サンマCololabis saira (BREVOORT)卵の発生

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EMBRYONIC DEVELOPMENT OF THE SAURY

COLOLABIS SAIRA (BREVOORT)*

By

Tatsuo YUSA

Introduction

Studies on the ovarian unmature eggs of Cololabis saira (BREVOORT) have been reported by Kitahara1). Kurakami2) described the normal course in the post-embryonic development of this species from the morula stage to the larval stage, and Nakamura3) published on the post-embryonic development of larvae. The samples used in their observations were obtained from the open sea. The experiment on the artificial fertilization has been carried out by Miyauchi4) with the material collected at the offshore of Minato, Ibaragi Prefecture, but his experiment was unsuccessful.

The embryological differences between the saury and Hyporhamphus sajori (T. & S.) have been reported by Inaba5) and the writer6).

The normal course in the embryonic development of this species by artificial fertilization has not hitherto been published, and in the present paper, the study is undertaken using the saury, Cololabis saira (BREVOORT).

Here the writer thanks Prof. Dr. Isao Motomura of the Biological Institute of the Tohoku University for reading the manuscript and for his kind suggestions.

Methods of procedure

The spawning season of this species in the western coastal waters of Hokkaido, Japan, is during the warming time of the year, from June to August. At the spawning time, the temperature of the surface sea water is from 14.0° to 21.0°C, according to the writer’s observations.

The material for study was artificially fertilized by means of the ordinary dry method, from June to August, during the years 1952–1954. But, the artificial fertilization was unsuccessful. On the other hand, the natural fertilized eggs collected in Ishikari Bay, Hokkaido, could be artificially incubated and hatched normally.

In 1958, the writer succeeded in this observations on the normal course of development in artificial fertilized eggs. The animals, from which either eggs or milts were obtained, were caught by primitive grasp fishing in Kikonai Bay facing Tsugaru Strait, southern Hokkaido, on June 14th, 1958. The standard body length of the female was 32.4 cm and that of the male 30.2 cm, in the materials used in the present study.

* Contribution from the Tohoku Regional Fisheries Research Laboratory. No. 154.
Artificial fertilization was successful for the saury by the ordinary dry method. The fertilized eggs were transferred into fresh sea water of the density of $1.0252 \text{ (15°C)}$. During the development the sea water was changed frequently to keep eggs from contamination. The glass vessels containing the eggs were provided with running tapwater of from 13.5° to 15.7°C.

The microscopic observation was made at frequent intervals to check the time and the stage of development, and on the living material, or with Tricaine methanesulfonate anesthetized to observe the larvae in detail. One part of the anesthetic was diluted with about 2,000 parts of sea water.

**Eggs**

The mature unfertilized eggs are transparent and ellipsoidal in form, with about 20 filaments at the chorion of one side of the major axis; moreover, a filament is observable at the equatorial plane as shown in Text-fig. 1; the former adhesive filaments are about 9.7μ in thickness, and the latter from 19.4 to 22.6μ in thickness.

The protoplasm is not found in the unfertilized mature eggs, but it is observed in the fertilized ones, and in activated eggs (by the sea water). As far as the writer’s observation is concerned the blastodisc is formed at the clumpy part of the about 20 adhesive filaments. Accordingly, the animal pole may be placed at the clumpy part of the filaments (Text-fig. 1), but the writer could not observe the microphyle of the egg.

The chorion is horny, about 15μ in thickness, and has no marking.

A large number of small oil globules, which are not the cortical alveoli, distribute over the surface of the cortex.

The specific gravity of the mature unfertilized eggs is clearly greater than that of the sea water.

**Development**

According to Kurakami²¹ the eggs are spherical with an extent diameter from 2.06 to 2.13 mm. Nakamura³⁷ reported that the eggs are spherical or ellipsoidal in form, having a major axis of 1.58 to 1.89 mm and a minor axis of 1.53 to 1.76 mm. The form of the
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egg is the same as described by Nakamura\(^1\), but it is ellipsoidal or spherical changing according to developmental stage, measuring 2.08 to 1.32 mm in pole axis and 2.00 to 1.48 mm in equatorial axis (Text-fig. 1).

The specific gravity of the eggs is large in comparison with sea water (1.025 15°C) measuring 1.0540 to 1.0627. Therefore, the eggs do not drift at the surface of the open sea, but tangle with about 20 filaments at the pole and a filament at the equator to the floating algae, chip of wood, straw, feathers, fishing-net and other foreign materials.

**Early development;**

A small perivitelline space appears between the chorion and delicate cortex, within a few minutes after coming into contact with the sea water. At about thirty minutes after fertilization, the protoplasm becomes clearly observable at the part of the bundle of about 20 adhesive filaments. This shows that the animal pole is at the side of the clumpy filaments (Pl. I, Fig. 1). In the fertilized eggs of the half-beak, *Hyporhamphus sajori* (T. & S.) the protoplasm is observed at the side of the clumpy filaments (YUSA 1958) (Text-fig. 2). According to Kuntz and Radcliffe\(^7\) the animal pole is not at the side of the clumpy filaments in the silverside, *Menidia menidia notata*.

At about two hours and forty minutes after fertilization, the blastodisc reaches its full development and appears as a rounded cap, thick at the center and gradually fading into the extremely thin layer of protoplasm investing the rest of the yolk. The surface overlying the yolk is flat, while the opposite surface, pressing against the chorion, is convex.

At about three hours after fertilization, the protuberance of the yolk as a transverse furrow flowing into the protoplasm is observable (Pl. I, Fig. 2). The phenomenon of the cleavage of this species is the same as for other teleost fishes.

The 2-cell stage is completed by the first division into two about equal blastomeres at about three and a half hours after fertilization (Pl. I, Fig. 3). Segmentation of this species takes the form of the typical meroblastic cleavage as in the other teleost fishes.

After the completion of the first cleavage, there is a resting period of about one hour and ten minutes. The second cleavage plane is also meridional and at right angles to the first; it occurs in the same manner as described in the starry flounder, *Platichthys stellatus*\(^8\). The second cleavage plane is completed at about for hours and fifty minutes after fertilization, and the four blastomeres are nearly equal in size (Pl. I, Figs. 4, 5).

The third cleavage is completed about five hours and forty minutes after fertilization.

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Text-fig. 2.

The eggs of *Hyporhamphus sajori*:

A — Fertilized egg.

B — Two hours after fertilization.
It is accomplished by two furrows appearing simultaneously on both sides of and parallel to the first plane of cleavage. The eight blastomeres are nearly equal in size and these cells are arranged in two parallel lines of four cells each (Pl. I, Fig. 7).

The fourth cleavage is completed about seven hours after fertilization (Pl. I, Fig. 8). At this time two simultaneous furrows appear on either side of and parallel to the second plane of cleavage. As the result of the fourth cleavage, 16-cell blastoderm always forms a unicellular layer. The blastoderm of this time is smaller than one half of the egg's diameter, when viewed from the animal pole (Text-fig. 3).

All the eggs do not divide at the same rate, the period of time between the cleavages is fifty minutes or one hour.

The fifth cleavage and further cleavages become more and more difficult to follow in the living material. If the fifth cleavage takes place at about eight hours after fertilization, it will be as shown in Pl. I, Fig. 9. As the result of the proceeding cleavage, a large number of blastomeres form three or four layers at the central portion of the blastoderm on the side view, at about fourteen hours after fertilization. At this stage it can be called the morula stage (Pl. I, Figs. 10, 11).

The early blastula is reached at about twenty-three hours after fertilization (Pl. I, Figs. 12, 13). As the segmentation advances, the blastoderm becomes distinctly dome-shaped and the segmentation cavity becomes apparent beneath its central area. The periblast is observed at the periphery of the blastoderms to form a somewhat flattened ridge. The formation of the periblast had been reported by Agassiz and Whitman9) and Kuntz9).

Post-embryonic development;

The germinal ring can be clearly discerned as a thickened peripheral zone of the blastoderm at about thirty-nine hours after fertilization (Pl. I, Fig. 14). At this stage, the embryonic shield is visible as a small tongue of cells protruding from the germinal ring into the segmentation cavity.

At about sixty-two hours after fertilization the germinal ring is almost equatorial in position; the embryonic area now presents more or less regular embryo form, and the head of the embryo is well formed, and the optic vesicles make their appearance at the two sides of the head but are without pupils. The optic vesicles measure about 184 μ in horizontal diameter. The notochord can be discerned, and the embryo has five to seven pairs of mesodermal somites in the central region of the embryo. The Kupffer's vesicle is observable, as a slight bulge of the ovalness into the yolk, when viewed from the ventral side, which is about 50 μ along the longest axis at the ventral side of the nearly
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posterior end of the embryo.

At about sixty-six hours after fertilization, the germinal ring has reached more than the equatorial plane. Kupffer’s vesicle appeared, embedded in the yolk near the posterior end of the embryo (Pl. I, Fig. 15). The constriction of the yolk by the germinal ring causing the uncovered portion of the yolk to bulge outward was observed in this species, but the excessive constriction of the germinal ring could not be observed as Pleurogrammus azonus, due to the small volume of the protoplasm in contrast with the yolk (Pl. I, Figs. 1, 2, 15, 16).

The germinal ring passes the equatorial plane; it draws away from the anterior end of the embryo, and by seventy-two hours, it is about four-fifths of the yolk sphere in diameter (Pl. I, Fig. 17). At this stage, the germinal ring has reached more than the equatorial plane, the embryo area can be distinguished, and the optic vesicles have the first appearance of the lense of each eye. The embryo has approximatively 15 pairs of mesodermal somites in the central region. The Kupffer’s vesicle has reached about 110 µ at the longest axis, when viewed from the ventral side of the embryo.

The blastopore is at the stage of before closure at about eighty-seven hours after fertilization (Pl. I, Fig. 18). At this time the length of the embryo extends more than halfway around the circumference of the yolk’s sphere. The embryo is relatively more slender than the embryo of the other demersal and adherent eggs. The eyes are about 306 µ in horizontal diameter, 173 µ in width, and the olfactory capsules make their appearance immediately anterior to the eyes, and the auditory vesicles can be observed posteriorly to the eyes.

The heart is making its first appearance into the yolk sac just below the nape, and the embryo has about 20-22 pairs of mesodermal somites in the center, and the Kupffer’s vesicle (about 100 µ) is decreasing in size at this stage.

At about ninety-six hours after fertilization, the blastopore remains as a trace at the posterior end of the embryo. The lense of each eye is about 70 µ in diameter. The intestine appears as a long tubule at the ventral side of the embryo. The Kupffer’s vesicle is decreasing in size.

At about one hundred and twenty hours after fertilization, the embryo extends approximately three-fourths around the circumference of the yolk’s sphere, and it has about 40 pairs of mesodermal somites (Pl. I, Fig. 19). The blastopore is closed completely. The delicate pectoral fin porch is observed posteriorly to the auditory vesicles, which have no otoliths. The heart of the embryo was observed best and minute corpuscles which appear to be colorless are moved about in the chamber during each beat.

At about one hundred and thirty-four hours after fertilization, the tail of the embryo has started to grow free from the yolk sac and the spasmodic movements of the embryo are observable. The pigment appears as a few scattered minute black specks on the surface of the body, except on the surface of the yolk sac.

At about one hundred and fifty-eight hours after fertilization, the embryo extends approximately four-fifths around the circumference of the yolk’s sphere, as a result of the growth of the tail (Pl. I, Fig. 20). At this stage the blood vessels can be observed over the yolk sac and minute black specks of chromatophores are observed on the surface of the

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yolk sac. On the other hand, the chromatophores of the embryo become black stellate chromatophore. When viewed from the dorsal side the three divisions of the brain can be clearly distinguished in the head of the embryo; the delicate fin fold can be seen at the tip of the tail when viewed from the side of it (Pl. II, Fig. 21).

After circulation becomes well established, the majority of the chromatophores in the extra-embryonic yolk sac become aggregated along the larger blood vessels (Pl. II, Figs. 22, 23). The distribution of chromatophores can be observed along the blood vessels after fertilization. Moreover, the distribution of the chromatophores of the yolk sac could be observed in Hyperhamphus sajori, at about one hundred and sixty-eight hours after fertilization (15.4–16.5°C). Spasmodic movements of the embryo are observable at this stage.

At about two hundred and seven hours after fertilization, the embryo surrounds the yolk as a result of the growth of the tail. It becomes active and often turns completely in the chorion. The auditory capsules now contain two black dots. The yolk is absorbed, and the yolk sac is smaller than in the preceding stage (Pl. II, Fig. 24).

At about two hundred and thirty-two hours after fertilization, the tip of the tail extends to the head region. The iris and pupils of the eyes have darkened slightly. The heart has been functioning for several days and the blood can be seen clearly passing through the vessels spread over the yolk sac and through the larger vessel of the body. The embryo twitches its tail spasmodically from side to side (Pl. II, Figs. 25, 26).

At about two hundred and fifty-three hours after fertilization, the tip of the tail reached the occipital region. The pectoral fin has become very large, and often the embryo can be observed twiching the pectoral fin (Pl. II, Fig. 27).

At about two hundred and seventy-four hours after fertilization, the pectoral fin had constantly rhythmic movements (Pl. II, Fig. 28).

At about three hundred and twelve hours after fertilization, the embryo turns over 1 i in its chorion (Pl. II, Fig. 29). The pigmentation becomes heavier than the preceding stage, and large black dendritic chromatophores are clearly observed on the head part, and the pigmentation of the yolk sac becomes slightly heavier by black small stellate chromatophores. The median larval fin fold is clearly observed beginning a little anteriorly of the dorsal part of the vent, continuing till about the posterior end of the trunk; one more ventral fin extends before the vent. From this stage to hatching, for about four days, a few changes occur. The yolk is absorbed, the yolk sac is shrunked, the pigmentation becomes heavier and the movements become more vigorous.

At about four hundred and eight hours (17 days)* after fertilization, the embryo turns 1 i in its chorion (Pl. II, Figs. 30, 31). The yolk sac is small, the eyes are jet black and

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* In the experiments which performed by the present author, during 1952-1954, it showed that the duration for hatching of this species was about 11 or 16 days at the temperature ranging between 15° and 19°C, instead of 17 days in the present experiment. [Report of the survey of fisheries resources from the Hokkaido Reg. Fish. Res. Lab. (Hokkaidoku Shigench'sa Yōdo) (8) 1954, in Japanese] Unfortunately, the previous observation did not succeed until hatching in all artificial fertilized eggs, but the natural fertilized eggs collected in Ishikari Bay, Hokkaido, could be artificially incubated and normally. Accordingly, the writer reported with these all previous experiments.
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silvery. At this stage, the dorsal side of the embryo is indigo-greenish, and the ventral side is white-greenish or silvery. The larvae hatched out through the rupture of the chorion (Pl. II, Fig. 32), but it could not be observed whether the head or the tail came out first. The hatching of this species is much more quicker than other pelagic eggs.

**Larval development**

The newly hatched larvae of this species have been described by Kurakami\(^2\) and Nakamura\(^3\), but their samples were not obtained by artificial fertilized eggs. The newly hatched larva of this species closely resembles that of *Hyperhampus sajori*. The former can be distinguished from the latter in the pattern of distribution of the chromatophores\(^6\). The larval form of this species agrees with Nakamura's description.

The well-developed larvae swim actively immediately after hatching. Their movements are perfectly directed and they show no difficulty in maintaining an upright position experienced by the early larvae from pelagic eggs.

Figure 33 is a lateral view of the newly hatched larvae. They are stable and non-transparent, consequently the mesodermal somites could not be counted in the living materials. Moreover, the surviving yolk could not be observed from outward aspect, but needless to say it could be ascertained by the section method as Text-fig. 4.

The dorsal fin fold has its origin as far posteriorly as the value of the ratio with the dis-
tance from the tip of the head to the origin of the dorsal fin fold for the total body length is 0.5438 as shown in Text-fig. 5, and the value of the ratio with the distance of anterior part of the vent for the total body length is 0.6328 as shown in Text-fig. 5. Both these value of ratio are not changed from newly hatched larva stage to ten days old larva stage (Post-larval stage). Accordingly, the origin of the dorsal fin fold is located at the anterior part of the dorsal side of the vent. The larval fin fold continues to about the posterior end of the trunk; it extends anteriorly to the vent as a ventral fin fold. Moreover, the ventral larval fin fold extends anteriorly beyond the vent and reaches the yolk sac.

The newly hatched larvae are from 6.81 to 7.60 mm in total body length, or with an average total body length of 7.19 mm (Text-fig. 5). The eyes are relatively large measuring about 400 μ in horizontal diameter, and its lens are about 140 μ in diameter. The head extends beyond to the yolk sac, which is not deflected as derived from pelagic egg or the flatfishes, *Platichthys stellatus* 10, *Limanda angustirostris* 11, *Hippoglossoides dubius* 11, and *Eopsetta grigorjewi* 11. But the head of the larvae derived from the adhesive demersal eggs of *Lepidopsetta mochigare* 13, *Limanda yokohamae* 14 and *L. schrenki* 14 of flatfish extends beyond the yolk sac as in this species.

The newly hatched larva of this species at this stage is already well organised: the mouth is well-developed, and definite movements of the jaw are observed in the living specimen; moreover, the lower jaw is slightly more portuberate than the upper jaw; the vent is probably completely opened; the yolk is relatively small in quantity; the pectoral fins are well developed and exhibit movements in continuous swimming, the dorsal and anal finfolds are continuous with the caudal, which alone possesses incipient raval 10-11 rays (Test-fig. 6. Pl. II, Fig. 33).

**Text-fig. 6.**

The vent part and the caudal fin fold of the nine days old larva, C. saira (B.)

A — Vent part.

odf, Origin of the dorsal fin fold; v., Vent; di., Dorsal incipient raval ray; ai., Anal incipient raval ray.

B — Caudal fin.

ci., Caudal incipient raval ray.

Dodging ability is found in the newly hatched larvae. Such dodging ability is increased in accordance with size of the larvae.

**Pigmentation** — The larval finfolds are almost perfectly transparent and show no evidence of pigmentation. But the eyes are conspicuously black. The dorsal side of the embryo is indigo-greenish, and also the crown of the head of the larva is covered with indigo-greenish color, however it had been observed that the melanophores of the crown region which is entirely indigo-greenish, at times changed into a yellow-whitenish color, when the larvae were imbibed by a syringe or other times. These color change phenomenons are observed in the larvae from artificial or unartificial incubated larvae. The
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ventral side of the body is white-greenish or silvery.

Three or four days after the hatching, the larvae absorbed the yolk completely and they became the so-called postlarvae.

Five days after the hatching (Pl. II, Fig. 34) the larvae are from 7.15 to 7.90 mm in total body length (Text-fig. 5). The value of the ratio with the distance from the tip of the head to the origin of the dorsal fin fold for the total body length is 0.5401. The value of the ratio with the distance of anterior part of the vent for the total body length is 0.6243.

The larvae are slender but with a somewhat big head as shown in Text-fig. 7. At this stage of the larvae, the incipient raval rays of the dorsal and anal finfolds make their appearance (Text-fig. 6). The dorsal finfold has 9–10 rays, the anal finfold has 10–12 rays, and the caudal finfold has 10–12 incipient raval rays.

The pattern of pigmentation is essentially the same as at the time of hatching. The ventral side of the body and the gill-cover become white-silvernish.

Nine days after hatching, the larvae are from 7.45 to 8.27 mm in total body length (Pl. II, Fig. 35). At this time the caudal fin of the larvae contains 12–15 incipient raval rays, the dorsal fin 10–12 rays, the anal fin 11–12 rays, as shown in Text-fig. 6.

The pattern of pigmentation and the manner of swimming are essentially the same as in the preceding stage.

It seems to be the "critical period" for survival in the larvae of the eighth or ninth day after hatching, since a high mortality is shown under laboratory conditions. The larvae which were not able to find special food for this species will die because of starvation. The writer was not able to keep the larvae alive for more than twelve days after hatching. It is suggested that there is no "critical period" at the time of yolk absorption in this species.

Summary

In the present paper, the normal course of development in the saury, Cololabis saira (BREVOORT) was reported.

The animals, from which eggs or milts were obtained, were caught by primeavally grasp fishing in Kikonai Bay bordering the Tsugaru Strait, southern Hokkaido, on June 14th, 1958. The standard body length of the female was 32.4 cm and that of the male 30.2 cm, in the material used in the present study. Both ovaries and testes were treated for artificial fertilization by the ordinary dry method. The fertilized eggs were transferred into fresh sea water of the density of 1.0252 (15°C) and of temperature ranging from 13.5° to 15.7°C.

The results are as follows;

1. The form of the eggs are spherical or ellipsoidal in form, and they are transparent.
The pole axis of the egg is 2.08 to 1.32 mm and the equatorial axis 2.00 to 1.48 mm.
2. The specific gravity of unfertilized mature eggs and fertilized eggs is from 1.0540 to 1.0627, viz, the specific gravity of the eggs is greater than that of the sea water.
3. The protoplasm is not found in unfertilized mature eggs, but in fertilized or in activated eggs (by the sea water) the blastodisc is formed at the clumpy part of the about 20 adhesive filaments.
4. The egg chorion is horny, about 15 μ in thickness, and is destitute of any marking.
5. A large number of minute oil globules which are not identical with the cortical alveoli distribute over the surface of the cortex.
6. Artificially fertilized eggs undergo meroblastic cleavage, which is typical in the other teleost eggs.
7. All the eggs do not divide at the same rate; the period of time between the cleavages is 50–60 minutes.
8. The larvae hatched about four hundred and eight hours after fertilization when they were kept in sea water of 13.5°–15.7°C during the period of incubation.
9. The newly hatched larva of this species closely resembles that of Hyporhamphus sajori. The former can be distinguished from the latter in the pattern of distribution of the chromatophores. The larval form of this species nearly agrees with Nakamura's description.

Bibliography

14) ———. The chief differences between the eggs and larvae of Mub Dab Limanda yokohamae Günther and Limanda schrenki Schmidt. (MS)
Embryonic Development of the Saury

～和文抄録～

サンマ Cololabis saira (BREVOORT) 卵の発生
遊佐多津雄

サンマの卵巢卵については北原 (1894) が報告し、この資料にもとづいて倉上 (1914)、中村 (37) がいずれも天然産卵の材料を得てサンマ卵の後期発生を観察しているが、両者の観察結果には可成りの差異が認められている。

本種の人工受精による発生については宮内 (32) が詳覧したが、初期卵割期に鰓死し失敗している。従って、本種の正常発生に関し初期卵割より孵化稚魚までの観察結果については未だ報告されていない。

著者は幸いにも 1958 年 6月 14 日津軽海峡に面する北海道木古内湾で成熟サンマを“摂取り漁法”によって採集し、人工受精を行って本種の正常発生に関する観察結果を得たので報告する。

この実験に用いた成熟親魚は♀32.4 cm、♂30.2 cm で、人工受精は普通一般に行われている乾燥法人工受精の方法で行った。飼養温度範囲は 15.7～13.5℃（最高最低温度計使用）で、使用海水比重は 1.0252（15℃）であり、海水の腐敗による悪影響を考慮してしばしば飼養海水を換えた。

観察方法は主として普通顕微鏡下で生の材料を観察した以外にブン固定後パラフィン切片とし、デラフィールドヘマトキシリン、エオシン二重染色法によって観察して次の結果を得たので要約する。

1. 成熟未受精卵と受精卵の卵比重は 1.054～1.0627 であった。従って卵比重は普通海水比重より遠かに重く、卵が他物に附着するか、可成りの流れがない限り海の表面近くに浮遊することは恐らくなかろうと思われる。

2. 卵形は球形、或は楕円球で、極軸は 2.08～1.32 mm、赤道閉幅は 2.00～1.48 mm である。成熟未受精卵は無色透明に近く、原形質はアサバガレイ Lepidopsetta mochigarei やマコガレイ Limanda yokohamae のように成熟未受精卵では観察することが出来ない。

3. 前項で述べたように未受精卵では卵形が観察されないが、受精卵は海水によって活性化されたものでは、卵形質は約 20 本ある附属条附着に集積し卵殻の形成が認められる。最も本種の卵の動物極は約 20 本の附属条附着に生することを認められる。

4. 卵膜の厚みは約 15μ である、不規則な網目構造が観察される。

5. 卵の表層 (Cortex) には微細な油球が多数散在しているが、この外表層層胞 (Cortical alveoli) があるかどうかは確めていない。

6. 卵割は他の硬骨魚卵の様に典型的な盤状分割を辿る。

7. 卵割間の時間は 50 分乃至 60 分を要する。

8. 受精後 17 日で孵化する。

9. 孵化稚魚は中村 (37) の報告とは一致し、サヨリ Hyporhamphus sajori の孵化稚魚に類似するが、色素の分布で両者は明確に識別出来る。

10. 孵化後 3～4 日で卵黄を吸収し後稚魚期に入り。卵黄観察による）

11. 孵化後 8～9 日に鰓死稚魚が多く現われたことは適当な飼料の欠乏によるものと考えられる。最も生存した卵殻は孵化後 12 日で、これ等のことから孵化後の危険期は卵黄吸収期（孵化後 3～4 日）よりずれるという暗示が強い。

* 他のサンマ親魚よりの材料で人工受精によって卵割した観察結果を含めてある。

(11)
Explanation

Plate I

Fig. 1. The protoplasm clearly observed at the part of about 20 adhesive filaments, lateral view, 30 minutes after fertilization.

Fig. 2. The transverse furrow flowing into the protoplasm is observable at the blastodisc, lateral view, three hours after fertilization.

Fig. 3. The 2-cell stage, lateral view, three and a half hours after fertilization.

Figs. 4, 5. The 4-cell stage, lateral view, four hours and fifty minutes after fertilization.

Fig. 6. The same as Figs. 4 and 5, surface view.

Fig. 7. The 8-cell stage, lateral view, five hours forty minutes after fertilization.

Fig. 8. The 16-cell stage, surface view, seven hours after fertilization.

Fig. 9. The 32-cell stage, surface view, eight hours after fertilization.

Fig. 10. The morula stage, lateral view, fourteen hours after fertilization.

Fig. 11. The same as Fig. 10, surface view, sixteen hours after fertilization.

Fig. 12. The early blastula stage, surface view, twenty-two hours after fertilization.

Fig. 13. The same as Fig. 12, lateral view.

Fig. 14. The early gastrula stage, lateral view, thirty-nine hours after fertilization.

Fig. 15. The gastrula stage, the germinal ring has reached more than the equatorial plane and the Kupffer's vesicle can be clearly discerned, lateral view, sixty-six hours after fertilization.

Fig. 16. The gastrula stage, ventral view of the embryo, seventy hours after fertilization.

Fig. 17. The gastrula stage, the germinal ring has reached about four-fifths of the yolk sphere diameter, surface view from the head region, seventy-two hours after fertilization.

Fig. 18. The blastopore is at the stage of before closure, lateral view eighty-seven hours after fertilization.

Fig. 19. The embryo has 40 pairs of mesodermal somites, side view, one hundred and twenty hours after fertilization.

Fig. 20. The embryo extends about four-fifths around the circumference of the yolk's sphere, side view, one hundred and fifty-eight hours after fertilization.

Plate II

Fig. 21. The three divisions of the brain can be clearly distinguished in the head, side view, one hundred and seventy-eight hours after fertilization.

Figs. 22, 23. The chromatophores in the extra-embryonic yolk sac become aggregated along the larger blood vessels, side view, one hundred and eighty hours after fertilization.

Fig. 24. The embryo surrounds the yolk's sphere, side view, two hundred and seven hours after fertilization.

Figs. 25, 26. The tip of the tail extends till the head region, ventral view, two hundred and thirty-two hours after fertilization.

Fig. 27. The tip of the tail reaches the occipital region, ventral view, two hundred and fifty-three hours after fertilization.

Fig. 28. The pectoral fin has constantly rhythmic movements, ventral view, two hundred and seventy-four hours after fertilization.

Fig. 29. The embryo turns over 1 1/2 in its chorion, side view, three hundred and twelve hours after fertilization.

Fig. 30. The embryo turns 1 1/2 in its chorion, dorsal view, shortly before hatching.

Fig. 31. The same as Fig. 30, ventral view.

Fig. 32. The chorion has rupture.

Fig. 33. Larval fish soon after hatching, side view.

Fig. 34. Five days old larva, side view.

Fig. 35. Nine days old larva, side view.
Plate I

Cololabis saira (Brevoort)
Plate II

Cololabis satira (Brevoort)