Bull. Fac. Fish., Mie Univ.
No. 14 : 1 – 10
September 30. 1987

Growth and Maturity Size of the Three-spined Stickleback *Gasterosteus aculeatus* in Rearing Pool

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Synopsis

The growth of three-spined stickleback, *Gasterosteus aculeatus*, was examined in the pool laboratory experiment under natural conditions as possible from March 1981 to December 1983.

On an average, the three-spined stickleback grew about 50 mm SL/yr and thereafter the growth slowed. The fish reached adult size 45 mm by the initial winter. The adults almost died after spawning and only one fish had a maximum life span of a year and ten months and a maximum size of 64.8 mm SL. The growth in length was very similar between 1981 and 1982 year class. The most rapid growth in length occurred during May to July. The fish matured at 10-12 months, and probably lived no more than 2 years. Most of the fish lived 1-1.5 years and did not live through the second winter. The fish presumably died shortly after completing their spawning activities, possibly as a result of physiological exhaustion. A small number of emaciated individuals was taken after the second summer.

Of three equations, Bertalanffy, Gompertz and Logistic growth curves, the Gompertz equation generally gave the most satisfactory result.

The growth rate of Japanese population was comparable to that of the fish in South England, Northwest England, mid Wales and Alaska, and the anadromous populations in the Netherland and Japan. *Leiurus* stickleback in Japan was nearly larger in growth rate than any three-spined stickleback population in other countries.

Key words : Growth, Maturity Size, Three-spined Stickleback

Introduction

The three-spined stickleback, *Gasterosteus aculeatus*, has received some attention and a comprehensive of the growth in Europe (Jones and Hynes, 1950; Mullem and Vlugt, 1964;

Mullem, 1967; Mann, 1971; Pennycuik, 1971; Wootton, 1976; Wootton, Evans and Mills, 1978; Allen and Wootton, 1982a, 1982b) and North America (Greenbank and Nelson, 1959; McPhail, 1977). However, in Asia area, there was only a brief report on the growth of the anadromous three-spined stickleback (Nakamura, 1974).

The present study provides a size at maturity and growth of the landlocked three-spined stickleback which has been reared in the artificial pool for three years. Among the freshwater population, the Japanese fish is larger in growth rate than the alien fish. The results were attempted to be explained by the difference in habitat environment.

In general, the freshwater type which is probably derived from the anadromous type is smaller in body size than the anadromous type. Small size of the freshwater type examined in this study is not caused by shorter life span owing to both larger growth rate and faster ceasing of growing up. This dwarfism might have correlated with ecological conditions of natural habitat and the historical problem of landlocked period.

Materials and methods

The experiments were performed in a concrete rectangular pool (1.3m × 7.5m, 0.2m in depth) under outside natural conditions (water temperature, photoperiod and food supply) from March 1981 to December 1983 (**Fig. 1**). The pool was filled with water from a moun-

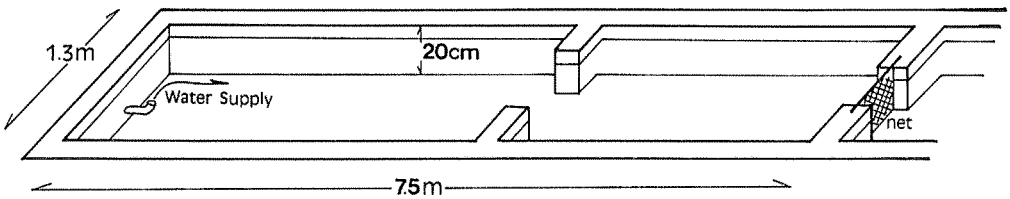

Fig. 1. Outside rearing pool made of concrete.

tain stream every time, and has a water depth ranging 18-23cm and slow flow of under 20cm /sec. Bottom substratum was slightly sandy mud (1-2cm deep) and flat relief. Aquatic vegetation (*Elodea nuttalli* and *Hydrilla verticillata*) was sparsely placed. **Fig. 2** shows the annual fluctuation of water temperature of the pool during 1981 to 1982. The temperature did not become over 20℃ even in summer and below 5℃ in winter, which corresponded to the range in their natural habitat. In May and October of each year, the water temperature became 15℃, the same as the field water areas where the subject fish inhabits. The day length approximately changes between 9 hrs and 14.5 hrs through the year (**Fig. 2**).

The fish examined in this study were obtained from the Yamayoke river, Gifu Prefecture in Central Japan (Mori, 1984, 1985). They belonged to the *leiurus* (low-plated morph). The

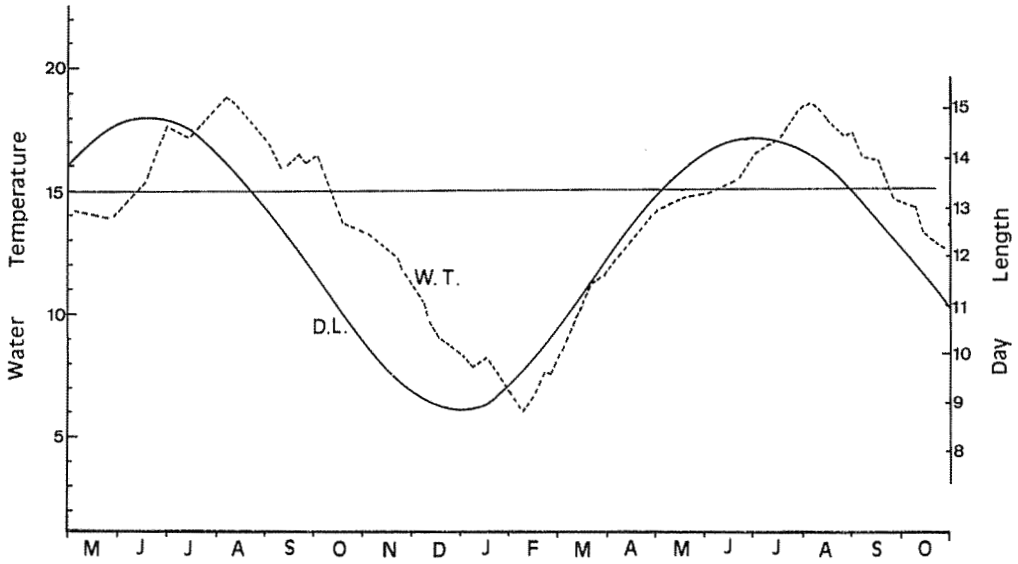

Fig. 2. The yearly fluctuation of water temperature (W. T.) and photoperiod (D. L.) in the pool. The horizontal line shows the mean water temperature of spring area.

fish have been reared in the experimenthl pool since 1978 and have lived in a normal manner with alternation of generations. So that it is assumed that enough food has been supplied to maintain the fish population of the pool.

Before the examination was started, the fish reared so far were completely excluded from the pool. Then, 27 adult fish (10 male; 17 female) were introduced in the pool on March 21th 1981. They have spawned from April to mid June. To examine growth of the fish, 167 progeny hatched from three nests in June 6-11th 1981, and 140 fry from three clutches produced by 1981 year-class in April 10-12th 1982, were utilized to rear in the pool.

The sample measurements of the body length were in regard to more than 20 fish collected with a small seine net once or twice a month from their hatch out time until the breeding season. The body length was measured to the nearest 0.1 mm, then the fish were returned to the pool. Every month from January, I counted each number of living and dead or missing fishes.

Results

Maturity size

Males and females matured at about the same size though females were somewhat larger in a mean body length than males. There was no definite difference ($p>0.05$) between males and females except that several females were both older and larger than any males. Most

females were sexually mature at 45 mm SL (standard length = body length). Although the smallest female with mature ova was 43 mm, the majority of females did not have mature ova until 45 mm SL. The breeding coloured male with a nest was 47 mm SL in the smallest body length.

Growth in length and survival

Hatched larvae 6-7 mm SL (6.55 mm in a mean length) can attain a length of about 15 mm within one month of hatching. The fish grew up to 45 mm SL with over 1.2 gram in weight in a half year before winter (**Fig. 3**). There was a increment of 5 mm during winter. At early

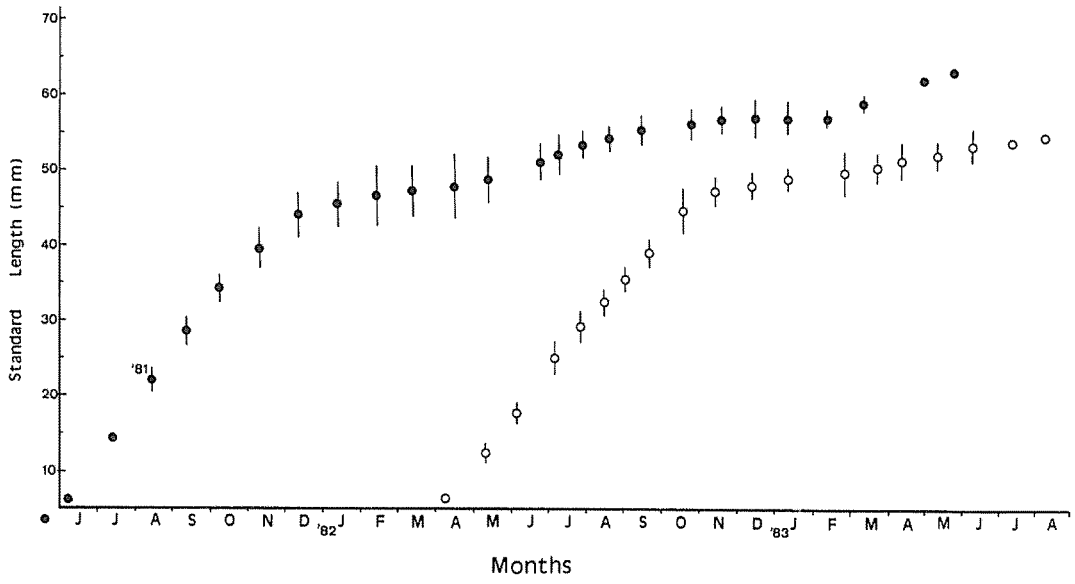

Fig. 3. Growth recorded at approximately 4 weekly intervals of the three-spined stickleback born in June 1981 and April 1982. The vertical lines show the range of body length.

breeding period (April and mid-May), the fish of 1981 and 1982 birth achieved 48.2 mm and 49.1 mm, respectively. The fish had a mean length of about 50 mm at the end of their first year of life. These results of growth agreed with most studies that there is a gradual decrease in growth rate of fish with increasing size (Bertalanffy, 1957; Jobling, 1983).

Growth curves of the 1981 and 1982 year class were compared in **Fig. 3**. Both fishes of 1981 and 1982 year class declined in growth rate from November ranging from 10℃ to 15℃ in temperature. They increased a little and grew in spring of the following year and, at the same time, entered the breeding period. In each breeding period of three years, mortality somewhat decreased. After the breeding season, though there was a large mortali-

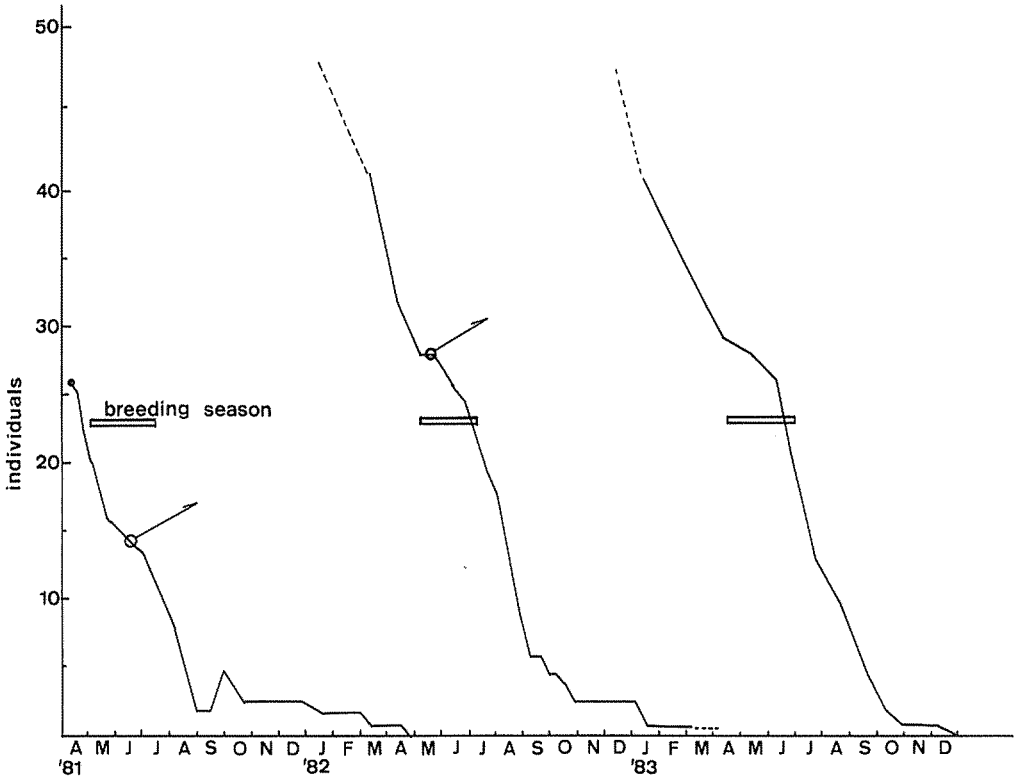

Fig. 4 Mortality and breeding season of each three year. Two arrows indicate the time when the fry was picked up to utilize in this experiment.

ty, a few of those remaining have experienced two summers and/or two winters (**Fig. 4**). A female fish of 1981 year-class lived about 22 months and and reached 64.8 mm in body length. This fish matured in the second spring also, but I do not know whether she spawned or not during the second breeding season.

Usually, the three-spined stickleback had a life-span of year and a few months. The growth pattern of longer living fish slowed up in the second summer and/or autumn of successive years.

Growth models

Accoording to the Walford lines which is drawn up on the basis of the growth of first year, the growth curves of von Bertalanffy, Gompertz and Logistic were designed in **Fig. 5** (Bertalanffy, 1957; Allen, 1966; Ricklefs, 1967; Ricker, 1979). These equations were:

$$\text{von Bertalanffy}: \quad 59.42\ (1-e^{-0.1253-0.1983t})$$

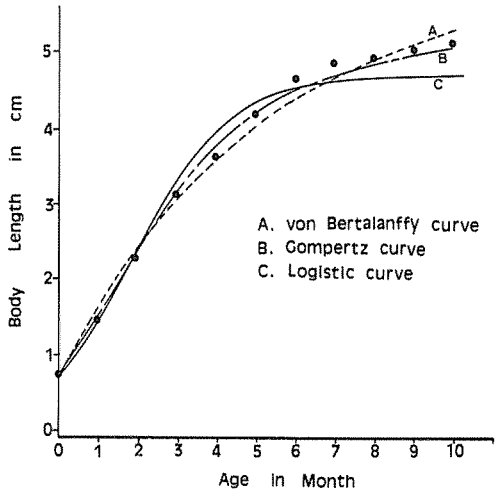

Fig. 5. Growth curves plotted from each equation for the von Bertalanffy, Gompertz and Logistic functions. These equations were shown in the text. The dots show the value observed in this study.

$$\text{Gompertz}: \quad 52.77e^{-2.0183e^{-0.4745t}}$$

$$\text{Logistic} \quad : \quad \frac{46.55}{1+5.4078e^{-0.8946t}}$$

Of three equations, Gompertz growth curve best fixed the relationship between age in month (t) and body length since logarithmic value was mostly straight plotted in the Walford line. Curves were fitted by using mean back-calcultured length at age. The maximum length expected from each equation was 59.42 mm, 52.77 mm (the fittest to the examined value) and 46.56 mm, respectively.

Discussion

Comparison to Other *leiurus* population

During the first autumn or winter, the fish from the Yamayoke river attained a mean length of 45 mm SL in about 7-8 months. In contrast, the freshwater sticklebacks in South England (Mann, 1971) and in mid Wales (Allen and Wootton, 1982b) were less in mean (below 45 mm) and maximum length than Japanese population though much more similar to a life span of a year and some months. Although the two English populations differed in the growth rate to each other, both of them stopped increasing their growth from three to eight months after hatching and in the following spring began to increase again (**Fig. 6**). This may have been thought of as a kind of compensation function.

Throughout the growing period (May to September) in the first year of hatching, the growth rate of *leiurus* living in two lakes on Kodiak Island, Alaska (Greenbank and Nelson, 1959) was similar to that of Japanese *leiurus*. Alaska *leiurus*, however, almost ceases increasing its growth during autumn and winter, and most survives a further year (up to and

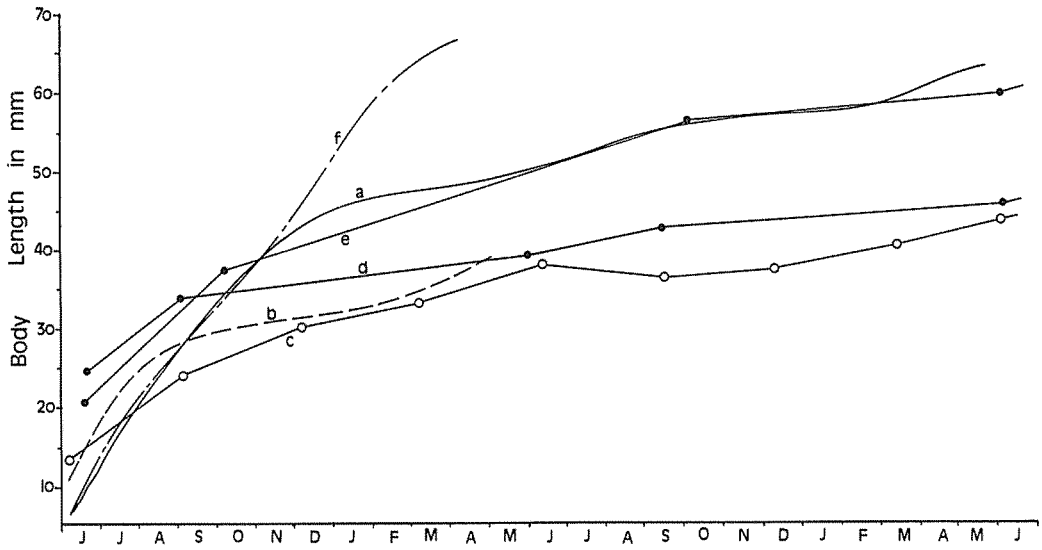

Fig. 6. Comparison of growth with population of alien three-spined stickleback. The line show growth for population of the following localities : a, *leiurus* of the present study ; b, *leiurus* in South England (Mann, 1971) ; c, *leiurus* in Northwest England (Jones and Hynes, 1950) ; d, *leiurus* in Bare Lake, Alaska ; e, *leiurus* in Karluk Lake, Alaska (Greenbank and Nelson, 1959) ; f ; the anadromous (*trachurus*) fish in the coast of Japan Sea (Nakamura, 1974).

a quarter years) and ranges in length from 45 mm to 65 mm (maximum length in each lake is 69 mm and 78 mm SL, **Fig. 6**). They spawn at the age of one or two years.

In the laboratory with the temperature maintained at about 20℃ and good food supply (Mullem, 1967), *leiurus* stickleback from the Netherlands can grow to a length of about 17 mm within 30 days of hatching and attain over 50 mm in length for 6 months (measured total length : tip of snout to end of tail of the fish). This high rate is similar to the result of the present study.

The growth rate of length in this study was greater than that found by the foreign workers. Such growth and maturation in Japanese population may be influenced by variations in food supply, the day length, the water temperature and the special history that each population has genetically experienced. In other words, among stickleback populations there is considerable variation in growth pattern, which is due to differences in race or environmental conditions.

It was evident that few fish lived for very long after spawning in June at the end of their first year. No stickleback more than 2 years old was recorded at any of years in the present study. This agreed with the findings of Heuts (1947), Mullem and Vlugh (1964), Mann (1971), Wootton et al., (1978) and Allen and Wootton (1982b), while Jones and Hynes (1950),

Greenbank and Nelson (1959) and Pennycuik (1971) found the fish could live for up to a range of 2-4 years. The large size of Japanese *leiurus* is probably a reflection of a higher growth rate, and not of a longer span of life.

Mori (1987) reported, however, the exceptionally large fish of 85.1 mm in a maximum length within more than 400 adult samples of the landlocked three-spined stickleback (*leiurus* form) collected in the Sohya stream, Shiga Prefecture, where the environment differed from the sample locality of fish collected and utilized in the present survey. This large fish has probably lived at least for 2 years, possibly 3 years. With the exception of the above large fish, we can conclude here at any rate that the freshwater type in Japan generally has faster growing and maturing, thereafter usually die out before 2 years old.

Comparison to the anadromous type

There is an idea about that the freshwater type is probably a landlocked fish, which derived from the anadromous type, and become a independent species (Hagen, 1967 ; McPhail and Hay, 1983 ; Mori, 1987, in press). Therefore, each difference in growth rate and length a maturity of the three-spined stickleback population must be considered on careful comparison between the anadromous (represented *trachurus* form) and the freshwater (represented *trachurus* and *leiurus* form) types as well as between the localities.

Mullem and Vlugt (1964) provided the age and the growth of the anadromous stickleback with mixed population (*trachurus*, *semiarmatus* and *leiurus* form) from the Netherlands. They reported from field observation that the stickleback lives the life span of 1 year and about 4 months, and reaches a mean length of about 60 mm in total length for one year, with a range from 42 mm to 85 mm. The growth rate of the freshwater stickleback in the present study was almost the same as that of the Netherlands population until 10 months after hatching, considering that Mullem and Vlugt measured the total length.

Also, in the laboratory experiments, the anadromous fish from the coast of Japan Sea grows in size as the freshwater type until five to six months from the time of hatching, thereafter, contrast to the freshwater type, continued to increase the body size up to 65 mm to 70 mm SL for 9 to 10 months by almost the same growth rate till then (Nakamura, 1974). Actually, the anadromous type raised into the freshwater area of Japan grew up to a range of 70-85 mm SL (Mori, in press).

The anadromous fish (*trachurus* form) are generally larger than the freshwater type regardless of their life span (Heuts, 1947 ; Jones and Hynes, 1950 ; Hagen, 1967). This dwarfism in the freshwater fish might have related to conditions of food supply, food web, osmotic pressure and the fluctuation of water temperature between the marine and the freshwater environments, and further the landlocked process or time.

Acknowlegments

I wish to express our gratitude to Prof. Hiroya KAWANABE (College of Science, Kyoto University) for valuable comments on the manuscript, and Mr. Takamasa ITOH (Chief of the Sakamoto Fish-farm) and Mr. Yoshihiro KODAMA (Fujiwara-cho town, Mie Pref.) for providing encouragement throghout the course of this work.

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