Growth of the Tidepool Gunnel in Ago Bay, Central Japan^{*1}Seishi Kimura,^{*2} Takaharu Okazawa,^{*3} and Koichiro Mori^{*8}

(Accepted May 23, 1987)

The present report deals with the growth of the tidepool gunnel *Pholis nebulosa* (Pisces: Pholididae) examined by the length-frequency data, based on 4,243 individuals taken from Ago Bay during the period from April 1980 to May 1982. The length frequency distribution of each month could be analyzed into 0- to 3-age groups. The length growth curve of the gunnel was described by fitting von Bertalanffy's model expanded by a periodic function as $L_t = 33.8(1 - \exp(-0.72(0.53t + 0.099 + 0.075 \sin(6.28t - 8.47))))$, where L_t = total length (cm) at age t , and t = the passage time (year) from December before hatching. The relationship between total length (TL , cm) and body weight (W , g) was expressed by the formula: $\log_{10} W = 3.48 \log_{10} TL - 3.045$. The length growth was intensive at the water temperatures between 10 to 17°C, and this species grew more rapidly in rather cool periods than in the warm seasons.

The tidepool gunnel *Pholis nebulosa* is a very common pholidid fish inhabiting mainly tide pools and eel-grass *Zostera marina* beds along the coasts from southern Hokkaido to Kyushu in Japan. This gunnel is rarely used for commercial food except the regions of Tokyo and its vicinity, where the fish is highly valued as a fried fish in the spring months. In Ago Bay, this species appears in large number in eel-grass beds at the mouth of the Bay in most seasons of the year except August and September.¹⁾ This appearance is a peculiar feature of the fish fauna of eel-grass beds in this area.

Although this gunnel commonly lives in shallow waters, little is known about the ecology of the fish. Fragmentary reports were made on only the spawning²⁾ and the incubating habits.^{3,5)} There is no information available yet about the age and growth of this species.

At the beginning of this study, we attempted to estimate the growth rate of this gunnel from otolith reading in the same way as the Atlantic rock gunnel *Pholis gunnelus*.^{4,6)} However, the zonation on the tidepool gunnel's otolith removed from either fresh or preserved fish was very indistinct. Thus, we concluded that the otolith reading was not an effective method for age determination of this species. Accordingly in the present paper, the growth rate of the tidepool

gunnel was estimated by analyzing the length frequency distributions, based on the specimens taken from Ago Bay.

Materials and Methods

The materials used in this study consisted of 4,243 specimens. Of these 3,687 specimens were caught by monthly tows with a small beam trawl in eel-grass beds at the mouth of Ago Bay, Mie Prefecture (lat. 34°17'20'' N, long. 136°46'30'' E) during the period from April 1980 to May 1982. The remaining 556 specimens were collected by monthly samplings with spoon nets and cast nets under the fish lamp on the shore of Zaga Island in the Bay (lat. 34°16'15'' N, long. 136°48'30'' E) from April 1980 to January 1982. These collecting methods were detailed in the previous papers.^{1,6)} All the specimens were preserved in 10% buffered formalin. The total length (TL) and body weight (W) of each specimen were measured in the laboratory. The adults were sexed by the histological examination of their gonads.

Using the computer programs described by Akamine,^{7,8)} the polymodal frequency distribution of the total length in each month was analyzed into a few normal distributions, and the von Bertalanffy's growth curve expanded by a periodic

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function was calculated from the monthly changes of the mean values and standard deviations of these normal distributions.

Results and Discussion

Separation of Age Groups

Monthly change of the length compositions were shown in Fig. 1. The frequency distribution of total length in each month could be clearly analyzed into one to four normal distributions. The larvae smaller than 2 cm *TL* appeared only in January. The larval population was recruited once a year in this month. Accordingly, each normal distribution could be regarded as an age group. The first mode, situated in the most left position in the length composition of January, was undoubtedly recognized to be 0-age group. This mode continued to appear prominently from February to December, subsequently the mode shifted to the right and became the second one in the next January. The second mode in January also could be traced until December, and it shifted to the right and became the third one in the next January. Thus the second to the fourth modes

were regarded as 1- to 3-age groups, respectively.

During the months from January to June, 0- to 2- or more age groups were observed. However, only 0-age group appeared in July and no fish in August and September. In October, only 2-age group reappeared. Accordingly, the elder fish left the shallow waters in summer earlier than the younger ones. Also the former reappeared in the same areas earlier than the latter.

According to Qasim⁴⁾ and Sawyer,⁵⁾ the rock gunnels in both the eastern and western North Atlantic moved from the shallow waters or intertidal areas to the deeper waters in winter when their spawning took place. While the tidepool gunnels remained in shallow water in their spawning season during late November and December,* they left there in summer as mentioned above. Therefore, it seems that the moving of the tidepool gunnels takes place because the water temperature of their habitats rise over their tolerance level.

Length-Weight Relationship

The relationship between total length in cm and body weight in g of 108 specimens ranging from 7.8 to 27.0 cm *TL* was expressed by the following

Fig. 1. Monthly change of the length compositions. The length frequency distribution of each month was analyzed into a few normal distributions indicated by the curves.

* T. Okazawa, unpublished data.

equation.

$$\log_{10} W = 3.48 \log_{10} TL - 3.045 \quad (r = 0.996)$$

where r = correlation coefficient

Growth

Von Bertalanffy's growth model expanded by periodic function⁶⁾ was calculated from the monthly change of the mean lengths and their standard deviations of each age group. The spawning of this species took place mainly in December. Hence, we took December 1st as the origin of its growth. The length growth curve of the fish was expressed by the following equation (Fig. 2).

$$L_t = 33.8(1 - \exp(-0.72(0.53t + 0.099 + 0.075 \sin(6.28t - 8.47))))$$

where L_t = total length (cm) at age t and t = the passage time (year) from December before hatching

From this equation, the mean total lengths of 1- to 4-years-old fish were estimated as 11.3 cm, 18.5 cm, 23.3 cm, and 26.7 cm, respectively. There was no significant growth difference between both sexes. From the equations of length growth and length-weight relationship, the weight growth curve was expressed by the following equation.

$$W_t = 169.7(1 - \exp(0.72(0.53t + 0.099 + 0.075 \sin(6.28t - 8.47))))^{3.48}$$

where W_t = body weight (g) at age t

The mean body weights of 1- to 4-years-old fish were estimated from this equation as 4.2 g, 23.2 g, 51.7 g, and 83.0 g, respectively.

The tidepool gunnels grew rapidly during the period from December to May, subsequently the

Fig. 2. Length growth curve of the tidepool gunnel. Circles indicate mean total length observed.

Fig. 3. Monthly changes in the water temperatures at Zaga Island (open circles) and the mouth of Ago Bay (solid circles), and the growth curves of tidepool gunnel for 0-age (solid line) and 1-age groups (dashed line).

growth rate decreased gradually, and the length growth was interrupted in October and November. Monthly changes of the water temperatures at the month of Ago Bay and Zaga Island, and the length growth curves of 0- and 1-age groups were shown in Fig. 3. The growths of both age groups were intensive at the temperatures between 10 to 17°C. This species grew more rapidly in somewhat cool periods than in warm periods. This fact well shows that the tidepool gunnel is essentially a northern or subarctic species. Decline of the growth rate in summer and autumn is attributable to the decrement of the physiological activities owing to the high water temperature, and/or to the gonadal maturation.

The asymptotic maximum total length was estimated at 33.8 cm, while the actual maximum length of the specimen used in this study was about 28 cm TL. The former was somewhat too large in comparison with the latter. However, it is generally known that this species attains to about 30 cm.³⁾ Judging from the basis of this general maximum length, the asymptotic maximum length obtained here was rather reasonable.

The rock gunnels from both eastern and western coasts of the North Atlantic reached to about 6.5–7.5 cm, 9.5–11 cm, 12–13 cm, 13–16 cm, and 15–18 cm at 1- to 5-years-old, respectively.^{4,5)} The growth of this gunnel was much slower than that of the tidepool gunnel estimated here. The growth difference between both species may be attributable to the difference of the water temperatures of their environments.

Acknowledgments

We wish to express our sincere gratitude to Dr. K. Suzuki, Faculty of Fisheries, Mie University, for helpful suggestions and critical reading of the manuscript. Thanks are also due to Mr. T. Akamine, Japan Sea Regional Fisheries Research Laboratory, for his advice in the computer programs.

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