STUDIES ON THE LOCAL FORM AND DISPERSAL OF THE CHIKA, *HYPOMESUS PRETIOSUS JAPONICUS* (BREVOORT) IN JAPAN

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I. Introduction

Chika, *Hypomesus pretiosus japonicus* (Brevoort), is a small shore fish which belongs to the family Osmeridae, Salmoniformes, and is a commercially important fish. Chika are distributed from Petropavlovsk, Kamchatka to Wonsan, Korea. In Japan, chika are found in Hokkaido and parts of the Tohoku regions. Specifically, chika occur on almost all coasts of Hokkaido, mainly on the southern to the eastern coasts. Also, chika are found in Mutsu Bay and at the Sanriku Beach, but never on the shores of the Japan Sea in the Tohoku.

Taxonomic studies of the chika began with Brevoort's work (1856) in which he described the new species *Osmerus japonicus* (=*Hypomesus pretiosus japonicus*), one of the osmerid fishes collected at Hakodate. Different taxonomic views are expressed by workers (Hubbs, 1925; Hamada, 1961; McAllister, 1963) about genus *Hypomesus* including this species, and most recent workers have gradually called the chika *Hypomesus pretiosus japonicus* proposed by McAllister (1963), although Klyukanov (1977) recognized it as a distinct species, *H. japonicus* most closely related to *H. nipponensis*. Many morphological studies of the chika have been published. Nojima (1938) reported on the meristic characters, measurements and the relative position of dorsal and pelvic fins of samples from Ishikari and Oshoro Bays. Hamada (1954) has compared chika with wakasagi, *H. transpacificus nipponensis*, collected from several parts of Hokkaido, and reported the measurements, meristic characters, length and shape of maxillary, the relative positions of dorsal and pelvic fins, and shape of stomach and pyloric caeca. Ito (1957a) has studied the meristic characters and length-weight relationship of the chika collected from Odaito. Furthermore, ecological studies of the chika have been made; Hamada (1956) studied growth using body length and scales collected from several parts of Hokkaido, Ito (1957b) reported on the gonads and the number of mature ovarian eggs collected from Odaito, and Okada (1957) compared the adaptation of fertilization and development of wakasagi and chika to salt density in Odaito. Also, experiments were made on the adhesion of the eggs of the chika by Terao (1958) and Ohigashi et al. (1958).

As stated above, many morphological and ecological studies have been made on the chika, but the population studies have not been reported. In general, in a species of fishes, the existence of shoals which show characteristic ecological or morphological features in each locality, is well known. These shoals are related to one another, but each spawns by themself. And the population is considered the fishery resource unit that contributes to its own maintenance and increase. Therefore, clarifying the growth patterns, fecundity, activities and so on of the population, we can infer the biological features of the species. The propagation of individuals in the population is one of the causes of dispersal (Udvardy, 1969). Therefore we can see the geographic dispersal of the species by means of population analysis. The existence of populations in the chika is expected, but there is no description of populations for this species. This study attempts to describe and

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discriminate the populations in the chika by studying geographic variation of the meristic characters and biological features. The zoogeographic studies which consider distribution, dispersal mechanisms, and routes in one animal are introduced by Keast (1977), and the zoogeography of fishes has been studied by Briggs (1955) and Rosen (1975). But, there are only a few zoogeographic studies that discuss the relationships between ecological conditions and dispersal which are closely related in infraspecific level, and I am not aware of such a study in fishes. Therefore, this paper studies the dispersal of the chika by considering of seasonal movement, spawning period, and the influence of the sea currents. It should be noted, however, that a few studies of dispersal routes of infraspecific level have been done not only on fishes but also on many living organisms as well because of less useful data. This study used the variation in the meristic characters in each population for studying dispersal routes in this species, and employed multivariate analysis. As mentioned above, this study accepted the local form defined by Lissner (1934) for the population of the chika, and discriminated the local forms. This study has also undertaken the task of clarifying the formation of the local forms, dispersal mechanisms and routes of the chika, *H. p. japonicus*, as a part of a zoogeographic study.

In this study, the author, first of all, collected samples from 15 localities in Hokkaido and Tohoku regions, compared the variances and the means of ten meristic characters, and then defined and confirmed the local forms of the chika. Of the results, only the samples from Sarufutsu and Kitami-Esashi showed no significant difference in all the meristic characters. Therefore the author concluded that these two belonged to the same local form while others formed distinct local forms. Next, selected Mori and Hakodate local forms which were distinguished based on the meristic characters, and clarified their biological features. And study was made on validity of discriminating the local forms of the chika using the meristic characters. Clear differences were found in the growth equations of body length and weight, sex ratios by ages and in the spawning period, age composition in the spawning period, and length-weight relationships between Mori and Hakodate. Therefore, the validity of defining the local forms based on the meristic characters has been justified. Further, considering seasonal movement, observations of spawning periods and effect of sea currents, dispersal of this species was presumed to be active to neighbouring coasts, and passive to neighbouring and distant coasts. Lastly, it can be concluded, based on the cluster analysis of the meristic characters, that there are two dispersal routes for the chika, *Hypomesus pretiosus japonicus*, in Japan.

The calculations, tests and scattergrams in this study were mainly carried out from FACOM 230–60/75 computer at the Hokkaido University Computing Center. Computer programs used in this study are SPSS (Nie et al., 1970; Miyake, 1973; Miyake et al., 1977) and FORTRAN.

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III. Geographic Variation in Meristic Characters

In a species of fishes, the existence of stocks with characteristic ecological or morphological features in each locality is well known. Many definitions and discussions on race, subpopulation, form or local form have been forwarded by various workers (Ehrenbaum, 1929; Lissner, 1934; Johansen, 1936; Marr, 1957) since Heinke (1898) had defined the race in the herring of the North Sea. But, definitions have not yet been entirely agreed upon for the various infraspecific forms. Among the reports defining stocks, Lissner (1934) studied the races of herring, and discussed race which was defined by Heinke (1898). Also, he showed the relation between the differences in the counts and localities by way of mean values for the vertebral counts in spring and autumn herrings, and gave the definitions of local form and race. Lissner (1934) gave a definition for the local form of such stocks, "Local forms are such shoals which deposit their eggs at the same season on more less neighbouring spawning places of the same or very similar conditions of the water and the bottom, disappear afterwards and return in the next year at the same time and in the same stage of maturity". This study accepted the "local form" as defined by Lissner (1934) for the stocks of the chika, *Hypomesus pretiosus japonicus*.

The stock or shoal discrimination studies in fishes are mainly based on the method of morphology, ecology, catch fluctuation and genetics. Racial characters are as follows: body length and weight composition, growth rates, age composition, fatness, egg-diameter, fecundity, scale features, ratios of body measurement, and meristic characters such as rays, gill rakers, branchiostegals, vertebrae and lateral line scale counts (Kubo and Yoshihara, 1969). Also, serum proteins (Kubo, 1967), karyotypes (Mayers and Roberts, 1969) and isozymes (Pantelouris et al., 1971; Iwata, 1975) are used for comparisons of races.

This study is based on the specimens collected from each of the localities in the range of the chika in Japan, and has discriminated and confirmed the existence of the local forms by means of using meristic characters which are well adapted for racial characters in many fishes.

1. Materials and Methods

Specimens used in this study were collected from 15 localities of Hokkaido and

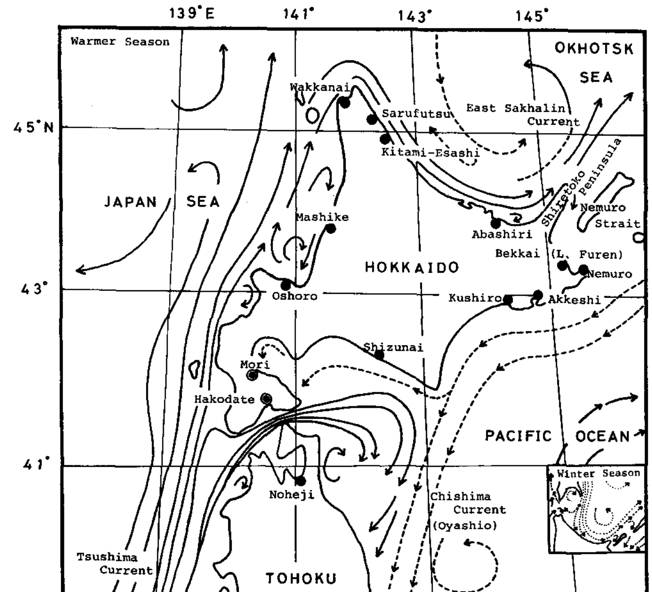

Fig. 1. Map showing the sampling localities and main currents of Hokkaido and Tohoku off shores (After Watanabe, 1964).
●, for morphometric study; ◉, for biological and morphometric studies
——, warm current; ----, cold current.

Table 1. *Locality, date, individual numbers and year class of chika, on which the meristic characters were examined.*

Locality	Date	N	Year class
Wakkanai	May 6, 1975.	40	1974.
Mashike	April 22, 1976.	65	1975.
Oshoro	August 4, 1973.	16	1973.
Sarufutsu	October 9, 1973.	67	1972.
Kitami-Esashi	October 7, 1973.	77	1972. 1973.
Abashiri	May 6, 1976.	80	1974. 1975.
Bekkai (L. Fûren)	April 28, 1971.	41	1969.
Nemuro	November 2, 1972.	71	1971. 1972.
Akkeshi	April 25, 1977.	90	1974. 1975. 1976.
Kushiro	October 14, 1972.	15	1970. 1971.
Shizunai	October 17, 1973.	48	1973.
Mori	June 12, 1974.	124	1973.
Hakodate	June 18, 1975.	75	1974.
Noheji	March 19, 1975.	42	1973.
Sanriku-chô	March 8, 1975. Winter in '75 to '76.	53 22 } 75	1973. 1974.

Tohoku regions (Fig. 1, Table 1). Specimens were preserved in 10% formalin. Numbers of abdominal, caudal and total vertebrae, and dorsal and anal fin rays were counted using radiography. Numbers of caudal, pectoral and pelvic fin rays, midlateral and pored scales, branchiostegal rays, and upper, lower and total gill rakers were counted under a binocular microscope. Counts were made according to the methods described by McAllister (1963), and caudal vertebrae were distinguished using the criteria of Yanagawa (1974).

Comparisons of variances and the means of each meristic character were made using subprogram "T-TEST" in SPSS.

2. *Selection of Meristic Characters*

Before studying the geographic variation of meristic characters of the chika, differences between sexes and year classes were first examined. Differences between sexes and year classes of 14 meristic characters (number of abdominal, caudal and total vertebrae; dorsal, anal, caudal, pectoral and pelvic fin rays; midlateral and pored scales; branchiostegal rays; upper, lower and total gill rakers) were examined using *t*-tests.

Firstly, there was no significant difference between sexes in 14 characters in age 1+ chika collected on April 24, 1970 (1969 year class) at Mori (Table 2). However, anal fin ray counts showed a statistical significance at the 5% level between sexes at age 1+ chika collected on June 12, 1974 (1973 year class) at Mori (Table 3). Next, the number of pectoral fin rays, and midlateral and pored scales showed a statistical significance at the 1% level between 1969 and 1973 year classes at Mori (Table 4).

In summary, specimens collected from Mori showed significant differences in anal and pectoral fin rays, and midlateral and pored scales. The ten remaining

Table 2. *Statistical significance of the means of 14 meristic characters between male and female. Chika examined were obtained from Mori at April 24, 1970. AV, number of abdominal vertebrae; CV, caudal vertebrae; TV, total vertebrae; D-fin, dorsal fin rays; A-fin, anal fin rays; C-fin, caudal fin rays; P-fin, pectoral fin rays; V-fin, pelvic fin rays; SC, midlateral scales; P-SC, pored scales; BS, branchiostegal rays; U-GR, upper gill rakers; L-GR, lower gill rakers; T-GR, total gill rakers. (* significant at the 5% level)*

Meristic character	Sex	N	Mean	S.D.	*F*-test	*t*-test	
					Fo	*to*	*t'o*
AV	M	29	41.379	0.903	2.33*		1.42
	F	35	41.657	0.591			
CV	M	29	22.793	0.620	1.08	0.14	
	F	35	22.771	0.646			
TV	M	29	64.172	0.889	1.19	1.20	
	F	35	64.429	0.815			
D-fin	M	29	10.690	0.471	2.27*		0.17
	F	35	10.714	0.710			
A-fin	M	29	14.897	0.557	1.59	0.11	
	F	35	14.914	0.702			
C-fin	M	29	19.000	0.0	0.00	0.91	
	F	35	19.029	0.169			
P-fin	M	29	13.345	0.670	1.04	1.19	
	F	35	13.543	0.657			
V-fin	M	29	8.000	0.0	0.00	0.00	
	F	35	8.000	0.0			
SC	M	29	64.241	1.185	1.06	1.19	
	F	35	64.600	1.218			
P-SC	M	29	14.345	1.857	1.16	1.15	
	F	21	13.714	2.004			
BS	M	21	7.762	0.436	1.19	1.95	
	F	26	8.000	0.400			
U-GR	M	29	11.655	0.670	1.10	0.82	
	F	35	11.514	0.702			
L-GR	M	29	25.310	0.761	2.38*		1.07
	F	33	25.576	1.173			
T-GR	M	29	36.931	1.163	1.59	0.47	
	F	33	37.091	1.466			

meristic characters which showed no significant differences between sexes and year classes were used for examining geographic variation.

3. Number of Abdominal, Caudal and Total Vertebrae

Abdominal Vertebrae

Range of abdominal vertebrae in all specimens was 38–44 with a mean of 41.560 and 95% confidence intervals of 41.506–41.614 (Table 5). The modal count was 41 at Wakkanai (faced on Soya Strait), Mashike and Oshoro (coast of Japan Sea), and Sarufutsu, Kitami-Esashi and Abashiri (coast of Okhotsk Sea). On the other hand, Bekkai and Nemuro (faced on Nemuro Strait), and Akkeshi and

Table 3. *Statistical significance of the means of 14 meristic characters between male and female. Chika examined were obtained from Mori at June 12, 1974. Abbreviations are the same as those in Table 2. (* significant at the 5% level; ** significant at the 1% level)*

Meristic character	Sex	N	Mean	S.D.	*F*-test	*t*-test	
					Fo	*to*	*t'o*
AV	M	57	41.579	0.905	1.47	0.69	
	F	66	41.687	0.747			
CV	M	57	22.895	0.817	1.01	0.43	
	F	65	22.831	0.821			
TV	M	57	64.474	1.037	1.56*		0.20
	F	65	64.508	0.831			
D-fin	M	57	10.649	0.517	1.33	0.07	
	F	67	10.642	0.595			
A-fin	M	57	14.912	0.714	1.07	2.14*	
	F	67	14.642	0.690			
C-fin	M	57	18.983	0.132	1.18	0.11	
	F	67	18.985	0.122			
P-fin	M	57	13.842	0.560	1.04	1.58	
	F	67	14.000	0.550			
V-fin	M	57	8.000	0.189	0.00	0.00	
	F	67	8.000	0.0			
SC	M	57	65.421	1.362	1.99**		1.02
	F	67	65.642	0.965			
P-SC	M	39	12.256	1.585	1.80*		0.78
	F	65	11.969	2.128			
BS	M	57	7.860	0.515	1.18	1.17	
	F	67	7.746	0.560			
U-GR	M	57	11.754	0.544	1.18	0.95	
	F	67	11.657	0.592			
L-GR	M	54	25.352	1.012	1.36	0.25	
	F	67	25.403	1.181			
T-GR	M	54	37.093	1.137	1.87**		0.13
	F	67	37.060	1.556			

Kushiro (Pacific coast of eastern Hokkaido) had a mode of 42, showing a modal difference from the area mentioned above. In other localities, there was no modal difference between marine areas. On the frequencies of the abdominal vertebrae counts, localities in north of Abashiri and coasts of Japan Sea showed lower values, and those in south of Bekkai showed higher values, bordering on Shiretoko Peninsula. Variances ranged from 0.379 (Wakkanai) to 1.174 (Bekkai). The means of abdominal vertebrae counts of all localities fell within the range of 41.136 (Sarufutsu) to 42.127 (Nemuro). Results of significance tests for the differences of variances and means of the number of the abdominal vertebrae are shown in Table 6. In the variance ratio, Bekkai showed the significant difference for all localities with the exceptions of Oshoro and Noheji, and other localities showed no tendency related to region. In the means, three remarkable groups were identified, i.e. 1) north of Shiretoko Peninsula and coast of Japan Sea (Wakkanai, Mashike, Oshoro, Sarufutsu, Kitami-Esashi and Abashiri), 2) eastern Hokkaido (Bekkai, Nemuro,

Table 4. *Statistical significance of the means of 14 meristic characters between 1969 and 1973 year classes. Chika examined were obtained from Mori. Abbreviations are the same as those in Table 2. (* significant at the 5% level; ** significant at the 1% level)*

Meristic character	Year class	N	Mean	S.D.	*F*-test	*t*-test	
					Fo	*to*	*t'o*
AV	1969	71	41.563	0.751	1.20	0.60	
	1973	123	41.634	0.823			
CV	1969	71	22.803	0.624	1.71*		0.55
	1973	122	22.861	0.816			
TV	1969	71	64.366	0.849	1.20	0.93	
	1973	122	64.492	0.929			
D-fin	1969	71	10.718	0.590	1.12	0.86	
	1973	124	10.645	0.559			
A-fin	1969	71	14.901	0.679	1.10	1.30	
	1973	124	14.766	0.711			
C-fin	1969	71	19.014	0.119	1.14	1.64	
	1973	124	18.984	0.126			
P-fin	1969	71	13.437	0.670	1.44*		5.22**
	1973	124	13.927	0.558			
V-fin	1969	71	8.000	0.0	0.00	0.00	
	1973	124	8.000	0.128			
SC	1969	71	64.437	1.168	1.01	6.33**	
	1973	124	65.540	1.165			
P-SC	1969	51	14.059	1.912	1.03	6.01**	
	1973	104	12.077	1.939			
BS	1969	53	7.868	0.440	1.51*		0.90
	1973	124	7.798	0.541			
U-GR	1969	71	11.606	0.707	1.54*		0.98
	1973	124	11.702	0.570			
L-GR	1969	69	25.449	1.065	1.08	0.42	
	1973	121	25.380	1.105			
T-GR	1969	69	37.058	1.381	1.00	0.08	
	1973	121	37.074	1.379			

Akkeshi and Kushiro), and 3) south of Shizunai (Shizunai, Mori, Hakodate, Noheji and Sanriku-cho). Within each group, there were no between locality significant difference and abdominal vertebrae counts were very similar to each other. In above three groups, eastern Hokkaido which had relatively higher counts showed the significant differences at the 1% level from both other groups. Also, there were many statistical significances between localities north of Shiretoko Peninsula, the coast of Japan Sea group, and south of Shizunai group. It is considered that localities south of Shizunai showed intermediacy between the other two groups in the number of abdominal vertebrae.

Caudal Vertebrae

Range of caudal vertebrae counts for all specimens was 21–25 with a mean of 22.874 and 95% confidence intervals of 22.824–22.924 (Table 7). The modal count was 23 at all localities with the exceptions of Bekkai and Akkeshi which

Table 5. *Percent frequencies in the number of abdominal vertebrae of the chika in 15 localities of Hokkaido and Tohoku regions. Asterisks show mode.*

Locality	N	Mean	S.D.	Variance	Number of abdominal vertebrae						
					38	39	40	41	42	43	44
Wakkanai	40	41.325	0.616	0.379	-	-	8	53*	40	-	-
Mashike	64	41.297	0.706	0.498	-	-	13	47*	39	2	-
Oshoro	16	41.438	1.031	1.063	-	-	19	38*	25	19	-
Sarufutsu	66	41.136	0.762	0.581	-	2	17	50*	30	2	-
Kitami-Esashi	77	41.260	0.785	0.616	-	1	14	44*	38	3	-
Abashiri	79	41.342	0.677	0.459	-	-	9	51*	38	3	-
Bekkai	41	41.976	1.084	1.174	2	-	-	24	51*	12	10
Nemuro	71	42.127	0.653	0.427	-	-	-	14	61*	24	1
Akkeshi	90	41.967	0.827	0.684	-	-	4	21	49*	24	1
Kushiro	15	41.867	0.640	0.410	-	-	-	27	60*	13	-
Shizunai	48	41.563	0.796	0.634	-	-	4	50*	31	15	-
Mori	123	41.634	0.823	0.677	-	1	5	37	48*	7	2
Hakodate	75	41.427	0.808	0.653	-	-	13	37	43*	7	-
Noheji	42	41.667	0.846	0.715	-	-	7	36	40*	17	-
Sanriku-chô	75	41.507	0.795	0.632	-	-	8	44*	37	11	-

Table 6. *Significance tests for the differences of variances and the means of the number of the abdominal vertebrae between the samples collected from 15 localities in Hokkaido and Tohoku regions. NS, not significant; * significant at the 5% level; ** significant at the 1% level.*

Locality	Wakk.	Mash.	Osho.	Saru.	Kita.	Abas.	Bekk.	Nemu.	Akke.	Kush.	Shiz.	Mori	Hako.	Nohe.	Sanr.
Wakkanai		NS	**	NS	NS	NS	**	NS	*	NS	NS	*	NS	*	NS
Mashike	NS		*	NS	NS	NS	**	NS	NS	NS	NS	NS	NS	NS	NS
Oshoro	NS	NS		NS	NS	*	NS	*	NS	NS	NS	NS	NS	NS	NS
Sarufutsu	NS	NS	NS		NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS
Kitami-Esashi	NS	NS	NS	NS		NS	*	NS	NS	NS	NS	NS	NS	NS	NS
Abashiri	NS	NS	NS	NS	NS		**	NS	NS	NS	NS	NS	NS	NS	NS
Bekkai	**	**	NS	**	**	**		**	*	*	*	*	*	NS	*
Nemuro	**	**	*	**	**	**	NS		*	NS	NS	*	NS	NS	NS
Akkeshi	**	**	*	**	**	**	NS	NS		NS	NS	NS	NS	NS	NS
Kushiro	**	**	NS	**	**	**	NS	NS	NS		NS	NS	NS	NS	NS
Shizunai	NS	NS	NS	**	*	NS	*	**	**	NS		NS	NS	NS	NS
Mori	*	**	NS	**	**	**	NS	**	**	NS	NS		NS	NS	NS
Hakodate	NS	NS	NS	*	NS	NS	**	**	**	*	NS	NS		NS	NS
Noheji	*	*	NS	**	**	*	NS	**	NS	NS	NS	NS	NS		NS
Sanriku-chô	NS	NS	NS	**	NS	NS	*	**	**	NS	NS	NS	NS	NS	

Variance ratio

t-test of mean

Table 7. *Percent frequencies in the number of caudal vertebrae of the chika in 15 localities of Hokkaido and Tohoku regions. Asterisks show mode.*

Locality	N	Mean	S.D.	Variance	Number of caudal vertebrae				
					21	22	23	24	25
Wakkanai	40	23.125	0.791	0.625	-	23	45*	30	3
Mashike	65	23.185	0.682	0.465	-	14	55*	29	2
Oshoro	16	22.938	0.680	0.462	-	25	56*	19	-
Sarufutsu	67	23.269	0.770	0.593	-	16	43*	37	3
Kitami-Esashi	77	23.052	0.776	0.603	3	18	52*	26	1
Abashiri	80	22.863	0.651	0.424	1	24	64*	10	1
Bekkai	41	22.317	0.722	0.522	12	46*	39	2	-
Nemuro	71	22.789	0.715	0.512	3	30	54*	14	-
Akkeshi	90	22.378	0.787	0.620	11	48*	33	8	-
Kushiro	15	22.533	0.743	0.552	7	40	47*	7	-
Shizunai	48	23.000	0.652	0.426	-	21	58*	21	-
Mori	122	22.861	0.816	0.666	3	29	49*	16	2
Hakodate	75	22.933	0.723	0.523	-	27	56*	15	3
Noheji	42	22.929	0.712	0.507	-	26	57*	14	2
Sanriku-chô	75	22.867	0.741	0.550	3	25	56*	15	1

Table 8. *Significance tests for the differences of variances and the means of the number of the caudal vertebrae between the samples collected from 15 loalities in Hokkaido and Tohoku regions. NS, not significant; * significant at the 5% level; ** significant at the 1% level.*

Variance ratio

Locality	Wakk.	Mash.	Osho.	Saru.	Kita.	Abas.	Bekk.	Nemu.	Akke.	Kush.	Shiz.	Mori	Hako.	Nohe.	Sanr.
Wakkanai		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mashike	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Oshoro	NS	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sarufutsu	NS	NS	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Kitami-Easashi	NS	NS	NS	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Abashiri	NS	**	NS	**	NS		NS	NS	NS	NS	NS	*	NS	NS	NS
Bekkai	**	**	**	**	**	**		NS	NS	NS	NS	NS	NS	NS	NS
Nemuro	*	**	NS	**	*	NS	**		NS	NS	NS	NS	NS	NS	NS
Akkeshi	**	**	**	**	**	**	NS	**		NS	NS	NS	NS	NS	NS
Kushiro	*	**	NS	**	*	NS	NS	NS	NS		NS	NS	NS	NS	NS
Shizunai	NS	NS	NS	NS	NS	NS	**	NS	**	*		NS	NS	NS	NS
Mori	NS	**	NS	**	NS	NS	**	NS	**	NS	NS		NS	NS	NS
Hakodate	NS	*	NS	**	NS	NS	**	NS	**	NS	NS	NS		NS	NS
Noheji	NS	NS	NS	*	NS	NS	**	NS	**	NS	NS	NS	NS		NS
Sanriku-chô	NS	**	NS	**	NS	NS	**	NS	**	NS	NS	NS	NS	NS	

t-test of mean

Table 9. *Percent frequencies in the number of total vertebrae of the chika in 15 localities of Hokkaido and Tohoku regions. Asterisks show mode.*

Locality	N	Mean	S.D.	Variance	Number of total vertebrae							
					60	61	62	63	64	65	66	67
Wakkanai	40	64.450	0.749	0.562	-	-	-	5	55*	30	10	-
Mashike	64	64.469	0.755	0.570	-	-	-	8	45*	39	8	-
Oshoro	16	64.375	0.957	0.917	-	-	6	6	38	44*	6	-
Sarufutsu	66	64.409	0.877	0.769	-	-	3	8	42*	41	5	2
Kitami-Esashi	77	64.312	0.977	0.954	1	-	1	9	49*	31	6	1
Abashiri	79	64.203	0.705	0.497	-	-	-	13	58*	25	4	-
Bekkai	41	64.293	1.250	1.562	-	2	5	12	41*	24	10	5
Nemuro	71	64.915	0.788	0.621	-	-	-	4	21	55*	18	1
Akkeshi	90	64.344	0.876	0.768	-	-	1	13	46*	30	10	-
Kushiro	15	64.400	0.828	0.686	-	-	-	7	60*	20	13	-
Shizunai	48	64.563	0.943	0.890	-	-	-	10	42*	31	15	2
Mori	122	64.492	0.929	0.864	-	-	1	12	38*	37	11	2
Hakodate	75	64.360	0.832	0.693	-	-	-	17	35	43*	5	-
Noheji	42	64.595	0.734	0.539	-	-	-	5	40	45*	10	-
Sanriku-chô	75	64.373	0.785	0.615	-	-	3	5	49*	37	5	-

Table 10. *Significance tests for the differences of variances and the means of the number of the total vertebrae between the samples collected from 15 localities in Hokkaido and Tohoku regions. NS, not significant; * significant at the 5% level; ** significant at the 1% level.*

Locality	Wakk.	Mash.	Osho.	Saru.	Kita.	Abas.	Bekk.	Nemu.	Akke.	Kush.	Shiz.	Mori	Hako.	Nohe.	Sanr.
Wakkanai		NS	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	NS	NS	NS
Mashike	NS		NS	NS	*	NS	**	NS	NS	NS	NS	NS	NS	NS	NS
Oshoro	NS	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sarufutsu	NS	NS	NS		NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS
Kitami-Esashi	NS	NS	NS	NS		**	NS	NS	NS	NS	NS	NS	NS	*	NS
Abashiri	NS	*	NS	NS	NS		**	NS	NS	NS	*	**	NS	NS	NS
Bekkai	NS	NS	NS	NS	NS	NS		**	**	NS	NS	*	**	**	**
Nemuro	**	**	*	**	**	**	**		NS	NS	NS	NS	NS	NS	NS
Akkeshi	NS	NS	NS	NS	NS	NS	NS	**		NS	NS	NS	NS	NS	NS
Kushiro	NS	NS	NS	NS	NS	NS	NS	*	NS		NS	NS	NS	NS	NS
Shizunai	NS	NS	NS	NS	NS	*	NS	*	NS	NS		NS	NS	NS	NS
Mori	NS	NS	NS	NS	NS	*	NS	**	NS	NS	NS		NS	NS	NS
Hakodate	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	NS	NS		NS	NS
Noheji	NS	NS	NS	NS	NS	**	NS	*	NS	NS	NS	NS	NS		NS
Sanriku-chô	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	NS	

Variance ratio (upper right)

t-test of mean (lower left)

had 22. The caudal vertebrae counts, however, for localities north of Abashiri and coast of Japan Sea showed a tendency of higher values, bordering on Shiretoko Peninsula. The variances ranged from 0.424 (Abashiri) to 0.666 (Mori). The means of caudal vertebrae counts of all localities fell within the range of 22.317 (Bekkai) to 23.269 (Sarufutsu). Results of significance tests for the differences of variances and the mean of the number of caudal vertebrae are shown in Table 8. There was no significant difference in variance ratios among the all localities with the exception of that between Abashiri and Mori. In the means, there was no significant difference among the localities in north of Shiretoko Peninsula with the exception of Abashiri and the south of Shizunai. In eastern Hokkaido, however, Nemuro showed a significant difference at the 1% level between Bekkai and Akkeshi. Furthermore, Mashike, Sarufutsu, Bekkai and Akkeshi showed significant difference at the 1% level from many localities. Thus the means of Mashike and Sarufutsu have a tendency towards higher values, and Bekkai and Akkeshi have a tendency towards lower values as compared with the other localities.

Total Vertebrae

Total vertebrae ranged from 60–67 with a mean of 64.432 and 95% confidence intervals of 64.375–64.489 (Table 9). The model count was 64 at all localities with the exception of Oshoro, Nemuro, Hakodate and Noheji which had 65. On the frequencies of the total vertebrae counts, localities which had mode of 64 showed the tendency of higher values than the mode. The variances ranged from 0.497 (Abashiri) to 1.562 (Bekkai). The means of total vertebrae counts of all localities fell within the range of 64.203 (Abashiri) to 64.915 (Nemuro). Results of significance tests for the differences of variances and the means of the number of total vertebrae are shown in Table 10. In the variance ratio, most localities showed no differences, with the exception of that Bekkai showed the statistically significant differences at the 5% or 1% level from many localities. In the means, Nemuro which showed the highest values showed a statistically significant differences at the 5% or 1% level from all localities. Abashiri which showed the lowest value showed statistically significant differences at the 5% or 1% level from Mashike, Nemuro, Shizunai, Mori and Noheji. However, there was no significant difference amongst other localities, and it was considered that there was less geographic variation of total vertebrae counts in all localities.

4. *Number of Dorsal, Caudal and Pelvic Fin Rays*

Dorsal Fin Rays

Range of dorsal fin rays in all specimens was 9–12 with a mean of 10.552 and 95% confidence intervals of 10.517–10.587 (Table 11). Modal counts were 10 or 11 in all localities, and counts of 9 and 12 were very rare. The variances ranged from 0.229 (Oshoro) to 0.410 (Kushiro). The means of dorsal fin ray counts of all localities fell within the range of 10.313 (Oshoro) to 10.760 (Hakodate). Results of significance tests for the differences of variances and the means of the number of dorsal fin rays are shown in Table 12. In the variance ratio, there was no

Table 11. *Percent frequencies in the number of dorsal fin rays of the chika in 15 localities of Hokkaido and Tohoku regions. Asterisks show mode.*

Locality	N	Mean	S.D.	Variance	Number of dorsal fin rays			
					9	10	11	12
Wakkanai	40	10.350	0.483	0.233	-	65*	35	-
Mashike	64	10.500	0.563	0.317	2	48*	48*	2
Oshoro	16	10.313	0.479	0.229	-	69*	31	-
Sarufutsu	67	10.522	0.503	0.253	-	48	52*	-
Kitami-Esashi	77	10.403	0.520	0.270	-	61*	38	1
Abashiri	79	10.620	0.562	0.315	3	34	62*	1
Bekkai	41	10.585	0.547	0.299	-	44	54*	2
Nemuro	71	10.493	0.557	0.311	1	49*	48	1
Akkeshi	90	10.511	0.525	0.275	-	50*	49	1
Kushiro	15	10.533	0.640	0.410	-	53*	40	7
Shizunai	48	10.604	0.536	0.287	-	42	56*	2
Mori	124	10.645	0.559	0.312	1	37	59*	3
Hakodate	75	10.760	0.541	0.293	-	29	65*	5
Noheji	42	10.429	0.501	0.251	-	57*	43	-
Sanriku-chô	75	10.640	0.536	0.288	-	39	59*	3

Table 12. *Significance tests for the differences of variances and the means of the number of the dorsal fin rays between the samples collected from 15 localities in Hokkaido and Tohoku regions. NS, not significant; * significant at the 5% level; ** significant at the 1% level.*

Locality	Wakk.	Mash.	Osho.	Saru.	Kita.	Abas.	Bekk.	Nemu.	Akke.	Kush.	Shiz.	Mori	Hako.	Nohe.	Sanr.
Wakkanai		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mashike	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Oshoro	NS	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sarufutsu	NS	NS	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Kitami-Esashi	NS	NS	NS	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Abashiri	*	NS	*	NS	*		NS	NS	NS	NS	NS	NS	NS	NS	NS
Bekkai	*	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS	NS	NS	NS
Nemuro	NS	NS	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS	NS	NS
Akkeshi	NS	NS	NS	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS	NS
Kushiro	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS
Shizunai	*	NS	NS	NS	*	NS	NS	NS	NS	NS		NS	NS	NS	NS
Mori	**	NS	*	NS	**	NS	NS	NS	NS	NS	NS		NS	NS	NS
Hakodate	**	**	**	**	**	NS	NS	**	**	NS	NS	NS		NS	NS
Noheji	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	**		NS
Sanriku-chô	**	NS	*	NS	**	NS	NS	NS	NS	NS	NS	NS	NS	*	

Variance ratio

t-test of mean

Table 13. *Percent frequencies in the number of caudal fin rays of the chika in 15 localities of Hokkaido and Tohoku regions. Asterisks show mode.*

Locality	N	Mean	S.D.	Variance	Number of caudal fin rays			
					17	18	19	20
Wakkanai	39	19.026	0.160	0.026	-	-	97*	3
Mashike	63	19.000	-	-	-	-	100*	-
Oshoro	16	19.000	-	-	-	-	100*	-
Sarufutsu	67	19.000	0.174	0.030	-	1	97*	1
Kitami-Esashi	72	18.972	0.165	0.027	-	3	97*	-
Abashiri	80	19.012	0.112	0.012	-	-	99*	1
Bekkai	41	18.976	0.156	0.024	-	2	98*	-
Nemuro	70	19.029	0.168	0.028	-	-	97*	3
Akkeshi	90	18.989	0.237	0.056	-	3	94*	2
Kushiro	15	19.000	-	-	-	-	100*	-
Shizunai	48	18.938	0.320	0.102	2	2	96*	-
Mori	124	18.984	0.126	0.016	-	2	98*	-
Hakodate	75	18.987	0.201	0.040	-	3	96*	1
Noheji	42	19.000	-	-	-	-	100*	-
Sanriku-chô	75	19.040	0.197	0.039	-	-	96*	4

Table 14. *Significance tests for the differences of variances and the means of the number of the caudal fin rays between the samples collected from 15 localities in Hokkaido and Tohoku regions. NS, not significant; * significant at the 5% level; ** significant at the 1% level.*

Locality	Wakk.	Mash.	Osho.	Saru.	Kita.	Abas.	Bekk.	Nemu.	Akke.	Kush.	Shiz.	Mori	Hako.	Nohe.	Sanr.
Wakkanai		NS	NS	NS	NS	*	NS	NS	**	NS	**	NS	NS	NS	NS
Mashike	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Oshoro	NS	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sarufutsu	NS	NS	NS		NS	**	NS	NS	**	NS	**	**	NS	NS	NS
Kitami-Esashi	NS	NS	NS	NS		**	NS	NS	**	NS	**	**	NS	NS	NS
Abashiri	NS	NS	NS	NS	NS		*	**	**	NS	**	NS	**	NS	**
Bekkai	NS	NS	NS	NS	NS	NS		NS	**	NS	**	NS	NS	NS	NS
Nemuro	NS	NS	NS	NS	*	NS	NS		**	NS	**	**	NS	NS	NS
Akkeshi	NS	NS	NS	NS	NS	NS	NS	NS		NS	*	**	NS	NS	NS
Kushiro	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS
Shizunai	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		**	**	NS	**
Mori	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		**	NS	**
Hakodate	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS	NS
Noheji	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
Sanriku-chô	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	*	*	NS	NS	

Variance ratio

t-test of mean

Table 15. *Percent frequencies in the number of pelvic fin rays of the chika in 15 localities of Hokkaido and Tohoku regions. Asterisks show mode.*

Locality	N	Mean	S.D.	Variance	Number of pelvic fin rays		
					7	8	9
Wakkanai	40	8.025	0.158	0.025	-	98*	3
Mashike	65	8.000	-	-	-	100*	-
Oshoro	16	8.000	-	-	-	100*	-
Sarufutsu	67	8.030	0.171	0.029	-	97*	3
Kitami-Esashi	77	8.026	0.160	0.026	-	97*	3
Abashiri	80	7.987	0.194	0.038	3	96*	1
Bekkai	41	8.000	-	-	-	100*	-
Nemuro	71	8.014	0.119	0.014	-	99*	1
Akkeshi	90	8.022	0.148	0.022	-	98*	2
Kushiro	15	8.000	-	-	-	100*	-
Shizunai	48	7.979	0.144	0.021	2	98*	-
Mori	124	8.000	0.128	0.016	1	98*	1
Hakodate	75	8.013	0.115	0.013	-	99*	1
Noheji	42	8.024	0.154	0.024	-	98*	2
Sanriku-chô	75	8.027	0.162	0.026	-	97*	3

Table 16. *Significance tests for the differences of variances and the means of the number of the pelvic fin rays between the samples collected from 15 localities in Hokkaido and Tohoku regions. NS, not significant; * significant at the 5% level; ** significant at the 1% level.*

Locality	Wakk.	Mash.	Osho.	Saru.	Kita.	Abas.	Bekk.	Nemu.	Akke.	Kush.	Shiz.	Mori	Hako.	Nohe.	Sanr.
Wakkanai		NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	*	NS	NS
Mashike	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Oshoro	NS	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sarufutsu	NS	NS	NS		NS	NS	NS	**	NS	NS	NS	**	**	NS	NS
Kitami-Esashi	NS	NS	NS	NS		NS	NS	*	NS	NS	NS	*	**	NS	NS
Abashiri	NS	NS	NS	NS	NS		NS	**	*	NS	*	**	**	NS	NS
Bekkai	NS	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS	NS	NS	NS
Nemuro	NS	NS	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS	NS	**
Akkeshi	NS	NS	NS	NS	NS	NS	NS	NS		NS	NS	NS	*	NS	NS
Kushiro	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS
Shizunai	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS	NS	NS	NS
Mori	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS	NS	*
Hakodate	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		*	**
Noheji	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
Sanriku-chô	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	

Variance ratio

t-test of mean

significant differences among any localities. In the means, Wakkanai, Mashike, Oshoro, Sarufutsu and Kitami-Esashi showed no significant differences from each other. In the localities in south of Abashiri, there was no significant differences in broad areas including Abashiri, eastern Hokkaido of Bekkai, Nemuro, Akkeshi and Kushiro, and Pacific coast of Shizunai and Mori. On the other hand, Hakodate showed a statistically significant difference at the 1% level from eight localities, and was recognized the differences against the most many localities in all.

Caudal Fin Rays

Range of counts in all specimens was 17–20 with a mean of 18.996 and 95% confidence intervals of 18.980–19.013 (Table 13). The modal counts was 19 at all localities. On the frequencies of caudal fin ray counts, all specimens at Mashike, Oshoro, Kushiro and Noheji showed 19, and almost specimens had concentrated to 19 at other localities. The variance was 0.102 at Shizunai, and all localities showed very low values. The means of caudal fin ray counts of all localities fell within the range of 18.938 (Shizunai) to 19.040 (Sanriku-cho). Results of significance tests for the differences of variances and the means of the number of the caudal fin rays are shown in Table 14. In the means, there was no geographic variation among almost localities. Therefore, it is considered that caudal fin ray count of the chika is a very stable character.

Pelvic Fin Rays

Range of counts in all specimens was 7–9 with a mean of 8.010 and 95% confidence intervals of 8.001–8.019 (Table 15). The modal count was 8 at all localities. In the frequencies of pelvic fin ray counts, all specimens at Mashike, Oshoro, Bekkai and Kushiro showed 8, and almost specimens had mostly 8 at other localities. The highest value of the variances was 0.038 at Abashiri, and all localities showed very low values. The means of pelvic fin ray counts of all localities fell within the range of 7.979 (Shizunai) to 8.030 (Sarufutsu). Results of significance tests for the differences of variances and the means of the pelvic fin rays are shown in Table 16. In the means, there was no geographic variation among localities. Therefore, it is considered that pelvic fin ray counts of the chika are as stable character as caudal fin ray counts.

5. *Number of Branchiostegal Rays*

Branchiostegal Rays

Range of all specimens was 6–9 with a mean of 7.772 and 95% confidence intervals of 7.737–7.807 (Table 17). The mode was 8 at all localities. On the frequencies of branchiostegal ray counts, specimens of over 90% at all localities with the exceptions of Oshoro and Kitami-Esashi which showed 7 or 8. The variances ranged from 0.174 (Bekkai) to 0.387 (Kitami-Esashi). The means of branchiostegal ray counts of all localities fell within the range of 7.533 (Kushiro) to 8.063 (Oshoro). Results of significance tests for the differences of variances and the means of the number of branchiostegal rays are shown in Table 18. In

Table .17. *Percent frequencies in the number of branchiostegal rays of the chika in 15 localities of Hokkaido and Tohoku regions. Asterisks show mode.*

Locality	N	Mean	S.D.	Variance	Number of branchiostegal rays			
					6	7	8	9
Wakkanai	40	7.725	0.452	0.204	-	28	73*	-
Mashike	65	7.738	0.538	0.290	-	31	65*	5
Oshoro	16	8.063	0.574	0.329	-	13	69*	19
Sarufutsu	67	7.910	0.514	0.265	-	18	73*	9
Kitami-Esashi	77	7.857	0.622	0.387	-	27	60*	13
Abashiri	80	7.600	0.518	0.268	-	41	58*	1
Bekkai	41	8.024	0.418	0.174	-	7	83*	10
Nemuro	70	7.614	0.572	0.327	-	43	53*	4
Akkeshi	90	7.700	0.507	0.257	-	32	66*	2
Kushiro	15	7.533	0.516	0.267	-	47	53*	-
Shizunai	48	7.708	0.582	0.339	2	29	65*	4
Mori	124	7.798	0.541	0.292	-	27	67*	6
Hakodate	75	7.867	0.528	0.279	-	21	71*	8
Noheji	42	7.595	0.587	0.344	-	45	50*	5
Sanriku-chô	75	7.893	0.452	0.205	-	16	79*	5

Table 18. *Significance tests for the differences of variances and the means of the number of the branchiostegal rays between the samples collected from 15 localities in Hokkaido and Tohoku regions. NS, not significant; * significant at the 5% level; ** significant at the 1% level.*

Locality	Wakk.	Mash.	Osho.	Saru.	Kita.	Abas.	Bekk.	Nemu.	Akke.	Kush.	Shiz.	Mori	Hako.	Nohe.	Sanr.
Wakkanai		NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mashike	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Oshoro	*	*		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sarufutsu	NS	NS	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Kitami-Esashi	NS	NS	NS	NS		NS	**	NS	NS	NS	NS	NS	NS	NS	**
Abashiri	NS	NS	**	**	**		NS	NS	NS	NS	NS	NS	NS	NS	NS
Bekkai	**	**	NS	NS	NS	**		*	NS	NS	*	NS	NS	*	NS
Nemuro	NS	NS	**	**	*	NS	**		NS	NS	NS	NS	NS	NS	*
Akkeshi	NS	NS	*	*	NS	NS	**	NS		NS	NS	NS	NS	NS	NS
Kushiro	NS	NS	*	*	NS	NS	**	NS	NS		NS	NS	NS	NS	NS
Shizunai	NS	NS	*	NS	NS	NS	**	NS	NS	NS		NS	NS	NS	NS
Mori	NS	NS	NS	NS	NS	**	*	*	NS	NS	NS		NS	NS	NS
Hakodate	NS	NS	NS	NS	NS	**	NS	**	*	*	NS	NS		NS	NS
Noheji	NS	NS	**	**	*	NS	**	NS	NS	NS	NS	NS	*		NS
Sanriku-chô	NS	NS	NS	NS	NS	**	NS	**	*	**	NS	NS	NS	**	

Variance ratio

t-test of mean

the variance ratio, there were statistical significance at the 5% or 1% level as follows: Kitami-Esashi from Wakkanai, Bekkai and Sanriku-cho; Bekkai from Kitami-Esashi, Nemuro, Shizunai and Noheji; Nemuro from Bekkai and Sanriku-cho. In the means, there was no significant difference among the Pacific coast of Akkeshi, Kushiro, Shizunai and Mori each other. On the other hand, Wakkanai and Mashike showed a significant difference from Oshoro and Bekkai, and other localities showed no differences.

6. *Number of Upper, Lower and Total Gill Rakers*

Upper Gill Rakers

Range of counts for all specimens was 9–14 with a mean of 11.369 and 95% confidence intervals of 11.322–11.415 (Table 19). The mode was 11 at Wakkanai which faces on Soya Strait, Japan Sea coast of Mashike and Oshoro, and Okhotsk Sea coast of Sarufutsu, Kitami-Esashi and Abashiri. At other localities, there was no clear difference of the mode depending on sea areas, however frequency distributions showed the tendency of higher values. The variances ranged from 0.325 (Mori) to 0.715 (Akkeshi). The means of upper gill raker counts of all localities fell within the range of 10.949 (Wakkanai) to 12.133 (Kushiro). Results of significance tests for the differences of variances and the means of the number of upper gill rakers are shown in Table 20. In the variance ratio, there were no differences between areas. In the means, Kushiro showed statistically significant differences at the 5% or 1% level from all other localities. Amongst localities north of Nemuro and coast of Japan Sea, there was no significant difference with the exception between Wakkanai and Abashiri. On the other hand, Pacific coast of Akkeshi, Kushiro and Mori, and Mutsu Bay of Noheji showed a significant difference at the 5% or 1% level from localities north of Shiretoko Peninsula and coast of Japan Sea. Also, other localities on the Pacific coast with the exception of Shizunai showed significant differences from many localities in north of Shiretoko Peninsula and coast of Japan Sea. Therefore, it is considered that localities on the Pacific coast of the south of Akkeshi showed the higher upper gill raker counts than localities north of Shiretoko Peninsula and on the coast of Japan Sea.

Lower Gill Rakers

Range of counts for all specimens was 22–29 with a mean of 25.201 and 95% confidence intervals of 25.134–25.267 (Table 21). The modal count was 25 at all localities north of Shiretoko Peninsula and on the coast of Japan Sea. At other localities, the mode of 25 was also the most frequent, 24 was next and 26 was the least. The variances ranged from 0.644 (Shizunai) to 1.317 (Hakodate). The means of lower gill raker counts for all localities fell within the range of 24.553 (Shizunai) to 25.568 (Hakodate). Results of significance tests for the differences of variances and the means of the number of lower gill rakers are shown in Table 22. In the variance ratio, there was no significant difference amongst localities with the exception that Mori and Hakodate showed statistically significant differences at the 5% or 1% level from Abashiri and Shizunai. In the means, Shizunai

Table 19. *Percent frequencies in the number of upper gill rakers of the chika in 15 localities of Hokkaido and Tohoku regions. Asterisks show mode.*

Locality	N	Mean	S.D.	Variance	Number of upper gill rakers					
					9	10	11	12	13	14
Wakkanai	39	10.949	0.605	0.366	-	21	64*	15	-	-
Mashike	64	11.297	0.582	0.339	-	6	58*	36	-	-
Oshoro	16	11.000	0.632	0.400	-	19	63*	19	-	-
Sarufutsu	67	11.299	0.697	0.485	-	10	52*	34	3	-
Kitami-Esashi	77	11.247	0.710	0.504	-	13	52*	32	3	-
Abashiri	80	11.075	0.671	0.450	-	19	55*	26	-	-
Bekkai	41	11.366	0.662	0.438	-	10	44	46*	-	-
Nemuro	71	11.254	0.788	0.621	-	14	54*	25	7	-
Akkeshi	90	11.600	0.845	0.715	1	9	29	52*	8	1
Kushiro	15	12.133	0.834	0.695	-	-	20	53*	20	7
Shizunai	46	11.087	0.626	0.392	-	15	61*	24	-	-
Mori	124	11.702	0.570	0.325	-	1	33	61*	5	-
Hakodate	75	11.467	0.759	0.577	-	8	45*	39	8	-
Noheji	41	11.610	0.703	0.494	-	5	37	51*	7	-
Sanriku-chô	74	11.351	0.584	0.341	-	5	54*	41	-	-

Table 20. *Significance tests for the differences of variances and the means of the number of the upper gill rakers between the samples collected from 15 localities in Hokkaido and Tohoku regions. NS, not significant; * significant at the 5% level; ** significant at the 1% level.*

Localith	Wakk.	Mash.	Osho.	Saru.	Kita.	Abas.	Bekk.	Nemu.	Akke.	Kush.	Shiz.	Mori	Hako.	Nohe.	Sanr.
Wakkanai		NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS
Mashike	**		NS	NS	NS	NS	NS	*	**	*	NS	NS	*	NS	NS
Oshoro	NS	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sarufutsu	**	NS	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Kitami-Esashi	*	NS	NS	NS		NS	NS	NS	NS	NS	NS	*	NS	NS	NS
Abashiri	NS	*	NS	*	NS		NS	NS	*	NS	NS	NS	NS	NS	NS
Bekkai	**	NS	NS	NS	NS	*		NS	NS	NS	NS	NS	NS	NS	NS
Nemuro	*	NS	NS	NS	NS	NS	NS		NS	NS	NS	**	NS	NS	*
Akkeshi	**	**	**	*	**	**	NS	**		NS	*	**	NS	NS	**
Kushiro	**	**	**	**	**	**	**	**	*		NS	*	NS	NS	*
Shizunai	NS	NS	NS	NS	NS	NS	*	NS	**	**		NS	NS	NS	NS
Mori	**	**	**	**	**	**	**	**	NS	*	**		**	NS	NS
Hakodate	**	NS	*	NS	NS	**	NS	NS	NS	*	**	*		NS	*
Noheji	**	*	**	*	**	**	NS	*	NS	*	**	NS	NS		NS
Sanriku-chô	**	NS	*	NS	NS	**	NS	NS	*	**	*	**	NS	*	

Variance ratio

t-test of mean

Table 21. *Percent frequencies in the number of lower gill rakers of the chika in 15 localities of Hokkaido and Tohoku regions. Asterisks show mode.*

Locality	N	Mean	S.D.	Variance	Number of lower gill rakers							
					22	23	24	25	26	27	28	29
Wakkanai	40	24.925	0.944	0.892	-	3	35*	35*	23	5	-	-
Mashike	64	24.938	1.022	1.044	-	5	31	38*	20	5	2	-
Oshoro	16	24.625	0.806	0.650	-	6	38	44*	13	-	-	-
Sarufutsu	66	25.364	0.971	0.943	-	5	9	42*	35	8	2	-
Kitami-Esashi	77	25.494	0.995	0.990	-	3	10	39*	32	14	1	-
Abashiri	80	24.925	0.897	0.804	-	3	33	39*	23	4	-	-
Bekkai	41	25.537	0.925	0.855	-	-	12	37	39*	10	2	-
Nemuro	71	24.859	0.990	0.980	-	7	30	39*	18	6	-	-
Akkeshi	90	25.278	0.936	0.877	-	2	16	44*	29	8	1	-
Kushiro	15	25.400	1.121	1.257	-	-	27*	27*	27*	20	-	-
Shizunai	47	24.553	0.802	0.644	-	2	55*	30	11	2	-	-
Mori	121	25.380	1.105	1.221	1	1	21	32*	31	13	1	1
Hakodate	74	25.568	1.148	1.317	-	-	19	32*	27	18	3	1
Noheji	41	25.463	0.977	0.955	-	2	7	49*	27	12	2	-
Sanriku-chô	74	25.122	1.033	1.067	-	3	30*	30*	28	9	-	-

Table 22. *Significance tests for the differences of variances and the means of the number of the lower gill rakers between the samples collected from 15 localities in Hokkaido and Tohoku regions. NS, not significant; * significant at the 5% level; ** significant at the 1% level.*

Locality	Wakk.	Mash.	Osho.	Saru.	Kita.	Abas.	Bekk.	Nemu.	Akke.	Kush.	Shiz.	Mori	Hako.	Nohe.	Sanr.
Wakkanai		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mashike	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Oshoro	NS	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sarufutsu	*	*	**		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Kitami-Esashi	**	**	**	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Abashiri	NS	NS	NS	**	**		NS	NS	NS	NS	NS	*	*	NS	NS
Bekkai	**	**	**	NS	NS	**		NS	NS	NS	NS	NS	NS	NS	NS
Nemuro	NS	NS	NS	**	**	NS	**		NS	NS	NS	NS	NS	NS	NS
Akkeshi	*	*	**	NS	NS	*	NS	**		NS	NS	NS	NS	NS	NS
Kushiro	NS	NS	*	NS	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS
Shizunai	*	*	NS	**	**	*	**	NS	**	**		*	**	NS	NS
Mori	*	**	**	NS	NS	**	NS	**	NS	NS	**		NS	NS	NS
Hakodate	**	**	**	NS	NS	**	NS	**	NS	NS	**	NS		NS	NS
Noheji	*	**	**	NS	NS	**	NS	**	NS	NS	**	NS	NS		NS
Sanriku-chô	NS	NS	NS	NS	*	NS	*	NS	NS	NS	**	NS	*	NS	

Variance ratio

t-test of mean

Table 23. *Percent frequencies in the number of total gill rakers of the chika in 15 localities of Hokkaido and Tohoku regions. Asterisks show mode.*

Locality	N	Mean	S.D.	Variance	Number of total gill rakers								
					33	34	35	36	37	38	39	40	41
Wakkanai	39	35.872	1.260	1.588	3	10	26	31*	23	5	3	-	-
Mashike	64	36.234	1.330	1.770	3	2	27	28*	23	14	2	2	-
Oshoro	16	35.625	1.310	1.717	6	13	25	31*	19	6	-	-	-
Sarufutsu	66	36.682	1.383	1.913	-	8	9	30*	24	20	8	2	-
Kitami-Esashi	77	36.753	1.406	1.978	-	6	9	27	32*	13	8	4	-
Abashiri	80	36.000	1.263	1.595	-	11	28*	28*	19	14	1	-	-
Bekkai	41	36.878	1.435	2.060	-	5	15	22	15	37*	5	2	-
Nemuro	71	36.085	1.461	2.136	4	7	27*	21	25	11	3	1	-
Akkeshi	90	36.878	1.467	2.153	2	1	12	24	28*	21	7	3	1
Kushiro	15	37.333	1.718	2.952	-	-	13	27*	13	20	20	-	7
Shizunai	46	35.652	1.159	1.343	-	17	30*	28	17	7	-	-	-
Mori	121	37.074	1.379	1.903	1	1	9	27*	21	26	11	2	1
Hakodate	74	37.027	1.587	2.520	-	3	18	18	27*	14	16	4	1
Noheji	41	37.073	1.456	2.120	2	-	7	29*	20	27	10	5	-
Sanriku-chô	74	36.473	1.295	1.677	-	7	18	26*	26*	20	4	-	-

Table 24. *Significance tests for the differences of variances and the means of the number of the total gill rakers between the samples collected from 15 localities in Hokkaido and Tohoku regions. NS, not significant; * significant at the 5% level; ** significant at the 1% level.*

Locality	Wakk.	Mash.	Osho.	Saru.	Kita.	Abas.	Bekk.	Nemu.	Akke.	Kush.	Shiz.	Mori	Hako.	Nohe.	Sanr.
Wakkanai		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mashike	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Oshoro	NS	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sarufutsu	**	NS	**		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Kitami-Esashi	**	*	**	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Abashiri	NS	NS	NS	**	**		NS	NS	NS	NS	NS	NS	*	NS	NS
Bekkai	**	*	**	NS	NS	**		NS	NS	NS	NS	NS	NS	NS	NS
Nemuro	NS	NS	NS	*	**	NS	**		NS	NS	NS	NS	NS	NS	NS
Akkeshi	**	**	**	NS	NS	**	NS	**		NS	NS	NS	NS	NS	NS
Kushiro	**	**	**	NS	NS	**	NS	**	NS		*	NS	NS	NS	NS
Shizunai	NS	*	NS	**	**	NS	**	NS	**	**		NS	*	NS	NS
Mori	**	**	**	NS	NS	**	NS	**	NS	NS	**		NS	NS	NS
Hakodate	**	**	**	NS	NS	**	NS	**	NS	NS	**	NS		NS	NS
Noheji	**	**	**	NS	NS	**	NS	**	NS	NS	**	NS	NS		NS
Sanriku-chô	*	NS	*	NS	NS	*	NS	NS	NS	*	**	**	*	*	

Variance ratio (upper right)

t-test of mean (lower left)

showed significant differences from most localities, however it was recognized that there was no clear tendency related to regions.

Total Gill Rakers

Range of counts for all specimens was 33–41 with a mean of 36.567 and 95% confidence intervals of 36.473–36.662 (Table 23). The modes ranged from 35 to 38, and 36 was the most frequent. Total gill raker counts had a tendency for higher values centering around 36. The variances ranged from 1.343 (Shizunai) to 2.952 (Kushiro). The means of total gill raker counts for all localities fell within the range of 35.625 (Oshoro) to 37.333 (Kushiro). Results of significance tests for the differences of variances and the means of the number of total gill rakers are shown in Table 24. In the variance ratio, there were no significant differences with the exception that Shizunai significantly different from Kushiro and Hakodate, and Abashiri showed statistical significance at the 5% level from Hakodate. In the means, there were many significant differences amongst localities as with the lower gill raker counts, and no tendency relating to region was recognized. Furthermore, the range of total gill raker counts was than in any other meristic characters examined in this study, and the modes varied greatly with locality, therefore it was considered that total gill raker counts were very variable.

7. Discussion

Concerning the discrimination of populations in osmerid fishes, Matsubara (1946), by analyzing the total length and body weight composition, showed that wakasagi, *H. t. nipponensis* did not consist of one population in Kitaura; Hamada (1953a) recognized that geographic variation exist in the wakasagi by studying scale structure; Ito (1959) reported that there were three populations in the shishamo, *Spirinchus lanceolatus*, by analyzing body length, age and fecundity. Kilambi et al. (1965) studies the population differences of surf smelt, *H. pretiosus pretiosus*, by serological methods, and Legault and Delisle (1968) compared the maturity index, relative fecundity, intergonadal ratio and so on between giant and small smelt, *Osmerus eperlanus mordax*; Copeman (1977) used multivariate analysis of meristics and morphometrics on these same two forms. Furthermore, studies of the population or stock discrimination using meristic characters mainly vertebrae, fin ray and gill raker counts have been published by Schaefer (1936), Sato and Kato (1951), Hamada (1953b), Ito (1957a) and Tanaka (1969).

Before studying geographic variation of meristic characters in chika, the author, first, examined differences between sexes and year classes. In other osmerid fishes, Schaefer (1936) and Hart (1937) demonstrated sexual dimorphism in the vertebral numbers, the former in the surf smelt and the latter in the capelin, *Mallotus villosus*. Ito (1970) studied sexual dimorphism of vertebral, gill raker and pyloric caeca counts in the kyuriuo, *O. e. mordax*. However, there was no significant difference between sexes. On the other hand, Hamada (1953c) stated that vertebral counts of the wakasagi had shown the annual variations at Lake Abashiri. From the present results of the tests in the chika, however, vertebral counts showed no significant difference between sexes, and between year classes. Only anal fin ray counts showed the significant differences between sexes, and the number of pectoral fin rays, midlateral scales and pored scales showed the significant differences between year classes.

In studies of geographic variation of meristic characters in the chika, Ito (1957a) examined the number of midlateral scales, dorsal fin rays, pectoral fin rays, anal fin rays and gill rakers at Odaito, and reported that these counts agreed well with former worker's counts of the chika. He has stated his vertebral count results as follows, "Chika which were obtained from Odaito showed one to three higher numbers than other districts, and these results were caused from the examined specimens number and the factors of the regions", therefore these results suggested the existence of the geographic variation in vertebral counts. Concerning the results of this examination, Nemuro showed the highest total vertebrae counts and differentiation from other localities. Odaito is one of the localities facing on Nemuro Strait, therefore these two results agree well. On the abdominal vertebrae counts, eastern Hokkaido of Bekkai, Nemuro and Akkeshi showed higher mean values, and Sarufutsu in the north of Shiretoko Peninsula showed a lower mean value. On the other hand, eastern Hokkaido of Bekkai and Akkeshi showed lower mean values of caudal vertebrae counts, and north of Shiretoko Peninsula of Sarufutsu and Mashike showed higher mean values. Therefore, the localities which are stated above showed significant differences from almost all other localities in the means of abdominal and caudal vertebrae counts. When examining the frequencies of abdominal and caudal vertebrae counts, the localities north of Shiretoko Peninsula and on the coast of the Japan Sea showed a tendency toward lower abdominal vertebrae counts and higher caudal vertebrae counts in contrast to the localities south of Shiretoko Peninsula. Therefore, the differences of the above two areas were well recognized. As stated above, the number of abdominal and caudal vertebrae have an opposite tendency between the two areas, while the differences in the total vertebrae counts between the two areas are negligible because the previous differences are due only to a shift in position of the first caudal vertebrae. Therefore, there are many reports which state that geographic variation was studied by using total vertebrae counts, it is clear that some geographic variation will be ignored when using this approach that will be uncovered by counting separately the number of abdominal and caudal elements. On the other hand, Sato and Kato (1951) reported that vertebral counts of wakasagi were not easily modified by transplantation, and if the counts had changed during a long period, it might possibly be due to natural selection rather than to the direct influence of temperature conditions. Kawamura (1940), Uchihashi et al. (1950) and Thompson (1926) have presumed that the variations in vertebral counts showed no relation to latitude, two of the former were on sand lances and the latter was on sardines. Also, in the present results, it has been recognized that the variations of the number of abdominal, caudal and total vertebrae showed no relation to the latitude.

When the means of the number of dorsal and caudal fin rays, and branchiostegal rays are compared among all localities, there is no significant difference relating to region. Also, the modes in the number of the caudal fin rays and the branchiostegal rays were the same at all localities. Pelvic fin ray counts showed no significant difference amongst all localities and the mode was also the same. Therefore, the number of caudal and pelvic fin rays, and branchiostegal rays in the above stated four characters have shown little geographic variation, and it was considered that numbers of caudal and pelvic fin rays were the most stable meristic characters in this species.

Gill raker counts have been used in various fishes as racial characters, e.g., comparisons have shown the seasonal and annual differences in the relationship between the number of gill rakers and the body length (Kinoshita, 1977a), and among the localities (Kinoshita, 1977b) in the populations of anchovy in northern Japan. In osmerid fishes, Ito (1963) reported that year class variations of gill raker counts were recognized in the shishamo. He considered the cause to be water temperatures and environmental factors which influence the gill raker counts because of the long time from fertilization to hatching in the shishamo. Also, Taniguchi (1974) showed that the variations of genetically differentiated populations had appeared in the gill raker counts, using the electrophoretic methods for nigorobuna, *Carassius buergeri grandoculis*, obtained from Lake Biwa. Therefore, gill raker counts are just as useful a racial character as vertebral counts and so on. Of these results of gill raker counts in the chika, upper and lower gill raker counts have the same mode at localities north of Shiretoko Peninsula and on the coast of the Japan Sea, and these areas have shown no modal variation as found in the localities in south of Shiretoko Peninsula. Therefore, it is understood that gill raker counts in the localities of north of Shiretoko Peninsula and on the coast of the Japan Sea showed less variation similarly in abdominal and caudal vertebrae counts. Total gill raker counts have the widest variation in the meristic characters examined in this study, and this result suggested that total gill raker counts depended on the lower gill raker counts which had wider variation than the upper, based on the frequency distributions.

Summarizing the comparisons of the means, each mode of the number of abdominal and caudal vertebrae, and upper and lower gill rakers showed the same pattern at Wakkanai on Soya Strait, Mashike and Oshoro along the coast of the Japan Sea, and Sarufutsu, Kitami-Esashi and Abashiri along the coast of Okhotsk Sea bordering the Shiretoko Peninsula; and the frequencies of other characters also showed the same tendency. On the other hand, the localities south of Bekkai showed a modal uniformity compared with the above areas. However, the frequencies of each character are similar within the areas. Therefore, distributions of the chika in Japan could be divided broadly into the areas of the north (including the coast of the Japan Sea) and south of Shiretoko Peninsula based on the meristic characters.

It is said that the number of meristic characters are determined by environmental conditions especially the water temperature and the salinity at an early period of the development of the fishes (Tåning, 1952; Itazawa, 1957). Also, it has been reported that meristic characters of some fishes showed geographic clines (Amemiya et al., 1934; Halliday, 1969). Thus, differences in the values are

Table 25. *Arrangement of the localities according to their number of five meristic characters. H, higher number; L, lower number.*

Abdominal vertebrae	Bekkai *H* 41.976 →	Kushiro 41.867 →	Noheji 41.667 →	Sanriku 41.507 *L*	Abashiri *H* 41.342 ←	Wakkanai 41.325 *L*	
Caudal vertebrae	Bekkai *L* 22.317 →	Kushiro 22.533 →	Mori 22.861 →	Sanriku 22.867 *H*	Abashiri *L* 22.863 ←	Esashi 23.052 ←	Wakkanai 23.125 *H*
Total vertebrae	Bekkai *L* 64.293 →	Akkeshi 64.344 →	Hakodate 64.360 →	Sanriku 64.373 *H*	Abashiri *L* 64.203 ←	Esashi 64.312 ←	Wakkanai 64.450 *H*
Dorsal fin rays		Bekkai *L* 10.585 →	Shizunai 10.604 →	Sanriku 10.640 *H*	Abashiri *H* 10.620 ←	Esashi 10.403 ←	Wakkanai 10.350 *L*
Lower gill rakers		Bekkai *H* 25.537 →	Noheji 25.463 →	Sanriku 25.122 *L*	Abashiri *H*24.9254 ←	Wakkanai 24.9250 *L*	

Table 26. *Significance tests for the differences of variances and the means of the number of the ten meristic characters between the samples collected from 15 localities in Hokkaido and Tohoku regions. NS, not significant; * significant at the 5% or 1% level; number of asterisks shows the number of significant meristic characters.*

Locality	Wakk.	Mash.	Osho.	Saru.	Kita.	Abas.	Bekk.	Nemu.	Akke.	Kush.	Shiz.	Mori	Hako.	Nohe.	Sanr.
Wakkanai		NS	*	NS	*	*	**	*	***	NS	*	*	*	*	NS
Mashike	*		*	NS	*	NS	**	*	*	*	NS	NS	*	NS	NS
Oshoro	*	*		NS	NS	*	NS	*	NS	NS	NS	NS	NS	NS	NS
Sarufutsu	***	*	**		NS	*	**	*	*	NS	*	**	*	NS	NS
Kitami-Esashi	***	**	**	NS		**	**	*	*	NS	*	***	*	*	*
Abashiri	*	***	**	*****	****		***	**	***	NS	***	****	****	NS	*
Bekkai	*******	*****	***	**	**	******		***	***	*	***	**	**	**	**
Nemuro	****	***	***	******	*******	**	*****		**	NS	*	***	NS	NS	***
Akkeshi	*****	*****	******	****	***	*****	*	*****		NS	**	**	*	NS	*
Kushiro	****	****	****	****	***	***	**	***	*		*	*	NS	NS	*
Shizunai	**	**	*	***	****	**	*****	**	*****	****		**	***	NS	*
Mori	*****	*****	****	***	***	******	***	******	**	*	***		**	NS	**
Hakodate	****	****	****	***	*	****	**	******	****	***	***	*		*	**
Noheji	****	****	****	****	***	*****	**	*****	*	*	***	*	**		NS
Sanriku-chô	***	*	***	**	***	***	***	***	****	***	****	***	**	****	

Variance ratio (upper right)

t-test of mean (lower left)

sometimes expressed as the differences of environmental conditions. But, Nelson (1969) examined the geographic variation in the brook sticklebacks, and he stated that clinal variation in spine lengths was observed and no marked geographic separation into groups was observed in the number of meristic characters. Also, Taniguchi (1974) showed that the variation of genetically differentiated nigorobuna populations had appeared in the gill raker counts by comparisons of starch gel using electrophoretic methods. Therefore, it can be noted that the variation of the meristic characters was not always the result of environmental conditions. Conversely, Sato and Kato (1951) stated that vertebral counts of the wakasagi did not easily vary by transplantations as stated before, but there are no reports about other species in the family Osmeridae. Therefore, this study has discussed the relationships in the chika between the variations of meristic characters and the environmental conditions especially water temperatures. Since it is said that the number of meristic characters are determined at an early period of the development of the fishes (Tåning, 1952; Itazawa, 1957), the surface water temperature distributions from the coast of eastern Hokkaido to the Pacific coast of Tohoku during the spawning period of April to May were obtained from the Report of the Hakodate Marine Observatory (1967, 1968). Consequently, it was clear that the sea temperature was low in the north and high in the south, but the variations of the meristic characters of the chika did not follow sea temperature patterns. Abashiri and Sanriku-cho which were far apart and had the greatest temperature differences had nevertheless similar meristic counts, see Table 25 where the localities are arranged according to their number of five meristic characters (Table 25). The tendency was recognized that the counts changed from high to low in regards to the direction from Bekkai to Sanriku-cho, but low to high from Wakkanai to Abashiri in the number of abdominal vertebrae and lower gill rakers. It was also recognized that the counts changed from low to high in regards to the direction from Bekkai to Sanriku-cho, but high to low from Wakkanai to Abashiri in the number of caudal and total vertebrae. Namely, it is understood that the similar counts between Abashiri and Sanriku-cho were produced from different directions. Therefore, it was concluded that the variations of meristic characters were due to the hereditary factors rather than the environmental conditions. These concluded results of the significance tests for the differences of variances and the means of all meristic characters are shown in Table 26 for the discrimination of local forms based on the meristic characters. Of these results, the only samples between Sarufutsu and Kitami-Esashi showed no significant difference and among the other localities there were statistically significant differences in one to seven of the meristic characters. Therefore, the author has concluded that Sarufutsu and Kitami-Esashi shared the same local form but the others consisted of distinct local forms.

IV. Comparisons of the Two Local Forms, Mori and Hakodate

Study of extensive material led to the discovery of many local forms. Therefore, in this chapter, two local forms are selected, namely Mori and Hakodate which are geographic neighbors and which show the least difference among the all local forms discriminated by the meristic characters, for examination in regard to biological features (growth, fecundity, sex ratio, age composition and length-weight relationship). These characteristics are then compared between the two local forms.

First growth is considered. Absolute growth is influenced by time, genetic limitations, and by environmental conditions such as water temperatures, diets and habitat density. There are many studies about the differences in growth of marine fishes: Takada (1930) about herring; Kohler (1964), cod; Hamai (1967), chum salmon; Hashimoto and Koyachi (1969), Iwata (1975), walleye pollock. These studies have correlated growth with differences in marine areas or races, and thus it has been shown that discrimination of races can be based on growth differences. Therefore, the body length and weight growth equations at Mori and Hakodate were examined, and growth between two localities was compared using growth equations. In general, it is known that the relations between the fecundity and body length, and between the fecundity and weight are well expressed by the parabolic equations. Simpson (1951) examined the relationship between the fecundity and body length of the plaice, and reported that the regression coefficients showed geographic variation. Therefore, this study examined variation in fecundity, relationships between the fecundity and body length, and between the fecundity and body weight. Regression lines between year classes, between ages and between the two local forms were examined. On the other hand, it is known that the sex ratio changes seasonally or with age (Burbidge, 1969), and proportions of sexes have a geographic variation in the wakasagi (Shiraishi, 1961). Length-weight relationship was held constant, and it is known that the equations varied geographically within a species (Ochiai, 1952). Therefore, it is considered that in examining the sex ratio, age composition and length-weight relationships are also useful for clarifying the differences between local forms of the chika. Thus these biological features were also compared between the two localities, Mori and Hakodate.

1. Materials and Methods

Chika used in this study were periodically collected from Mori and Hakodate (include Kamiiso), southern Hokkaido, during the period from May 1973 to April 1976 (Table 27, 28). Specimens were collected mainly by small set nets and beach seines; they were preserved in 10% formalin and studied.

Mean values for each month were used for the study of the growth equations in body length and weight. Body length was taken from the anteriormost tip of the body, the tip of the lower jaw with the mouth closed, to the caudal flexure, by calipers reading to 0.1 mm. Body weight was measured 0.01 g by Sartorius balance after drying the outside surface of the body. Growth in body length and weight was examined using Logistic, Gompertz and Bertalanffy growth equations according to the graphical method (Ricklefs, 1967). In graphical method, however, two growth equations without Bertalanffy were examined for growth in body length, because the cube equation is used in Bertalanffy equation in this method, thus this equation is unsuitable for growth in body length.

Table 27. *Sampling data for biological studies of chika at Mori, from May 1973 to April 1976.*

Date	Total	♂	♀	Date	Total	♂	♀	Date	Total	♂	♀
1973. May 4.	135	74	61	1974. May 10.	139	61	78	1975. May 29.	14	8	6
17.	99	29	70	28.	53	33	20	June 19.	49	20	29
June 1.	111	54	57	June 11.	115	62	53	July 18.	123	56	67
20.	41	17	24	25.	106	51	55	Aug. 15.	137	84	53
July 1.	81	37	44	July 10.	84	36	48	Oct. 14.	26	11	15
23.	109	50	59	17.	151	78	73	26.	77	39	38
30.	124	69	55	26.	106	59	47	27.	56	32	24
Aug. 10.	2	1	1	Aug. 14.	39	14	25	Dec. 14.	43	21	22
29.	120	56	64	29.	138	79	59	1976. Jan. 27.	57	32	25
Sep. 16.	120	73	47	Sep. 12.	134	69	65	Feb. 6.	25	4	21
Oct. 5.	114	53	61	Oct. 11.	3	2	1	16.	8	5	3
17.	42	23	19	Nov. 14.	75	29	46	Mar. 11.	21	13	8
Nov. 8.	73	34	39	29.	8	5	3	Apr. 12.	37	24	13
21.	116	53	63	Dec. 20.	2	1	1	30.	34	8	26
Dec. 8.	75	31	44	1975. Mar. 17.	48	6	42				
19.	77	35	42	Apr. 4.	46	15	31				
1974. Jan. 11.	9	6	3	18.	51	15	36				
Mar. 28.	65	21	44								
Apr. 16.	76	19	57								

Table 28. *Sampling data for biological studies of chika at Hakodate, from May 1973 to April 1976.*

Date	Total	♂	♀	Date	Total	♂	♀	Date	Total	♂	♀
1973. May 1.	106	99	7	1974. May 10.	93	32	61	1975. May 26.	63	31	32
16.	58	57	1	28.	39	16	23	June 18.	73	29	44
June 1.	51	27	24	June 25.	76	17	59	July 15.	87	28	59
15.	56	30	26	July 12.	104	54	50	18.	152	73	79
July 5.	1	0	1	24.	135	62	73	Aug. 2.	38	16	22
6.	73	40	33	Aug. 30.	122	63	59	15.	124	64	60
18.	239	116	123	Sep. 13.	132	63	69	Sep. 23.	120	52	68
Aug. 3.	130	64	66	Oct. 11.	148	84	64	1976. Mar. 24.	61	53	8
11.	96	41	55	22.	126	70	56	Apr. 9.	82	29	53
Sep. 1.	107	49	58	Dec. 28.	73	34	39	27.	104	24	80
15.	90	47	43	1975. Jan. 20.	43	19	24				
Oct. 4.	104	49	55	Feb. 15.	19	11	8				
16.	108	60	48	Mar. 25.	82	55	27				
Nov. 2.	132	76	56	Apr. 17.	116	44	72				
15.	39	24	15								
1974. Mar. 21.	126	84	42								
Apr. 6.	85	55	30								
18.	93	26	67								

Growth in body length and weight can not find the growth equations which were lumped together from age 0+ to 2+, thus growth equations have been examined for each age group. Asymptote length and asymptote weight have been first estimated with average length and weight of the last age in month of each age group, and those asymptotes have been examined the fitness by the graphical method. When the asymptote does not fit the equation, refining the estimate of the asymptote. Standard of age in months has fixed as follows. First, peak of the spawning in the chika has varied annually, and in 1973 year class, maximum of the gonad somatic index has shown in early April at Mori and that has shown in late March at Hakodate, and 15 days have taken from the fertilization to hatching in the chika (Yanagawa, in preparation). Therefore, the peak of the hatching is presumed to be about late April, and monthly ages are calculated on the 20th of each month.

Measurements of fecundity are made using the weight method, and 0.5–2.0 g was weighed from each gonad. Fecundity-length and fecundity-weight relationships, expressed as parabolic equation, $\log E = \log a + b \log L$ (or W), were calculated, where E is fecundity, L is body length in mm, W is body weight in g, b is the regression coefficient and $\log a$ is the intercept.

In regards to sex ratio, the proportion of each sex against total counts and the male/female ratio was calculated, and examined using the χ^2-test. Age determination was done from body length frequencies and the number of annual rings on the scales. Age composition was examined during the spawning period in 1974.

Length-weight relationship was examined in 1973 year class chika during the spawning period. Length-weight relationships, expressed as parabolic equations, $\log W = \log a + b \log L$, were regression, where W is body weight in g, L is body length in mm, b is the regression coefficient and $\log a$ is the intercept.

Age groups were established as follows. Those fish which live within a year from hatching are 0+ and, following ages are treated the same. Indication of ages in the spawning period are used age in full.

The t-test of the means in the fecundity in each age were computed using subprogram "T-TEST", and scatter diagrams of fecundity-length and fecundity-weight relationships were plotted subprogram "SCATTERGRAM" in SPSS respectively. F-test of regression lines were calculated using FORTRAN program after the data were purified by a rejection region at the 5% significance level.

2. *Body Length Growth Equations*

Growth in body length was examined at ages 0+ to 2+ respectively in the 1973 year class. First, I calculated the conversion factors in Logistic and Gompertz for sexes and age groups at Mori and Hakodate, and examined the fitness of the growth curves. Logistic growth equations were well fitted for the body length at the asymptotes which are shown in Table 29. The Logistic growth equations are expressed as follows, $Lt = \frac{L_\infty}{1+e^{-k(t-t_0)}}$, where Lt is the body length in mm, L_∞ is asymptote in mm, k is growth coefficient, t is the age in month and to is the age in month when growth inflection has appeared. Furthermore, results of fitness in the above two growth equations, and the relations between calculated body length and measured body length were shown in figures in Yanagawa (1980).

Mori

When compared the body lengths which were calculated from the growth equations with measured body length in sex distinction and in each age, above two

Table 29. *Constants of growth equations in body length at Mori and Hakodate.* L_∞, *asymptote*; *k*, *growth coefficient*; *to*, *age in month when growth inflection has appeared.*

Age	Sex	Mori			Hakodate		
		L_∞	*k*	*to*	L_∞	*k*	*to*
0+	Male	100	0.356	4.08	112	0.412	5.22
	Female	100	0.416	4.28	115	0.404	5.34
1+	Male	155	0.196	−1.37	160	0.176	−3.59
	Female	160	0.204	−1.18	165	0.160	−4.13
2+	Male	180	0.132	−9.82			
	Female	190	0.172	−7.05			

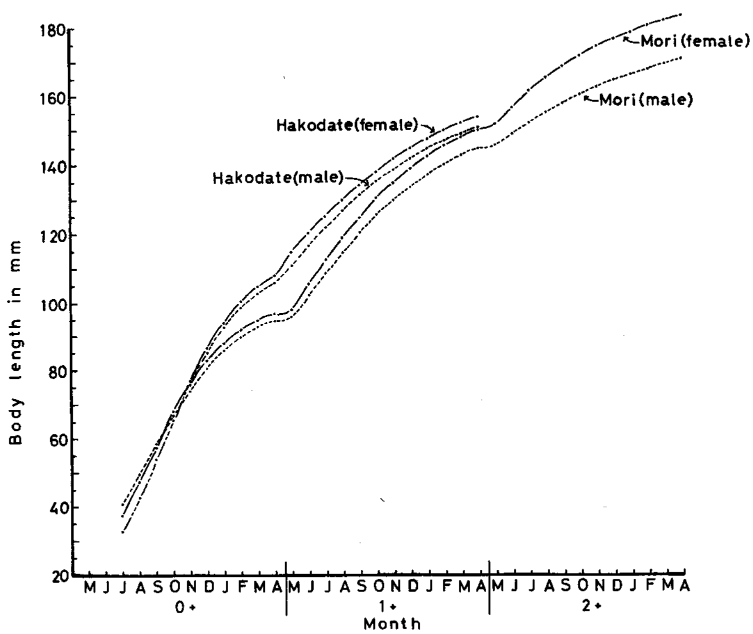

Fig. 2. **Distributions of calculated body length from Logistic growth equations of each sex, age, and station.**

values were well agreed. Asymptote lengths were equal in both sexes at 100 mm at age 0+, females became larger than males at age 1+, and the difference became wider and it was shown 10 mm difference between sexes at age 2+. Values of *k* in females were 1.17 times at age 0+ and 1.30 times at age 2+ higher than those of males, and the values were almost equal at age 1+. Values of *to* showed less difference between sexes at ages 0+ and 1+, however 2.77 difference was shown at age 2+. Differences in body length were shown not to be marked at age 0+, however body lengths in females were always larger than males over age 0+, and these differences became greater as the time proceeded (Fig. 2).

Hakodate

When compared the body lengths which were calculated from the growth equations with measured body length in sex distinction and in each age, above two values were well agreed. Asymptote lengths of females were 3 mm at age 0+ and 5 mm in age 1+ larger than those of males. Values of k were almost equal in both sexes at age 0+, however the value for males was 1.10 times higher than that of females at age 1+. Values of *to* showed less differences at age 0+, and a difference of 0.54 was shown at age 1+ between sexes. Body lengths in females were always larger than those in males at age 1+, however these differences were relatively small (Fig. 2).

3. *Body Weight Growth Equations*

Growth in body weight was examined at ages 0+ to 2+ respectively in 1973 year class. First, I calculated the conversion factors in Logistic, Gompertz and Bertalanffy for sexes and age groups at Mori and Hakodate, and examined the fitness of the growth curves. Logistic growth equations were well fitted for the body weight at the asymptotes which are shown in Table 30. The Logistic growth equations are expressed as follows, $Wt=\frac{W_\infty}{1+e^{-k(t-t_0)}}$, where Wt is the body weight in g, W_∞ is asymptote in g, k is growth coefficient, t is the age in month and *to* is the age in month when growth inflection has appeared. Furthermore, results of fitting in the above three growth equations, and the relations between calculated body weight and measured body weight were shown in figures in Yanagawa (1980).

Table 30. *Constants of growth equations in body weight at Mori and Hakodate. W_∞, asymptote; k, growth coefficient; to, age in month when growth inflection has appeared.*

Age	Sex	Mori			Hakodate		
		W_∞	k	*to*	W_∞	k	*to*
0+	Male	9.5	0.612	7.39	16	0.680	9.41
	Female	10.5	0.620	7.66	18	0.656	9.92
1+	Male	40	0.284	4.87	43	0.264	3.45
	Female	50	0.260	5.89	58	0.256	4.75
2+	Male	65	0.268	0.66			

Mori

Growth in body weight of age 2+ females were not fitted for Logistic growth curves, because the body weight increased rapidly from the 10th to 12th month.

Also, since the specimens were few, only means were shown in Fig. 3. When comparing the body weight calculated from the growth equations with measured body weight for the two sexes and for each age, the above two values were very close. Asymptote weights in females exceeded that for males by only 1 g, then the difference became larger and they differed by 10 g at age 1+. Values of k were almost equal in both sexes at age 0+, however those of males were 1.09 times higher than those of females at age 1+. Values of *to* showed less differences between sexes at age 0+, however 1.02 difference was shown at age 1+. Differences of body weight were shown to be not marked at age 0+, however body weight in females were always larger than males over age 0+, and these differences became higher as the time passed (Fig. 3).

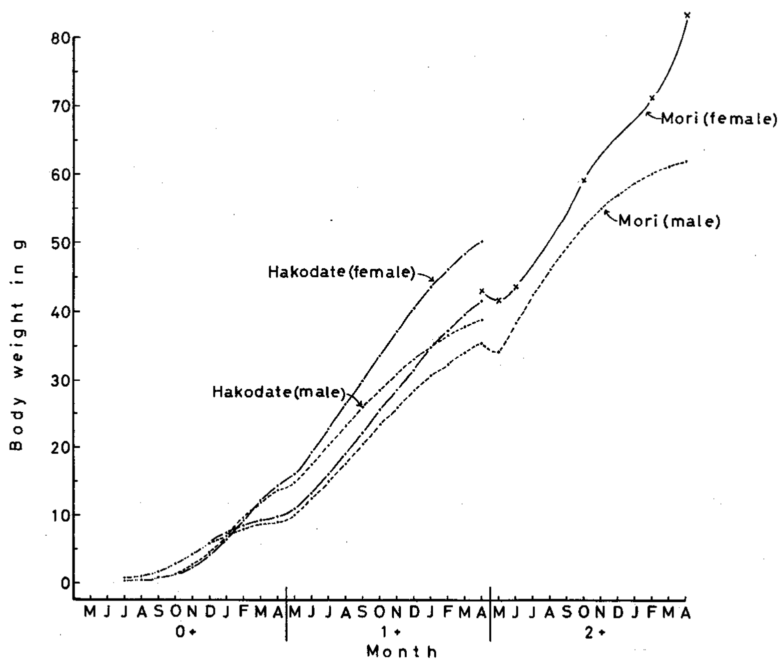

Fig. 3. Distributions of calculated body weight from Logistic growth equations of each sex, age, and station.

Hakodate

When compared the body weight which were calculated from the growth equations with measured body weight in sex distinction and in each age, above two values were well agreed. Asymptote weights in females exceeded that of males by only 2 g, however the difference became larger and the difference was 15 g at age 1+. In regard to the values of k, it was only apparent that the values for males were less high than those of females at the ages 0+ and 1+, thus those values were almost equal between the sexes. The difference in the values between the sexes of *to* was 0.51 at age 0+, and a difference of 1.30 was shown at age 1+. Body weights in females were always larger than those of males at age 1+, and these differences became rapidly higher as the age in months increased (Fig. 3).

4. Growth Rate

Body length and weight of females tended to be larger than those of males in each age group at Mori and Hakodate, and the differences of body weight were clearer than those of body length.

Next, on the growth rates which ignored the year classes, they were shown 50.2–70.2% in body length and 240.8–524.4% in body weight with great changes between 1 and 2 years old, however 13.1–21.8% in body length and 44.5–106.1% in body weight between 2 and 3 years old, and the tendency was clearly recognized that the growth rates became lower moreover between 3 and 4 years old at Mori. At Hakodate, growth rates were 36.8–56.0% in body length and 158.1–440.6% in body weight with great changes between 1 and 2 years old, and it was recognized that the growth rates became lower between 2 and 3 years of age same as at Mori.

When annual growth rates in each year class were compared (Table 31), they were shown 41.5–52.5% in body length and 210.9–338.2% in body weight in 1973 year class and growth rates were also shown 50.3–65.4% in body length and 300.3–431.2% in body weight in 1974 year class respectively between 1 and 2 years old at Mori and Hakodate. Furthermore, the tendency was recognized that growth rates for females were less high than those for males in both body length and weight. Growth rates between 2 and 3 years old rapidly decreased from that between 1 and 2 years old in both body length and weight, and the tendency continued with the annual growth rates between 3 and 4 years old further becoming even lower.

Table 31. *Annual growth rates of body length (B. L.) and weight (B. W.) in each year class chika at Mori and Hakodate.*

Locality	Year class	Sex	Age	Growth rate (%)	
				B.L.	B.W.
Mori	1971	Female	3-4	12.8	49.8
	1972	Female	2-3	15.4	79.8
		Female	3-4	8.3	32.2
	1973	Male	1-2	52.5	299.8
		Female	1-2	52.4	338.2
		Male	2-3	17.1	59.7
		Female	2-3	22.4	105.5
	1974	Male	1-2	61.9	390.4
		Female	1-2	65.4	431.2
Hakodate	1971	Female	3-4	13.1	21.9
	1973	Male	1-2	42.4	219.1
		Female	1-2	41.5	210.9
	1974	Male	1-2	50.3	300.3
		Female	1-2	53.0	340.4

5. *Fecundity*

Age-Fecundity Relationship

The number of ovarian eggs for each age at Mori and Hakodate, and results of significance test for the differences of the fecundity between localities, and between ages were shown in Tables 32 and 33. Namely, there was no significant difference of the number of ovarian eggs for the same age of 1 to 3 years old between Mori and Hakodate, therefore it was recognized that there was no variation of the fecundity in each age between two localities. When compared with the fecundity between ages, there was no significant difference between fish 3 and 4 years old at Mori only, although there was statistical significance at the 5% level between 3 years old at Hakodate and 4 years old at Mori. Therefore, the variations in the fecundity between ages tend to show that chika over 2 years old have less variability than 1 and 2 years old.

Table 32. *Number of ovarian eggs, body length and body weight classified by ages at Mori and Hakodate. Figures in parentheses represent 95% confidence intervals of mean.*

Locality	Age	N	Number of eggs		Mean BL in mm	Mean BW in g
			Mean	Range		
Mori	1	52	3842 (3338-4346)	1552-9044	104.8	14.23
	2	30	12863 (11900-13826)	7834-19716	151.7	46.82
	3	18	24781 (22634-26928)	18871-36127	182.2	86.80
	4	4	29233 (23403-35062)	25094-33470	200.4	116.84
Hakodate	1	38	4506 (3882-5130)	1722-11029	113.4	17.67
	2	17	12679 (11102-14255)	8222-17793	157.8	51.47
	3	3	19793 (13805-25782)	17370-22191	179.2	79.57

Table 33. *Comparison of the means of the number of ovarian eggs between age groups in each stations. NS, not significant; * significant at the 5% level; **significant at the 1% level; using t-test.*

	Mori 1	Mori 2	Mori 3	Mori 4	Hako 1	Hako 2	Hako 3
Mori 1	—						
Mori 2	**	—					
Mori 3	**	**	—				
Mori 4	**	**	NS	—			
Hako 1	NS	**	**	**	—		
Hako 2	**	NS	**	**	**	—	
Hako 3	**	**	NS	*	**	**	—

Length-Fecundity Relationship

Regarding the relationship between body length and fecundity, relationships were compared first with the year classes. In this study, each year class was composed of 1 and 2 year old chika which were major spawning groups, and length-fecundity relationships were well fitted for parabolic equations. Regression lines at Mori and Hakodate were compared between year classes using the F-test (Table 34). From the results at Mori, regression coefficients between 1972 and 1973 and also the 1972 and 1974 year classes showed significant differences, the value of 1972 year class was higher. Therefore, the 1972 year class showed a higher increment in the fecundity than the other two year classes. Regression coefficients between 1973 and 1974 year classes showed no significant difference, however adjusted means showed the statistical significance, and the fecundity of 1973 year class showed higher values at the same body length. At Hakodate, regression coefficients between 1973 and 1974 year classes showed no significant differences, however adjusted means showed a statistical significance, therefore there was no increment in the fecundity between these two year classes, and the fecundity of 1974 year class showed higher values at the same body length. When regression lines for the same year classes were compared between Mori and Hakodate (Table 35), regression coefficients for the 1973 year classes showed no significant difference, however the adjusted means showed a statistically significant differences, therefore the fecundity at Mori showed higher values at the same body length. For 1974 year class, regression lines showed no significant difference between the two localities. As stated, the tendency for increment in fecundity showed no difference and the 1973 year class showed a different fecundity only at the same body length, between Mori and Hakodate.

Next, regression lines at Mori and Hakodate were compared between ages using the F-test (Table 36). From the results at Mori, there was no difference between 1 and 2 years old, 1 and 3 years old, 1 and 4 years old, and 3 and 4 years old chika. Regression coefficients between 2 and 3 years old, and between 2 and 4 years old showed no significant difference, however adjusted means showed the statistical significance. Therefore, there was no tendency for increment in the fecundity on

Table 34. *Comparison of regression coefficient and the adjusted mean in the number of ovarian eggs and body length relationship between year classes at Mori and Hakodate.*

Locality	Relation	F-test of slope			F-test of adjusted mean		
		Fo	*df*	*P*	*Fo*	*df*	*P*
Mori	1972–1973	18.245	1, 55	$P<0.005$			
	1972–1974	5.573	1, 32	$0.025>P>0.010$			
	1973–1974	0.555	1, 41	$0.50>P>0.25$	7.790	1, 42	$0.010>P>0.005$
Hakodate	1973–1974	0.995	1, 31	$0.50>P>0.25$	5.775	1, 32	$0.025>P>0.010$

Table 35. *Comparison of regression coefficient and the adjusted mean in the number of ovarian eggs and body length relationship between stations.*

Year class	Relation	F-test of slope			F-test of adjusted mean		
		Fo	*df*	*P*	*Fo*	*df*	*P*
1973	Mori-Hakodate	3.273	1, 49	$0.10>P>0.05$	37.543	1, 50	$P<0.005$
1974	Mori-Hakodate	0.053	1, 23	$P>0.50$	0.078	1, 24	$P>0.50$

Table 36. *Comparison of regression coefficient and the adjusted mean in the number of ovarian eggs and body length relationship between ages at Mori and Hakodate.*

Locality	Relation	F-test of slope			F-test of adjusted mean		
		Fo	*df*	*P*	*Fo*	*df*	*P*
Mori	1-2	1.966	1, 74	$0.25>P>0.10$	1.973	1, 75	$0.25>P>0.10$
	1-3	0.091	1, 62	$P>0.50$	2.190	1, 63	$0.25>P>0.10$
	1-4	0.193	1, 49	$P>0.50$	0.242	1, 50	$P>0.50$
	2-3	0.812	1, 42	$0.50>P>0.25$	13.166	1, 43	$P<0.005$
	2-4	0.170	1, 29	$P>0.50$	4.227	1, 30	$0.050>P>0.025$
	3-4	0.751	1, 17	$0.50>P>0.25$	1.010	1, 18	$0.50>P>0.25$
Hakodate	1-2	0.201	1, 50	$P>0.50$	0.056	1, 51	$P>0.50$
	1-3	0.057	1, 36	$P>0.50$	0.029	1, 37	$P>0.50$
	2-3	0.267	1, 16	$P>0.50$	0.004	1, 17	$P>0.50$

Table 37. *Comparison of regression coefficient and the adjusted mean in the number of ovarian eggs and body length relationship between stations.*

Age	Relation	F-test of slope			F-test of adjusted mean		
		Fo	*df*	*P*	*Fo*	*df*	*P*
1	Mori-Hakodate	0.277	1, 82	$P>0.50$	2.477	1, 83	$0.25>P>0.10$
2	Mori-Hakodate	3.486	1, 42	$0.10>P>0.05$	3.270	1, 43	$0.10>P>0.05$
3	Mori-Hakodate	0.029	1, 16	$P>0.50$	8.631	1, 17	$0.010>P>0.005$

the body length at the ages from 1 to 4 years old, and fecundity had increased equally with age. From the results at Hakodate, there was no difference at all between ages, therefore there was no increment in fecundity for the body length at the ages from 1 to 3 years old also at Mori. When regression lines at the same ages were compared between Mori and Hakodate (Table 37), regression coefficients at 1, 2 and 3 years old showed no significant difference, however 3 years old chika showed statistically significant differences in the adjusted mean. Therefore, the increment in the fecundity of the two localities was equal, while higher fecundity at same body length at 3 years old was recognized at Mori.

Weight-Fecundity Relationship

Body weight and fecundity relationships were compared first for the year classes. In this study, each year class was composed of 1 and 2 years old chika which were the dominant spawning groups, and weight-fecundity relationships could be closely fitted using parabolic equations. Regression lines at Mori and Hakodate were compared between year classes using the *F*-test (Table 38). At Mori, regression coefficients between 1972 and 1973 year classes showed a significant difference, the value of 1972 year class was higher, and this year class had a higher increment in fecundity. Regression coefficients between the 1972 and 1974 year classes showed no significant differences, however adjusted means showed a significant difference. Therefore, the increment in the fecundity was the same in these year classes, but the fecundity of 1974 year class showed higher values for the same body weight. Regression lines between 1973 and 1974 year classes showed no significant differences. Also at Hakodate, regression lines between 1973 and 1974 year classes showed no significant differences, and weight-fecundity relationships were the same between these year classes. When regression lines for the same year classes were compared between Mori and Hakodate (Table 39), regression coefficients of the 1973 year class showed no significant difference, however the adjusted means showed a statistically significant difference. At 1974 year class, regression lines showed no significant difference between the two localities. As stated, the increment in the fecundity showed no significant difference between Mori and Hakodate, and the fecundity at Mori showed higher values for the same body weight in the 1973 year class.

Table 38. *Comparison of regression coefficient and the adjusted mean in the number of ovarian eggs and body weight relationship between year classes at Mori and Hakodate.*

Locality	Relation	F-test of slope			F-test of adjusted mean		
		Fo	*df*	*P*	*Fo*	*df*	*P*
Mori	1972–1973	16.469	1, 54	$P<0.005$			
	1972–1874	2.450	1, 32	$0.25>P>0.10$	5.392	1, 33	$0.050>P>0.025$
	1973–1974	3.683	1, 40	$0.10>P>0.05$	1.377	1, 41	$0.25>P>0.10$
Hakodate	1973–1974	0.768	1, 31	$P>0.50$	2.617	1, 32	$0.25>P>0.10$

Table 39. *Comparison of regression coefficient and the adjusted mean in the number of ovarian eggs and body weight relationship between stations.*

Year class	Relation	F-test of slope			F-test of adjusted mean		
		Fo	*df*	*P*	*Fo*	*df*	*P*
1973	Mori-Hakodate	3.710	1, 48	$0.10>P>0.05$	25.081	1, 49	$P<0.005$
1974	Mori-Hakodate	0.522	1, 23	$0.50>P>0.25$	0.517	1, 24	$0.50>P>0.25$

Table 40. *Comparison of regression coefficient and the adjusted mean in the number of ovarian eggs and body weight relationship between ages at Mori and Hakodate.*

Locality	Relation	F-test of slope			F-test of adjusted mean		
		Fo	*df*	*P*	*Fo*	*df*	*P*
Mori	1–2	0.933	1, 75	$0.50>P>0.25$	1.778	1, 76	$0.25>P>0.10$
	1–3	0.216	1, 63	$P>0.50$	1.812	1, 64	$0.25>P>0.10$
	1–4	1.468	1, 49	$0.25>P>0.10$	0.236	1, 50	$P>0.50$
	2–3	0.030	1, 44	$P>0.50$	5.451	1, 45	$0.025>P>0.010$
	2–4	2.433	1, 30	$0.25>P>0.10$	1.802	1, 31	$0.25>P>0.10$
	3–4	3.643	1, 18	$0.10>P>0.05$	0.019	1, 19	$P>0.50$
Hakodate	1–2	0.001	1, 50	$P>0.50$	0.055	1, 51	$P>0.50$
	1–3	0.064	1, 36	$P>0.50$	0.001	1, 37	$P>0.50$
	2–3	0.087	1, 16	$P>0.50$	0.066	1, 17	$P>0.50$

Table 41. *Comparison of regression coefficient and the adjusted mean in the number of ovarian eggs and body weight relationship between stations.*

Age	Relation	*F*-test of slope			*F*-test of adjusted mean		
		Fo	*df*	*P*	*Fo*	*df*	*P*
1	Mori-Hakodate	0.281	1, 82	$P>0.50$	1.439	1, 83	$0.25>P>0.10$
2	Mori-Hakodate	1.039	1, 43	$0.50>P>0.25$	3.248	1, 44	$0.10>P>0.05$
3	Mori-Hakodate	0.001	1, 17	$P>0.50$	3.349	1, 18	$0.10>P>0.05$

Next, regression lines at Mori and Hakodate were compared between ages using the *F*-test (Table 40). At Mori there was no significant difference between 1 and 2 years old, 1 and 3 years old, 1 and 4 years old, 2 and 4 years old, and 3 and 4 years old chika. Regression coefficients between 2 and 3 years old showed no significant difference, however adjusted means showed statistical significance. Therefore, there was no increment in the fecundity for the body weight from 1 to 4 years old, and fecundity increased equally with ages. At Hakodate there was no difference between any age group, therefore there was no increment in the fecundity for the body weight at the ages from 1 to 3 years old also at Mori. When regression lines at the same ages were compared between Mori and Hakodate (Table 41), it was recognized that there was no significant difference between the two localities. Therefore, the increment in the fecundity with the body weight between two localities was the same for each age group.

6. *Sex Ratio*

Sex Ratio in Each Age

Sex ratios at each age and comparisons of the proportion of sexes using the χ^2-test at Mori are shown in Table 42. For 1973–74, the sex ratio of age 0+ was almost equal, however age 1+, 2+, and the total count showed significant differences in the proportion of sexes, with female proportions higher and age 2+ showing the highest difference. In 1974–75, sex ratios for age 0+, 1+ and total sample were almost equal, however age 2+ and 3+ showed significant differences in ratios, and female proportions were higher and at age 3+ only females were found. In 1975–76, sex ratios of age 0+ and for the total sample were almost equal, however age 1+ and 2+ showed significant differences in the proportion, and males in age 1+ and females in age 2+ were respectively more numerous, while age 3+ was composed only of a few females.

Sex ratios at each age and comparisons of the proportion in sexes using the χ^2-test at Hakodate are shown in Table 43. In 1973–74, the sex ratio at age 0+ was almost equal, however age 1+ and the total sample showed significant differences in the proportion in sexes with the male proportion being higher. In 1974–75, sex ratios of age 0+, 2+ and total count were almost equal, however age 1+ showed significant difference in the ratios, and the female proportion was higher while for age 3+ only one female was found. In 1975–76, the sex ratio at age 0+ was almost equal, however age 1+ and total count showed significant

Table 42. *Sex ratio of chika collected at Mori, from 1973 to 1976.*

Year	Age group	Number		Percentage		Sex ratio	Ho (M: F=1:1)		
		Male	Female	Male	Fmeale	M/F	χ^2	df	P
1973–74	0+	462	484	48.8	51.2	0.95	0.466	1	0.50>P>0.25
	1+	267	324	45.2	54.8	0.82	5.306	1	0.025>P>0.010
	2+	6	44	12.0	88.0	0.14	27.380	1	P<0.005
	Total	735	852	46.3	53.7	0.86	8.479	1	P<0.005
1974–75	0+	253	231	52.3	47.7	1.10	0.911	1	0.50>P>0.25
	1+	353	405	46.6	53.4	0.87	3.431	1	0.10>P>0.05
	2+	9	25	26.5	73.5	0.36	6.618	1	0.025>P>0.010
	3+	0	20	0.0	100.0	—	18.050	1	P<0.005
	Total	615	681	47.5	52.5	0.90	3.260	1	0.10>P>0.05
1975–76	0+	245	234	51.1	48.9	1.05	0.209	1	P>0.50
	1+	101	52	66.0	34.0	1.94	15.059	1	P<0.005
	2+	19	63	22.2	76.8	0.30	22.548	1	P<0.005
	3+	0	7	0.0	100.0	—	—	—	—
	Total	365	356	50.6	49.4	1.03	0.089	1	P>0.50

Table 43. *Sex ratio of chika collected at Hakodate, from 1973 to 1976.*

Year	Age group	Number		Percentage		Sex ratio	Ho (M:F=1:1)		
		Male	Female	Male	Female	M/F	χ^2	df	P
1973–74	0+	650	619	51.2	48.8	1.05	0.709	1	0.50>P>0.25
	1+	292	122	70.5	29.5	2.39	68.987	1	P<0.005
	2+	4	9	30.8	69.2	0.44	—	—	—
	Total	946	750	55.8	44.2	1.26	22.420	1	P<0.005
1974–75	0+	538	525	50.6	49.4	1.02	0.136	1	P>0.50
	1+	58	133	30.4	69.6	0.44	28.670	1	P<0.005
	2+	28	25	52.8	47.2	1.12	0.076	1	P>0.50
	3+	0	1	0.0	100.0	—	—	—	—
	Total	624	684	47.7	52.3	0.91	2.661	1	0.25>P>0.10
1975–76	0+	276	324	46.0	54.0	0.85	3.682	1	0.10>P>0.05
	1+	120	172	41.1	58.9	0.70	8.908	1	P<0.005
	2+	3	9	25.0	75.0	0.33	—	—	—
	Total	399	505	44.1	55.9	0.79	12.196	1	P<0.005

differences in the ratios, the female proportions were higher and at age 2+ females were more numerous.

Monthly Changes in Sex Ratio

Monthly changes in sex ratios at Mori are shown in Table 44. In the period from May just after spawning period to February, males showed a predominance in September and January in 1973–74 and October in 1974–75, and in August while females were predominant in February in 1975–76, but in other months the sex ratio was almost equal. As shown during the monthly changes in sex ratios from 1973 to 1976, the ratios of the sexes during the growing periods from May to January were almost equal, however changes in sex ratio appeared in February, and it was clearly recognized that sex ratios had changed in March just before spawning and in April during spawning period.

Monthly changes in sex ratio at Hakodate are shown in Table 45. Males were predominant in May in 1973–74, and females in May and June in 1974–75, but sex ratios of the following months to February were almost equal. Therefore, as shown the monthly changes in sex ratios of total counts from 1973 to 1976, the proportion in sexes during the growing periods from May to February were almost equal with the exception of male predominance in May which was influenced by extreme predominance of male in 1973–74, however it was recognized that the sex ratio had changed in March just before spawning and in April during the spawning period.

Sex Ratio in the Spawning Period

Sex ratios for each age group and total counts in the spawning period at Mori from March to May in 1974 are shown in Table 46 and Fig. 4. In the 1 year olds, the sex ratio was almost equal in March, females showed predominance in April, however the ratio was almost equal again in early May, and the proportion of females was lower in late May. In the 2 year olds, the sex ratio was almost equal in March,

Table 44. *Monthly change in sex ratio of chika at Mori, from May 1973 to April 1976.*

	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
1973–74												
N ♂	103	71	156	57	73	76	87	66	6	-	21	19
N ♀	131	81	158	65	47	80	102	86	3	-	44	57
% ♂	44.0	46.7	49.7	46.7	60.8	48.7	46.0	43.4	66.7	-	32.3	25.0
% ♀	56.0	53.3	50.3	53.3	39.2	51.3	54.0	56.6	33.3	-	67.7	75.0
♂/♀	0.79	0.88	0.99	0.88	1.55	0.95	0.85	0.77	2.00	-	0.48	0.33
1974–75												
N ♂	94	113	173	93	69	2	34	1	-	-	3	30
N ♀	98	108	168	84	65	1	49	1	-	-	40	67
% ♂	49.0	51.1	50.7	52.5	51.5	66.7	41.0	50.0	-	-	7.0	30.9
% ♀	51.0	48.9	49.3	47.5	48.5	33.3	59.0	50.0	-	-	93.0	69.1
♂/♀	0.96	1.05	1.03	1.11	1.06	2.00	0.69	1.00	-	-	0.08	0.45
1975–76												
N ♂	8	20	56	84	-	82	-	21	32	9	13	32
N ♀	6	29	67	53	-	77	-	22	25	24	8	39
% ♂	57.1	40.8	45.5	61.3	-	51.6	-	48.8	56.1	27.3	61.9	45.1
% ♀	42.9	59.2	54.5	38.7	-	48.4	-	51.2	43.9	72.7	38.1	54.9
♂/♀	1.33	0.69	0.84	1.58	-	1.06	-	0.95	1.28	0.38	1.63	0.82
Total												
N ♂	205	204	385	234	142	160	121	88	38	9	37	81
N ♀	235	218	393	202	112	158	151	109	28	24	92	163
% ♂	46.6	48.3	49.5	53.7	55.9	50.3	44.5	44.7	57.6	27.3	28.7	33.2
% ♀	53.4	51.7	50.5	46.3	44.1	49.7	55.5	55.3	42.4	72.7	71.3	66.8
♂/♀	0.87	0.94	0.98	1.16	1.27	1.01	0.80	0.81	1.36	0.38	0.40	0.50

Table 45. *Monthly change in sex ratio of chika at Hakodate, from May 1973 to April 1976.*

		May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
1973–74													
N	♂	156	57	156	107	96	109	100	-	-	-	84	81
	♀	8	50	156	122	101	103	71	-	-	-	42	97
%	♂	95.1	53.3	50.0	46.7	38.7	51.4	58.5	-	-	-	66.7	45.5
	♀	4.9	46.7	50.0	53.3	51.3	48.6	41.5	-	-	-	33.3	54.5
	♂/♀	19.50	1.14	1.00	0.88	0.95	1.06	1.41	-	-	-	2.00	0.84
1974–75													
N	♂	48	17	116	63	63	154	-	34	19	11	55	44
	♀	84	59	123	59	69	120	-	39	24	8	27	72
%	♂	36.4	22.4	48.5	51.6	47.7	56.2	-	46.6	44.2	57.9	67.1	37.9
	♀	63.6	77.6	51.5	48.4	52.3	43.8	-	53.4	55.8	42.1	32.9	62.1
	♂/♀	0.57	0.29	0.94	1.07	0.91	1.28	-	0.87	0.79	1.38	2.04	0.61
1975–76													
N	♂	31	29	101	80	53	-	-	-	-	-	53	53
	♀	32	44	138	82	68	-	-	-	-	-	8	133
%	♂	49.2	39.7	42.3	49.4	43.8	-	-	-	-	-	86.9	28.5
	♀	50.8	60.3	57.7	50.6	56.2	-	-	-	-	-	13.1	71.5
	♂/♀	0.97	0.66	0.73	0.98	0.78	-	-	-	-	-	6.63	0.40
Total													
N	♂	235	103	373	250	212	263	100	34	19	11	192	178
	♀	124	153	417	263	238	223	71	39	24	8	77	302
%	♂	65.5	40.2	47.2	48.7	47.1	54.1	58.5	46.6	44.2	57.9	71.4	37.1
	♀	34.5	59.8	52.8	51.3	52.9	45.9	41.5	53.4	55.8	42.1	28.6	62.9
	♂/♀	1.90	0.67	0.89	0.95	0.89	1.18	1.41	0.87	0.79	1.38	2.49	0.59

Table 46. *Sex ratio of spawning population in chika at Mori from March to May, 1973.*

1974			1	2	3	Total
March 28	N	♂	14	7	0	21
		♀	17	10	17	44
	%	♂	45.2	41.2	0.0	32.3
		♀	54.8	58.8	100.0	67.7
		♂/♀	0.82	0.70	-	0.48
April 16	N	♂	16	3	0	19
		♀	31	9	17	57
	%	♂	34.0	25.0	0.0	25.0
		♀	66.0	75.0	100.0	75.0
		♂/♀	0.52	0.33	-	0.33
May 10	N	♂	60	1	0	61
		♀	66	3	9	78
	%	♂	47.6	25.0	0.0	43.9
		♀	52.4	75.0	100.0	56.1
		♂/♀	0.91	0.33	-	0.78
May 28	N	♂	33	0	0	33
		♀	20	0	0	20
	%	♂	62.3	-	-	62.3
		♀	37.7	-	-	37.7
		♂/♀	1.65	-	-	1.65

Table 47. *Sex ratio of spawning population of chika at Hakodate from March to May, 1974.*

1974			1	2	3	Total
March 21	N	♂	68	14	2	84
		♀	35	5	2	42
	%	♂	66.0	73.7	50.0	66.7
		♀	34.0	26.3	50.0	33.3
		♂/♀	1.94	2.80	1.00	2.00
April 6	N	♂	37	18	0	55
		♀	17	10	3	30
	%	♂	68.5	64.3	0.0	64.7
		♀	31.5	35.7	100.0	35.3
		♂/♀	2.18	1.80	-	1.83
April 18	N	♂	24	2	0	26
		♀	51	14	2	67
	%	♂	32.0	12.5	0.0	28.0
		♀	68.0	87.5	100.0	72.0
		♂/♀	0.47	0.14	-	0.39
May 10	N	♂	15	17	0	32
		♀	57	4	0	61
	%	♂	20.8	81.0	-	34.4
		♀	79.2	19.0	-	65.6
		♂/♀	0.26	4.25	-	0.52
May 28	N	♂	6	10	0	16
		♀	9	14	0	23
	%	♂	40.0	41.7	-	41.0
		♀	60.0	58.3	-	59.0
		♂/♀	0.67	0.71	-	0.70

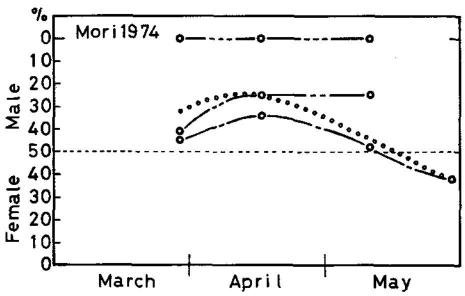

Fig. 4. Sex ratio of spawning population of chika at Mori from March to May, 1974. —-—, 1-year old chika; —--—, 2-year old chika; ——--—, 3-year old chika; ∘∘∘∘, mean value

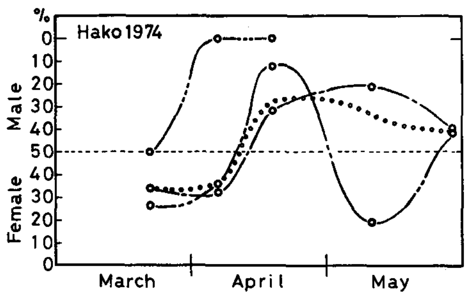

Fig. 5. Sex ratio of spawning population of chika at Hakodate from March to May, 1974. —-—, 1-year old chika; —--—, 2-year old chika; ——--—, 3-year old chika; ∘∘∘∘, mean value

however females showed predominance from April to May, and the 3 year olds were all female.

Sex ratios in each age group and the total count in the spawning period at Hakodate from March to May in 1974 are shown in Table 47 and Fig. 5. In 1 year olds, the ratio of females was lower from March to early April, however females showed clear predominance from the middle of April to early May, and ratio was almost equal in late May. In 2 year olds, changes of sex ratio were the same as for the 1 year olds with the exception that females showed a lower proportion in early May. In 3 year olds, the sex ratio was almost equal in March, however females only were present in April.

7. *Age Composition*

Age Composition

Changes in age composition during the spawning period in 1974 at Mori are shown in Fig. 6. In males, the proportion of 1 year olds became higher from 66.7% to 98.4% during the spawning period, however the proportion of 2 years old became lower from 33.3% to 1.6%. In females, the proportion of 1 year olds became higher from 38.6% to 84.6% during the spawning period, however the proportions of 2 and 3 years olds became lower, the former from 22.7% to 3.8% and the latter from 38.6% to 11.5% respectively. The age compositions changed through the spawning period, and 1 and 2 years olds accounted for 89.1% and 10.9 % in males, 1, 2 and 3 years old accounted for 63.7%, 12.3% and 24.0% in females, respectively. The age composition when sexes were combined through the spawning period was as follows: 1, 2 and 3 years old accounted for 72.9%, 11.8% and 15.4% respectively.

Changes of age composition during the spawning period in 1974 at Hakodate were shown in Fig. 7. In males, 1 year olds in March and on April 18, and 2

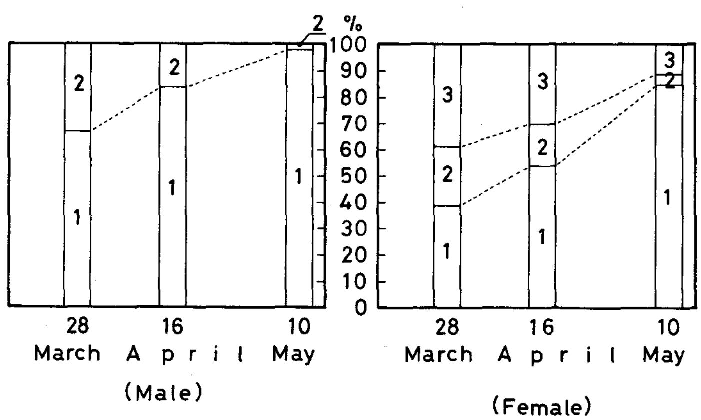

Fig. 6. Changes in age composition of spawning groups at Mori during 1974 spawning period.

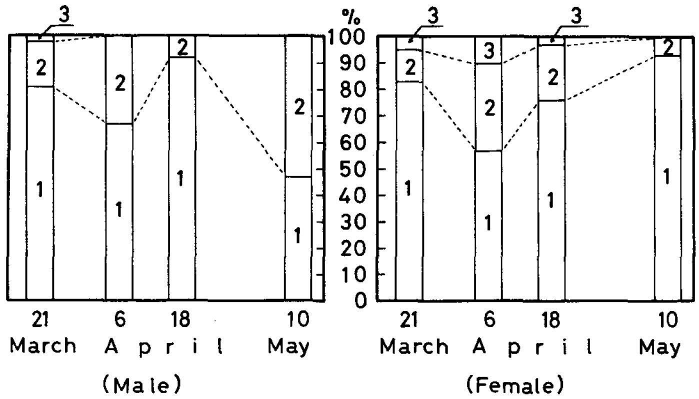

Fig. 7. Changes in age composition of spawning groups at Hakodate during 1974 spawning period.

years old on April 6 and May accounted for large proportions respectively, however 3 years old accounted for 2.4% in March only. In females, the proportion of 1 year olds increased from 56.7% to 93.4% during the spawning period, however rates of 2 and 3 years old decreased, the former from 33.3% to 6.6% and the latter from 10.0% to 0% respectively with the exception of March. Of the age compositions through the spawning period, 1, 2 and 3 years old accounted for 73.1%, 25.9% and 1.0% in males, 80.0%, 16.5% and 3.5% in females respectively. Of the age composition when sexes were combined through the spawning period, 1, 2 and 3 years old accounted for 76.6%, 21.2% and 2.3% respectively. It may be seen the proportions became extremely small with age.

The oldest aged specimens of the chika which were collected in all researching periods were age 3+ females found in March and April at Mori and Hakodate. Therefore, those specimens were nearly 4 years old chika, and their ovaries were filled with ripe ovarian eggs.

8. *Length-Weight Relationship*

Length-Weight Relationship

Sex and distinctions in length-weight relationships for Mori and Hakodate were well expressed by parabolic equations (Fig. 8, 9). Correlation coefficients (r) between body length and weight ranged from 0.747–0.986, and showed high positive correlation. Regression coefficients (b) ranged from 2.991–3.613 in males and 3.042–3.570 in females (Table 48).

Regression lines for sexes were compared between ages using the F-test (Table 49). There was no significant difference between 1 and 2 year olds in males, between 1 and 2 year olds, 1 and 3 year olds in females at Mori, and between 1 and 2 years olds in females at Hakodate. On the other hand, regression coefficients between 2 and 3 year olds in females at Mori, and between 1 and 2 year olds in males at Hakodate showed no significant differences, however adjusted means showed statistical significance. Therefore, it is recognized that the increase of weight with length showed no difference between ages in both sexes at Mori and Hakodate.

Next, regression lines for each age group were compared between sexes using the F-test (Table 50). Regression coefficients between sexes at 1 year old showed

Table 48. *Regression coefficient b and intercept log a in the lengthweight relationship of 1973 year class chika at Mori and Hakodate during the spawning period. r, correlation coefficient. Figures in parentheses represent 95% confidence intervals of b.*

Locality	Age	Sex	N	log a	b	r
Mori	1	Male	85	−5.647	3.336 (3.226-3.447)	0.986
		Female	79	−6.103	3.570 (3.377-3.763)	0.968
	2	Male	30	−4.913	2.991 (2.399-3.584)	0.890
		Female	61	−5.050	3.068 (2.583-3.554)	0.839
	3	Male	-	-	-	-
		Female	7	−5.904	3.471 (1.487-5.456)	0.895
Hakodate	1	Male	68	−6.224	3.613 (3.451-3.774)	0.979
		Female	75	−5.285	3.143 (2.995-3.331)	0.962
	2	Male	18	−5.071	3.053 (2.056-4.050)	0.851
		Female	14	−5.056	3.042 (1.325-4.759)	0.747

Table 49. *Comparison of regression coefficient and the adjusted mean in the length-weight relationship between ages at Mori and Hakodate during the spawning period in 1973 year class chika.*

Locality	Sex	Relation	F-test of slope			F-test of adjusted mean		
			Fo	df	P	Fo	df	P
Mori	Male	1-2	1.399	1, 111	$0.25>P>0.10$	0.453	1, 112	$P>0.50$
	Female	1-2	3.163	1, 136	$0.10>P>0.05$	3.692	1, 137	$0.10>P>0.05$
		1-3	0.010	1, 82	$P>0.50$	0.836	1, 83	$0.50>P>0.25$
		2-3	0.202	1, 64	$P>0.50$	4.737	1, 65	$0.05>P>0.01$
Hakodate	Male	1-2	1.904	1, 82	$0.25>P>0.10$	17.050	1, 83	$P<0.005$
	Female	1-2	0.048	1, 85	$P>0.050$	0.665	1, 86	$0.50>P>0.25$

Table 50. *Comparison of regression coefficient and the adjusted mean in the length-weight relationship between sexes at Mori and Hakodate during the spawning period in 1973 year class chika.*

Locality	Age	Relation	F-test of slope			F-test of adjusted mean		
			Fo	df	P	Fo	df	P
Mor	1	Male-Female	4.541	1, 160	$0.05>P>0.01$			
	2	Male-Female	0.032	1, 87	$P>0.50$	13.515	1, 88	$P<0.005$
Hiakodate	1	Male-Female	13.980	1, 139	$P<0.005$			
	2	Male-Female	0.001	1, 28	$P>0.50$	0.144	1, 29	$P>0.50$

Table 51. *Comparison of regression coefficient and the adjusted mean in the length-weight relationship between Mori and Hakodate during the spawning period in 1973 year class chika.*

Age	Sex	Relation	*F*-test of slope			*F*-test of adjusted mean		
			Fo	*df*	*P*	*Fo*	*df*	*P*
1	Male	Mori-Hakodate	7.692	1, 149	$0.010>P>0.005$			
	Female	Mori-Hakodate	8.840	1, 150	$P<0.005$			
2	Male	Mori-Hakodate	0.014	1, 44	$P>0.50$	6.934	1, 45	$0.05>P>0.01$
	Female	Mori-Hakodate	0.002	1, 71	$P>0.50$	23.133	1, 72	$P<0.005$

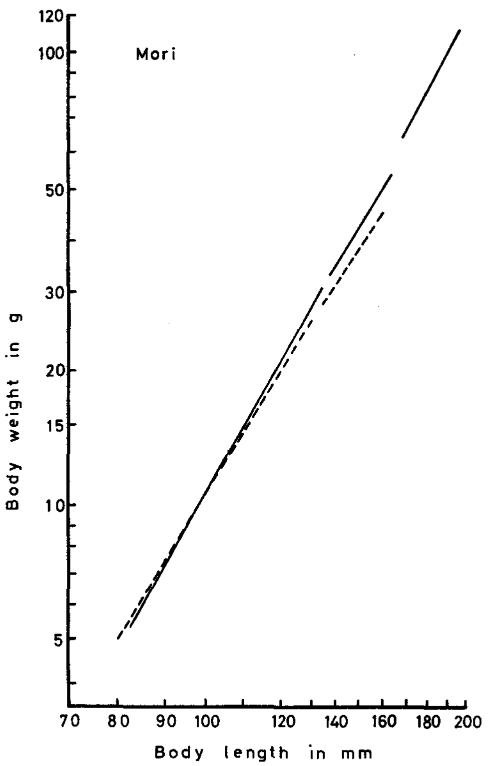

Fig. 8. Length-weight relationship of chika collected at Mori during the spawning period in 1973 year class.
—, female; ---, male

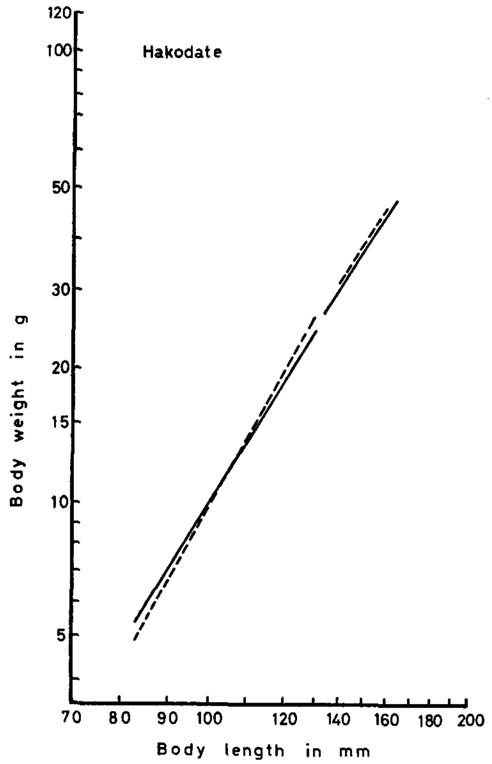

Fig. 9. Length-weight relationship of chika collected at Hakodate during the spawning period in 1973 year class.
—, female; ---, male

a significant difference at Mori and Hakodate, and females at Mori and males at Hakodate had higher values respectively. The regression coefficients for the two sexes at 2 years old showed no significant difference, however adjusted means showed statistical significance at Mori. The increase of weight with length at 1 year old, in females at Mori and males at Hakodate had higher values respectively.

At Mori, the tendency of increase of weight of the two sexes at 2 years old showed no difference, however it was recognized that weight at same length between sexes showed the difference and females were heavier. At Hakodate, conversely, regression lines between sexes at 2 years old showed no significant difference.

Lastly, regression lines in males and females for each age group were compared between Mori and Hakodate using the *F*-test (Table 51). Regression coefficients between two localities at 1 year old showed a significant difference in both sexes, and the male specimens at Hakodate and these females at Mori had higher values. On the other hand, regression coefficients between the two localities showed no significant difference for 2 year olds, however adjusted means showed statistical significance. Therefore, in the tendency for the increase in weight at the two localities for 1 year olds, the male specimens at Hakodate and these females at Mori had higher values. And for 2 year olds, the male specimens at Hakodate and these females at Mori were heavier at same length.

9. *Discussion*

There are many studies on the growth of the osmerid fishes (McKenzie, 1958; Burbidge, 1969; Saunders and Power, 1970), but only two studies used growth equations, those of Shiraishi et al. (1955) and Shiraishi (1961) on the wakasagi, *H. t. nipponensis*. Shiraishi et al. (1955) using Logistic growth equations looked at the growth in body length and weight as Logistic curves, however, Shiraishi (1961) fitted the growth curves of body length and weight based on graphic tests. First, this study has examined the fitting of each growth curve based on the graphic method (Ricklefs, 1967), because there were some lacking data during 12 months. The growth in body length and weight of the chika were well fitted by the Logistic growth curves for sex distinction and in each age at Mori and Hakodate with the exception of 2+ female body weight at Mori. The different equations are shown for each age, and it was shown that growth changes with age (Fig. 2, 3). A growth example for repetition of sigmoid growth in each age had been reported by Hamai (1941) for the growth of the carp. And, the calculated body length and weight agree well with the measured values. Therefore it is concluded that the Logistic growth equations are valid for the growth of the chika.

Each growth equation at Mori and Hakodate has been discussed in detail by Yanagawa (1980), and is summarized as follows. It has been made clear that asymptote length and weight are almost equal between sexes at 0+, however the female asymptote became larger with age at Mori and Hakodate. It has been recognized that the values of k in each age become lower with age and growth rates become lower with age in both body length and weight at the two localities. Further, the growth inflections for body length usually appear earlier than those for body weight at both Mori and Hakodate, and this result agrees with the report by Shiraishi (1961) on the wakasagi. Therefore, it has been suggested that the increments of body weight are limited by body length.

Next, body length and weight growth equations which showed the same growth patterns were compared between Mori and Hakodate. For body length, asymptotes at Hakodate are larger than those at Mori for 0+ and 1+ in both sexes. Values of the growth coefficient k in females are higher than those in males at 0+ and 2+ at Mori, but on the other hand that for males is higher than that in females at 1+ at Hakodate. Thus, it has been recognized that the growth speeds in females are higher at Mori and those in males are higher at Hakodate. Growth inflections at 0+ appear in late August in both sexes at Mori, but these appear in late September for males and early October for females at Hakodate. Further, the above differences between the two localities have become more marked at 1+, and the growth inflections appear in late May for females and early June for males at Mori, but those appear in early August for males and late August for females at Hakodate. Thus, the chika at Hakodate where the asymptotes are larger have shown later growth inflections. When the growth equations of the body weight were compared between the two localities, asymptotes at Hakodate are larger than those at Mori as well as body length. Therefore, it is suggested that body of the chika at Hakodate clearly become larger than those at Mori. Values of growth coefficient k at Hakodate are clearly higher than those at Mori in both sexes at 0+, but those at Mori to the contrary have become higher at 1+. Thus, it has been recognized that the growth rates at Hakodate are higher at 0+ and those at Mori are slightly higher at 1+. Asymptote weight at Hakodate is 1.68 times heavier than that at Mori in males and 1.71 times that in females at 0+; 1.08 times heavier in males and 1.16 times that in females at 1+. Therefore the ratios become lower with age but the body weights at Hakodate are clearly heavier than those at Mori in both sexes. Growth inflections at 0+ appear in early December in both sexes at Mori but appear in early February for males and middle February for females at Hakodate. That is, there is about a two months difference between the two localities. Further, at 1+, growth inflections appear in early August at Hakodate against middle September at Mori in males. In females, inflections appear in middle September at Hakodate against middle October at Mori. A month differences is thus recognized between the two localities. As stated above, coefficients of growth for females at Mori are higher than for males except for body weight of 1+, and those for males are on the other hand higher than for females at Hakodate. Also, there are clear differences between the periods occurring in growth inflections between the two localities. Therefore, these differences in growth equations for fish of the same year class between the two localities suggests that there are different local forms at Mori and Hakodate.

On the growth rates, Saunders and Power (1970) reported that males were slightly longer than females in the younger age-groups, but this trend was reversed in the older age-groups in the rainbow smelt, *O. e. mordax*. However, it is clear that body length and weight of females tend to be larger than in males of the chika. These causes are considered to be due to the following differences: rainbow smelt which live until eight years of age reach sexual maturity in two or three years, but the chika which live until only four years old reach sexual maturity in one year after hatching. Namely, these results stem from the facts that there are certain years which the body length and weight in males are larger than those in females of the chika and that the body length and weight in females have become larger than those in males after the age of maturity or the next year for the rainbow smelt (Saunders and Power, 1970).

When growth rates are compared between the ages a trend for growth quantities and growth rates to become lower with age of the chika has been recognized. Further, McKenzie (1958), Bailey (1964) and Saunders and Power (1970) have also recognized the same trends especially over 2+ in the rainbow smelt. It is considered that these facts may be associated with the attainment of sexual maturity as Saunders and Power (1970) have pointed out. On the growth rates between sexes in each year class, the values of females were observed to be slightly higher than males. Thus it is considered that females grow larger than males.

When the fecundity of the chika were compared with those of other osmerid fishes, data of comparable body length was selected from other studies. Fecundity of the shishamo, *S. lanceolatus*, is 4702 for a 103 mm body length (Ito, 1958) and that of the chika is 3842 for a 105 mm mean body length, therefore the tendency was recognized that fecundity of the shishamo was slightly higher than the chika. Fecundity of the kyuriuo, *O. e. mordax*, is 23184 for a 182 mm body length (Shibata, 1950) and that of the chika is 24781 for a 182 mm mean body length, and it was recognized that the fecundity was similar between those species. Fecundity of the wakasagi is 16204 for a 106 mm body length (Sato et al., 1950), and it showed a very higher number than that of the chika. Fecundity of the pond smelt, *H. olidus*, is 18870 for a 109 mm body length (Ito and Okada, 1960), and it had the same tendency of a very higher number than that of the chika just as the wakasagi. Fecundity of the capelin, *M. villosus*, is 17310 for a 188 mm total length (Gjøsaeter and Monstad, 1973), and that of the chika showed a higher number than this species. Further, fecundity of the surf smelt, *H. p. pretiosus*, is 4020 for a 150 mm body length obtained from Cedar Creek, Washington (Thompson et al., 1936) and showed a relatively lower number. However, Loosanoff (1937) counted 39250 for a 180 mm body length obtained from Puget Sound and it showed a higher number than that of the chika. On the other hand, Ito (1957b) reported the fecundity of the chika for each age at Odaito. In his results, 1 year old chika had 7353 on the average (125.8 mm mean B.L.) and it clearly showed a higher number than the 4506 on the average (113.4 mm mean B.L.) at Hakodate of same age in this study. 2 year old chika from Odaito have 18240 on the average (166.8 mm mean B.L.) clearly showing a higher number than the 12679 average (157.8 mm mean B.L.) at Hakodate, the same as 1 year olds. 3 year olds have 25632 on the average (183.7 mm mean B.L.) and which almost equalled the 24781 average (182.2 mm mean B.L.) at Mori for the same age. 4 year olds chika from Odaito had 35828 on the average (201.0 mm mean B.L.) so fecundity of that age group was clearly higher than the 29233 average (200.4 mm mean B.L.) at Mori of same age in this study. As stated above, geographic variations in the fecundity of the chika have been suggested, however there is no signfiicant difference from 1 to 3 years old between Mori and Hakodate. There are statistical differences among the ages with the exception between the 3 and 4 year olds at Mori. The fecundity of the individuals became higher with age.

When regression lines of the fecundity and body length relationship at Mori and Hakodate are compared between year classes, there are signfiicant differences at all points, and for the fecundity and body weight relationship, there are significant differences between the 1972 and 1973 year classes and between the 1972 and 1974 year classes at Mori. Therefore, it is recognized that the relationships between fecundity and length and between fecundity and weight showed annual variations especially those concerning length. Gjøsaeter and Monstad (1973) stated that capelin in the Barents Sea showed similar annual variation in regression lines between fecundity and total length. When regression lines of the same year classes are compared between Mori and Hakodate, there is no significant difference in the increase in fecundity against length and weight of both in 1973 and 1974 year classes. However, the fecundity at Mori for the same body length and weight was shown to be statistically higher than those at Hakodate. Therefore, Yamamoto (1948) compared the regression lines of fecundity-total length relationship at several localities and stated that the slopes varied with localities. However, the fecundity variations between year classes and between the two localities are clearly more due to the number of ovarian eggs against the same length and weight than the tendency for increase of the ovarian egg counts of the chika. For the mean number of ovarian eggs, there are significant differences among the ages with the exception between 3 and 4 years old at Mori. For the comparisons of regression lines in fecundity-length, weight relationships between ages, there are significant differences between 2 and 3 years old, and between 2 and 4 years old against length, and there is only significant difference of the adjusted mean between 2 and 3 years old against weight at Mori. At Hakodate, when the regression lines are compared between ages, there are no significant differences. Therefore, it is considered that the fecundity has rectilinearly increased according to the increment of length and weight at the two localities. Those relationships are expressed as follows and scatter diagrams are shown in Figs. 10–13.

Mori	$\log E = -3.252 + 3.370 \log L$
Hakodate	$\log E = -3.152 + 3.298 \log L$
Mori	$\log E = 2.404 + 1.018 \log W$
Hakodate	$\log E = 2.407 + 0.989 \log W$

Where E is the fecundity, L is the body length in mm and W is the body weight in g. When the regression lines are compared between Mori and Hakodate for same age, 3 year old chika showed a significant difference for the adjusted means. 1 and 2 year old chika showed no significant difference as well as in the mean ovarian egg counts. Therefore the lower ages were more similar than higher ages between Mori and Hakodate in terms of fecundity.

There are many papers on sex ratios in the osmerid fishes, mainly on the spawning period, but some on monthly changes during the year. Shiraishi (1961) reported monthly changes in sex ratio for the wakasagi at Lake Suwa during the year, and he discussed the sex ratios for various lakes in Japan. On the other hand, Terao and Imai (1963) examined sex ratios in the wakasagi at Katsurazawa Reservoir mainly from spring to autumn. This study discussed the monthly changes of sex ratio in each age class during the spawning periods and the year at Mori and Hakodate.

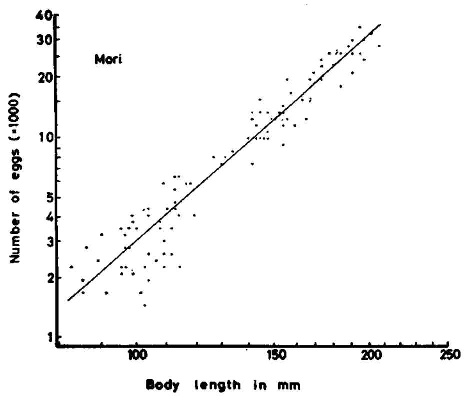

Fig. 10. Fitted straight line to show the relationship between number of ovarian eggs and body length at Mori.

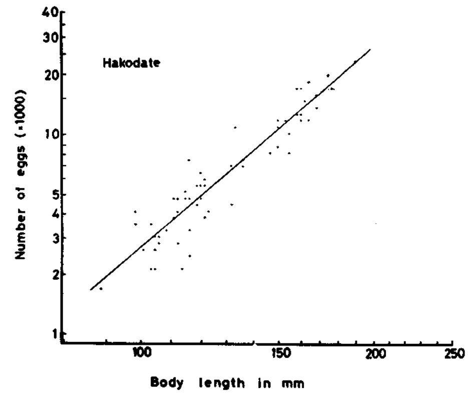

Fig. 11. Fitted straight line to show the relationship between number of ovarian eggs and body length at Hakodate.

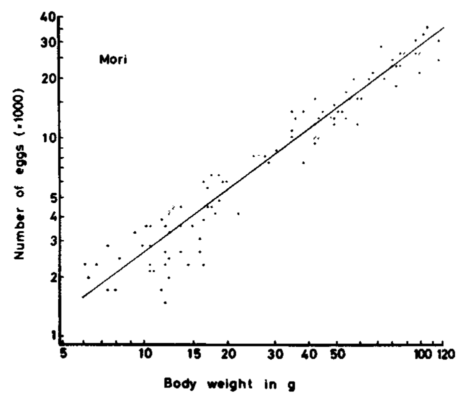

Fig. 12. Fitted straight line to show the relationship between number of ovarian eggs and body weight at Mori.

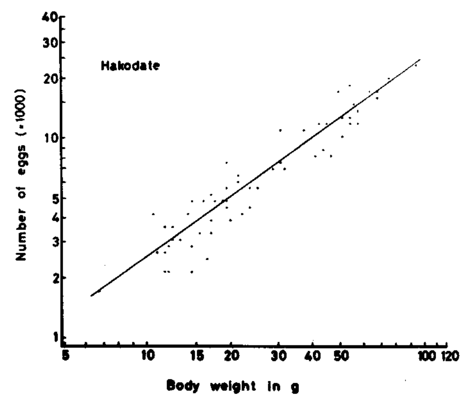

Fig. 13. Fitted straight line to show the relationship between number of ovarian eggs and body weight at Hakodate.

Concerning the sex ratio at each age, age 0+s have an almost equal ratio with few annual variations at Mori and Hakodate, and therefore it is concluded that there is no significant difference in survival rates between the sexes in a year from hatching. On the other hand, over age 0+ and total count showed significant differences among the proportions of the sexes in almost all cases, and the proportion of females was higher especially over age 1+, and age 3+ were all females. Similar results in which the female proportion increased with age are reported in the wakasagi (Shiraishi, 1961) and the rainbow smelt (Beckman, 1942; Bailey, 1964; McKenzie, 1964; Burbidge, 1969). The causes are based on the suggestions that males had a faster growth rate, reached maturity at an earlier age, and had a shorter life span than females in the rainbow smelt at Matamek Lake (Saunders and Power, 1970). On the other hand, Burbidge (1969) stated that if males expend more energy than females during the spawning act and must maintain their position in the stream, they could be in generally poorer condition, and thus would be more susceptible to disease, parasites, predation, starvation, or extreme weather according to Hoover's (1936) observations. However, there is thought to be no difference between sexes of the chika relating to spawning activities, and the difference in survival rates is only recognized in life span. Of the sex proportion, males predominance are present at age 1+ in 1975–76 at Mori and in 1973–74 at Hakodate, and total counts of those years while the next years showed a higher ratio of males or no significant difference between sexes. These results came from considerations that male predominance has appeared from some reasons and the dominant shoals have been undergoing a transition as recognized at age 2+ in 1974–75 at Hakodate.

In the monthly changes of sex ratios, from May just after spawning to January of the growing period, one observed almost equal ratios at both Mori and Hakodate. Females showed a predominances in February and March just before spawning and in the April spawning period at Mori. At Hakodate, though, males showed a predominances in February and March, and females showed a predominances in April. Those results have shown no different movements of both sexes during the growing period and have reflected the total count sex ratio, and agree with the sex ratios of the wakasagi (Shiraishi, 1961; Terao and Imai, 1963) during the growing period.

Concerning the sex ratio in the spawning period, Shiraishi (1952) reported that sex ratios of ascending shoals of spawning had greatly changed in a day for the wakasagi at Lake Suwa. Also Okada and Ito (1960) showed that sex ratio of the pond smelt had changed at each period during the spawning season in Ishikari-Furukawa. Therefore, predictions of sex ratio is not easy during the spawning period. In these results, it is recognized that females became predominant in the period before spawning, were most predominant during the spawning period, and then had decreased towards the end of spawning at Mori. At Hakodate, males showed predominance in the early spawning period, females became predominant during the period, and females then decreased gradually towards the end of the spawning. Sex ratio during the spawning period showed some differences between Mori and Hakodate as mentioned above, and the geographic variations were also reported in the rainbow smelt as follows. It was reported that the rainbow smelt at Crystal Lake (Beckman, 1942) and at Lake Superior (Bailey, 1964) showed females to be predominant, and at Sunapee Lake (Kendall, 1926) showed males to be predominant during the spawning period.

The age of a sexual mature shishamo is 2 and kyuriuo is 3 years old (Matsubara and Ochiai, 1965), and a sexual mature capelin is 2 or 3 years old (Templeman, 1948). On the other hand, wakasagi mature at 1 year old and join the spawning in a year. Pond smelt spawn mainly at 1 year old, so only a few specimens survive to be 2 years old (Shiraishi, 1961). Meanwhile, Hamada (1953c) reported that 1, 2 and 3 year old wakasagi were in Lake Abashiri, and it was recognized that there were different age groups in various habitats in the same species. Yapchiongco (1949) reported that the spawning shoals of the surf smelt consisted of three age groups and no specimen was found over 3 years old. However, chika have been recognized to be from 1 to 4 years old at Mori and Hakodate. The chika, therefore, have more spawning age groups than the surf smelt and pond smelt. Further, surf smelt reach maturity and spawn at the end of the second year of their life (Loosanoff, 1937), whereas the chika reach maturity at 1 year of age and spawn just as pond smelt, and then age groups decrease rapidly with age. It is recognized that the proportion of 3 years old was larger than 2 years old in females at Mori inspite of that at Hakodate, and the age compositions at Mori also differentiated from those of Hakodate.

Considering the regression lines of length-weight relationship, the slopes in sex distinction between ages showed no significant difference in both sexes at Mori and Hakodate, thus it was considered that length-weight relationships were maintained almost at equal rates for each age. There are significant differences in the adjusted mean between 2 and 3 year old females at Mori and between 1 and 2 year old males at Hakodate, however all other combinations showed no significant difference, and it was considered that less variation was present. When the regression lines for each age are compared between sexes, the slopes showed significant differences in 1 year olds at both Mori and Hakodate, and the straight lines of both sexes crossed each other. Therefore, males are fatter than female when less than 95 mm body length and females are fatter over 95 mm at Mori. On the other hand, females are fatter than males when less than 105 mm body length and males are fatter beyond 105 mm at Hakodate, thus the above results are conflicting and the causes remain unknown. Of 2 year old chika, there is a significant difference in the adjusted mean at Mori and no difference appeared at Hakodate, therefore it was considered that there were greater differences in fatness between sexes at Mori. When regression lines are compared between Mori and Hakodate, 1 year old chika showed a significant difference in slopes and 2 year old chika showed a significant difference in the adjusted mean of both sexes, therefore it is clear that the differences are present in the two localities. Further, Ito (1957a) reported the regression coefficient of 3.3951 based on the body lengths from 60 to 210 mm in both sexes of the chiks at Odaito, and it was considered that this value suggested geographic variations.

This study has clarified the biological features of local forms of the chika, *H. p. japonicus*, at Mori and Hakodate. It was shown that many differences existed between the two local forms in the growth equations of body length and weight, in sex ratios by ages and in the spawning periods, age compositions in the spawning periods, and length-weight relationships. This biological evidence supports the validity of local forms recognized on the basis of meristic characters.

V. Movement and Activity

It became clear that every local population of the chika was independent following comparison of growth and other biological features between the two least distinct localities of Mori and Hakodate, southern Hokkaido. The soundness of discriminating local forms using meristic characters has been demonstrated, however the movements and activities of the local forms of chika were still not clear. Therefore, it was necessary to investigate the movements and activities of the chika to further our understanding of the constitution of the local forms.

Concerning the life history of osmerid fishes, Hamada (1961) reported that the ishikari-wakasagi (pond smelt) live in fresh water throughout their life and the wakasagi are separated into a land-locked form and two types of anadromous forms. Shishamo and kyuriuo usually live in the sea and ascend rivers only in the spawning season (Matsubara and Ochiai, 1965), on the other hand the rainbow smelt which live in North America have three types, anadromous, normal land-locked and stunted land-locked (Copeman, 1977). Capelin live in sea water throughout their life and come to the coast in the spawning season (Templeman, 1948). On the other hand, it is considered that the chika live in sea water throughout their life same as do the capelin, but their movements are not known yet. Therefore, this chapter attempts to analyze movements and activities of the chika.

1. Materials and Methods

Seasonal movements were deduced from the biological data and observations from May, 1973 to April, 1976 at Mori and Hakodate, which had been made using the large set net, bottom set net and fishing, but principally the small set net and beach seine. Activities during the spawning period were deduced by means of observations during three years at the two localities and during spawning period in 1979 at Hakodate. Sea water and air temperatures at Hakodate in 1979 spawning period were measured to 0.1°C at Nanaehama, Kamiiso-cho at 6:00 p.m.

2. Seasonal Movement

In southern Hokkaido, the spawning period of the chika extended from late March to early May. The chika usually spawned at night on sand beaches at a depth of about 1 m. Since the spent chika were often caught by a small set net which was built at about 0.4 km offshore from the spawning ground till late May, it was considered that they were moving in the shore region. In June, few adult chika were found in the small set net at Mori and Hakodate, therefore it was presumed that they were moving to the harbour and offshore. On the other hand, it is believed that chika moved to further offshore during bad weather in this period, and many chika were caught by the set net built at 1 km offshore where they were not usually found. This occurred on June 13, 1973 during the rough weather at Mori. Juveniles had grown about 30 mm B.L. and had begun to appear near the shore from middle June. When the waves are high, juveniles move to the mouth of a river; those activities were observed from June to July in 1973 and 1974 at Hakodate, however juveniles formed shoals and usually inhabited the shore zone. From July to August, juveniles had grown about 45–60 mm B.L. and moved not only to the shore also into the harbour, thus they were sometimes found in the small set net which was built near the jetty in the harbour (August 3 and 11, 1973 at Mori; July 12, 1974 and July 15, 1975 at Hakodate). On the other hand, adults which moved into the harbour remained there, and juveniles and adults were caught at the same time by seine at Mori Harbour on July 18, 1973. And it was deduced that adult shoals which had moved offshore moved still further offshore, as adults were caught by a large set net which was built at 2 km offshore from the beach on August 4, 1973 at Mori.

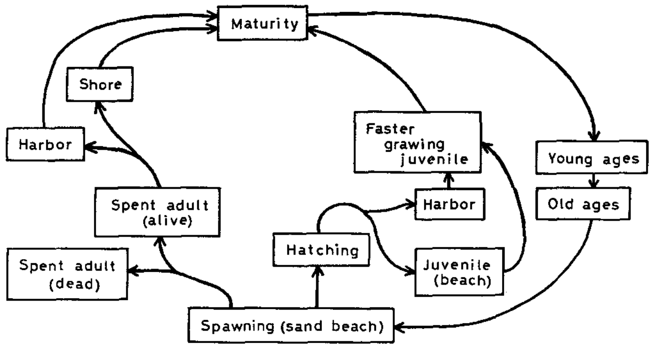

Fig. 14. Diagram to show the life cycle of the chika, *Hypomesus pretiosus japonicus*.

By September to October, juveniles had grown about 60–70 mm B.L. It appeared that juveniles were beginning to leave the harbour and shore, therefore it was concluded that large juveniles had moved offshore little by little in November. However, in the harbour, with good living conditions, both immature and adult fish were present till January and early February at Mori and Hakodate every year. On the other hand, it was considered that those chika which moved offshore from the harbour and shore were located in the still bottom layer, and age 1+ and 3+ large adults were caught by bottom gill nets which were built 1.5 km offshore from the beach on February 6 and 11, 1976 at Mori. From the middle February, chika which had inhabited the harbour and shore also moved offshore, and no chika were to be found close to shore. From the middle March, chika which had inhabited the harbour and offshore where there were relatively calm places during the winter had begun to move in shore for spawning. And spawning shoals had become caught in the small set net near the coast (the earliest spawners were found on March 11, 1976 at Mori and on March 15, 1974 at Hakodate), and the spawning began at the sand beach from late March. Seasonal movements of the chika above mentioned were summarized in Fig. 14.

3. *Activity in Spawning Period*

In southern Hokkaido, the spawning period of the chika usually extended from late March to early May, and the spawning peak from early to mid-April with annual variations. To identify the sea temperatures when chika spawn, the water and air temperatures were recorded from late March to early May in 1979 at

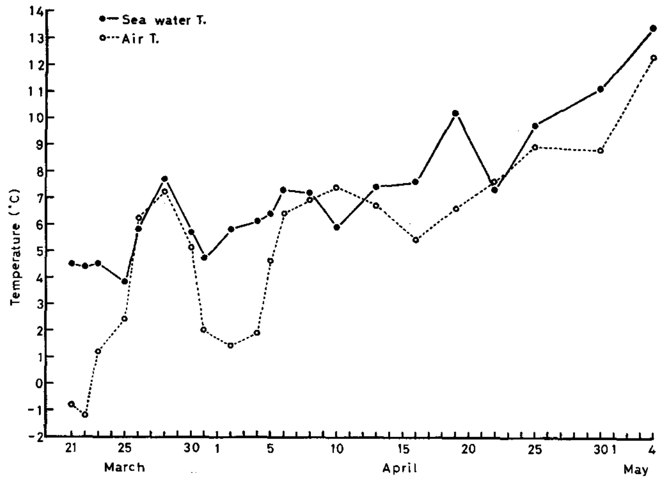

Fig. 15. Changes of the sea water and air temperature during the spawning period at Hakodate, 1979.

Hakodate and their changes are shown in Fig. 15. The first spawning run was observed on March 28 in this year at Hakodate, and the water temperature was 7.7°C. However, few spawners were found after March 29 because of the low water temperature (below 6.5°C), and after April 6 at 7.3°C water temperature one found spawning shoals every day. After that date, sea water temperature continued over 7°C with the exception on April 10 of 5.9°C. Therefore it is clear that the sea water temperature necessary for the initiation of spawning was 7°C or more. The peak of spawning was about 10–14 days centering around May 20 that is about two weeks after the beginning of the spawning based on the observations of 1979 spawning period at Hakodate. Furthermore, the ending of the spawning period could not be clearly confirmed, however a few spawning shoals were found on May 4 (water temperature was 13.4°C) and no spawners had been found on May 15, thus it was presumed that ending of the spawning was about on May 10 when the temperatures were 14°C.

Concerning the activities of spawning shoals, it was observed that the spawning run was usually found at night and that spawning shoals moved 100–300 m offshore from the beach in the daytime, based on the observations at Mori and Hakodate. The spawning shoals which were just before the spawning came to the spawning ground after the sun set, and the fact that they had been moved to 2–3 m from the beach at a depth of about 1 m was observed on May 4, 1973 at Mori. Based on the observations at Mori and Hakodate, it was clear that the spawning ground was a sand beach about 2–3 m from shore with a depth of about 1 m. Also it was observed that they came not only during calm periods but also when there were small waves, and eight fertilized eggs laying on the sand (the major axis ranged from 1.5–4.0 mm) were obtained from the spawning ground on April 16, 1979 at Hakodate. The relationships between spawning period and the frequencies of spawning shoals were found as follows based on the observations at Mori and Hakodate (Fig. 16). In the early spawning period (Fig. 16-A), spawning shoals were sparsely scattered over the wide spawning ground, and the age compositions in the mean were as follows: 1 year olds accounted for 43%; 2 and 3 year olds, 25% respectively; 4 year olds, 7%. At the peak of the spawning when the spawning

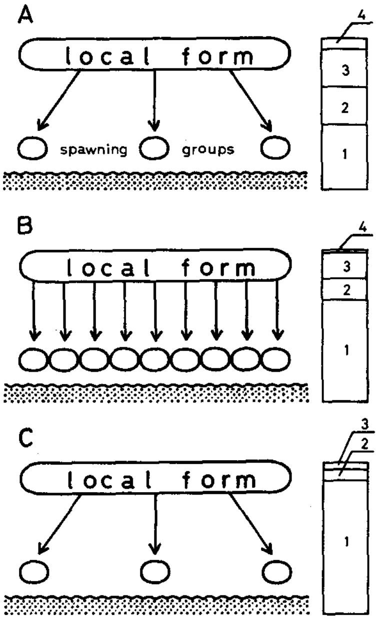

Fig. 16. Diagram to show the relationship between the spawning periods and the frequency of the spawning groups, and age composition of chika.

shoals were suddenly increased (Fig. 16-B), numerous spawning shoals came to the ground, and the mean age compositions were as follows: 1 year olds accounted for 67%; 2 year olds, 14%; 3 year olds, 17%; 4 year olds, 2%. In the late period of the spawning (Fig. 16-C), spawning shoals were scattered as in the early period, and age compositions in the mean were as follows: 1 year olds accounted for 88%; 2 year olds, 7%; 3 year olds, 5%, therefore it was established that spawning shoals consisted of almost low ages.

4. *Discussion*

It is thought that chika live in sea water throughout their lives and does not enter the fresh water areas according to observations throughout the year. These habits are same as the capelin (Templeman, 1948) and the surf smelt (Yapchiongco, 1949), and the fact that the spawners come to the shore is also similar, although capelin sometimes spawn on offshore banks. On the other hand, in the genus *Hypomesus*, ishikari-wakasagi live in fresh water throughout their life and wakasagi are separated into two forms and two types; a land-locked form and two anadromous forms one type of which ascends into rivers to spawn in the spring, and one type of which ascends fresh waters in the autumn and spawns after the close of the winter (Hamada, 1961). Therefore, some species belonging to the same genus sometimes show different life history patterns. It is believed that chika usually inhabit the shore region, and move offshore about 2 km from the beach, based on the observations at Mori. Furthermore, chika lives offshore from the spawning ground for a while after the spawning, and this species is also found in the neighbouring region after that period, therefore it is concluded that the chika have homing behavior.

In osmerid fishes, the species which inhabit the sea throughout their life are as follows: *Spirinchus starksi*, *Allosmerus elongatus*, *Mallotus villosus*, *Hypomesus pretiosus pretiosus* and *H. p. japonicus* (McAllister, 1963). Among them, however, the only *H. p. pretiosus* and *M. villosus* have well known spawning grounds and spawning activities. The fact that chika, surf smelt and capelin are shore spawners has already been mentioned. The environmental conditions of the spawning ground are as follows. In the chika, it was believed that this species spawns on sand beaches based on the observation that spawning shoals come to the shore and on the report that fertilized eggs which were attributed to the chika had been collected on May 3, 1957 at Mori (Hamada, 1961), but this fact had not been confirmed. In this study, however, the facts have confirmed that the spawning shoals have come to 2–3 m from the waters edge at a depth of 1 m along a wide spread spawning ground. Eight fertilized eggs attributed to the chika were collected by the investigation in 1979 at Hakodate. These eight fertilized eggs were reared in the salt water, and five fry were hatched. These fry were compared with the fry which had been hatched artificially (Yanagawa, in preparation); fry from the two groups were very similar. This confirm that the eight fertilized eggs collected on the shore were eggs of the chika, therefore it has been proved that spawning ground of the chika is located the sand beach of the shore. Spawning ground of the surf smelt is also the sand beach of the shore (Loosanoff, 1937), and Yapchiongco (1949) reported that the ova were often encrusted with gravel of a size retained by screens of 8 and 10 meshes to the inch. Therefore, it is considered that the spawning ground conditions of the chika and the surf smelt are similar because the two species favour relatively fine gravel. On the other hand, Templeman (1948) have observed the activities of spawning capelin at Grand Beach, Newfoundland. Also Saetre and Gjøsaeter (1975) investigated the spawning grounds of the Barents Sea capelin and reported that eggs were found at depth of 350 m, although most spawning took place in the upper 75 m and bottom cobbles and gravels were used for the spawning. Therefore, the spawning grounds of chika and surf smelt are different from those of the capelin. On the composition of spawning shoals, it was presumed that 1 year old chika which accounted for over 70% of the peak of the spawning run had played the most important role, based on the relationships between processing of spawning period and the frequencies of spawning shoals, and age compositions.

It is suggested that chika have homing behaviour based on the knowledges of seasonal movements and spawnings. And, it is concluded that useful informations which can be used for explication extensions in distribution have been obtained.

VI. Dispersal Routes

The existence of the local forms in the chika in Japan has been confirmed. But, it is entirely unknown whether each local form has any relationships with any others and how chika dispersed from which sources. Chika have many local forms in a relatively narrow region, and it was observed that their movement areas were narrow, spawners laid adhesive eggs to the sands near the beach and adults inhabited the shore and the offshore of near the spawning ground. Therefore, it is suggested that the chika possess homing behaviour and that each local form has a place of origin or refugium. For the above reasons, the chika are more suitable than the species which inhabit the offshore, have had wide migrating power and have laid floating eggs, concerning the study of relationships amongst local forms and their dispersal routes.

Study of dispersal in fishes have been attempted using paleogeography and fossils, and by zoogeographic studies of the numbers of extant species (Briggs, 1955) and the distributional patterns (Croizat et al., 1974) used by Rosen (1975). For a single species with a narrow distribution, however, these methods stated can not be adopted for determination of dispersal routes. Therefore, this chapter has attempted to clarify the relations and dispersal routes of the local forms in the chika based on the same meristic characters used for the discrimination of local forms.

1. Materials and Methods

Dispersal routes of the chika were studied using cluster analysis of the meristic characters. Samples used in this study were the same as those used in the study of geographic variation of meristic characters (Table 1), Sarufutsu and Kitami-Esashi which were concluded same local form had consisted for Sarufutsu-Esashi local form, and the value for each character used the mean difference between the two localities. The characters for the analysis selected from among 14 meristic characters as follows: number of abdominal, caudal and total vertebrae; dorsal, anal, caudal, pectoral and pelvic fin rays; midlateral and pored sacles; branchiostegal rays; upper, lower and total gill rakers. Some characters were excluded from the analysis as follows. First, the number of anal fin rays, pectoral fin rays, midlateral scales and pored scales that showed significant differences between sexes or year classes, were excluded. Also, the number of lower gill rakers which showed a wide range and had plural modes in many localities was excluded. When using cluster analysis, characters which are correlated to each other and have no variation were excluded according to Sneath and Sokal (1973). Characters are correlated to each other are the number of total vertebrae and total gill rakers, the former consists of the number of abdominal and caudal vertebrae, while the latter is consists of the upper and lower gill rakers. Characters which have no variation are the number of pelvic fin rays and caudal fin rays, furthermore the number of branchiostegal rays also excluded, because it had little variation and no variation in mode. This study has adopted the four meristic characters that of the number of abdominal and caudal vertebrae, dorsal fin rays and upper gill rakers, based on the above operations.

Methods for the analyses with above four characters were as followed. Cluster analysis was computed using subprogram "CLUSTER"* in SPSS. First, PCA-mode was performed, where normalizations of the data and extractions of principal components of more than 5% of variance were done. Normalizations ($Y_{ij}=\frac{X_{ij}-\min X}{\max X-\min X}$, where Y is the value of X after normalized) were done for the sake of making the data uniform, because each character showed various ranges of values. Principal component analysis reduces the original data matrix into a matrix with a few synthetical components. It made a scatter diagram which showed the relationships of all local forms based on the factors which were selected. Next, Q-mode cluster analysis was done with the principal components selected from PCA-mode (principal component analysis), from which was computed the matrix of initial distances among all local forms for the dendrogram. This Q-mode cluster analysis has adopted the Euclidean distance for distances among all local forms. For the Euclidean distance, the centroid method was used for the calculation of the distance between the clusters. Euclidean distance and distance between the centroids are as follows (Okuno et al., 1971).

Euclidean Distance

$$D_{ij}^2=\sum_{k=1}^{n}(x_{ki}-x_{kj})^2$$

Where i, j are local forms and n is the number of variables.

Distance Between the Centroids

$$D_{fg}^{(i+1)}=\frac{n_h}{n_g}D_{fh}^{(i)}+\frac{n_l}{n_g}D_{fl}^{(i)}-\frac{n_h n_l}{n_g^2}D_{hl}^{(i)}$$

Where $n_g=n_h+n_l$ and n_g, n_h, n_l are the individual numbers belonging to the cluster which has corresponding letters added respectively.

2. *Dispersal Routes Based on the Cluster Analysis*

Two factors which were selected from the principal component analysis were shown in Table 52, and factor loadings of each character were shown in Table 53. 14 local forms were plotted against the principal components I and II (Fig. 17), and the matrix of the Euclidean distances based on the two principal components is shown in Table 54. Sequences of the local forms' name which were shown in this matrix of initial distance had been rearranged in order to the sequence of the output results of the cluster analysis.

When Q-mode cluster analysis was performed on the Euclidean distances among all local forms, clustering was done in order to the sequences and the amalgamated distances as follows. Area compositions of the clusters were shown in Fig. 17. First, Bekkai joined Akkeshi at the amalgamated distance 0.059, and formed the cluster (BEKK, AKKE). Next, Shizunai joined Sanriku-cho at 0.122

* subprogram "CLUSTER" has existed in only FACOM and HITAC editions

Table 52. *Values of two factors in principal component analysis based on normalized four meristic characters.*

Locality	Factor I	Factor II
Wakkanai	0.11485	0.87372
Mashike	0.57218	0.85930
Oshoro	0.00000	0.67714
Saru-Esashi	0.40877	0.90431
Abashiri	0.40249	0.71815
Bekkai	0.71043	0.00000
Nemuro	0.85474	0.29651
Akkeshi	0.76776	0.01267
Kushiro	0.96167	0.05003
Shizunai	0.64891	0.66770
Mori	0.99501	0.47324
Hakodate	1.00000	0.60943
Noheji	0.72547	0.44039
Sanriku-chô	0.73046	0.57658

Table 53. *Values of factor loadings of normalized four meristic characters in principal component analysis.*

Meristic character	Factor I	Factor II
Number of abdominal vertebrae	0.839	−0.380
Number of caudal vertebrae	0.743	0.638
Number of dorsal fin rays	0.879	0.041
Number of upper gill rakers	0.887	−0.216

and formed the cluster (SHIZ, SANR); Mori joined Hakodate at 0.136 and formed the cluster (MORI, HAKO); Mashike joined Sarufutsu-Esashi at 0.169 and formed the cluster (MASH, SARU). The cluster (SHIZ, SANR) joined Noheji at 0.185 and formed the cluster (SHIZ, SANR, NOHE); the cluster (MASH, SARU) joined Abashiri at 0.186 and formed the cluster (MASH, SARU, ABAS). The cluster (BEKK, AKKE) joined Kushiro at 0.227 and formed the cluster (BEKK, AKKE, KUSH); Wakkanai joined Oshoro at 0.228 and formed the cluster (WAKK, OSHO); the cluster (BEKK, AKKE, KUSH) joined Nemuro at 0.279 and formed the cluster (BEKK, AKKE, KUSH, NEMU). The cluster (SHIZ, SANR, NOHE) joined the cluster (MORI, HAKO) at 0.297 and formed the cluster (SHIZ, SANR, NOHE, MORI, HAKO). Furthermore, the cluster (MASH, SARU, ABAS) joined the cluster (WAKK, OSHO) at 0.407 and formed the cluster (MASH, SARU, ABAS, WAKK, OSHO), thus all local forms which belonging to the coasts of Japan and Okhotsk Seas were connected into a single cluster. Then, the cluster (BEKK, AKKE, KUSH, NEMU) joined the cluster (SHIZ, SANR, NOHE, MORI, HAKO) at 0.464 and formed the cluster (BEKK, AKKE, KUSH, NEMU, SHIZ, SANR, NOHE, MORI, HAKO), thus all local forms which belonging to the coast of the Pacific Ocean were connected into a single cluster. The cluster including the local forms belonging to the coasts of Japan and Okhotsk Seas joined the cluster which

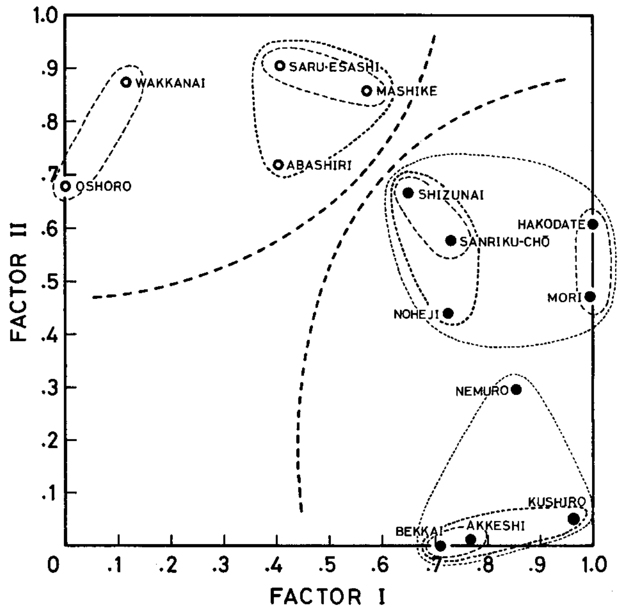

Fig. 17. Fourteen local forms from Hokkaido and Tohoku regions, plotted against factor I and II. The factors are extracted from four meristic characters using principal component analysis.

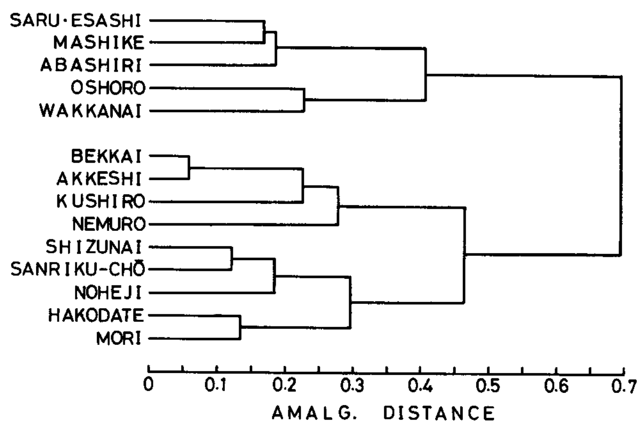

Fig. 18. Dendrogram from unweighted centroid method cluster analysis on the distance matrix computed from two principal components.

including the local forms belonging to the Pacific coast at the amalgamated distance of 0.695, at which point all clustering had been completed (Fig. 18).

From above results, dispersal routes of the chika were presumed as follows. First, Japanese chika can be separated into two major groups. First was the

Table 54. *Matrix of the Euclidean distance estimates for 14 local forms of the chika, Hypomesus pretiosus japonicus.*

Locality	Mori	Hako.	Nohe.	Sanr.	Shiz.	Nemu.	Kush.	Akke.	Bekk.	Wakk.	Osho.	Abas.	Mash.	Saru.
Mori	—													
Hakodate	0.14	—												
Noheji	0.27	0.32	—											
Sanriku-chô	0.28	0.27	0.14	—										
Shizunai	0.40	0.36	0.24	0.12	—									
Nemuro	0.23	0.34	0.19	0.31	0.42	—								
Kushiro	0.42	0.56	0.46	0.58	0.69	0.27	—							
Akkeshi	0.51	0.64	0.43	0.57	0.67	0.30	0.20	—						
Bekkai	0.55	0.67	0.44	0.58	0.67	0.33	0.26	0.06	—					
Wakkanai	0.97	0.92	0.75	0.68	0.57	0.94	1.18	1.08	1.06	—				
Oshoro	1.02	1.00	0.76	0.74	0.65	0.94	1.15	1.02	0.98	0.23	—			
Abashiri	0.64	0.61	0.43	0.36	0.25	0.62	0.87	0.79	0.78	0.33	0.40	—		
Mashike	0.57	0.50	0.45	0.32	0.21	0.63	0.90	0.87	0.87	0.46	0.60	0.22	—	
Saru-Esashi	0.73	0.66	0.56	0.46	0.34	0.75	1.02	0.96	0.95	0.30	0.47	0.19	0.17	—

group which is distributed on the coasts of Japan and Okhotsk Seas, and second was the group which was distributed along the coast of Pacific from the south of Nemuro Strait to Tohoku region. Concerning dispersal routes within each group, the first, probably expanded its distribution toward Wakkanai and Oshoro, others toward Mashike on the coast of Japan Sea, and toward Sarufutsu and Kitami-Esashi from the Okhotsk Sea region, and further towards Abashiri. In the second, the chika spread first to Nemuro Strait, then expanded its distribution toward Bekkai, Akkeshi and Kushiro from Nemuro, while others spread toward Noheji and Shizunai, and toward Sanriku-cho, with further dispersal toward Mori and Hakodate (Fig. 19).

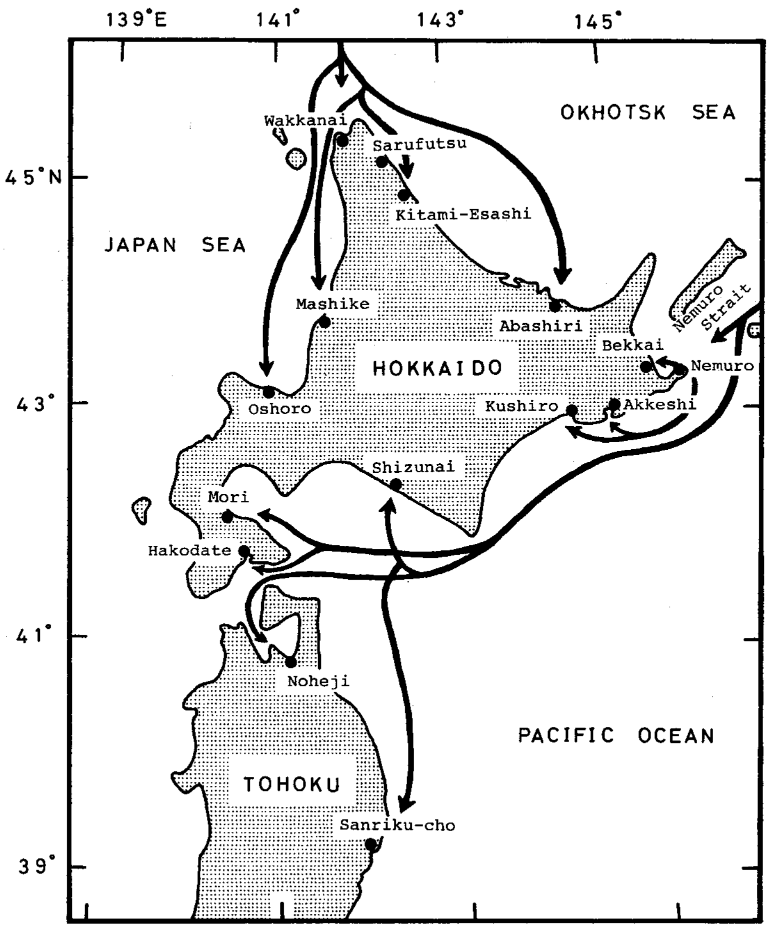

Fig. 19. Dispersal routes of the chika, *Hypomesus pretiosus japonicus*, based on the cluster analysis.

3. *Discussion*

Meristic characters are commonly used for grouping and recognizing races in fishes, but it has not been used for the tracing of the dispersal routes, yet. However, it is concluded that the variations of meristic characters in the chika are not due to the environmental conditions especially the direct influence of water temperature (III–7). Therefore it is considered that the description of dispersal routes is possible based on meristic variations. Thus, this study explains dispersal routes in chika using cluster analysis following the principal component analysis based of the meristic characters.

Cluster analysis has employed numerous techniques and has been frequently used in the numerical taxonomy of mammals, reptiles and fungi at present. In fishes, Cowan (1972) adopted the cluster analysis for one of the methods of analysis of the relationships of the cottid fishes. Multivariate analysis has also been used for the study of races, among these Johnston (1969) have worked out the two species of European sparrows and their hybrids. On the other hand in fishes, Copeman (1977) analized rainbow smelt populations using the multivariate analyses, but these analyses had not been used for the presumption of the dispersal routes yet. However, author considered that the cluster analysis, joining related clusters in turn, could be applied to analize dispersal routes.

On the origin of the osmerid fishes, McAllister (1963) stated that the eastern Pacific would seem more likely to have been the center of origin than the western Pacific, based on presentday species density. He also stated that the only known fossils were Atlantic Pleistocene, and discussed the extension of distribution and speciation in osmerid fishes connected with the reciprocations of climatic warming

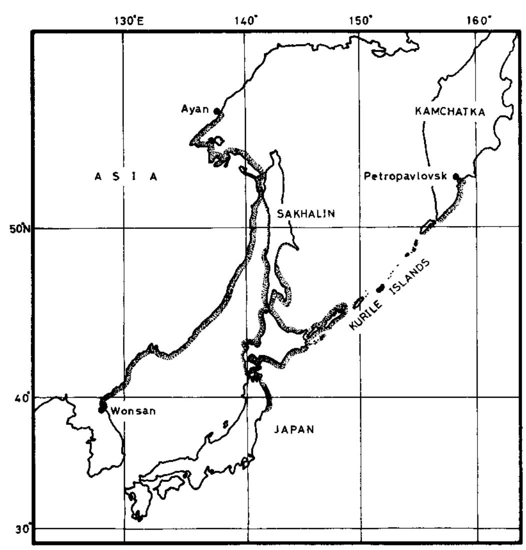

Fig. 20. Distribution of the chika, *Hypomesus pretiosus japonicus*.

and cooling. Namely, it was considered that *Hypomesus pretiosus* became continuous around the northern perimeter of the Pacific from east to west, and climatic cooling then resulted in southward depression and consequent separation into two populations, one on each side. Therefore, it was presumed that the surf smelt (*H. p. pretiosus*) originated on eastern side and the chika (*H. p. japonicus*) on western side respectively. Complementary to that hypothesis, the results in this study using the cluster analysis, suggest that chika in Japan can be separated into two major groups, one on the coasts of Japan and Okhotsk Seas, and the other on the coast of the Pacific from the south of the Nemuro Strait to Tohoku region. In these two groups, it is deduced that each group of chika has dispersed separately and the dispersal of each group can be followed based on the recent distribution and meristic variation of the chika (Fig. 20). Concerning the group which occurs on the coasts of Japan and Okhotsk Seas, it was presumed that shoals of chika occurring on the coast of Asia south of Ayan in Okhotsk Sea spread to Wakkanai region via Sakhalin. Concerning the group is distributed south of Nemuro Strait, it was deduced that shoals of the chika spread from Petropavlovsk to Kurile Islands proceeded southward and entered Nemuro Strait. Therefore, the author considers that this result can support the reciprocating isolation mechanism in the North Pacific in osmerid fishes suggested by McAllister (1963).

VII. Synthesis

In this study, the investigator first collected samples from 15 localities in Hokkaido and Tohoku regions where *Hypomesus pretiosus japonicus* occurs, compared the variances and the mean of the meristic characters and discriminated and confirmed the local forms of the chika. From the results of these tests using the ten meristic characters, it was established that only the samples between Sarufutsu and Kitami-Esashi facing on the Okhotsk Sea showed no significant difference in variances and the means, therefore it was concluded that these two consisted of the same local form and the other localities were distinct local forms. Discrimination of the races or comparisons among the races using the meristic characters have been done widely in fish species (Sano and Kubo, 1946; Amos et al., 1963; Moodie and Reimchen, 1976) and Schaefer (1936), Ito (1963) and Tanaka (1969) have done this in osmerid fishes. On the other hand, there are many reports which have discriminated races using non-meristic characters in osmerid fishes: Kubo (1946) used the parasite ratio of cysts; Matsubara (1946) used the composition of total length and weight; Ito (1959) used the relationships among body length, age and fecundity; Kilambi et al. (1965) used blood serum; Legault and Delisle (1968) used the maturity index, fecundity and so on. This study discriminated local forms based on the meristic characters, and has also examined the propriety of discrimination from different view points. The investigator selected two neighbouring local forms, Mori and Hakodate which were separated by the fewest difference among the all local forms discriminated by the meristic characters, and it had examined and compared in the biological features. The results made clear the many differences that existed between the two local forms in the growth equations of body length and weight, the appearance of years of malés predominant shoals, sex ratios and age compositions in the spawning periods, and length-weight relationships. Therefore it has been clearly shown that the propriety of the creation of the local forms based on the meristic characters.

The existence of local forms in the chika in Japan has been confirmed, but it was entirely unknown what relations each local form has with each other and where the chika dispersed from and by what routes and mechanisms. There are only a few zoogeographic studies that discuss the relationships between ecological conditions and dispersal of higher taxonomic units and also infraspecific level. However, Udvardy (1969) stated in detail the relations between dispersal and the ecology in "Dynamic Zoogeography with Special Reference to Land Animals". Concerning the dispersal mechanisms, both active and passive dispersal may be involved in the regular process whereby most or all individuals of a species disperse from the parental stock or domicile (Udvardy, 1969), and it can consider that these processes are also involved in the chika. First, it is suggested that there has been active dispersal through movements to neighbouring areas at some periods of life history and passive dispersal to neighbouring areas by coastal currents and long distance dispersal by sea currents. Although one can not decide that the dispersal of the chika has been carried out by what processes and at what stages or by what combinations processes, however this study discusses the dispersal mechanisms as follows. Concerning active dispersal, since Kalela (1944) stated that successful reproduction in marginal areas creates a population surplus which disperses, and the individuals which pioneer beyond the range limits or into marginal areas thus achieving range extensions, it was considered that population growth of local forms was one of the dispersal mechanisms of chika. Thus, overpopulation or high population density at certain periods have been important factors in dispersal of the chika. There is a fair chance that dense shoals have dispersed from the usual habitat. Then, those shoals that have moved to a new suitable habitat grew and reproduced there, thus forming new local form.

Of the many processes of passive dispersal, anemochore, hydrochore, anemohydrochore, biochore and anthropochore dispersals, phoresy, adventives, and introductions (Udvardy, 1969), it is considered that hydrochore, namely coast currents or sea current are involved in the passive dispersal of marine fishes in the natural world. Furthermore, as Keast (1977) stated that all living forms had a dispersal phase in their life history, so the investigator found the younger life history stages adapted to passive dispersal. Locally the chika has been dispersed through coastal currents at certain life history stages. Egg phase dispersal is not possible because the eggs are demersal and adhesive. On the other hand, juveniles compose shoals that live near shore areas and harbours, and their swimming power has increased, therefore it can be considered that juvenile phase passive dispersal is less likely. It is concluded that passive dispersal to neighbouring areas is most likely in the fry phase between hatching and the juvenile phase. Long distance dispersal in the chika is influenced by sea currents, particularly during the period that adults move offshore from summer to winter. Therefore it is suggested that long distance, as opposed to short distance, passive dispersal occurs mainly in the adult phase. As stated above for passive dispersal to succeed the shoals must move

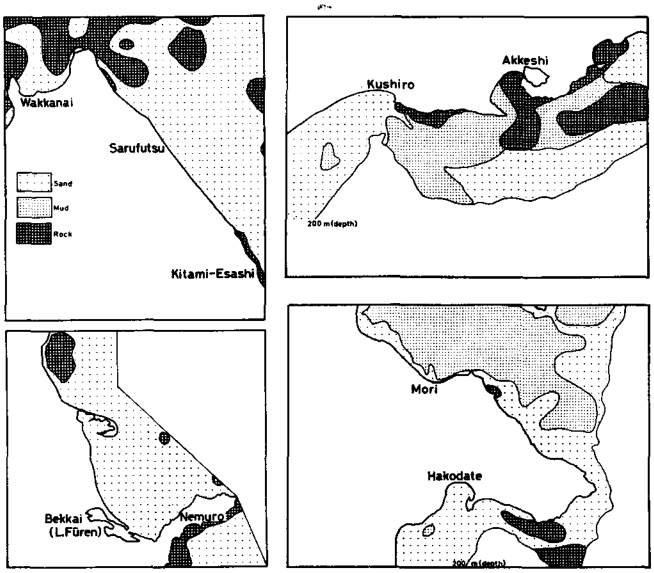

Fig. 21. Diagram to show the bottom materials of the coast of Hokkaido (After Zengyoren, 1977) and nine sampling localities of the chika, *Hypomesus pretiosus japonicus*.

to new suitable habitats and reproduced there, and form a local form, just as in active dispersal.

Reasons have been discussed for recognizing the local forms as distinct group based on the results of the tests in the meristic characters and the bottom materials of the shore. First, when the significance tests were applied to ten meristic characters among 15 localities, only two localities, Sarufutsu and Kitami-Esashi, showed no geographic variation, and the bottom materials are shown in Fig. 21 (Zengyoren, 1977). Since the coast between Sarufutsu and Cape Kamui is sand beach, it is suitable feeding habitat and spawning grounds for the chika. The coast between Cape Kamui and Kitami-Esashi is suitable for feeding but not for spawning, due to the unbroken rocky coast with a smaller offshore region. Therefore, when the chika which occur at Sarufutsu formed dominant shoals, they can easily enlarge the spawning grounds and their feeding habitats, thus Sarufutsu local form has expanded its range and spread to about Kitami-Esashi. Consequently, specimens from Sarufutsu and Kitami-Esashi consisted of the same local form, and displayed no geographic variation. Conversely, since the regions between Wakkanai and Sarufutsu, between Mashike and Oshoro, and between Mori and Hakodate also have rocky shores but with enlarged offshore areas, each neighbouring locality consists of a distinct local form. Unborken rocky and muddy coast is found between Akkeshi and Kushiro, and it is suggested that the two local forms are separated by these barriers. On the other hand, the region between Bekkai and Nemuro facing on Nemuro Strait is wholly sand beach, but populations at these two localities are separated into different local forms by a difference in habitat, because the specimens collected at Bekkai are obtained from Lake Furen (a salt water lake) while those at Nemuro are obtained from the open sea coast. Therefore, it is concluded that the factors which maintain the distinctness of each local form in the chika are physical barriers between the spawning grounds.

Dispersal in fishes have been studied zoogeographically studies using the number of extant species (Briggs, 1955) and distributional patterns of related taxa and distribution (Croizat et al., 1974) and so on up to now, but these methods can not be applied to a single species. On the other hand, few fossils are recorded in osmerid fishes, and even if more fossils were discovered, it is not considered that these fossils would necessarily be useful in explaining dispersal routes at the infraspecific level. Characters that distinguished each local form are variable meristic characters because of the no unique anatomical feature characterizes any local forms. Since it is concluded that the variations of the selected meristic characters in the chika are not due to environmental influence, these characters were adopted for analyses. Cluster analysis has been employed as an effective tool in scientific inquiry (Anderberg, 1973) and in the numerical taxonomy to explain relationships and phylogeny (Sneath and Sokal, 1973). The author extended these applications and used cluster analysis of principal components in the study of dispersal routes. That only a few characters were used in the cluster analysis did not hinder the analysis, and useful results were obtained.

In the cluster analysis, all local forms separated into two major clusters, one for the coasts of Japan and Okhotsk Seas samples and the other for the coast of Pacific samples from south of the Nemuro Strait to Tohoku region, as suggested in the results of geographic variation in individual meristic characters. Chika occur from Petropavlovsk, Kamchatka to Wonsan, Korea, including south of Ayan on the Asian coast facing the Okhotsk Sea. Dispersal of chika to Japan probably followed two routes, one is from the coast of Asian Continent to Wakkanai region, northern Hokkaido via Sakhalin, and the other is from Kamchatka along the Kurile Islands to Nemuro Strait, eastern Hokkaido, based on the results of the cluster analysis and distributional features of the chika. Furthermore, when the dispersal of the chika is discussed in relation to sea currents, two directions are suggested, one from Wakkanai region to Abashiri which is influenced by the East Sakhalin Current from the Okhotsk Sea, and the other from the Nemuro Strait to Shizunai and Tohoku region which is influenced by the Chishima Current along the coast of Pacific Ocean.

Dispersal of the chika has been discussed above, where it is suggested that this species enlarged its distribution through interactions of various dispersal mechanisms based on the active and passive dispersal, they then reproduced in the new habitat and have formed new local forms. And the dispersal of the chika was clarified using principal component analysis and cluster analysis of meristic characters. This study has established that multivariate analyses using meristic characters are useful methods for explaining dispersal routes at the infraspecific level.

VIII. Summary

1. Samples were collected from 15 localities in Hokkaido and Tohoku regions where chika, *Hypomesus pretiosus japonicus*, occurs, and the variances and the means of ten meristic characters were compared and local forms of the chika were distinguished and confirmed. Major results are as follows.

(a) Localities north of Shiretoko Peninsula and on the Japan Sea coast showed a tendency for lower numbers of abdominal vertebrae, eastern Hokkaido showed higher number and the area south of Shizunai showed an intermediate number.

(b) Localities north of Shiretoko Peninsula and on the Japan Sea coast showed a tendency for higher numbers of caudal vertebrae and eastern Hokkaido showed lower number.

(c) Little geographic variation was shown amongst the three areas in the total vertebral count because the above two counts offset one another.

(d) No clear difference in dorsal ray count was recognized among the localities.

(e) Number of caudal and pelvic fin rays, and the branchiostegal rays showed the same modes in all localities, and the means of pelvic fin ray counts were very stable showing no significant difference among all localities.

(f) Number of upper and lower gill rakers showed similar modes north of Shiretoko Peninsula and Japan Sea coast despite of the variability in the southern areas. The total number of gill rakers had the widest variation of the ten meristic characters.

(g) Of the 15 localities only the Sarufutsu and Kitami-Esashi samples showed no significant difference in variances and means of the ten meristic characters, therefore it was concluded that above two samples were drawn from the same local form while other samples were drawn from distinct local forms.

2. Two neighbouring local forms, Mori and Hakodate, which were separated by the fewest difference among the all local forms discriminated by the meristic characters were selected, and these two local forms were found capable of discrimination with biological features on the basis of samples from May, 1973 to April, 1976. Those results are as follows.

(a) Body length growth equations cannot be properly calculated when ages are lumped together, but when the growth equations of Gompertz and Logistic were applied to each age group, growth of the chika could be well described with Logistic equations, $Lt=\frac{L_\infty}{1+e^{-k(t-t_0)}}$ for sex and age comparison at both Mori and Hakodate. When the growth equations at Mori were compared with those at Hakodate, it was concluded that there were growth differences between the two localities.

(b) Body weight growth equations cannot be properly calculated when ages are lumped together, but when the growth equations of Bertalanffy, Gompertz and Logistic were applied to each age group, growth curves of the chika were well fitted by Logistic equations, $Wt=\frac{W_\infty}{1+e^{-k(t-t_0)}}$ for sex and age comparison at

both Mori and Hakodate with the exception of age 2+ females at Mori. When the growth equations at Mori were compared with those at Hakodate, it was demonstrated that growth in body weight was different at the two localities.

(c) Growth rates in body length and weight showed the greatest increment between 1 and 2 years old, and became lower in both sexes with age. Furthermore, it was recognized that there were variations in annual growth rates between year classes, and the rates for females were observed to be slightly higher than males in each age.

(d) Fecundity showed significant differences amongst ages, and the means were as follows: 1 year olds averaged 3842, 2 year olds 12863, 3 year olds 24781, 4 year olds 29233, at Mori; 1 year olds averaged 4506, 2 year olds 12679, 3 year olds 19793, at Hakodate. Therefore, fecundity increases with age.

(e) Length and weight-fecundity relationships for 1 to 4 year olds were closely fitted by parabolic equations, $\log E = \log a + b \log L$ (or W), and regression coefficients showed little variations among ages. When regression lines for the same year class for Mori and Hakodate were compared, the 1973 year class showed significant differences in both length and weight-fecundity relationships.

(f) The age 0+ sex ratio was almost 1:1 at both Mori and Hakodate, however females were more numerous from age 1+ to 3+. Male dominantated shoals occurred in different years at both localities.

(g) Proportions of sexes were almost equal except during the spawning period.

(h) When sexes were combined through the spawning period in 1974: 1 year olds accounted for 72.9%, 2 year olds for 11.8%, 3 year olds for 15.4%, at Mori; while 1 year olds accounted for 76.6%, 2 year olds for 21.2%, 3 year olds for 2.3%, at Hakodate. It is concluded that 1 year olds showed the highest proportion in the spawning age groups, and the proportions of successive age groups rapidly declines with age.

(i) Length-weight relationships at Mori and Hakodate were well expressed using parabolic equations, $\log W = \log a + b \log L$. Length-weight relationships showed equal rates at each age in both sexes. When regression lines were compared between Mori and Hakodate, there were significant differences in both sexes and therefore it is concluded that geographic variations exist between the two localities.

(j) The validity of defining local forms based on the meristic characters was verified using biological characteristics of Mori and Hakodate populations.

3. In southern Hokkaido, the spawning period of the chika is usually from late March to early May and chika spawn near sand beaches usually at night. Sea temperatures at the beginning of spawning are above 7°C. Spent chika live near the shore till late May. After that they move to calm harbours and offshore. Juveniles begin to appear in mid-June, and grow near the shore and in harbours. Juveniles and some adults live in harbours from July to early next February, however all of them move offshore in late February and the spawning shoals return to shore starting mid-March, and spawning begins in late March. Chika move offshore about 2 km from the beach and movements along the coast restricted suggesting that the chika have a homing behaviour.

4. When principal component analysis and Q-mode cluster analysis based on the four meristic characters (number of abdominal and caudal vertebrae, dorsal fin rays and upper gill rakers) are used to analyze the relations and dispersal routes among the local forms in the chika, two dispersal routes were recognized in Japan. One was the route led from the Wakkanai region to the coasts of Japan and Okhotsk Seas, the other route led from Nemuro Strait to the Pacific coast and Tohoku region.

5. Dispersal mechanisms and the routes of the chika were discussed in detail and it was demonstrated that multivariate analysis was a useful method for the study of dispersal routes at the infraspecific level.

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