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ON FEEDING HABITS OF THE LARVA OF POND SMELT, *HYPOMESUS OLIDUS* (PALLAS)*

By

Ryuhei SATO

Department of Fisheries, Faculty of Agriculture, Tohoku University, Sendai, Japan

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Introduction

The pond smelt, *Hypomesus olidus* (Pallas), is one of the most important landlocked fish in the inland waters of Japan. It is fished commercially in such lakes as Abashiri, Kogawara, Hachiro-gata, Kasumiga-ura, Shinji and others. As it has high adaptability to various environmental conditions, it can be transplanted easily from one water to another all over Japan. The pond smelt reaches the adult stage and spawns at the end of one year after hatching. Such O-age group usually comprises the main part of commercial landing in many lakes as reported by Kobayashi (1936) and Amemiya & Hiyama (1940). The yearly production of fry in the lake, however, varies greatly as was noted in Lake Kogawara, Aomori Prefecture (Sato 1950). Therefore production of fry is considered to be the most fundamental problem for the increase of catch in many inland waters. We have little knowledge of the food on which the larval fish feeds, though it is one of the most important factors in controlling the abundance and growth of fry. Not all organisms found in alimentary tracts of the larvae can be considered as favorite food. The food value of these organisms can only be determined by feeding experimentally under controlled condition and by comparing the rate of growth of the larva. This paper reports the results of feeding experiments in vessels or tanks and also in small ponds to find the best food organism of larvae of the pond smelt. I wish to express my hearty gratitude to Prof. T. Imai for his kind direction and encouragement and to Mr. S. Suganami for his help during the experiment.

Experiments

In spring of 1947, 1948 and 1949, eggs of pond smelt were collected and fertilized artificially at Lake Kogawara, Aomori Prefecture. The fertilized eggs were transplanted to the lakeside laboratory and also to the tanks at

* Contribution from Onagawa Fisheries Laboratory

the Onagawa Fisheries Laboratory of Tohoku University and the small ponds around Onagawa, where they were used for feeding experiments.

I. *Rearing the larvae on unicellular organisms.*

About a hundred newly hatched larvae were put into vessels of 25 litres capacity and were fed with five kinds of unicellular organisms, namely non-colored naked flagellate, *Chlamydomonas* sp., *Scenedesms* sp., *Navicula* sp. and *Coscinodiscus* sp. Among these organisms, naked flagellate and *Chlamydomonas* sp. were eaten by the larvae and were readily identified in the alimentary tracts. Some of the larvae which were fed on these organisms lived longer than those fed on other organisms as shown in Table 1.

Table 1. Result of rearing on unicellular organisms in small vessels. Water temperature during experiment was 5.5–14.2°C and pH 7.4–7.5.

Days after hatching	Food organisms	No. 1 Non-colored flagellate	No. 2 *Chlamydomonas* sp.	No. 3 *Scenedesmus* sp.	No. 4 *Navicula* sp.	No. 5 *Coscinodiscus* sp.	No. 6 None
0	Number of larvae	100	100	100	100	100	100
	Food organisms in alimentary tract	none	none	none	none	none	none
7	Number of larvae survived	ca. 25	ca. 25	ca. 25	ca. 25	ca. 26	ca. 25
	Food organisms in alimentary tract	non-colored flagellate with few *Chlamydomonas* sp.	*Chlamydomonas* sp. with few non-colored flagellate	none	none	none	none
9	Number of larvae survived	15	8	0	0	0	0
	Food organisms in alimentary tract	non-colored flagellate with few *Chlamydomonas* sp.	*Chlamydomonas* sp. with few non-colored flagellate	none	none	none	none

From such evidence it was suggested that either naked flagellate or *Chlamydomonas* sp. may be available as food for the early larvae. There was no indication that other unicellular organisms namely *Scenedesms* sp., *Navicula* sp. and *Coscinodiscus* sp. were taken by early larvae.

In order to re-examine the suitability of *Chlamydomonas* sp. as food of the early larvae, about a thousand larvae were reared in a tank of 800 litres capacity and fed *Chlamydomonas* sp. which had been grown there previously. The larvae began to ingest the organisms before it had not completely absorbed the yolk (Fig. 1) and some of the larvae lived over seven days. But the larvae showed no growth after 5th day and eventually most of the larvae died in a few days as shown in Table 2. From such evidence it can be concluded that *Chlamydomonas* sp. cannot be a favorite food for the early larvae, though they are ingested abundantly.

Table 2. Result of rearing on *Chlamydomonas* sp. in tank. Water temperature during experiment was 9.2–10.4°C and pH 7.4–8.0.

Days after hatching	Average total length in mm.	Number of larvae survived	Food organisms in alimentary tract
0	6.0	abundant	none
3	6.5	abundant	*Chlamydomonas* sp.
5	6.7	abundant	*Chlamydomonas* sp. with few non-colored flagellate
7	6.5	few	*Chlamydomonas* sp.
9	6.8	rare	*Chlamydomonas* sp.
12		none	

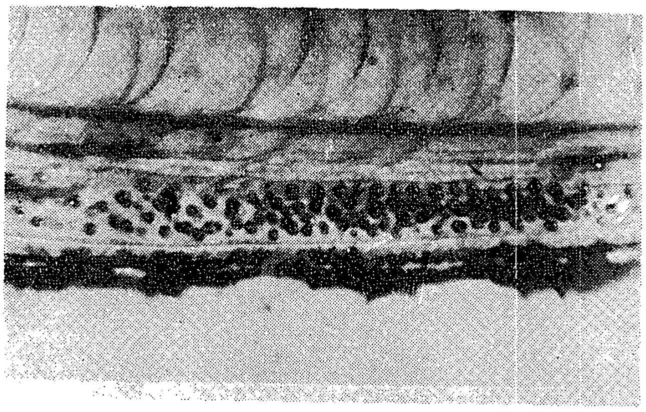

Fig. 1. *Chlamydomonas* sp. in alimentary tract of the larva of pond smelt on eighth day after hatching. ×150

Table 3. Result of rearing on a non-colored naked flagellate in tank. Water temperature during experiment was 11.2–15.2°C and pH 7.2–7.5.

Days after hatching	Average total length in mm.	Number of larvae survived	Food organisms in alimentary tract
0	5.95	abundant	none
4	6.6	abundant	none
6	6.8	abundant	non-colored flagellate with few *Chlamydomonas* sp.
9	6.8	few	non-colored flagellate
12	6.8	few	non-colored flagellate, pollen of a pine and indigestible substance
15	6.8	rare	
20		none	

A test of the suitability of non-colored naked flagellate as food was also carried in a tank. About ten thousand larvae were reared in the tank of 320 litres capacity and fed naked flagellate which had been grown there previously. In this case again the larvae ingested the organism before they had completely absorbed the yolk and a few of the larvae survived over 12 days. But no growth was observed after sixth day and this was followed by a high mortality as shown in Table 3. It is clear from this result that non-colored naked flagellate is not a favorite food by itself, though it may be of some value for a few days of early larval development.

II. *Rearing the larvae on larger planktonic organisms.*

In the rearing experiment just referred, it was noted that the larvae were able to take much larger food than the author expected. One of the larvae, 12 days old and 6.85 mm. long, was found to have had ingested pollen of the pine, *Pinus Thunbergii* Parl, with a diameter of 80 μ (Fig. 2).

Fig. 2. A pollen of the pine, *Pinus Thunbergii* Parl, in alimentary tract of the larva of pond smelt on 12 day after hatching. ×150

Such evidence suggested the possibility that the larvae can utilize larger planktonic forms than the unicellular organisms already tried as food. Therefore in the following experiment, the larvae were fed on a mixture of zooplankton and unicellular algae. Nearly ten thousands newly hatched larvae were put in a rearing pond having an area of 40 square metres and a depth of 50 centimetres, which had previously been inoculated with planktonic organisms collected from a pond. The main organisms and their abundance in the pond during experiment are shown in Fig. 3. The larvae fed on these organisms and showed a good growth. As a result, 420 larvae attained average length of 20.9 mm. in 47 days. The growth rate here obtained was higher than that of the larvae of an allied fish, "Ayu", *Plecoglossus altivelis*, which was reported by Fishery Experimental Station of Tokyo (1936) as shown in Table 4. From such facts it can be stated that the growth rate here obtained is close to the normal one. The growth of the larvae during rearing can be expressed by an exponential function, $y=0.72\,e^{0.0122x}$.

Where x is the days after hatching and y is the total length of the larvae in mm. In the case of the larvae of "Ayu", the formula of growth has been reported as $y=0.81\,e^{0.0076x}$.

The relative importance of each kind of food organisms at different stages of larval development is shown by percentage of occurrence in the intestine of larvae examined in Fig. 5. Though it only shows the percentage of larvae which ingested particular food organisms, it was found to be parallel with the amounts of ingestion. Therefore we can see, from the figure, the preference of larvae for foods, at various stage of development. Young larvae only four to six days old took many rotifers, *Brachionus bakeri*, and few nauplius larvae of a copepod, *Cyclops* sp., besides small unicellular algae as seen in Fig. 6. Among them *Brachyonus bakeri* seems to be the most important. It is striking to find that larvae less than 8 mm. in length

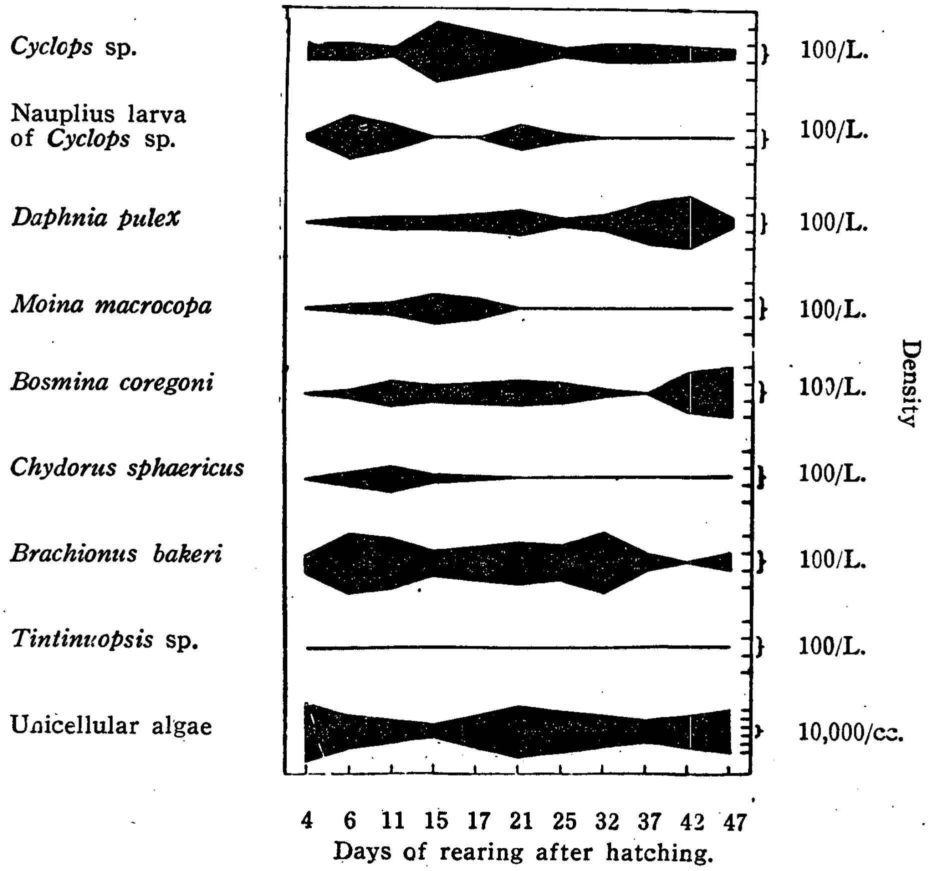

Fig. 3. Abundance of planktonic organisms in the rearing pond of the larva of pond smelt.

can ingest organisms 80 to 215 μ in length. It was noticed under the microscope that these rotifers were digested in the intestine. Soon after the larvae reach 8 mm., they began to take a cladocera, *Bosmina coregoni*, as a main food organism. Besides *Bosmina coregoni* another cladocera, *Moina macrocopa*, and a copepod, *Cyclops* sp., were also found in alimentary tracts of the larvae, though in lesser quantity. From these findings it can be said that principal food organisms of the larvae change from small one such

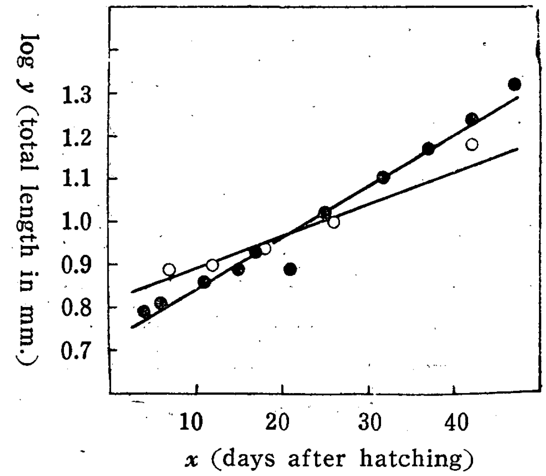

Fig. 4. Growth cf larvae of pond smelt (●) and "Ayu" (○). Logarism of total length in mm. is plotted in the ordinate.

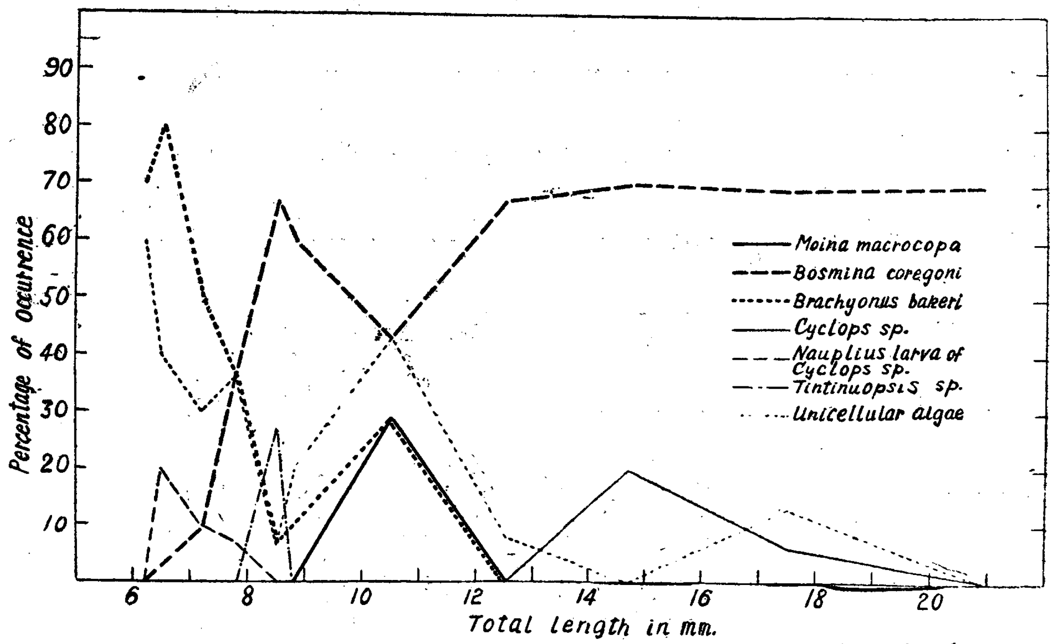

Fig. 5. Percentage of occurrence of various planktonic organisms in the intestine of larvae.

as *Brachionus bakeri* to larger one such as *Bosmina coregoni* as the larvae grow.

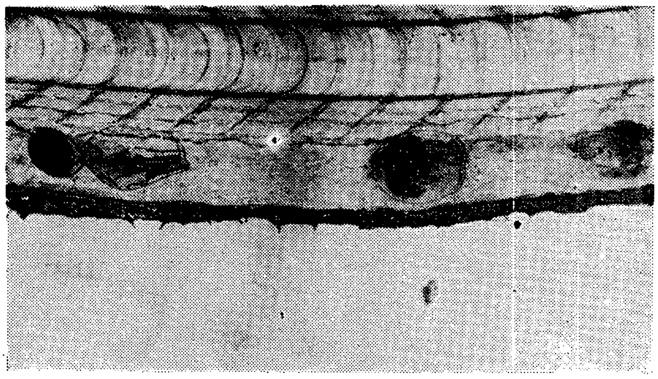

Fig. 6. *Brachionus bakeri* in alimentary tract of the larva of pond smelt on eighth day after hatching. ×80

Conclusion

It has been considered to be difficult to rear the early larvae of pond smelt in a small pond, because favorite foods of young larvae were unknown. In the foregoing experiments the writer succeeded in rearing them on planktonic organisms to the average size of 20.9 mm. in total length in a small pond. It was proved in the study that unicellular organisms namely *Navicula* sp., *Coscinodiscus* sp., *Scenedesms* sp., *Chlamydomonas* sp. and non-colored naked flagellate are not suitable as food themselves, though some of them may be utilized by early larvae. Finally it was proved that zooplanktons such as *Brachionus bakeri* and nauplius larvae of *Cyclops* sp. are a favorite food for very early larval fish.

In the rearing experiment of larvae of an allied fish "Ayu", Nishioka (1932) reported that the larvae feed on unicellular algae, while according to the report of Fishery Experimental Station of Tokyo (1936), it was lately shown that the larvae of three days old ingested *Brachyonus* sp. and nauplius larvae of *Cyclops* sp. besides unicellular algae. The ingestion of *Brachyonus* spp. was also recognized by Matsui (1938). Such findings seem to support the present conclusion as to the importance of a rotifer such as *Brachyonus bakeri* as main food organism of very early larvae of the pond smelt.

As the larvae grow, other food organisms such as cladocera, *Bosmina coregoni* and *Moina macrocopa*, and a copepod, *Cyclops* sp. may replace the rotifers. On these food organisms the larvae continues to grow. Such successive changes of food organisms in the very early stage of the larvae may be regarded as due to the choice in the part of larvae as in the cases reported in the large-mouthed black bass, *Micropterus salmoides*, and the sole, *Solea solea*, by Morphy (1949) and Dannevig & Dannevig (1950).

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