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INFLUENCE OF NATURAL ENVIRONMENTAL CONDI-  
TIONS ON THE VERTEBRAL NUMBER OF THE  
POND SMELT, *HYPOMESUS OLIDUS* (PALLAS)\*

By

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Environmental conditions, particularly that of water temperature during the embryonic development, have been known to exert an influence on the vertebral number of the fishes, by which, however, each species, race or population characterizes itself. On this subject, experiments (Taning, 1950 and Kubo, 1950) as well as observation (Hubbs, 1922 and Uchihashi et al, 1950) have been made on several fishes along with Fujita's observation on the pond smelt, *Hypomesus olidus* (Pallas) (1926).

The pond smelt lives naturally in the Lakes of Abashiri, Kogawara, Hachirogata, Kasumiga-ura and Shinji etc. in Japan. The transplantations of the fish from these native waters to some other waters, where the environmental conditions are different, have often been practised in this country. They provide us with opportunities to compare the morphological differences between native and stocked fish groups. Among morphological characters the vertebral number shows the most characteristic feature in each species and race. For example, the modal number of vertebrae in "chika," *Hypomesus japonicus*, is 63 while those of the pond smelt, *Hypomesus olidus*, in Lake Kogawara, Lake Kasumiga-ura and Mutsu Bay are 55, 56 and 57, respectively. In the case of the surf smelt, *Hypomesus pretiosus*, the vertebral number is known to be significantly different among groups caught in Puget Sound, Washington, U. S. A. (Schaefer, 1936).

This paper reports our attempt to see how the changes in natural environmental conditions influence the vertebral number of the pond smelt after the transplantation.

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### Materials and Methods

Native groups of the pond smelt were collected from Lake Abashiri, Mutsu Bay, Lake Kogawara, Lake Hachiro-gata, Lake Kasumiga-ura and Lake Shinji, while stocked groups were sampled from Lake Akan, Lake O-numa, Pond Bagyu, Lake Suwa and Lake Kahoku-gata (Fig. 1).

The material used were fishes measuring more than 30 mm. in total length and having the caudal vertebrae completed. The urostyle was included in the count of vertebral numbers.

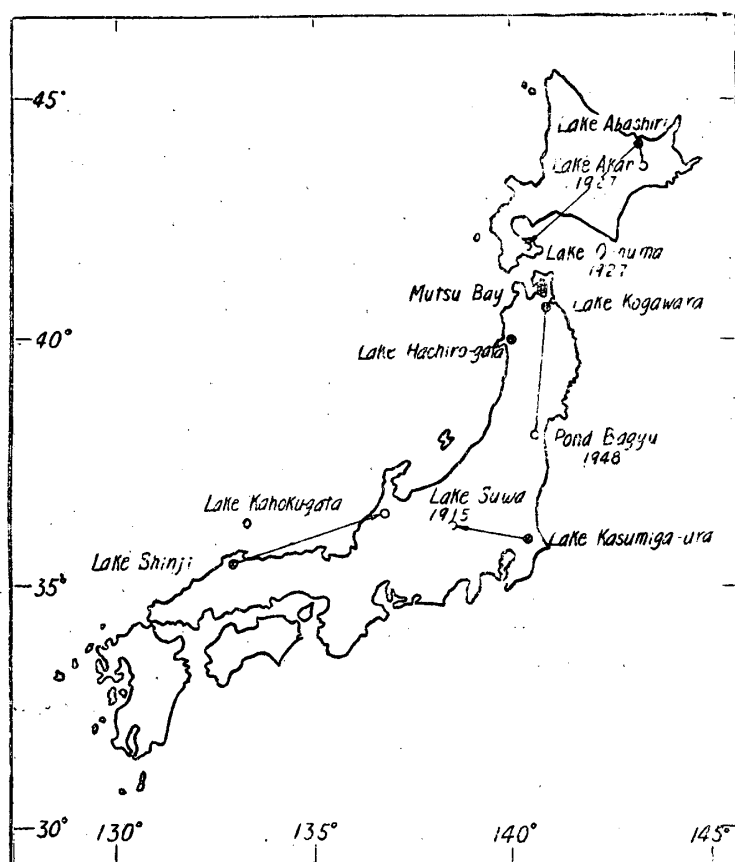


Fig. 1 Transplantation of the pond smelt in Japan. ● indicates the native lakes, ○ indicates the newly stocked lakes. The numbers refer to the year of transplantation.

### Results

#### 1. Examination of Materials.

At first it was statistically examined whether pond smelts living in one lake belong to one population, race or not. Samplings were made at three stations in Lake Kogawara in the spring of 1948 and the counts of vertebral numbers are

shown in Table I. After it was proved that there was no significant difference among group variances, F-test was applied to test the significance of differences between mean values of vertebral number of each group. As a result, no difference of significant magnitude was observed among them.

The same results were obtained for the three samples collected in 1948, 1949 and 1950, as is shown in Table I. The results are summarized in Table II.

Table I. Vertebral number of the pond smelts sampled from different parts of Lake Kogawara in various years.

Locality	Date of sampling	Number of fish	Number of vertebrae							Mean	Variance
			53	54	55	56	57	58			
Anedo stream	Apr. 1, 1948	100	1	16	58	25	0	0	55.07	0.45	
Hachimandai shoal	June 18, 1948	50	0	5	30	14	1	0	55.22	0.44	
Kogawara shoal	Apr. 4, 1948	100	0	14	68	17	1	0	55.05	0.33	
Kogawara shoal	Apr. 7, 1949	50	1	6	33	9	1	0	55.06	0.47	
Kogawara shoal	Apr. 10, 1950	100	0	7	67	26	0	0	55.19	0.30	

Table II. Results of the significance test for the difference of the means of the vertebral numbers between the pond smelts sampled from different parts of Lake Kogawara in various years. ○ and ● indicate significance and no significance respectively.

Locality	1	2	3	4	5
1 Anedo stream, 1948	/				
2 Hachimandai shoal, 1948	●	/			
3 Kogawara shoal, 1948	●	●	/		
4 Kogawara shoal, 1949	●	●	●	/	
5 Kogawara shoal, 1950	●	●	●	●	/

From the fact that the pond smelt living in Lake Kogawara consists of one and the same race or population, it can be suggested that the circumstances are alike in other native lakes, though in Kita-ura, several groups were distinguished by Matsubara (1946) and Kubo (1946) from dimensional character of the body and also from amounts of parasites. However, they made no observation on vertebrae.

## 2. Comparisons of vertebral numbers among native groups.

The material were sampled from the Lakes of Kogawara, Abashiri, Mutsu Bay, Hachiro-gata, Kasumiga-ura and Shinji. Statistics of their vertebral num-

bers are shown in Table III. F-test revealed that there were significant difference among the means of vertebral numbers by locality with one exception of the case between Abashiri and Hachiro-gata as is shown in Table IV.

Table III. Vertebral number of the pond smelts in six native lakes and six stocked lakes.

Locality	Date of sampling	Number of fish	Number of vertebrae					Mean	Variance	
			53	54	55	56	57			58
Lake Abashiri	June 2, 1949	100	0	3	24	65	8	0	55.78	0.40
<i>Lake Akan</i>	Sept. 1, 1948	100	0	0	26	52	22	0	55.96	0.48
<i>Lake O-numa</i>	Oct. 5, 1949	100	0	1	32	60	7	0	55.73	0.36
Mitsu Bay	Apr. 11, 1949	30	0	0	0	4	13	13	57.30	0.49
Lake Kogawara	Apr. 1-June 18, 1948	250	1	35	156	56	2	0	55.09	0.64
<i>Pond Bagyu</i>	Dec. 8, 1948	90	1	18	48	22	1	0	55.04	1.03
<i>Pond Bagyu</i>	Dec. 2, 1949	50	0	1	48	1	0	0	55.00	0.04
Lake Hachiro-gata	May 10, 1949	100	0	4	41	41	13	1	55.66	0.64
Lake Kasumiga-ura	Mar. 25, 1950	100	0	1	20	50	28	1	56.08	0.56
<i>Lake Suwa</i>	Feb. 9, 1949	90	2	3	22	50	12	1	55.78	0.88
Lake Shinji	Mar. 10, 1950	100	0	1	8	51	32	8	56.38	0.62
<i>Lake Kahoku-gata</i>	Feb. 8, 1950	100	0	0	11	47	37	5	56.36	0.56

Localities indicated in Italics are those with stocked fish.

### 3. Comparison of vertebral numbers between a native group and a transplanted one.

Eggs of the pond smelt of about one week old after fertilization were transplanted from Lake Kogawara to Pond Bagyu in the spring of 1948. Comparison of the vertebral numbers of the grown fish were made in the fall of the same year and of their offsprings naturally propagated in the following year. From F-test, no significant difference was recognized between them as is seen in Table IV in spite of the difference of water temperature between them as is shown in Fig. 2.

Similar comparisons were made between the native fish group and transplanted ones; namely between Abashiri and Akan, Abashiri and O-numa, Kasumiga-ura and Suwa, and Shinji and Kahoku-gata. No significant differences were observed between them with an exception of the case between Kasumiga-ura and Suwa, where the transplantation was made 34 years ago, in 1915.

### Discussion

So far as the vertebral number is concerned, native groups of the pond smelt in several lakes in Japan are considered to be independent race or population. The

Table IV. Results of the significance test for the difference of the means of the vertebral number among native groups and among native and stocked group. ○ and ● indicate significance and no significance respectively.

Locality	1	2	3	4	5	6	7	8	9	10	11	12
1 Lake Abashiri		●	●									
2 <i>Lake Akan</i>												
3 <i>Lake O-numa</i>												
4 Mutsu bay	○											
5 Lake Kogawara	○			○		●	●					
6 <i>Pond Bagyu, 1948</i>												
7 <i>Pond Bagyu, 1949</i>												
8 Lake Hachiro-gata	●			○	○							
9 Lake Kasumiga-ura	○			○	○			○		○		
10 <i>Lake Suwa</i>												
11 Lake Shinji	○			○	○			○	○			●
12 <i>Lake Kahoku-gata</i>												

Localities indicated in Italics are those with stocked fish.

difference in vertebral numbers seemed, however, not to be correlated with latitude of localities as was reported in the cases of sand lances (Kawamura, 1940; Uchihashi et al, 1950 and Hatanaka & Okamoto, 1950) and sardines (Thompson, 1926). At any rate, pond smelts in Japan can be divided into several populations or races such as in Abashiri, Mutsu Bay, Kogawara, Hachiro-gata, Kasumiga-ura and Shinji etc. The vertebral number of these native fish populations is not changed by transplanting to other waters where the environmental condition such as water temperature is evidently different. In the case of the first year of transplantation from Lake Kogawara to Pond Bagyu it was suspected that the so-called supersensitive period which determine vertebral numbers might have passed by the time of transplantation when they were one week old after fertilization. But no change in vertebral numbers was observed even in the offsprings naturally spawned in Pond Bagyu. Furthermore, no change occurred in vertebral numbers between other native and stocked populations, namely between Lakes Abashiri and Akan, between Lakes Shinji and Kahoku-gata, where several years elapsed after transplantation.

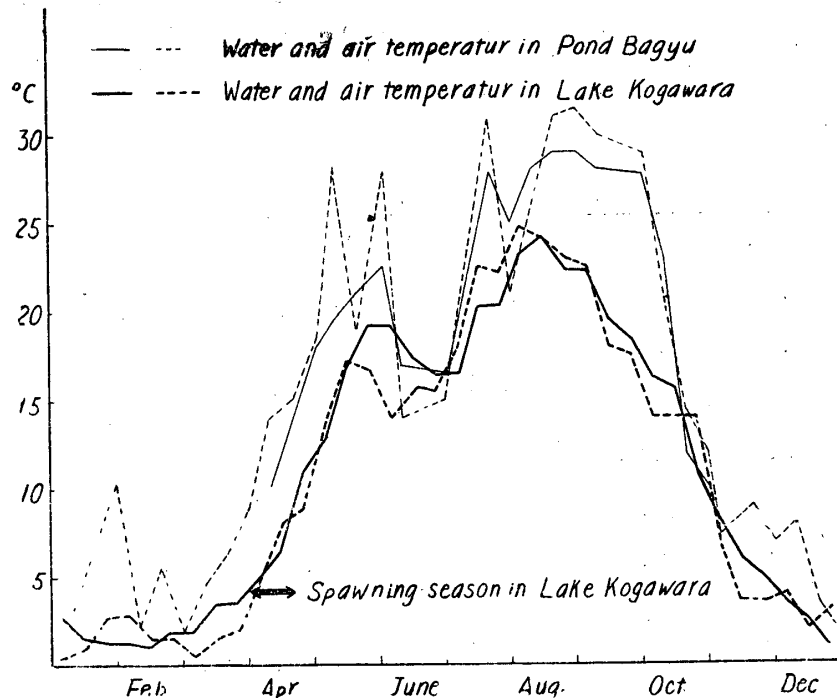


Fig. 2 Comparison of water temperature between Lake Kogawara and Pond Bagyu during 1949.

A single exception was the case between fishes of Lakes Kasumiga-ura and Suwa where the transplantation was done 34 years ago, in 1915. This result is contrary to the report of Fujita (1926) who studied fishes of both lakes in 1926, 11 years after transplantation and found no difference between them. Taning (1950) showed in the sea trout that there was specially a sensitive short period during the embryonic development against temperature effective to the number of vertebrae, and demonstrated experimentally that temperature-change of not so great degree (3-6°C) could produce a difference of about 1.5 vertebrae, which is by no means a small difference in nature. The similar effect was shown by Kubo (1950) in the dog salmon. We have yet no experimental evidence of the effect of change in temperature on the vertebral numbers of the pond smelt. Therefore we cannot give a definite conclusion in the case of the pond smelt. If the experimental result in other fishes described above is also applicable to the pond smelt, we can assume that the pond smelt spawned at the same temperature regardless of whether they were transplanted to colder waters or warmer ones.

It should be added here that we could not give any explanation to the existence of the difference between populations of the native Kasumiga-ura and the stocked Suwa in 1949, 34 years after transplantation, which was not

proved in 1926 (Fujita). It may possibly be due to natural selection rather than to the direct influence of temperature conditions.

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