



Title	A Comparative Study on the Lipid Class Composition and the Fatty Acid Composition of Sweet Smelt, <i>Plecoglossus altivelis</i> , from Marine and Fresh-Water Habitat
Author(s)	OTA, Toru; TAKAGI, Toru
Citation	北海道大學水産學部研究彙報, 28(1), 47-56
Issue Date	1977-04
Doc URL	<a href="http://hdl.handle.net/2115/23604">http://hdl.handle.net/2115/23604</a>
Type	bulletin (article)
File Information	28(1)_P47-56.pdf



[Instructions for use](#)

## A Comparative Study on the Lipid Class Composition and the Fatty Acid Composition of Sweet Smelt, *Plecoglossus altivelis*, from Marine and Fresh-Water Habitat

Toru Ota\* and Toru Takagi\*

### Abstract

The lipid class composition and the fatty acid composition of lipid classes of sweet smelt, *Plecoglossus altivelis*, caught from different habitats were determined by column chromatography and gas-liquid chromatography.

The lipid contents in the flesh of young sweet smelt obtained from the sea and the lake were 1.7% and 2.4% respectively. On the contrary, those of the river sweet smelt caught in June were 5.4% in male and 4.6% in female, and furthermore, decreased to 1% in the spawning season. The content of cholesteryl esters in the flesh lipids of young fish had a high level compared with that of the adult fish from the river. The triglyceride content of the adult fish in June was more than that of the young fish, but decreased in the spawning season. In the fatty acid composition of triglyceride fraction in flesh lipids, those of the young fish had relatively high contents of 20:5 $\omega$ 3 and 22:6 $\omega$ 3, whereas those of the river-caught adult fish were characterized by relatively high amounts of C<sub>18</sub> polyunsaturated acids.

The comparison of the fatty acids of neutral lipids in each organ between male and female fish in the spawning season indicated slightly higher contents of 16:1, 18:1, 20:5 $\omega$ 3 and 22:6 $\omega$ 3 in the female.

From the fatty acid analyses, it was suggested that there are differences in the feeding behavior and the activity in connection with sexual maturation between male and female fish in the spawning season.

### Introduction

Few studies on the lipids of sweet smelt, *Plecoglossus altivelis*, have been published. Shimma and Taguchi<sup>1)</sup> reported the differences in the fatty acid composition between wild and cultivated sweet smelt lipids. They observed that in the dorsal muscle triglycerides of the wild fish, a sum of C<sub>14</sub> and C<sub>16</sub> acids reached more than 50% of the composition, while the cultivated fish had around 40%. Ota and Yamada<sup>2)</sup> revealed that the fatty acids of the flesh lipids of the wild sweet smelt contained more C<sub>18</sub> unsaturated acids compared with those of three other fresh-water fish lipids examined, and were very similar to those of algae which are the major diet of sweet smelt.

It is well known that the fatty acid composition in fish lipids is largely dependent on environmental conditions<sup>3-6)</sup>. Thus, sweet smelt living in some different habitats may have the characteristic lipid constitution reflected by the environmental factors to some degree; furthermore, it is estimated that the

\* Laboratory of Chemistry of Fish Oil, Faculty of Fisheries, Hokkaido University  
(北海道大学水産学部魚油化学講座)

Table 1. *Biological characteristics and lipid content of sweet smelt.*

Habitat	Date of catch	Sex* <sup>1</sup>	Number of fish sampled	Body length (cm)	Body weight (g)	H.I.* <sup>2</sup>	G.I.* <sup>3</sup>	Lipid content (%)		
								Flesh	Liver	Gonad
Sea (Coast of Himi)	Apr. 4, '72	M.F	23	7.5	4.6	1.4	—	1.7	16.3	—
Lake (Lake Biwa)	May 12, '72	M.F	20	7.7	4.8	1.4	—	2.4	13.3	—
River (River Jinzu)	June 29, '72	M	5	15.7	57.5	1.2	—	5.4	9.4	—
		F	5	15.9	60.5	1.4	—	4.6	9.0	—
	Aug. 11, '71	M	4	14.9	54.9	1.5	—	4.0	4.7	—
		F	1	17.0	76.7	1.7	—	2.9	3.8	—
	Sept. 21, '71	M	2	17.4	73.8	0.5	8.6	3.4	4.8	4.4
		F	3	17.8	70.8	2.2	12.8	2.8	4.0	4.2
	Sept. 28, '72	M	2	18.3	80.0	0.7	5.8	2.1	5.0	2.8
		F	2	17.5	93.0	1.5	26.3	2.9	3.1	6.9
	Oct. 12, '72	M	5	18.8	88.3	0.9	7.1	3.1	3.6	2.3
		F	5	17.2	65.3	3.9	15.3	2.4	3.7	6.8
Oct. 29, '73	M	5	13.1	25.4	1.0	4.5	1.0	3.1	2.2	
	F	6	14.4	35.1	2.9	13.9	1.0	3.0	4.1	

\*<sup>1</sup> M-Male, F-Female\*<sup>2</sup> Hepatosomatic index (Liver weight  $\times$  100/Body weight)\*<sup>3</sup> Gonadosomatic index (Gonad weight  $\times$  100/Body weight)

changes in the lipid components occur during the life cycle.

In the present paper, the lipid contents, the lipid class composition and the fatty acid composition of each organ of sweet smelt collected at sea, in a lake and in a river were investigated in order to clarify the characteristic of lipid composition.

### Materials and Methods

*Materials* The sweet smelt used in the experiments were collected along the coast of Himi, in River Jinzu in Toyama Prefecture and in Lake Biwa in Shiga Prefecture. The fish obtained from the sea and the lake were both young fish, while the fish collected from the river were adult fish. The date of catch, the number of fish sampled and the biological characteristics of sweet smelt are shown in Table 1.

*Lipid extraction* Lipids in the tissues were extracted according to the method of Bligh and Dyer<sup>7)</sup>.

*Column chromatography (CC) and thin-layer chromatography (TLC)* The lipids were separated by silicic acid-celite 545 (2:1 W/W) CC using chloroform and methanol into neutral lipids and phospholipids. Neutral lipids were subjected to CC on silicic acid (Kanto Chemical Co. 100 mesh) as described in a previous paper<sup>8)</sup>. The incomplete portions of fractionation by CC were further separated and purified

preparative TLC (Wakogel B-10, thickness 0.5 mm) with the solvent system of n-hexane: ethyl ether: acetic acid (70:30:1 V/V).

*Gas-liquid chromatography (GLC)* GLC was carried out on a Yanagimoto G80 gas chromatograph equipped with a hydrogen flame ionization detector. Two columns (75 cm in length, 3 mm i.d. glass and 30 cm in length, 3 mm i.d. stainless steel) packed with 2% OV-17 on Chromosorb W AW DMCS (80-100 mesh) were used for hydrocarbon, steryl ester and sterol analyses. The column temperature was programmed from 160°C to 220°C at 4°C/min for the analysis of hydrocarbons, from 240°C to 330°C at 4°C/min for the analysis of steryl esters, and it was maintained at 240°C for the analysis of sterols as acetates. The peaks were identified by comparison with standards (e.g. pristane, squalene and cholesteryl C<sub>14</sub>-C<sub>20</sub> esters). The fatty acids from each lipid class were esterified with boron trifluoride-methanol reagent or diazomethane in ether.

Two glass columns (150 cm in length, 3 mm i.d.) were packed one with 10% diethylene glycol succinate (DEGS) on Chromosorb W AW (80-100mesh) and the other with 5% DEGS on Chromosorb W AW DMCS (100-120mesh) for the analysis of fatty acid methyl esters.

The column temperature was maintained at 185°C. The identification of the peaks was made by the comparison with standards and by the semilog-plot procedure. The fatty acid composition was calculated from the peak areas determined by the halfband width method. The column packed with 5% DEGS was well suited for the separation of C<sub>16</sub> polyunsaturated methyl esters.

## Results and Discussion

*Lipid content* The lipid contents in the liver, gonad and flesh of sweet smelt are summarized in Table 1. The lipid contents in the flesh of young fish from the sea and the lake were 1.7% and 2.4% respectively; on the contrary, the lipid contents in the flesh of the fish caught in the river in June were 5.4% in the male and 4.6% in the female, but decreased to ca. 1% at the stage of sexual maturation. The liver contained more lipids than the flesh; the lipid contents of the liver of the young fish were especially higher compared with those of the adult fish. The difference in lipid content between the male and the female was not clear in both flesh and liver.

The seasonal changes of the lipids in the flesh of fish have been examined by several investigators<sup>9-11</sup>). Wada<sup>12</sup>) revealed that the decrease of the lipids in the flesh, liver and head of the lean sardine was related to the sexual maturation. Takashima et al.<sup>13</sup>) observed that in the maturing female rainbow trout, the level of lipid content in the viscera was lower compared to the immature one. Consequently, it is estimated that the decrease in the lipid content of the liver and flesh of sweet smelt in the spawning season is related to starvation, the lipid being used as source of energy for maturation.

*Lipid class composition* The lipid class composition in the lipids of the flesh and ovary of the female sweet smelt are shown in Table 2. From GLC analyses, it was recognized that in hydrocarbons, squalene was a major component and pristane was particularly detected as a minor component in the lipids of the young fish

Table 2. Lipid class composition of the flesh and ovary lipids of sweet smelt (as % of the total lipids).

Lipid class	Habitat		River			
	Sea	Lake	Flesh			Ovary
	Apr. 4	May 12	June 29*	Sept. 28*	Oct. 29*	Oct. 29
Hydrocarbons	0.2	0.6	0.3	0.3	0.5	1.0
Steryl esters	2.2	2.7	0.6	0.4	1.0	2.9
Triglycerides	17.8	35.7	75.1	71.6	19.0	47.9
Diglycerides	3.2	3.7	2.8	2.4	1.0	2.8
Free fatty acids	24.3	29.3	3.3	6.8	17.4	6.0
Sterols	4.7	4.4	1.6	2.4	8.0	6.0
Phospholipids	42.6	20.7	14.9	14.6	51.5	31.5
Unknowns**	5.0	2.8	1.4	1.5	1.6	1.9

\* Female flesh lipids were used for the experiments.

\*\* Monoglycerides may be present.

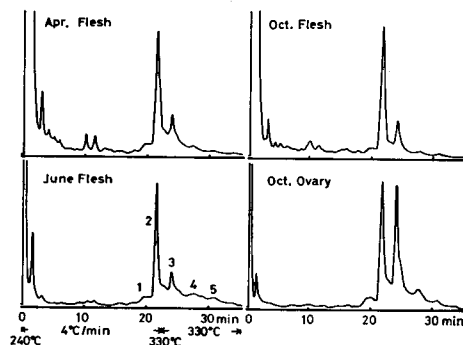


Fig. 1. Gas liquid chromatogram of cholesteryl esters in the flesh and ovary lipids of sweet smelt.

1-Cholesteryl  $C_{14}$  ester, 2-Cholesteryl  $C_{16}$  ester, 3-Cholesteryl  $C_{18}$  ester,  
 4-Cholesteryl  $C_{20}$  ester, 5-Cholesteryl  $C_{22}$  ester

caught from the sea. Sterol in steryl esters and free sterol was almost cholesterol. Cholesteryl esters were composed of the  $C_{14}$  to  $C_{22}$  esters and cholesteryl  $C_{16}$  ester was the major component as shown in Fig. 1. Such results were slightly similar to the results obtained by Ikekawa et al.<sup>14)</sup> The cholesteryl ester pattern of the young fish from the lake was similar to that of the fish from the sea and the river. The cholesteryl esters of the ovary contained more  $C_{18}$  and  $C_{20}$  esters than those of the flesh lipids. The comparison of the lipid classes of the flesh indicated a higher content of cholesteryl esters in the young fish compared with the adult fish.

Shimma and Taguchi<sup>15)</sup> observed that the cholesterol content in the dorsal flesh lipids was higher in the fresh-water and brackish water fish than in the marine fish; they<sup>1)</sup> also observed that the free cholesterol contents of the flesh lipids of the wild sweet smelt were 41.0 mg/100 g of flesh in the male and 33.4 mg/100 g in the female. In this investigation, the cholesterol contents in the flesh lipids

were slightly higher than the values reported by Shimma and Taguchi. Especially, the flesh lipids of the young fish from the lake had high cholesterol contents (65 mg in cholesteryl esters and 106 mg in free cholesterol) compared with those of the other two groups from the sea and the river.

Comparing the lipid class composition of the young fish with that of the adult fish in June, it is clear that the former contained more free fatty acids and less triglycerides. These results suggest that the lipid metabolism in the young fish is more vigorous and the rate of lipolysis is larger than in the adult fish.

In the spawning season, a pronounced reduction of triglycerides in the flesh lipids was recognized. On the other hand, the levels of triglycerides and cholesteryl esters in the ovary lipids were higher than those in the flesh lipids. Takashima et al.<sup>13)</sup> observed that in the maturing female rainbow trout, the contents of free fatty acids and of triglycerides in the liver as well as the plasma were larger, while triglycerides in the visceral adipose tissue and phospholipids in the liver decreased. From these results, they estimated that the stored lipids were moved into the liver and then extruded into the blood in form of lipoprotein, and transported to the ovary. Watanabe and Ando<sup>16)</sup> studied the changes of cholesterol in the egg of the rainbow trout during its development and suggested that the cholesteryl ester played an important role in the fat metabolism in the development of the egg. In this investigation, the differences in lipid class composition between the flesh and the ovary were recognized clearly. Hence, it was considered that in the spawning season the consumption and the transportation of stored lipids in the tissue occurred. The high concentration of cholesteryl esters in the flesh lipids of the young fish and in the ovary lipids may be correlated with the transfer of the lipid component in the lipid metabolism of the fish.

*Fatty acid composition* The comparison of the fatty acid composition among various lipid classes of flesh lipids indicated that triglycerides were rich in 14:0 and 16:1, while phospholipids were rich in 18:1 and low in C<sub>18</sub> polyunsaturated acids (Table 3). The composition of free fatty acids was partially similar to that of triglycerides, showing a slightly higher level of C<sub>18</sub> polyunsaturated acids. Generally, free fatty acids of the flesh are believed to arise from hydrolysis of phospholipids<sup>17)</sup>, but the composition of free fatty acids in this investigation was not necessarily the same as that of phospholipids. Consequently, this fraction may be derived not only from the hydrolysis of phospholipids but also from the lipolysis of triglycerides. The triglycerides of the young fish collected from the sea and the lake contained more 18:4 $\omega$ 3, 20:5 $\omega$ 3 and 22:6 $\omega$ 3 as compared with that of the river-caught adult fish. Especially in the triglycerides of the fish from the sea, a high percentage (12.1%) of 22:6 $\omega$ 3 was determined; furthermore the ratios of  $\omega$ 3 to  $\omega$ 6 acids and (18:2+18:3) to the total of polyunsaturated acids were 6.9 and 0.2 respectively. These values are typical of marine fish lipids<sup>18)19)</sup>. On the other hand, in the river-caught fish a relatively high amount of C<sub>16</sub> polyunsaturated acids as compared with the fatty acid composition of the fresh-water fish lipids<sup>2)</sup> was determined. It is estimated that the relatively high contents of C<sub>16</sub> polyunsaturated acids depend largely upon the dietary fatty acids as described in a previous paper<sup>2)</sup>.

As we compared the fatty acid composition in the triglycerides of the ovary lipids with that of the flesh lipids in the spawning season, it was clear that the

Table 3. Fatty acid composition of various lipid classes

Fatty acid	Flesh								
	Apr. 4			May 12			June 29		
	TG* <sup>1</sup>	FFA* <sup>1</sup>	PL* <sup>1</sup>	TG	FFA	PL	TG	FFA	PL
Saturated acids									
12:0	0.2	Tr* <sup>2</sup>	Tr	Tr	Tr	Tr	Tr	Tr	—
14:0	8.0	4.4	2.3	10.0	3.8	8.6	8.5	4.3	3.0
15:0	1.1	1.2	0.7	1.5	0.9	2.1	0.4	0.4	1.0
16:0	21.6	43.5	22.6	18.7	33.2	31.8	28.2	32.0	48.2
17:0	1.2	1.3	1.8	1.4	1.0	3.2	0.9	0.9	1.6
18:0	2.8	3.2* <sup>3</sup>	4.4* <sup>3</sup>	2.9	3.7* <sup>3</sup>	8.1* <sup>3</sup>	1.5	5.9* <sup>3</sup>	7.0* <sup>3</sup>
19:0	—	0.4	—	0.6	0.2	—	—	—	—
Total	34.9	54.0	31.8	35.1	42.8	53.8	39.5	43.5	60.8
Monoenoic acids									
14:1	1.4	0.6	0.3	1.8	0.5	1.5	0.4	0.3	1.0
15:1	0.2	0.6	0.6	0.2	0.2	1.5	0.1	0.3	0.6
16:1	10.0	7.2	3.2	17.0	9.4	11.3	21.9	16.9	6.9
17:1* <sup>4</sup>	0.8	0.8	0.8	1.5	0.8	2.2	3.7	2.5	1.6
18:1	12.8	8.2	9.6	11.5	8.3	18.9	8.9	8.0	13.4
19:1	0.7	0.5	0.4	—	Tr	0.5	0.1	0.3	0.5
20:1	1.1	1.1	0.5	Tr	Tr	Tr	0.1	0.4	0.4
22:1	0.4	Tr	Tr	Tr	Tr	Tr	—	—	—
24:1	Tr	Tr	0.7	—	Tr	—	—	—	—
Total	27.4	19.0	16.1	32.0	19.2	35.9	35.2	28.7	24.4
Polyenoic acids									
16:2 $\omega$ 7	—	—	—	—	—	—	0.6	0.8	—
16:3 $\omega$ 4	—	—	—	—	—	—	5.5	—	—
16:4 $\omega$ 3	—	—	—	—	—	—	1.0	0.8	—
16:4 $\omega$ 1	—	—	—	—	—	—	0.8	0.5	—
18:2 $\omega$ 6	2.8	2.1	0.9	4.3	3.1	1.5	1.7	1.8	1.4
18:3 $\omega$ 6	0.2	Tr	Tr	0.5	0.2	0.2	0.5	0.2	0.6
18:3 $\omega$ 3	3.0	1.8	0.8	5.1	3.9	0.9	6.0	8.5	3.4
18:4 $\omega$ 3	5.1	3.3	1.0	4.3	2.7	0.7	1.1	0.9	Tr
20:2 $\omega$ 6	0.2	—	Tr	0.3	0.2	0.4	Tr	Tr	Tr
20:3 $\omega$ 6	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr
20:4 $\omega$ 6	1.4	1.4	1.3	1.5	2.9	1.3	0.2	0.7	0.5
20:4 $\omega$ 3	1.9	1.7	0.7	1.8	1.3	0.7	0.4	1.0	Tr
20:5 $\omega$ 3	8.2	8.1	10.9	6.3	9.2	1.4	5.1	8.1	5.2
21:5 $\omega$ 2?	1.5	Tr	0.6	—	—	—	—	—	—
22:4 $\omega$ 6	—	—	—	1.3	0.7	—	0.6	0.3	Tr
22:5 $\omega$ 6	—	—	—	1.1	1.3	—	—	—	—
22:5 $\omega$ 3	1.4	Tr	1.5	1.2	1.3	1.1	0.9	1.3	0.9
22:6 $\omega$ 3	12.1	8.6	34.5	5.2	11.3	2.1	0.9	3.0	2.8
Total	37.8	27.0	52.2	32.9	38.1	10.3	25.3	27.9	14.8

\*<sup>1</sup> TG-Triglycerides, FFA-Free fatty acids, PL-Phospholipids\*<sup>2</sup> Trace \*<sup>3</sup> Includes 16:3 $\omega$ 4 \*<sup>4</sup> Includes 16:2 $\omega$ 4

OTA & TAKAGI: Lipids of sweet smelt from different habitats

*in the flesh and ovary lipids of sweet smelt (%)*.

						Ovary		
Sept. 28			Oct. 29			Oct. 29		
TG	FFA	PL	TG	FFA	PL	TG	FFA	PL
0.1	Tr	Tr	0.2	Tr	Tr	0.2	Tr	—
6.4	1.6	1.9	8.7	1.6	1.7	5.4	2.4	3.3
0.6	0.3	0.2	0.8	0.3	0.3	0.7	0.4	0.6
29.0	31.3	23.8	22.4	43.7	24.1	24.7	21.3	43.7
1.4	0.8	0.6	2.0	0.6	1.1	1.0	1.0	1.3
2.6	4.2**	6.4**	2.9	2.9**	7.1**	1.6	2.9	3.9
—	—	—	—	—	0.3	—	—	—
40.1	38.2	32.9	37.0	49.1	34.6	33.6	28.0	52.8
0.9	0.2	0.2	1.3	0.2	0.2	0.6	0.5	0.6
0.1	0.2	0.9	0.1	Tr	0.1	0.1	0.1	0.4
23.8	11.0	5.4	21.4	5.3	5.0	26.9	26.6	11.0
2.4	1.6	0.9	2.9	0.8	0.8	3.6	2.9	1.6
10.5	10.1	12.1	10.4	5.7	14.9	11.9	11.5	11.6
—	0.2	0.2	0.4	0.3	0.3	0.3	0.4	0.3
0.2	0.4	0.5	—	0.2	0.3	0.4	0.4	—
—	—	—	—	—	—	Tr	—	—
—	—	—	—	—	—	—	—	—
37.9	23.7	20.2	36.5	12.5	21.6	43.8	42.4	25.5
0.8	0.3	—	0.9	0.1	—	0.6	0.8	—
2.4	—	—	2.5	—	—	2.6	1.5	—
0.7	0.2	—	0.6	—	—	0.4	0.3	Tr
—	—	—	0.3	—	—	0.6	—	—
3.3	3.8	3.1	3.5	2.2	2.4	1.9	1.8	1.0
0.4	0.2	0.2	0.3	0.2	0.2	0.3	0.3	0.5
7.6	10.6	5.6	10.5	7.7	5.4	6.6	7.0	2.6
0.8	0.7	0.2	0.6	1.0	0.4	1.1	1.0	1.0
0.2	Tr	0.2	0.2	Tr	0.3	—	—	—
Tr	0.5	0.3	0.3	0.3	0.7	0.3	Tr	—
0.5	2.3	3.0	0.7	2.2	3.4	0.7	1.5	1.7
0.3	0.8	0.3	0.6	1.0	1.1	0.7	0.5	Tr
2.9	10.7	8.6	3.2	11.9	11.0	4.7	8.8	6.5
—	—	—	—	—	1.9	—	—	—
Tr	0.4	0.5	0.3	0.1	0.5	—	—	—
—	—	—	—	Tr	—	—	—	—
1.3	2.1	3.9	1.4	3.0	5.1	0.7	1.2	3.0
0.8	5.5	21.0	0.7	8.7	11.5	1.5	4.9	5.4
22.0	38.1	46.9	26.6	38.4	43.9	22.7	29.6	21.7



Table 4. Fatty acid composition of neutral lipids obtained from the flesh, liver, testis and ovary of sweet smelt in the spawning season (%).

Fatty acid	Oct. 29		Oct. 12					
	Flesh				Liver		Testis	Ovary
	M*1	F*1	M	F	M	F		
Saturated acids								
12:0	0.4	0.2	0.2	0.2	0.2	Tr**2	0.4	0.3
14:0	7.7	7.2	7.2	6.8	2.9	2.0	4.0	5.3
15:0	1.0	0.7	0.4	0.3	0.4	0.3	0.5	0.4
16:0	26.2	30.0	33.6	27.6	42.9	35.5	50.2	30.1
17:0	1.3	1.4	0.6	0.4	1.1	0.6	1.1	0.6
18:0	2.8	3.2	5.5*3	5.5*3	5.6*3	3.4*3	4.7*3	3.8*3
Total	39.4	42.7	47.5	40.8	53.1	41.8	60.9	40.5
Monoenoic acids								
14:1	1.3	1.0	0.5	0.5	0.4	Tr	0.5	0.3
15:1	0.2	0.1	Tr	Tr	Tr	Tr	Tr	Tr
16:1	15.1	15.4	25.3	29.0	10.2	17.6	16.6	27.5
17:1*4	2.3	2.0	2.2	3.3	1.2	1.2	1.2	2.9
18:1	6.1	8.2	6.3	6.7	6.2	13.3	9.5	11.1
19:1	0.2	0.2	Tr	Tr	0.5	0.6	Tr	0.4
20:1	0.4	0.2	—	0.2	—	1.7	—	0.5
Total	25.6	27.1	34.3	39.7	18.5	34.4	27.8	42.7
Polyenoic acids								
16:2 $\omega$ 7	0.9	0.7	0.6	Tr	—	—	—	—
16:3 $\omega$ 4	4.3	1.9	—	—	—	—	—	—
16:4 $\omega$ 3	1.2	0.3	0.3	0.6	0.4	Tr	—	—
18:2 $\omega$ 6	3.1	2.8	1.9	1.8	1.2	0.9	0.8	1.4
18:3 $\omega$ 6	0.3	0.3	0.3	0.3	Tr	Tr	—	0.3
18:3 $\omega$ 3	11.5	8.8	6.4	4.6	3.1	1.7	1.1	3.3
18:4 $\omega$ 3	1.0	0.7	0.5	0.4	Tr	Tr	Tr	0.4
20:2 $\omega$ 6	0.1	0.2	Tr	Tr	0.6	Tr	Tr	Tr
20:3 $\omega$ 6	0.2	0.2	Tr	0.2	Tr	Tr	Tr	0.4
20:4 $\omega$ 6	1.4	1.4	0.7	0.8	1.5	1.3	1.1	0.8
20:4 $\omega$ 3	0.7	0.8	Tr	Tr	Tr	Tr	Tr	0.4
20:5 $\omega$ 3	4.9	6.4	4.2	6.5	7.5	6.1	3.6	5.1
22:4 $\omega$ 6	0.7	0.5	Tr	0.6	1.1	Tr	Tr	Tr
22:5 $\omega$ 6	—	—	Tr	Tr	Tr	Tr	Tr	Tr
22:5 $\omega$ 3	1.5	1.7	1.5	1.7	2.5	1.5	2.0	1.3
22:6 $\omega$ 3	3.2	3.5	1.8	2.0	10.6	12.4	2.7	3.3
Total	35.0	30.2	18.2	19.5	28.5	23.9	11.3	16.7

\*1 M-Male, F-Female \*2 Trace \*3 Includes 16:3 $\omega$ 4 \*4 Includes 16:2 $\omega$ 4

former contained more 16:0, 16:1, 18:1 20:5 $\omega$ 3 and 22:6 $\omega$ 3 than the latter. It is suggested that these changes in the fatty acid composition between the flesh and the ovary lipids reflect the influence of the feeding behavior and the transfer of the stored lipids into the ovary.

The fatty acid composition of neutral lipids in the flesh, liver, ovary and testis in the spawning season are shown in Table 4. In each organ, the contents of 16:1, 18:1 20:5 $\omega$ 3 and 22:6 $\omega$ 3 were slightly higher in the female than in those of the male except for 20:5 $\omega$ 3 in the liver.

Kawanabe et al.<sup>20)</sup> and Miyadi<sup>21)</sup> observed the difference in the feeding behavior between male and female sweet smelt in the spawning season; they also observed that the male sweet smelt maintains its sexual activity throughout the spawning season, while the maturation in the females was not constant and the activity to maturation differed with the individual. Such biological characteristics may be closely related to the sexual difference in fatty acid composition. That is to say, it was considered that the low contents of 16:1, 18:1, 20:5 $\omega$ 3 and 22:6 $\omega$ 3 in the male fish lipids indicated cessation of feeding and a high degree of utilization of the stored lipids as a source of energy for sexual maturation.

### Acknowledgements

Thanks are due to Mr. K. Kawasaki, Toyama Prefectural Office, for supplying the samples. The authors are grateful to Associate Professor K. Takano of the Faculty of Fisheries, Hokkaido University and Dr. N. Mizuno, Ehime University for helpful suggestions.

### References

- 1) Shimma, Y. and Taguchi, H. (1964). A comparative study on fatty acid compositions of wild and cultivated "Ayu", sweet smelt (*Plecoglossus altivelis*). *Bull. Jap. Soc. Sci. Fish.* **30**, 918-925. (In Japanese with English abstract).
- 2) Ota, T. and Yamada, M. (1975). Fatty acids of four fresh-water fish lipids. *Bull. Fac. Fish. Hokkaido Univ.* **26**, 277-288. (In Japanese with English abstract).
- 3) Kayama, M., Tsuchiya, Y. and Mead, J.F. (1963). A model experiment of aquatic food chain with special significance in fatty acid conversion. *Bull. Jap. Soc. Sci. Fish.* **29**, 452-458.
- 4) Kelly, P.B., Reiser, R. and Hood, D.W. (1958). The effect of diet on the fatty acid composition of several species of freshwater fish. *J. Am. Oil Chem. Soc.* **35**, 503-505.
- 5) Knipprath, W.G. and Mead, J.F. (1966). Influence of temperature on the fatty acid pattern of mosquito fish (*Gambusia affinis*) and guppies (*Lebistes reticulatus*). *Lipids* **1**, 113-117.
- 6) Farkas, T. and Csengeri, I. (1976). Biosynthesis of fatty acids by the carp, *Cyprinus carpio* L., in relation to environmental temperature. *Lipids* **11**, 401-407.
- 7) Bligh, E.G. and Dyer, W.J. (1959). A rapid method of total lipid extraction and purification. *Can. J. Biochem. Physiol.* **37**, 911-917.
- 8) Ota, T. and Yamada, M. (1974). Lipids of Masu Salmon - III Differences in the lipids of residual type and seaward migration type of Masu salmon parr during the period of seaward migration. *Bull. Jap. Soc. Sci. Fish.* **40**, 707-713. (In Japanese with English abstract).
- 9) Ota, T. and Yamada, M. (1974). Ditto-II Seasonal variations in the lipids of Masu salmon parr during the life in fresh-water. *Ibid.* **40**, 699-706. (In Japanese with English abstract).
- 10) Jangaard, P.M., Brockerhoff, H., Burgher, R.D. and Hoyle, R.J. (1967). Seasonal changes in general condition and lipid content of cod from inshore water. *J. Fish. Res. Bd. Canada* **24**, 607-612.
- 11) Maki, I. (1967). Population studies of Honmoroko, *Gnathopogon caeruleus*, Pisces, in Lake Biwa, Japan. III. On the seasonal fluctuation of the fat content in the fish body of the under-yearling and the "over-wintering" of them. *Jap. J. Ecol.* **17**, 199-205. (In Japanese with English abstract).

- 12) Wada, M. (1955). Biochemical studies on the fat of the sardine body. Part 3. On the seasonal variation in the fat content in different tissues of male and female sardine fish. *Nippon Nogeikagaku Kaishi* 29, 465-471. (In Japanese with English abstract).
- 13) Takashima, F., Hibiya, T., Watanabe, T. and Hara, T. (1971). Endocrinological studies on lipid metabolism in rainbow trout-I. Differences in lipid content of plasma, liver and visceral adipose tissue between sexually immature and mature females. *Bull. Jap. Soc. Sci. Fish.* 37, 307-311.
- 14) Ikekawa, N., Matsui, M., Yoshida, T. and Watanabe, T. (1972). The composition of triglycerides and cholesteryl esters in some fish oils of salt, brackish and fresh water origins. *Ibid.* 38, 1267-1274.
- 15) Shimma, Y. and Taguchi, H. (1964). A comparative study on fatty acid composition of fish. *Ibid.* 30, 179-188. (In Japanese with English abstract).
- 16) Watanabe, E. and Ando, K. (1972). Changes in cholesterol in developing rainbow trout egg. *Ibid.* 38, 711-715. (In Japanese with English abstract).
- 17) Addison, R.F., Ackman, R.G. and Hingley, J. (1972). Lipid composition of the queen crab (*Chionoecetes opilio*). *J. Fish. Res. Bd. Canada* 29, 407-411.
- 18) Ackman, R.G. (1967). Characteristics of the fatty acid composition and biochemistry of some fresh-water fish oils and lipids in comparison with marine oils and lipids. *Comp. Biochem. Physiol.* 22, 907-922.
- 19) Ota, T. (1976). Lipids of Masu Salmon-IV. Changes of lipid composition and fatty acid composition in flesh lipids of juvenile masu salmon in the early stage of sea water life. *Bull. Fac. Fish. Hokkaido Univ.* 27, 30-36. (In Japanese with English abstract).
- 20) Kawanabe, H., Mizuno, N., Miyadi, D., Mori, S., Ohgushi, R. and Nishimura, N. (1957). Ecology of natural stock of salmon-like fish, Ayu. II The mode of life in relation to its population density. *Seiri Seitai* 7, 145-167. (In Japanese with English abstract).
- 21) Miyadi, D. (1960). *Ayu no hanashi*. 226p. Iwanami Shoten, Tokyo. (In Japanese).