight) in stomachs of cresthead flounder juveniles by size groups in Lake Notoro in July 1992 and June-August 1993.

significantly from that in July 1993 (61.5 individuals, U-test: $Us=2{,}026.5$, $n=80$, 47, $P=0.46$).

The gravimetric compositions of the diet by fish size at each sampling period are shown in Fig. 4. Food organisms that composed the highest W% in each size group were *Eurytemora* spp. or harpacticoid copepods other than *Microsetella* spp., except for the 30.1-35.0 mm SL size range in July 1992 (caprellids: W%=46.2) and the 20.1-25.0 mm SL size range in June 1993 (polychaetes: W%=61.3). Harpacticoid copepods other than *Microsetella* spp. composed the highest W% in the 14.2-20.0 mm SL size ranges over all months. Mysids were abundant for the 30.1-35.0 mm SL size range in July 1993 (W%=28.0) and the 35.1-38.5 mm SL size range in August 1993 (W%=21.4). There was an ontogenetic shift in the diet from harpacticoid copepods other than *Microsetella* spp. to *Eurytemora* spp., but these differences by predator size groups were smaller than monthly differences in the diet.

The prey widths of cresthead flounder juveniles ranged from 0.08 to 1.78 mm in July 1993 and from 0.06 to 2.45 mm in August 1993 (Fig. 5). The maximum widths of prey increased with fish size, but the minimum widths of prey (most measured 0.08-0.10 mm) did not differ among predators. *Eurytemora* spp. and harpacticoid copepods other than *Microsetella* spp. were smaller (0.23-0.33 mm width and 0.08-0.28 mm width, respectively) than the other prey. In July 1993, the maximum widths of prey eaten by juveniles of 15.6 mm SL, 23.2 mm SL and 30.1 mm SL were 0.55 mm (Mysidacea), 1.60 mm (Caligidae) and 1.78 mm (Caligidae), respectively. In August 1993, aphroditid polychaetes of 1.80 mm and 2.45 mm width were found in juveniles of 33.6 mm SL and 38.5 mm SL, respectively.

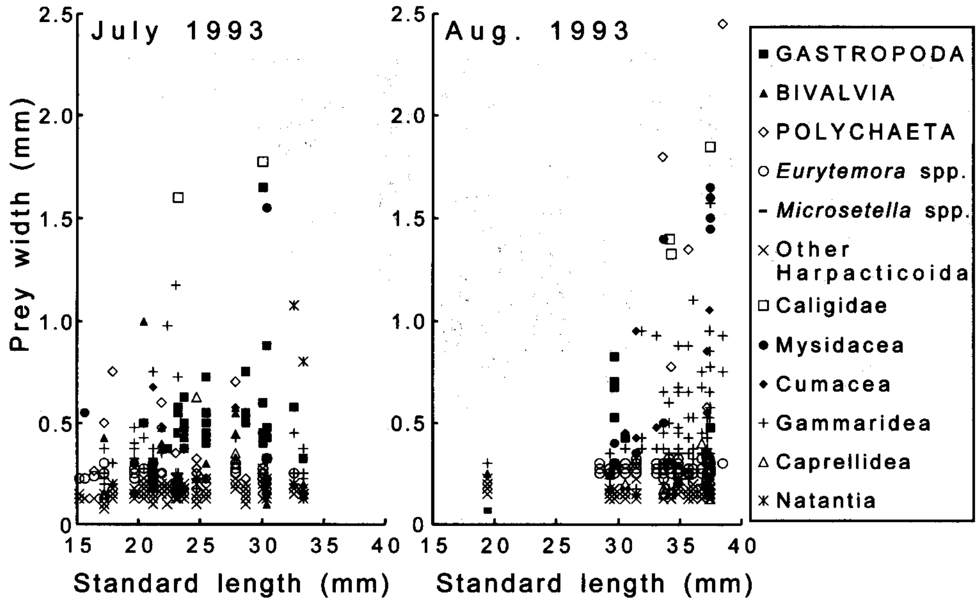

Fig. 5. Prey width distribution of cresthead flounder juveniles in Lake Notoro in July (left) and August (right) 1993.

Somatic Conditions of Cresthead Flounder Juveniles in July

Allometric growth curves between standard length and body weight of cresthead flounder juveniles were compared between July 1992 and July 1993 (Fig. 6). The results of ANCOVA revealed significant differences between the two allometric growth coefficients (2.50 and 2.87 in July 1992 and 1993, respectively, $P=0.0093$) and the two intercepts ($7.91\cdot10^{-5}$ and $2.06\cdot10^{-5}$ in July 1992 and 1993, respectively, $P=1.2\cdot10^{-12}$). From these two allometric growth equations, the body weight (excluding the stomach content weight) at 20 mm SL was 26% higher in July 1992 (0.141 g) than in July 1993 (0.112 g), and at 30 mm SL, it was 9% higher in 1992 (0.390 g) than in 1993 (0.357 g). In conclusion, juveniles in July 1992 were heavier than in July 1993.

Vertical Distribution of Copepods

The densities of copepods collected with the Van Dorn bottle were usually lowest at the subsurface level (Fig. 7). *Eurytemora* spp. were chiefly distributed at the near-bottom levels at all stations, except at Stn. 2 and 3 in July. Results of three-way ANOVA on densities of *Eurytemora* spp. indicated that there was a highly significant month×depth interaction ($P=0.0024$), but neither a month×station interaction ($P=0.051$) nor a depth×station interaction ($P=0.25$). It was clear that there was no station effect, and the depth levels where *Eurytemora* spp. were concentrated depended on sampling month. Similarly, *Pseudocalanus* spp. and harpacticoids other than *Microsetella* spp. were distributed at near-bottom levels at all stations, except Stn. 2 in May (three-way ANOVA, *Pseudocalanus* spp. : month×

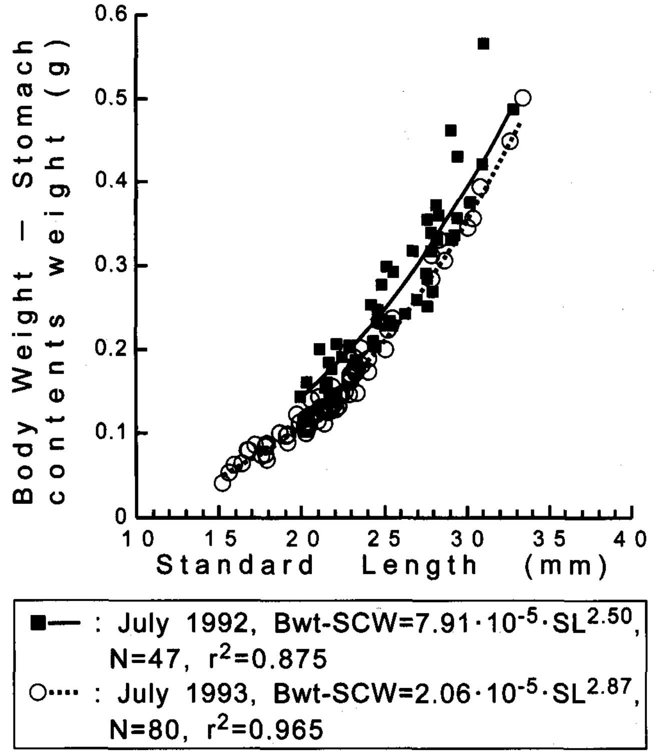

Fig. 6. Allometric growth curves of cresthead flounder juveniles between standard length (mm) and body weight (g, excluding stomach-content weight) in Lake Notoro in July 1992 and 1993.

depth: $P=0.013$, month×station: $P=0.080$, depth×station: $P=0.35$, harpacticoids other than *Microsetella* spp.: month×depth: $P=0.022$, month×station: $P=0.94$, depth×station: $P=0.25$). *Oithona* spp. concentrated at the subsurface or mid-water level from June to August (three-way ANOVA, month×depth: $P=0.013$, month×station: $P=0.56$, depth×station: $P=0.45$). No consistent patterns in vertical distribution were observed for *Microsetella* spp., *Paracalanus parvus* and *Acartia* spp. (three-way ANOVA, all interactions of these three taxa: $P>0.05$). In conclusion, *Eurytemora* spp., *Pseudocalanus* spp. and harpacticoids other than *Microsetella* spp. were identified as demersal copepods in Lake Notoro, however *Oithona* spp. were pelagic and occurred in the upper water column. *Microsetella* spp., *P. parvus* and *Acartia* spp. were pelagic, but did not concentrate at specific levels. The variations in densities among sampling stations were insignificant over all taxa.

Discussion

No cresthead flounder juveniles were collected in June 1992 or in May 1993 (Fig. 2). A few juveniles were found in June 1993. The highest median density of their

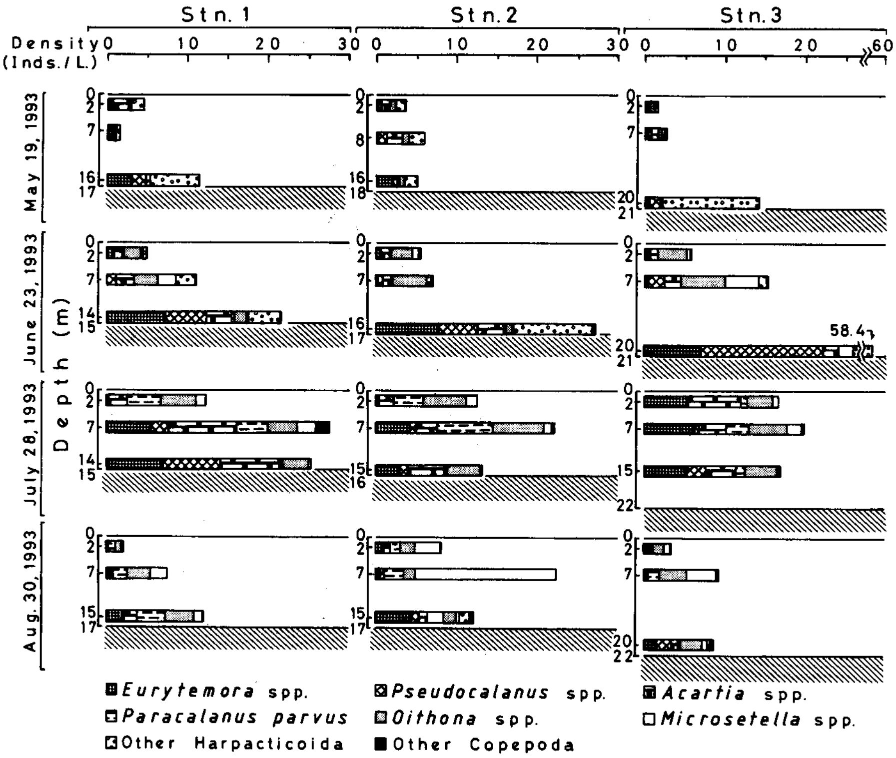

Fig. 7. Vertical distribution of copepods collected with a Van Dorn bottle at Stn. 1-3 in Lake Notoro from May to August 1993.

distribution occurred in July 1993 (7.1 inds. • 100 m^{-2}), and decreased slightly, but not significantly, in August 1993 (5.7 inds. • 100 m^{-2}). The standard length distributions differed significantly among the four sampling periods, and the median SL was larger in August 1993 than in July 1993. In addition, most juveniles were 28.5 mm SL and larger in August 1993 (Fig. 3). These facts suggest that most juveniles occurred on the bottom in July, with some occurring in June. Although juveniles of cresthead flounder were distributed in areas with sandy bottom or sandy bottom with scattered seaweed beds, few individuals were found on muddy bottom and seaweed beds. It seems that juveniles select their habitat based on their preference for sediment type. The distribution of juvenile stone flounder *Kareius bicoloratus* in the estuary of Nanakita River is affected not only by sediment type, but also by the chemical features and organic carbon content in the sediments (Omori et al., 1976). Additional chemical surveys of bottom sediments are needed to elucidate the preferred habitat of cresthead flounder juveniles.

Eurytemora spp. and harpacticoids other than *Microsetella* spp. in Lake Notoro are demersal (Fig. 7). Cresthead flounder juveniles fed on them heavily from June to August (Table 2 ; N%=79.6-95.8% ; W%=49.6-67.1%). Although gastropods, polychaetes, mysids, cumaceans, gammarids and caprellids are large food organisms (Fig. 5), these prey were seldom found in stomachs (Table 2). It is probable that demersal copepods are the main food organisms for cresthead flounder juveniles, and large food organisms are subsidiary prey. Juveniles rarely consumed pelagic copepods, such as *P. parvus*, *Acartia* spp., *Oithona* spp. and *Microsetella* spp. *Pseudocalanus* spp. were demersal during daylight (Fig. 7), however few *Pseudocalanus newmani* were consumed by juveniles (Table 2). *Pseudocalanus* spp. may not be demersal, since they are pelagic in offshore waters (Yamaguchi and Shiga, 1997). In contrast, *E. herdmani* is distributed in coastal and estuarine waters (Johnson, 1966), and *E. pacifica* is found in low salinity waters together with *E. herdomani* (Brodskii, 1967). These coastal and demersal copepods could sustain the growth of cresthead flounder juveniles in Lake Notoro at their nursery ground. The main food organisms of 16 black plaice juveniles (31.6-41.6 mm SL) in Lake Notoro in July 1992 were polychaetes ($F\%=100$, $N\%=92.1$, unpublished data), and their diet differed from that of cresthead flounder. It is possible that the food sources did not overlap much between these flatfish juveniles in Lake Notoro in July.

Allometric growth curves indicated that juveniles were heavier in July 1992 than in July 1993 (Fig. 6). Median *SCIs* of juveniles and the numbers of food items consumed did not differ between July 1992 and July 1993 (Table 2). Water temperature influences the feeding rate and metabolic rate of flatfishes (Takahashi et al., 1987), and the median temperatures where juveniles were collected did not differ between July 1992 and July 1993 (Table 1). The only point of difference was the diet composition; juveniles fed chiefly on *Eurytemora* spp. and demersal harpacticoids in July 1992 and July 1993, respectively (Table 2). This difference may not be caused by fish size (Fig. 4), or restricted food size, because both *Eurytemora* spp. and demersal harpacticoids were smaller than the other available food organisms (Fig. 5). It seems probable that *Eurytemora* spp. are a more effective food source for juvenile somatic growth than demersal harpacticoids in July.

Acknowledgments

The authors thank former Associate Professor, Dr. Tetsuichiro Kinoshita, and Associate Professer, Dr. Toshikuni Nakatani for their valuable suggestions, and Dr. Kazuya Nagasawa, National Research Institute of Far Seas Fisheries, who introduced literature concerning parasitic copepods. Thanks are due to Mr. Toshifumi Kawajiri, Nishi-Abashiri Fisheries Cooperative Association, the staff of the Abashiri Fisheries Science Center, Mr. Fumiaki Kitano and Miss Mieko Sasaki for their help with field sampling.

References

Anderson, J.T. (1988). A review of size dependent survival during pre-recruit stages of fishes in relation to recruitment. *J. Northw. Atl. Fish. Sci.*, **8**, 55-66.

Aota, M. (1975). Studies on the Soya Warm Current. *Low temperature Science*, **A**, **33**, 151-172 (in Japanese).

Brodskii, K.A. (1967). *Calanoida of the Far Eastern Seas and Polar Basin of the USSR*. p. 281-283, (Translated from Russian by A. Mercado), Israel Program for Scientific Translations, Jerusalem.

Campana, S.E. (1996). Year-class strength and growth rate in young Atlantic cod *Gadus morhua*. *Mar. Ecol. Prog. Ser.*, **135**, 21-26.

Fukuda, M., Yano, M., Nakano, H. and Sugiyama, M. (1986). Protein and nucleic acid changes during early development stages of cresthead flounder. *Nippon Suisan Gakkaishi*, **52**, 951-955 (in Japanese).

Hikita, T. (1952). On the development of *Limanda schrenki* (Schmidt). *Sci. Rep. Hokkaido Fish hatchery*, **7**, 133-144 (in Japanese).

Houde, E.D. (1987). Fish early life dynamics and recruitment variability. *Am. Fish. Soc. Symp.*, **2**, 17-29.

Hubbs, C.L. (1915). Flounders and soles from Japan collected by the United States Bureau of Fisheries steamer "Albatross" in 1906. *Proc. U.S. Nat. Mus.*, **48**, 449-496.

Hunter, J.R. (1981). Feeding ecology and predation of marine fish larvae, p. 33-77, Lasker, R. (ed.), *Marine Fish Larvae*. Univ. of Washington Press, Seattle.

Ishida, R. (1948). On regional differences in morphology of cresthead flounder (*Limanda schrenki* Schmidt). *Sci. Rep. Hokkaido Fish hatchery*, **3**, 16-22 (in Japanese).

Ishida, R. (1949). Investigative report of cresthead flounder (*Limanda schrenki* Schmidt). III Tagging experiments of cresthead flounder in Lake Notoro. *Sci. Rep. Hokkaido Fish hatchery*, **4**, 62-72 (in Japanese).

Ishida, R. (1950). Investigations on cresthead flounder. (IV) Relationships between body length, and available eggs and body weight in cresthead flounder. *Sci. Rep. Hokkaido Fish hatchery*, **5**, 140-144 (in Japanese).

Ito, K. (1953). On the flounder, *Limanda schrenki*, taken from the coast of Nemuro Province. *Sci. Rep. Hokkaido Fish hatchery*, **8**, 125-130 (in Japanese).

Johnson, M.W. (1966). The nauplius larvae of *Eurytemora herdmani* Thompson & Scott, 1897 (Copepoda, Calanoida). *Crustaceana*, **11**, 307-313.

Kurata, M. and Nishihama, Y. (1987). Seasonal change of the hydrographic condition on Lake Notoro, Hokkaido. *Sci. Rep. Hokkaido Fish. Exp. Stn.* **29**, 17-24 (in Japanese).

Meekan, M.G. and Fortier, L. (1996). Selection for fast growth during the larval life of Atlantic cod *Gadus morhua* on the Scotian Shelf. *Mar. Ecol. Prog. Ser.*, **137**, 25-37.

Minagawa, H. (1956). On the computation of body-length composition, length-weight relationship and egg-number of a flounder (*Limanda schrenki* Schmidt) in Lake Notoro, Hokkaido. *Sci. Rep. Hokkaido Fish hatchery*, **11**, 171-180 (in Japanese).

Morita, S. (1964). Cresthead flounder in Ishikari Bay. Distribution in spawning season. *Hokusuishi Geppo* (*J. Hokkaido Fish. Exp. Sta.*), **21**, 49-53 (in Japanese).

Morita, S. and Ohara, M. (1965a). Ecological studies of "Kurogashiragarei" (*Limanda schrenki* (Schmidt)) of Hokkaido. (I) On the life of spawning population. *Bull. Hokkaido Natl. Fish. Res. Inst.*, **30**, 45-59 (in Japanese).

Morita, S. and Ohara, M. (1965b). Ecological studies of "Kurogashiragarei" (*Limanda schrenki* (Schmidt)) of Hokkaido. (II) Consideration on the population. *Bull. Hokkaido Natl. Fish. Res. Inst.*, **30**, 60-66 (in Japanese).

Morita, S. and Ohara, M. (1967). Ecological studies of "Kurogashira-garei" (*Limanda schrenki* (Schmidt)) of Hokkaido. (III) Consideration of the constitution of a pre-spawning shoal by tagging experiments. *Bull. Hokkaido Natl. Fish. Res. Inst.*, **32**, 8-14 (in Japanese).

Morita, S., Tanaka, T. and Ohara, M. (1963). Life history of cresthead flounder. *Hokusuishi Geppo* (*J. Hokkaido Fish. Exp. Sta.*), **20**, 62-65 (in Japanese).

Morita, S., Matsuyama, H. and Yamamoto, M. (1966). Age and fishing condition of cresthead flounder. *Hokusuishi Geppo* (*J. Hokkaido Fish. Exp. Sta.*), **23**, 14-19 (in Japanese).

Nakabo, T. (1993). Pleuronectidae. p. 1175-1185, Nakabo, T. (ed.), *Fishes of Japan with Pictorial Keys to Species*. Tokai University Press, Tokyo, (in Japanese).

Okubo, S. (1951). Investigation on the flounder (*Limanda schrenki*). (V) The growth-rate obtained from the results of marking experiments and the feeding habit. *Sci. Rep. Hokkaido Fish hatchery*, **6**, 145-150 (in Japanese).

Okubo, S. (1952). Investigation on the flounder (*Limanda schrenki* Schmidt). (VI) On the growth rate of flounder, using the otolith in Lake Notoro. *Sci. Rep. Hokkaido Fish hatchery*, **7**, 163-182 (in Japanese).

Omori, M., Kinno, H. and Nishihata, I. (1976). Study of the habitat of juvenile stone flounder, *Kareius bicoloratus* (BASILEWSKY), in the estuary of the Nanakita River. *Tohoku J. Agr.*

Res., **27**, 79-91.

Sugiyama, M., Nakano, H., Yano, Y., Fukuda, M. and Murakami, N. (1985). Studies on the culturing technique for flatfish larvae-I. The effect of rate of water supply into rearing tank on the abundance of albinism and reversal larvae. *Bull. Hokkaido Natl. Fish. Res. Inst.*, **50**, 63-69 (in Japanese).

Takahashi, T., Tominaga, O. and Maeda, T. (1987). Effects of, water temperature on feeding and survival of righteye flounder *Limanda herzensteini* and *Limanda yokohamae*. *Nippon Suisan Gakkaishi*, **53**, 1905-1911 (in Japanese).

van der Veer, H.W. and Bergman, M.J.N. (1987). Predation by crustaceans on a newly settled 0-group plaice *Pleuronectes platessa* population in the western Wadden Sea. *Mar. Ecol. Prog. Ser.*, **35**, 203-215.

Yamaguchi, A. and Shiga, N. (1997). Vertical distributions and life cycles of *Pseudocalanus minutus* and *P. newmani* (Copepoda ; Calanoida) off Cape Esan, southwestern Hokkaido. *Bull. Plankton Soc. Japan*, **44**, 11-20 (in Japanese).

Yamamoto, K. and Ishida, R. (1947). Investigations on cresthead flounder. On *Limanda schrenki* and *Liopsetta obscura*. *Sci. Rep. Hokkaido Fish hatchery*, **2**, 35-40 (in Japanese).

Yamamoto, K. (1951). On the egg and larva of *Limanda schrenki* and the synonymatic problem between *L. schrenki* and *L. yokohamae*. *Sci. Rep. Hokkaido Fish hatchery*, **6**, 173-179 (in Japanese).

Yokoyama, S. (1998). Morphometric analysis and tagging experiments for stock discrimination of cresthead flounder *Pleuronectes schrenki* around Hokkaido. *Fisheries Sci.*, **64**, 373-378.

Yokoyama, S. and Shimoyama, N. (1995). Movements of tagged cresthead flounder *Pleuronectes schrenki* off northeastern Hokkaido, Japan. *Sci. Rep. Hokkaido Fish. Exp. Stn.*, **47**, 15-24 (in Japanese).

Yokoyama, S. and Tanaka, M. (1996). Effect of temperature and salinity on the hatch of cresthead flounder *Pleuronectes schrenki*. *Sci. Rep. Hokkaido Fish. Exp. Stn.*, **48**, 1-7 (in Japanese).

Yusa, T. (1960). Differences of structures of eggs and larvae between *Limanda yokohamae* Günter and *Limanda schrenki* Schmidt. *Bull. Mar. Biol. Sta. Asamushi, Tohoku Univ.*, **10**, 127-131.