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AGE AND GROWTH OF THE RIBBONFISHES *TRICHIURUS* (PERCIFORMES: TRICHIURIDAE) OF TAIWAN[1]

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Wen-Yie Chen and Sin-Che Lee (1982) Age and growth of the ribbonfishes *Trichiurus* (Perciformes: Trichiuridae) of Taiwan. *Bull. Inst. Zool., Academia Sinica.* **21**(1): 9-20. The otoliths of 536 *Trichiurus lepturus* and 711 *T. japonicus* collected from the waters near Hualien, Chengkong, Tungkang and Kaohsiung during April 1976 through November 1977 were examined. Rings on the otoliths of each species believed to be formed once a year in June and April for *Trichiurus lepturus* and *T. japonicus* respectively. The period of ring formation corresponded to the period of their gonad maturation. The largest *T. lepturus* with 672 mm in preanal length obtained from Tungkang has been aged 11^+ years while the largest *T. japonicus* with 873 mm in preanal length from Chengkong has been aged 15^+ years.

The von Bertallanfy' growth equations expressed in lengths (L_t) and Weights (W_t) for *Trichiurus* from SW and E Taiwan are as the following:

Trichiurus lepturus

SW Taiwan $L_t=550(1-e^{-0.289(t+0.76)})$, $W_t=1989(1-e^{-0.289(t+0.76)})^{3.2268}$

E Taiwan $L_t=502(1-e^{-0.271(t+0.22)})$, $W_t=2086(1-e^{-0.271(t+0.22)})^{3.4467}$

T. japonicus

SW Taiwan $L_t=524(1-e^{-0.340(t+0.39)})$, $W_t=1288(1-e^{-0.340(t+0.39)})^{3.7247}$

E Taiwan $L_t=595(1-e^{-0.250(t+0.08)})$, $W_t=1576(1-e^{-0.250(t+0.08)})^{2.5924}$

The time of maximum growth (in weights) has been estimated as 3.44 and 4.36 years for *T. lepturus* of SW Taiwan and E Taiwan and 4.26 and 4.64 years for the *T. japonicus* for SW Taiwan and E Taiwan respectively. The growth curves for these two species vary with different localities (See Figs. 9-10). The growth rate for a species seems to be slower in the northern populations than that of the southern populations. Different environmental conditions, i. e., temperatures and food abundance, may be attributed for the slow growth for the northern populations.

There was a single species of ribbonfish (*Trichiurus lepturus*) recorded in the fisheries yearbook of the Taiwan area[6]. In fact, it includes 2 nominal species, *T. lepturus* and *T. japonicus*, and a further third species *Tentoriceps cristatus* has been reported by Lee *et al.*[3].

Age and growth studies of the ribbonfishes

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of East China Sea and Yellow Sea were carried out by Misu[4] and Hamada[2] and that of Kii Channel by Sakamoto[5]. As yet, no information on the age and growth of Taiwan populations have been investigated.

Age and growth of *Trichiurus lepturus* and *T. japonicus* occuring in the surrounding waters of Taiwan by examining the ear otolith have been carried by us. The growth patterns of the present study has been studied to compare with the investigations of Misu[4] and Hamada[2] from East China Sea and Yellow Sea and Sakamoto[5] from Kii Channel.

MATERIALS AND METHODS

Ribbonfishes were collected monthly from the inshore waters near Hualien, Chengkong, and Kaohsiung, either by longliners or gill nets during April 1976 through November 1977. Fresh specimens were weighed, and measured for their total length (snout tip to tail tip) and preanal length (snout tip to vent). Their sexes were identified instantly by dissection and both ears were removed by forceps and preserved in 70% alcohol. Otoliths were surface grinded with 3 S rubbing stone. The left otolith was placed in a watch-glass with xylol and examined under 6 CT Nikkon profile projector for its length (R) and ring radius (r_n) (Fig. 1). Coefficient of marginal growth of otolith (α) was obtained from the equation,

$$\alpha = R - r_n / r_n - r_{n-1}$$

where r_n and r_{n-1} representing the radii of the ultimate and penultimate rings, respectively.

A total of 536 *Trichiurus lepturus* and 711 *T. japonicus* specimens were examined.

RESULTS

External feature of otolith

The otolith of the ribbonfish (Fig. 1) when viewed from the convex surface is ellipse-shaped, with an anterior notch. The anterior upper edge (f) is narrowly protruded. The rest of dorsal is roundly edged, the ventral edge is slightly arched. The opaque focus (a, or nucleus) is situated slight posterior 1/3 to the midline in the longitudinal sulcus (c) (Fig. 1). The ventral side of focus has surrounded opaque $CaCO_3$ growth rings and translucent, collagenous fiber, resting rings alternated each other.

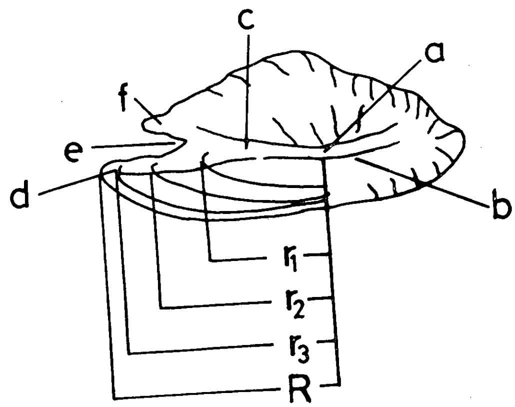

Fig. 1. The diagram of the left otolith, a, focus; b, crista; c, sulcus; d, anterior ventral rostrum; e, exsisur; f, anterior ventral rostrum; R, radius of otolith; r_{1-3}, radii of annual rings 1-3.

A regression analyses of each ring radius vs. otolith radius of I-V ring group *T. lepturus* from Tungkang (Fig. 2) and those of I-III and V ring group *T. japonicus* from Hualien (Fig. 3) appear with highly significant correlation coefficient (r) for each ring group. Therefore, it may confirm that the rings on the otoliths (Fig. 4) are formed regularly.

The time of ring formation

From the coefficient of marginal growth of otolith (α) shown in Figs. 5-6, the lowest level of α in April and June suggested that the period between April and June is time for ring formation in *T. japonicus* and *T. lepturus.* It was noted that only one ring is laid down each year.

Age composition and longevity

The otolith without any ring is designated as 0^+ year old and that with one ring 1^+ year, and so on. Among the samples investigated

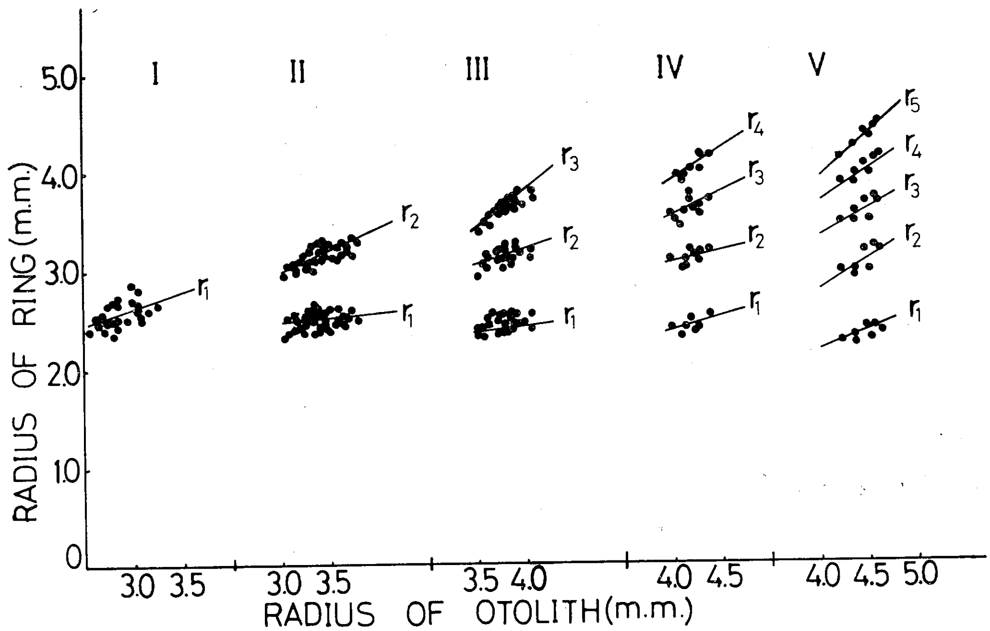

Fig. 2. The relationship between radii (r_i) of rings and radius of otolith (R) of I-V ring group *Trichiurus lepturus*, with highly significant coefficient ($p<0.01$) in each regression line.

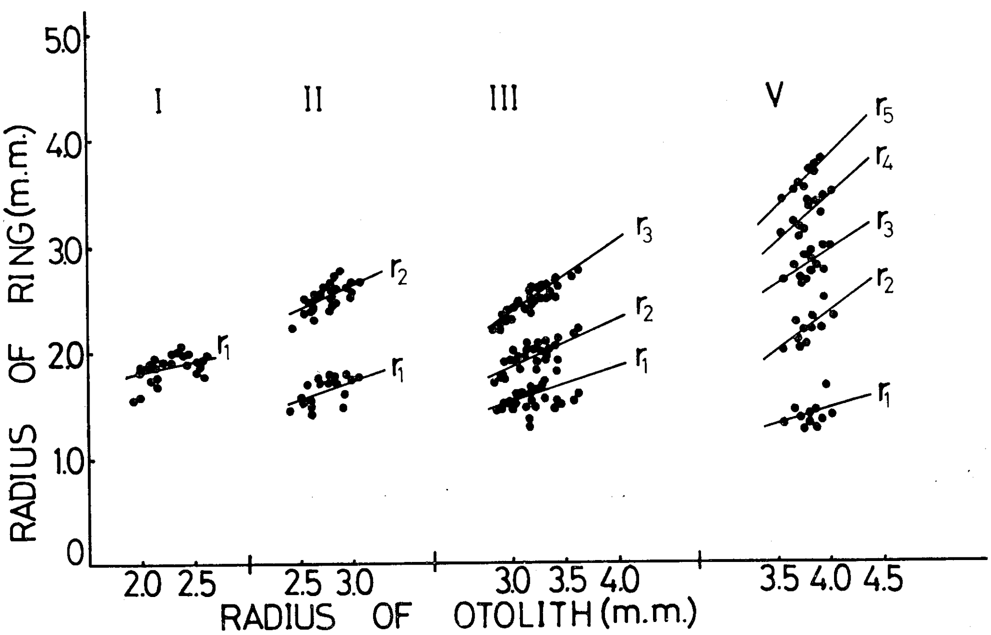

Fig. 3. The relationship between radii of rings (r_i) and radius of otolith (R) of I-III and V ring group *Trichiurus japonicus*, with highly significant coefficients ($p<0.01$) in each regression line.

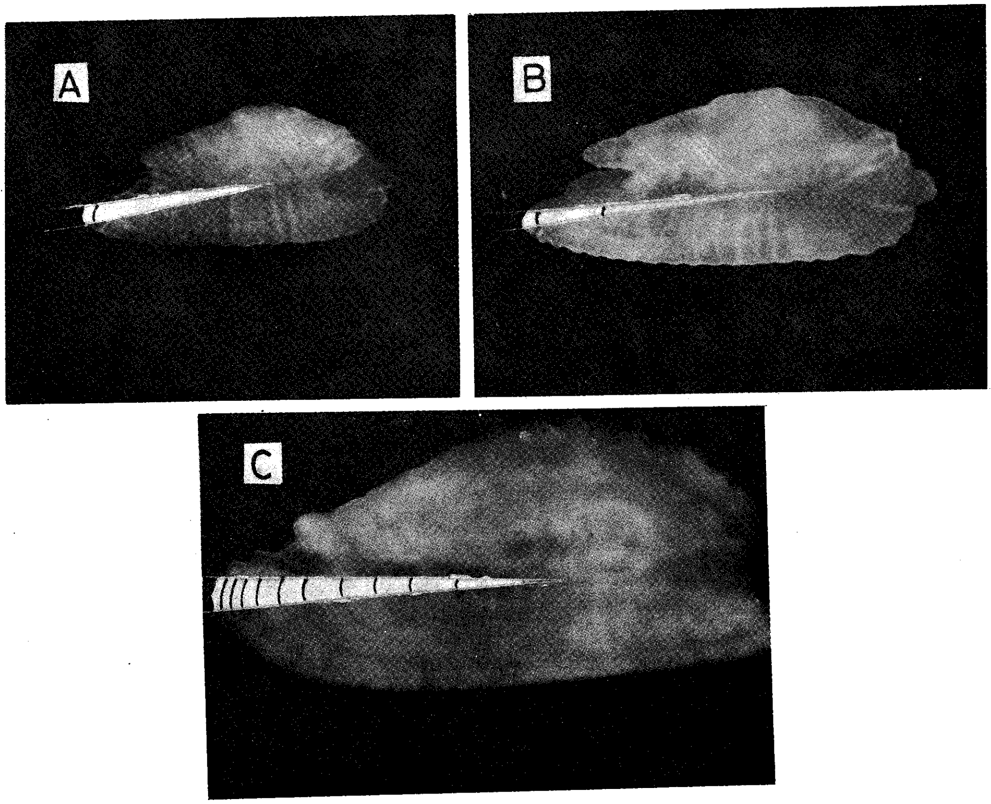

Fig. 4. Photographs of the left otolith of ***Trichiurus lepturus*** showing annual rings. A, 1^+ year (specimen 174 mm in preanal length); B, 2^+ years (specimen 237 mm in preanal length); C, 10^+ years (specimen 620 mm in preanal length).

during the study period, the oldest *T. lepturus* (672 mm preanal length) from Tungkang in October 1976 was 11^+ years old while a *T. japonicus* (873 mm *PL*) from Chengkong in March 1977 was 15^+ years old.

In *T. lepturus*, age groups 1^+ and 2^+ (Fig. 7) were the most abundant, consisting 66% and 69% of the total fish collected from E Taiwan and SW Taiwan, respectively. The oldest fish obtained from SW coast of Taiwan did not exceed 4^+ years. Age groups 1^+ and 2^+ of *T. japonicus* (Fig. 8) were the most abundant in SW Taiwan, consisting 70% of the entire samples while age groups 2^+ and 3^+, consisting 60% of the entire E Taiwan samples.

Readius of otolith and fish length

The covariance analysis showed no significant difference of otolith radius against preanal length (*PL*) between sexes. The following data were combined for both sexes. In order to make the conversion easily between parameters of preanal length (*PL*) and total length (*TL*), the following equations for *T. lepturus* from SW Taiwan $PL=-55.4+0.4564\ TL$ ($r=0.99$) and from E Taiwan $PL=-30.4+0.4134\ TL$ ($r=0.99$) and for *T. japonicus* from SW Taiwan $PL=-149.7+0.5152\ TL$ ($r=0.99$) and from E Taiwan $PL=-78.3+0.4461\ TL$ ($r=0.99$), were used.

The regressions derived from plotting of preanal length (*PL*) against otolith radius (*R*) for each species from different localities were:

T. lepturus

SW Taiwan $PL=-49.5+116.2\ R$ ($r=0.94$) 1a

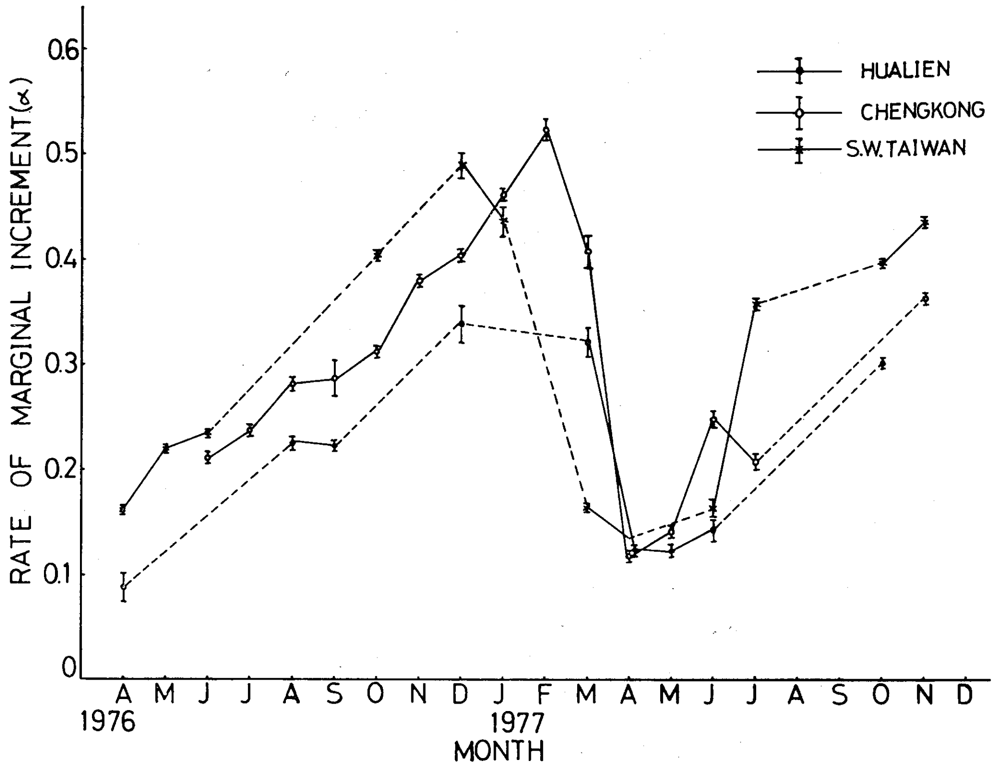

Fig. 5. Monthly changes in the rate of marginal growth of otolith (α) for *Trichiurus japonicus.*

E Taiwan $PL= \quad 7.3+ \ 93.2\ R\ (r=0.96)$ 1b

T. japonicus

SW Taiwan $PL=-132.5+146.4\ R\ (r=0.92)$ 1c

E Taiwan $PL=- \ 68.2+134.2\ R\ (r=0.94)$ 1d

By substituting $R=0$ to the above equations, the theoretical preanal length (total length in bracket) at the time when otolith was first produced, were gained as −49.5 mm(12.9 mm)and 7.3 mm (91.2 mm) for *Trichiurus lepturus* from SW andE Taiwan, while −132.5 mm (33.3 mm) and −68.2 mm (22.6 mm) for *T. japonicus* from SWand E Taiwan respectively. The presence of negative lengths at the commence of otolith production was similar to those found in the *T. lepturus* of SE Japan[5]. The error was probably due to the failure in obtaining otoliths that are smaller than 1 mm for this study. The expected body lengths were entirely based on the otoliths that are larger than 1 mm.

Growth equations and growth curves

When substituting mean ring radius (r_n) of Tables 1 and 2 for the R values in the equations 1a-d, preanal length at the time of ring formation were back calculated on a ring per year basis. The results were in Tables 3 and 4.

By applying Walford's graphic method, the regressions between L_t and L_{t+1} of Tables 3 and 4 were then given below:

T. lepturus

SW Taiwan $L_{t+1}=138.0+0.749\ L_t\ (r=0.99)$ 2a

E Taiwan $L_{t+1}=119.0+0.763\ L_t\ (r=0.99)$ 2b

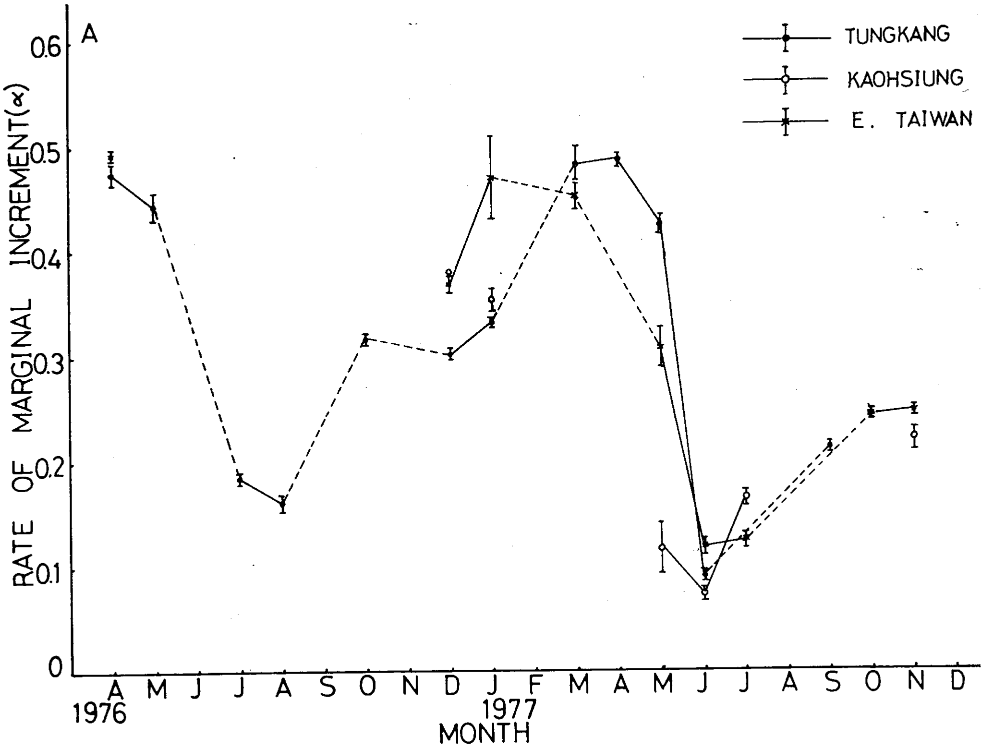

Fig. 6. Monthly changes in the rate of marginal growth of otolith (α) for *Trichiurus lepturus.*

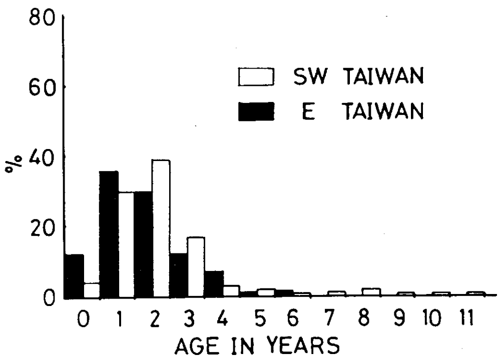

Fig. 7. Age composition of *Trichiurus lepturus.*

T. japonicus

SW Taiwan $L_{t+1}=151.0+0.712\ L_t\ (r=0.99)$ 2c

E Taiwan $L_{t+1}=132.0+0.778\ L_t\ (r=0.99)$ 2d

The asymptotic preanal length (L_∞) was

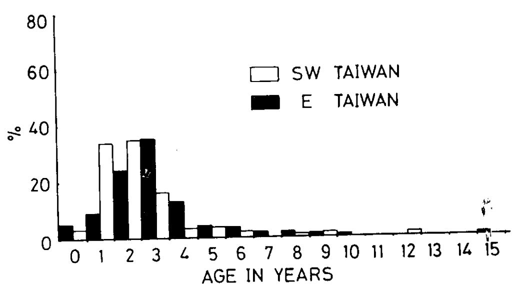

Fig. 8. Age composition of *Trichiurus japonicus.*

obtained from the intercept of the above regression lines with 45° diagonal line. The results were 550 mm and 502 mm for *T. lepturus* of SW and E Taiwan, and 524 mm and 595 mm for *T. japonicus* of SW and E Taiwan respectively.

The growth equations of *Trichiurus lepturus* and *T. japonicus* from different areas were that of the von Bertallanfy's growth equation $L_t=L_\infty\,(1-e^{-k(t-t_0)})$, where $L_t=PL$ at age t, $K=-$

TABLE 1
Mean ring radius measured for each age group of *T. lepturus* of southwestern (SW) and eastern coasts (E) of Taiwan

Age group	Regions	Sample size	Mean ring radius (mm)							
			r_1	r_2	r_3	r_4	r_5	r_6	r_7	r_8
I	SW	110	2.24							
	E	63	1.68							
II	SW	140	2.12	2.93						
	E	52	1.50	2.48						
III	SW	62	2.32	3.05	3.56					
	E	21	1.50	2.48	3.09					
IV	SW	12	2.43	3.12	3.63	4.03				
	E	13	1.40	2.38	3.02	3.47				
V	SW	7	2.36	3.06	3.58	4.00	4.32			
	E	2	1.29	2.33	3.07	3.59	3.95			
VI	SW	3	2.35	3.09	3.64	4.03	4.43	4.63		
	E	3	1.34	2.31	3.03	3.60	4.00	4.31		
VII	SW	4	2.30	2.94	3.41	3.82	4.18	4.38	4.51	
VIII	SW	3	2.33	3.01	3.50	3.89	4.19	4.45	4.67	4.83
Mean	SW		2.31	3.03	3.55	3.95	4.28	4.31	4.59	4.83
	E		1.45	2.40	3.05	3.55	3.97	4.31		

TABLE 2
Mean ring radius measured for each age group of *T. japonicus* of southwestern (SW) and eastern (E) coasts of Taiwan

Age group	Regions	Sample size	Mean ring radius (mm)								
			r_1	r_2	r_3	r_4	r_5	r_6	r_7	r_8	r_9
I	SW	52	1.84								
	E	52	1.85								
II	SW	53	1.65	2.57							
	E	136	1.69	2.56							
III	SW	25	1.57	2.47	3.02						
	E	198	1.60	2.47	3.04						
IV	SW	5	1.44	2.37	2.99	3.49					
	E	72	1.51	2.38	2.97	3.41					
V	SW	6	1.43	2.32	2.94	3.38	3.68				
	E	23	1.42	2.28	2.88	3.35	3.69				
VI	E	21	1.36	2.28	2.87	3.31	3.67	3.93			
VII	E	11	1.34	2.18	2.77	3.21	3.58	3.86	4.09		
VIII	E	10	1.27	2.08	2.72	3.21	3.59	3.95	4.19	4.38	
IX	E	5	1.25	2.04	2.63	3.14	3.57	3.87	4.13	4.32	4.47
Mean	SW		1.59	2.43	2.99	3.44	3.68				
	E		1.48	2.28	2.84	3.27	3.62	3.90	4.14	4.35	4.47

TABLE 3

Back calculated preanal length (mm) of the fish at the time of ring formation for *T. lepturus* of southwestern (SW) and eastern (E) coasts of Taiwan

Age group	Regions	Sample size	Back calculated preanal length (mm)							
			L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8
I	SW	110	211							
	E	63	166							
II	SW	140	197	291						
	E	52	147	239						
III	SW	62	220	305	364					
	E	21	147	238	295					
IV	SW	12	233	313	372	419				
	E	13	138	229	289	331				
V	SW	7	225	306	367	415	453			
	E	2	127	224	293	342	375			
VI	SW	3	224	310	374	419	465	489		
	E	3	132	223	290	343	380	409		
VII	SW	4	218	292	347	394	436	460	475	
VIII	SW	3	221	300	357	403	437	468	493	512
Mean	SW		208	297	365	413	448	471	483	512
	E		143	230	292	339	378	409		

TABLE 4

Back calculated preanal length (mm) of the fish at the time of ring formation for *T. japonicus* of southwestern (SW) and eastern (E) coasts of Taiwan

Age group	Region	Sample size	Back calculated preanal length (mm)								
			L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8	L_9
I	SW	52	137								
	E	52	180								
II	SW	53	109	244							
	E	136	159	275							
III	SW	25	97	228	310						
	E	198	147	263	340						
IV	SW	5	78	215	306	379					
	E	72	134	251	330	389					
V	SW	6	77	207	297	363					
	E	23	122	238	318	381	427				
VI	E	21	114	238	317	376	424	459			
VII	E	11	112	224	304	363	418	450	481		
VIII	E	10	102	211	297	363	414	462	494	520	
IX	E	5	100	206	285	353	411	451	486	511	531
Mean	SW		100	224	305	371	406				
	E		148	260	332	381	422	457	487	517	531

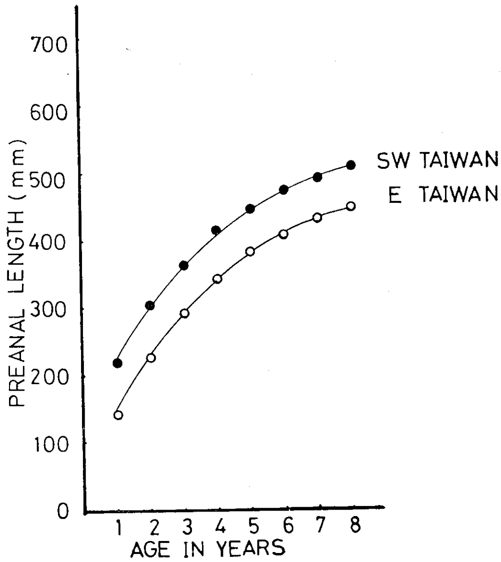

Fig. 9. Growth curves drawn by plotting the back calculated preanal length (mm) of *Trichiurus lepturus.*

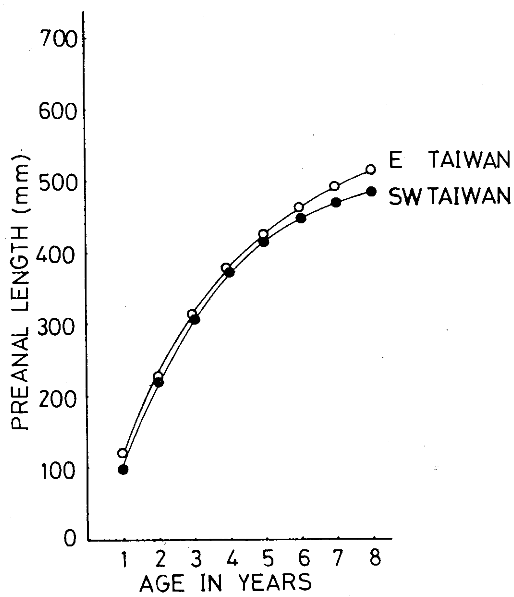

Fig. 10. Growth curves drawn by plotting the back calculated preanal length (mm) of *Trichiurus japonicus.*

$\ell_n b$ (b=slope on the equations 2a-d), t_0=the age when $PL=0=t+1/K\,(\ell_n((L_\infty-L_t)/L_\infty))$. The growth equations were then given:

T. lepturus

SW Taiwan $L_t=550\ (1-e^{-0.289(t+0.76)})$....3a

E Taiwan $L_t=502\ (1-e^{-0.271(t+0.22)})$....3b

T. japonicus

SW Taiwan $L_t=524\ (1-e^{-0.340(t+0.39)})$....3c

E Taiwan $L_t=595\ (1-e^{-0.250(t+0.08)})$....3d

The growth curves in lengths shown in Figs. 9 and 10 were derived from the above equations 3a-d.

There was good fit between body weight and total length of each species listed below:

T. lepturus

SW Taiwan $W=1.67\times10^{-7}\ TL^{3.2268}$ (r=0·95)..............4a

E Taiwan $W=3.986\times10^{-8}\ TL^{3.4467}$ (r=0.99)..............4b

T. japonicus

SW Taiwan $W=3.176\times10^{-9}\ TL^{3.7247}$ (r=0.97)..............4c

E Taiwan $W=9.060\times10^{-6}\ TL^{2.5924}$ (r=0.82)..............4d

The following growth equations expressed in weights were consequently converted from the above equations:

T. lepturus

SW Taiwan $W_t=1989\ (1-e^{-0.289(t+0.76)})^{3.2268}$ 5a

E Taiwan $W_t=2086\ (1-e^{-0.271(t+0.22)})^{3.4467}$ 5b

T. japonicus

SW Taiwan $W_t=1288\ (1-e^{-0.340(t+0.39)})^{3.7247}$ 5c

E Taiwan $W_t=1576\ (1-e^{-0.250(t+0.08)})^{2.5924}$ 5d

By adopting the formula $t=(Kt_0+\ell_n\,n)/K$, the time of the maximum growth (in weights) were estimated as 3.44 and 4.36 years for the *T. lepturus* of SW and E Taiwan, and 4.26 and 4.64 years for the *T. japonicus* of SW and E Taiwan respectively.

DISCUSSIONS

As the result of this study, annual ring of the otolith is formed in June for *Trichiurus* *lepturus* and in April for *T. japonicus*. As many other tropical fishes, ring formation corresponds quite well to the annual gonad maturation, that are between May and August (peak in June) for *T. lepturus* and between March and June (peak in April) for *T. japonicus*. In the Taiwan area, the lowest temperatures in SW and E coasts are measured 21°C[7] in January and 23°C[8] in February. It is clear that the period of ring formation on the otolith is more likely to correlate with the timing of peak spawning and not correlate with low water temperatures.

Comparing the present results with those investigated elsewhere by some Japanese workers[2,4,5], the ring formation of *T. lepturus* from Kii Channel (SE Japan) is between April and June (breeding season between May and June)[5] and that from E China Sea and Yellow Sea are between February and March (breeding season between April and August). They do not completely synchronize with the declining water temperatures. The results obtained by the above Japanese workers are probably due to the taxonomic confusion of the two *Trichiurus* species presented in their studied samples. It is quite possible that the ribbonfish from Kii Channel[5] were mostly *T. lepturus* while those from E China Sea and Yellow Sea[2,4] were probably *T. japonicus*. Since *T. lepturus* and *T. japonicus* are recognized as two valid species[3], the toxonomic confusion of the two *Trichiurus* species by the Japanese workers seem to be possible.

The growth patterns may vary with areas. The coefficient K (designated as the indication of the catabolism of fish) of the population in Taiwan (0.289 and 0.271 for SW and E Taiwan respectively) were higher than those of E China Sea and Yellow Sea (0.139)[2] and Kii Channel (0.261)[5], with an exception of a higher value of 0.411 estimated by Misu[4] on the population of E China Sea and Yellow Sea. This might due to the smaller fish in his studied sample. It is suggested that growth rate of the Taiwan *Trichiurus lepturus* is slightly faster than that of more northern population. This faster growth rate might related to environmental factors such as temperatures, food source and population density of the fish. Unfortunately, the data for the latter two parameters are not available to make a more detail analyses. However, the importance of the food source had been demonstrated: The growth rate of Nigerian *Labeo senegalensis* slowed down when limited food supply in the Lake Kainiji during the low water period[1].

Further consideration of the fishes from Taiwan area alone, the growth patterns also vary with localities, i.e., the growth rate of *Trichiurus lepturus* from SW Taiwan is slightly higher than that of E Taiwan while the growth rate of *T. japonicus* from E Taiwan is higher than that of SW Taiwan.

Reviewing the back calculated body length of these fishes, there is a clear existence of Lee's phenomenon. However, it has not been found in the results of the Japanese workers. The Lee's phenomenon in this may be caused by inadequate sampling technique, i.e., the fish used in this study are sampled by handliners and longliners while those by Japanese workers are entirely by the bottom trawlers. The different fishing gears may result the different feature of age composition, consequently a Lee's phenomenon is expected.

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REFERENCES

1. BLAKE, C. and B. F. BLAKE (1978) The use of opercular bones in the study of age and growth in *Labeo senegalensis* from Lake Kainiji, Nigeria. *J. Fish. Biol.* **13**: 287-295.
2. HAMADA, R. (1971) Age and growth of ribbon fish *T. lepturus* based on the transverse section of the otolith. *Bull. Seikai Reg. Fish. Res. Lab.* **41**: 53-62.
3. LEE, S. C., K. H. CHANG, W. L. WU and H. C. YANG (1977) Formosan ribbonfishes (Perci-

formes: Trichiuridae). *Bull. Inst. Zool Academia Sinica* **16**(2): 77–84.

4. MISU, H. (1958) Studies on the fisheries biology of the ribbon fish *Trichiurus lepturus* in the East China and Yellow Seas. I. On the age and the growth. *Bull. Seikai Reg. Fish. Res. Lab.* **15**: 1–14.
5. SAKAMOTO, T. (1976) Age and growth of the ribbon fish in the Kii Channel. *Bull. Jap. Soc. Sci. Fish.* **42**(1): 1–11.
6. Taiwan Fisheries Bureau (1978) Fisheries yearbook of the Taiwan area of 1977. Taiwan Fisheries Bureau. Taipei. 178pp.
7. TSENG, W. Y. (1977) Report on fisheries and oceanographic investigation along Taiwan coast. *Bull. Taiwan Fish. Res. Inst.* **29**: 1–100.
8. YEH, K. H. (1978) Investigation on resources of fishing ground in Eastern Taiwan. *Bull. Taiwan Fish. Res. Inst.* **30**: 165–186.

臺灣產白帶魚 (*Trichiurus*) 之年齡與成長

陳 文 義　　李 信 徹

本報告乃根據 1976 年 4 月～1977 年 11 月間在花蓮、成功、東港及高雄近海採集之 536 尾肥帶 (*Trichiurus lepturus*) 及 711 尾瘦帶 (*T. japonicus*) 之耳石研究結果。每種帶魚耳石上之輪紋，每年各形成一輪，其形成期，肥帶約在 4 月，瘦帶約在 6 月間，與二種帶魚之生殖期配合。全部樣品中，肥帶之最長年齡為採自東港之 11^+ 歲（肛前長 672 mm）而瘦帶則為採自成功之 15^+ 歲（肛前長 873 mm）。

經推算出之成長式，臺灣西南海域之肥帶為 $L_t=550(1-e^{-0.289(t+0.76)})$ 或 $W_t=1989(1-e^{-0.289(t+0.76)})^{3.2286}$ 其來自臺灣東部海域者為 $L_t=502(1-e^{-0.271(t+0.22)})$ 或 $W_t=2086(1-e^{-0.271(t+0.22)})^{3.4467}$。

臺灣西南海域之瘦帶為 $L_t=524(1-e^{-0.340(t+0.39)})$ 或 $W_t=1228(1-e^{-0.340(t+0.39)})^{3.7247}$，其來自臺灣東部海域者為 $L_t=595(1-e^{-0.250(t+0.08)})$ 或 $W_t=1576(1-e^{-0.250(t+0.08)})^{2.5924}$。

帶魚最大增重期經估計，西南及東方海域之肥帶分別為孵化後之 3.44 及 4.36 年；西南及東方海域之瘦帶則分別為 4.24 及 4.64 年。

每種帶魚之成長曲線略呈地理上之差異，一般而言，如肥帶之成長率，其北方族羣（東海、黃海）似較南方族羣（臺灣）緩慢，可能與棲息海域之水溫，餌料生物之密度及其他環境因素有關。