On the Forming Season of Annual Rings (Opaque and Translucent Zones) in the Otoliths of Several Marine Teleosts

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(Plate 1; Text-figs. 1–2; Table 1)

INTRODUCTION

Though the so-called "annual rings" in the otolith of the fishes are often used for the estimation of the age and the examination of growing process of the fishes, the forming season of the zones of these two kinds, i. e. opaque and translucent, has not been investigated clearly yet. It has been considered for some ten fishes[(1)-(16)] that in some fishes the opaque zones are formed in winter and the translucent ones in summer, while in the other fishes the opague zones are formed in summer and the translucent ones in winter.

Previously, the crystal texture of the annual rings and the distribution of calcium carbonate in the otolith of *Pseudosciaena* were investigated by the writer,[(17)] and the mechanism of formation of the annual rings has been studied. In the present study which is a continuation of the previous one, the forming season of the opaque and translucent zones in the otoliths of *Argyrosomus*, *Lateolabrax* etc. caught in the Inland Sea of Seto was clarified.

MATERIALS AND METHODS

The marine teleosts used in the present study are 398 specimens of *Argyrosomus argentatus* (HOUTTUYN), 303 of *Lateolabrax japonicus* (CUVIER) and 136 of *Mylio macrocephalus* (BASILEWSKY) caught in the Inland Sea of Seto (Seto-naikai) during July 1955～June 1956. Moreover, 340 of *Pseudosciaena manchurica* (JORDAN et THOMPSON) caught in the East China Sea (the Tung-Hai) during December 1954～February 1956 were used.

The otoliths were taken out from these fishes, and then each otolith was so polished down to a thin slice (about 0.1～0.2 mm. thick), as the surface plane is perpendicular to the longitudinal axis of otolith and across its center as is shown in Text-fig. 1. These slices of otoliths were divided into monthly groups respectively by the month in which the fishes were caught, and were observed as to whether the opaque or translucent zone was in the edge of the slices.

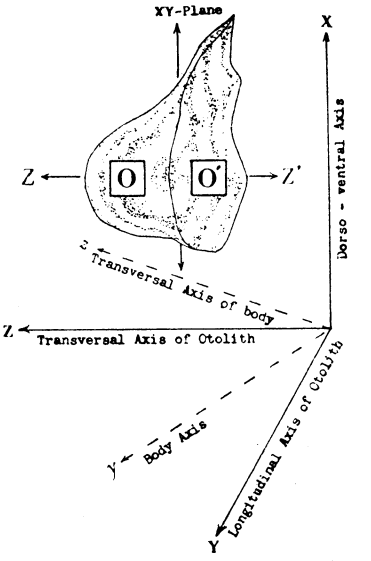
Then, in the present study, each monthly group of the otolith slices was further divided into two groups respectively by observing the condition of the edge. The first group includes the otolith slices whose edges are occupied by the opaque zones, and the second

one the slices whose edges are occupied by the translucent zones.

Now, in 1955, the writer found the significant differences of the crystal texture and patterns of annual rings between the outside half (the part **O** shown in Text-fig. 1) of a middle plane (XY-Plane in Text-fig. 1) of the otolith and the inside half (the part **O′**) of it. But in most slices, surrounding edges of both parts **O** and **O′** had been occupied by the translucent zone of the same kind or by the opaque. However, in some of the slices, there were found exceptions. Though the edge of part **O′** was occupied by the opaque band, opaque substance could not be observed in the edge of part **O** as shown in Plate 1, figs. 2 and 3. Such an opaque band along the edge of part **O′** was regarded as the opaque zone when the edge of part **O′** is occupied distinctly by the opaque substance.

In each monthly group, the number of fishes of the first group was compared with that of the second group, by obtaining the percentage of the number of the fishes of these two kinds to the total number.

From these results the forming seasons of the annual rings of two kinds were concluded.



Text-fig. 1. Cross section of otolith of *Argyrosomus*.

Perpendicular to the axis Y (longitudinal axis of the otolith) which is inclined abont 30° to the body axis y of the fish. XY-Plane which is a middle plane of the otolith, is inclined about 30° to the median plane of the fish body. Z side is the outer side of the fish body, and Z′ side is the inner side of it.

RESULTS

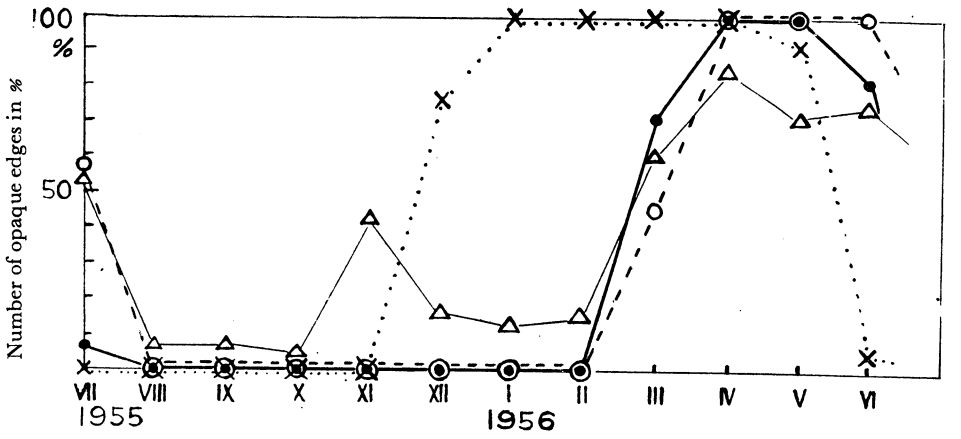
The typical behaviours of the annual rings appeared on the slices of various ages of fishes are firstly stated. The number of the fishes examined in each month and the percentages of the number of the fishes whose otolith has opaque or translucent edge to the number of each monthly group are tabulated in Table1, and are plotted in the graph as in Text-fig. 2.

(1) *Argyrosomus argentatus* (Japanese name : Shiroguchi or Ishimochi).

In these otolith slices, opaque and translucent zones in the inside half (part **O′**) of middle plane in the otolith are regularly arranged, while the zones in the outside half (part **O**) have much of irregular forms which have a number of bumpy bands as is shown in Plate 1, fig. 1. In the otoliths of the fishes (8～12 cm. in length, believed to be of the zero age from the fish length) which were caught in September and October, faint opaque portion was found often in the edge of part **O**, still the edge of part **O′** was translucent. However, in the otoliths of the fishes (above 14 cm. in length, believed to be more than one age) which were caught in the same season, such faint opaque portion could not be found. Though such a faint opaque portion was found in the edge of part **O**, in the present comparison the edge of this slice was regarded as the translucent zone, if the opaque band could not be observed distinctly in the edge of part **O′**.

Table 1. The number of the fishes examined in each month and the percentage of the number of the fishes whose otolith has opaque or translucent edge to the number of each monthly group.

Month	*Argyrosomus*			*Lateolabrax*			*Mylio*			*Pseudosciaena*		
	Number of fishes	Opaque edge in %	Translucent edge in %	Number of fishes	Opaque edge in %	Translucent edge in %	Number of fishes	Opaque edge in %	Translucent edge in %	Number of fishes	Opaque edge in %	Translucent edge in %
1955												
July	26	58	42	56	0	100	14	7	93	11	54	46
August	120	0	100	15	0	100	23	0	100	20	7	93
September	98	0	100	33	0	100	18	0	100	42	7	93
October	22	0	100	13	0	100	12	0	100	20	5	95
November	13	0	100	25	0	100	7	0	100	12	42	58
December	10	0	100	19	74	26	6	0	100	110	16	84
1956												
January	11	0	100	12	100	0	5	0	100	16	12	88
February	9	0	100	16	100	0	8	0	100	32	16	84
March	24	46	54	8	100	0	7	71	29	15	60	40
April	12	100	0	15	100	0	11	100	0	20	85	15
May	32	100	0	70	91	9	9	100	0	18	72	28
June	21	100	0	21	5	95	16	81	19	24	75	25
Total number	398			303			136			340		



Text-fig. 2. Monthly changes in the percentage of the number of the fishes whose otolith has opaque edges.

Argyrosomus
Lateolabrax
Mylio
Pseudosciaena

From Table 1 or Text-fig. 2, it can be seen that the translucent zone appears on the edge from August to February of the next year, while the opaque one from March to July. It may be said therefore that the translucent zones will be formed in August～February of the next year, while the opaque ones in March～July.

(2) *Lateolabrax japonicus* (Japanese name: Suzuki).

In the otoliths of the fishes (8～13 cm. in length, believed to be of the zero age) which were caught in July, faint opaque portion was often found in the edge. But in the fishes (believed to be more than one age) which were caught in the same season, such faint opaque portion could not be found in the edge. So, these otoliths were classified in the same manner as in the case of *Argyrosomus*.

From Table 1 or Text-fig. 2, it can be observed that the translucent zone appears on the edge from June to November, while the opaque one from December to May of the next year. Accordingly, it may be said that the translucent zones will be formed in June～November, while the opaque ones in December～May of the next year.

(3) *Mylio macrocephalus* (Japanese name: Kurodai).

Similarly to *Lateolabrax*, it may be said from Text-fig. 2 that the translucent zones will be formed in July～February of the next year and the opaque ones in March～June.

(4) *Pseudosciaena manchurica* (Japanese name: Kiguchi or Kinguchi).

In this fish, the annual zones in the inside half (part **O'**) of middle plane appear regularly, while the zones in the outside half (part **O**) appear irregularly, similar to the case of *Argyrosomus*. The opaque portions which could be hardly decided whether they are opaque zones or not similarly as in the case of *Argyrosomus* appeared, and they were classified in the same way as in the case of *Argyrosomus*.

From Table 1 or Text-fig. 2, it can be seen that the translucent zone appears on the edge much more than the opaque one from August to October, while the opaque one ap-

pears much more than the translucent from March to July. Therefore, it may be said that the translucent zones will be formed mainly in August~October, while the opaque ones mainly in March~July. In many specimens of *Pseudosciaena* caught in November~February of the next year, the edges were occupied by also opaque zones though they were narrow in these portions. Accordingly it can be considered that the opaque zones will be formed throughout the year except August~October, and that the formation of the annual zones in the otolith of *Pseudosciaena* and the form of the zones will be changed by the condition of the living environment.

In the otoliths of *Pseudosciaena* which was caught in December and was believed to be of zero age from the scales and fish length (9~13 cm.), a clear but narrow opaque band was observed between the center and the edge of part **0**. Perhaps these narrow opaque bands might be formed in September~October similar to *Argyrosomus*, but it can not be said directly, because young *Pseudosciaena* believed to be of zero age could not be caught in this season.

(5) Forming season

According to the results above stated, it can be seen that, when the translucent zone or opaque zone begins to form in the otolith, only the same kind of zone will be formed continuously for a couple of month. Then only the other zone will be formed instead of the former one for a next couple of month, viz. one translucent zone and one opaque zone is alternately formed, and these two different zones are formed completely in one year, excepting the cases of *Pseudosciaena* and also zero-age fishes.

Moreover, the translucent zones are formed mostly from summer to autumn, the and opaque zones from winter to spring of the next year, but in most cases in spring.

It was made clear previously by the writer that calcium carbonate which is the main constituent of the otolith is contained more abundantly in the translucent zone than in the opaque one, and that a kind of organic substances is contained more abundantly in the opaque zone than in the translucent one. It is very reasonable that the translucent zones (which contain calcium carbonate abundantly) are formed mostly during summer~autumn, in which season the fishes are generally considered to be active, and that the opaque zones (which contain a small amount of calcium carbonate and a large amount of organic substances) are formed from winter to spring of the next year, mostly in spring, when the fishes are considered to be inactive. The mechanism of the formation of annual rings which are formed by deposition of calcium carbonate containing in the food or environmental sea water, is not yet clear, but now it is being studied.

From the data obtained above, it is clear that the status of the formation of the annual rings is different between the fishes of two kinds, *Pseudosciaena* (the East China Sea) and the others (the Inland Sea of Seto); viz. (1) the annual rings are quite conspicuously shown in the latter than in the former, (2) the percentage of the number of fishes in which the edge of otolith is margined by the opaque or translucent zones is sharply demarcated seasonally in the latter than in the former.

CONCLUSIONS

According to these results obtained in the present study, the following conclusions have

been led.

(1) The translucent zones in the otolith of these fishes are formd generally from summer to autumn, and the opaque ones from winter to spring of the next year.

(2) Accordingly, calcium carbonate is mostly deposited on the surface of otolith abundantly from summer to autumn during which period the fishes are generally considered to be active and to take food vigorously. However, a small amount of calcium carbonate and a large amount of organic substance are deposited from winter to spring (mostly in the spring), during which period the fishes are considered to be inactive and to take little food.

(3) In the otolith of *Argyrosomus*, *Lateolabrax* and *Mylio*, one translucent zone and one opaque zone are distinctly formed each year, except the otolith of *Pseudosciaena*. Therefore, these zones can be used for the estimation of age of the fishes in the same way as in the zones of scales. In the case of *Pseudosciaena*, sometimes the two zones are formed in the same period, though the depositing power of two zones is different.

(4) Perhaps, such difference between *Pseudosciaena* in the East China Sea and the other fishes in the Inland Sea of Seto may be caused by the status of environmental sea water.

SUMMARY

The forming season of annual rings, i. e. translucent and opaque zones, in the otoliths of marine teleosts *Argyrosomus*, *Lateolabrax* and *Mylio* caught in the Inland Sea of Seto and *Pseudosciaena* caught in the East China Sea, have been made clear as follows:

(1) The translucent zones in the otolith of these fishes are formed generally from summer to autumn, and the opaque ones from winter to spring of the next year.

(2) Accordingly, calcium carbonate is deposited abundantly on the surface of otolith during summer～autumn, while it is scantily deposited during winter～spring.

(3) The translusent and opaque zones in the otolith of *Argyrosomus*, *Lateolabrax* and *Mylio* can be used for the estimation of age. But the zones of *Pseudosciaena* must be used carefully for this purpose.

(4) The status of the formation of the annual rings is different between *Pseudosciaena* in the East China Sea and the others in the Inland Sea of Seto.

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EXPLANATION OF PLATE 1

Fig. 1. Photomicrograph of the otolith slice of one-age *Argyroscmus* caught in September. The edge of this slice is occupied by the translucent zone. (9 ×).
Fig. 2. Photomicrograph of the otolith slice of four-age *Argyrosomus* caught in April. The edge of part **0′** is occupied by the opaque band. But in the edge of part 0, it can not be found. (9 ×).
Fig. 3. Photomicrograph of the otolith slice of four-age *Lateolabrax* caught in March. The edge of part **0′** is occupied by the opaque zone. But in the part **0** it is hard to find the zone. (9 ×).
Fig. 4. Photomicrograph of the otolith slice of two-age *Mylio* caught in February. The edge of part 0′ is occupied by the translucent zone. But in the part **0**, it is hard to find the annual zones. (18 ×)

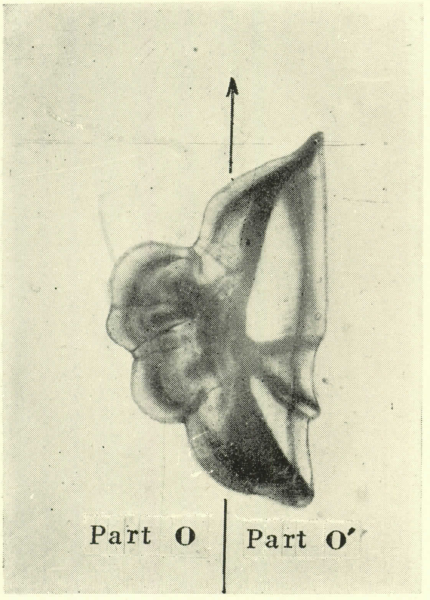

Fig. 1

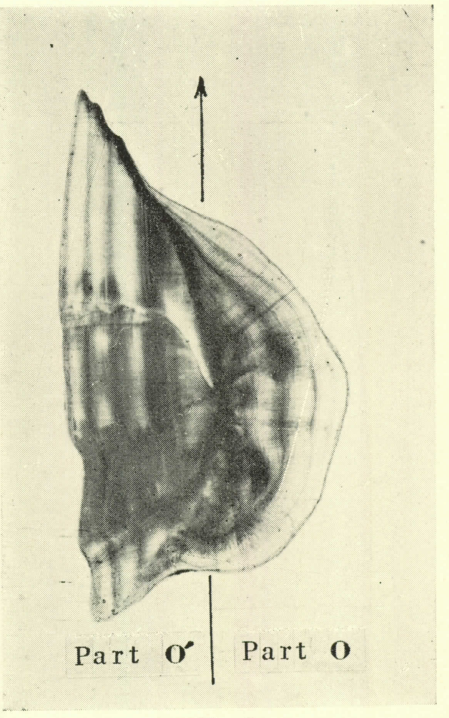

Fig. 2

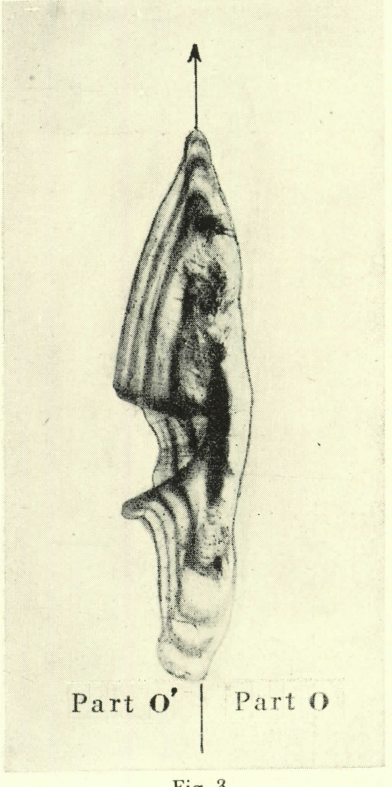

Fig. 3

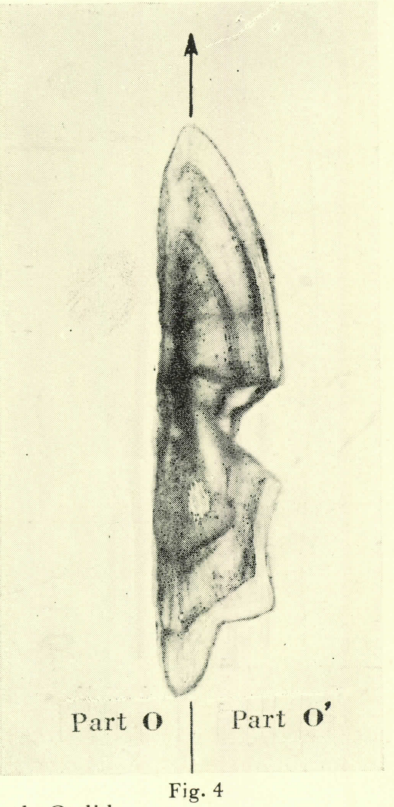

Fig. 4