Age and Growth of White Croaker, *Pennahia argentata*, in Ariake Sound, Japan

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Age and growth of the white croaker *Pennahia argentata* distributed in Ariake Sound were estimated from right sagittal otoliths of 381 specimens. Seasonal examination of the outer margins of otoliths showed that the opaque zone was formed once a year with the peak in May - June, coinciding with spawning season. The relationship between otolith radius and total length showed a significant difference between males and females. The von Bertalanffy growth equations were established as follows: males, L_t=294 [1-exp {-0.360 (t +1.21)}] ; females, L_t=312 [1-exp {-0.384 (t +0.873)}], where L_t is total length in mm and t is age in years. The maximum age of the collected specimen was 6 years for both sexes. Males and females showed similar growth at age 1, and after age 2, females grow larger than males. The growth equations between males and females differed significantly.

Key Words: 年齢と成長 Age and Growth, シログチ *Pennahia argentata*, 有明海 Ariake Sound, 耳石 Otolith

Ariake Sound is the largest bay in Kyusyu, Japan, and is famous for its high biological production.[1] Isahaya Bay, a part of Ariake Sound, was shut for reclamation in 1997. After the reclamation, there have been many problems in Ariake Sound, such as damage of seaweed farming due to red tide,[2] and great decrease in catches of clams (ex. *Tapes philippinarum, Atrina pinnata*) and fish (ex. *Pennahia argentata, Nibea albiflora, Lateolabrax japonicus*).[3] These problems suggest that the environmental degradation due to Isahaya Bay reclamation resulted in the great changes of the life histories of many species in Ariake Sound. It is essential to investigate the condition of those species occurring in Ariake Sound after Isahaya Bay reclamation.

White croaker, *Pennahia argentata,* is an important commercial bottom fish in Japan, and is one of the dominant species in Ariake Sound. The traits of the life history of *P. argentata* were studied on the reproduction in the East China Sea,[4] and on the age and growth in the East China Sea and the Yellow Sea[5] using scale for age determination. There have not been studies on the life history of *P. argentata* in Ariake Sound, so we cannot compare the life history of *P. argentata* before Isahaya reclamation with that afterwards. However, it is important to elucidate the present traits of life history of dominant species, to understand the fishing condition of fishery resources in Ariake Sound today. In the present study, we clarified age and growth of *P. argentata* in Ariake Sound using otoliths.

materials and methods

Specimens were collected from April 2001 to November 2002 with commercial bottom trawling and set net off Shimabara, central waters of Ariake Sound (Fig.1). The size distribution and the number of speci-

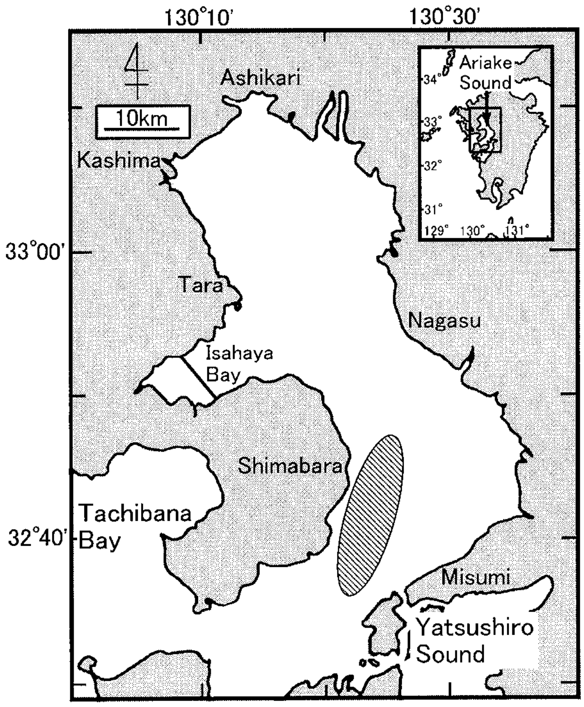

Fig. 1 Fishing ground of *Pennahia argentata* examined in the present study.

Table 1. Size distribution of specimens

Total length (mm)	Number of specimens		
	Males	Females	Total
51-100	1	2	3
101-150	45	48	93
151-200	22	31	53
201-250	70	100	170
251-300	25	36	61
301-350		1	1
Total	163	218	381

mens are shown in Table 1. Fresh specimens were measured for total length in mm, and their sagittal otoliths collected.

Otoliths of white croaker are large in size, and oval in shape. They were embedded in orthodontic acrylic resin, and cut vertically into a 0.5 mm thick section with an electric saw, Maruto Cutter MC - 501. The sections were observed, dipped in xylene under Nikon Profile Projection, and the sizes were measured to the nearest 0.05 mm. The otolith radius (R) and ring radii (r_n) were measured from the focus to the outer margin of the otolith, and to the outer margin of the opaque zones, respectively (Fig.2). The right and left otoliths were symmetrical, and right ones were used for the analysis unless right ones were broken or lost.

The time of annulus formation was determined by monthly changes in percentage occurrence of otoliths with opaque or translucent margins. The von Bertalanffy growth equation was estimated using the Solver on MS - Excel, which implements quasi - Newton method for nonlinear least squares parameter estimation.[6,7)]

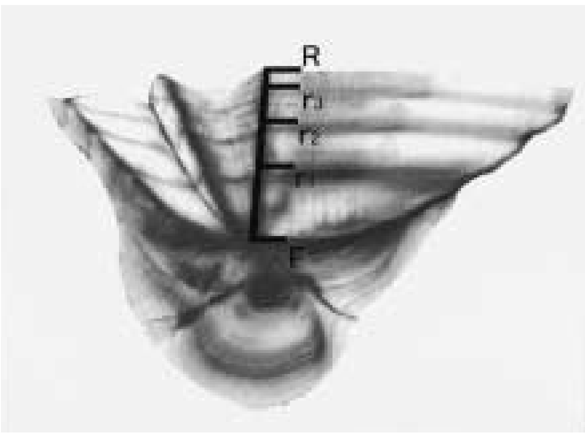

Fig. 2 Otolith section of *Pennahia argentata*, female, 230 mm in total length. R, otolith radius (2.65 mm); r_1 - r_3, annual ring radii 1 - 3; F, focus.

results

Monthly changes in percentage occurrence of the otoliths with a opaque margin are shown in Fig.3. The formation of the translucent zone began from August - September and ended in March. An opaque zone appeared in April - August with a peak in May - June. The peak of the opaque zone formation coincides with the spawning season of *P. argentata* in Ariake Sound (T. Higuchi, unpubl. data, 2002). These data indicate that the opaque zone is formed once a year and it can be used as an annual mark (annulus) for age determination.

The relationships between otolith radius and total length are shown in Fig.4. The equations are as follows,

males : $TL = 147R^{0.575}$ ($R^2 = 0.952$),
females: $TL = 148R^{0.615}$ ($R^2 = 0.943$)

where TL is total length in mm and R is otolith radius in mm. Analysis of covariance showed a significant difference between males and females (p <0.01), and these

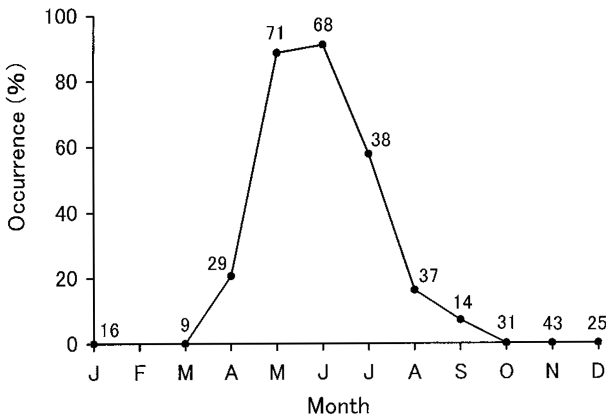

Fig. 3 Monthly changes in percentage occurrence of otolith with opaque margin in *Pennahia argentata*. Numbers represent total number of otoliths each month.

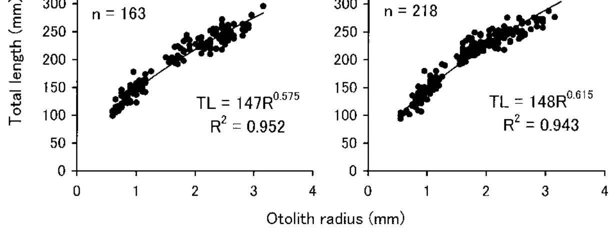

Fig. 4 Relationships between otolith radius and total length for males and females *Pennahia argentata*.

Table 2. Mean otolith ring radii (±SD) at estimated age for males and females *Pennahia argentata*

Males							
Estimated age (year)	Number of individuals	Mean otolith ring radii (mm)					
		r_1	r_2	r_3	r_4	r_5	r_6
1	14	1.08±0.10					
2	31	1.23±0.08	1.78±0.15				
3	38	1.16±0.10	1.76±0.09	2.20±0.09			
4	19	1.15±0.12	1.71±0.10	2.14±0.10	2.50±0.13		
5	3	0.98±0.14	1.48±0.12	1.98±0.06	2.38±0.06	2.70±0.07	
6	1	1.25	1.65	2.10	2.40	2.75	2.95
Mean±SD		1.17±0.11	1.75±0.13	2.17±0.11	2.48±0.12	2.71±0.06	2.95
Back calculated total length (mm)		161	203	229	248	261	274

Females							
Estimated age (year)	Number of individuals	Mean otolith ring radii (mm)					
		r_1	r_2	r_3	r_4	r_5	r_6
1	29	1.12±0.11					
2	64	1.13±0.14	1.71±0.11				
3	32	1.17±0.09	1.78±0.10	2.21±0.10			
4	21	1.12±0.12	1.76±0.11	2.21±0.12	2.57±0.13		
5	4	1.18±0.13	1.71±0.07	2.19±0.05	2.56±0.08	2.89±0.07	
6	1	1.15	1.65	2.00	2.30	2.65	2.95
Mean±SD		1.14±0.12	1.74±0.11	2.21±0.11	2.56±0.14	2.84±0.12	2.95
Back calculated total length (mm)		160	208	241	264	281	288

data were treated separately for sexes. The mean radius of each otolith ring at each estimated age for males and females are shown in Table 2. Neither Lee's nor reversed Lee's phenomenon was found, and the weighted mean radii of each ring were used for back - calculating the fish length at each age for both sexes.

The von Bertalanffy growth equations derived from the back - calculated length were as follows,

males : $L_t = 294\ [1\text{-exp}\ \{-0.360\ (t + 1.21)\}]$

females: $L_t = 312\ [1\text{-exp}\ \{-0.384\ (t + 0.873)\}]$

where t is age in years and L_t is total length in mm at age t (Fig.5). The maximum age of the collected specimen was 6 year - old for both sexes. Males and females show a similar growth until age 1, and after age 2, females become larger than males. The comparison of von Bertalanffy equation according to Yamaguchi *et al.*[8] showed a significant difference in growth between sexes (p<0.01, df=7, 4; F=19.08).

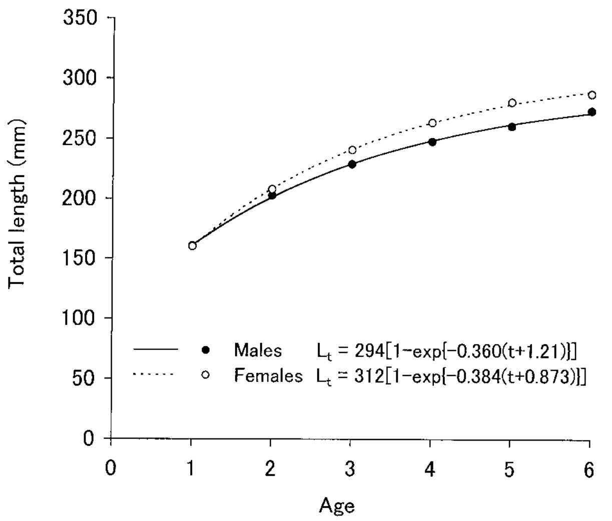

Fig. 5 The von Bertalanffy growth curves for males and females *Pennahia argentata*. The closed and opened circles are the back - calculated total length at estimated age for males and females, respectively.

discussion

In the present study, otoliths were used for aging *P. argentata*. Rings of otoliths were clear and easy to read, and all otoliths examined were readable. Kojima[5] suggested that the scales of *P. argentata* in the South China Sea sometimes have an end ring and are difficult to read. Otolith is more suitable than scale for age determination of this fish.

The maximum total lengths observed were 296 mm in males and 315 mm in females. Difference in growth equation between males and females was significant. Females grew larger than males after age 2.

P. argentata in Ariake Sound grew smaller than the East China Sea population[5] and the Yellow Sea

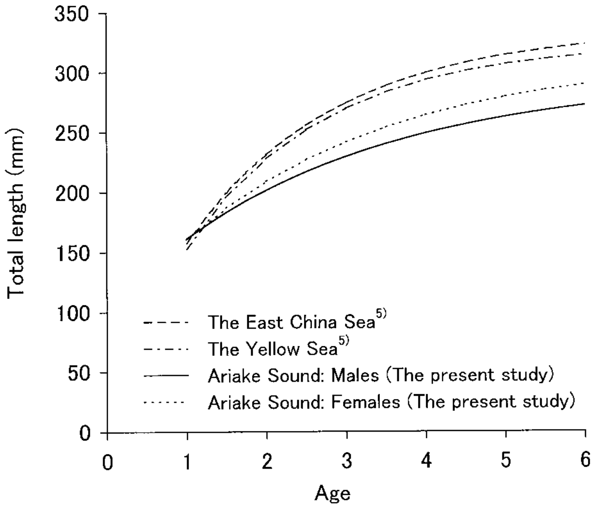

Fig. 6 The von Bertalanffy growth curves of *Pennahia argentata* in each area.

population[5] after age 2, although the maximum observed age is 6 years for all populations (Fig.6).

For effective stock management in Ariake Sound, it is necessary to clarify the population structure. There are methods to utilize mtDNA, parasites, and life history traits (ex. growth pattern), and so on, to distinguish the populations. Kojima[9] suggested that the East China Sea population and the Yellow Sea population were separated with number of soft rays of pectoral fin. The present study suggested that the growth pattern of Ariake Sound population differed greatly from the East China Sea population[5] and from the Yellow Sea population,[5] and therefore, at least 3 separated populations exist around the northeastern Kyushu district. According to Kitamori *et al.*,[10] *P. argentata* in Seto Inland Sea has been regarded as 3 populations.

However, it may not be reasonable to compare the growth pattern of Ariake Sound population with that of other localities obtained in old time. It is suggested that the growth increment of red sea bream *Pagrus majar* changed each year, due to the variation in water temperature.[11] The growth pattern of the populations of the East China Sea and the Yellow Sea might also have changed. To recognize exactly the population structure around the northeastern Kyushu district including Ariake Sound, it is necessary to clarify the latest growth pattern of *P. argentata* inhabiting around northeastern Kyushu district with consideration of small geographic scale.

acknowledgements

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＊ In Japanese.
＊＊ In Japanese with English summary.

有明海産シログチの年齢と成長

樋口　貴彦，山口　敦子，田北　　徹

有明海産シログチの年齢と成長を耳石を用いて明らかにした。耳石の輪紋は６月前後の産卵期に形成されており，満年齢を示すことがわかった。耳石径と全長との関係には雌雄間で有意差が見られた。L_tを全長（mm），t を年齢とした時のvon Bertalanffyの成長式は，雄：$L_t = 294\,[1\text{-}\exp\{-0.360\,(t+1.21)\}]$，雌：$L_t = 312\,[1\text{-}\exp\{-0.384\,(t+0.873)\}]$ で示された。標本の最高年齢は雌雄とも６歳であった。２歳以降雌は雄よりも大きかった。成長式には雌雄間で有意差が見られた。