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AGE AND GROWTH OF THE GROUPER, *EPINEPHELUS DIACANTHUS* (CUVIER ET VALENCIENSIS) IN THE WATERS OF NORTHERN TAIWAN[1]

CHANG-PO CHEN, HWEY-LIAN HSIEH
and KUN-HSIUNG CHANG

*Institute of Zoology Academia Sinica, Taipei Taiwan
Republic of China*

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Chang-Po Chen, Hwey-Lian Hsieh and Kun-Hsiung Chang (1980) Age and growth of the grouper, *Epinephelus diacanthus* (Cuvier et Valenciensis) in the Waters of Northern Taiwan. *Bull. Inst. Zool., Academia Sinica* **19**(1): 1-9.. Three hundred and eighty groupers, *Epinephelus diacanthus* (Cuvier et Valenciensis), collected monthly from June 1975 to October 1977, were used in this study. Age was determined by means of scale reading and the annual ring formation was found to be once a year occuring during March and April. The growth curves, revealed by employing the von Bertalanffy equation, were as follows:

$$SL_t = 228.0(1 - e^{-0.3571(t+0.6993)}),$$

$$W_t = 314.17(1 - e^{-0.3571(t+0.6993)})^{2.99790}.$$

The grouper, *Epinephelus diacanthus*, is a dominant and economically important benthic fish in the coastal waters of northern Taiwan[16], but no biological references about it have been previously reported.

Thompson and Munro (1978) recently noted that the age and growth had been determined only for a few of the groupers and most of these were determined by the otolith analysis or by length distribution[18]. The scale reading method has not yet been used to determine age in groupers.

This study reports on the age and growth of *E. diacanthus* determined by the scale reading method. Other biological characteristics of the fish will be reported in future papers.

MATERIALS AND METHODS

A total of 380 specimens of the grouper, *Epinephelus diacanthus* (Cuvier et Valenciensis) were caught at monthly intervals from June 1975 to October 1977 by local fishermen using hand lines in the waters off northern Taiwan. The sampling was carried out under the following conditions: time of catching: 0500–0600; duration of operation time: 30–60 mins; number of size 3 hooks: 500; fishing depth: 10–15 meters. The sampling stations and details of each sample are shown in Fig. 1 and Table 1, respectively.

Within a day of catch, the abdomen of each fish was injected with 5 ml of 10% formalin solution and then preserved in 10% formalin for up to one month. Since regenerated scales are very common in these fish, scales were carefully checked during examination to ensure that more than 10 normal scales had been removed from the left side of body portion 6 (see Fig. 2), bounded by the 6–9th dorsal spines and the 15–20th scale lines below lateral line. The standard length and body weight

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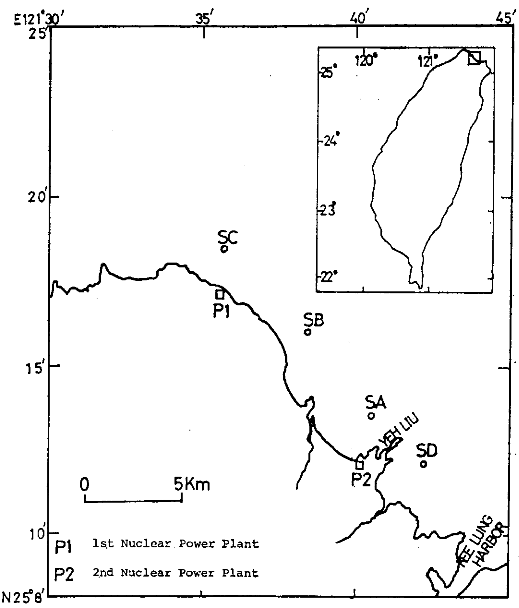

Fig. 1. The locations of sampling stations and nuclear power plants. SA, Yeh-liu; SB, Tiao-shih; SC, Shin-men; SD, Kue-hoe.

TABLE 1
The materials used in this study

Date of sampling	Number of specimens	Location of sampling			
		SA*	SB	SC	SD
Jun. 1975	11		4	7	
Oct. 1975	32		14	18	
Nov. 1975	16		4	12	
Dec. 1975	18		5	13	
Jan. 1976	14		5	9	
Mar. 1976	12			12	
May 1976	35		22	12	1
Jun. 1976	37		24	13	
Jul. 1976	19	6	11	2	
Aug. 1976	13		5	7	1
Oct. 1976	12		10	2	
Nov. 1976	28		9	19	
Dec. 1976	3		3		
Feb. 1977	15		8	7	
Apr. 1977	36	10	16	10	
May 1977	41	12	17	12	
Jul. 1977	11		8	3	
Aug. 1977	12		2	10	
Oct. 1977	15		9	6	
Total	380	28	176	174	2

* The sampling station is illustrated in Fig. 1.

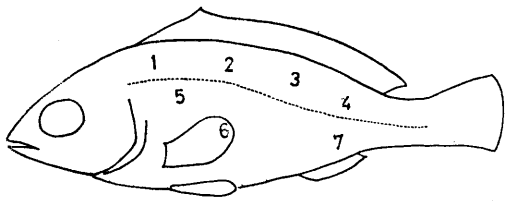

Fig. 2. The body parts of scales sampling.

(without viscera) were measured to 1 mm and 0.01 g, respectively. The sex of the fish was determined by microscopic examination of gonads using the aceto-carmine squash method[5].

Scales were stained with Alizarin Red-S and mounted on slides with glycerine. The Nikon Profile Projector (Model 6 C) set at 20 magnification was employed in observing and measuring the scales. The annual rings were distinguished from regular bony-ridges (circuli) in the following two ways: (1) the annual ring has a discontinuous ridge (cutting over) in the scale's lateral field, and also shows compact ridges in the scale's anterior field; (2) when stained with Alizarin Red-S, the annual ring becomes a red line which shows bright red in color when observed under a transmitted light. The annual rings are considered to be at the outer border of this red line (Fig. 3). A false ring may be present when two red lines lie very close to each other.

The length of a scale's radius (R) and annual rings (r_n) was measured as the shortest distance from the center of the scale's focus to its anterior margin (see Fig. 3). The values of the length of the radius and rings of a particular fish were obtained from the average values of the three largest and most symmetric scales of the selected scales.

The correlation between the length of radii and length of annual rings in a particular age group were tested by the linear regression analysis[15]. The skewness of the frequency distribution of a particular age groups' standard length was tested after Sokal and Rohlf[15]. To determine the time of ring formation, the marginal increment of a scale is defined as follow:

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

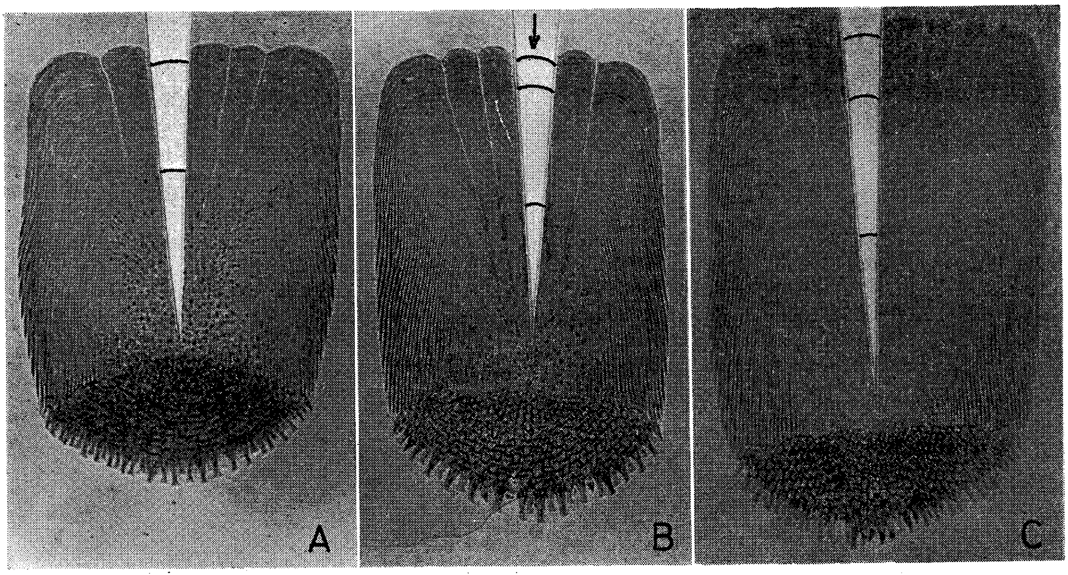

Fig. 3. The scales characters of *E. diacanthus*. Scales A and B were age 2^+; scale C was age 3^+; a false ring was indicated with an arrow in scale B.

The back calculation of the growth of the fish from the results of scale readings follows Tesch[17]. Since Lee's phenomenon was revealed in the *E. diacanthus*, both Ricker's curve *A* and curve *D*[10] were fitted to the von Bertalanffy equation by Allen's computer method[1]. The conversion of the von Bertalanffy equation from length to weight was adopted with "between-ages-*b*", not "individuals-*b*"[10].

RESULTS

Good correlation between the length of radii and the length of annual rings in each age group are revealed in Fig. 4. The results of these scale readings can be used to determine the age and growth of the fish. Fig. 5 shows that the marginal increment of the scales decreased abruptly in March and remained low through July in 1976 then gradually increased through December and again decreased during February to June in 1977. Since only one ring was formed in each year, the rings can be judged as annual rings.

In this study, about 94% of fish (357 individuals), were age-determinated. The age composition of the *E. diacanthus* is shown in Fig. 6. The age ranged from 1^+ to 7^+ and the dominant age groups were 2^+ and 3^+, composing 30.2% aud 37.5% of the sample, respectively. No fish younger than one year old had been caught by hand lines. Fig. 6 also shows that the range of standard length in each age group overlaps. The frequency distribution of standard length in age 2^+ had a significiant positive skewness ($g_1=0.4855$, $g_1/sg_2=2.08>1.96$), but no skewness was observed in age 3^+ ($g_1=0.1468$, $g_1/sg_2=0.70<1.96$).

Table 2 shows the mean length of all annual rings in each age group. The length of a particular annual ring became progressively smaller as counted from younger fish to older ones.

The relationship between standard length (*SL*) and the length of radii (*R*) is plotted in Fig. 7 and then fitted as below:

$$SL=29.852+43.333\ R \qquad (1)$$

The standard length of the fish at the time of ring formation was back calculated using equation (1) and the length of annual rings. As shown in Table 3, the calculated lengths became

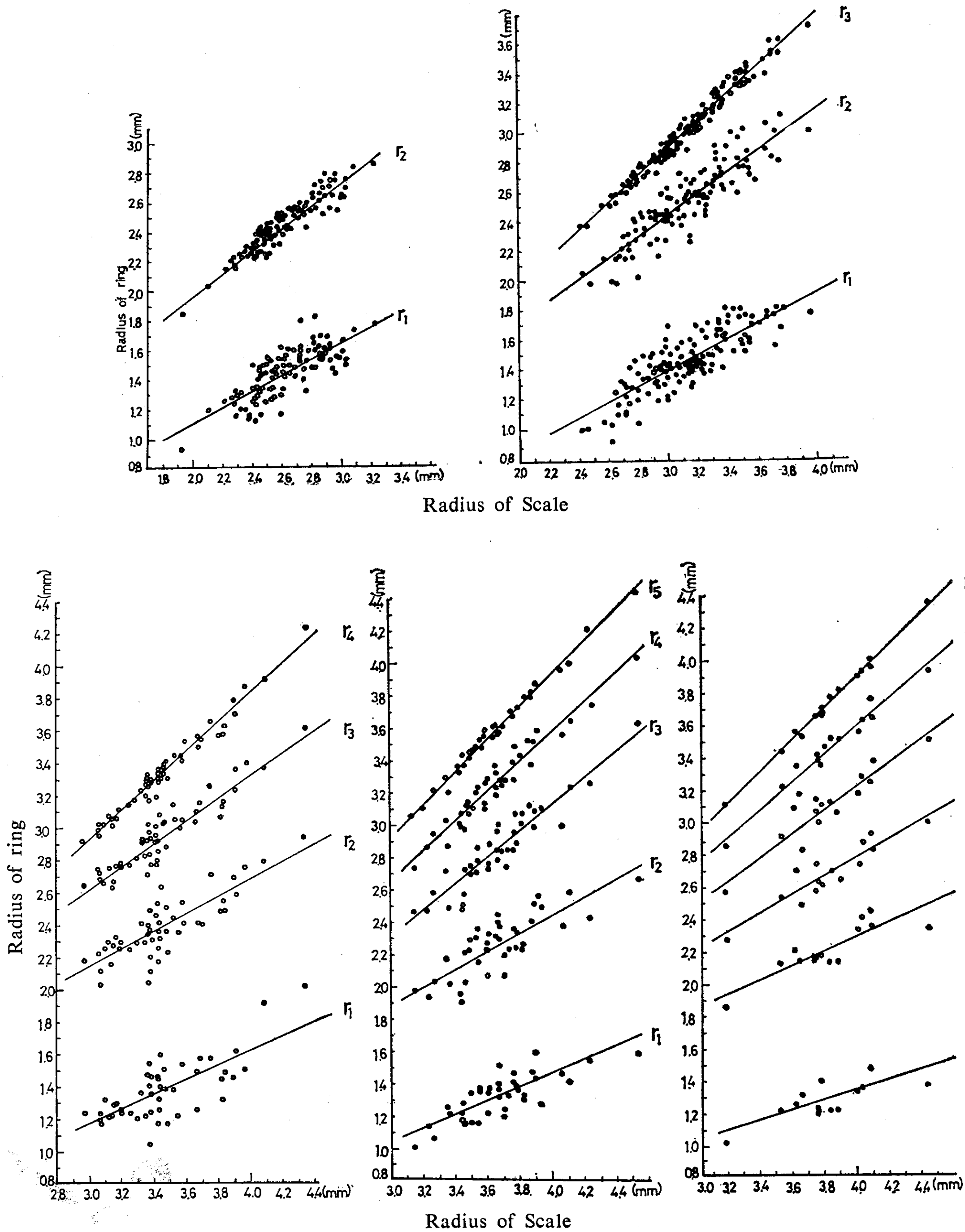

Fig. 4. Correlation of ring formation among individuals.

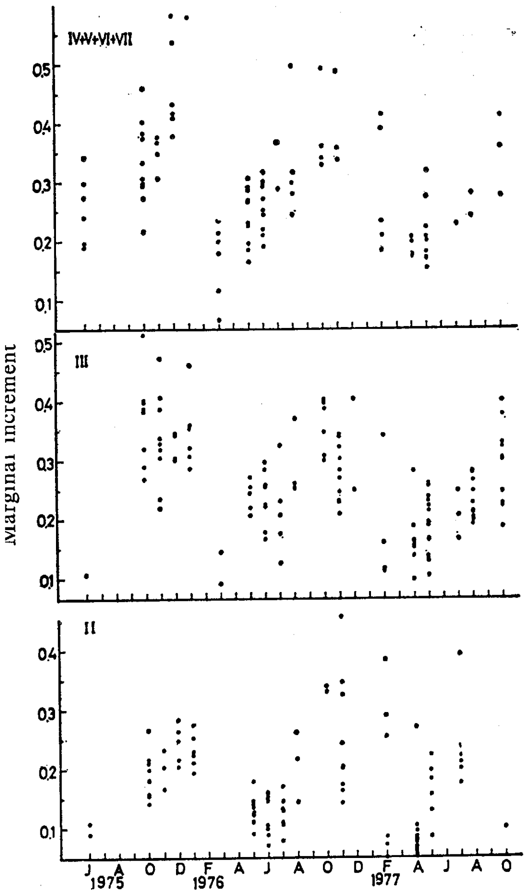

Fig. 5. Monthly change of the marginal increments of scales.

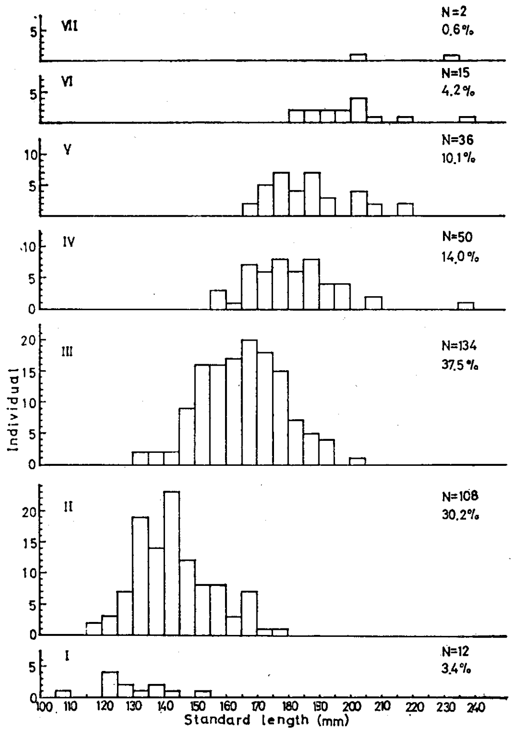

Fig. 6. The distribution of standard length in each age group.

TABLE 2

The mean radii of scales (R) and rings (r_n) in mm

Number of rings	Number of fish	R	r_1	r_2	r_3	r_4	r_5	r_6
6	15	3.8297	1.3036	2.2233	2.6987	3.1053	3.4604	3.7508
5	36	3.6403	1.3159	2·2467	2.8277	3.2330	3.5591	
4	50	3.4633	1.3795	2.3922	2.9540	3.3419		
3	134	3.1238	1.4493	2.5274	3.0021			
2	108	2.6296	1.4570	2.4582				
1	12	2.4014	1.6664					

TABLE 3
The back-calculated standard length (mm) at the time of ring formation

Age (i)	SL_{i1}	SL_{i2}	SL_{i3}	SL_{i4}	SL_{i5}	SL_{i6}
6	86.34	126.19	146.79	164.41	179.80	192.38
5	86.87	127.25	152.38	169.95	184.08	
4	89.63	133.51	157.86	174.67		
3	92.65	139.37	159.94			
2	92.98	136.37				
1	102.06					
d*	9.08	−3.00	2.08	4.72	4.28	

* $d = SL_{ii} - SL_{i+1,i}$; after Ricker (1969).

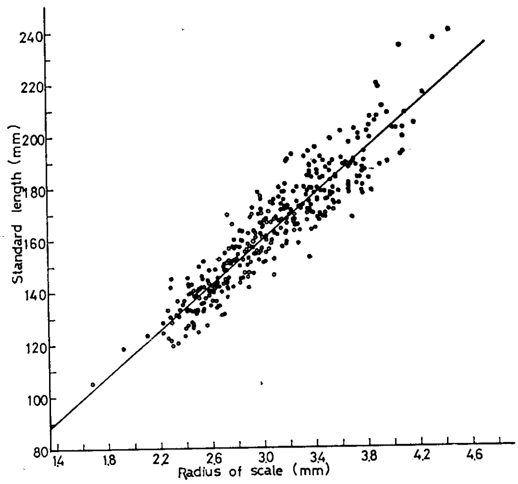

Fig. 7. Relationship between radius of scale and standard length of the grouper.

progressively smaller when they were calculated from successively older fish, indicating that Lee's phenomenon does obviously exist.

Results of the von Bertalanffy growth equation for curves *A* and *D* are shown in Fig. 8 and Table 4. The maximum length of this grouper, estimated by curve *A* and *D* was 205.4 and 228.8 mm, respectively. All the maximum lengths were underestimated because the largest fish caught in this study was 239 mm, however curve *D* seems closest to natured size. The growth equation of curve *D* is shown below:

$$SL_t = 228.0\ (1 - e^{-0.3571(t+0.6993)}) \qquad (2)$$

The length-weight relationship of individuals is shown in Fig. 9 and its equation is shown below:

$$W = 1.621 \times 10^{-5}\ SL^{3.08968} \qquad (3)$$

The equation of length-weight relationship of between-ages-*b* is shown below:

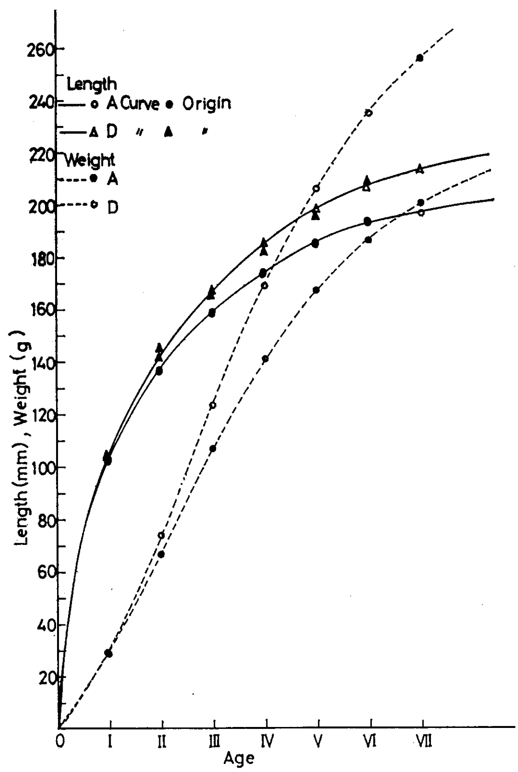

Fig. 8. The von Bertalanffy growth curves of *E. diacanthus*.

TABLE 4
The statistics of the von Bertalanffy growth equation fitted to the grouper's back-calculated standard length

Curve	Statistics ($\bar{x}\pm$s. e.)		
	k	t_0	L_∞
A*	0.40467	−0.69767	205.44
	±0.01439	±0.00530	± 1.60
D	0.35711	−0.69928	228.06
	±0.06230	±0.24904	± 10.19

* Curve A and D named after Ricker (1958), Curve A is calculated with $SL_{ij,i=j}$; Curve D with SL_{11}, $(SL_{22}-SL_{21})$,..., $(SL_{ii}-SL_{i,i-1})$.

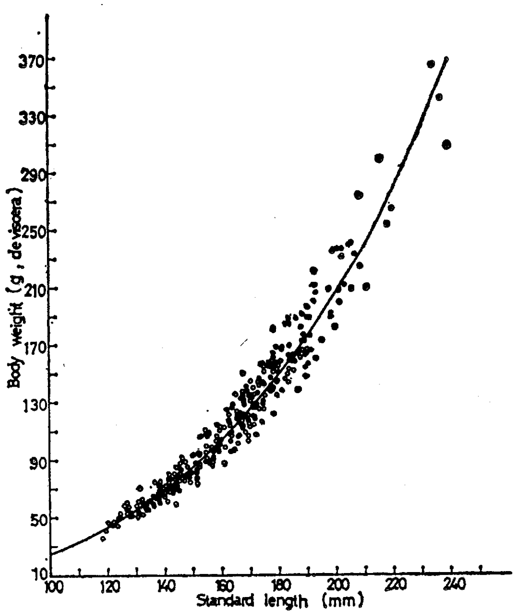

Fig. 9. Relationship between standard length and body weight (without viscera) of the grouper.

$$W=2.679\times10^{-5}\ SL^{2.99790} \qquad (4)$$

Both b values are very close to 3, that is, the growth of this grouper is very "isometric"[10].

Combining equations (4) and (2), the body weight growth curve is shown in Fig. 8 and its equation is

$$W_t=314.7\ (1-e^{-0.3571\ (t+0.6993)})^{2.99790} \qquad (5)$$

DISCUSSION

Although the physiological mechanism of ring formation in fish scales is still not yet completely clear, Simkiss (1974) emphasized that it was due to the change of the calcium metabolism in the scales[13]. External environmental factors, such as temperature, salinity, food and light have been thought likely to influence the deposition of annual rings and the fish physiological relationship between the relative rates of calcium deposition and calcium resorption may also influence the formation of annual rings. For example, a decrease in the calcium content of the scales was associated with the development of the ovary in *Tilapia esculenta*[13]; scales were resorbed during the spawning season in salmon, sea trout[13] and *Alosa pseudoharengus*[8] and the recovery of the scales would form a spawning mark which can be treated as an annual ring. In addition to the spawning mark, the time of ring formation in many fishes matches very well with its spawning season, such as in *Miichthys imbricatus*[6], *Chrysophrys major*[3,7,9], etc. The red sea bream, *C. major* changes both the time of ring formation and spawning season coincidently from south to north. For example, off Pescadores Isl the ring forms during November to January[3]; in Keelung waters, northern off Pescadores Isl, it occurs during January to March[7]; more northward to East China and the Yellow Seas, the ring formation lasts from March to June[9]. In the case of *E. diacanthus*, the time of ring formation also matches with its spawning season[4], therefore, the connection between reproductive cycle and ring formation is suggested.

As mentioned above, many factors can influence ring formation in fish scales, so it will not be unexpected to find false rings in fish. In grouper, Thompson & Munro[18] mentioned that the false ring in *Mycteroperca venensa* and *E. stratus* could be caused by the change of sex from female to male or loss of a scale may produce an accessory check on adjacent scales. Present data on *E. diacanthus* indicates that its false rings are not caused by either on these reasons, since (1) when a fish had a false ring, all of its scales exhibited that ring, (2) false rings occured on both males and females, (3) false rings were found mainly on the interval between 1st and 2nd annual rings and the interval between 2nd and 3rd annual rings, a few between 3-4 rings and none appeared between 4-5 rings. There is evidence showing that the sex change of *E. diacanthus* occurs during age 2 to 6[4]. No explanations are given here for the formation of false rings in *E. diacanthus*.

Among those age-undetermined individuals of *E. diacanthus*, one was caused by man-made error, i. e., missing the data, 2 had only abnormal scales, 4 had only regenerative scales, 16 others were confused in the ring reading results. These fish's standard lengths ranged from 141 to 223 mm and averaged 185 mm, that is, only the larger fish were difficult to age by the scale reading method. This situation is similar to that in many other fish such as *Chrysophrys major*[3], *Ophiodon elogatus*[2], etc.

Lee's phenomenon has been the subject of many studies[11,12], and three possible causes have been suggested: (1) incorrect technical procedure for back calculation; (2) biased, non-random sampling of the stock; (3) selective mortality, the mortality rate among the larger fish of an age-group is different from that among smaller. Size selective mortality may arise either from natural mortality factors, or from differering catchability of fish of different sizes when fishing is a significiant source of mortality in the population. In coastal waters of the northern Taiwan, the hand-lines are traditional fishing gear, that is, the grouper population is not an unfished population. Additionally, the significant positive skewness in the distribution of standard length of the age 2^+ fish (see Fig. 6) indicates the faster-growing fish became vulnerable first and were gradually recruimented into the fishery; no skewness in age 3^+ revealed that all the fish in this age class had reached a plateau vulnerability. Therefore, it seems clear that selective fishing mortality was responsible for the observed Lee's phenomenon in this grouper.

The first nuclear power plant has been operating since November 1977 at Chinshan in the northern Taiwan and the cooling water of the plant is discharging directly into the coastal waters[16]. According to Smith's brief life history on groupers, "Adult grouper are reef fishes, that is they live in relatively shallow water ... Many species spend most of their time lying in contact with the bottom. The spawning season seems to be temperature correlated. The newly hatched larvae float at the surface ... It seems certain that the larvae are for time pelagic ... "[14]. All of these characters hint that the grouper may be influenced by the long term effect of the thermal discharge from the nuclear power plant. Results of this study offer some baseline information for future comparative studies to determine whether or not the thermal discharge from this power plant will influence local fish populations.

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臺灣北部海域擬青石斑之年齡與成長

陳章波 謝蕙蓮 張崑雄

擬青石斑係臺灣北部核能電廠附近海域手釣漁業之重要魚種之一。本研究以鱗片讀輪法研究該魚種之年齡及成長。材料取自民國64年6月至民國66年10月，共計380尾。該魚種每年 3～4 月在鱗片上形成一年輪。成長測定結果如下：標準體長成長式爲：$SL_t=228.0[1-e^{-0.3571(t+0.6993)}]$，除臟體重成長式爲 $W_t=314.17[1-e^{-0.3571(t+0.6993)}]^{2.99790}$。文中並論及僞輪、李氏現象及輪紋形成期與生殖期相配合的問題。