Bull. Inst. Zool., Academia Sinica **14**(1): 35–46 (1975)

THE AGE AND GROWTH OF THE RED SCAD, *Decapterus kurroides aka-adsi* ABE, IN THE WATERS OF TAIWAN*

KUN-HSIUNG CHANG AND I-NUOH SHAW

Institute of Zoology, Academia Sinica, Taipei,
Taiwan 115, Republic of China

Received for publication April 16, 1975

ABSTRACT

K. H. Chang and I. N. Shaw (1975) *The age and growth of the red scad* Decapterus kurroides aka-adsi *Abe, in the waters of Taiwan.* Bull. Inst. Zool., Academia Sinica **14**(1): 35–46. The age and growth of the red scad in Taiwan were studied by means of scale reading. Two specimens were used to determine the axis measured for scale radius and the most suitable part for scale sampling before population analysis. Morphology of scales were described. Similarity and correspondence of ring formation were tested. Fork length-body weight relationship and scale radius-fork length relationship were represented by equations. Growth curves were derived from Von Bertalanffy equation. Asymptotic length 390.753 mm, the fork length at scale appearance 53.983 mm, the ring formation time and the fit of modal lengths with growth curves were discussed.

The red scad, *Decapterus kurroides aka-adsi* Abe, is one of the economically important fish in Taiwan. The maximum yield of a stock can be obtained and maintained in the same time by way of reasonable management. For this purpose, we must realize the status and dynamics of the population.

Age data and growth pattern are invaluable in studying population dynamics. The growth of fish varies with their living areas under the influence of the factors of environments. There has no disquistion yet on the growth of the red scad in Taiwan. The present report is just a part of the basic work on the resources investigation of scads. This is to study the stock compositions and the growth patterns of two stocks using scale reading. These two stocks are in Nanfangao and Kaohsiung, located northeast and southwest in Taiwan respectively.

MATERIALS AND METHODS

The study was based on the data from 1679 specimens, which were purchased monthly from Feb. 1971 to Dec. 1973, caught by hand liner in waters off Nanfangao and Kaohsiung. However, there were discontinuities of the collection of the samples caused by climates, capture conditions and some other reasons. The used materials were given in Table. 1.

The red scad has quadrangular cycloid scales. The scale consists of four fields: anterior, posterior, and two lateral fields as indicated in Fig. 1. The posterior field has vague circuli for being exposed outside. There are 0–5 grooves, mostly 2 or 3, radiating from the

* Paper No. 92 of the Journal Series of the Institute of Zoology, Academia Sinica, Nankang, Taipei Taiwan 115, Republic of China.

TABLE 1
The specimens of red scads for collecting scales

Nanfangao			
Date	Sample size	Female: Male	Range of fork length (mm)
'71- 4-14	49	40 : 9	240-289
'71- 5-12	39	28 : 11	234-307
'71- 7-30	32	18 : 14	242-283
'71- 8-16	49	29 : 20	261-294
'71- 9-17	50	22 : 28	261-293
'71-10-31	44	21 : 23	250-279
'71-11-27	50	27 : 23	256-291
'72- 4-17	28	13 : 15	263-294
'72- 6-10	46	42 : 4	265-316
'72- 8-10	48	32 : 16	213-265
'73- 3-27	49	26 : 23	217-243
'73- 4-30	48	35 : 13	221-242
'73- 7-18	50	26 : 24	229-256
'73- 8-28	30	18 : 12	229-248
'73- 9-24	50	29 : 21	228-251
'73-10-24	48	27 : 21	238-258
'73-11-29	49	26 : 23	238-274
'73-12-19	49	18 : 31	232-262

TABLE 1
The specimens of red scads for collecting scales (Continued)

Kaohsiung			
Date	Sample size	Female: Male	Range of fork length (mm)
'71- 2- 3	43	18 : 25	273-333
'71- 4-27	53	17 : 36	254-337
'71- 5-31	66	26 : 40	219-319
'71- 6-15	78	22 : 56	261-298
'71- 7- 9	76	40 : 36	236-343
'71- 8- 2	36	9 : 27	267-337
'71- 9- 2	34	14 : 20	264-295
'72- 2-23	27	14 : 13	285-313
'72- 4-14	32	13 : 19	270-319
'72- 5-26	46	22 : 24	263-298
'72- 6-22	32	18 : 14	258-298
'73- 2-13	36	15 : 21	290-340
'73- 5- 2	50	11 : 39	290-340
'73- 6- 1	46	42 : 4	248-302
'73- 7-26	51	26 : 25	236-325
'73- 8-28	51	19 : 32	236-316
'73- 9-24	49	23 : 26	237-321
'73-10-24	20	5 : 15	268-308
'73-12-16	45	13 : 32	241-318

focus to the margin of the anterior field. The circuli of the two lateral fields are symmetrical. The feature serving as the principal indicator of the annular ring is the "cutting over" of circuli, and in some scales the grooves end or bend at the ring mark.

Scales vary in sizes and circuli patterns by their positions. According to their distribution, scales may be divived into two groups (Fig. 1):

1. Scales in the central portion of the body:

They are large and uniform. Circuli extend to the lateral margin along a horizontal axis to form depressed diamond shapes. Outer circuli break in lateral fields and circuli of these fields are in looser order than those of the anterior and the posterior fields.

2. Scales in the dorsal or the ventral portion of the body:

They are small and irregular. They have waved concentric circuli which often extend to the posterior margin, so the outer circuli break here and circuli of this field are more widely spaced. This phenomenon is more conspicuous for scales in the dorsal portion. That, in addition to the smaller size and black granules in the posterior field, differentiates them from scales in the ventral portion.

The detail distribution and the appearance order of these two groups of scales have not been studied. It is one of the characteristics of the scad that the scales in the tail region of the lateral line transform into scutes.

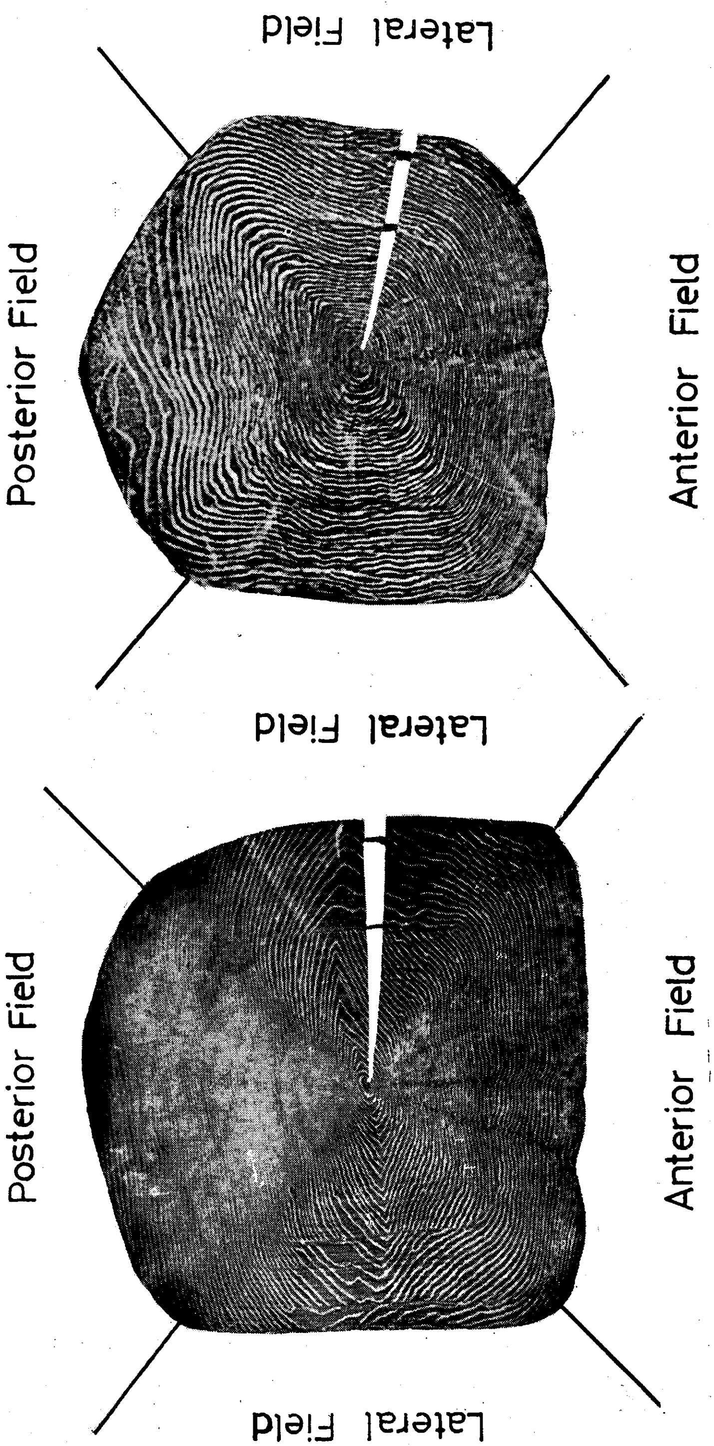


Fig. 1. Scales of red scads. (A) Scales in the central portion of the body. (B) Scales in the dorsal or the ventral portion of the body.

Scales were cleaned with detergent, which was then washed away, mounted between glass slides and examined through a Nikon profile projector (Model 6 C) at the magnification of 20× [1].

Two specimens were used to determine the proper axis measured for scale radius and the most suitable part for scale sampling. About twenty scales were respectively taken from ten body parts indicated in Fig. 2 and four axes indicated in Fig. 3 were measured on five scales sampled from each part.

The correlation between the scale radius and the ring radius was significant for all of the four radii, so there was a similarity of relative position of rings on scales from different body parts and it was reasonable to use scale as an age characteristic. From the four radii, the anterior radius was selected to represent the scale radius because of its least variance. Its similarity was shown in Fig. 4.

The selection of the body part was based on that scales are large, symmetrical, with little variance and with a high readable-ratio (the ratio of the readable scales to the total scales sampled). By the test of the analysis of variance, scale symmetry did not change significantly among body parts but the scale radius differed from part to part. So the mean scale radii and their coefficients of variance were calculated. Judging this result and making reference to the readable-ratio, we selected part F to sample scales for population analysis. The distances respectively from the focus to the margin of the anterior field (anterior radius) and from the focus to the annual ring were measured as scale radius and ring radius. Five scales were

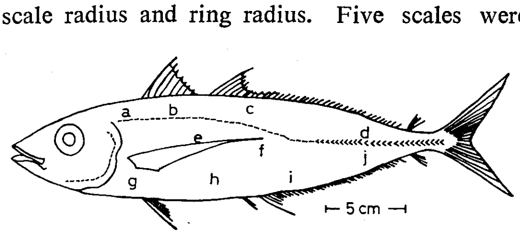


Fig. 2. A diagram showing the body parts for scale sampling.

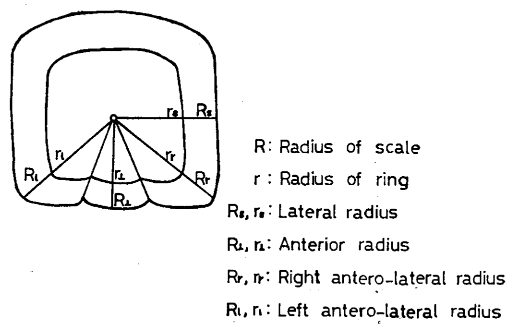


Fig. 3. A diagram of a scale with one ring showing the measurements.

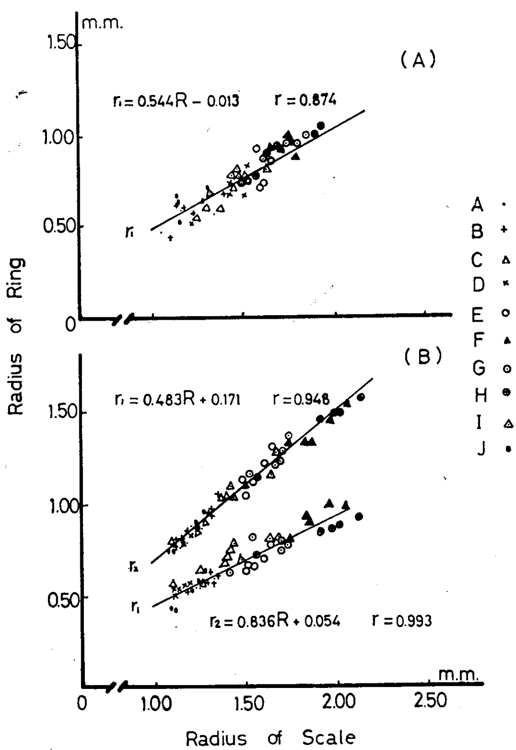
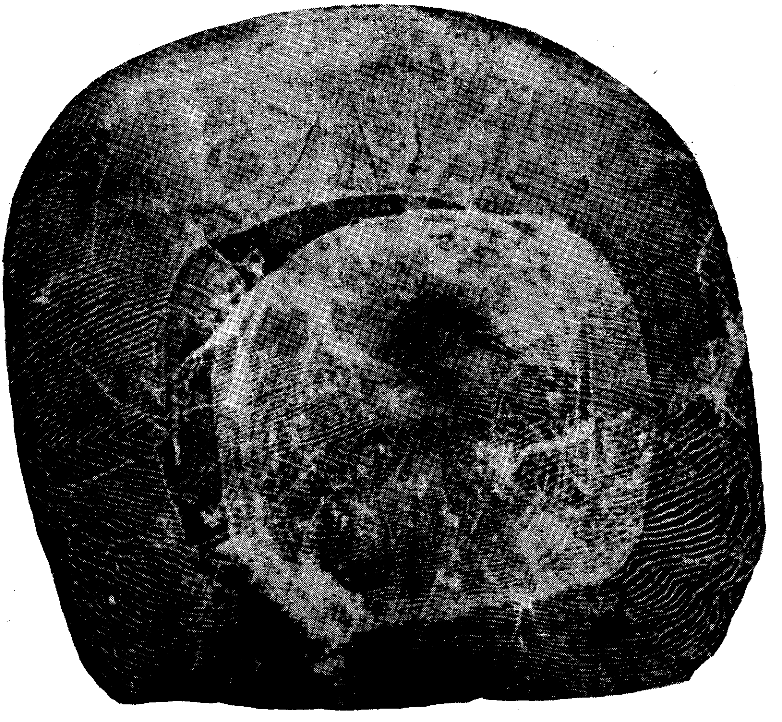


Fig. 4. Relationship between radii of scales (R) and radii of rings (r_i) in the scales sampled from the ten body parts of an individual fish. (A) Specimen I, with one ring. (B) Specimen II, with two rings.

(A)

Fig. 5. Abnormal scales. (A) Three scales showing false rings.



(B)

Fig. 5. Abnormal scales. (B) A scale showing the falling of the portion within a false ring.

measured for each individual fish. These data in conjunction with fork length, body weight and sex were used for growth study.

There were some abnormal scales. Each of them had a very clear ring mark which divided the circuli into two asymmetric portion (Fig. 5 A). The portion within the ring was apt to fall off (Fig. 5 B). The interior portion of a wet normal scale could also be torn away. But the bad similarity and correspondence of the scales mentioned above made them deviate from the regression line, so they were treated as false rings. Although a scale of this kind was often found to be accompanied by many, they were not in the case of all-or-none. The cause was unknown. It might be related to the injury or an accidental cease of growth.

RESULTS

1. Correspondence of ring formation:

Individuals with the same number of rings should exhibit the corresponding positions of rings on scales. The correspondence of an age II group of Kaohsiung, May 1973, was tested as an example. As indicated in Fig. 6, the correlation coefficients of the regression lines ($R-r_i$ regression lines) approximated to unity and they were significantly different. So there existed a correspondence of relative position of rings on scales and the scales measurements were validated.

2. Fork length-body weight relationship:

The equation $W=aL^b$, where L is fork length and a, b are constants, was assumed to express the relation of length to weight(4).

By the test of the analysis of covariance, the difference between sexes was not significant, so male and female data were combined. There were significant differences among monthly samples. But an examination of the sample distribution revealed that many samples concentrated in different length ranges respectively, so combining all samples would approach the result to a true value of the population. Thus the general equations of fork length-body weight ($L-W$) relationships of the two areas are given in the following (Fig. 7):

Nanfangao: $W=0.709\ L^{1.054}$ $r=0.937$
Kaohsiung: $W=0.239\ L^{1.289}$ $r=0.860$

3. Scale radius-fork length relationship:

By the same reason as in $L-W$ relationship, general equations of scale radius-fork length ($R-L$) relationships were obtained from the combined monthly samples of the two areas, which were given in the following:

Nanfangao: $L=113.904\ R+\ 53.983$ $r=0.911$
Kaohsiung: $L=\ 82.533\ R+120.072$ $r=0.832$

The $R-L$ equation and ring radius (Table. 2) were used in back-calculation to obtain the fork length at the time of ring formation which was shown in Table. 3. This table indicated that samples of Kaohsiung were larger than those of Nanfangao of the same age group.

4. Growth curve:

Here we use Von Bertalanffy equation to describe the growth pattern. Von Bertalanffy equation is:

$l_t = L_\infty(1-e^{-k(t-t_0)})$ where
l_t : the fork length at t age
L_∞: asymptotic fork length
k : growth parameter
t : age
t_0 : the age when fork length equals to zero.

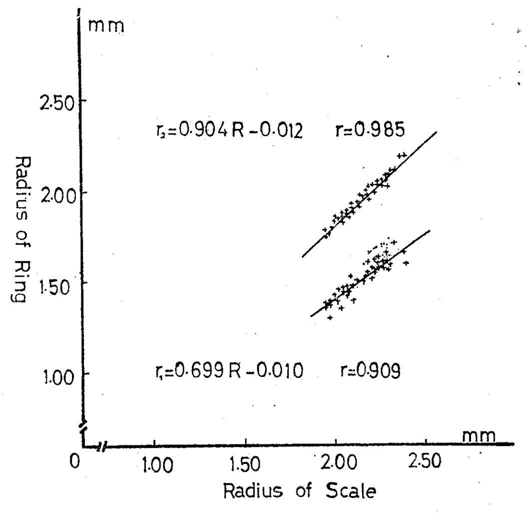


Fig. 6. Relationship between the radii of scales (R) and the radii of rings (r_i) in the scales sampled from 38 fishes of age II.

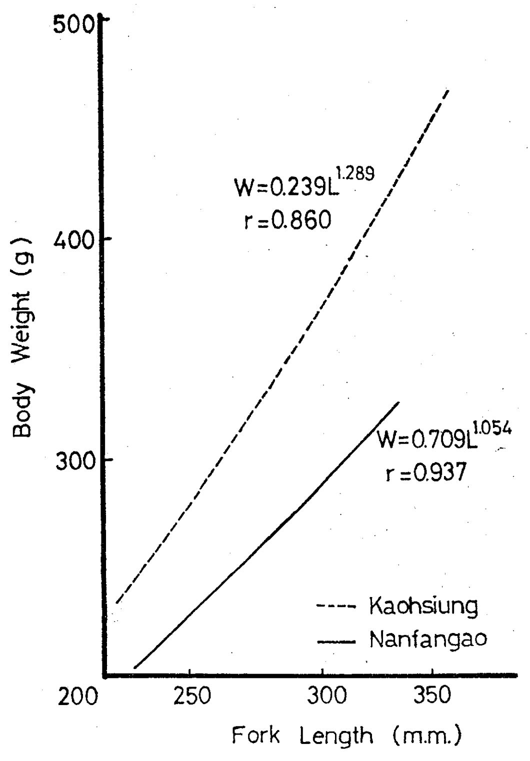


Fig. 7. Relationship between fork length and body weight.

TABLE 2
Mean calculated radius of each ring group

Nanfangao				
Ring group	No. of specimens	Radius of ring (mm)		
		r_1	r_2	r_3
I	429	1.446		
II	79	1.358	1.781	
III	3	1.387	1.869	2.199
Average		1.397	1.825	2.199

Kaohsiung				
Ring group	No. of specimens	Radius of ring (mm)		
		r_1	r_2	r_3
I	356	1.593		
II	320	1.487	1.958	
III	24	1.554	2.036	2.331
Average		1.545	1.997	2.331

To obtain the parameters in this equation, the Ford–Walford Plot was applied[3]. When l_{t+1} was plotted against l_t (Fig. 8) a linear equation was obtained:

Nanfangao: $l_{t+1}=0.873\ l_t+\ 75.776$
Kaohsiung: $l_{t+1}=0.739\ l_t+101.830$

The point where the line cuts the 45° diagonal from the origin is asymptotic length, L_∞; the negative natural logarithm of the slope is the growth parameter, k; and the theoretical age of growth-start is estimated according to the following equation:

$$t_o=t+\frac{1}{k}\ln\frac{L_\infty-l_t}{L_\infty}$$

In this study the average of values from every age(t) was taken as t_o. Thus the growth equation of the red scad was represented by:

Nanfangao: $l_t=598.547\ (1-e^{-0.135(t+2.250)})$
Kaohsiung: $l_t=390{\cdot}753\ (1-e^{-0.302(t+2.326)})$

Based on the growth equation in length and the $L-W$ equation, the growth equation in weight was obtained as following:

Nanfangao: $W_t=599.388\ (1-e^{-0.135(t+2.250)})^{1.054}$
Kaohsiung: $W_t=524.035\ (1-e^{-0.302(t+2.326)})^{1.289}$

TABLE 3
Mean calculated fork length at the time of ring formation

Nanfangao				
Ring group	No. of specimens	Calculated fork length (mm)		
		L_1	L_2	L_3
I	429	218.653		
II	79	208.641	256.834	
III	3	211.910	266.925	304.514
Average		213.068	261.879	304.514

Kaohsiung				
Ring group	No. of specimens	Calculated fork length (mm)		
		L_1	L_2	L_3
I	356	251.523		
II	320	242.824	281.689	
III	24	248.354	288.094	312.491
Average		247.567	284.892	312.491

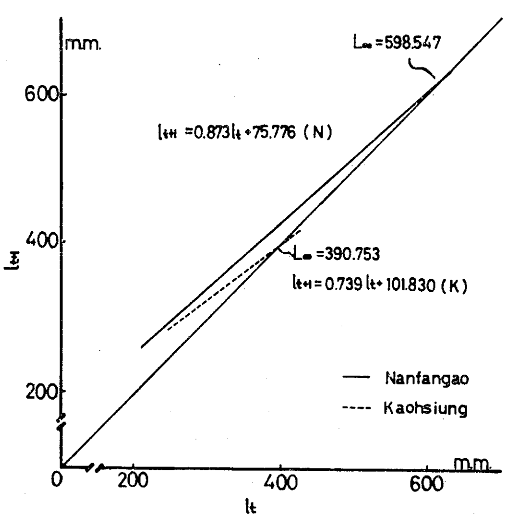


Fig. 8. Ford-Walford Plot.

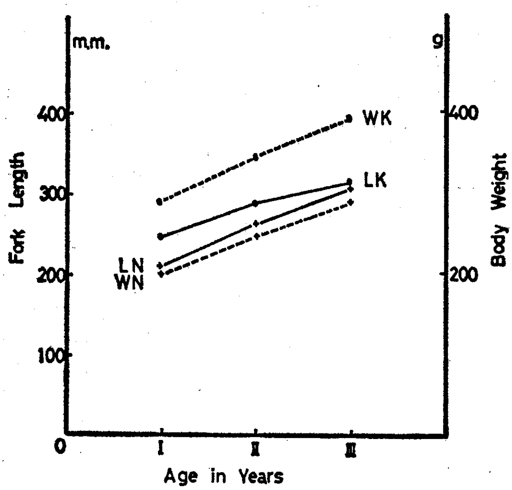


Fig. 9. Growth curves for red scads.
WN: in body weight, of Nanfangao
WK: in body weight, of Kaohsiung
LN: in fork length, of Nanfangao
LK: in fork length, of Kaohsiung

From these equations the growth curves of the two areas in length and in weight were drawn in Fig. 9.

5. The fit of the monthly modal lengths with the growth curves:

The spawning season of the red scad began in April(2), when many recruitments entered the population. So the growth curves drawn in accordance with months began with every April. The observed modal lengths of the samples were plotted into these curves. As indicated in Fig. 10 there came out a fair fit.

DISCUSSION

A previous paper from our laboratory has discussed the migration of red scads in Taiwan(2). They probably migrate northward from the spawning ground off Nanfangao, around the north end, and then come down along the west coast, southward to the nursery ground off

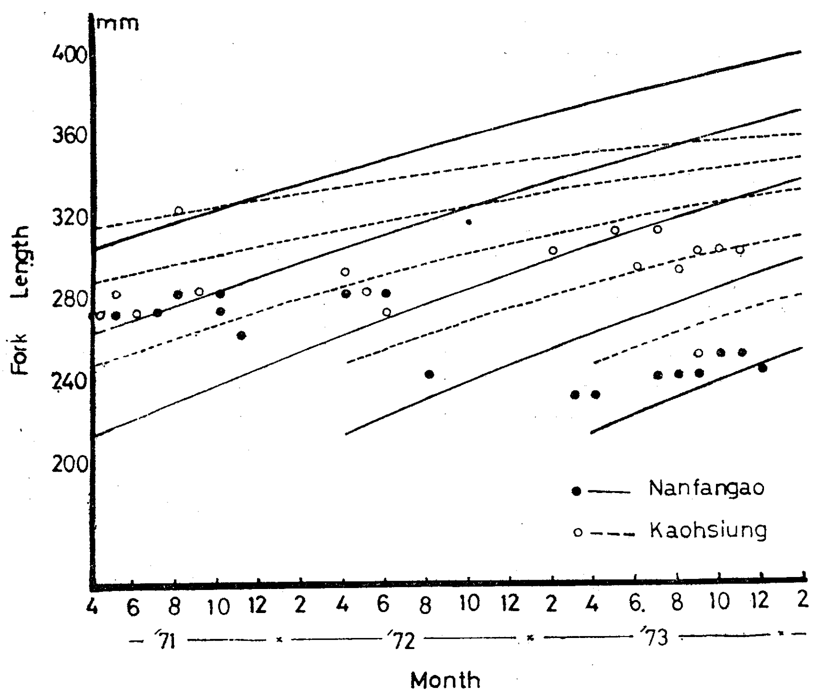


Fig. 10. The progression of the monthly modal length along the growth curve.

Kaohsiung. During the spawning season, the big fish may migrate around the south end to Nanfangan.

Of the samples from Nanfangao, except the two of May 1971 and June 1972, the age composition and the mean of fork length are noticeably smaller than those of samples from Kaohsiung. The growth in fork length of Nanfangao increases faster than that of Kaohsiung. The former was computed from the younger stock with addition of big fish from Kaohsiung. That elevated the slope of $l_{t+1}-l_t$ line (Fig. 8) and consquently delayed its intersection with the 45° diagonal to 598.547 mm. The asymptotic fork length 390.753 mm obtained from the samples of Kaohsiung is more reliable. However, the fork length at scale appearance is in favor of that obtained from the $R-L$ equation of Nanfangao, 53.983 mm.

The growth curves in body weight indicate that samples from Nanfangao are evidently inferior to those from Kaohsiung. This perhaps resulted from the fact that samples of the two areas are on the different growth stages. On the other hand, the more advantageous condition of the environment in the latter area, such as higher temperature and more food supply, may be another reason for that.

From the plot of the rate of marginal increment,

$$\alpha=\frac{R-r_t}{r_t-r_{t-1}}$$

against the month, the ring formation time could not be concluded. Othder related indicators described below did not show any real change during the whole year either.

1. Standard error of α: The new annual rings of some fishes may have not been formed at the ring formation time. The marginal increments have reached their peaks. The drop down of α was adjusted when a mean value was calculated. But an increased standard error should have existed under this condition.

2. Correspondence of the ring formation: Scales sampled at the ring formation time were likely separated into two groups. One of them has a new ring, which has not been formed in the other group. At this time there should be a low correlation coefficient of the $R-r_t$ regression line representing the poorly corresponding position of the ring.

3. Frequency distribution of fork length: The peak of the frequency distribution of fork length of an age group would diverge to each end at ring formation time. There were more small individuals, which just entered this age group, and big ones, which were ready to leave.

There are two hypotheses about the annual ring formation: one attributes it to the periodical changes of seasons, the other attributes it to an adaptive reconstruction of the course of metabolism within the fish body. If the first is true, no regular occurrence of ring formation time for red scads may be explained as follows: the short life span makes them grow rapidly and vary greatly among individuals, so, in length distribution, there should be no alternative periods of fast and slow growth. That is the direct cause of ring formation. It is not available to discuss the second hypothesis by reason of no information about other aspects at present. But according to it, in fish of different ages the ring formation time may occur in different seasons. The materials used in this study may be on a transitionary stage that ring formation can occur over a difficulty detected protracted period. But in Fig. 10 most modal lengths of Nanfangao are observed above the growth curves, so it is deduced that the ring formation occurs earlier than spawning season by a few months. Because the curve was derived from back calculation, its theoretical start should be the ring formation time. Yet in Fig. 10 it started at April, the beginning of the spawning season. A little late start of the curves makes the modal lengths above them. This deduction is not suitable for samples of Kaohsiung. It is perhaps related to their less changes during spawning season(2).

The growth curves of Nanfangao and Kaohsiung intersect each other near 320 mm and there are some modal lengths of Kaohsiung progress along the curves of Nanfangao during the spawning season. These conditions also indicate the mixture of stocks of the two areas by migration. Yet the complexity of the sample composition also affects the fit of observed modal lengths with growth curves, obscuring the characteristics of the population and stunting advanced analysis.

Acknowledgments: The study was a part of a project supported by the Joint Commission on Rural Reconstruction. The accomplishment is owed to the cooperation of the colleagues of the Laboratory of Fisheries Biology.

REFERENCES

1. Chang, K. H. and S. Chen (1972). The age and growth of red sea bream in Pescadores Island. Bull. Inst. Zool., Academia Sinica **11**(2): 11-19.
2. Chang, K. H. and J. C. Lee (1972). Study on the reproductive ecology of *Decapterus kurroides akaadsi* Abe, in the waters of Taiwan. Master Thesis. Dep. Zool. National Taiwan Univ.
3. Gulland, J. A. (1969). Manual of methods for fish stock assessment. Part I. Fish population analysis. F. A. O. Rome, 154pp.
4. Ricker, W. E. (1968). Methods for assessment of fish production in fresh waters. I. B. P. London, 313pp.

臺灣扁紅鰺之年齡與成長

張崑雄　邵一諾

此實驗爲藉鱗片判讀方法，探討臺灣近海扁紅鰺之年齡與成長。族羣分析以前，先以兩尾標本選擇採鱗部位及鱗徑測量之位置。內容包括鱗片之描述，年輪相似性及對應性之檢定，體長與體重之關係式，鱗長與體長之關係式，藉 Von Bertalanffy 方程式所得之成長曲線。並討論其極限體長 390.753 公厘，鱗片初生時之體長 53.983 公厘，年輪形成時間，以及每月份標本型量與成長曲線相配合的情形。