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By Shin-ichi Mio

Original title: Nihon-Kai san nigisu (Glossanodon semifasciatus (KISHINOUYE)), no nenrei, seicho oyobi seijuku.

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The age, growth and maturity of deep-sea smelt (Glossanodon semifasciatus (KISHINOUYE)) in the Japan Sea

By Shin-Ichi Mio[1]

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1 Present address: Seikai Regional Fisheries Research Laboratory, Nagasaki, Japan.

Nigisu (Glossanodon semifasciatus) is found over all the areas along the coast of Honshu in the Japan Sea and because it has been caught in large quantities since 1958, its importance in trawl fishing along the coastal areas of the Japan Sea has increased especially in view of the fact that there has been a decrease in the quantities of catch in other important species of fish in recent years.

With respect to the age, growth and maturity, investigations on age by means of otolith were made and reported by Haneue (?) (1956) on data found along the coastal areas of the Pacific Ocean in the central section of Honshu and by Watanabe (1956, 1957) mainly on specimens found off the coast of Hyogo-Ken* The present work is based

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Translator's note: Approximate location - 134°30' - 135°30' E and. 34°30' N.

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on the 1,760 specimens, which were collected monthly by survey ships and fishing boats during a 12 month period extending from Apr. 1966 to Mar. 1967 off the coast of Niigata-Ken.* Each specimen was measured for its

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*Translator's note: Approximate location -137°30' - 139°30' and 37° - 37°30 N.

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body length (from the tip of the proboscis to the end of vertebra), weight and weight without internal organs (organs in the abdominal cavity and attached fat). Further, the otolith and the gonad were removed from each specimen.

The author wishes to express his deep-felt appreciation to Dr. Shigeaki Mamichi, the chief of the Bottom Fish Resources Div. of the Seikai Regional Fisheries Research Laboratory and Dr. Yuho Ito, the chief of the Resources Div. of the Japan Sea Regional Fisheries Research Laboratory (Nihon-Kai Suisan Kenkyu-Sho) who read the manuscript. Further, he wishes to thank Technical Officer Tetsuo Ogata of the Japan Sea Regional Fisheries Research Laboratory, the staff members of the Bottom Fish Research Group and those who were associated with the survey ship Mizuho-Maru for aiding the author in the collection and measurement of the specimens.

1. Age

The scales of nigisu fall off very easily. By the time they are caught in a trawl net and hauled in the ship, almost all the scales are gone and one can occasionally observe the lateral line scales. Thus, it was decided to use the otolith for the determination of age. The otolith is large in comparison to the body; it is flat on the right and left and tapers off to a point in the front. When the two flat surfaces are polished and observed by means of transmitted light, several strands of opaque zones, which run approximately parallel to the edge of the otolith in a somewhat concentric fashion, are clearly observed. The outer edge of this opaque zone was defined as an age mark (Plate I). As the axis of measurement, the line, which joins the tip of the pointed portion in the front and the centre, is most suitable on account of the clarity in age determination and the length of axis. However, since this portion is easily damaged, it was decided to adopt as the axis of measurement the line which joins the centre and the corner (Translator's note: can this be "angle"?), which can be observed in the curved section on the ventral side. Measurements were made on this axis by magnifying the otolith diameter and the indicator diameter 20 times. Comparative studies were made of the position of the indicators on the left and the right otoliths in the same individual. There was no difference between the two. Thus, for the age determination the otolith on the right side was used. However, when the right otolith was not available through damage and other reasons, the otolith from the left side was used.

Between the male and the female, there is no difference in the relation between the otolith diameter (R) and the body length (BL) and a linear relationship is observed between the two. The

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relationship can be expressed by the following equation (Fig. 1).

$$BL = 69.0\hat{R} - 1.2$$

Haneue and Watanabe selected as the axis of measurement the diameter of the long axis and the line joining the centre to the tip of the front, respectively, and calculated the relationship between these factors and the body length. In each case the relationship was represented by a straight line. On the basis of these findings it appears as though the otolith of nigisu grows in proportion to the body length approximately evenly in all directions. On the basis of the above-mentioned relationship between the body length and the otolith size, the standardization of the mark size was carried out by multiplying individual mark size by $\hat{R}/R$. $\hat{R}$ is taken from the line expressing the relationship between the body length and the otolith size and R represents the otolith size of an individual.

When the growth is considered as a biologically characteristic value, one must assume the existence of a difference in growth due to a genealogical difference. Further, one must assume that even in the same genealogical group the growth differs between groups with different year of occurrence and consequently with different past. Thus, when the age is determined one should not compare all the individuals uniformly. Any investigation must be conducted systematically. First individual specimens must be divided into genealogical groups. Then they are divided into groups by year of occurrence. Then a comparison is made between groups with different periods of occurrence on the basis of the values, which are obtained by a comparative examination of individual specimens within the group with the same year of occurrence.

The specimens, which were used in the present investigation, were caught off the coastal areas of Niigata-Ken and appear to belong to the same genealogical group on the basis of their movement and their mode of spawning. Thus, as the first step in the determination of the relationship between the body length and the mark size, it becomes necessary to classify the individual specimens into groups of the same year of occurrence. The classification into groups by the year of occurrence by means of the number of marks is not appropriate since the number of formation of marks is not the same even within the group with the same year of occurrence. Thus, it was decided to classify the specimens into appropriate groups on the basis of the finding that in an individual with a large size of otolith the mark size was also proportionately large. That is to say, when the specimens are grouped by month and the relationship between the otolith size and the mark size is calculated, one finds

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that even in specimens with the same body, if the year of occurrence differs, the mark size in the individual of n-years, whose growth was delayed, is smaller in comparison to the mark size of the individual of (n - 1)-years with good growth, and consequently that there is no continuity in the relationship between the otolith size and the mark size among groups classified by the year of occurence. One finds discontinuity between the two groups and on the basis of this dicontinuity one is able to classify them into groups by the year of occurrence.

On examining the relationship between the otolith size and the mark size, one notes, along with the difference due to the difference in the years of occurrence, the fact that within the groups of the same year of occurrence the specimens can be divided into two groups on the basis of the size of the first mark. The group with a smaller first mark was defined as A-group and the group with a larger first mark was defined as B-group (Fig. 2). The points of intersection of the regression lines, which had been derived from marks of these groups and the groups based on the year of occurrence, and the Y-axis, which corresponded to the mode of the mark sizes, were defined as the representative otolith sizes for

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A and B groups (Table 1). Both in A and B groups there were individual specimens in which a pseudomark was observed between the 2nd and the 3rd marks. There was a great deal of difference in the rate of appearance depending on the month of collection. Generally the rate was higher in A group being 77% in A group and 53% in B group.

An attempt was made to obtain the relationship between the representative values of the mark sizes which had been obtained for each group and in each group/three regression lines, which were parallel to the X-axis, were obtained (Fig. 3). On the basis of the relationship between these regression lines, body length and the otolith size, the body length at the time of the formation of each mark was obtained.

In order to establish the period of formation of the mark, the seasonal variations in the growth of otolith after the formation of the final mark were investigated. That is to say, the marginal growth indices ($\alpha = R - r_n / r_n - r_{n-1}$) were calculated by month, A and B groups and by groups with the same number of marks and their seasonal variations in mode were investigated. The changes were found to be independent of A-B grouping or of grouping by number of marks; the maximum values were observed in Sept. and Oct. and the minimum values were observed in Oct. and Nov. (Fig. 4).

Both Haneue and Watanabe state that the formation of an opaque zone in the otolith of nigisu finishes in the winter season followed by the formation of a transparent zone. However, the confirmation of the completion of the formation of an opaque zone can be made only when a transparent zone can be observed in the edge of the otolith; generally, the completion of the formation of opaque zone takes place before the time of confirmation. An examination of Fig. 4 shows that in Oct. the indices exhibit the maximum and the minimum values. This indicates that in Oct. individuals immediately before the mark formation and those immediately after the mark formation are found together. Further, in the light of the fact that these specimens were collected on Oct. 25, it appears that the mark is formed once every year over a period extending approximately from Sept. - Nov. centering around Oct.

II Growth

An observation of the ovaries of nigisu shows the presence throughout the year of ovaries with oocytes of the "yolk-sphere-period" which contain a large quantity of yolk. Further, an examination of males reveals similarly throughout the year the presence of individuals

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with relatively large and thick testes. In view of these findings, it appears as though nigisu spawns throughout the year; however, an examination of the composition of body length among the catch shows a clear composition among smaller fishes and this composition moves with the passage of time; thus, it is possible to pursue roughly the process of growth of young fish. On the basis of this observation one can assume that the spawning does not take place uniformly throughout the year, but that there are active spawning periods. Since it is not possible to observe distinct changes due to season of the process of maturation of ovaries in individual groups, it is impossible to recognize clearly the seasonal variations in maturation simply on the basis of monthly variations in ovarian weight or the rate of appearance of transparent eggs. Thus in order to investigate accurately the spawning period, it will be necessary to collect ovarian specimens throughout the year, to investigate the composition of the diameter of eggs, to ascertain accurately the degree of maturity of each individual specimen, and to seek its seasonal variations. However, on account of the fact that the fishing is closed for two months during the summer, or the fact that the autolysis is extremely rapid in nigisu, it was extremely difficult to obtain samples of fresh ovaries which maintained the original conditions throughout the year. However, since 1966 it has been possible to collect samples by survey ships; further, by preventing the autolysis of ovaries by fixing the fish in formalin either immediately after landing them on board the ship or in market places, it was possible to obtain 626 somewhat perfect specimens of ovaries once every month. Approximately 1/10 by weight of these specimens of ovaries were used as samples for measurement. Eggs were loosened into 100 cc of

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water. The mixture was stirred and 1 cc of the mixture was extracted with a stencil-pipette. This was magnified by means of a universal projector and the number and the diameter of the eggs were measured.

The ovary of nigisu consists of the right, left, front and back sections. The composition of the diameters of eggs in these sections was obtained and compared, and no difference was observed between them. Thus, it became clear that all the sections of the ovaries of nigisu matured evenly.

The composition of the diameters of eggs in nigisu is of a multi-peak type and each group is isolated relatively clearly. When individual specimens are arranged in the order of the magnitude of the maximum egg diameters in the monthly composition of egg diameters, in each month the modes of the maximum diameters collect in the neighbourhood of 0.10 mm, 0.25 mm, 0.50 mm, 0.80 mm, 1.00 mm and 1.60 mm. That is to say, the oocytes and eggs of nigisu appear to enter a period of temporary dormancy when their diameters reach these values. Thus on the basis of this condition of the composition of egg diameters the ovaries were classified on the basis of maturity. That is to say, they were classified into the following five types: a type; ovaries whose egg diameter mode of the largest egg group is less than 0.40 mm: b type; ovaries of 0.40 ~ 0.65 mm: c type; ovaries of 0.65 ~ 0.90 mm: d type; ovaries of 0.90 ~ 1.10 mm and e type ovaries with egg groups of transparent eggs. (Fig. 5, Plate II).

If the conditions of monthly appearance of these five types are obtained by A.B group and by age, it is found that the ovaries which belong to three types, b, c and d are found throughout the year but that the appearance of the ovaries of a and e types is somewhat reversed (Fig. 6). That is to say, e type appears in large quantities during Jan. ~ Mar. and Aug. ~ Oct., and a type ovaries appear in large quantities during Dec. ~ Jan. and May ~ June which correspond to the centre of the appearance of e type ovaries. Further, if the seasonal variations in the weight of testes are obtained by A.B group and by age, it is found that the mode is located in Mar. and Sept., and that especially large testes are observed in Sept. and at the same time immature testes weighing less than 4.5 g are totally absent (Fig. 7). On the basis of these observations it may be inferred that nigisu spawns over a three month period centering around Mar. and Sept., and that it hardly spawns during the period intermediate between the two.

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Further, an examination of the monthly variations in the composition of the body length shows, among the group of individuals which belong to A group, a group with a mode of 80 mm in Dec. and a group with a mode of 105 mm in Apr; among B group, a group with a mode of 105 in Nov. and a group with a mode of 135 mm in Mar. are caught. An examination of these seasonal variations of the composition of body length by A.B groups along with the period of formation of marks and the body length at the time of formation leads to the conclusion that A group occurred in Mar. and B group in Sept..

A comparison of the growth of the two broods shows that the growth is slightly better in the Mar. brood. However, the difference is negligible and both groups show somewhat the same degree of growth (Table 2). In both groups, marks only up to the third are available and an examination whether the growth is linear on a "finite difference" diagram cannot be made. However, if it is assumed to be linear, the following equations are obtained.

Mar. brood

$$l_{n+1} = 0.712\, l_n + 94$$

$$L_t = 326\,(1 - e^{-0.314t + 0.010})$$

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Sept. brood

$$l_{n+1} = 0.721\ l_n + 85$$

$$L_t = 305\ (1 - e^{-329\ t\ -\ 0.40})$$

As shown by Ochiai (1952) the relationship by month between the cube of the body length and the weight without the internal organs can not be expressed by a straight line passing through the origin; however, if it is examined by age and by brood, the relationship is well represented by a straight line passing through the origin and it is possible to obtain the condition coefficient of nigisu (Table 3). A comparison of the condition coefficients so obtained shows that in almost all the months Sept.-1963 and Mar.-1964-broods, and Sept.-1962 and Mar.-1963 broods are very close in their values. However, as a whole, the condition coefficient is maximum in the 2 year group and the coefficient of the current year group is slightly larger than that of the 3 year group. It seasonal variations show an identical tendency in all the age groups; it attains its highest values in July and August and falls to its minimum value in Dec.. The seasonal variations undergo a pattern different from other species of fish wherein the condition coefficient becomes maximum several months before spawning, decreases gradually, and becomes minimum immediately after spawning.

It has been established that the habitat of nigisu moved towards the deeper region off the coastal area as the growth progresses. The habitat is less than approximately 200 m deep and the whole area is totally included in the range of operation of dragnet fishery off the coast of Niigata area. The material used in the present report was taken from the catch made by a single-ship-dragnet operation off the coast. During the period of the present survey no specimen over 240 mm was collected. Further, merely 17 specimens with 4 marks were counted. Thus the number of individuals with 4 marks is extremely small. The spawning group of 3.5 years was recognized in a relatively large number; however, the number of individuals of over 3.5 years showed a sudden decrease. On the basis of this finding it appears that in the case of nigisu almost all the individuals die after spawning at 3.5 years and that only a very small number of individuals remains alive up to the age of four years.

III Maturity

Nigisu is caught by fishing vessels when the body length becomes approximately 100 mm and becomes the object of fishing from the time when it is a full one year old. An examination of the genital glands of the current year crop of fish, which have been found among the fish in the market, or which have been caught by the survey ships, shows that the genital glands are extremely small and it is almost impossible to distinguish the sexes. At 1.5 years when the body length becomes approximately 125 mm, it is possible to distinguish the sexes; however, almost all the genital glands weigh less than 0.1 g. Among the two year old group with the body length of approximately 150 mm, specimens with the genital glands exceeding 1.0 g begin to be observed; in the case of the female, oocytes with large quantities of yolk begin to be observed in the ovaries. An examination of the coefficient of maturity (GW/L^3) shows that both in the male and the female the specimens can be divided into two groups on the basis of the magnitude of the indeces. Their ratio is approximately equal between the male and the female. However, there is a difference between the broods. In Sept.-group 75%

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(74 ~ 79%) belong to the group with a larger coefficient of maturity while in the latter merely 33% (22 ~ 36%) belong to the larger group. Few data are available concerning the two year group during the spawning period. Further, when a group joins the spawning group for the first time, it is likely that the period of maturity has been short, and it is unlikely that the time of the collection coincides with the period of the most advanced stage of maturity. Thus, it is possible that the data are biased; however, the value does not change too greatly during the spawning period. In the case of the female of Mar.-brood the values are 29% in Feb., 36% in Mar. and 33% in Apr.. The maximum value appears in the height of the spawning season. These observations suggest that these values may be regarded as indicating the percentages of maturity of the two year group. Thus it appears that in nigisu a part of a brood joins the spawning group at two years, that in comparison to the Mar.-brood the proportion of mature two year individuals are higher in the Sept.-brood, and that 1/3 of the two year group in the former and 3/4 in the latter join the spawning group. Further, it became clear that there was no difference in the process of maturation between the male and the female.

Next an examination of the conditions of appearance of the mature ovaries of various types by age and by brood of individuals two years and older in age, which completely joined the mature group, shows that the a-type ovaries do not appear during the spawning period except in Mar. which corresponds to 2.5 years and 3.5 years of the Sept.-brood. The ovaries of b-type are also very scarce during the spawning period. Further, the appearance of the e-type ovaries with transparent eggs is limited to the period of spawning; there is a period when they are totally absent between Mar. and Sept., the two spawning periods, i. e., an examination of the seasonal variations in the mature types of ovaries in individuals two years and over generally as a group shows a pattern in which a zone, which extends three of the five mature types alternates between the mature and the immature stages with a period of six months. In the examination of the tissue sections of ovaries, during Mar. Sept. and Oct. ovaries in the absorptive process were observed.

A consideration of the conditions of maturity of individuals on the basis of observation made on the seasonal variations in the process of maturation as a group suggests the following possibilities:

i) After spawning the ovary immediately enters into the next stage of development, matures slowly and in half a year develops into c- or d-type, matures further slowly, matures fully in a year, and spawns several times during a spawning period, i. e., an individual ovary spawns once a year.

ii) After spawning an ovary enters into a period of suspension as a c-type ovary and spawns again in half a year. The spawning takes place twice a year.

iii) Each individual spawns twice a year. Each spawning period is independent and the spawning takes place several times during each spawning period.

The acceptance of the first case will mean that, in the light of the fact that a-type ovaries are observed over several months after spawning and b-type ovaries are few during the spawning period, the maturation of an ovary takes place very rapidly from the a- to the c-type, slows down at the d-type, and speeds up again to the e-type. Thus maturation takes place at extremely varying speeds. However, to accept these irregular speeds of maturation, the proportion which is occupied by the b-type ovaries seems to be a little too high. The second case means that the period of maturation occupies a good portion of a year and that the stages such as the disintegration and the absorption of residual eggs or oocytes, the suspension at the immature ovary (a-type ovary) and the development of oocytes (transition from the b- to the c-type) are completed in several months. Further in this case, the population must be divided into individuals with immature ovaries and those with mature ovaries between spawning periods. Such a phenomenon is not observed. Thus, the consideration of the processes of the seasonal variations in maturation leads us to the belief that the spawning in nigisu corresponds to the third case and that nigisu individually and collectively has two independent periods of spawning in a year.

The best way to investigate the number of eggs released at a single spawning is to examine the number of eggs in the aggregate of transparent eggs in the ovary. However, the specimens with aggregate of transparent eggs are extremely rare; further, there are cases in which a part of the aggregate of transparent eggs is forced out by an external force. This reduces the number of specimens still further. Thus it is impossible to estimate the number of eggs spawned by a group of individuals on the basis of the number of eggs in the aggregate of transparent eggs. An examination of the composition of egg dia-

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meters of the eggs in the ovary shows that development advances to the point where the mode becomes 0.58 ~ 0.60 mm that group of eggs become completely separate from other groups of eggs. Thus the group with the maximum egg diameter of the c- and d-type ovaries becomes isolated from other groups with smaller diameters. Thus it was decided to investigate the number of eggs in the largest egg groups of the c- and d-type ovaries, which are developing as a single group separate completely from other egg groups instead of the aggregate of transparent eggs.

An examination by age and by brood, although there is a bias in the number of data, shows that there is a difference in the range of distribution of the number of eggs by age, and that the distribution spreads towards the larger number with increase in age. This tendency is observed in both broods and the range of distribution of the number of eggs is somewhat similar in the same age group. Although an examination of the distribution of the number of eggs shows one to two modes in 2 and 2.5 year groups and 3 modes in 3 year and older groups, since 4 individuals, in which the number of eggs in the maximum egg aggregates fell in the range exceeding 6000 eggs in the range of the distribution of number of eggs, were found among those, which had already spawned and which had transparent eggs which had not been released, it appears that the compositions of the number of eggs do not indicate the number of eggs released at each spawning (Fig. 8). However, an examination of the weight of ovaries during the spawning periods by age shows that the weight is maximum during the two spawning periods in Mar. and Sept approximately at the height of spawning activity. The weight decreases following these periods. The main component in the weight of an ovary is the maximum egg aggregate which contains a large quantity of yolk. It appears as though the decrease in the weight of ovary must be due to the decrease in the number of eggs in the maximum egg aggregate. Thus the number of eggs probably decreases as the number of spawning increases. The number of eggs actually spawned will be less than the number of eggs in the maximum egg aggregate in the ovary since some eggs are not spawned; however, since the egg aggregates, which were used to estimate the number of eggs spawned, were completely isolated from other egg aggregates, and since immature eggs, which had not kept the pace of the development of other eggs in the same aggregates, were not observed, it appears as though the eggs, which were contained in these isolated maximum egg aggregates, become transparent eggs undergoing the identical stages of development and are released at the same time. That is to say, one may regard the number of eggs in isolated maximum egg aggregates in the ovary to be somewhat equivalent to the number of eggs spawned, i. e., the number of eggs released in one spawning is approximately 1,500 ~ 3,000 at 2 years, 1,500 ~ 6,000 at 2.5 years, and 2,000 ~ 3,000 at 3 and older years.

IV. Discussion

A comparison of the results of the present investigations on the growth of nigisu in the central section of the Pacific Ocean to results, which have been published in the past, shows that Haneue came to the conclusions that nigisu spawned once a year and that the growths were 130 ~ 150 mm during the 1st full year and 170 ~ 190 mm during the 2nd full year; thus the results of his investigations are entirely different from those of the present investigations. However, since he assumes the spawning period to be during the winter season, if a comparison is made, assuming the brood to have occurred in March, the 1st ring of Haneue corresponds to the 2nd mark of the present report and the 2nd ring corresponds to the 3rd mark. He describes the central section of otolith to be transparent and states that it occupies a circular area or an area resembling the outer shape of otolith. However, in nigisu, which is found in the Japan Sea, the central portion is opaque. If the otolith is ground sufficiently from both sides, the central section becomes transparent. In making measurements on otolith, Haneue polished both surfaces with a grindstone; thus it is possible

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that the 1st mark was missed due to excessive polishing. Mainly on data, which have been collected of the coastal areas of Hyogo-Ken*, Watanabe in 1957 reported that the spawning took place twice

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* Translators' note: approximate location - $134-135^{\circ}$ E and 34° 30' N

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a year in the spring and the fall; he further investigated the age of these two broods. An examination of the growth curves of the two groups shows that they are identical in form with a lag of $\frac{1}{2}$ year. A comparison of full ages, which are read off these curves, and the results of the present investigations shows that the growth is somewhat better in the case of nigisu off the coast of Hyogo-Ken at 1 and 2 years, and that it is somewhat identical at 3 years. In general there is agreement between the two results.

With respect to the spawning period, Haneue classified the gonads on the basis of their degree of maturation into the mature and the immature, showed the conditions of their appearance by month, and concluded that the spawning took place once a year during the winter season. However, even among the specimens, which measure 150 ~ 190 mm in length during the period extending from the end of January to the beginning of February, which is defined to be the height of the spawning season, approximately equal number of cases are observed in the mature and the immature groups, and in Sept. an individual, even though it is one specimen, which belonged to the mature group, is observed. However, the standards set to define the degree of maturation are not clear and consequently detailed comparative examinations are not possible. Watanabe states that the spawning takes place throughout the year with markedly large occurrences in the spring and the fall. However, an examination of the proportion of appearance by month of individuals with "water-fry-eggs"* only a few such individuals are ob-

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* Translator's note: the original expression is "suishiran".

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served in the results for Jan. and Feb in 1953 ~ 1955, and in the results of other investigations no such individual is observed. Other investigations were not made; thus it is not possible to make detailed examinations. However, viewed in the light of the proportion of the appearance of individuals with "water-fry-egg" also, it appears as though it is appropriate to assume that there are two independent spawning periods a year.

Generally even in the case of a group which spawns more than once a year, in many cases an individual in the group spawns once a year during the season when it is hatched, and it is probably rare that an individual as well as the group spawn twice a year and many times during one spawning season as in the case of nigisu. A comparison in detail of the maturation in nigisu with that of other species shows that the maturation of nigisu differs from fish of other species not only with respect to the number of spawnings of individual members but also with respect to many other features. That is to say, 1) the gonads are divided not only into the right and the left halves but each half is further divided into the anterior and the posterior regions and each section undergoes a similar process of maturation: 2) despite the fact that the oviposition takes place several times during a spawning season, the diameter of egg, being 1.6 mm, is large and the number of eggs borne, being 1,500 ~ 8,000, is extremely small: 3) and the index of maturation is small in comparison to those of fish of other species; the value of the mode during the spawning season is 0.438×10^{-3} and even the maximum value is 0.656×10^{-3}. These facts indicate that the maturation and oviposition take place in relatively a small scale. Further, an examination of the seasonal variations of the condition coefficient, which are related closely to the seasonal variations in the growth in body length, shows that the variations are related solely to the variations in season, and that one can hardly recognize their relation to the two spawning periods. These findings suggest that the maturation of nigisu does not affect the growth in the body of fish markedly as seen in fish of other species, and that the two annual spawnings take place with no undue stress on individual fish.

A comparison of the conditions of oviposition at the two spawning periods shows that there is absolutely no difference in the mode of the diameters of transparent egg aggregates, the mode of the diameters of eggs in the egg aggregates in the period of tempo-

page 13 in the original text

rary suspension in development, which is observed during the process of development of eggs, the mode and the range of variations in the number of eggs per unit weight of ovary, and the number of eggs in the isolated egg aggregates, i. e., the coefficients related to the size and the quantity of eggs. That is to say, the two annual spawnings take place in nigisu in an identical fashion. However, an examination of the quantitative relationship between the two broods shows that, although there are differences from month to month, the Mar. brood is more numerous; as a whole the Mar. brood is approximately twice as large (65.8%: 34.2%) as the Sept. brood (Table 4). In view of the fact that the growth is somewhat better in the Mar. brood in comparison to the Sept. brood, it appears as though the Mar. brood is blessed with better living conditions and has a higher survival rate.

V. Summaries

Investigations were made of the age, growth and maturation using data which had been caught off the coastal areas of Niigata-Ken.

1) The scales fall off quite readily; thus the otolith was used for the age investigation. As indicators for age, the outer edge of the opaque zone, which is most distinct, was used.

2) There is no difference due to sex in the relationship between the length of the body and the otolith size. The relation is linear. On the basis of the regression line the mark size was standardized.

3) An examination of the relationship between the otolith size and the mark size by month shows that the sample can be divided into a group (A-group) with a small 1st mark and a group (B-group) with a large 1st mark. For each of these groups and for each group

with the same number of marks the relationship between the mark size and the otolith size can be determined. The points of intersection of these equations with the Y axis on the modes of the otolith sizes were obtained and defined as the representative values of the mark size for groups with the same number of mark sizes and for A- and B-groups for various months.

4) An attempt at establishing the relationship between the representative values of monthly mark sizes and the body length in both A- and B-groups resulted in 3 linear regression lines which were parallel to the X-axis. On the basis of these regression lines and the relationship between the body length and the otolith size the body lengths at the time of the formation of each mark for A- and B-groups were obtained.

5) The seasonal variations in the marginal growth indices by A-B group and by group with the same number of marks show the identical tendency in both groups and in all the mark groups. The maximum values were observed in Sept. and Oct. and the minimum in Oct. and Nov.. It appears that a mark is formed in both groups once a year during Sept. to Nov..

6) An examination of the rates of appearance by month of 5 types of ovaries, which are based on the composition of the egg diameters, shows that the appearance of the most mature and the least mature ovaries is reversed. The most mature ovaries are observed twice a year in Mar. and Sept.. Thus it was established that the oviposition in nigisu took place twice a year over 3 month period centering in Mar. and Sept..

7) An examination of the seasonal variations in the composition of body length, the period of formation of marks and the

body length at the time of formation and the spawning periods of young groups established the fact that A-group was the Mar. brood and B-group the Sept. brood.

8) The condition coefficient (the weight of the body without internal organs/(body length)^3) differs by age and varies with the season. It is maximum at 2 years. The coefficient of the current group is somewhat larger than that of the 3 year group. The seasonal variations do not differ by age. It is maximum in July and Aug; the least value is observed in Dec..

9) In both broods a part of the population joins the spawning group at the age of full two years and in 2½ years becomes almost fully matured adults. On the basis of the conditions of appearance of fully mature individuals and immature individuals and of the ovaries in the process of absorption it was established that each individual had 2 independent spawning periods a year and spawned several times during each period.

10) There is no difference between the two groups in the number of eggs laid. The range of the number of eggs laid at each spawning extends towards the larger side with the increase in age.

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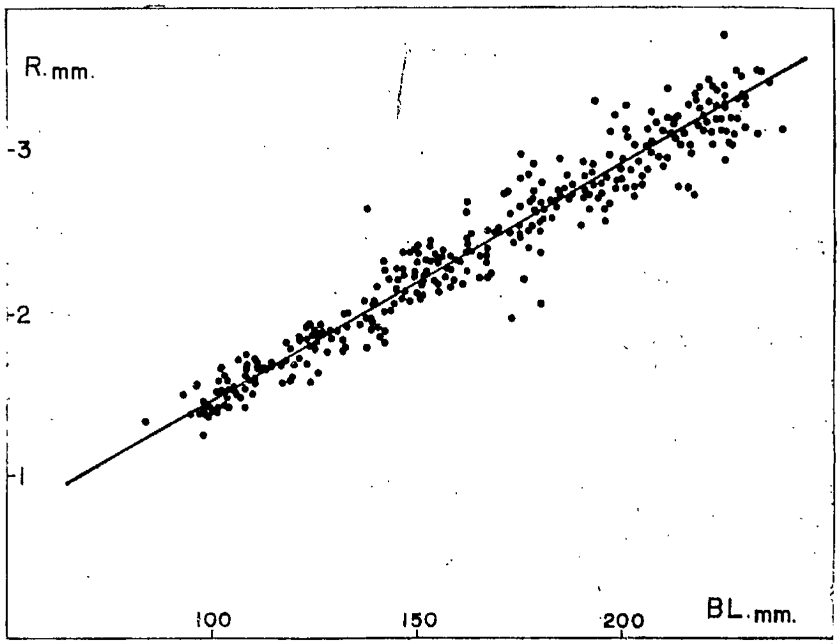
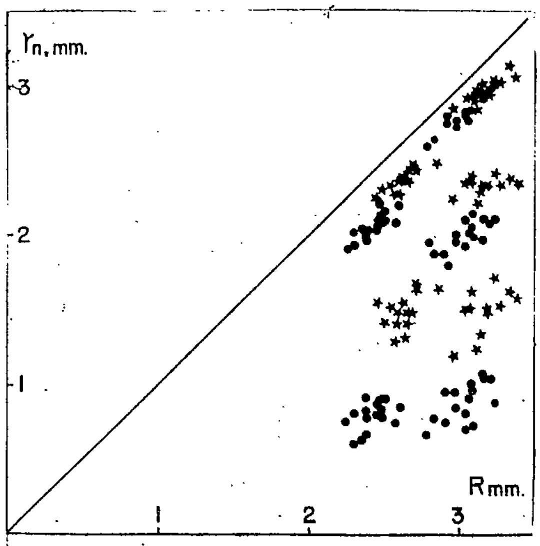


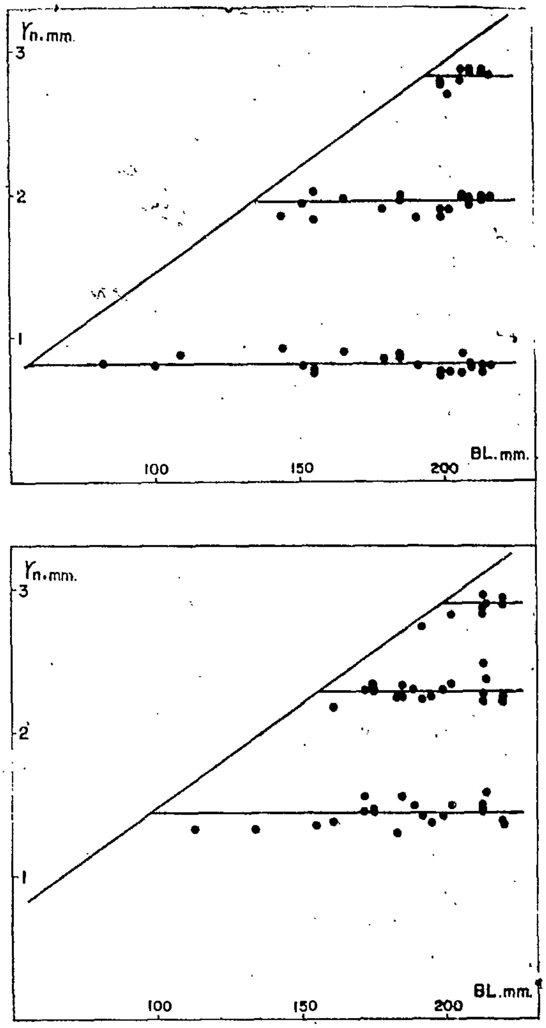
第1図　体長（*BL*）と 耳石径（*R*）との関係

Fig. 1　The relationship between body length (*BL*) and otolith size (*R*)



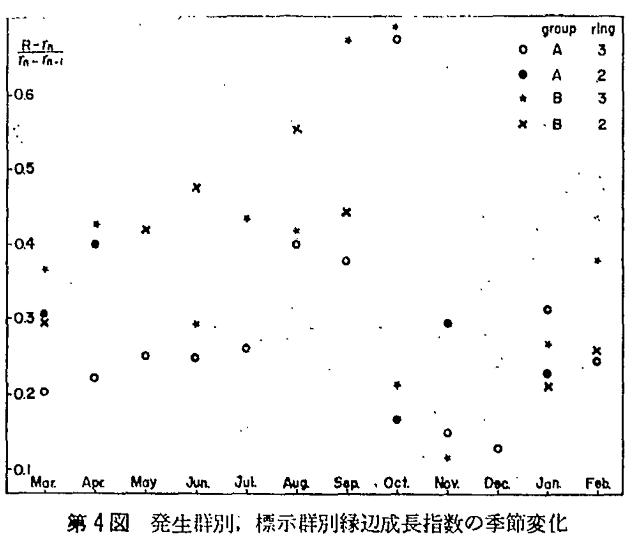
第2図　耳石径（*R*）と標示径（r_n）との関係（3月）

Fig. 2　The relationship between otolith size (*R*) and mark size (r_n) in March.



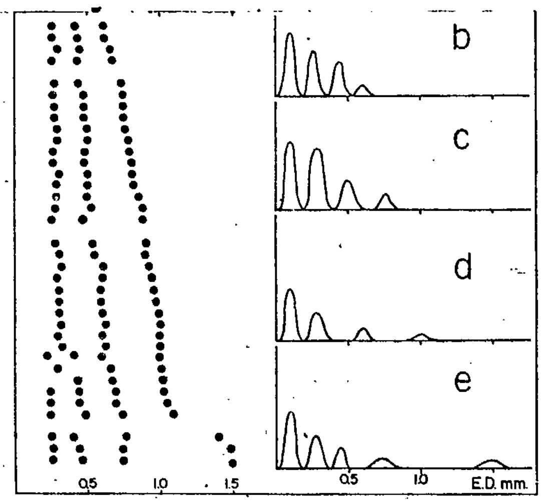
第３図　月別，標示群別の資料から求められた標示径 (r_n) と体長 (BL) との関係

Fig. 3 The relationship between body length (BL) and mark size (r_n) derived from each month and brood data
Upper, A group; lower, B group



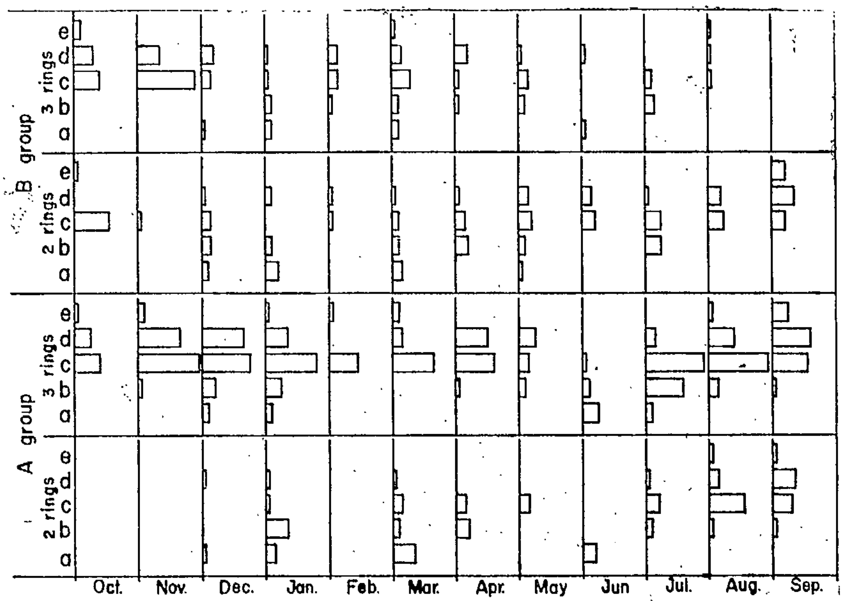
第４図　発生群別，標示群別縁辺成長指数の季節変化

Fig. 4 Monthly change in marginal growth index $(\alpha = R - r_n / r_n - r_{n-1})$ by each brood and mark group



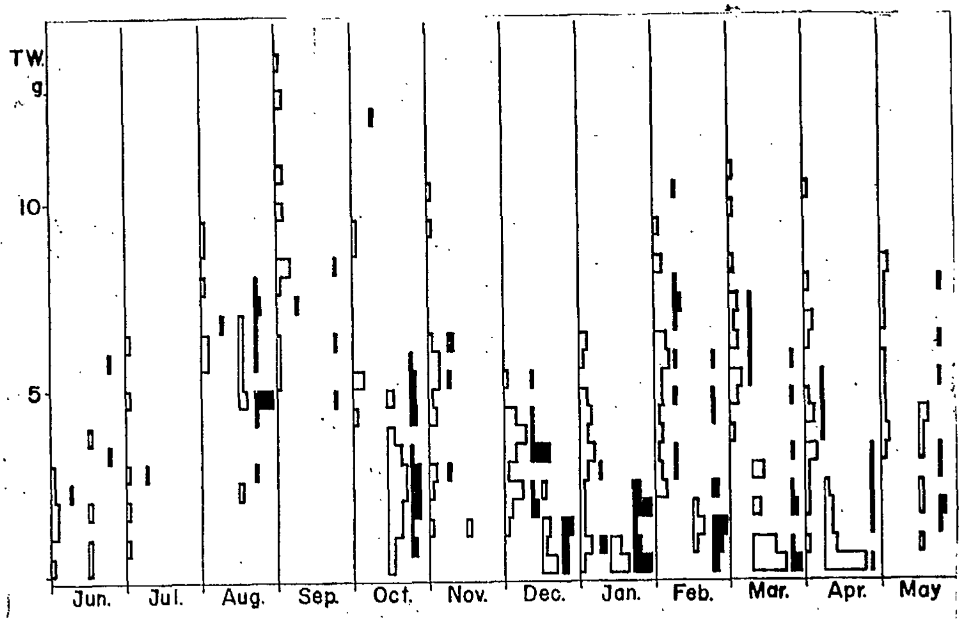
第5図　各卵団の卵径モードと卵径組成に基づく卵巣の成熟型（9月）

Fig. 5 The mode of egg diameter distribution and types of ovary based on the frequency distribution of egg diameter in September



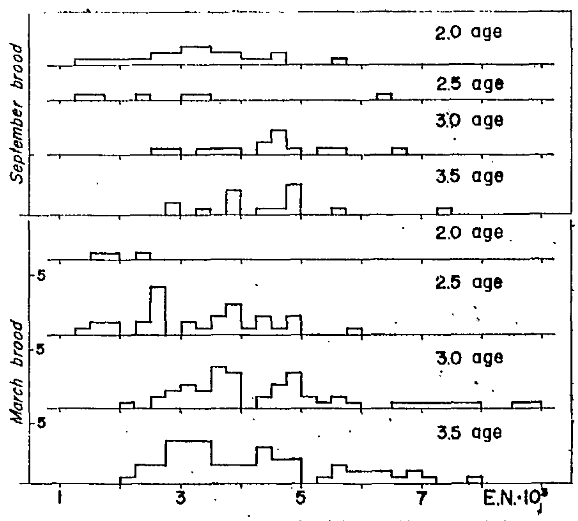
第6図　発生群別，標示群別卵巣の成熟型の月別出現割合

Fig. 6 The seasonal change in appeared number of five types of the ovary in each brood and annual group



第7図 発生群別，標示群別精巣重量の季節変化
□；A群，■；B群
右側；2標示群，左側；3標示群

Fig. 7 The seasonal change of the testis weight in each brood and annual group
□; A group, ■; B group
right side; 2 annulus group, left side; 3 annulus group



第8図 発生群別，年令別分離成熟卵団の卵数

Fig. 8 The egg number of the ripening egg mass separated from smaller egg mass in each brood and age

Table 1 The mark sizes and otolith sizes derived from the data of each mark group and month

A group

date		L	R	r_1	r_2	r_3
Apr.	13	100	1.47	0.80		
		165	2.40	0.90	1.97	
		209	3.05	0.78	1.93	2.85
May	12	109	1.60	0.88		
		207	3.02	0.88	2.02	2.83
June	30	192	2.80	0.81	1.84	
		220	3.20	0.75	1.82	2.74
July	28	213	3.10	0.75	1.98	2.87
Aug.	30	179	2.60	0.85	1.90	
		213	3.10	0.80	1.95	2.85
Sep.	29	185	2.70	0.87	2.00	
		216	3.15	0.80	1.98	2.83
Oct.	25	144	2.10	0.92	1.93	
		185	2.70	0.87	1.96	
Nov.	29	155	2.25	0.75	1.83	
		199	2.90	0.74	1.90	2.77
Dec.	22	199	2.90	0.75	1.85	2.78
Jan.	27	82	1.20	0.82		
		151	2.20	0.80	1.94	
		202	2.95	0.75	1.90	2.70
Feb.	21	158	2.30	0.72	2.00	
		206	3.00	0.75	1.97	2.80
Mar.	27	165	2.40	0.77	2.02	
		209	3.05	0.80	1.97	2.87

B group

date		L	R	r_1	r_2	r_3
Apr.	13	213	3.10	1.60	2.45	2.90
May	12	134	1.97	1.33		
		183	2.67	1.30	2.25	
June	30	185	2.70	1.55	2.33	
		213	3.10	1.50	2.48	2.96
July	28	214	3.13	1.58	2.37	2.90
Aug.	30	185	2.70	1.56	2.25	
		213	3.10	1.45	2.22	2.84
Sep.	29	155	2.25	1.35		
		192	2.80	1.41	2.24	
		220	3.20	1.40	2.22	2.90
Oct.	25	161	2.35	1.38	2.18	
		199	2.90	1.42	2.30	
Nov.	29	190	2.77	1.37	2.25	2.74
Dec.	22	172	2.50	1.55		
		189	2.75	1.50	2.30	
Jan.	27	113	1.65	1.33		
		172	2.50	1.45	2.30	
		202	2.95	1.50	2.33	2.82
Feb.	21	175	2.55	1.47	2.33	
		220	3.20	1.36	2.25	2.94
Mar.	27	175	2.55	1.45	2.30	
		213	3.10	1.47	2.28	2.88

Table 2 The standard mark size (r_n), the back calculated body length (l_t) and the body length (L_t) at t years after spawning in each age and brood (in m.m.)

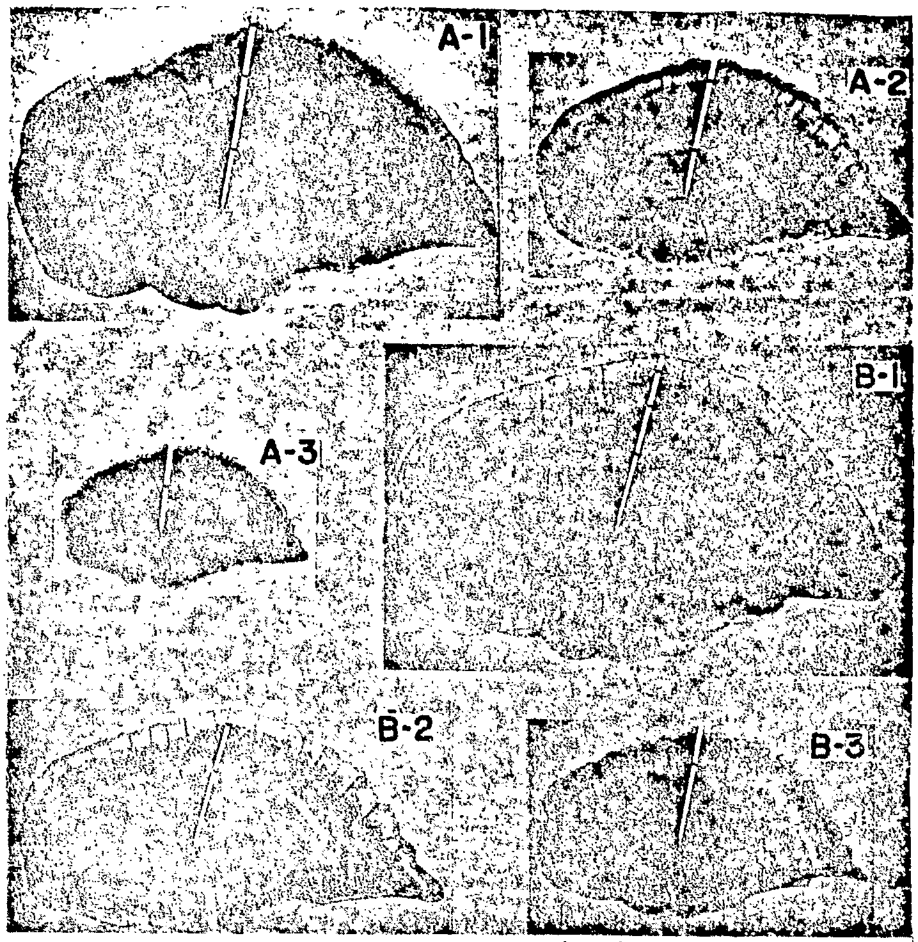
	r_n		l_t		L_t	
brood	A	B	A	B	A	B
age						
I	0.81	1.44	55	99	91	92
II	1.95	2.28	135	157	161	154
III	2.82	2.90	192	199	209	197

Table 3 Monthly change in condition coefficient (body weight without internal organs / (length)³) by each brood and annual group

month	March brood			September brood		
	I	II	III	I	II	III
Oct.		0.690	0.683		0.715	0.690
Nov.			0.675			0.675
Dec.		0.643	0.643		0.675	0.643
Jan.		0.714	0.696	0.652	0.705	0.714
Feb.			0.680		0.713	0.680
Mar.		0.706	0.704		0.724	0.704
Apr.	0.700	0.750	0.692		0.750	0.692
May		0.771	0.726	0.750	0.771	0.726
June		0.765	0.690		0.765	
July		0.750	0.742		0.750	0.742
Aug.		0.775	0.738	(0.740)	0.775	
Sep.		0.700	0.722		0.638	

Table 4 The number of fishes by each annual group and brood in the sampling date

date	March brood				September brood				sum
	I	II	III	IV	I	II	III	IV	
Oct. 13	1	79	30	3		53	18		184
Nov. 29	2	1	75			2	35		115
Dec. 22	2	12	91	4		23	28	2	160
Jan. 27	2	31	58	1	7	46	13		158
Feb. 21		8	49	2		31	18		109
Mar. 27		59	54	1		22	39		175
Apr. 13	50	30	41	2		17	11	1	153
May 12	9	10	25	1	51	19	6		121
June 30		10	17			7	7		41
July 28		8	123			20	12		163
Aug. 30	2	27	44		4	35	5		117
Sep. 29	2	18	115		3	30	5		173
sum	70	361	618	14	65	200	219	3	1665



図版 1　ニギスの耳石

A；3月発生群

1.　3標示　*BL*：210mm，　1966年7月26日
2.　2標示　*BL*：163mm，　1967年3月27日
3.　1標示　*BL*：100mm，　1966年4月13日

B；9月発生群

1.　3標示　*BL*：219mm，　1967年3月27日
2.　2標示　*BL*：178mm，　〃
3.　1標示　*BL*：140mm，　1966年5月12日

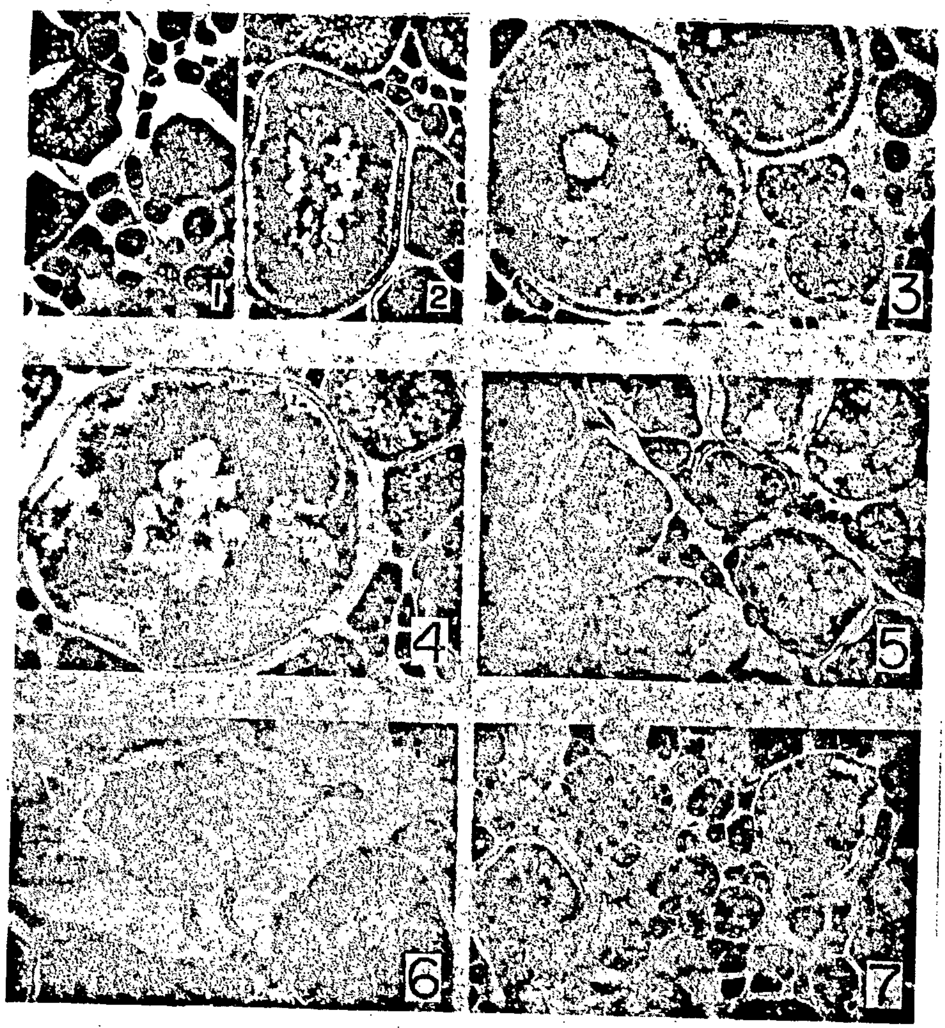
Plate I. Otolith of the deep-sea smelt (*Glossanodon semifaciatus* (KISHINOUYE))

A; March brood

1. 3-marks, *BL*: 210mm, July 26th, 1966.
2. 2-marks, *BL*: 163mm, March 27th, 1967.
3. 1-mark, *BL*: 100mm, April 13th, 1966.

B; September brood

1. 3-marks, *BL*: 219mm, March 27th, 1967.
2. 2-marks, *BL*: 178mm, March 27th, 1967.
3. 1-mark, *BL*: 140mm, May 12th, 1966.



図版 2 ニギスの卵巣内卵

1. a 型の卵巣 1966年6月30日, 3月発生群
2. b 型の卵巣 1967年2月20日, 3月発生群
3. c 型の卵巣 1966年6月30日, 9月発生群
4. d 型の卵巣 1967年3月27日, 3月発生群
5. e 型の卵巣 1966年9月28日, 9月発生群
6. 残留透明卵 1966年9月28日, 3月発生群
7. 崩壊過程の卵 1967年3月27日, 3月発生群

Plate II. Intraovarian eggs of the deep-sea smelt (*Glossanodon semifasciatus* (KISHINOUYE))

1. a type ovary, June 30th, 1966, March brood
2. b type ovary, February 20th, 1967, March brood
3. c type ovary, June 30th, 1966, September brood
4. d type ovary, March 27th, 1967, March brood
5. e type ovary, September 28th, 1966, September brood
6. Remained ripening egg, September 28th, 1966, March brood
7. Egg of decaying stage, March 27th, 1967, March brood