A THESIS

FOR THE DEGREE OF MASTER OF SCIENCE

AGE AND GROWTH OF THE JACK MACKEREL, *Tranchurus japonicus* (TEMMINCK et SCHLEGEL) CAUGHT WITH A SET NET ON THE COAST OF SHINYANG, CHEJU ISLAND

DEPARTMENT OF OCEANOGRAPHY

GRADUATE SCHOOL

CHEJU NATIONAL UNIVERSITY

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1992. 12.

新陽沿岸定置網에서 漁獲된 전갱이의 年齡과 成長

指導敎授 高 有 峰

孫 明 浩

이 論文을 理學 碩士學位 論文으로 提出함.

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AGE AND GROWTH OF THE JACK MACKEREL, *Tranchurus japonicus* (TEMMINCK et SCHLEGEL) CAUGHT WITH A SET NET ON THE COAST OF SHINYANG, CHEJU ISLAND.

Myoung-Ho Sohn

(Supervised by Professor You-Bong Go)

A THESIS SUBMITTED IN PARTIAL FULFILLMENT

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SUMMARY

Age and growth of the Jack Mackerel, *Tranchurus japonicus* (TEMMINCK et SCHLEGEL) have been studied with the data of 808 samples, which are obtained by the set net on the coast of Shinyang, Cheju Island during Feburary to November 1987.

The annual ring is defined as the outer margin of each opaque zone of otolith. It is analyzed by monthly change of marginal increment of otolith, which is formed once a year from May through June.

According to the monthly change of fatness condition, the peak of spawning was occurred from June to August.

The relationship between standard length (SL in mm) and otolith radius (OR in mm) is represented by the following equation.

$SL = -15.379 + 56.685 \times OR$ ($r^2 = 0.955$)

The relationship between standard length and body weight (W in gr.) is given by the following equation.

$W = 2.710\ SL^{2.897} \times 10^{-5}$ ($r^2 = 0.981$)

Applied to the von Bertalanffy's growth equation for length, the relationship between the standard length (mm) and the age (t) is represented by the following equation.

$L_t = 305.9[1-e^{-0.251(t+0.6627)}]$

Therefore, the standard length of full one year to four years is calculated as 104.4, 149.1, 183.9 and 211.0 mm, respectively.

The result applied to the von Bertalanffy's growth equation for body weight is as follow.

$W_t = 441.6[1-e^{-0.251(t+0.6627)}]^3$.

The body weight at age of 1 - 4 is 17.5, 51.1, 96.0 and 144.9 gr., respectively.

Ⅰ. INTRODUCTION

As the technics and equipments for fishing have been developed, the amount of fishery resources has decreased. In order to maintain maximum yield through the reasonable use, it is necessary that ecological dynamic rules should be determined. It requires that growth rate, mortality rate, reproduction and population size in relation to numerical dynamics are first examined from population dynamics point of view to investigate these rules (Zhang, 1991).

The Jack Mackerel (*Tranchurus japonicus*, TEMMINCK et SCHLEGEL) belongs to the Carangidae family and Trachurus genus. This species is a fusiform with long and thin body and its total length is about 40 cm (Chyung, 1973). It inhabits all the coastal areas of Korea and the southern parts of Japan. However, it is almost caught around Cheju Island in recent years (Ann, 1973). This species is temperate migration fish, which goes to the north in summer and spring, and to the south in fall and winter. It inhabits mainly in the pelagic zone when young and mid-water zone when mature (Sasaki, 1970).

The Jack Mackerel is an important coastal fishing resources of the south sea of Korea. Most of them are caught through a steamboat purse seine and extremely small amount is caught through a set net, drift gill net and steamboat ottor trawl. The catch was greatly decreased from maximum 48000 M/T in 1958 to minimum 883 M/T in 1973 and the yield per unit effort is decreasing every year.

Up to now, the researches have been performed on the ecological character of fisheries resources and population dynamics (Moore, 1951; Pitt, 1967;

Bailey, 1972; Donald, 1974; Ricker, 1975; Doyle *et al.*, 1987; Schunte *et al.*, 1989; Radtke *et al.*, 1990), population estimation (Walter, 1977; Towes *et al.*, 1979; Pauly, 1982; Schunte, 1984; Healey, 1984; Lawson *et al.*, 1984; Deriso *et al.*, 1985; Welch, 1985; Reed, 1986) and population management (Maclean *et al.*, 1981; Smith *et al.*, 1981; Pikitch, 1987; Murawski *et al.*, 1989). In Korea, some studies have been fulfilled in a several fishes on the population dunamics (Go *et al.*, 1983; Kang *et al.*, 1983; Choi *et al.*, 1988; Huh *et al.*, 1989), population estimation and management (Lee, 1976; Lee, 1977; Kim *et al.*, 1989; Kim *et al.*, 1990).

Many papers have been reported on the growth and age of Jack Mackerel around Japan by the vertebral bone (Aikawa *et al.*, 1949), scale (Muraue *et al.*, 1949; Marukawa *et al.*, 1949; Mitsuta, 1957; Mitani *et al.*, 1958) and otolith (Mitsuhuchi *et al.*, 1958; Mitani *et al.*, 1964). However, they still show the differences between resesrchers on the fitness of age character, growth rate, ring formation time and ring formation number (Ann, 1973).

Though some papers were reported on the systematical study (Ann, 1970), reproduction and maturity (Lee, 1970), ecological characteristics (Kim, 1960; Lee *et al.*, 1965) and age - growth relationship (Ann, 1973) of the Jack Mackerel at the coastal area of Korea, it has been little known on the population dynamics and the ecological characteristics of this species.

This study puts stress on the growth and age to analyse the estimation of population dynamics, management, maximum sustainable yield on the Jack Mackerel caught with the set net at the eastern area of Cheju Island.

Ⅱ. MATERIALS AND METHODS

1. Study area

In this study, samples were collected with a set net (mesh size: 27.6 mm x 27.6 mm) at Shinyang in the eastern parts of Cheju Island from Feburary to November 1987.

This average depth of this area is about 15 m. The sampling site is shown in Fig. 1.

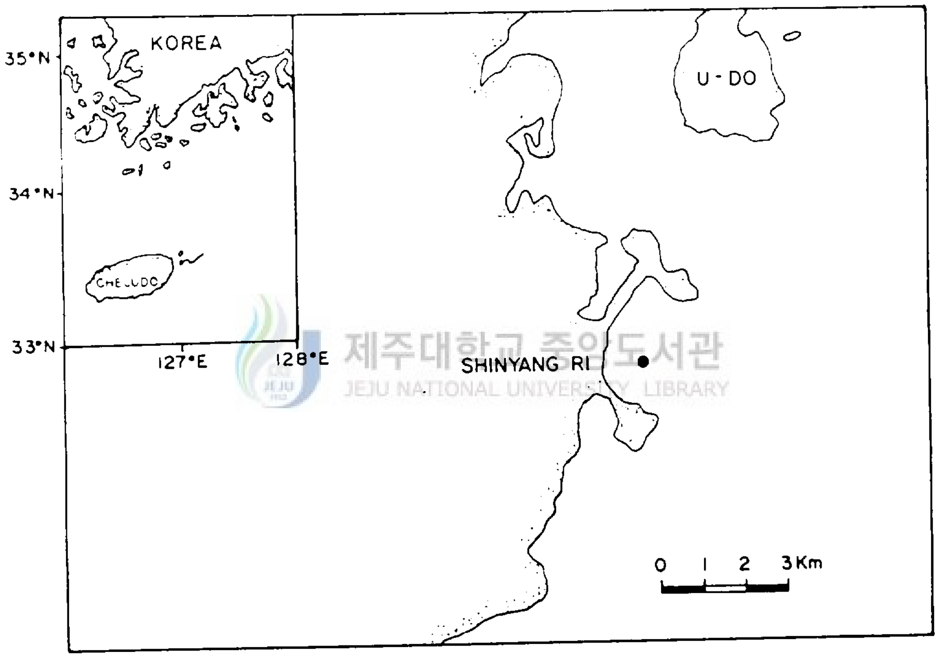

Fig. 1. Map showing the sampling site in Cheju Island.

2. Collecting samples and preparations

The 808 samples were randomly collected from Feburary to November 1987.

Otoliths were extracted to age from 808 specimens by Bückmann's (1929) method. The number of samples and sampling months were shown in Table.1.

The body weight was measured to the nearest 0.1 g and the standard length (SL) was measured to the nearest 1 mm. Among the Sagitta, Asteriscus and Lapillus in the inner ear of fish, Sagitta is generally treated as otolith (Pannella, 1971, 1980; Brothers *et al*, 1976). Otoliths were stored in vials after being removed organic matter with 80 % ethyl alcohol and dried.

The convex side of otolith was ground with grind podwer in the order of #400, #600, #800 and the otolith with partially unclear ring was treated with 5 % HCl solution. The otolith, immersed in distilled water on black cavity slider, was examined by tne dissective microscope (Olympus,SZ-ST) with a magnification of 30x. Otolith radii (OR) were measured from focus to the longest posterior margin by 0.1 mm unit. Annual rings (r_n) were measured from focus to the outer margin of opaque zone by 0.1 mm using ocular micrometer (Fig.2).

Ages were determined by dissective microscope after that the surface of otolith was moistened with 95 % ethyl alcohol and the opaque zones were regarded as a annual rings.

3. Estimation of spawning season

The otoliths with more than 2 rings were extracted and then the fatness condition was calculated by standard length and weight. And the monthly change of fatness condition was investigated. It is regarded as the spawning season that the fatness condition is decreased sharply.

The Fatness Condition (FC) (Spencer, 1871; Hile, 1936; Kasahasa, 1955) is given by following equation.

$$FC = (W/SL^3) \times 10^3$$

W : body weight (g)

SL : standard length (mm)

Table.1. Fishing date, locality and number of samples.

Location	Date of catch	N.of samples
Shinyang	1987.2.14	30
	4.24	45
	5.13	80
	6.12	203
	7.25	60
	8.11	115
	9.24	154
	10.14	42
	11.24	79
Total		808

4. Calculation of the growth equation

Beverton and Holt (1957) showed that it is useful to discribe the growth of a particular species in mathematical terms for certain problems in population dynamics. The most widely accepted expression in recent years is that of von Bertalanffy (1938) (Stephen, 1974; Cloern *et al.*, 1978):

$L_t = L_\infty[1 - e^{-K(t-t_0)}]$: The growth equation for length

$W_t = W_\infty[1 - e^{-k(t-t_0)}]^3$: The growth equation for weight

- W_t : weigth at age t (in year)
- W_∞ : theoretical maximum weight
- L_t : length at age t (in year)
- L_∞ : theoretical maximum length
- K : constant expressing the rate of change in the length increments with respect to t
- t : age
- t_0 : hypothetical age at zero length

The parameters - W_∞, L_∞, K, t_0 - in these growth equations have been estimated from Walford's plot and calculated from length-weight relationship.

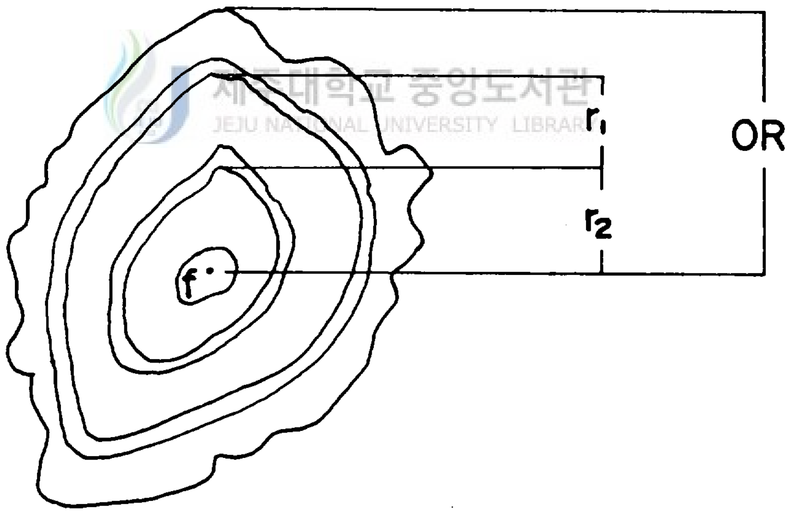

Fig. 2. Showing the measurement method of otolith and annual ring radius.

OR:otolith radius, r_n:ring radius, f:focus

5. Analysis of data

Data and regression analysis were treated by the SPSS/PC+ (Norusis, 1986) statistics program.

The regression equation by the least square method between otolith radius and length has linear relationship as follow.

$$SL = a + b \times OR$$

SL : standard length (mm)

OR : otolith radius (mm)

a, b : constants

The back-calculated length of ring formation time in year-classes has been estimated with above regression equation. The regression equation between L_{t+1} and L_t by the least square method was given by following equation using Walford's plot (1946).

$$L_{t+1} = a + b \times L_t$$

L_{t+1} : length (mm) at age t+1

L_t : length (mm) at age t

a, b : constants

The parameters - L_∞, K, t_0 - were estimated using these regression equation and the growth equation for length.

Ⅲ. RESULTS

1. Distribution of temperature and salinity

The sampling site is located at the eastern parts of Cheju Island (Fig.1). The set net located about 800 m away from the beach and about 15 m deep. The temperature and salinity distributions were measured with surface water of sampling site (Fig.3, Table.2).

Table.2. Monthly variations of temperature and salinity in sampling site from Feburary to November 1987.

Month	Temperature(℃)	Salinity(‰)
1987.2	13.7	34.957
3	14.3	34.848
4	14.2	34.373
5	15.9	33.469
6	17.9	33.553
7	21.8	33.062
8	24.2	32.249
9	23.5	32.701
10	20.4	32.899
11	15.5	34.578

The temperature varied from the lowest 13.7 ℃ at Feburary to the highest 24.2 ℃ at September and the difference was 10.5 ℃.

The salinity varied from the lowest 32.249 ‰ at August to the highest

34.957 ‰ at Feburary and the difference was 2.712 ‰. It showed that the variations of temperature and salinity were greatly affected by the season.

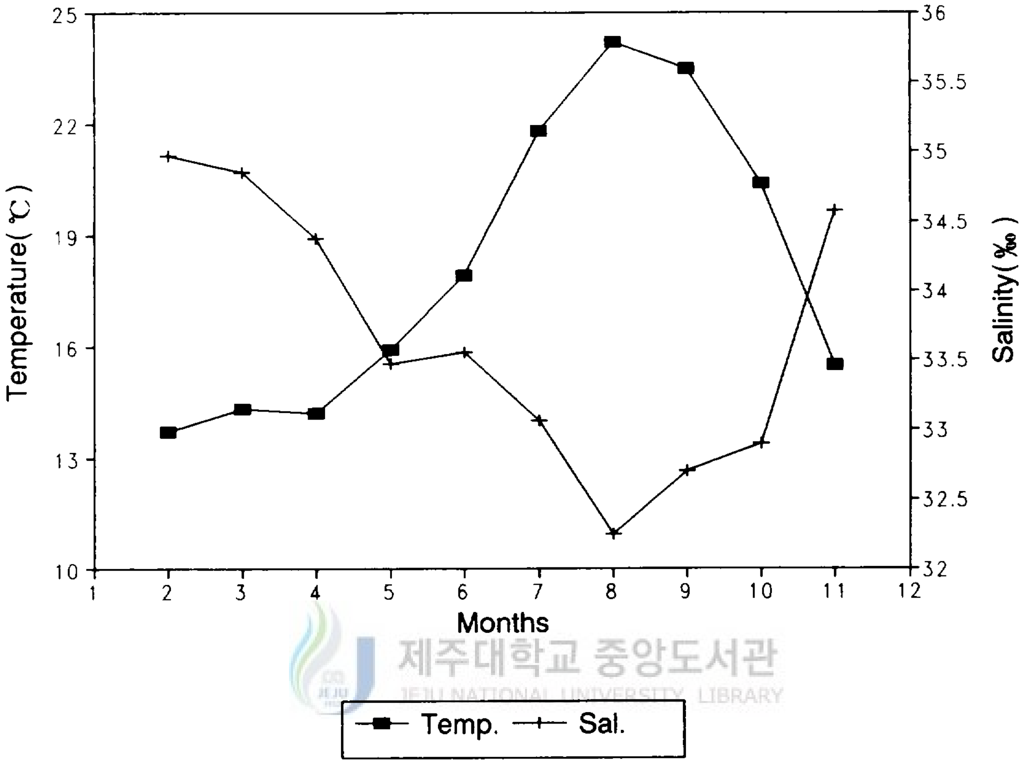

Fig.3. Monthly variations in surface water temperature and salinity of the sampling site from Feburary to November 1987.

2. Variation of length - weight distribution

The total 808 samples were represented as following table to analyze the monthly change of standard length and body weight (Table.3, Fig.4,5).

1) Variation of length distribution

The standard length collected at Feburary was 166.0±2.56 mm (M±S.E., n=30) and the length range was from the smallest 137.0 mm to the largest 194.0 mm. The standard length sampled at April was 119.7±5.86 mm (n=45), and the standard length distributions of May, June and July showed a decreasing trend with 119.3±3.30 mm (n=80), 170.6±4.72 mm (n=203) and 99.5±1.50 mm (n=60), respectively. The standard length variations of August, September, October and November showed a increasing trend with 123.8±2.75 mm (n=115), 129.3±1.68 mm (n=154), 138.9±1.25 mm (n=42) and 164.3±1.97 mm (n=79), respectively (Fig.4).

During these months, except for June, the decreasing and increasing trends of standard length appeared clearly. It was inferred that these trends were mainly caused by not the variation of standard length in general but the catch of small fishes by set net fishery characteristics (Lee *et al.*, 1988). The range of standard length at June was more widely distributed and higher than other months, which was probably caused by the catch of large fishes.

2) Variation of weight distribution

Fig.5 represented the variation of mean weight distribution range at the sampling month.

The body weight was 74.9±20.3 g (m±s.d., n=30), 34.9±19.7 g (n=45), 29.5±11.5 g (n=80), 111.5±81.2 g (n=203) and 18.0±8.1 g (n=60) at Feburary, April, May, June and July, respectively. And the body weights were 37.4±34.3 g (n=115), 36.7±23.3 g (n=154), 42.2±8.5 g (n=42) and 71.8±23.3 g (n=79) at August, September, October and November, respectively. The monthly variation of body weight showed same trend with the standard length variation. This was also caused by the characteristics of the set net fishery. The range of body weight was widely distributed at June, it considered that this was also resulted from the catch of large fishes.

Table.3. Summary of changes in standard length and body weight collected in the sampling site.
SL:standard length(mm), W:body weight(g), N:N.of samples
M:mean, S.E:standard error

Sampling Month	N	SL(mm)		W(g)	
		M	S.E.	M	S.E.
'87.2	30	166.0	2.56	74.9	3.71
4	45	119.7	5.86	34.9	2.94
5	80	119.3	3.30	29.5	1.29
6	203	170.6	4.72	111.5	5.70
7	60	99.5	1.50	18.0	1.05
8	115	123.8	2.75	37.4	3.20
9	154	129.6	1.68	36.7	1.88
10	42	138.9	1.25	42.2	1.31
11	79	164.3	1.97	71.8	2.62

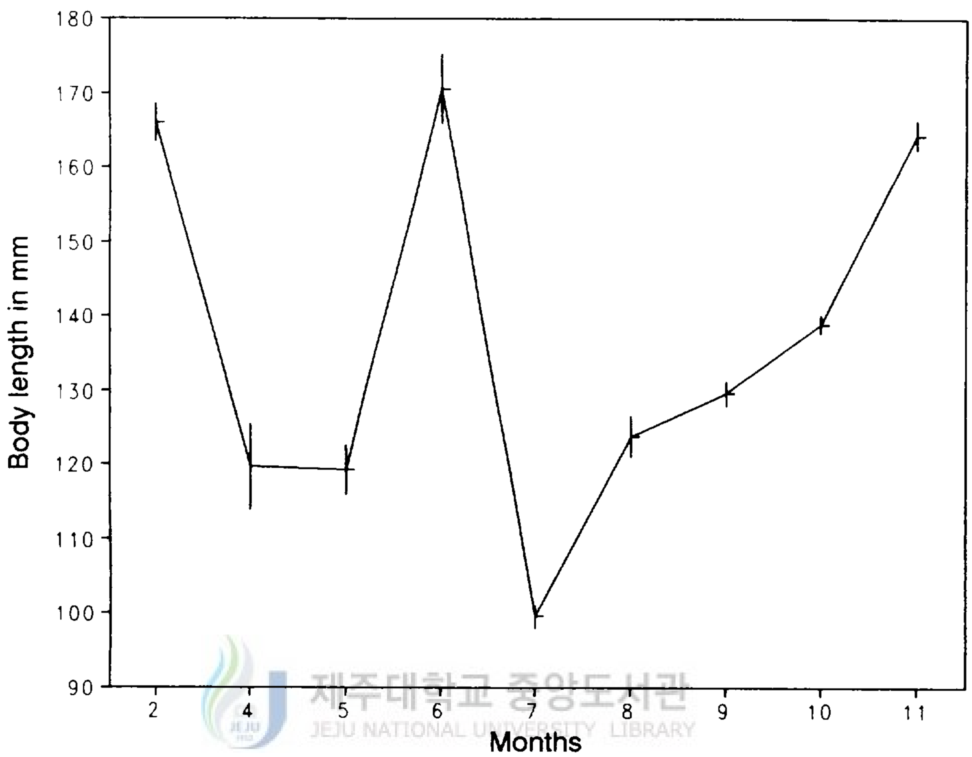

Fig. 4. Plots of the mean standard length(+) and its standard error (vertical bar) of *T. japonicus* collected in sampling site.

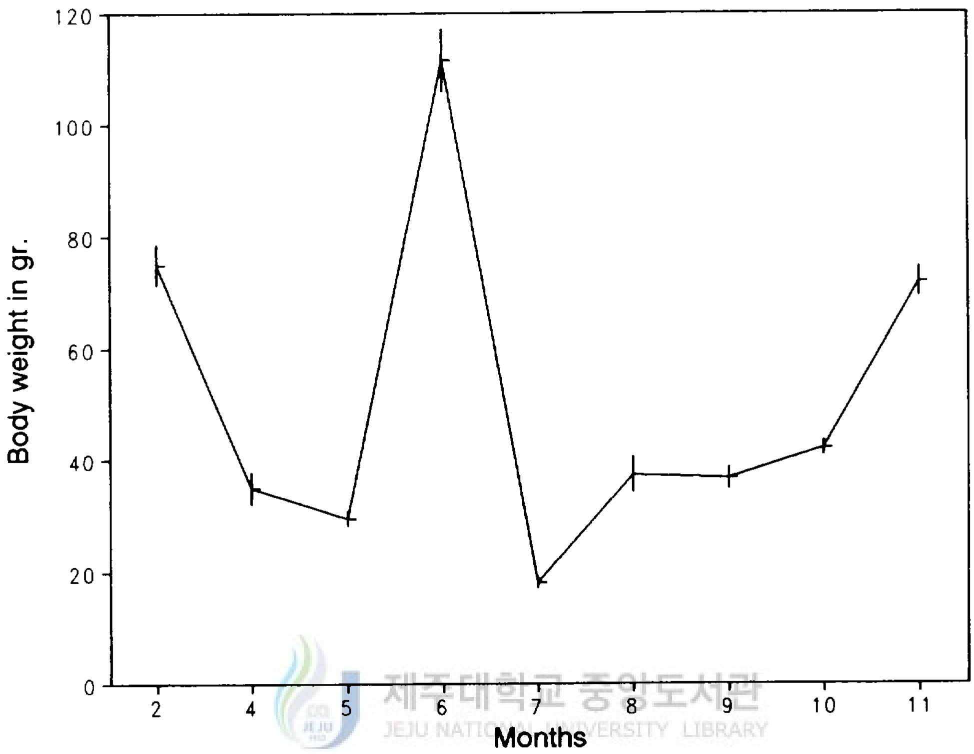

Fig. 5. Plots of the mean body weight(+) and its standard error (vertical bar) of *T. japonicus* collected in sampling site.

3. Relationship among age structure, otolith radius (OR) and ring radius (r_n)

The otolith of Jack Mackerel is a medium size, an oval type and has thicker focus than otolith edge. The otolith is a bipartite structure, usually formed once a year, consisting of incremental and discontinuous zones. When viewed with a dissective microscope, the incremental zone appears as a board, opaque while the discontinuous zone is relatively narrow and translucent band (Blacker, 1974; Compana and Neilson, 1985).

Generally, the large otolith has large ring radius and small otolith has small ring radius. In consequence, the ring radius of otolith is formed with relation to the fish size (Blacker, 1974). If we considered that the length between focus and ring radius was coped with the otolith size, it was inferred that ring radius was faced with fish size (Hickling, 1933; Trout, 1954).

Among the 808 total samples, 388 (48.0 %), 293 (36.3 %), 99 (12.3 %) and 28 (3.4 %) specimens were aged clearly, able to be aged, not read and broken during the grinding, respectively (Table. 4).

Table. 4. Otolith readability

(%)

Good	Readable	Difficult	Broken	Total
388 (48.0)	293 (36.3)	99 (12.3)	28 (3.4)	808 (100)

1) Age structure of otoliths

Among the 576 samples which were able to be aged, the ages, except for 0-age group, were 360 (62.5 %), 161 (28.0 %), 47 (2.8 %) and 8 (1.4 %) at the Ⅰ, Ⅱ, Ⅲ and Ⅳ-age group, respectively (Table.5).

Table.5. Number of samples and percentages for observed length and weight ranges by age.

Age	Range of L(mm)	Range of W(g)	No.of samples	%
Ⅰ	90.0-230.0	11.0-173.5	360	62.5
Ⅱ	99.0-252.0	12.4-240.0	161	28.0
Ⅲ	125.0-248.0	29.1-236.1	47	8.1
Ⅳ	179.0-237.0	94.2-227.7	8	1.4

2) Relationship between otolith radius and length

The relationship between otolith radius and standard length was estimated using the mean otolith radius with the 10 mm interval of 780 not broken samples (Table.6).

The regression equation by least square method using Table 6.'s data was represented by following equation (Fig.6).

$SL = -15.379 + 56.685 \times OR \quad (r^2 = 0.955)$

SL : standard length (mm), OR : otolith radius (mm)

Table.6. Summary of standard length and otolith radius by the length class.
N:N.of samples, SL:standard length, OR:otolith radius

Class(mm)	N	SL(mm)	OR(mm)
40-49	1	49.0	0.933
50-59	14	56.0	1.286
60-69	27	64.9	1.521
70-79	15	75.9	1.505
80-89	23	85.8	1.788
90-99	53	95.2	2.182
100-109	71	104.9	2.408
110-119	34	113.4	2.472
120-129	78	125.0	2.704
130-139	99	134.5	2.858
140-149	80	144.2	3.056
150-159	34	153.6	2.928
160-169	29	165.5	2.798
170-179	54	174.4	2.875
180-189	24	182.5	3.249
190-199	22	194.2	3.447
200-209	17	209.0	4.200
210-219	21	214.9	4.384
220-229	47	224.2	4.365
230-239	26	233.0	4.348
240-249	9	243.2	4.378
250-259	2	251.0	4.400

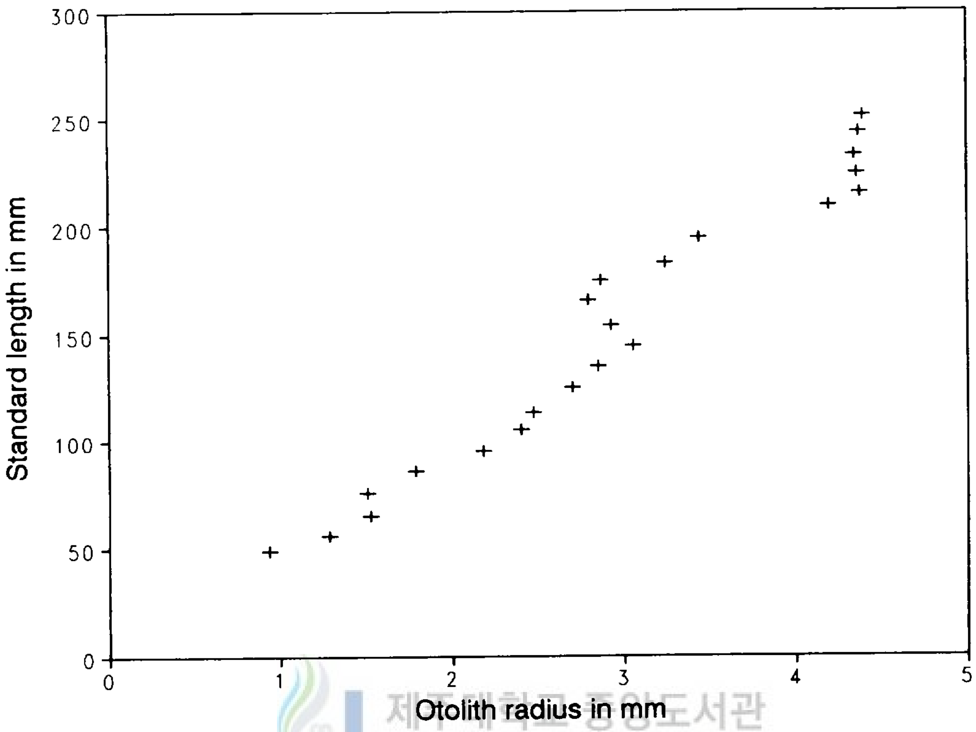

Fig. 6. Relationship between otolith radius and standard length.

3) Validation of ring formation

The relationship between otolith radius and ring radius was plotted with each ring group to validate age determination. The ring radius of each ring groups showed a liner regression equation with positive relationship. From this relationship, there was similarity between otolith radius and ring radius (Fig. 7).

4. Estimation of ring formation time

In order to estimate formation time and regularity of ring, it was plotted that the the monthly variation of the marginal increment of the second ring group which considered mature and had many samples relatively (Kim, 1978). And the monthly composition of hyaline and opaque zone of the otolith edge was investigated to revalidate of ring formation time.

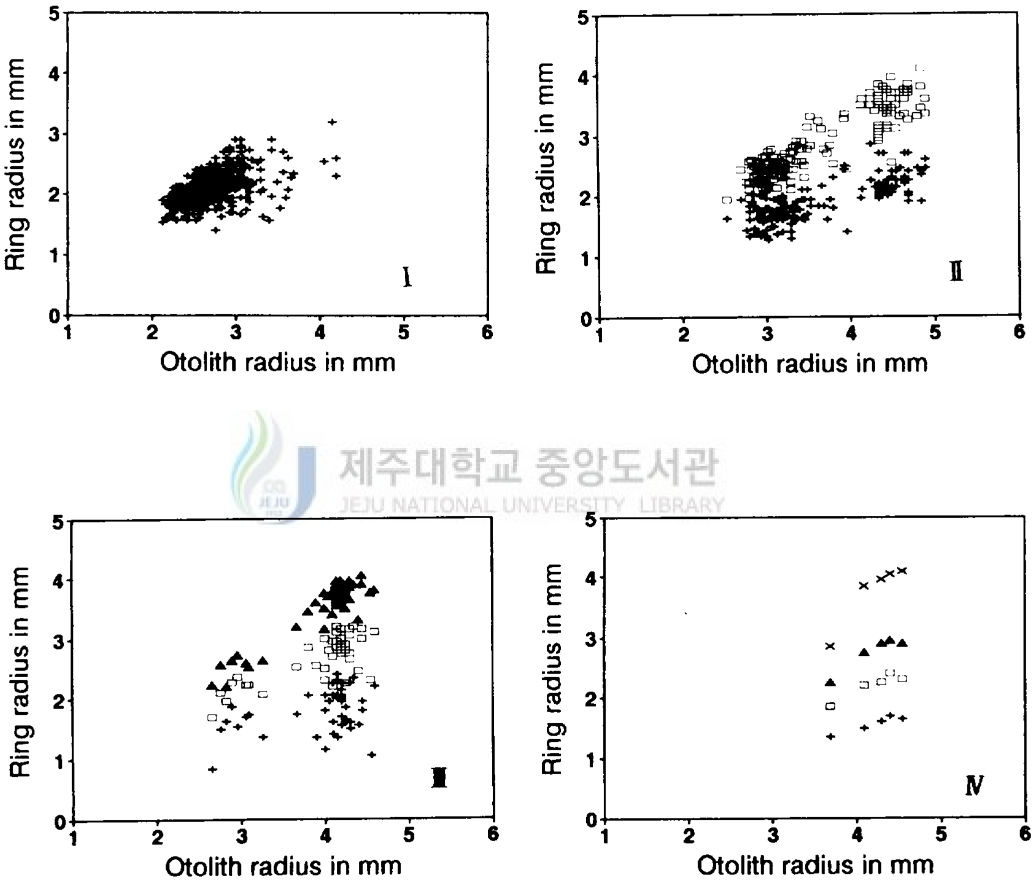

Fig.7. Relationship between the radius of otolith(OR) and ring(r_n).

1) Interpretation of otolith edges

As the method of ring formation time estimation, the monthly composition of hyaline and opaque zone of the otolith edge at the sampling month was determined (Table. 7).

Table.7. Monthly changes in percentage composition of the marginal state of samples.

Date	No. of Hyaline	No. of Opaque	% Hyaline	% Opaque
1987.2	22	8	73.3	26.7
4	39	6	86.7	13.3
5	20	60	25.0	75.0
6	24	191	5.9	94.1
7	2	58	3.3	96.7
8	47	68	40.9	59.1
9	138	16	89.6	10.4
10	36	6	85.7	14.3
11	69	10	87.3	12.7

The rate of opaque zone showed a similar level from September to April and increased from May to June and had the highest rate 96.7 % at July. Consequently, it could be estimated that the ring formation time was mainly from May to July.

2) Analysis of marginal increments

The marginal increment (M.I) was calculated by following equation to estimate ring formation time of otolith which shows similarity between fish size and rings.

$$M.I = (R-r_n)/(r_n-r_{n-1})$$

The monthly variation of marginal increment was represented using the second ring group which is considered relatively mature (Table.8, Fig.8).

The marginal increment was very high from May to July with 0.935, 0.963 and 0.994, respectively and decreased from July to September as much as 0.693 at September. It was estimated that the opaque zone began to form after August from these results.

Table.8. Monthly changes of marginal increment of otolith.

Month	$(R-r_2)/(r_2-r_1)$
'87. 2	0.805
4	0.833
5	0.935
6	0.963
7	0.994
8	0.870
9	0.693
10	0.896
11	0.902

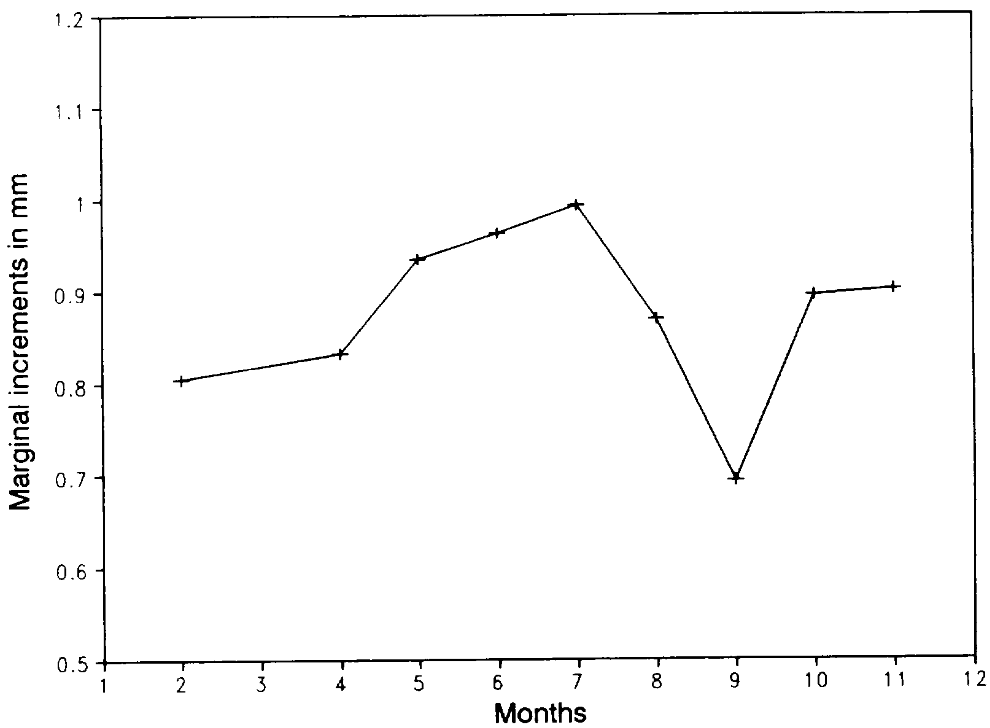

Fig. 8. Monthly changes marginal increment of otolith on the second ring group. The M.I. was given by $(R-r_n)/(r_n-r_{n-1})$.

It is estimated that the peak ring formation time is from May to July which had relatively high marginal increment value compared with other months. On the other hand, there was a high mode with 0.902 at November. It wasn't certain whether it caused by measurement error or mixing with other population.

5. Correction of Lee's phenomenon

The average value and standard deviation of each ring radius were calculated and represented at each age group to validate Lee's phenomenon

(Table.9). And when the distribution of ring radius was plotted with ring number group (Fig.9), the position of each ring was distinguished distinctly.

Table. 9. Average value and standard deviation of ring radius in each ring group.

Ring Group	No. of samples	Ring radius in mm			
		r_1	r_2	r_3	r_4
I	360	2.108 (0.272)			
II	161	1.914 (0.333)	2.856 (0.564)		
III	47	1.803 (0.361)	2.698 (0.371)	3.472 (0.484)	
IV	8	1.613 (0.122)	2.288 (0.190)	2.875 (0.272)	3.988 (0.489)

When the average ring radius of each ring was plotted with ring number group, each point was represented almost linear and the ring radius became smaller as the ring number increased (Fig.10). In other words, the Lee's phenomenon that the ring radii become smaller as the fish grow older in otolith was shown dictinctly.

After the ring radius was corrected by the linear regression equation of each ring group, the ring radius of each age was determined with the ring radius (r_n) of outermost margin (Table.10).

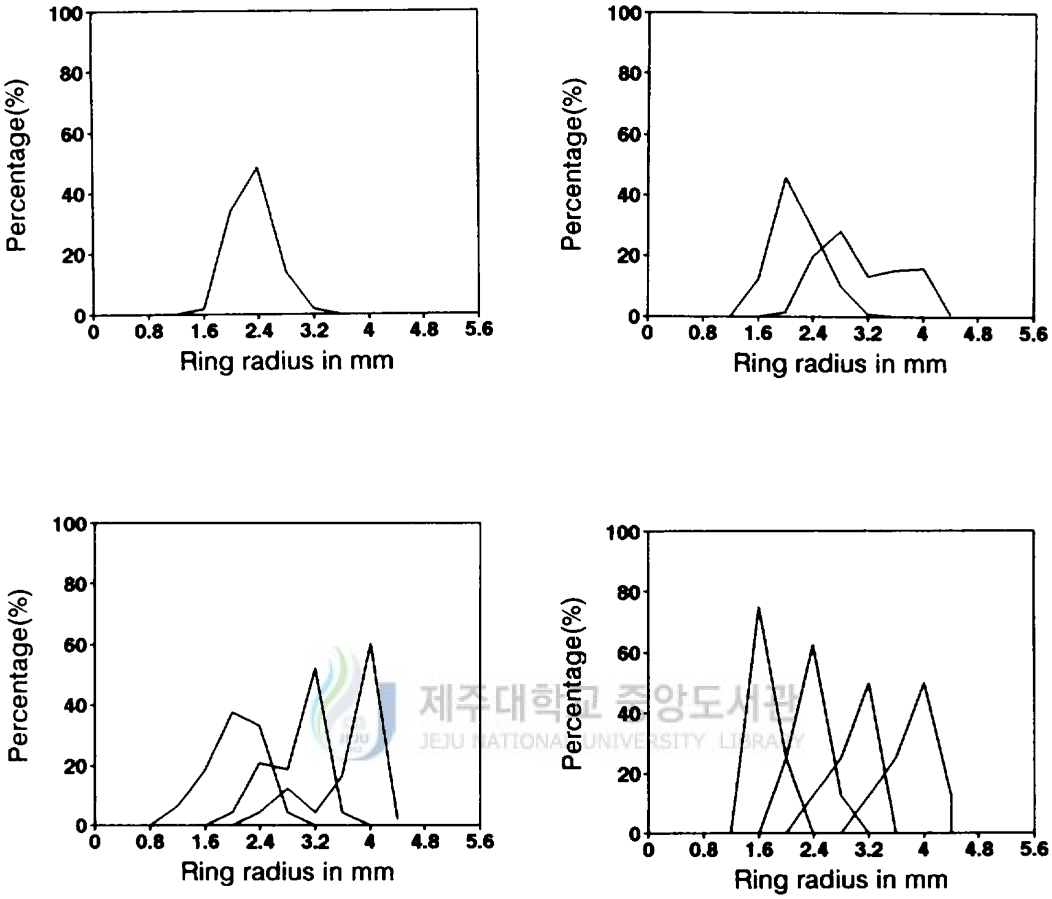

Fig. 9. Composition of otolith radii for each annual ring group(r_1-r_4).

Table.10. Corrected ring radius(mm) of otolith at the ring formation time.

r_1	r_2	r_3	r_4
2.100	2.912	3.472	3.988

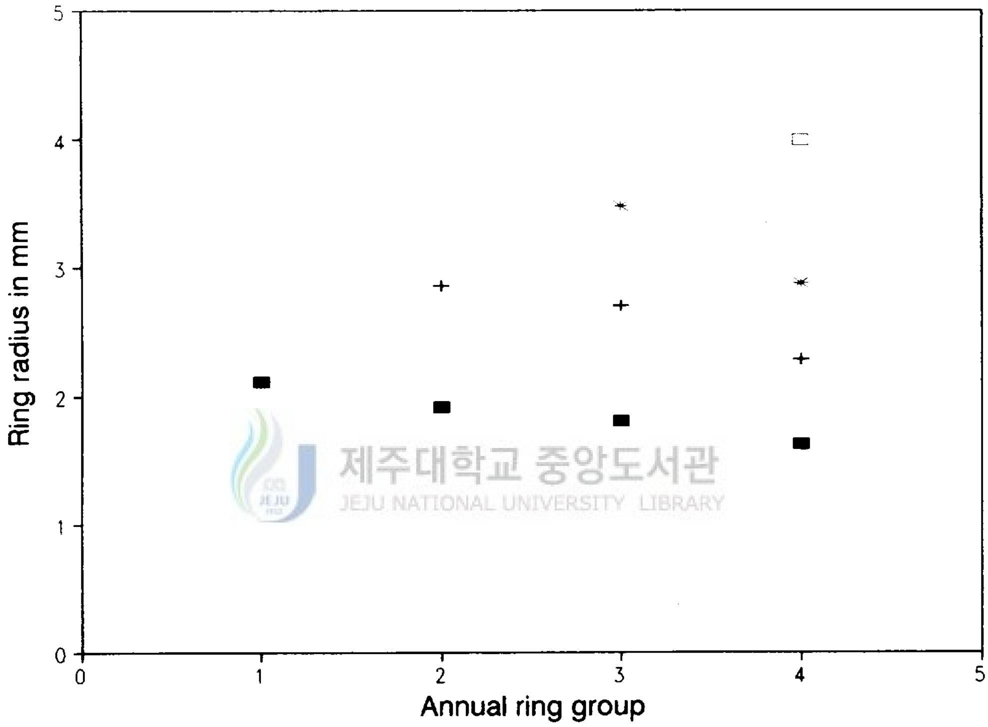

Fig.10. Showing Lee's phenomenon observed on otolith for each annual ring group.

6. Back-calculated length of ring formation time

The back-calculated standard length of ring formation time was estimated by following equation,

$$SL = -15.379 + 56.685 \times OR \quad (r^2 = 0.955)$$

and the back-calculated standard length at the each ring radius was represented as follow (table.11).

Table.11. Back-calculated standard length(mm) at the ring formation time.

L_1	L_2	L_3	L_4
103.7	149.7	181.5	210.7

7. Estimation of spawning season

It was estimated that the opaque zone was formed from May to July. But the required time to form the first ring could not be considered exactly one year. The exact age of the first ring formation time was necessary to determine the age at zero weight that one of the parameters in von Bertalanffy's growth equation. The exact age of it was the time that taken from spawning to the first ring formation. Generally, it was known that the ring was formed just before spawning season (Trout, 1954; Irie, 1960), in consequence the spawning season was estimated to compare with ring formation time measured formerly.

Among the samples, otoliths having more than 2 rings were extracted and the fatness condition was calculated from standard length and weight. The monthly change of fatness condition was represented (Fig.11). The fatness condition had a high value from May to June. It began to decrease from June to September and increase from September to Feburary, but, during these periods, it showed low value through the year. Therefore, the spawning season could be determined from June to August.

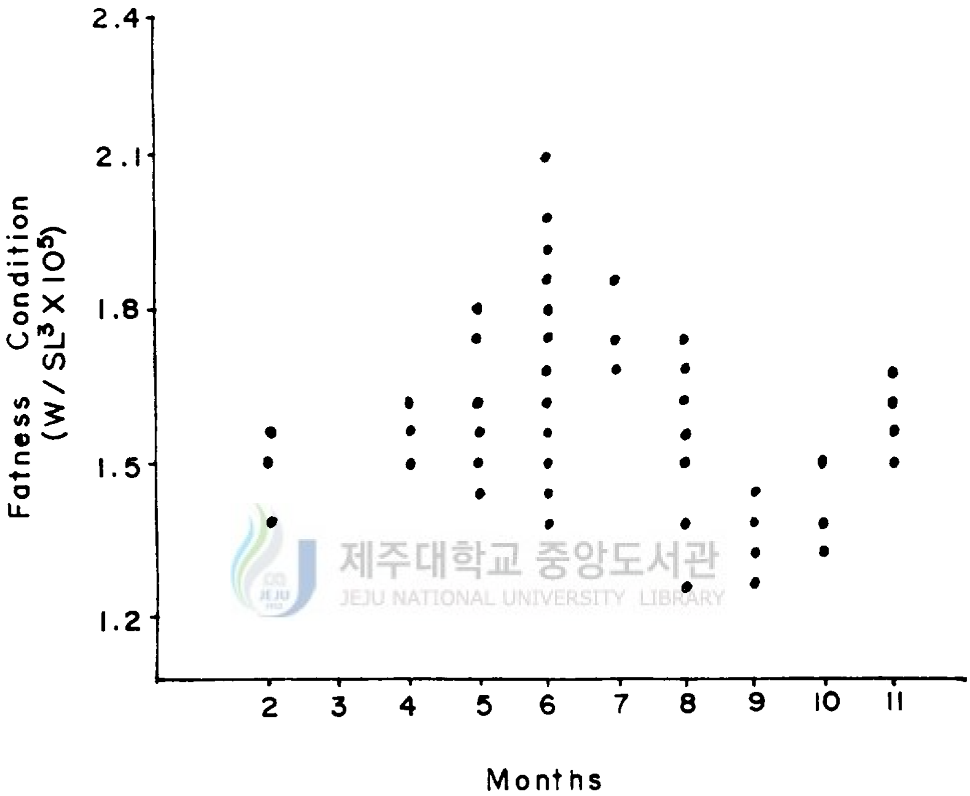

Fig. 11. Monthly changes of fatness condition in *T. japonicus* from sampling site.

8. Relationship between standard length and body weight

The relative growth relationship of fish is very important both distinction of population and estimation of age composition and spawning season.

Generally, the relative growth of length and weight can be represented by allometric equation as follow (Tesch, 1968).

$$Y = AX^{B} \quad (\log y = \log A + B \log x)$$

Here, A and B are constants, the constant B has approximately 3 in fishes but the constant A varys with body type of fishes (Kim, 1977).

Among 808 samples measured length and weight, except for 0-age group, the relationship between length and weight was estimated with regression equation by least square method on the 644 samples (length range 90-252 mm, weight range 13.6-237.8 g) (Fig.12).

$$W = 2.710\ SL^{2.897} \times 10^{-5} \quad (r^2 = 0.981)$$

W : body weight (g)

SL : standard length (mm)

Using this equation, the body weight at each age was back-calculated as follows (Table.12).

Table.12. Back-calculated weight by the relationship between body weight and standard length in each ring group.

(g)

Age	I	II	III	IV
W_t	18.7	54.3	94.7	146.1

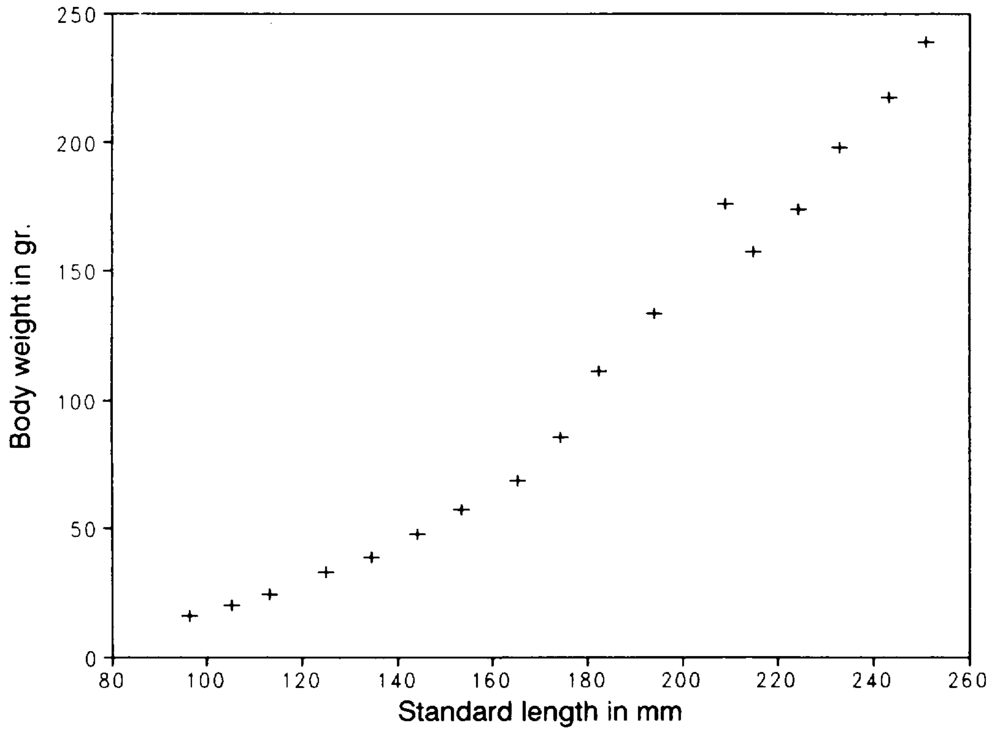

Fig. 12. The relationship between body weight and standard length.

9. Estimation of von Bertalanffy's growth equation

Lee (1970) reported that the spawning season of this species which is migrating to the Korean coastal sea is June-August. Compared it with the ring formation time May-July in this paper, the ring was formed one by one almost a year. Therefore, each ring number represented each age.

1) The von Bertalanffy's growth equation for length

Using the back-calculated standard length at ring formation time (table.11), the relationship between age and length could be represented as von Bertalanffy's (1938) growth equation for length.

The regression equation between L_{t+1} and L_t (Table.13) was calculated by least square method with the Walford's plot (1946) (Fig.13).

Table.13. The relationship between L_t and L_{t+1} for the Walford's plot.

Age	L_t (mm)	L_{t+1} (mm)
Ⅰ	103.7	149.7
Ⅱ	149.7	181.5
Ⅲ	181.5	210.7

$$L_{t+1} = 67.9 + 0.778\ L_t$$

L_∞ and K were calculated by this regression equation.

$$L_\infty = 305.9\ (mm)$$

$$K = 0.251$$

The t_0 was calculated by $\ln(L_\infty - L_t) = (\ln L_\infty + kt_0) - kt$ using L_∞, K and the length of ring formation time.

$$t_0 = -\ 0.6627$$

Therefore, the relationship between age and length was estimated as following von Bertalanffy's growth equation (Fig.14).

$$L_t = 305.9\{1 - e^{-0.251(t+0.6627)}\}$$

t : age

L_t : length (mm) at age t

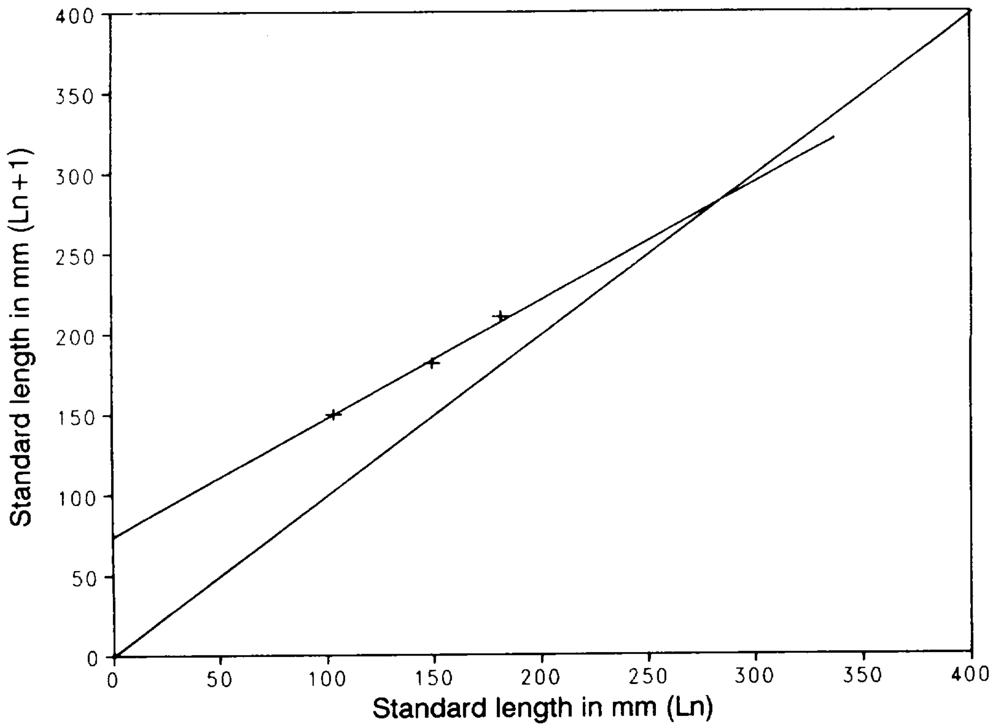

Fig. 13. Walford's plot of growth in calculated standard length.

The back-calculated length was estimated as follows by the von Bertalanffy's growth equation for length (Table. 14).

Table. 14. Back-calculated standard length by the Bertalanffy's growth equation. (mm)

Age	I	II	III	IV	∞
L_t	104.4	149.1	183.9	211.0	305.9

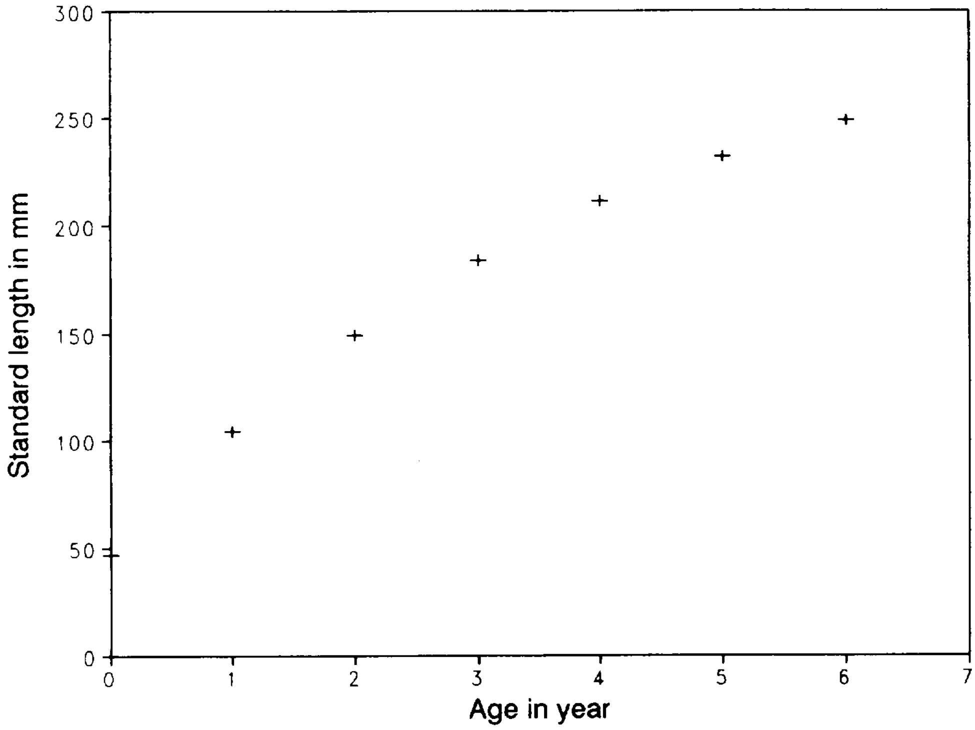

Fig. 14. Theoretical growth curve of standard length obtained by the Bertalanffy's growth equation.

2) The von Bertalanffy's growth equation for weight

The relationship between age and weight was estimated by following von Bertalanffy's growth equation (Fig. 15).

$$W_t = 441.6\{1-e^{-0.251(t+0.6627)}\}^3$$

t : age

W_t : weight (g) at age t

Using von Bertalanffy' growth equation for weight, the back-calculated weight was estimated as follows (Table. 15).

Table. 15. Back-calculated body weight by the Bertalanffy's growth equation.

(g)

Age	I	II	III	IV	∞
W_t	17.5	51.1	96.0	144.9	441.6

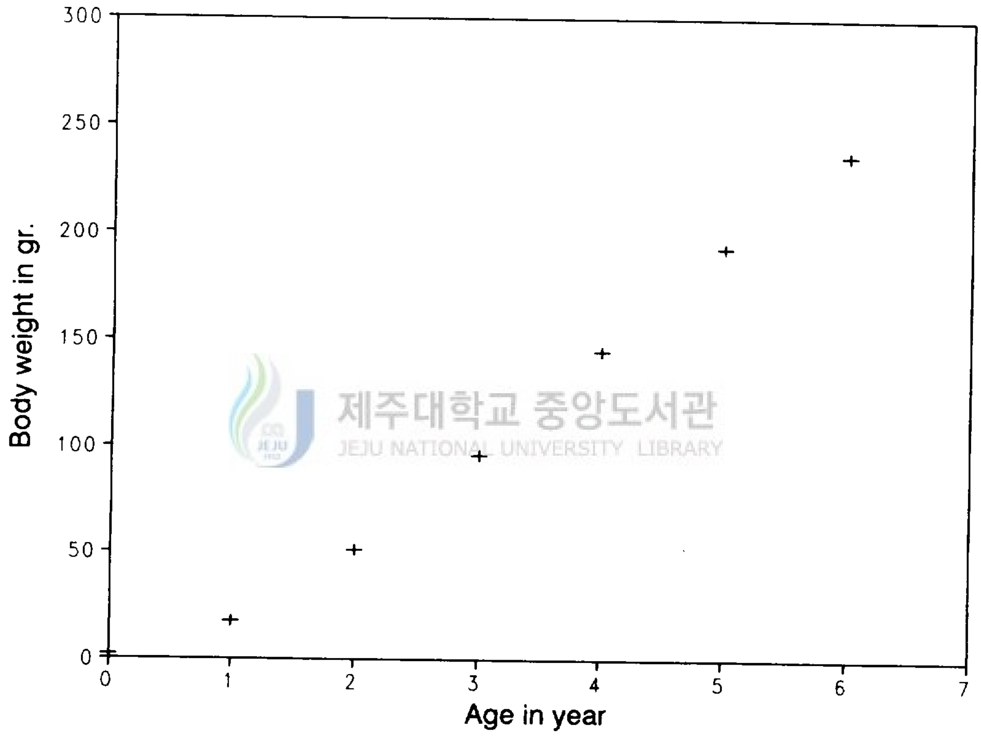

Fig. 15. Theoretical growth curve of body weight obtained by the Bertalanffy's growth equation.

Ⅳ. DISCUSSION

Scales, otoliths, opercular bones, fin rays and vertebrates are examples of structures that are commonly used for age and growth inferences (Rollefsen, 1935; Blackburn, 1951; Backiel, 1962; Lawrie, 1963 ; Blacker, 1974). However, interpretation of age and growth from any bony structure of fish is based on the assumptions that periodic features are formed at a constant frequency, and that the distance between consecutive features such as otolith circuli or annuli is proportional to fish growth.

In the age determination of Jack Mackerel, *Tranchurus japonicus* (TEMMINCK et SCHLEGEL), the scale (Mitsuta, 1957; Mitani *et al.*, 1964; Ann, 1973) and otolith (Mitsuhuchi *et al.*, 1958; Mitani *et al.*, 1964) are commonly used.

In order to use the rings of scale or otolith as age characters, the rings must be formed at a constant frequency with fish growth (Irie, 1960). The following proceedings are generally accepted to validate this regularity. The larger the body size or the better the growth , the larger the otolith or scale, and the larger the measured ring radius (Hickling, 1933; Trout, 1954; Templeman *et al.*, 1956; Mina, 1967; Johnes, 1968). It was necessary to investigate the similarity on the relative size among the body length, otolith radius and ring radius. If the ring did not formed regularly, the ring was only shown the degree of aging. The regularity of ring formation appeared through the investigation of marginal increment of otolith or scale and state of otolith edge (Kang, 1982).

In this paper, the borderline of hyaline and opaque zone was regarded as a ring, and the similarity and formation regularity were validated between size of otolith and fish.

The monthly change of length distribution of samples was 137 - 194 mm, 49 - 154 mm, 62 - 156mm, 51 - 253 mm, 81 - 159 mm, 89 - 187 mm, 88 - 193 mm, 124 - 172 mm and 128 - 215 mm at Feburary, April, May, June, July, August, September, October and November, respectively. The length and weight showed the decreasing trend from April to July except for June and the increasing trend from July to Feburary. It inferred that the decrease of length - weight distribution trend was resulted from the catch of small fishes which spawned during January - May (Lee *et al.*, 1983) and migrated to the south to grow as the water temperature became lower. The length and weight showed increasing trend from July to Feburary. It was inferred that these fishes spawned during June - August in this study and, migrating to the south, were caught in the set net during growth. Considered the following conditions that the fishes generally became dispersed when they came coastal area from open sea (Tahara *et al.*, 1982), the catch of small Jack Mackerel occupied about 27 % of total catches in the set net fishery (Lee *et al.*, 1988) and this study area is shallow water, it inferred that these variations of length and weight were caused by the characteristics of set net fishery.

The Lee's phenomenon (1912) which ring radii become smaller as the fishes grow older was distinctly shown and the correction method of Lee's phenomenon by linear regression used in this paper was the most effective method because it showed the most approximate ring radius comparing to the actual ring radius before its shrinkage.

In the monthly change of the otolith edge's state for estimation ring formation time, the rates of opaque edges were similar from September to

April and were maximum from May to July. The marginal increment was estimated very high at May and June in the monthly change of marginal increment. It could be estimated that the the opaque zone was formed from May to July from these results. Lee (1973) reported that the spawning season of this species migrating to the Korean coastal sea is June - August. It was approximately agree with this paper that the ring is generally formed when the feeding is strong just before spawning season (Trout, 1954; Irie, 1957, 1960). The other mode of 0.902 appeared at November was probably caused by mearurement error or sampling method, so it was estimated that the formation time of opaque zone was from May to July.

In the other papers on the ring formation time, Ann (1973) estimated it from March to June, Muraue *et al.* (1949) estimated it from April to July and Marukawa *et al.* (1949) estimated it from March to July. These are relatively agree with this paper. Mitani *et al.* (1964) was somewhat different from this study but their result was similar in that the ring was formed just before spawning season.

The estimation of spawning season was determined by monthly change of fatness codition using length and weight data only. Generally, the spawning season could be estimated effectively by the gonad index represented in the ratio of gonad weight to length or by the direct observation the gonad (Kang, 1982). Horita *et al.* (1971) estimated that the spawning season of this species in the nothern parts of Japan was from Feburary to August, but the peak spawning season was from April to May. The spawning seasons were estimated as Feburary - May in the southern area of Japan and May - June in the southwestern sea of Japan, but it is shown that the spawning season extremely varied according to the place (Sasaki, 1970). In this study, though the spawning season was estimated from June to August, but considering that it was based on the monthly change of fatness condition and the gonad weight was small comparing to body weight, the estimation of spawning season was relatively incorrect. Generally, it was known that fishes accumulate nutrition before spawning season by the strong feeding and consume nutrition at the spawning season (Kang, 1982). Considering that the decreasing fatness condition from June to August and icreasing from September to June were caused by consumption of nutrition with relation to spawning activity, it was relatively good that May - August was regarded as spawning season.

The relationship of growth between length and weight is very important in estimating parameters of growth equation. Therefore, many papers related to the length-weight relationship has been accompanied such as the growth of Yellowtail (Mitani, 1960), the growth of Pacific cod (Chung *et al.*, 1971), the growth of Alaska pollack (Yamaguchi *et al.*, 1972), the growth of Yellowfin sole (Kim, 1974) and the growth and age of White croaker (Koo, 1971) and so on.

The relationship between length and weight was estimated as $W = 2.1344\ L^{2.896} \times 10^{-2}$. In order to know the approximate trend of constant A, it was examined on the other fishes. The Jack Mackerel had high value of constant A comapred with Alaska pollack (0.0028), Yellowtail (0.01193), Rikuzen sole (0.01381) and Japanese needlefish (0.00141). In the other hand, the constant B had lower value compared with Jack Mackerel than Cod (3.4271) of the Yellow sea, Japanese needlefish (3.26) and Finespotted flounder (3.0477), but higher than Alaska pollack (2.599) of the East sea, Blackthroat seaperch (2.78650) and Board alfonsino (2.8343). These trends showed that the B value was decreased with increasing body length and increased with decreasing body length (Kim, 1977). The relationship between length and weight played an important role in growth of fish and was affected by environmental factors (Kim, 1977). It was considered that the Jack Mackerel was well fitted with allometric equation from these results.

In this study, the calculated parameters of growth equation were L_∞ = 305.9mm, W_∞ = 441.6g, K = 0.251 and t_0 = - 0.6627. The back-calculated standard length was estimated by the von Bertalanffy's growth equation for length as 104.4 mm , 149.1 mm, 183.9 mm and 211.0 mm from age-Ⅰ to age-Ⅳ, respectively. Compared these lengths with 103.7 mm, 149.7 mm, 181.5 mm and 210.7 mm back-calculated length at ring formation time, it was considered that both values were well matched. There were some differences compared with the result of Ann (1973), but the growth coefficient, growth trend and t_0 were estimated similarly. The growth equation in this study was probably underestimated (Parker *et al.*, 1959) because Ann (1973) treated large species caught in a steamboat purse seine and this study treated small species caught in a set net.

It was thought that these differences were caused by measurement method, age character and sampling method.

Ⅴ. CONCLUSION

Age and growth of Jack Mackerel, *Tranchurus japonicus* (TEMMINCK et SCHLEGEL) were studied based on the data of 808 samples caught by the set net at Shinyang in the eastern area of Cheju Island from Feburary to November 1987.

The annual ring was defined to the outer margin of each opaque zone of otolith.

1. Among the total 808 samples, except for the 0 age group, the ages of 576 samples were determined as follows.

Ⅰ group : 360 specimens (62.5 %)

Ⅱ group : 161 specimens (28.0 %)

Ⅲ group : 47 specimens (2.8 %)

Ⅳ group : 8 specimens (1.4 %)

2. It was estimated by monthly change of marginal increment $(R\text{-}r_n/r_n\text{-}r_{n-1})$ of otolith and by monthly distribution of otolith edge that the annual ring was formed once a year from May to July.

3. According to the monthly change of fatness condition (FC), the peak of spawning occurred from June to August.

4. The relationship between standard length (SL) and otolith radius (OR) was represented by the following equation.

$$SL = -15.379 + 56.685 \times OR \quad (r^2 = 0.955)$$

SL : standard length (㎜)

OR : otolith radius (㎜)

5. Lee's phenomenon appeared clearly in each otolith and the calculated

length at the ring formation time after correction is represented as follows.

Ⅰ ring group : 103.7 mm

Ⅱ ring group : 149.7 mm

Ⅲ ring group : 181.5 mm

Ⅳ ring group : 210.7 mm

6. $L\infty$, k, t_0 were estimated respectively by using Walford's plot as follows.

$L\infty$ = 305.9 mm

k = 0.251

t_0 = - 0.6627

7. The relationship between standard length (SL) and body weight (W) was given by the following equation.

$W = 2.710\ SL^{2.897} \times 10^{-5}$ (r^2 = 0.981)

W : body weight (g)

SL : standard length (mm)

With this equation, the calculated body weight of ring formation time was estimated as follows using calculated standard length of ring formation time.

Ⅰ ring group : 18.7 g

Ⅱ ring group : 54.3 g

Ⅲ ring group : 94.7 g

Ⅳ ring group : 146.1 g

8. In the relationship between standsrd length (SL) and body weight (W), the $W\infty$ was estimated as follows using $L\infty$ = 305.9 mm.

$W\infty$ = 441.6 g

9. Applied to the von Bertalanffy's growth equation for length, the

relationship between standard length (SL) and the age (t) was represented by the following equation.

$$L_t = 305.9[1-e^{-0.251(t+0.6627)}]$$

t : age

L_t : standard length (mm) at age t

Therefore, the standard length of full one year to four year was calculated as follows.

Ⅰ group : 104.4 mm

Ⅱ group : 149.1 mm

Ⅲ group : 183.9 mm

Ⅳ group : 211.0 mm

10. The results applied to the von Bertalanffy's growth equation for body weight was given by following equation.

$$W_t = 441.6[1-e^{-0.251(t+0.6627)}]^3$$

t : age

W_t : body weight (g) at age t

Therefore, the body weight at 1-4 age was estimated as follows.

Ⅰ group : 17.5 g

Ⅱ group : 51.1 g

Ⅲ group : 96.0 g

Ⅳ group : 144.9 g

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