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Studies on Groundfish Communities in the Coastal Waters of Northern Niigata Prefecture

II. Seasonal Changes of Feeding Habits and Daily Rations of Young Flounder, *Paralichthys olivaceus*.[1]

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Abstract

Seasonal changes of the feeding habits of young flounder, *Paralichthys olivaceus*, such as composition of food items, feeding periodicity and daily rations, by samples caught in the waters of northern Niigata Prefecture during the years 1981-1986, were studied. ELLIOTT and PERSSON's (1978; originally derived by MORISHITA 1972, theoretically) model was used to estimate daily rations. The model required field observations of stomach content weight during a consecutive 3 hours over 24 hours and values of the gastric evacuation rate (R). The values of R were estimated for each prey group, pisces and crustacea, from the field data. Highest and lowest estimates of daily rations were 4.51 % body weight (BW) in June and 1.33 %BW in November, respectively.

Key words : flounder, feeding habit, daily ration

Introduction

Recently, several attempts have been made to simulate a multispecies model and energy flow dynamics (LAEVASTU and LARKINS 1981). In their model, the prey-predator relationships defined by qualitative and quantitative parameters play important roles. Though many studies on feeding habits, such as food selectivity, were available, few were on quantitative studies. Recently several studies to examine daily rations of fish, based on field data, have been made (DWYER et al. 1983, DURBIN et al.1983, NASHIDA et al. 1984, TOMIYAMA et al. 1985). These studies were based on

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Elliott and Persson's (Morishita's) model. Morishita (1972) introduced the exponential model to estimate food consumption using stomach content weight measurements. Elliott and Persson (1978) independently derived the equation and proved its validity experimentaly using brown trout in the laboratory. In this paper, seasonal changes of feeding habits and daily rations of young flounder, *P. olivaceus* in the coastal waters of northern Niigata Prefecture were discussed.

Materials and Method

The surveyed area where stomach samples were taken from is shown in Fig. 1. The study was conducted from November, 1981 to May, 1986. Two rivers, the Shinano and the Agano, flow into the area, and the bottom surface is mainly covered with muddy sand. Though it had been a good fishing ground of plaice and flounder, their catches have declined in recent years due to overfishing.

The station surveys were conducted at Stns. 1-8 by commercial fishing boats equipped with small otter board trawl nets or the research vessel "Mizuho-Maru" (150.44 t). The 24-hr surveys were conducted at area A or Stn. 6 by a fishing boat with the same gear and the samplings were continued over 24 hours (Fig. 1). Towing lasted about 1 hour at speeds of about 3 knots. In order to check the seasonal changes of feeding habits, stomach samples were taken occasionally at the ports of Niigata and Iwafune.

Samples were preserved with ice or frozen in the station surveys, and in 15% sea water formalin immediately after landing on board in the 24-hr surveys. In the

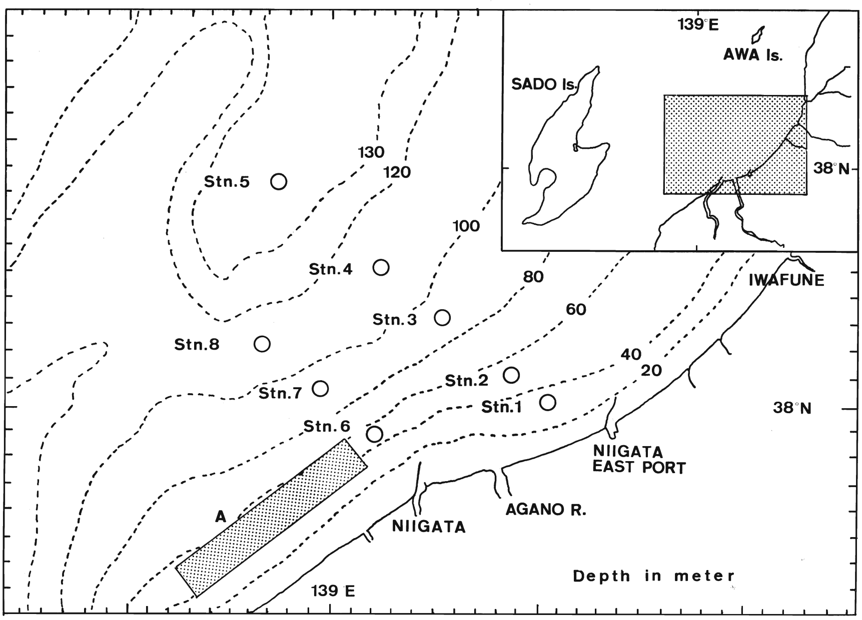

Fig. 1. Sampling area for feeding habit surveys of the flounder in the coastal waters of northern Niigata Prefecture. Stns. 1–8 were for the station surveys, area A and Stn. 6 were for the 24–hr surveys.

laboratory, total length, body length (BL), sex, gonad weight and liver weight were measured for each fish. Otoliths were taken for age determination and the stomachs were removed and preserved in 10% formalin for this study. The food items, divided into four groups; pisces, crustacea, cephalopoda and others, were weighed (wet weight) and the state of digestion was observed.

In order to estimate the gastric evacuation rate, *P. olivaceus*, ($14 < BL < 22$ cm) were caught by the "Mizuho-Maru" on July 20, 1985 and reared in 500 *l* containers on board with running sea water. Several individuals were picked out for testing at every two hours for 18 hours. The same measurements as above were conducted for these samples on board and stomachs were removed and preserved in 15% formalin, and in the laboratry the same method of stomach content analysis was conducted.

The indices used in this report were calculated as follows.

Stomach Content Weight Index (*SCWI*) $SCWI_i = \Sigma\,(SCWI_{ij}/BW_j)/n \times 100$
(*SCW* : Stomach Content Weight, *BW* : Body Weight, *i* : prey group, $j=1, 2, \cdots, n$)

Liver Weigt Index (*LWI*) $LWI = (\Sigma\, LW_j/BW_j)/n \times 100$
(*LW* : Liver Weight, $j=1, 2, \cdots, n$)

Group Feeding Rate (*GFR*) $GFR = \frac{\text{No. of fish with food in stomach}}{\text{No. of fish caught}} \times 100$

(Yokota et al. 1961).

Results

Feeding Habit

Results of stomach content analysis of the station surveys are shown in Table 1. and Fig. 2. The values of GFR were constantly high, ranging from 30 to 95%, throughout the years and no seasonal changes were observed (Nashida 1984). The main components of stomach content were the pisces group, such as sardine, *Sardinops melanosticta*, anchovy, *Engraulis japonica* and goby, *Chaeturichthys sciistius*, and the percentages were especially high from winter to early spring. From early summer to autumn, the values of the crustacea group, such as shrimp, *Metapenaeopsis dalei*, and crangon, *Crangon affinis*, increased (45-80% by weight) and the highest values were observed in early autumn. The values of the cephalopoda group were incidentally high because of their relatively heavy weight.

The ranges of SCWI values observed were 0-12.1 %BW for pisces group, 0-3.5 % BW for crustacea group and 0-22.5 %BW for the total. Namely, there was a specimen which ingested 22.5 %BW prey items.

As mentioned above, the pisces group made up large proportion of the stomach content, and the seasonal change of SCWI values could be explained by those of the pisces group. The SCWI values of the pisces group were relatively high from win-

Table 1. Number of fish, group feeding rate (GFR), range of stomach content weight and stomach content weight index (SCWI) of the flounder caught in station surveys.

Date	Sampling station	Total no. of fish	GFR (%)	Range of stomach content weight (%BW)			SCWI (%BW)		
				Pisces	Crustacea	Total	Pisces	Crustacea	Total
Nov. 18, 1981	1–4	112	37.5	0– 7.89	0– 1.07	0–22.51	0.428	0.034	0.918
Jan. 11, 1982	N G*	17	70.6	0– 9.34	0– 0.00	0–11.98	3.320	0.000	4.025
Mar. 20, 1982	1–8	122	65.6	0–12.07	0– 0.42	0–12.07	1.768	0.014	1.832
Apr. 21, 1982	N G	35	31.4	0– 1.20	0– 0.00	0– 8.02	0.073	0.000	0.507
May 12, 1982	1–8	42	57.1	0– 3.76	0– 0.26	0– 3.76	0.600	0.020	0.619
June 20, 1982	NG, IW	49	65.3	0– 4.74	0– 1.62	0– 4.73	0.610	0.203	0.813
Sept. 6, 1982	1–8	231	61.0	0– 7.93	0– 3.37	0– 7.93	0.396	0.283	0.744
Oct. 13, 1982	I W	18	55.6	0– 1.12	0– 0.00	0– 4.06	0.262	0.000	0.839
Nov. 4, 1982	1–8	70	45.7	0– 9.92	0– 0.76	0– 9.91	0.709	0.047	0.754
Feb. 17, 1983	N G	40	37.5	0– 9.76	0– 0.00	0– 9.75	1.579	0.000	1.577
Mar. 26, 1983	1–8	207	62.3	0– 7.46	0– 1.44	0– 7.46	0.935	0.088	1.021
June 22, 1983	1–5	14	78.6	0– 2.58	0– 1.54	0– 2.57	0.469	0.366	0.831
Sept. 17. 1983	1–5	80	67.5	0– 1.74	0– 3.48	0– 3.48	0.136	0.449	0.582
Feb 19, 1985	1–5	46	39.1	0– 4.10	0– 1.60	0– 4.10	0.504	0.093	0.595
May 16, 1985	1–5	50	78.0	0– 8.19	0– 1.96	0– 8.18	1.845	0.094	1.935
July 19, 1985	1–5	106	76.4	0– 7.32	0– 3.39	0–13.87	0.333	0.804	1.268
Sept. 26, 1985	1–5	12	75.0	0– 9.08	0– 1.75	0–10.22	1.883	0.384	2.263
Dec. 23, 1985	I W	45	97.8	0– 6.12	0– 0.01	0– 6.12	2.438	0.000	2.434
Apr. 10, 1986	1–5	18	77.8	0– 4.56	0– 0.15	0– 4.55	1.644	0.015	1.656
May 16, 1986	1–5	13	76.9	0– 5.89	0– 0.09	0– 5.88	1.453	0.012	1.487

* NG: Niigata, IW: Iwafune

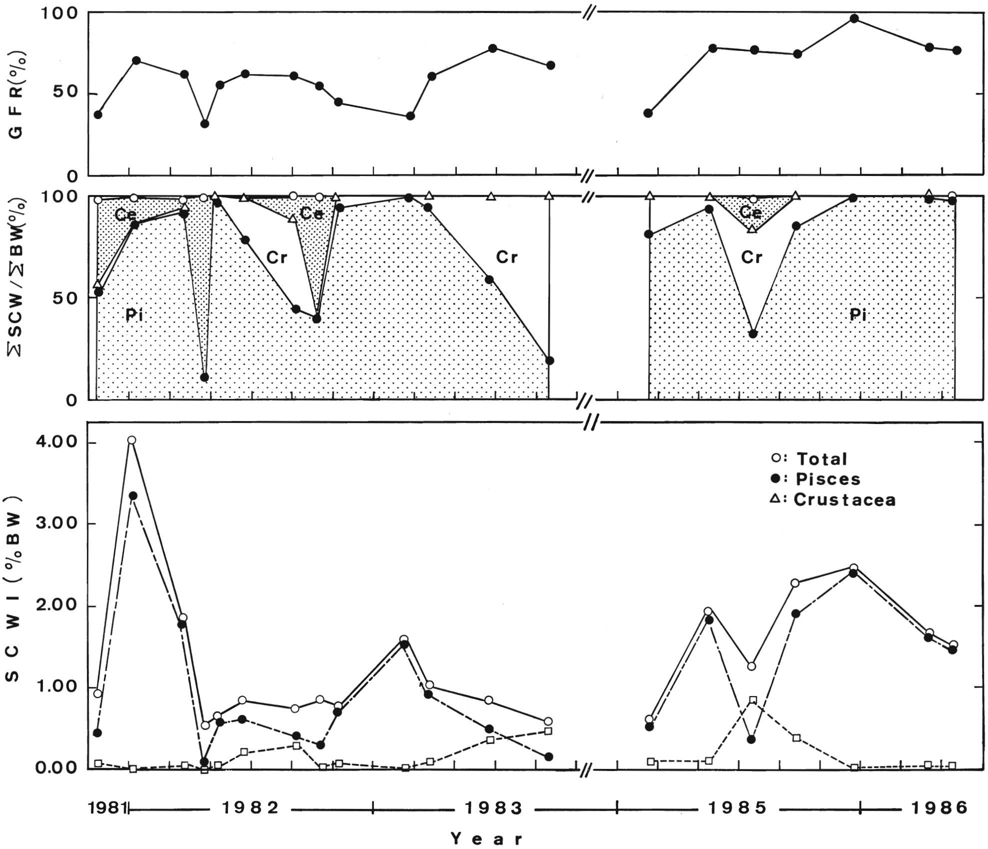

Fig. 2. Seasonal changes of group feeding rate (GFR), percent weight of food organisms in the stomach content weight and stomach content weight index (SCWI). Pi: pisces, Cr: crustacea, Ce: cephalopoda.

ter to early spring, and decreased from summer to autumn. Those of the crustacea group were low from winter to early summer, increased from late summer to autumn and sometimes higher than those of the pisces group in those seasons.

Daily Ration

1. Length Distribution

Table 2. shows the results of 24-hr surveys and Fig. 3. shows length distributions of *P. olivaceus* caught. The range of body length observed was 9-49cm, and mainly was 10-26cm. The recruitments to the area varied from year to year, relatively abundant in 1982 and 1984 and few in 1983 in recent years. The main age groups consisted of, as the main spawning season is from May to June (NIIGATA Pref. Fish. Exp. Stn. 1986), 0-year in February and March, 1985, 1-year in June, 1983, 1- and 2-year in July, 1984, 0-(mode : BL=11cm) and 1-(mode : BL=21cm) year in September, 1982 and 0-year in November, 1984.

There were no statistically significant differences ($P<0.05$) of numbers of catches

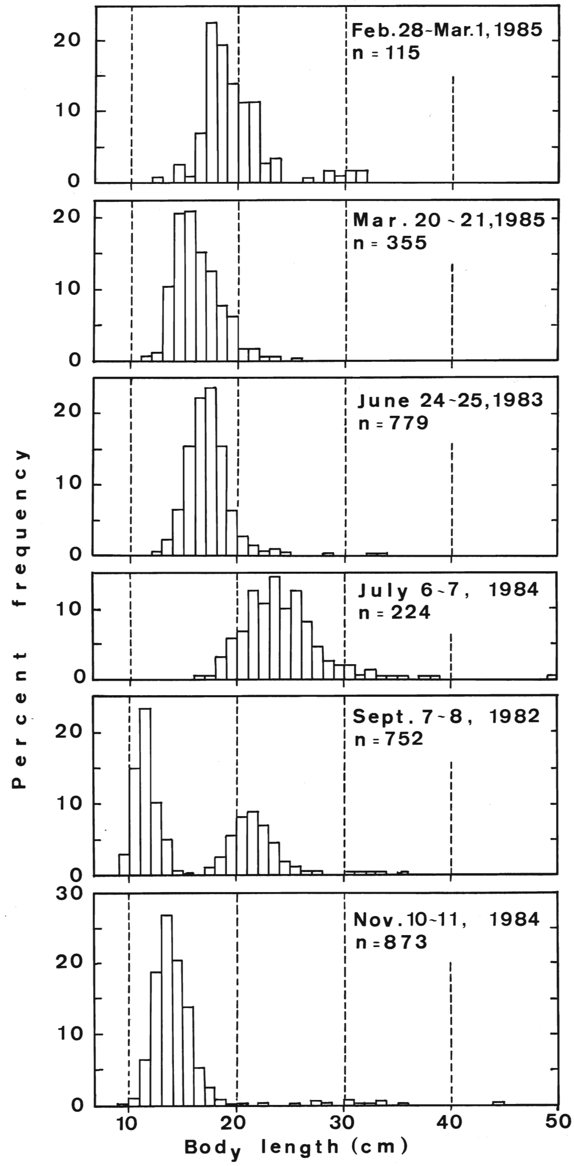

Fig. 3. Size-frequency distributions of the flounder caught in the 24-hr surveys.

Table 2. Number, duration and time interval between tows and number of sample of the flounder caught in 24-hr surveys. The area A is indicated in Fig. 1.

Date	Sampling area	Tow duration (min)	Tow no.	Time interval between tows (h)	Total no. of fish	Mean no. of fish/tow
Sept. 7-8, 1982	A	58-60	8	1.9-4.1	752	94.0
June 24-25, 1983	A	57-62	12	1.7-2.1	779	64.9
July 6-7, 1984	A	58-67	9	1.9-4.2	224	24.9
Nov. 10-11, 1984	A	38-59	9	2.7-3.1	873	97.0
Feb. 28-Mar. 1, 1985	Stn. 6	40-61	9	2.9-3.3	115	12.8
Mar. 20-21, 1985	A	38-60	9	2.9-3.2	355	39.4

per tow between day and night.

2. Feeding Periodicity

Diel changes of SCWI values of the pisces and crustacea groups in the 24-hr surveys are presented in Fig. 4. Those values of the pisces group often tended to increase at dawn and dusk, especially in July and September. The values of the pisces group in March were relatively high in the day, increased after sunset and then decreased gradually until next morning. Unlike the pisces group, there were no marked diel changes for the crustacea group.

3. Gastric Evacuation Rate (R)

Elliott and Persson (1978) introduced the following equation which assumes

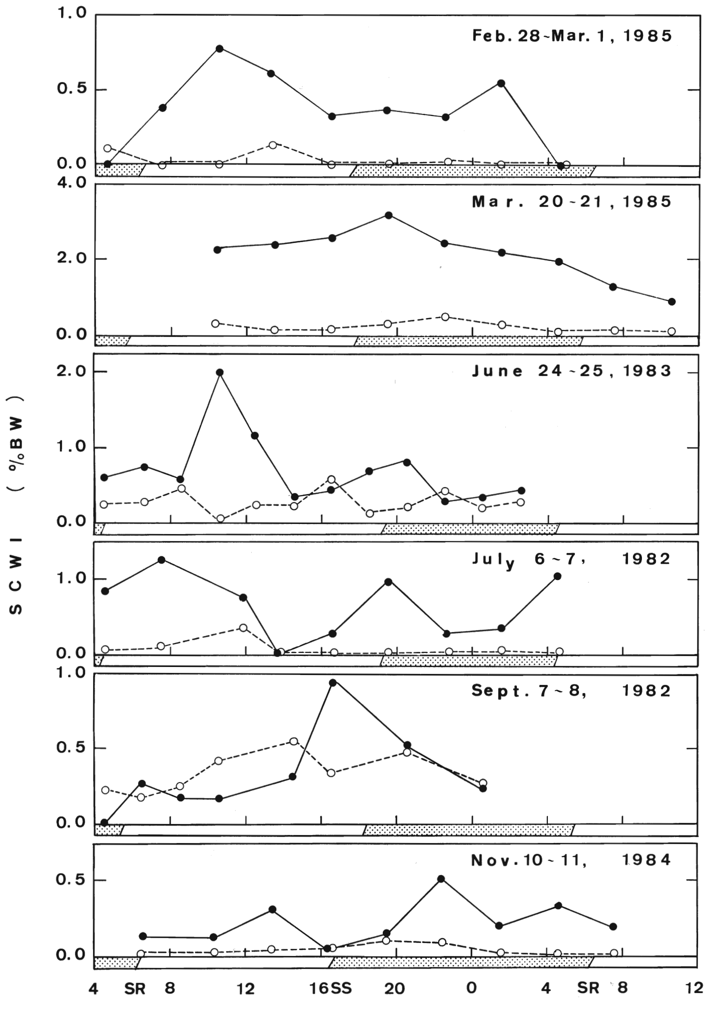

Fig. 4. Diel changes of stomach content weight index (SCWI) of the flounder in the 24–hr surveys. Pisces (●), crustacea (○). Shaded part : night. SR : sunrise, SS : sunset.

exponential evacuation,

$$S_t = S_o \; exp\,(-Rt) \qquad (1)$$

where,

S_o, S_t : amount of food in the stomach at time o and t, respectively

R : instantaneous gastric evacuation rate.

In the rearing experiment on board to estimate R, values of crustacea were obtained although those of pisces were not. The data to estimate R of pisces were derived from the set of SCWI values from 20:00 to 04:00 in March 20-21, 1985, on the assumption that no feeding activities had occurred during the night. These data were plotted in semi-log graph (Fig. 5.), and two linear regressions were derived by the least squares method, one for pisces and another for crustacea. The values of R obtained from the equations were 0.0535 for pisces (water temperature, 8.6℃) and 0.0928 for crustacea (23.3℃).

Durbin et al.(1983) proposed the next equation between R and water temperature T(℃).

$$R = a \; exp\,(0.115\;T) \qquad (2)$$

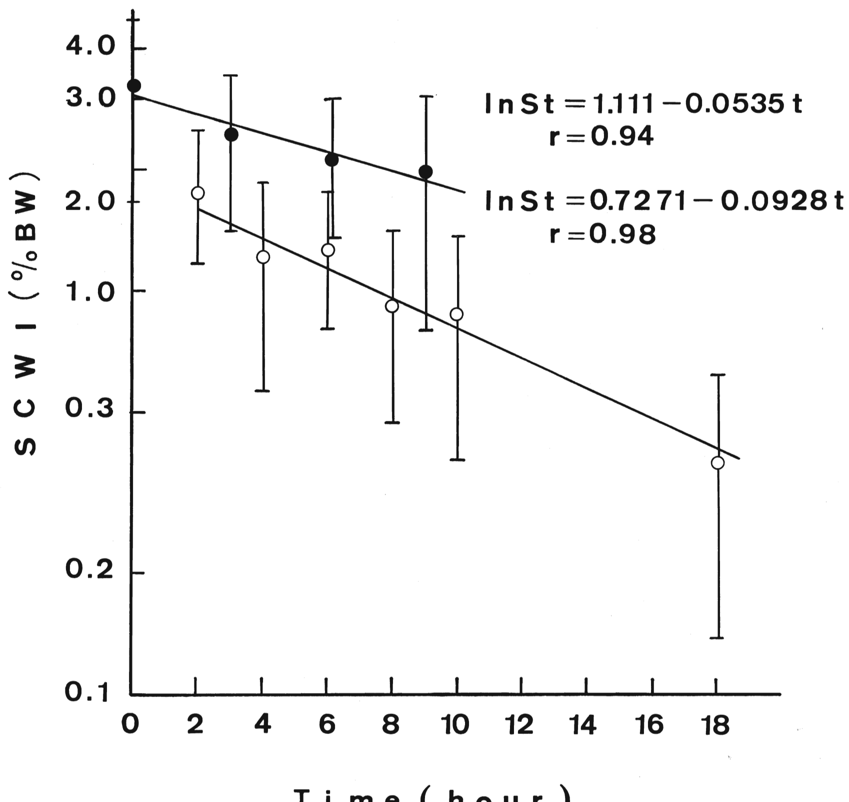

Fig. 5. Semi-log plot of stomach content weight index (SCWI) against hours for the flounder to be starved. Bars indicate 95% confidence limits. Pisces (●), crustacea (○).

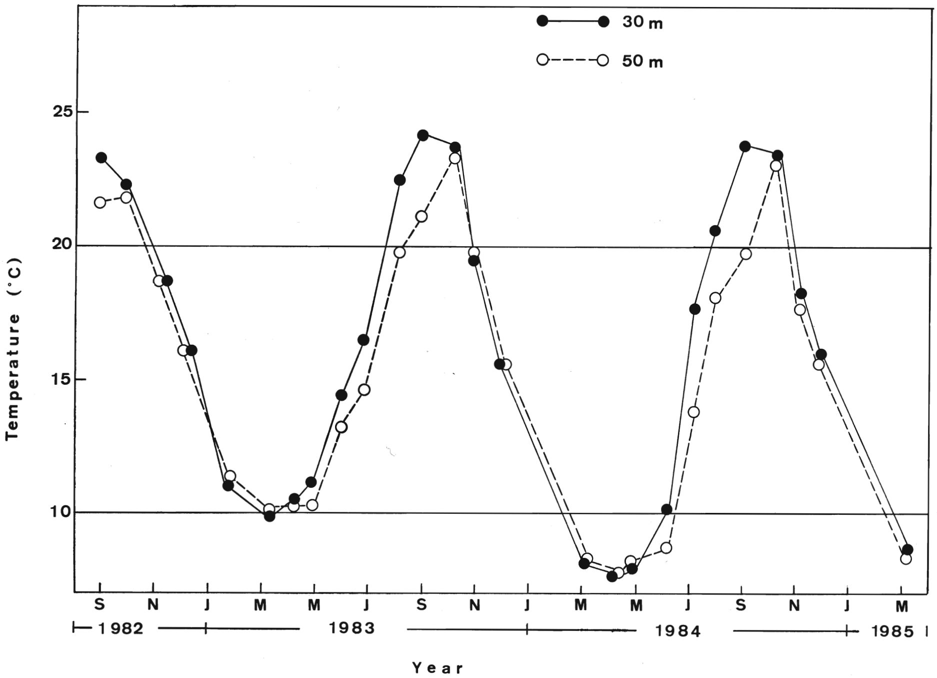

Fig. 6. Seasonal changes of water temperature in adjacent waters

Table 3. Water temperature in adjacent waters and estimated gastric evacuation rates.

Month	Feb, Mar.	June	July	Sept	Nov.
Temperature (°C, depth 50m)	8.6	14.6	13.9	21.6	17.7
Pisces	0.0535	0.1067	0.0984	0.2386	0.1524
Crustacea	0.0171	0.0341	0.0315	0.0764	0.0488

where, a: a constant defined by prey group.
The following equations were obtained substituting R and T values in equation (2) by the above values.

Pisces : $R = 0.0199 \, exp\,(0.115\,T)$ (3)

Crustacea : $R = 0.0064 \, exp\,(0.115\,T)$ (4)

The seasonal changes of water temperature of 30 and 50m depth layers in the adjacent waters are shown in Fig. 6 (NIIGATA Pref. Fish. Exp. Stn. 1983, 1984, 1985). Table 3. indicates R values obtained by substituting T in equations (3) and (4), by values (50m depth layer) of Fig. 6.

4. Daily Rations

In the ELLIOTT and PERSSON's model, the consumption of food (C_t) by a fish over the time interval t_o to t_t is calculated from the amount of food in the stomach at time t_o (S_o), t_t (S_t), and the instantaneous gastric evacuation rate R :

Table 4. Number of fish, stomach content weight index (SCWI, mean ±95% confidence limit) and estimated food consumption by body size classes, BL < 16cm and 16≦ BL < 28cm, of the flounder caught in September 7-8, 1982.

Time	Inter-mediate time	Time interval (hour)	No. of fish examined	SCWI mean ± 95%C.L., %BW		Estimated food consumption/hour (%BW)		Estimated food consumption (%BW)	
				Pisces	Crustacea	Pisces	Crustacea	Pisces	Crustacea
BL<16cm									
04 : 06-05 : 06	04 : 36	1.90	27	0.038±0.050	0.000±0.000	0.34	0.03	0.65	0.07
06 : 01-07 : 01	06 : 30	2.07	21	0.549±0.851	0.070±0.105	-0.11	0.09	-0.22	0.20
08 : 04-09 : 03	08 : 34	2.00	42	0.155±0.115	0.247±0.178	0.12	0.15	0.25	0.30
10 : 04-11 : 03	10 : 34	3.98	36	0.296±0.188	0.493±0.281	0.14	0.09	0.56	0.36
14 : 04-15 : 02	14 : 33	2.00	45	0.477±0.237	0.679±0.270	0.42	-0.14	0.84	-0.28
16 : 03-17 : 03	16 : 33	4.07	83	0.964±0.278	0.314±0.148	0.08	0.02	0.36	0.10
20 : 07-21 : 06	20 : 37	3.92	90	0.598±0.211	0.319±0.125	0.02	-0.02	0.11	-0.08
00 : 04-01 : 00	00 : 32	4.07	80	0.311±0.165	0.160±0.081	-0.03	-0.03	-0.12	-0.13
				0.038	0.000				
16≦BL<28cm									
04 : 06-05 : 06	04 : 36	1.90	33	0.005±0.010	0.397±0.214	0.06	-0.05	0.12	-0.09
06 : 01-07 : 01	06 : 30	2.07	28	0.103±0.139	0.251±0.201	0.02	0.04	0.04	0.09
08 : 04-09 : 03	08 : 34	2.00	33	0.099±0.084	0.301±0.153	-0.00	0.04	-0.00	0.09
10 : 04-11 : 03	10 : 34	3.98	39	0.061±0.079	0.343±0.183	0.06	0.06	0.24	0.23
14 : 04-15 : 02	14 : 33	2.00	58	0.183±0.185	0.460±0.188	0.58	0.01	1.17	0.03
16 : 03-17 : 03	16 : 33	4.07	36	1.046±0.692	0.430±0.235	-0.01	0.15	-0.06	0.62
20 : 07-21 : 06	20 : 37	3.92	43	0.352±0.316	0.855±0.274	-0.02	-0.03	-0.09	-0.15
00 : 04-01 : 00	00 : 32	4.07	39	0.076±0.094	0.499±0.236	-0.00	0.00	-0.03	0.03
				0.005	0.397				

$$C_t = \frac{(S_t - S_o\ exp\ (-Rt))\ Rt}{1 - exp\ (-Rt)} \qquad (5)$$

To apply the model, fish samples should be collected from the field at an interval within 3 hours for at least 24 hours, and mean stomach content weight (SCWI) is used to estimate S_o and S_t for each time interval. The positive values of estimated C_t for each time interval during 24 hours are then summed to give the daily ration. As in September, 1982 and June, 1983, where the last values of SCWI for 24 hours were not present, the first values of data were used instead of those values. These values were calculated for each prey group, pisces and crustacea.

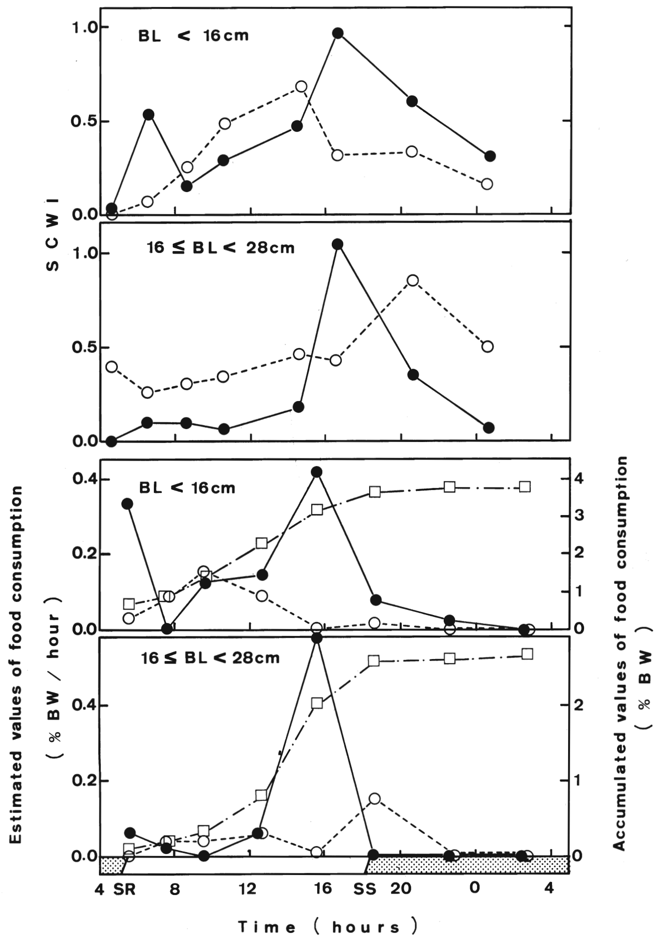

Fig. 7. Diel changes of stomach content weight index (SCWI), food consumption per hour and accumulated food consumption (□) by body size classes, BL<16cm and 16≦BL<28cm, of the flounder.
Pisces (●), crustacea (○). Shaded part : night. SR : sunrise, SS : sunset. Marks were plotted at the mid point of each successive sampling time except SCWI.

Table 5. Number of fish caught, stomach content weight index (SCWI, mean±95% confidence limit) and estimated food consumption of the flounder.

Time	Inter-mediate time	Time interval (hour)	No. of fish examined	SCWI mean ±95%C.L., %BW		Estimated food consumption /hour (%BW)		Estimated food consumption (%BW)	
				Pisces	Crustacea	Pisces	Crustacea	Pisces	Crustacea
Feb. 28–Mar. 1,	1985			R=0.0535	R=0.0171				
04 : 06–05 : 07	04 : 37	2. 95	7	0. 006±0. 010	0. 110±0. 133	0. 17	-0. 03	0. 52	-0. 10
07 : 03–08 : 05	07 : 34	2. 95	16	0. 488±0. 490	0. 000±0. 000	0. 13	0. 02	0. 40	0. 07
10 : 10–10 : 52	10 : 31	2. 87	29	0. 789±0. 466	0. 070±0. 105	-0. 02	0. 02	-0. 06	0. 07
13 : 03–13 : 43	13 : 23	3. 07	24	0. 619±0. 508	0. 136±0. 145	-0. 07	-0. 04	-0. 21	-0. 12
16 : 06–16 : 48	16 : 27	3. 02	7	0. 324±0. 588	0. 009±1. 683	0. 04	-0. 00	0. 12	-0. 00
19 : 07–19 : 48	19 : 28	3. 07	8	0. 393±0. 418	0. 000±0. 000	-0. 00	0. 01	-0. 01	0. 03
22 : 10–22 : 54	22 : 32	2. 90	10	0. 323±0. 462	0. 030±0. 055	0. 10	-0. 01	0. 30	-0. 02
01 : 02–01 : 50	01 : 26	3. 25	12	0. 559±0. 615	0. 000±0. 000	-0. 15	0. 00	-0. 51	0. 00
04 : 17–05 : 05	04 : 41		2	0. 000±0. 000	0. 000±0. 000				
Mar. 20–21,	1985			R=0.0535	F=0.0171				
10 : 03–10 : 41	10 : 22	3. 22	37	2. 287±1. 012	0. 283±0. 143	0. 15	-0. 05	0. 48	-0. 17
13 : 06–14 : 03	13 : 35	2. 97	48	2. 371±0. 955	0. 102±0. 096	0. 20	0. 01	0. 61	0. 04
16 : 04–17 : 02	16 : 33	2. 95	49	2. 589±0. 872	0. 138±0. 093	0. 36	0. 03	1. 07	0. 10
19 : 00–20 : 00	19 : 30	3. 03	20	3. 209±1. 573	0. 238±0. 216	-0. 11	0. 07	-0. 34	0. 23
22 : 04–22 : 59	22 : 32	3. 00	22	2. 412±1. 011	0. 457±0. 332	0. 03	-0. 06	0. 11	-0. 19
01 : 02–02 : 02	01 : 32	3. 03	36	2. 157±0. 806	0. 243±0. 144	0. 04	-0. 05	0. 12	-0. 17
04 : 06–05 : 02	04 : 34	3. 02	15	1. 951±1. 141	0. 063±0. 074	-0. 13	0. 01	-0. 39	0. 05
07 : 07–08 : 02	07 : 35	2. 92	86	1. 296±0. 484	0. 111±0. 069	-0. 08	-0. 00	-0. 25	-0. 02
10 : 00–10 : 59	10 : 30		42	0. 875±0. 491	0. 081±0. 086				
June 24–25,	1983			R=0.1067	R=0.0341				
03 : 59–05 : 01	04 : 30	2. 15	61	0. 588±0. 299	0. 237±0. 195	0. 14	0. 02	0. 30	0. 04
06 : 09–07 : 09	06 : 39	2. 08	45	0. 742±0. 378	0. 266±0. 240	-0. 00	0. 10	-0. 00	0. 20
08 : 13–09 : 14	08 : 44	1. 78	37	0. 587±0. 386	0. 450±0. 257	0. 94	-0. 18	1. 68	-0. 33
10 : 02–10 : 59	10 : 31	1. 90	27	2. 019±0. 976	0. 099±0. 110	-0. 28	0. 07	-0. 53	0. 15
11 : 55–12 : 55	12 : 25	2. 07	19	1. 160±0. 891	0. 239±0. 223	-0. 31	0. 00	-0. 65	0. 00
14 : 00–14 : 58	14 : 29	2. 07	24	0. 343±0. 257	0. 229±0. 187	0. 08	0. 18	0. 18	0. 38
16 : 04–17 : 02	16 : 33	1. 95	56	0. 438±0. 259	0. 587±0. 198	0. 17	-0. 21	0. 34	-0. 41
18 : 00–19 : 00	18 : 30	2. 08	47	0. 667±0. 460	0. 147±0. 120	0. 15	0. 03	0. 32	0. 06
20 : 06–21 : 04	20 : 35	1. 92	72	0. 824±0. 399	0. 198±0. 120	-0. 23	0. 11	-0. 45	0. 21
22 : 00–23 : 00	22 : 30	2. 00	121	0. 262±0. 160	0. 392±0. 166	0. 07	-0. 08	0. 15	-0. 17
00 : 00–01 : 00	00 : 30	2. 00	170	0. 353±0. 142	0. 196±0. 075	0. 08	0. 04	0. 16	0. 08
02 : 00–03 : 00	02 : 30	2. 00	100	0. 434±0. 232	0. 268±0. 111	0. 13	-0. 00	0. 26	-0. 01
				0. 588	0. 237				
July 6–7,	1984			R=0.0984	R=0.0315				
04 : 04–05 : 03	04 : 34	3. 02	20	0. 854±0. 748	0. 062±0. 080	0. 24	0. 01	0. 73	0. 04
07 : 05–08 : 04	07 : 35	4. 25	17	1. 267±1. 128	0. 097±0. 104	-0. 01	0. 07	-0. 08	0. 29
11 : 20–12 : 20	11 : 50	1. 93	18	0. 767±0. 733	0. 365±0. 346	-0. 36	-0. 18	-0. 69	-0. 35
13 : 16–14 : 17	13 : 46	2. 82	11	0. 000±0. 000	0. 000±0. 000	0. 11	0. 00	0. 31	0. 00
16 : 05–17 : 04	16 : 35	2. 97	16	0. 277±0. 163	0. 000±0. 000	0. 30	0. 01	0. 90	0. 03
19 : 03–20 : 03	19 : 33	3. 23	38	0. 989±0. 695	0. 038±0. 033	-0. 15	0. 00	-0. 50	0. 03
22 : 16 23 : 18	22 : 47	2. 82	31	0. 286±0. 227	0. 064±0. 067	0. 05	0. 05	0. 14	0. 16
01 : 08–02 : 04	01 : 36	2. 92	28	0. 344±0. 214	0. 213±0. 191	0. 31	-0. 00	0. 90	-0. 00
03 : 58–05 : 05	04 : 31		45	1. 048±0. 484	0. 188±0. 106				
Sept. 7–8,	1982			R=0.2386	R=0.0764				
04 : 06–05 : 06	04 : 36	1. 90	61	0. 020±0. 023	0. 233±0. 129	0. 16	-0. 01	0. 32	-0. 03
06 : 01–07 : 01	06 : 30	2. 07	53	0. 272±0. 351	0. 171±0. 117	-0. 00	0. 05	-0. 01	0. 12
08 : 04–09 : 03	08 : 34	2. 00	78	0. 156±0. 088	0. 260±0. 116	0. 04	0. 10	0. 09	0. 20
10 : 04–11 : 03	10 : 34	3. 98	76	0. 171±0. 102	0. 417±0. 164	0. 09	0. 07	0. 37	0. 28
14 : 04–15 : 02	14 : 33	2. 00	104	0. 309±0. 148	0. 550±0. 159	0. 47	-0. 07	0. 95	-0. 14
16 : 03–17 : 03	16 : 33	4. 07	124	0. 952±0. 276	0. 335±0. 121	0. 05	0. 06	0. 23	0. 28
20 : 07–21 : 06	20 : 37	3. 92	135	0. 511±0. 174	0. 487±0. 128	0. 01	-0. 02	0. 05	-0. 10
00 : 04–01 : 00	00 : 32	4. 07	121	0. 238±0. 115	0. 268±0. 097	-0. 02	0. 01	-0. 10	0. 04
				0. 020	0. 233				
Nov. 10–11,	1984			R=0.1524	R=0.0488				
07 : 03–08 : 02	07 : 33	2. 73	180	0. 133±0. 099	0. 024±0. 020	0. 01	0. 00	0. 04	0. 00
09 : 56–10 : 37	10 : 17	3. 10	95	0. 121±0. 085	0. 023±0. 023	0. 09	0. 00	0. 29	0. 02
13 : 04–13 : 42	13 : 23	2. 97	58	0. 309±0. 306	0. 045±0. 039	-0. 06	0. 00	-0. 18	0. 00
16 : 01–16 : 41	16 : 21	3. 05	146	0. 044±0. 042	0. 044±0. 042	0. 04	0. 02	0. 13	0. 07
19 : 05–19 : 43	19 : 24	2. 97	91	0. 134±0. 161	0. 107±0. 082	0. 17	-0. 00	0. 52	-0. 00
22 : 01–22 : 42	22 : 22	3. 08	93	0. 510±0. 313	0. 089±0. 076	-0. 05	-0. 01	-0. 15	-0. 05
01 : 08–01 : 46	01 : 27	3. 00	73	0. 195±0. 188	0. 021±0. 024	0. 08	-0. 00	0. 26	-0. 01
04 : 05–04 : 48	04 : 27	2. 98	80	0. 338±0. 074	0. 002±0. 003	-0. 00	0. 00	-0. 02	0. 00
07 : 04–07 : 47	07 : 26		57	0. 191±0. 143	0. 008±0. 010				

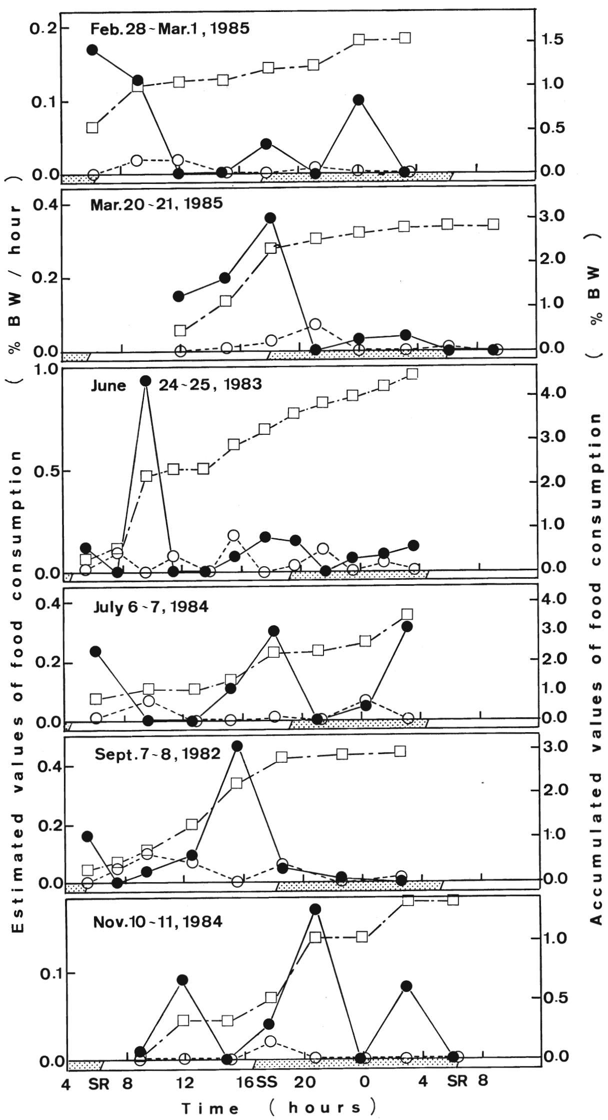

Fig. 8. Diel changes of food consumption per hour and accumulated food consumption (□) of the flounder. Pisces (●), crustacea (○). Shaded part : night. SR : sunrise, SS : sunset. Marks were plotted at the midpoint of each successive sampling time.

In order to examine the size-dependent differences of feeding habits, diel changes of SCWI, food consumption per unit time (hour) and accumulated food consumption for the data of September, 1982, were divided into two size groups, S-group (BL<16cm) and M-group (16≦BL<28cm) are shown in Table 4. and Fig. 7. The S-group was considered to be 0-year, and the M-group to be 1-year. The values of SCWI increased sharply at dawn and dusk (M-group) for pisces, at 14 : 00 (S-group) and at 20:00 (M–group) for crustacea. The values of food consumption per hour peaked twice, 0.33%BW/h at dawn, 0.39%BW/h at 15:00 (S-group) and sharply peaked, 0.56%BW/h at 15 : 00 (M–group) for pisces. Whereas the peak (0.15%BW/

h) was observed at 10:00 (S-group), the values were relatively low (0.04-0.06%BW/h) in the day and peaked (0.15%BW/h) at dawn (M-group) for crustacea. The values of summed (pisces and crustacea) accumulated food consumption increased sharply in the early morning and increased gradually in the day and almost constant at night for the S-group, and increased sharply from 15:00 to dusk and were constant at night for the M-group. Daily rations were 2.50%BW (pisces), 1.03%BW (crustacea) and the summed 3.53%BW for the S-group, and 1.51%BW (pisces), 1.11%BW (crustacea) and the summed 2.62%BW for the M-group. Whereas the daily ration of pisces of the S-group was larger than that of the M-group, those of crustacea were not different between the two size groups.

The values of food consumption per hour and accumulated food consumption of pisces and crustacea are shown in Table 5. and Fig. 8. The values of food consumption per hour of pisces often peaked at dawn and dusk, whereas the values of crustacea were relatively low without distinct peaks. The increasing tendencies of

Table 6. Daily rations and liver weight index (LWI, mean±95% confidence limit) of the flounder.

Date		Daily ration (%BW)			LWI (mean±95%C. L.)
		Pisces	Crustacea	Total	
Feb. 28–Mar. 1,	1985	1.34	0.17	1.51	1.047±0.049
Mar. 20–21,	1985	2.39	0.42	2.81	1.382±0.038
June 24–25,	1983	3.39	1.12	4.51	0.786±0.012
July 6–7,	1984	2.98	0.55	3.53	1.026±0.040
Sept. 7–8,	1982	2.01	0.92	2.93	0.732±0.024
Nov. 10–11,	1984	1.24	0.09	1.33	0.685±0.012

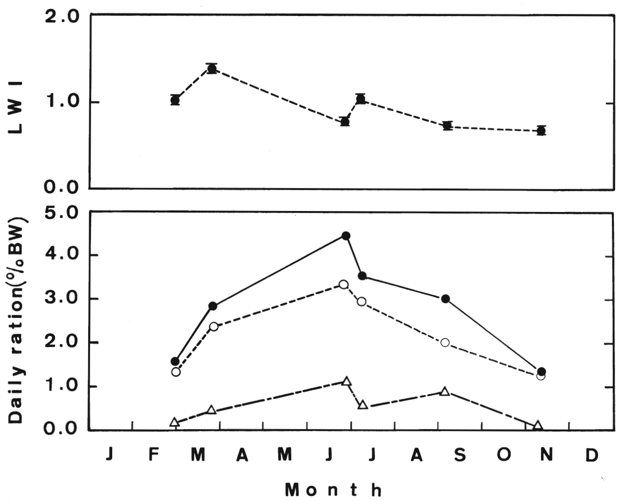

Fig. 9. Seasonal changes of daily ration and liver weight index (LWI) of the flounder. Pisces (○), crustacea (△) and the summed (●). Bars indicate 95% confidence limits.

accumulated food consumption were divided into two groups, one that showed an increase in the day but not at night (March, July and September), another showed apparent increases in the day and at night (February, June and November).

The seasonal changes of daily ration and liver weight index (LWI) are shown in Table 6. and Fig. 9. The values of daily ration, sum of pisces and crustacea, increased from February (1.51% BW/d), to March (2.81%BW/d), and peaked in June (4.51%BW/d) and then declined in July (3.53% BW/d), September (2.93% BW/d) and November (1.33% BW/d). The seasonal change of pisces values was similar to that of the sum, whereas that of crustacea peaked in June and September. The values of LWI slightly increased from February to March, declined in June, increased in July and then declined until November.

Discussion

Application of E*LLIOTT and* P*ERSSON's (*M*ORISHITA's) model*

In application of this model, the following two conditions must be satisfied (Morishita 1972),

(i) a constant gastric evacuation rate

(ii) a constant instantaneous food consumption within the defined time intervals.

Condition (i) was considered to be satisfied because of the high correlation coefficients (see Fig. 5., r=0.94 (pisces), r=0.98 (crustacea)) between SCWI and time. Elliott and Persson (1978) proposed that condition (ii) would be satisfied by reducing the sampling time interval within 3 hours for many fish species. In the present surveys, though the intervals were sometimes over 3 hours, this condition was satisfied.

The model also required such data as mean stomach content weight for more than 24 hours and *R* values according to prey groups. Though the number of samples per tow should be greater to minimize sampling errors, such are few species where a large number of samles can be obtained in a short period. Though the present surveys were aimed at the nursery grounds where 0-1 year *P. olivaceus* were distributed densely, in some cases only insufficient numbers of samples per tow were obtained because of the poor year-class strength of recruitment.

The values of *R* should be confirmed by laboratory rearing experiment, but in cases where the fish is difficult to rear or appropriate prey items cannot be obtained, other methods should be attempted. In the present study, rearing experiments on board was carried out with wild fish. As the *R* value of pisces could not have been obtained by the experiment, it was estimated from the data of 24-hr survey (at night, March, 1985) based on the assumption that no feeding activities had occurred during the night. Although the *R* values of pisces were greater than those of crustacea as introduced by Durbin et al. (1983), in the *P. olivaceus* laboratory rearing experiment by using fish (anchovy, *Engraulis Japonica*) and thawed crustacea (shrimp, *Euphausia* *pacifica*), the crustacea was evacuated faster than the fish (KOSHIISHI personal communication). It should be identified by accumulating experimental data.

The values of food consumption sometimes appeared to be negative. DURBIN et al. (1983) considered that those negative values were caused when the decline in the amount of food in stomach from one period to the next was greater than that predicted from the evacuation rate used in the calculation, and they summed the amount of food ingested during each period, including negative values, to obtain the daily ration. In this report, daily rations were obtained by summing positive values without negative ones. For this reason, the daily rations in this report may be overestimated in comparison with theirs. Further studies will be needed to treat negative values.

In conclusion, although this model largely depends on the reliability of the parameters available, it will still be a valid method to estimate the daily ration if the condition is appropriate.

Feeding habits and stomach content weight

Although *P. olivaceus* is piscivorous, crustacea is also ingested in some conditions. The cephalopoda group is considered to be an incidental prey for the fish. The present area was considered to be nursery grounds for young *P. olivacevs* because the main age groups were 0- or 1-year (NASHIDA et al. in press).

The proportion of crustacea in the stomach content weight increased from early summer to autum. In these seasons, 0-year fish settled in shallower water than 10m depth began to disperse offshore, and the percentage of 0-year in the populations became highest in all seasons. Though an assumption that the percentage weight of crustacea increased because 0-year fish, that could not catch fast-moving pisces, prevailed in the population may be considered, it would not be acceptable because of the high percentage weight of crustacea in the stomach contents before 0-year fish recruitment (June, 1985) or in the time when few 0-year fish were recruited (September, 1985). It would be a more realistic assumption that crustacea groups were eaten because small pisces had decreased. A survey of seasonal changes of composition of *benthos* is going on in the present area.

Feeding periodicity

The two peaks were commonly observed at dawn and dusk in pisces consumption, whereas no clear peaks were observed in crustacea. Although there was some evidence of feeding at night, *P. olivaceus* is considered to be a diurnal feeder. When the authors observed the diel rhythms of organisms near the bottom layer at 19m depth in Ryotsu Bay in October, 1985, using an underwater video camera system installed in an autovehicle robot, small shrimps and fish were observed moving around near the bottom at dusk. SUDO (1984) reported the diet of young red sea bream, *Pagrus major*, and that mysidacea species in the diet can be divided by their life styles and the composition in the stomach contents is correlated with the diel changes of their availabilities to the fish. The peaks of SCWI observed at dawn and dusk are considered to be the combined results of diel rhythm in the activities and hungriness of *P. olivaceus*, of diel rhythms in prey activities, and of light intensity.

Daily ration

There were no marked differences between the feeding periodicities and daily rations due to body size (see Table 4., Fig. 7). From these results, large errors might not be introduced even if daily rations were calculated without dividing body size groups in the present study.

The values of the daily ration increased from early spring to June and then decreased until winter (see Fig. 8.) whereas those of SCWI were highest in winter, decreased from early spring to summer and were lowest from summer to autumn. It was the result of apparently high values of SCWI because food items were staying in the stomach for longer periods at lower temperatures. It is a good case that the daily ration is a better index of feeding intensity than SCWI. The relationship between population density and feeding condition of *P. olivaceus* by year were not considered in the present study. Those should be considered in future studies.

The value of LWI is considered to be an index of nutritive condition (Tominaga and Maeda 1984) and of energetic balance. The result of low LWI value in spite of vigorous feeding activity in June may suggest the possibility that an increase of energy income were devoted to growth, increases of motion and basal metabolism as the water temperature rose.

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新潟県北部沿岸域における底生魚類の群集構造

II. ヒラメ若齢魚の摂餌生態と日間摂餌量の季節変化

梨田一也・富永　修

1981–86年にかけて，新潟県北部沿岸域において採集されたヒラメ若齢魚を用いて，胃内容物組成，摂餌日周期性および日間摂餌量の季節変化を調べた。日間摂餌量の推定には，ELLIOTT and PERSSON（1978；森下1972）のモデルを用いた。このモデルを適用するためには，24時間以上にわたり3時間ごとにサンプル採集を行い平均胃内容物重量を求め，絶食試験等により胃外排出速度（R）を求めなければならない。本報告では，野外におけるデータを用いて，ヒラメの主要な餌となっている魚類および甲殻類の各分類群について，それぞれRを推定した。推定された日間摂餌量の最大値および最小値は，それぞれ4.51% BW（6月）および1.33% BW（11月）であった。