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Population Structure and Maturation of Whitelimbed Goby (*Acanthogobius lactipes*) of a Mud Flat Area at the Mouth of the Kutanabe-gawa Brook, Yamaguchi

Kei Takizawa*, Hiroshi Maruta*, Masaki Ikawa*,
Masao Nakamura*, and Takayuki Nakamoto*

In the fish assemblage around the mouth of the Kutanabe-gawa brook, Yamaguchi, whitelimbed goby (*Acanthogobius lactipes*) dominates just like the other gobies such as yellowfin goby (*Acanthogobius flavimanus*) do. We collected 2,289 specimens in 145 hauls within the sampling duration of the 1980s and 1990. The median in TL was 50 mm, and the minimum and the maximum were 16 and 95mm, respectively. The monthly arrangement of the length composition demonstrates that the goby has a calendrical cycle which starts with the occurrence of the individuals below 30mm TL in August or September, and terminates with the appearance of those with larger size but unknown sex in the same season of the next year, and such implies that the whitelimbed goby can be categorized as an annual. While the size composition in the recruit was stabilized, the subsequent growth of the individual was precarious.

Sexually matured individuals mingled from April to July. The matured group had larger TL and BW than the sexually indistinct group which coincided with the matured, but the condition factor (*K* value) did not differ between them. By comparison with the nurturing females, which settled in the spawning nests, we can conclusively speculate that the adults we observed consisted mainly of the population surviving the preliminary term prior to the nurturing period.

1. Introduction

The coastal region of the western part of the Inland Sea features the mud flat area, where the complicated relationship among various dwellers proceeds. Among them whitelimbed goby (*Acanthogobius lactipes*) dominates just like the other gobies do.[1,2] It is a congener of yellowfin goby (*Acanthogobius flavimanus*) which is another dominant species around the mouth of the Kutanabe-gawa brook and possesses common fashion in several facets: they tend to occur concurrently; therefore, they may undergo the ecological competition for niche, but it has been seldom focused on the life history, much remained unknown.[3,4] No doubt it prevails in number on the yearly inventory, but it subtly alters the number sampled or the dates collected each year. It may cause the difficulty in researching the subject precisely. A certain criterion for inspect-

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* Laboratory of Fisheries Resources, Department of Biology and Aquaculture, Shimonoseki University of Fisheries
(滝澤　敬・丸田祐司・井川雅樹・中村正男・中本孝幸：水産大学校増殖学科水産資源学講座).

ing the inconsistency should be installed. Applying some suitable stochastic procedure against phenomena repeats several times is a convenient way. In order to investigate it, we applied some statistic tests on the data with respect to morphometry and gonad inspection which are collected out of the 11 years observation duration.

2. Materials and Methods

The specimens were collected in spring tide periods from 19 January, 1980 to 18 December, 1990, except for the duration from January to August in 1988. The sampling gear we employed was a cod hoop net *fukuro-machi-ami*. Information as to gear design and its treatment is detailed in Takizawa (1994).[2] All the specimens were fixed with 10% freshwater formalin immediately after captured. Then they were measured to the nearest 1mm (total length: TL), and weighed to the nearest 0.01 g (body weight: BW), but several specimens that had rather smaller physiques sampled in 1981-1983 and 1987 were missing the BW value. Then the condition factor [K value: $10^5 \times$ BW/TL^3 (g/mm^3)] was gauged. In 1984 and 1987-1990, we investigated the sex depending upon the observation of the aspect of gonads and classified male, female and the indistinct.

In the statistical analysis in this study, probability intervals of $^{*}0.05 > p > 0.01$; $^{**}\ p < 0.01$ were used.

3. Results and Discussion

Annual Change in Population

We collected 2,289 whitelimbed gobies in 145 hauls. The median in TL was 50mm, and the minimum and the maximum were 16 and 95mm, respectively. The monthly arrangement of the measurements of all the specimens demonstrates the characteristics on the life history of this species.[2] The monthly averages in TL are not identical (F-test, $p < 0.001$). Figure 1 shows that the averaged TL decreases in August, and the standard deviation clearly increases in August and September. In and after October, however, the averaged TL reduces to *ca.* 30mm and the standard deviation stabilizes again. Without 28 September, 1981, an obvious differentiation in the TL composition was never observed. These indicate that although there were occasional coexistence of the recruitments and the larger individuals in August and September, we can principally distinguish the calendrical cycle of the population which starts with the occurrence of the individuals below 30mm TL in these months, and terminates with the appearance of the large sized ones in the same season of the next year. Table 1 shows the dates of the initial and the final appearance, and details in the several statistical parameters of each populations. The ranges and medians in TL fluctuate considerably and F-tests revealed that the averaged TL and the allometric condition among the populations are not equal. However these may be possibly influenced by the irregularity in the sampling date. Then we inspected the homogeneity in TL compositions of the populations within the same month. Table 2 shows that the constancy in both TL and BW was observed in October and December, and the body sizes of the other months could be unstable. Namely, the size composition in the recruit of this goby was stabilized (20-30mm TL, 0.05-8.00 g BW), but the subsequent growth of the individual was precarious. The feeding condition and the water temperature may affect this.[1,2]

Several fishes inherit such a characteristics that the somatic growth in individual differentiates in some developmental stages, which can be recognized as the process that the variance or standard deviation of the sample increases through the development.[5] Nevertheless, except for few months when recruitment occurs, the monthly arrangement of the standard deviation in TL of this goby seems to be hardly flexible (Fig. 1). Then we investigated the monthly change de-

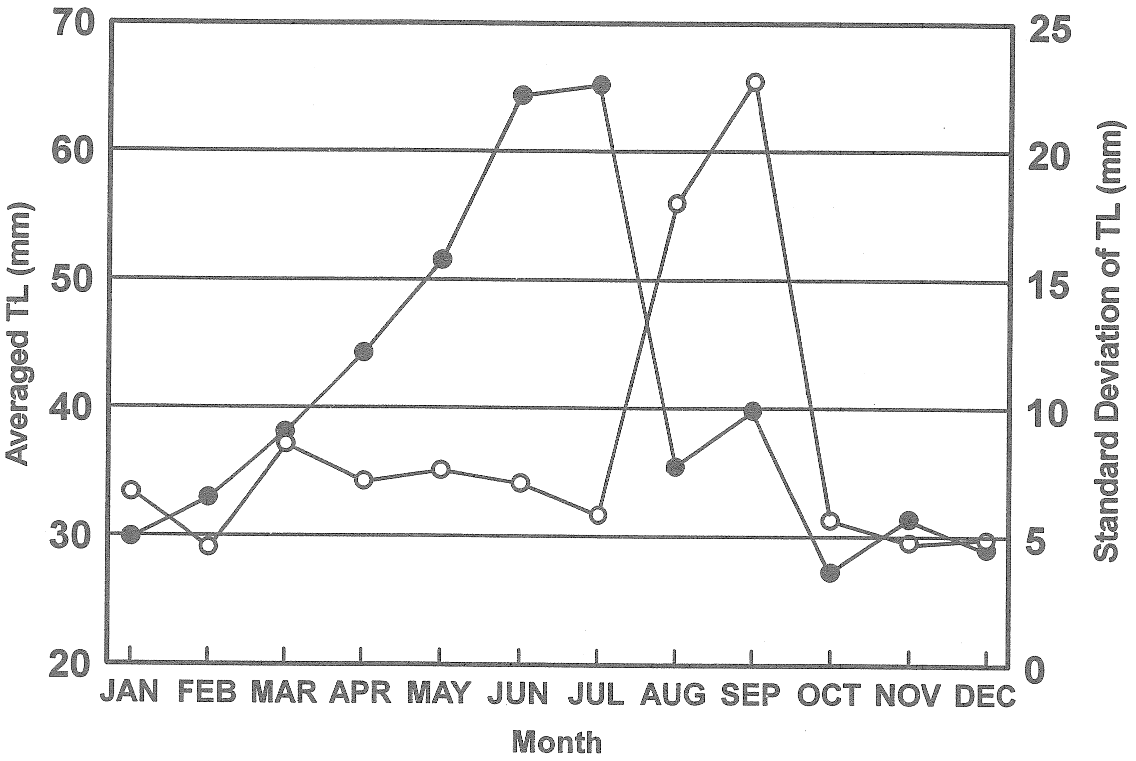

Fig. 1 Fluctuation of the statistics of monthly arranged TL measurement. closed circle: average; open circle: standard deviation.

Table 1. Appearance duration of populations yearly discriminated, the statistics in the total length (TL) and the allometric parameter

Originated Year	Captured Duration		TL (mm)			allometry parameter[+]
	Initial date	Final date	Minimum	Maximum	Median	*a*
79	31 March,1980	29 July,1980	35	85	54	3.112
80	19 February,1981	28 September,1981	26	81	60	3.209
81	13 September,1981	6 August,1982	16	68	28	3.152
82	15 December,1982	27 July,1983	27	76	58	3.025
83	23 August,1983	15 June,1984	20	75	32	3.345
84	24 October,1984	22 June,1985	21	72	31	3.246
85	9 October,1985	18 June,1986	17	75	50	3.119
86	4 September,1986	26 June,1987	20	61	30	3.180
87[++]	24 August,1987	24 August,1987	20	30	25	—
88	27 September,1988	5 August,1989	20	69	47	3.289
89	28 November,1989	7 September, 1990	27	95	55	3.016

[+] log (BW) = $a\log(TL) + b$. An analysis of covariance revealed the inconstancy in a ($p<0.001$).
[++] Data from January to August 1988 were missing.

Table 2. Results of analysis of variance (F_o) for the statistics in TL and BW measurements and the condition factor (K value) inspecting the homogeneity among populations

	TL	BW	K	DF1+	DF2+
January++	8.519*	—	—	1	12
February	6.368*	3.673	10.846**	3	6
March	3.774**	3.484**	2.025	9	33
April	8.172**	10.265**	14.485**	7	291
May	8.718**	6.440**	13.576**	8	323
June	8.057**	12.410**	16.842**	9	363
July	9.464**	9.225**	3.728**	5	116
August	22.666**	8.251	9.955*	3	3
September	58.292**	14.178**	3.990**	4	84
October	0.389	0.065	3.635**	5	42
November	3.078*	3.377*	1.615	3	112
December	1.235	3.984	4.845*	1	75

+ Degrees of freedom.
++ Specimens sampled in 1982 were missing the BW value but those in 1987 were not.

pending upon the comparison of each populations, and detected the similarity among them ($p = 0.074$). A similar consequence was gained in BW analysis ($p=0.169$). Besides, the comparison among months demonstrated that the monthly deviation in TL was stable ($p=0.445$). Namely, the former indicates that through the experimental duration there was no year when the size composition suffered irregularity, and the latter does that the goby appeared with rather homogeneous TL size every month, respectively. Therefore the population cycles mentioned above may exhibit those of each year classes. In this regard, Dotsu(1959) mentioned the same goby dwelling around intertidal zones of Fukuoka suburban area (33°36′N; 130°24′E) and suggested, through the analysis of the seasonal alteration of TL composition, that several individuals survive more than two years to mature again or initially.[3) Meanwhile, Takai(1992) showed, through the scale analysis of this goby, the parental fish which built spawning nest and nurtured eggs just ahead of our study area belonged to one-year-old cohort.[4) We monitored the growth mode of the individuals that were the potential and/or the substantial spawners and nurturers, and detected the homogeneity in the TL composition. This implies that the whitelimbed goby can be categorized as an annual.

Maturation

Sexually matured individuals mingled from April to July (Table 3). We collected 123 males and 116 females. The median in TL for male was 57mm, and the minimum and the maximum were 39 and 70mm, respectively. Those for female were 58, 39 and 75mm, respectively. Between both sex, TL and BW measurements ranged similarly ($p=0.479$ for TL and $p=0.224$ for BW) but the K value of female was larger than that of male ($p=0.009$). Matured group has larger TL and BW than the indistinct one which coincided with matured ($p<0.001$ for both TL and BW) but the K value does not differ between them ($p = 0.722$). Takai(1992) evidenced the morphometric analysis of female parent that settled in spawning rooms from mid July to early August.[4) These female group shows larger TL and BW than the female individuals we sampled ($p<0.001$ for both TL and BW), and the K value is smaller ($p=0.005$).

The appearance period of adults has the

accordance to Dotsu(1959) who showed that the spawning mainly occurred from May to June.[3] The female represent to appear prior to the male (1984, 1987 and 1990), and in 1990 female had larger body sizes than the indistinct individuals ($p = 0.038$). In the six months when male and female coexisted, we seldom observed the distinction in physique except for the distinction in the K value in May 1989 (female > male; $p = 0.049$) and TL in June 1989 (male > female; $p = 0.009$). Also, the comparison of TL, BW and the K value between the indistinct and matured does not discriminate the characteristics in body size and allometric condition clearly. These indicate that although the sexual maturation correlates to somatic growth to some extent, it is dependently conditioned by more integrated situations in individuals. More detailed information on maturation could be obtained through the inquiry in the continuous change in several statistics on body size we measured. Among the facts we gained, a remarkable succession of the size composition containing both the indistinct and matured groups can be shown in the data from March to August 1989. On the sequences of F-tests, we delineate the monthly process and research the maturation dynamics as below (Tables 3,4).

Table 3. Monthly arrangement in averaged TL (mm) of several year class populations

	Originated year											
	1983			1986			1988			1989		
Month	I^{+}	M^{+}	F^{+}	I	M	F	I	M	F	I	M	F
August	25.0^{++}											
September	20.0^{++}			23.6^{++}			24.0	–	–			
October	29.0^{++}			26.2^{++}			29.3	–	–			
November	31.3^{++}			27.8^{++}			32.0	–	–	34.0	–	–
December	29.5^{++}			28.0^{++}								
January				40.0	–	–						
February	32.0	–	–	33.0	–	–						
March	31.0	–	–	31.2	–	–	53.5	–	–	46.8		
April	35.8	–	–	44.0	–	–	43.7	46.5	46.6	47.8	–	–
May	50.0	–	–	51.1	–	44.0	49.3	57.9	55.5	52.4	–	62.0
June	69.8	–	72.0	–	57.8	56.0	–	62.8	60.0	57.5	62.9	59.4
July							63.4	61.5	59.9	58.8	–	–
August							50.0	–	–			
September							68.1	–	–			

$^{+}$ I: indistinct; M: male; F: female.
$^{++}$ Sex is not identified.

In March 1989 the indistinct group occurred only. In April matured group which has larger TL, BW and the K value than the indistinct one occurred, but there was no difference between two sex in these parameters. Those parameters of the indistinct group reduced from those of the previous month. In May the averaged TL of three groups increased, but the indistinct group was still smaller in TL and BW. The K value was larger in female than in male. In June the indistinct group faded out of samples. The averaged TL and BW of both sex increased but male group was larger in TL than female one. In July an indistinct individual with larger BW than matured ones occurred. Averaged BW of female and the K value of both sexes increased. Between two sex

Table 4. Monthly changes in averaged BW (g) and the *K* value concerning the 1988 year class population

	BW			*K*		
Month	I+	M+	F+	I	M	F
March	13.5	—	—	8.48	—	—
April	6.5	8.5	8.8	7.25	8.25	8.50
May	10.6	16.5	15.6	8.31	8.43	8.89
June	—	21.3	19.1	—	8.47	8.76
July	26.2	22.6	22.4	10.22	9.73	10.40
August	14.0	—	—	11.20	—	—

+ I: indistinct; M: male; F: female.

there was no difference in the parameters. In August there occurred only an indistinct individual whose TL and BW reduced.

The monthly alteration in estimated parameters indicates that the 1988 year class continued somatic growth and had increment in the *K* value during the spawning season irrespective of gonad development or sex. Also, there was no sexual differentiation in physique estimates but for the *K* value (female > male). This can be verified by the two-way layout analysis (month × sex).[2] Nevertheless, the comparison between spawner female parents introduced in Takai(1992) and those which were sampled in May and June when there appeared the largest individuals still suggests the similar relationship on size ranges and the allometric condition mentioned above. Dotsu(1959) and Takai(1992) suggested that male parents be not smaller in TL than female one;[3,4] therefore, male group we sampled can be smaller than nurturing male. Moreover, if the less estimate in the *K* value of the spawner female was caused by their behavioral feature of having done with feeding during the nurturing period, the result that 71.9 % of females we sampled had any stomach contents such as copepods and amphipods shows the contradistinctive situation against it(own observation). Therefore, we can conclusively speculate that the adult we observed consists mainly of the population surviving the preliminary term prior to the nurturing period. In addition, some females were possibly involved in spawning behavior, because Dotsu(1959) reported that relatively smaller females were pairing with males in the termination of the spawning period.[3] If this was the case, the continuous somatic growth which eventually balanced the indistinct group to matured one operates such that almost all the individuals in this period were totally developing to achieve enough size to couple within this season.

Here we drew the relationship between somatic growth and sexual maturation, but as it was deduced from only the data on one year out of the 11 years observation duration, and it does not endorse the statistical rigor, admitting there may be another occasion. In order to verify the reproductive process of this species, more detailed information must be accumulated and we are now coping with it.

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百済部川河口域に棲息するアシシロハゼ（*Acanthogobius lactipes*）の成長と成熟

滝澤　敬・丸田祐司・井川雅樹・中村正男・中本孝幸

アシシロハゼ（*Acanthogobius lactipes*）を百済部川河口域で1980年から1990年まで採集し，その成長過程と成熟状況を調べた。体長組成の月変化から，本種の加入群は８・９月に出現して翌年の同期まで成長すること，体長の個体差が各月とも小さいことがわかった。また生殖腺の発達した個体は４－７月に出現したが，これらの体軀サイズは雌雄とも営巣中の個体よりも小さかった。これらのことは，本水域に棲息するアシシロハゼは単一年級群から成り，成熟個体が営巣予備軍であることを示唆している。