Age and Growth of the Two Japanese Scombropids, *Scombrops boops* and *S. gilberti*

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Abstract Age and growth of the two Japanese representatives of the Scombropidae, *Scombrops boops* and *S. gilberti*, were examined by means of otolith reading. Examination of the marginal growth of the otolith showed the availability as annual rings of the outer margins of hyaline zones formed in the period from November to January. Growth of the two species was expressed by the von Bertalanffy's equation based on the estimation of standard lengths at the time of annual ring formation. As a result, it was revealed that *S. gilberti* is larger than *S. boops* in standard length up to two years of age, and then *S. boops* becomes larger than *S. gilberti*. The estimated maximum standard length is 880 mm for *S. boops* and 514 mm for *S. gilberti*. Growth of *S. boops* estimated from length composition agreed well with that based on the otolith reading. Growth in terms of body weight was also examined.

The family Scombropidae is represented in Japanese waters by two allied species, *Scombrops boops* (Houttuyn) and *S. gilberti* (Jordan et Snyder). Though the two species show close morphological similarities, and hence have been regarded as synonymous by some workers (Jordan and Hubbs, 1925; Tanaka, 1931; Matsubara, 1955; etc.), their specific distinctness has been accepted by most recent authors, on the basis of the difference in squamation, coloration, and other morphological characters (Hiyama and Yasuda, 1971; Yasuda et al., 1971). However, comparisons of the two species from an ecological standpoint are scarce: only those by Yasuda and Iehisa (1939) and Yasuda (1939).

In this study the growth of *S. boops* and *S. gilberti* was examined, using the otolith as an age character, in order to provide an ecological basis for the comparison of these two closely related species.

Materials and methods

Examination of the otolith was made in 380 specimens of *S. boops*, 59～709 mm in standard length, and 117 specimens of *S. gilberti*, 60～498 mm, collected from Sagami Bay, the Izu Islands, Torishima Island and off Choshi, Japan, from November, 1970 to January, 1976, by means of set nets, hand lines, trawls and beach seines. Samples of *S. boops* used for the determination of growth by length composition include 840 specimens from other lots, ranging from 59 to 224 mm in standard length, caught by set nets in Sagami Bay, from July, 1968 to December, 1973.

Identification of specimens to species was based chiefly on the counts for pored lateral-line scales, following Yasuda et al. (1971). Namely, specimens with 50～56 scales were identified as *S. boops* and those with 59～69 scales as *S. gilberti*. Specimens with intermediate scale counts, 57 (1 specimen) or 58 (2 specimens), were identified based on the counts for transverse scales and gill-rakers, body color, shapes of the premaxillary, skull and teeth, again following Yasuda et al. (1971).

Otoliths were removed from the head, cleaned, and observed under a binocular microscope with reflected light. All measurements were taken with a slide calliper at 1/20 mm, along the long axis of the outer surface from the nucleus toward the posterior tip (Fig. 1).

Results

1. Relationship between the otolith radius and standard length. The relative growth patterns between the otolith radius and standard length in the two species were represented by curves (Fig. 2) to which the following quadratic equations were adaptable.

S. boops: $L=34.07+16.05R+3.08R^2$

S. gilberti: $L=-10.36+36.74R+1.02R^2$

(R=otolith radius in mm; L=standard length in mm)

2. Growth of otolith margin. Observations of otolith margins showed the formation of their opaque margins mainly in the period from January to July and that of hyaline zones from July to December. However, seasonal changes in marginal increment of the otolith [$(R-r_n)/(r_n-r_{n-1})$; where r_n is the distance in mm from the nucleus to the outer edge of the n-th, or outermost, complete hyaline zone] were considered necessary to examine, because these two zones were difficult to distinguish in some, mostly large, specimens in both species.

Fig. 3 shows the seasonal changes in marginal growth of the otolith in the two species. In *S. boops*, low increments of the hyaline zones occurred in December and January and high increments from September to January. In *S. gilberti*, low increments were seen in December and January, and high increments from October to December. In both species, the outer margin of the hyaline zones was therefore considered to be formed in the period from November to January, and utilizable for age determination.

3. Annulus radius. Mean for each annulus radius (r_n: distance between the nucleus and the outer margin of the n-th hyaline zone) showed no significant difference at 5% level between age groups in $0^+\sim5^+$ specimens of *S. boops* and in $0^+\sim6^+$ specimens of *S. gilberti* (Table 1).

4. Standard length and growth equation. The constancy of the annulus radius indicated in 3) above made it possible to calculate mean standard lengths at the time of annual ring formation ($L_1\sim L_n$) by the above-mentioned quadratic equations for all age groups. They are as follows (length in mm):

S. boops: $L_1=147$, $L_2=230$, $L_3=305$, $L_4=371$, $L_5=428$, $L_6=480$, $L_7=518$, $L_8=552$, $L_9=577$, $L_{10}=606$

S. gilberti: $L_1=182$, $L_2=252$, $L_3=301$, $L_4=342$, $L_5=373$, $L_6=403$, $L_7=426$, $L_8=445$

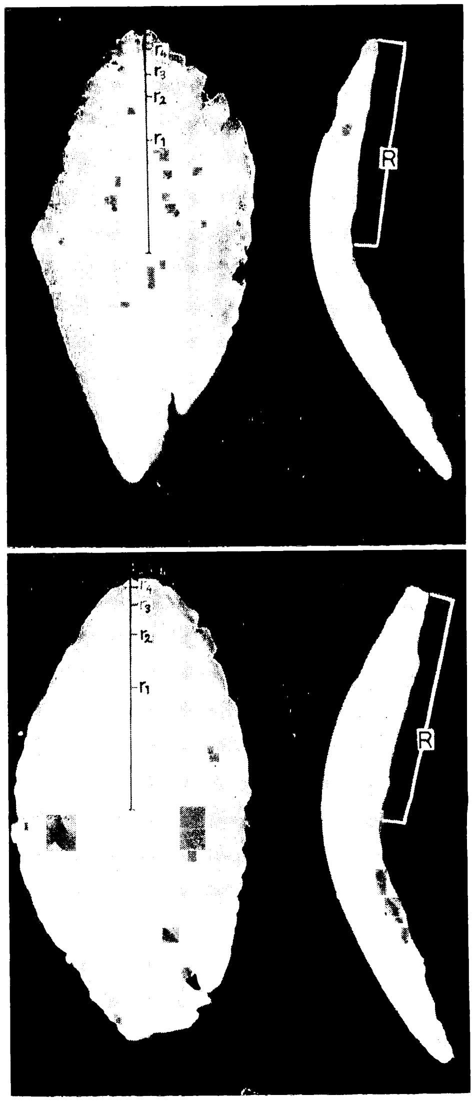

Fig. 1. Outer surface of right otolith and cross section along the long axis of left otolith of *S. boops* (top) and *S. gilberti* (bottom). *R*, otolith radius; $r_{1\sim4}$, annual radii $1\sim4$.

The relationship between L_n and L_{n+1} (in *S. boops*, $n\leqq5$; in *S. gilberti*, $n\leqq7$) was obtained on the basis of the above values. In each species, the L_n-L_{n+1} coordinates were almost completely on a straight line (Fig. 4). Using the least square method, the following equations were obtained for the straight lines (L in mm):

S. boops: $L_{n+1}=100.3+0.886L_n$

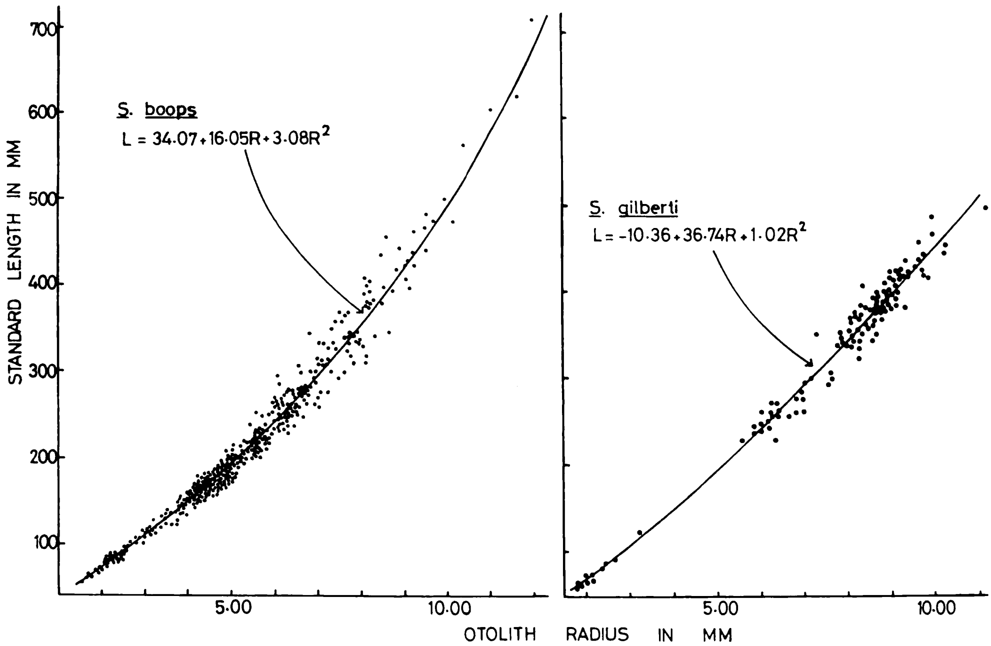

Fig. 2. Relationship between otolith radius (R) and standard length (L) in *S. boops* and *S. gilbert*.

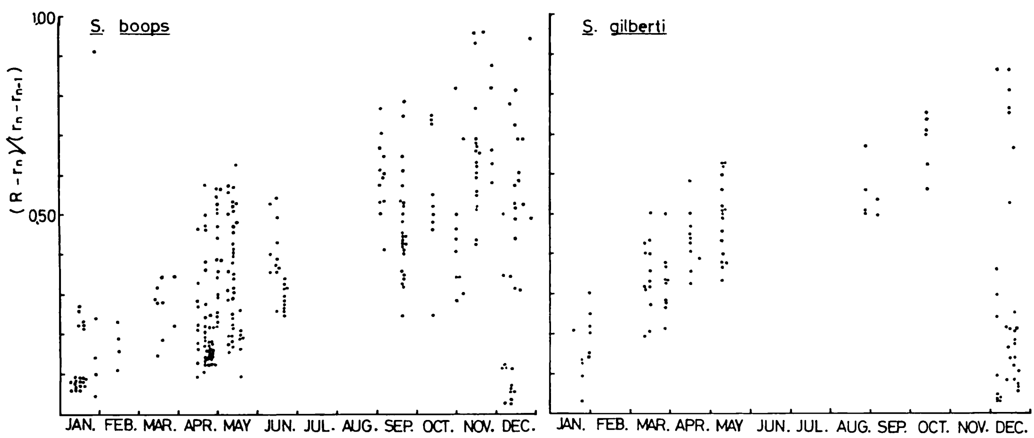

Fig. 3. Seasonal change in the marginal increment of otolith $[(R-r_n)/(r_n-r_{n-1})]$ in *S. boops* and *S. gilberti*. R, otolith radius; r_n, distance between the nucleus and the outer edge of the n-th (outermost) comple hyaline zone.

S. gilberti: $L_{n+1}=102.7+0.800L_n$

From the above relationships between L_n and L_{n+1}, maximum standard length (L_{max}) and von Bertalanffy's growth equations (L_t; Fig. 5) were computed as follows:

S. boops: $L_{max}=880$ mm,

$$L_t=880(1-e^{-0.121(t+0.513)})$$

S. gilberti: $L_{max}=514$ mm,

$$L_t=514(1-e^{-0.223(t+0.929)})$$

5. Body weight. The relationship between standard length and body weight in *S. boops* (Fig. 6) was represented by the following two lines:

$$\log W=-5.507+3.422 \log L \quad (L \leqq 170 \text{ mm})$$

$$\log W=-4.532+2.975 \log L \quad (L>170 \text{ mm})$$

(W=body weight in g, L=standard length in mm)

Body weights in g of *S. boops* at the time

Table 1. Mean annual radii of *S. boops* and *S. gilberti*.

Age group	Number of specimens	Means of annulus radii (mm)											
		r_1	r_2	r_3	r_4	r_5	r_6	r_7	r_8	r_9	r_{10}	r_{11}	r_{12}
S. boops													
1	147	4.00											
2	72	4.00	5.73										
3	28	3.87	5.75	7.10									
4	17	4.02	5.97	7.15	8.17								
5	8	4.00	5.90	7.11	8.13	8.97							
6	2	4.07	5.75	7.08	8.20	9.00	9.79						
7	1	4.50	6.25	7.38	8.40	9.25	9.80	10.30					
8	1	4.70	6.50	7.65	8.60	9.35	9.90	10.40	10.80				
9	0	—	—	—	—	—	—	—	—	—			
10	1	4.00	5.88	7.25	8.15	8.85	9.55	10.15	10.65	11.05	11.40		
11	0	—	—	—	—	—	—	—	—	—	—	—	
12	1	4.05	5.60	6.80	7.85	8.85	9.45	9.95	10.40	10.80	11.15	11.45	11.75
Mean of annulus radii		3.99	5.79	7.13	8.17	9.00	9.71	10.20	10.62	10.93	11.27	11.45	11.75
Range of annulus radii		3.15 ~ 5.05	5.00 ~ 6.80	6.55 ~ 7.75	7.70 ~ 8.98	8.80 ~ 9.35	9.45 ~ 9.90	9.95 ~ 10.40	10.40 ~ 10.80	10.80 ~ 11.05	11.15 ~ 11.40		
Total number of specimens		278	131	59	31	14	6	4	3	2	2	1	1
S. gilberti													
1	4	4.75											
2	16	4.61	6.02										
3	10	4.53	6.07	7.07									
4	23	4.58	6.08	7.09	7.89								
5	30	4.67	6.09	7.05	7.81	8.41							
6	13	4.72	6.17	7.13	7.90	8.53	9.01						
7	5	4.71	6.22	7.20	7.92	8.52	9.02	9.43					
8	4	4.67	6.22	7.19	7.92	8.52	8.97	9.36	9.70				
9	0	—	—	—	—	—	—	—	—	—			
10	1	4.40	5.93	7.15	8.05	8.55	9.05	9.53	9.98	10.40	10.83		
Mean of annulus radii		4.64	6.10	7.09	7.87	8.46	9.00	9.41	9.75	10.40	10.83		
Range of annulus radii		4.15 ~ 5.18	5.60 ~ 6.50	6.50 ~ 7.53	7.20 ~ 8.43	7.80 ~ 9.00	8.60 ~ 9.48	8.93 ~ 9.90	9.43 ~ 9.98				
Total number of specimens		106	102	86	76	53	23	10	5	1	1		

of annual ring formation calculated using the above equations were:

$W_1=81$, $W_2=312$, $W_3=722$, $W_4=1294$, $W_5=1979$, $W_6=2784$, $W_7=3492$, $W_8=4220$, $W_9=4814$, $W_{10}=5570$

The length-weight relationship in *S. gilberti* (Fig. 6) was represented by the following two lines:

$\log W=-5.001+3.177 \log L \quad (L \leqq 113 \text{ mm})$

$\log W=-5.925+3.510 \log L \quad (L \geqq 226 \text{ mm})$

Unexpectedly, the two lines intersect at $L=$ 595 mm. This is most likely impossible in natural populations, but, in the absence of specimens of intermediate sizes and with the small number of small-sized specimens, complete growth patterns were not obtainable for this species.

Body weights at the time of ring formation in *S. gilberti* were therefore calculated based solely on the equation for larger specimens. The calculated values in *g* were as follows:

$W_1=102$, $W_2=319$, $W_3=595$, $W_4=932$, $W_5=1264$, $W_6=1658$, $W_7=2015$, $W_8=2348$

6. Growth of *S. boops* based on length composition. Fig. 7 shows seasonal changes in the length composition of immature *S. boops*

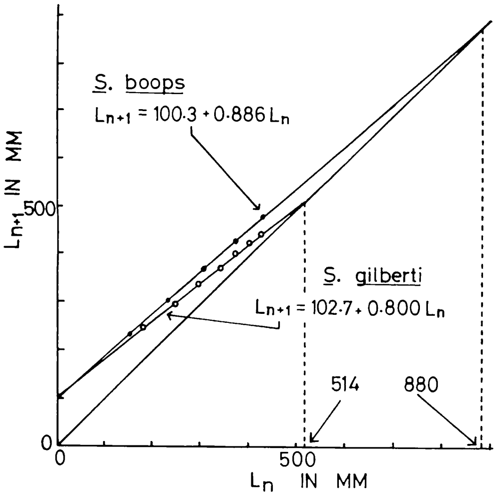

Fig. 4. Walford's growth transformation of standard length for *S. boops* (solid circles) and *S. gilberti* (open circles).

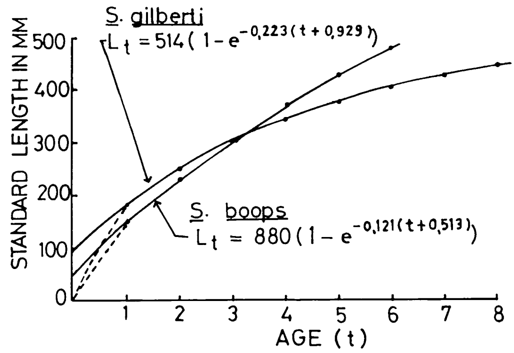

Fig. 5. Von Bertalanffy's growth equations for *S. boops* and *S. gilberti*.

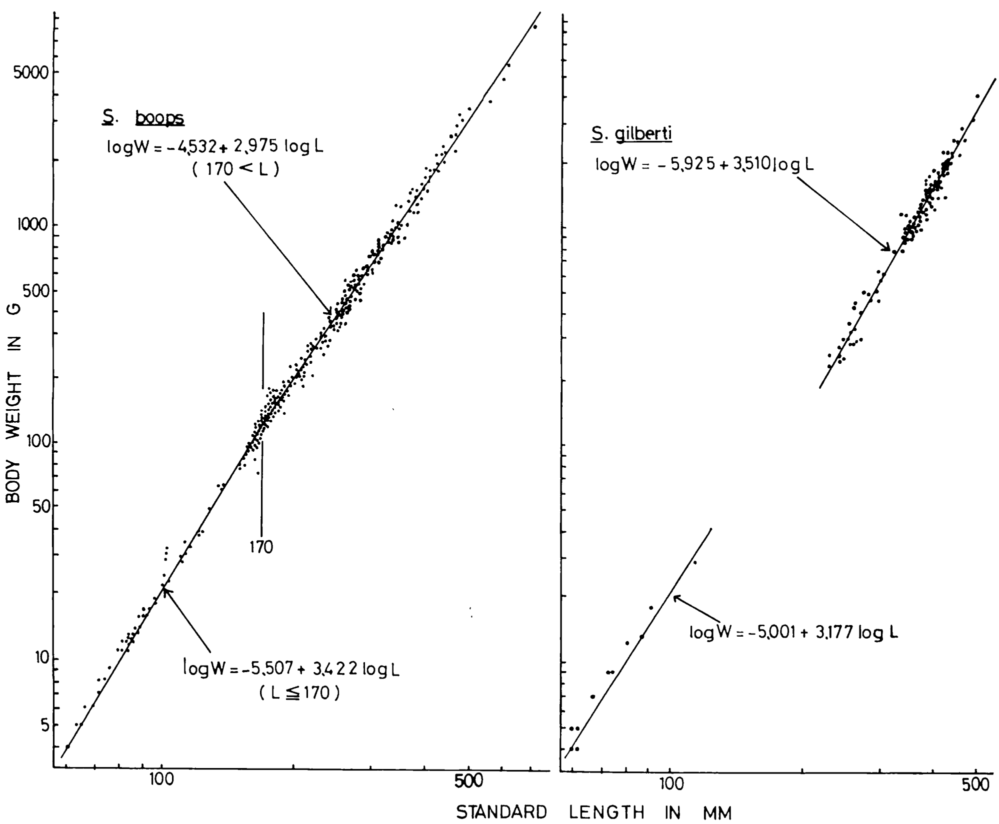

Fig. 6. Relationship between standard length (L) and body weight (W) in *S. boops* and *S. gilberti*.

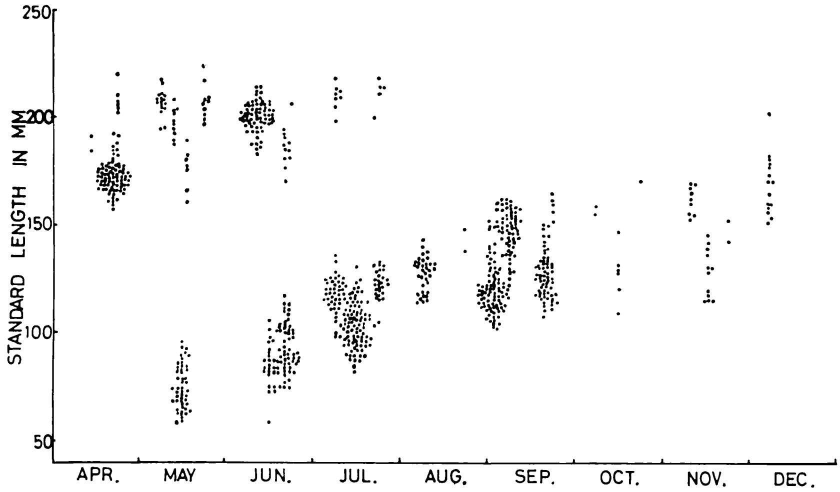

Fig. 7. Seasonal change in the length composition of immature *S. boops* caught by set nets.

caught by set nets in Sagami Bay. The standard lengths at the age of one year estimated by length composition (ca. 130~210 mm, mean 150 mm) agree well with those calculated by the mean annulus radius and the relationship between otolith radius and standard length (136~214 mm, mean 147 mm).

Discussion

All of the data on growth obtained in this study show the presence of a pronounced difference in growth patterns between the two closely related scombropids, *S. boops* and *S. gilberti*. In short, *S. boops* is smaller than *S. gilberti* in both standard length and body weight during the first and second years after birth, and becomes larger from the third year and on. The estimated maximum standard length is greater also in *S. boops*. The largest specimen of *S. boops* I have ever observed is 990 mm SL (at the Odawara Fish Market, Kanagawa Pref.), and that of *S. gilberti* is 660 mm SL (at the Inatori Fish Market, Shizuoka Pref.). These sizes are greater than those estimated in this study. This inconsistency seems attributable to the insufficient sample sizes of aged individuals of both species.

The well-established difference in growth patterns furnishes strong support to the view that *S. boops* and *S. gilberti* are genetically segregated and hence constitute distinct species, though they are very close in morphological features.

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ムツおよびクロムツの年令と成長

望月賢二

耳石を年令形質として，ムツ *Scombrops boops* およびクロムツ *S. gilverti* の年令と成長を調査した．両種とも 11 月～1 月に形成される透明帯外縁を年令表示とすることが出来た．これに基づき，年令表示形成時の体長を推定し，定差図を作成し，さらに von Bertalanffy の成長式を適用した．その結果，満 3 才未満ではクロムツのほうが大きいが，満 3 才以上ではムツのほうが大きくなることが示された．推定最大標準体長はムツで 880 mm，クロムツで 514 mm であった．また，体重における成長についても検討した．定置網で漁獲されたムツ未成魚の体長組成による成長は，耳石の結果とよく一致した．

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