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OBSERVATIONS ON HOTARU-IKA WATASENIA SCINTILLANS.

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(With 3 plates and 1 text figure.)



PREFACE.

I had an opportunity to observe the living state of *Hotaru-ika* **Watasenia scintillans** (*Berry*) and the actual scene of fishing for them at Namerikawa, Toyama Prefecture in 1913. I was there twice in that year, first in spring from April 17 to May 10, and again in summer, from July 21 to August 23.

The present investigation embodies the studies concerning mainly the habits of the *Hotaru-ika*. The observations on their living state as well as the references to the fishery were made in the visits mentioned above¹⁾ and the materials used in this study consist of the specimens obtained there as well as of those from other localities.

The fishing season of *Hotaru-ika* in Toyama Bay and its coasts is commonly late April and the whole of May. The coast where this fishing is carried on, extends from Ôta, Himi-gun, Etchu Province to Itoigawa, Echigo Province, which forms the deepest inlet of the Japan Sea in Honshu.

1) I express my warmest thanks to Mr. K. Koishi, Principal of the local Fishery Institute, Namerikawa, and his staff, especially Mr. S. Matsuno, for their efforts in helping me in every way in my investigation.

The total amount of the annual catch reaches generally about 1000 tons, though it shows some fluctuation, and in 1913 it reached a little above 900 tons, the statistics here being taken directly from the notes of fishermen engaged in that fishery. *Hotaru-ika* caught there are mostly mature females; young ones have not been found.

For facilities and useful advice given me in the present work, it is my pleasant duty herewith to return my cordial thanks to Prof. Dr. T. Fujita.

I. HABITS OBSERVED FROM THE ZOOLOGICAL POINT OF VIEW.

1. Sexual Dimorphisms.

The characteristics of the female *Hotaru-ika* have been already made public by S. S. Berry (Proc. Acad. Nat. Sci. Philadelphia, 1912, p. 425), and the specimens examined by me practically agree with his description except in details, which do not seem sufficiently important to be stated here.

The principal sexual differences based on the study of 20 formalin specimens of each sex obtained in the period from April 25 to May 7 are as follows:

Female.—The mantle-length is 54–67 mm. This is about the minimum and maximum limits of the mantle-length of the fully mature female, for I have never met with any beyond these extremities.

Two-sevenths of the mantle at the anterior is cylindrical. From thence it tapers gradually and is pointed at the posterior end. The fin is large and very broad, the breadth being distinctly greater than the length, which is slightly less than $\frac{2}{3}$ of the mantle-length (Pl. I, fig. 1).

The pen is of the *Loligo*-type and wide, the breadth being a little less than $\frac{1}{5}$ of the length (Pl. II, fig. 1).

Male.—The body is a little smaller than that of the female, the mantle-

length being 44-54 mm.; this may also be taken as the length of the fully mature male for the same reason as stated above. The mantle is slenderer than that of the female and rather conical in shape, the broadest part being in the anterior. The fin is of equal breadth and length, and is proportionately smaller than that of the female, the length being only a little longer than half the mantle-length (Pl. II, fig. 4).

The hectocotylus is the right ventral arm, and provided with 2 small semilunar membranes in the terminal portion, but beyond that it shows no special modification (Pl. II, fig. 3).

The pen is distinctly narrower than that of the female, the breadth being about $1/7$ of the length (Pl. II, fig. 2).

2. Luminous Organs and their Phosphorescence (Pl. II, figs. 2-5).

Prof. Dr. S. Watase was the first to make zoological observations on the phosphorescence of the luminous organs of *Hotaru-ika* at Namerikawa, and he described it in the *Dôbutsugaku Zasshi*, Tokyo (1905, p. 119), and also announced it at the Seventh International Zoological Congress at Boston, U. S. A., 1907. The luminous organs are classified here also into 3 kinds according to Prof. Watase, i. e. (a) brachial organs, (b) minute organs scattered on the ventral surface of the whole body, (c) ocular organs.

Brachial Organ. This is the largest organ, and when I made observations in the fishing season, it was much more active in phosphorescence than other organs. It is situated at the end of each ventral arm, composed of 3 globules arranged in a series. The globules are ovoid in shape and nearly squal in size, but the middle one in the series is generally a little larger than the others, the dimensions being 1.4 mm long and about 1 mm broad. In fresh specimens they show a greenish cobalt colour, and there are 2 or 3 layers of large brownish chromatophores covering a part of the preceding substance (Pl. I, fig. 4). These chromatophores are constantly contracting and expanding. When they were observed at night on the living animals, they were seen to discharge light in all directions much brighter than any of Japanese fireflies. The colour of the light is

Prussian-blue or tinged a little with purple, and the luminosity is strong enough to absorb the light of other luminous organs. When the living animal was placed on a glass plate, which was put directly on the case of the dry plate of the photographic camera, and then exposed for 4 seconds with the Lion's dry plate of the special rapid no. 230, the light of this brachial organ was distinctly taken on the dry plate, although those of other organs made no impression.

Minute Organs Scattered on the Ventral Surface of the Whole Body. There are numerous minute organs distributed on the ventral surface of the mantle, head and siphon, and they are also on the third and fourth arms. The external appearance as well as the histological character is the same but with some diversity in size.

The organs on the mantle differ in number between male and female, i. e. 566-687 in the female and 450-543 in the male as counted in 10 specimens of each sex. They are entirely found on the ventral half of the mantle, and the arrangement is not quite regular, but more or less in series showing slight bilateral symmetry. The distances between the organs are nearly equal but with slight gradual increase towards the lateral sides as well as towards the posterior end of the mantle.

The organs on the siphon are about 47 in number, alike in male and female, and the arrangement resembles those of the mantle.

The organs on the head are about 180, alike in male and female, arranged somewhat in several series with the anterior organs of these series connecting with the series of the same organs on the arms. Besides, along the margin of each eye-lid there is another series, which consists of larger and smaller organs arranged alternately.

The organs on the fourth arms are arranged in 3 series, the middle one of which is the longest, consisting of about 28 organs, and connecting distally with the brachial organs, beyond which yet 3 other small organs are found. The brachial organ from the point of view of situation appears to have evolved from the minute organ but of course with great

histological differences. The third arms have only about 7 organs arranged in a series.

Each organ in the fresh specimen has a substance of purplish hue in the centre; this substance seems to be that discharging light when the animal is living. When the organ is exposed in the air, the purplish hue of the substance changes to greenish blue after a while, and finally resolves into a true green (Pl. I, fig. 3). The substance is covered by a pigment layer of darkish brown or deep purple which has a hole resembling the pupil of an eye, through which the substance can easily be seen. The light of the substance at night is whiter and less luminous than that of the brachial organ.

Ocular Organ. When the eyelid of the fresh specimen is removed and the eyeball exposed, there are seen 5 luminous organs arranged in a series along the ventral circumference of the eyeball, the organ on either end of the series being a little larger than the remaining 3. The colour of all these organs is pearly white (Pl. I, fig. 5). When the organ is seen at night in the living animal, the phosphorescence is not distinguishable from that of the minute organ on the body.

Difference of Phosphorescence in the Sexes. On examining the preserved specimens to discover the difference of the external forms as well as the histological structures of their luminous organs as occurring in the male and female, none could be discerned. But in the female specimens there are one hundred or so more of the minute organs of the mantle than in the male. Whether there is any meaning as to sexual selection, it is difficult to say, the data concerned being insufficient at present to announce any opinion.

Next, as to the difference of phosphorescence between the sexes in their living state, the means of investigation proved to be very difficult. At first I repeatedly undertook to keep the animal in an aquarium, but no success was attained. The reason for the failure is that first of all, the animals are very delicate, and next the aquarium was defective. The

animals are so weak that in carrying them from the sea to the aquarium they wasted and died. As they wasted, the luminosity in question became very feeble, and naturally with their expiration, the light of the luminous organs gradually vanished altogether. This being so, I then tried to observe the animals directly while they were swimming in the net. But no good means were found easily to distinguish the sexes on such dark nights, even with the feeble light of the moon or of a lantern.

However in my examinations at night, no special variety of the light could be found, the colour of the light being always the same. And in one case, putting in a vessel and observing about 30 specimens in a fishing boat while they were yet actively on motion, I verified the fact that their luminosity is uniform. In the morning, to my surprise, a male was found dead among those 30 specimens; this proves that it had the same colour of light with the female on that night. The above data seem to prove the fact that the colour of the light of the luminous organs is the same in both sexes.

Again, in late July of the same year, I made another observation on the phosphorescence under consideration and then it was quite evident to me that the luminosity of the brachial organ was at this season noticeably feebler than in the spring.

The phosphorescence of the immature animal can never be studied in Namerikawa, young ones thus far not being found there.

3. Food.

The contents of the stomachs were examined 4 times on the preserved specimens and they were as follows:

- i) Among 20 females caught with the *Fukube-ami* (see p. 91) on April 25, were 4 specimens with some amount of silvery blackish substance like the iridocytes of fishes and some pieces of shells of small crustaceans, but the remaining 16 had nothing in the stomach.
- ii) In 20 females obtained with the same kind of net on April 27, the stomach was found to be quite empty.

iii) In 6 specimens out of 50 females caught with the same net, April 29, the stomachs contained rich and rather fresh contents, consisting mainly of small fishes, *Mysis* sp. and pelagic Copepods¹⁾ (*Corycaeus* sp. & *Oncaea* sp. etc.).

iv) 3 specimens out of 10 females obtained, July 26, had some iridocyte-like substance, some pieces of the back bone of a fish and 2 pieces of its skull.

Besides, there were also found in the stomach some plankton-animals which were indistinguishable on account of their maceration.

Judging by the facts stated above, it seems that the animals having food in the stomach are few in percentage, and we may say that the *Hotaru-ika* caught during the night at Namerikawa and vicinity are not of those kinds which visit the sea coast for the purpose of getting food, i. e. feeding migration.

4. Seasonal Changes of Liver Content.

The fresh female *Hotaru-ika* in the fishing season are at a glance distinguishable from other kinds of cuttle-fish, being reddish in colour. This colour is caused by the liver, which is seen externally through the transparent mantle. If the liver be dissected in water, many reddish oily globules (reserved nutriment?) come up to the surface of the water. And if the liver be split into small pieces with a dissecting needle and looked at under the microscope, it is easily seen that the same reddish substance is also contained in the tissue. But in the males which were taken at the same time with the females, the liver shows no such reddish hue, but is gray and provided with only a small amount of such reddish oily substance in the tissue. This difference in colour between the sexes is so easily distinguishable in the spring time that above 10,500 specimens were assorted into male and female by 5 or 6 students of the Fishery Institute in about one hour and a half.

But, on my second visit, which lasted from the middle of August till late September, it was soon observed that the reddish hue of the liver of the female was changed into a gray hue resembling that of the male in spring. The

1) I owe the identification of the Copepoda to Mr. S. Kokubo, to whom I express my thanks for it.

consistency of the liver at this season is soft, and the oily content is poor as compared with that of the reddish-hued liver in the spring, which is thick and rich.

Besides the diminution of the oily substance in the liver, all the organs generally seem to undergo degeneration, and the vitality of the animals is considerably lessened. They expired soon even with gentle handling, and though they were caught by hand they were very quiet, while in the spring time they attacked us violently, biting our hands with their jaws. From the middle of July, the catch of *Hotaru-ika* became gradually less and less, until in August and September, a net which had in the spring fishing season caught about 500 pounds at a time caught only a very small number. Later it became yet smaller, and very feeble animals only were occasionally trawled from the depth of 100 or more fathoms.

By the above facts, we are justified in saying that they probably die with the passing of summer.

5. Female Genital Organ.

When the mantle of the female caught with the *Fukube-ami* was dissected along the ventral median line, it was seen that its posterior half is filled up with many transparent small eggs of fairly greenish hue.

Most of the eggs are mature and are freely contained in the ovarial sac, which is divided into 2 parts by a median septum. And a comparatively small number of immature eggs are imbedded in the ovarial tissue. From the central portion of each half of the ovarial sac there arises an oviduct with a thin and transparent wall. This oviduct runs backward along its surface till near the posterior end of the sac. Then it turns forward, and opens to the nidamental gland attached at the anterior end of the sac. In this season the oviduct is found to contain a quantity of the fully mature eggs (Pl. II, fig. 10).

The nidamental gland is a slightly pinkish body of inverted V-shape situated behind the siphon; each ramus of the gland is split dorso-ventrally into 2 lobes with the exception of its posterior $1/6$ part. The oviduct arrives

at the posterior end of this ramus, and piercing through the matrix of the gland it finally opens to the posterior end of the inner face of the lobe. The inner face of the lobes are divided into numerous fine lamellae and secrete some albuminous substance (Pl. II, fig. 11).

Judging from the above facts, it seems that the eggs when mature, are finally discharged between the lobes of the nidamental gland, whence they are covered with albuminous substance secreted from the lamellae thereon. Then they are dispelled through the siphon.

6. Number of Ovarian Eggs of the Female.

The number of the mature eggs was reckoned from the females which were directly obtained from the net, on the ground that otherwise the specimens might have sustained some harsh treatment and so have lost some of their eggs. By this count, it was found that the number of mature eggs varies in the different individuals, and the largest number is about 1200. The actual numbers of the mature eggs of 25 females caught at the same time, together with the numbers of spermatophores fixed by the male on both sides of the nape of these females, are shown in the following table :

Characters Specimens	Mantle-length	Approximate number of eggs	Number of spermatophores	
			left	right
	<i>m m.</i>			
1	68.4	730	7	6
2	67.6	960	7	7
3	67.0	950	7	7
4	67.0	950	5	4
5	65.5	1,200	5	7
6	65.5	850	5	6
7	65.0	1,080	6	7
8	64.0	1,050	8	8
9	63.0	1,100	1	6
10	63.0	850	6	8
11	63.0	600	7	3

Characters Specimens	Mantle-length	Approximate number of eggs	Number of spermatophores	
			left	right
	m m.			
12	62.5	720	4	12
13	62.5	980	7	5
14	62.0	960	8	7
15	60.8	1,200	3	3
16	60.5	950	6	5
17	60.0	480	6	6
18	58.5	470	7	6
19	56.8	1,070	8	7
20	55.6	730	9	5
21	55.0	850	5	1
22	53.0	860	5	3
23	53.0	720	8	9
24	52.0	950	6	8
25	46.0	730	8	8

Such a diversity in the number of the mature eggs according to the individuals is attributable either to their premature condition or to their discharged effect, but here the latter cause is more reasonable to explain the fact. That is to say, the diversity is due to the fact that they are in the midst of the spawning season.

7. Male Genital Organ.

The anatomical relation of the male genital organ does not differ on the whole from that occurring generally in the Enoploteuthidae. The number of the spermatophores in Needham's sac differs according to the individuals, and there are 73 in the fully extended sac of a male.

The spermatophore (Pl. II, fig. 7) examined under the microscope shows a delicate organ covered with an outer sheath. This organ consists of 3 parts: a packet of spermatozoa which fills nearly 1/10 of the outer sheath of the spermatophore (Pl. II, fig. 7, A); a long elastic spiral spring (ibid. fig. 7, B); and a tubular sheath connecting the preceding 2 parts (ibid. fig. 7, C). And

as soon as the spermatophore is stimulated with the point of the dissecting needle, the spring and connecting sheath coil together forming a ball-shape. By this action the packet of the spermatozoa moves toward the other extremity, and at the same time, the outer sheath of the spermatophore breaks up. Now the packet comes out, and by its rupture the spermatozoa are discharged therefrom (Pl. II, figs. 8, 9).

8. Spermatophores Fixed in the Female.

All the females which were caught from the latter part of April till the middle of May had without exception 2 bundles of spermatophores, so far as I am aware, which were tightly fixed on the nape under the velum of the siphon. Here it has a special adjustment in a form of a pit so as to receive the bundles of spermatophores (Pl. II, figs. 5,6). The number of spermatophores in a bundle differs with the individuals as well as with the bundles of each individual. This number varies from 1 to 13 but as a rule it is about 7. This was ascertained from 50 specimens caught at the same time.

The spermatophores show no greater variation in their number than that just described, even in the specimens of the later seasons. Here it must be emphasized that the female individuals with spermatophores fixed have no new addition by other males. The spermatophores are seen always to fuse together in a bundle at the basal extremity, thus proving that they were fixed at one time. Each spermatophore of an attached bundle shows the same configuration as those treated artificially as mentioned before.

9. Facts Concerning Fate of the Male.

Discovering, from the fresh specimens which I obtained at Namerikawa, that every female has a more vividly coloured liver than the opposite sex and in this season always carries 2 bundles of spermatophores at its nape, I showed these differences to some students of the Fishery Institute, who henceforth were able easily to select 132 male specimens from about 10,500 specimens of the total catch on April 25, 1913. In like manner, many males were obtained as given in the following tables, which show at the same time the ratio of the male to the female.

Table I : *Hotaru-ika* Caught with *Fukube-ami* at Night.

	Total number of specimens	Number of males	Ratio of males to females	Locality	Date
I	circa 10,500 (calculated from the weight 282 lb, reckoning one piece as 0.43 oz)	132	1 : 78.8	Namerikawa	April 25
II	circa 5,333	26	1 : 204.1	do.	April 30
III	282	1	1 : 281	do.	May 4
IV ¹⁾	circa 12,326 (calculated from the weight.)	10	1 : 1,231.6	do.	May 28
V ²⁾	circa 15,550 (calculated from the weight.)	19	1 : 817.4	do.	May 29

The above table shows clearly that the male becomes rarer as the season advances.

Table II : *Hotaru-ika* Gathered with a Drag-net³⁾ during the Daytime at a Depth of 100 or a few more Fathoms.

	Total number of specimens	Number of males	Ratio of males to females	Date
I	3	1	1 : 2	April 24
II	653	3	1 : 216.7	May 2
III	85	2	1 : 42.5	May 2
IV	52	1	1 : 51	May 3

Table III : *Hotaru-ika* Obtained from the Stomachs of *Theragra chalcogramma* (Pallas).⁴⁾

	Number of fish	Total number of <i>Hotaru-ika</i>	Number of males	Ratio of males to females	Locality	Date
I	10	5	0	0 : 1	Namerikawa market	April 19
II	30	6	0	0 : 6	Off Ikuji	April 23
III	30	7	1	1 : 6	Namerikawa market	April 30

1); 2) found out by Mr. S. Matsuno.

3) This net is used for fishing for *Nigisu* (*Argentina semifasciata* Kishinoue).

4) *Theragra chalcogramma* is caught with the line from the depth of 100 or a few more fathoms and in the sea 3 or more miles off the coast.

The preceding tables clearly show that the male is less in number than the female whether it was caught with *Fukube-ami* at night, or with the dragnet during the day, or obtained from the stomach of fish.

From the preceding pages we get the following data: 1) the number of spermatophores comprised in a fully extended Needham's sac is about 73 (see p. 84); this number may be reckoned as the total sum of the spermatophores produced by a male in a year for such an animal finishing its mating in a short period, 2) the number of the spermatophores fixed on the nape of the female is 14 on an average, for each female has 2 bundles of spermatophores, each comprising 7 ones on an average (see pp. 83, 85). If we assume that all the spermatophores of the male are entirely fixed into the females, then it is necessary at least that there should be one male to about 5 females, considering from the above two facts. But Table I on page 86 shows that the ratio of the males is less than one against 79 of the females so that there are in the animals caught by the *Fukube-ami* at night, only $1/5$ enough males to suffice for mating. So too in the specimens obtained either from the deep of the sea or from the stomachs of the *Theragra*, we get the same tendency in the numerical relation of the two sexes.

Further, there may be some mistake as to the fixation of the spermatophores by the male. Consequently the enumeration of males by the number of spermatophores becomes uncertain and many more of them should naturally be expected.

10. Eggs Floating on the Sea.

The egg is ovoid in shape, being 1.5 mm. long and 1.2 mm. broad. Those obtained between April 19 and May 7, 1913, showed either the segmented condition or a further developing stage. The sea condition at the time of the surface collection of the egg is as follows:

Date	Beginning of collection	Duration of collection	Condition of sea	Specific gravity of sea water	Number of eggs
1913 April 19	X a. m.	50 minutes	calm	1.0152	2
April 20	VI 1/2 a. m.	1 hour	calm	1.0165	11
April 22	VI a. m.	40 minutes	calm	1.0150	3
April 29	I a. m.	1 hour	calm	1.00695	0
May 2	X a. m.	1 hour	calm	1.0111	0
May 6	VI a. m.	1 hour	calm	1.0144	21
May 7	IX a. m.	1 hour	calm	1.0154	12

The repeated investigations made by Mr. S. Matsuno had verified the fact that the eggs float in greatest numbers on the sea surface a little more than half a mile off the coast. And the season in which the eggs are collected most thickly on the surface agrees with the fishing season along the coast of Toyama Bay. The eggs obtained early in the fishing season show an earlier developmental stage, thus confirming the opinion that the littoral migration of this animal is simply for the purpose of spawning.

11. Conclusion.

Hotaru-ika caught in enormous quantities in Toyama Bay have the following habitual characters :

- a. A large percentage of them belong to the female sex ; these are sufficiently matured, carrying spermatophores fixed by the male.
- b. There should be many more males than are caught in spring.
- c. The littoral migration is for spawning.

After the preceding investigation, I examined many specimens of *Hotaru-ika* from Sagami Bay preserved at the Zoological Institute, Science College, Imperial University, Tokyo, and found from them many interesting facts which seem to verify my preceding opinions. These specimens in the order of seasons caught are arranged as follows :

- i) 81 specimens,— all matured males, captured at Shirahama, Awa Province, Feb. 9, 1908. The mantle-length being measured from 12 out of the whole number varies from 36–45 mm.

ii) 4 specimens,— all mature males, donated by Prof. Dr. A. Oka who obtained them at Hazama-mura, Awa Prov., in the middle of Feb., 1907. The mantle-length, 36-42 mm.

iii) 16 specimens,— all mature males, obtained at Nishimisaki, Awa Province, Feb., 16, 1891. The mantle-length, 36-44 mm.

iv) 104 specimens,— ♂ 37 + ♀ 17, Odawara, Sagami Province, March 9, 1907. The males are here also all matured, and the number of spermatophores carried by the females is as follows :

Female specimens		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Characters																		
Mantle-length in mm.		37	39	39.5	40	40	40	41	41	41	41.5	42	42	42	42.5	44	44	45
spermatophores in nape	right	0	0	7	0	0	5	7	8	0	7	7	4	6	0	7	8	7
	left	0	0	0	0	0	5	7	5	0	4	7	5	8	0	4	8	7

v) 33 specimens,— ♂ 10 + ♀ 23, Odawara, Sagami Province in the middle March, 1900. The males are matured, and the females, except only one, carry numerous spermatophores.

vi) 4 specimens,— all mated females, caught by Mr. H. Ôshima, at Manazuru; Sagami Prov., March 18, 1909. The mantle-length, 45-49 mm.

The above specimens convince us that on the coast there exist numerous males especially in the early fishing season, that diminish in inverse proportion with the female as the season advances.

The first females caught do not carry any spermatophores on the nape, i. e. are unmated. Such specimens constitute about 35 % of all the females in the fourth bottle, and about 3.4 % in the fifth bottle, thus the unmated females diminish gradually in that ratio; this seeming to show that all the females that come to spawn are unmated at first. So in Suruga Bay the mating of this animal probably takes place in early March and the spawning probably in April.

By these differences in the mating and spawning habits of the same animal

but living on the opposite sides of the Empire I am convinced that these different modes of reproduction are in reality a single and continuous process; this means that passing through such a habitual progress in Sagami Bay, the animal arrives at the condition of its life at Namerikawa and vicinity.

The fact that only unmated females come to spawn naturally means that those once mated never come. This seems to confirm my opinion that they probably die as the summer passes (see p. 82). The male probably dies after the fixing of spermatophores in the nape of the female, and the few lately matured ones are caught in company with the female in *Fukube-ami* in April and May.

II. HABITS OBSERVED FROM THE FISHERY POINT OF VIEW.

Methods of Investigation.— The statistics of the annual catch were derived from the daily notes of fishing of the persons who are carrying on the *Hotaru-ika* fishery, also from information given by the fishermen who were directly doing the fishing. The maps of the fishing places with their depth were made according to the following method:

- i) Maps published at the Hydrographic Office, Naval Bureau, as follows:
 - a) Main part of Japan and Korea.
 - b) Tsuruga Wan to Niigata Kô.
 - c) Noto Peninsula.
 - d) Fushiki and Yuwase Anchorage.

The isobathymic lines and coast-lines in this paper are mainly dependent upon the preceding maps, their details being referred to the maps and to notes of the fishing places, according to which fishermen fix the nets, as well as upon the soundings taken by myself.

- ii) Maps of the fishing places used for Fishery Legislation in the Toyama Prefectural Office.

The situations of *Fukube-ami* in the maps contained in this paper are drawn from these maps, some corrections being made through the kindness

of the influential persons carrying on the *Hotaru-ika* fishery as to the situations of the nets in 1913.

A. FISHING CONDITION OF THE WHOLE COAST.

The coast-line of Toyama Prefecture is curved in and embraces Toyama Bay. It is very deep along the whole coast, the 100-fathoms line being nearer the shore than anywhere along the coast of the Japan Sea. And the middle portion of Toyama Bay has a depth of above 600 fathoms.

The sea bottom inclines generally very irregularly at the coast and there are many valley-like places near the sea-shore, this being especially the case at Namerikawa, while the bottom consists generally of darkish gray mud. The tidal current on the coast is a tributary of the Tsushima Current and comes from the Noto Peninsula, running toward the Province of Echigo. The surface temperature of the sea water in the *Hotaru-ika* fishing season is about 10°C at the beginning, increasing to about 14°C at the most prosperous season of the fishing, and reaches 18°C towards the latter end.

Hotaru-ika are obtained very frequently in spring from the depth of 100 or more fathoms in the sea, about 2-7 miles off the coast, proving that at least some part of them are living in that region during the fishing season.

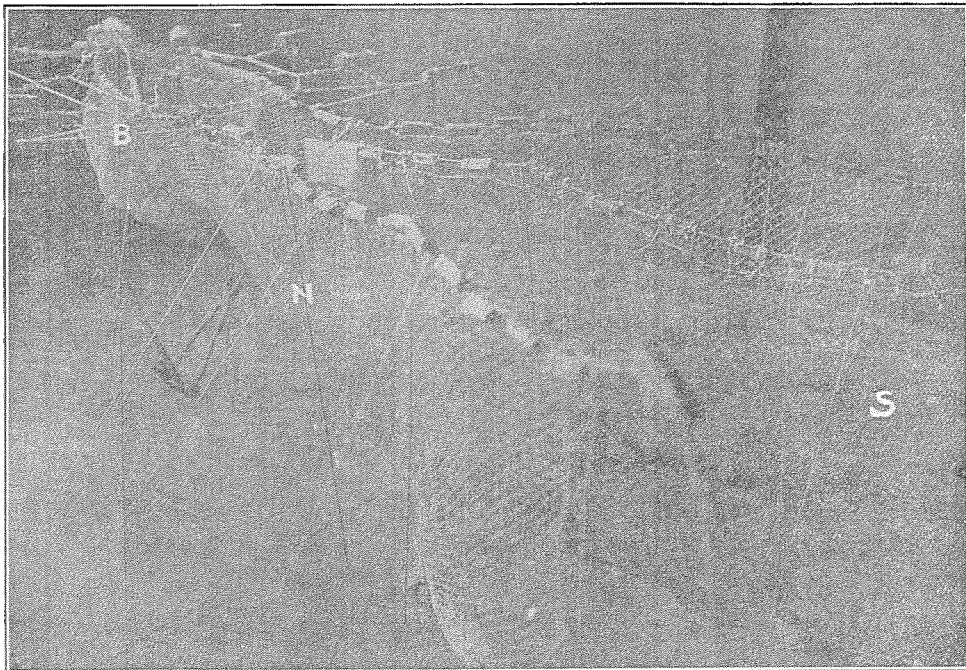
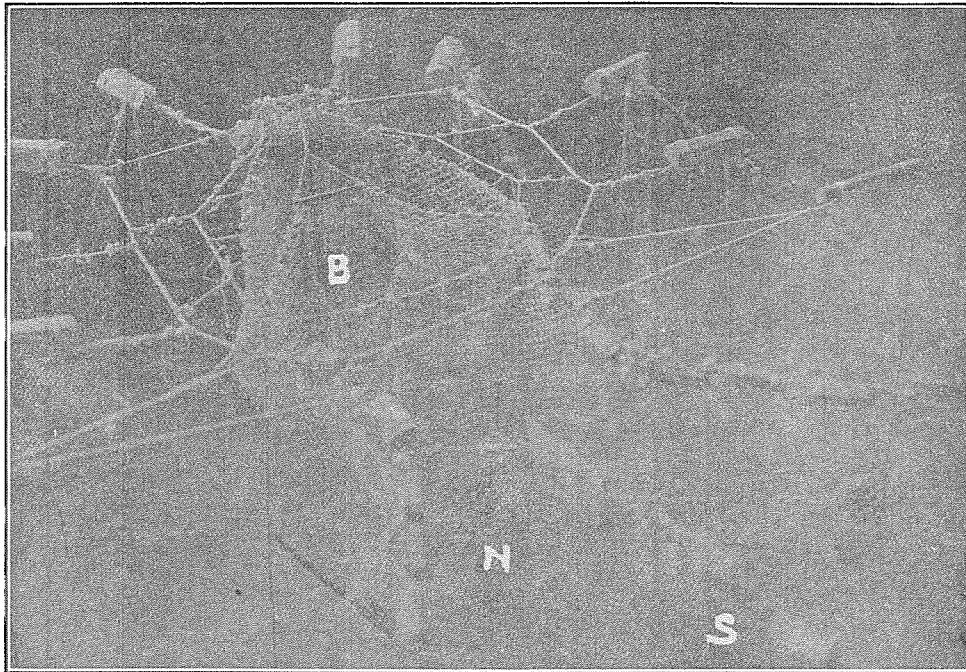
The most useful fishing implement used by the fisherman for the *Hotaru-ika* fishery in the Toyama Bay is the "*Fukube-ami*". On the coast of Toyama Prefecture, the *Fukube-ami* is generally fixed sometimes in ranges on the steep slopes of the valley-like depressions or on the submarine banks; these stand at right angles to the shore-line.

The *Fukube-ami* is made of 2 principal parts, i. e. a bag-net and a screen-net. The screen-net is about 20 meters in extent and is fixed in the same direction as that of the submarine valleys or banks to cut off the way of the fish driving them into the bag-net toward the open sea, its under edge being generally fixed into the sea bottom. The bag-net is fixed at the extremity of the screen-net, and has a funnel-like mouth opening toward the shore, the

bottom of the funnel having an inclination which becomes lower toward the shore, fixed with its edge into the sea bottom as in the case of the screen-net. Therefore the fish, even those moving near the sea bottom, being driven in this direction, run on the funnel and are entrapped in the bag-net. The *Fukube-ami* has many forms, but it is only necessary to mention two in this paper. The first is made with a double opening, the bag-net has a mouth on both sides of the screen-net so that it entraps the school equally from both sides. This kind is used for fixing on the back of narrow banks with the deep sea at both sides. The second is made with only one opening,— the bag-net has a mouth on only one side of the screen-net, so that the school comes into it only from the mouth-bearing side. This is used for fixing on the slopes of these submarine valleys, which have a depth only at one side and a shallow vast floor on the other.

The schools of *Hotaru-ika* come into the net in the fishing season after sunset and never during the day, and the net drawn up at 9 or 10 p.m. is better filled than that drawn up at 3 or 4 a.m. This fact seems to suggest that the schools come near the coast from the deep in the offing when sunset approaches, and as soon as they have laid the eggs towards evening go back in to the deep sea, and are entrapped in the net on their way back. They come very rarely to the surface of the sea even at night.

There are 2 or 3 special submarine valleys of 100 or more fathoms, where various deep sea animals are caught, for example, *Nigisu-sebikiba* at Uozu (Pl. III, fig. 5; p. 86, footnote) and *Hirataebi-teguri-amiba* at Shimminato (ibid. fig. 2; p. 93). In those places, even in the daytime in the fishing season, *Hotaru-ika* are always gathered by a drag-net, though in other shallow parts, they are never caught. So it suggests that in such a depth even near the sea coast, they live also in daytime. And there are also several places where in the fishing season *Hotaru-ika* are gathered by a hauling seine from land, after sunset, for example, Takatsuki at Namerikawa (ibid. fig. 4), *Tai-jibikiba* at Uozu (ibid. fig. 5) and *Baichi* at Kyoden (ibid. fig. 6), where there seem to be some suitable slopes for *Hotaru-ika* to approach to the coast, having a vast



Two views of distal part of *Fukube-ami* (model). B : Bag-net, N : funnel-like part of bag-net, S : screen-net.

valley very near.

Those facts show that *Hotaru-ika* is a deep-sea animal, living during the day in a depth of 100 or more fathoms, and when the night is at hand, they approach to the coast, and after sunset they lay the eggs, and as soon as they finish their spawning, go back to the deep sea.

B. FISHING CONDITION IN LOCAL PARTS.

The whole coast of Toyama Prefecture is divided for convenience's sake, into 3 regions,— i. e. Shimminato region, Namerikawa region and Ikuji region.

1. Shimminato Region.

This consists of the western part extending from Yokata along the whole coast of Toyama Prefecture. The 100-F-line is the farthest off the coast in all that region, especially in Himi-gun, where the distance from the shore is about 3 or more miles generally, and the bottom of this coast shows a more gradual slope than that of others.

This part has two principal submarine valleys coming near the shore, the first being that off Shimminato and Fushiki, and the second that off Yokata. And the greatest number of *Fukube-ami* are settled at the boundary walls of those two valleys and the nets which catch *Hotaru-ika* in great quantities also belong to those *Fukube-ami*. This region is again divided into 3 coasts.

a) *Shimminato coast* (Pl. III, fig. 2). This coast is the central part of the whole and has 3 rivers, i. e. Shô river, Shinshô river and the river flowing from Hôjôzu Lake, and there is, in front, the valley off Fushiki and Shimminato, the central part of which showed about 170 fathoms by my sounding. In the spring, *Hotaru-ika* are gathered during the day with a drag-net which is used for catching the *Hirata-ebi*, a deep-sea shrimp, from a depth of 100 or more fathoms.

The following table shows the amount of *Hotaru-ika* caught with *Fukube-ami* along this coast in 1913.

Situation of net	Number showing net in map	Name of net	Direction of net to tidal current	Catch
Off Elbie	—	Senaka-niban	Following	Kan (= 8.26 lb +) 800
do.	—	Nakashôji	Against	640
do.	—	Nawatake	Against	800
Off Horioka	1	Ikirei	Against	748
do.	2	Dairaiboku	Against	368
do.	3	Kiawase-segata-samban	Against	520
do.	4	Kiawase-segata-niban	Against	464
do.	6	Higashi-samban	Following	300
do.	5	Kaguradashi	Following	400(1912)
Off Shimminato	8	Kuroyama-goban	Against	842
do.	9	Kuroyama-yoban	Against	500
do.	10	Kuroyama-samban	Against	1,500
do.	7	Tonaka-niban	Against	1,000(1912)
do.	11	Sambyôme	Against	400
do.	12	Nihyôme	Against	500
do.	16	Dôgo	Both	60
do.	15	Yokobiki-niban	Against	20
do.	13	Ônakase	Following	248
do.	14	Kaburatobikoe-niban	Following	20
do.	17	Senaka	Following	400
do.	18	Noborihata-kônoue	Both	1,315
do.	19	Nakashôji	Against	450
Off Fushiki	20	Kojirigaeshi	Against	400
do.	21,22	Karimata series	Following	a little
do.	23,24	Suzushima series	Following	a little

The above table shows approximately that the amount caught in the net fixed against the tidal current is double that of the amount caught in that fixed to follow the current. That the latter kind of *Fukube-ami* are fewer in number, is accounted for by the fact that though much liberty is permitted by the authorities, only a few which are profitable in fishing are so fixed, the others bringing so little profit that their fixture would not compensate for the expenditure. These facts seem to show that in this region the former kind of *Fukube-ami* is more efficient in fishing than the latter in this region. This result seems to be caused by the influence of the tidal current, for regard to other external influences, such as the temperature, pressure, food and topographical features of the sea bottom, both kinds of *Fukube-ami* would seem to have equal conditions. In fact, when one observes their movements at

night in the spring, he will see that they are sure to follow the tidal current, for their movements at that time, are not so rapid or active as those of the migratory fish or other cuttle-fish such as the *Ommastrephes* or *Loligo*. They swim slowly, with the head forward, swinging in front the luminous organs of the ventral arms which lighten their course like a lantern.

Comparing the statistics for the last 5 years, the best class of *Fukube-ami*, as to the amount caught in this region, are the following nets: *Kuroyama* series, *Sambyōme*, *Nihyōme* and *Noborihata-kōnoue*, which are in such a position that the school of *Hotaru-ika* very easily enters the nets, the deepest bed of this region being situated very near in front.

In this region, it seems as if the distance of the net from the sea-shore has no special reference to the catch. Is this caused by the fact that the submarine valley is so broad in area that the schools move at the same rate towards the nets of the offing as towards those near coast?

The matter to be noticed with reference to fresh water is that *Dōgo* and *Yokobiki-niban* being washed by the waters of the *Shō* river, the *Shinshō* river and the excurrent river of Lake *Hōjōzu*, stand in a low class, as to the amount caught, but whether that depends upon the fresh water or not, can not be determined until still further evidence has been found. For on the other hand, at *Namerikawa* there is the interesting fact that the school of feeble *Hotaru-ika* come to the mouth of a river in the late season (June).

That the *Karimata* series and *Suzushima* series are inferior in amount, depends upon the fact that they are very near the shallow beds of the *Himi* coast, for the same reason as is verified later.

b) *Yokata coast* (Pl. III, fig. 3). This coast has a submarine valley in front as mentioned before, the central portion of which reaches about 100 fathoms and the 50-F-line also approaches very closely to the shore, and the east boundary wall of the valley shows a very sudden incline. The tidal current runs eastwards as is the case with the before mentioned coast. The *Fukube-ami* fixed there at present (1913) are only 9, all facing towards the current, the catch of which is shown in the following table:

Number showing net in map	Name of net	Catch (1913)
2	Ko-ushi	Kan 10,000
3	Makaridashi	5,000 (but 14,000 in average for the late 3 years)
4	Wakura	5,000
5	Natsunaka	1,500 (5,170 in average for the late 3 years)
6	Maenoami	do.
8	Yarigasaki	7,000
9	Goshanomiya	7,000

The average catches are much greater than those of the before mentioned coast. *Ko-ushi* and *Makaridashi* which are superior to the others, have a model situation, facing towards the tidal current and having the deepest bed of the Yokata valley in front. The reference of the catch to the various conditions of the fishing place, agree in the main with those of the before mentioned coast and show such an aspect as to verify the former explanation.

c) *Himi coast* (Pl. III, fig. 1). This is the whole coast westward from Ôta village, which is the shallowest, and of which the sea bed has the most gradual incline along the coasts of Toyama Prefecture. And the 50-F-line is generally off the shore as far as 2 or 3 miles, and only on this coast are there found many Molluscan shells. The shore consists mainly of sand, and the water is not so clear as that of Namerikawa.

As this coast is the original part of Toyama Prefecture where the *Fukube-ami* was used, there are many of these nets fixed there. Drag-nets as well as seines from land are also found there, being used as the ordinary fishing implements of the fishermen.

It is not only that the *Hotaru-ika* has been never caught on this coast and that the *Fukube-ami* are only used there to catch other fish such as sardine-allies, but the fishermen have no knowledge of the *Hotaru-ika*. When I went there in May 1913, I asked the fishermen whether they had sometimes observed on this coast the cuttle-fish which discharged light. They answered that they knew well about a kind which they called *Chôchin-ika* (lantern cuttle-fish). So I went in their boat to the fishing place on a dark night, and observed there the

so-called *Chōchin-ika*, which proved to be not the *Hotaru-ika* but a Sepiolid: *Iniotheuthis iniotheuthis* (Naef). This was really discharging a faint cobaltish light from a great luminous organ which is situated in the mantle cavity near the ink-bag.

The fact that on this coast, the *Hotaru-ika* is not caught, agrees with the fact that the amount of the whole catch by the *Fukube-ami* in the western part of Shimminato coast is very small, as well as for the fact that it is rarely caught on a shallow coast such as Fushiki, and Ishida of Shimonikawa-gun. And it agrees also inversely with the fact that *Hotaru-ika* are caught in the valleys or on the inclined walls bounding the valleys.

In view of these facts, though the school of *Hotaru-ika* approaches the shallow coast at evening from its dwelling in the daytime, there is some limit in its migration and it seems that it either can not, or will not, move so far as 2 or 3 miles along a shallow bed such as 30 or 40 fathoms.

2. Namerikawa Region.

This region is the coast from Jintsū river eastward to the eastern part of Uozu, occupying the central portion of the whole coast of Toyama Prefecture. The bed of the coast is very deep, the 100-F-line reaching very near the shore, and the valleys are numerous, especially at Namerikawa-cho, where they are so frequent that the boundary of the valley-like inlets shows a zig-zag line. The catch in this region is also very great especially at Namerikawa-cho, where it reaches generally as much as 70 % of the total catch in Toyama Prefecture. Of course this amount arises from the profusion of *Fukube-ami* used there, but also because the catch of each individual net is greater than that of other regions. And the fishermen at Namerikawa make their living mainly by this fishery.

This region is also divided for convenience's sake into 2 coasts: Namerikawa coast and Uozu coast.

a) *Namerikawa coast* (Pl. III, fig. 4). This coast is bounded by 2 shoals, one of which is off Yuwase and the other off the mouth of the Hayatsuki river. *Fukube-ami* of this coast belong entirely to the kind that has the opening in

both sides of the screen-net, being settled in series on the tops of the banks extending toward the offing. The beach consists only of gravel and the sea water is very clear.

The catch of this coast in the following table is the average for 3 years (1911-1913).

Number showing net in map	Name of net	Catch	Number showing net in map	Name of net	Catch
7	Nakase	Kan 4,000	15	Gosha	Kan 7,000
8	Kesagane	5,000	16	Furudatami	9,000
9	Wakizume	15,000	17	Okinoami	12,000
10	Kumajishi	10,000	18	Nakanoami	20,000
11	Nakamurasaki	11,000	20	Nagisaryokei	14,000
12	Komurasaki	18,000	22	Doko	13,000
13	Koami	18,000	23	Takatsuki-nakanoami	20,000
14	Maenoami	7,000			

The *Fukube-ami* which makes the best catch along this coast is always the nearest one to the beach in every series of the net. This is caused, if the preceding various explanations be true, by the fact that the 100-F-line is very near the beach and the tidal current in deeper water is slackened by the submarine banks, so that the *Hotaru-ika* can easily come near the coast along the quite valley-like depression with clear water. And it seems also to depend upon the fact that this coast is situated in the central part of the whole coast in Toyama Prefecture where *Hotaru-ika* are caught.

b) *Uozu coast* (Pl. III, fig. 5). The eastern part of this coast is very deep, the 50-F-line as well as 100-F-line being very near the shore. In this western part, though the valleys are as numerous as at Namerikawa their depth is not so great as there, and the 100-F-line is very far from the shore. There are in this coast about 10 *Fukube-ami*, 2 of which are fixed at the eastern end of this coast and used to catch other fish. The remaining 8 belong either to the *Fukube-ami* following the current or that with a double-opening.

Number showing net in map	Name of net	Catch	Number showing net in map	Name of net	Catch
1	Kôzu	Kan 12,500	5	Okitakase	Kan 2,100
2	Dôgata	4,000	6	Aogake	1,950
3	Nakajima-atari	1,300	7	Fukaguri	1,800
4	Takase/Uchitakase	1,800	8	Kawanakajima	2,500

If the table be compared with the map, it will easily be seen that the catch of *Fukube-ami* of this coast is in direct proportion to the degree of its approach to the 100-F-line. It is to be noticed that the net *Kôzu* with the depressions on both sides, reaches in the amount caught nearly to that of the *Fukube-ami* at Name rikawa.

The Hayatsuki river generally contains a very small amount of water, so that its influence upon the net *Nakajima-atari*, seems to be very small.

3. Ikui Region (Pl. III, fig. 6).

This region is the eastern part extending from Kyoden-mura on the whole coast of Toyama Prefecture. The coast is very deep and the tidal current is very rapid, especially so at the eastern coast from Kurobe river. The fishermen of this coast say that the current coming from Noto Peninsula, in some seasons, runs against the Point of Ikuji and it is divided by the point into 2 currents, one of which goes back toward Ishida-mura, making a whirl-current off Ikuji, and the other goes on its course to Echigo. There are at present (1913) only 4 of the ordinary *Fukube-ami* fixed, these all being situated westward from Ikuji-cho, and from what the fishermen say, the coast eastward from Ikuji-sho is not suitable for fixing the ordinary *Fukube-ami*, for the tidal current is so rapid, that the net is driven sideways. The following table shows the average of the catch for the last 3 years (1911-1913).

Fishing place	Number showing net in map	Name of net	Catch
Off Ikuji	1	Sainokami	Kan 1,500
Off the boundary between Ishida and Kyoden	2	Ôshimanoami	400
Off Kyoden	3	Matsunoatari	800
do.	4	Gakenata	600

Hotaru-ika are caught in small quantities by a hauling seine on the beach at Ikuji-cho in the evenings of the fishing season. They are also caught by the same kind of net in great quantity, often to the extent of 50 Kan at Baichi, Kyoden, as mentioned above.

At Tomari farther east from Ikuji-cho, *Hotaru-ika* are often caught by a kind of *fix-net*. And by the investigation of Shimoniikawa District Office, at Iino-mura a special kind of *Fukube-ami*, called "*Ryono-Fukube-ami*", is used made with 2 bag-nets and 2 openings, which is suitable to the coast, the tidal current being very rapid. It was fixed for the first time in 1913, and caught about 35 Kan every evening in spring and sometimes an even greater quantity.

Again at Miyazaki-mura, which is situated near the boundary line between Etchû Province (Toyama Pref.) and Echigo Province (Niigata Pref.), the *Hotaru-ika* is often caught by a drag-net, though the quantity is small.

In view of these facts, though this region is not so well known among those living in Toyama Prefecture as a fishing place for *Hotaru-ika*, as those of other Prefectures, it is clear that in this region also it is caught to some extent. This, according to the preceding explanations, arises from the facts that the 100-F-line is very near the coast and the water is very clear. And the reason that the catch is much less than that of Namerikawa, depends either upon the facts that the current is much more rapid and the banks fewer here than at Namerikawa, or that a net more suitable to that region, would produce a longer catch.

If the preceding facts of all the regions in Toyama Prefecture be summarised, we reach the conclusion that the most favorable coast for the *Hotaru-ika* fishery is (1) one whose 100-F-line is sufficiently near the beach, (2) where some steep depression in a form valley extends at right angles to the shore, and (3) where the tidal current is not too rapid, but where the water is clear enough.

III. SUMMARY.

In view of all the facts stated above, we arrive at the following conclusions:

i) *Hotaru-ika* is a small cuttle-fish, the mantle-length being about 44-54 mm. in the mature male and about 54-67 mm. in the mature female, showing some sexual dimorphisms.

ii) It is a pelagic species, living generally in the deeper water, i. e. 100 or more fathoms, and it is carnivorous.

iii) The ratio of the number of females to that of males caught on the coast differs according to the season: the males are more numerous than the females in late winter or early spring, while the females, on the contrary, increase in number as the fishing season progresses.

iv) They mate probably in early spring.

v) The spawning season is commonly in late April and the whole of May in Toyama Bay, and is also probably the same, or a little earlier in Sagami Bay.

vi) *Hotaru-ika* which are caught in enormous quantities along the coast of Toyama Prefecture in the fishing season, are mostly females mature and mated, each carrying about 14 spermatophores. They are in the deeper water of 100 or more fathoms in the day time, and in the evening, moving as much as possible in deeper water, approach the shore or shallow sea floor to spawn. But they either can not or will not come more than 2 miles along a shallow floor of more than about 30 fathoms. And as soon as they spawn, they retreat to the deep.

vii) The egg is small and ovoid in shape, floating separately on the sea-surface.

viii) The male dies probably after the fixation of spermatophores in the nape of the female, and the female also dies after she has finished spawning.

I must express my opinion as to the eggs and larvae of an *Abraliopsis*

once mentioned by Mr. T. Nishikawa¹⁾. He collected, in early February 1898, many eggs of the *Abraliopsis* of an earlier Embryological stage²⁾—*Nepioteuthion* stage of *Compsoteuthis Nishikawae* of Pfeffer's³⁾— at Aburatsubo Bay, Misaki. And again, he obtained, in April, 1900, like the above, as well as some developed larvae⁴⁾ (*Compsoteuthis Nishikawae* Pfeffer)⁵⁾— *Compsoteuthis* stage of Chun's⁶⁾— at Enoura, Suruga Province. But, judging by the maturation of the specimens from Awa Province and Sagami Bay mentioned before (see p. 89), as they should be mated there in March at the earliest, the first kind of Nishikawa's egg seems to have been collected too early to identify them with the present species *Watasenia scintillans*, while the second kind may be said to be the *Compsoteuthis* stage of the present species for the same reason.

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- 1). Dōbutsugaku Zasshi, XVIII, 1906, pp. 310-314, pl. 6, figs. 1-15.
 - 2). Ibid. pp. 310-311, pl. 6, figs. 1-11.
 - 3). Erg. Pl.-Exp. Humboldt-Stift. II, F. a, 1912, p. 149.
 - 4). Dōbutsugaku Zasshi, pp. 311-313, pl. 6, figs. 13-15.
 - 5). Erg. Pl.-Exp. Humboldt-Stift. II, F. a, 1912, pp. 450, 162.
 - 6). Wiss. Erg. Deutschen Tiefsee-Exp., Cephal. Oego. 1910, p. 97.

EXPLANATION OF PLATES.

Plate I.

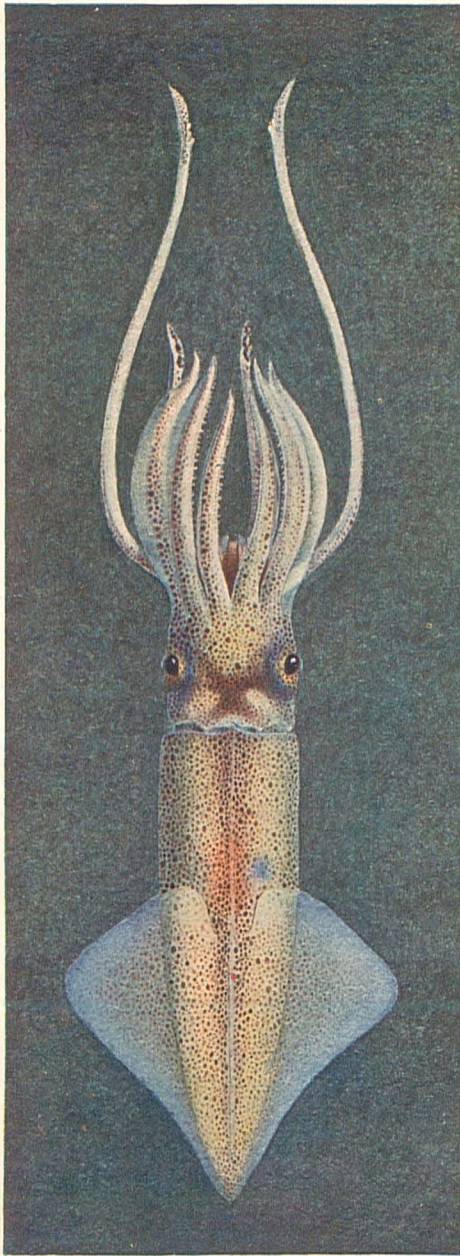
- Fig. 1. Body color of living female *Hotaru-ika* in spring, nat. size. In the natural specimen it was a little more reddish in color than here painted.
- Fig. 2. Phosphorescence of the same, nat. size.
- Fig. 3. External view of minute organs of mantle of the same, $\times c. 100$.
- Fig. 4. External view of brachial organs of the same, $\times 10$.
- Fig. 5. External view of ocular organs of the same, $\times 2.5$.

Plate II.

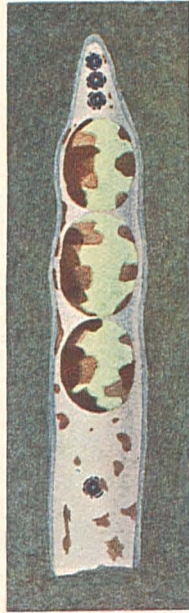
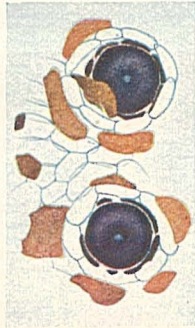
- Fig. 1. Pen of female, $\times 2$.
- Fig. 2. Pen of male, $\times 2$.
- Fig. 3. Hectocotylus, $\times c. 4$.
- Fig. 4. Male, nat. size.
- Fig. 5. Bundle of spermatophores fixed in nape of female, $\times 12$.
- Fig. 6. Nape of female showing the same bundle fixed.
- Fig. 7. Spermatophores from Needham's sac, $\times 23$. A) Packet of spermi; B) discharging spring; C) connective sheath.
- Fig. 8. Same at the moment when inner organs are moving.
- Fig. 9. Same when the movement of inner organs are completed.
- Fig. 10. Ventral view of female genital organs, a little magnified. A) Opening of oviduct into ovary; B) oviduct; C) nidamental gland.
- Fig. 11. Inner surface of nidamental gland showing external opening of oviduct.
- Fig. 12. Radula, $\times 80$. Mi) Middle teeth; La) lateral teeth; Mr) marginal teeth.

Plate III.

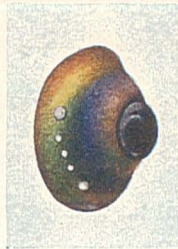
- Fig. 1. Whole coast of Toyama Prefecture.
- Fig. 2. Shimminato coast, $\times c. 1/40,000$.
- Fig. 3. Yokata coast, do.
- Fig. 4. Namerikawa coast, do.
- Fig. 5. Uozu coast, do.
- Fig. 6. Ikuji region, do.



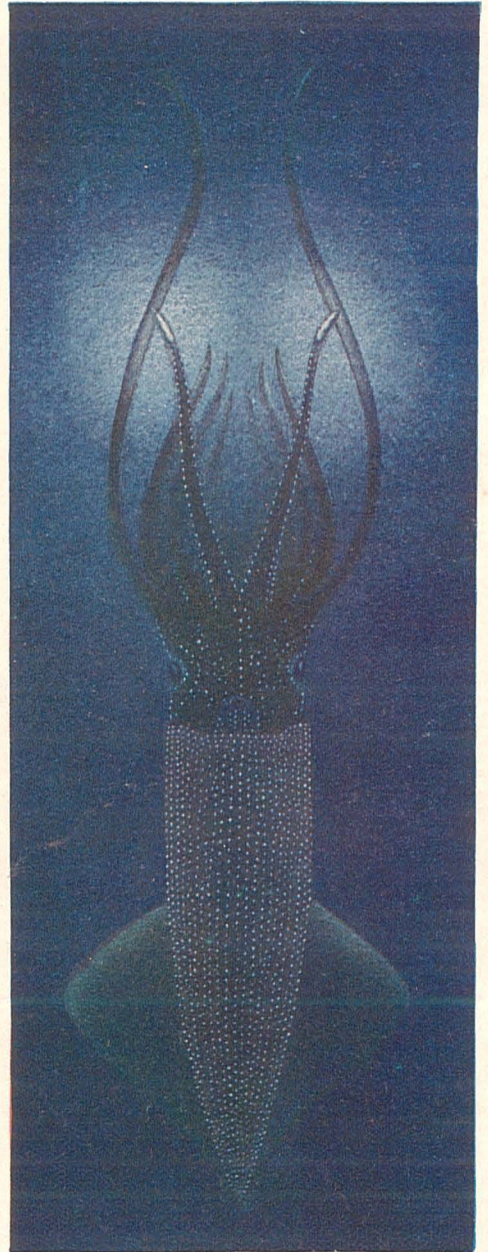
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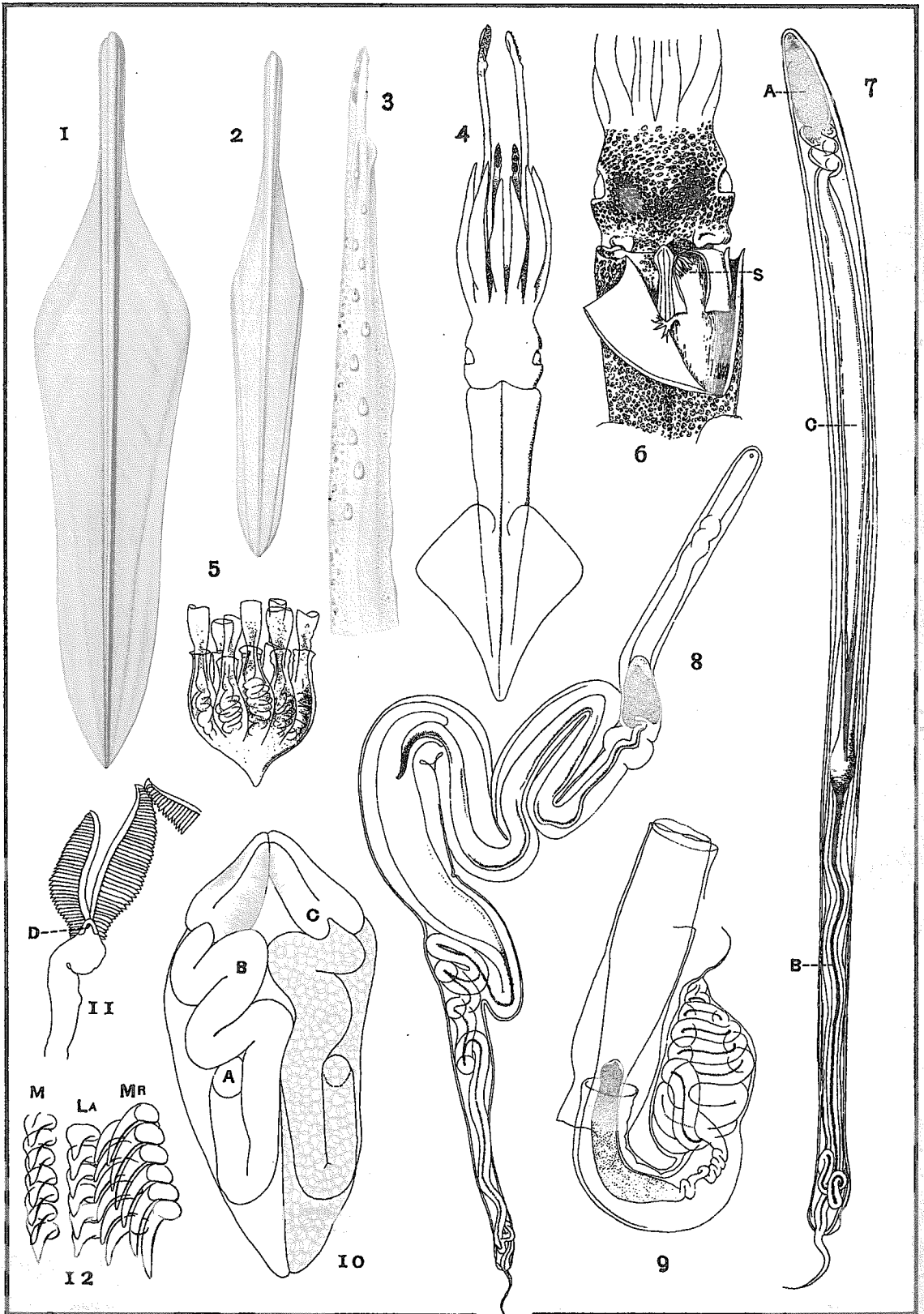
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