# Rays and Skates (*Raiæ*).

## No. I.—Egg-Capsules and Young.

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With Figures 1-20 in the Text.

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## INTRODUCTION.

THE family Raiidæ belongs to the division Batoidei of the sub-order Hypotremata, and is represented by the principal genera Raia, Psammobatis, and Sympterygia (Regan, 1906). The genus Raia (an altered spelling of Raja) was instituted by Linnæus, after Artedi, for the type *Raja batis* in the Systema Naturæ, Ed. X, Vol. I, 1758. The species are numerous and mostly of northern distribution. They are not very well defined, and the synonymy of many of them is distinctly doubtful, and in some cases quite erroneous, e.g.

(1) *R. bathyphila* Holt and Byrne=*R. ingolfiana* Lütken=*R. lintea* Fries.

(2) *R. falsavela* Smitt (non. synonymy)=*R. circularis* Collett=*R. fyllæ* Lütken.

(3) *R. miraletus* Le Danois (non. syn.)=*R. nævus* Müller und Henle.

The extraordinary amount of variation in individuals of the same species has led the more recent systematists to adopt a classification according to geographical distribution, e.g. Jordan and Evermann (1896) and Garman (1913). Commercially, they are known to the Trade as Rays and Skates, but this distinction is not sharply defined, though the idea might be copied with advantage in making a subdivision of the genus.

Little is known of the life history and rate of growth of these fishes.

The present paper deals with the egg-capsules and young of nine British species, and is based on living eggs which were secured at Plymouth from known adult fish, and which were kept alive through the period of incubation under the circulation of sea water in the Laboratory tanks. The particular objects of the investigation were to obtain more precise information of the less known features of embryonic development, to determine the period of incubation of the embryo, to secure the newly hatched young fish, and to fix the character and extent of the post-embryonic changes.

The more interesting and important points with reference to the structure and function of the branchial filaments and to the absorption of the caudal fin require more comprehensive treatment than has been possible in the present work.

The photographs are reproduced from non-contact prints which were taken from the writer's negatives by Mr. C. Gill, Press Photographer, Plymouth.

The writer is greatly indebted to Mr. A. J. Smith, of Plymouth Labora-

tory, for securing a regular series of egg-capsules from Plymouth fish quay; to Professor A. Meek and Mr. B. Storrow for a consignment of *R. batis* capsules from North Shields; and to Dr. A. Bowman, Aberdeen, for the loan of an excellent series of young forms of rare species from the deeper waters of the North Sea and from the North-West of Scotland.

## Explanation of Measurements of Capsules and Post-embryonic Stages.

*Capsules.*

| | |
|---|---|
| Length | Length along the median longitudinal axis of the shell, excluding the horns. |
| Width | Greatest width of the shell, excluding attachment threads. |

*Post-embryonic Stages.*

| | |
|---|---|
| Total length | Tip of snout to tip of caudal. |
| Length of disc | Tip of snout along median longitudinal axis of the fish to the line joining the posterior margins of the pectorals. |
| Width of disc | Greatest width across the outer angles of the pectorals. |
| Snout | Tip of snout along the median axis to line joining anterior margins of orbits. |
| Interorbit | Narrowest width between the orbits. |
| Snout to tip of ventrals | Tip of snout along the median axis to line joining the posterior margins of the distal lobes of the ventrals. |
| Snout to vent | Tip of snout along median axis to anterior margin of vent. |
| Tail | Tip of caudal to junction of tail and ventrals. |
| 2nd dorsal to tip of tail | Posterior margin of base of second dorsal fin to tip of caudal. |
| Præoral | Tip of snout along median axis to middle of closed mouth (meeting of middle series of teeth of both jaws). |
| Internasal | Narrowest width between inner margins of nostrils (anterior groove). |
| Prænasal | Tip of snout along median axis to line joining anterior margin of nostrils. |
| Teeth | Vertical rows in upper jaw. |

To obtain a certain amount of uniformity in the measurements, each

fish was placed ventral side downwards on a flat surface and the outline traced out. The measurements were then taken from the tracing. Those measurements which were recorded in this way were total length, length of disc, and snout to tip of ventrals.

*Stage* 1 represents the newly hatched young.

„ 2 represents the young a few months old undergoing changes in shape of disc and in length of caudal.

*Stages A* and *B* of *Raia fyllæ* represent stages approximate to 1 and 2.

## GENERAL SCHEME.

The following scheme was adopted on the strength of our knowledge that the egg is fertilised in the upper reaches of the oviduct, is completely enclosed with its yolk and albumen in a capsule which is formed by the shell gland, passes down the oviduct comparatively quickly as a complete fertilised product and is ejected from the cloaca.

Most of the egg-capsules which are treated here were taken from the cloaca of the adult fish as they were landed on the fish quay. After being received at the Laboratory, they were measured and labelled and transferred to tanks under the usual circulation of sea water. Small opal-glass labels were used with numbers and dates appended in pencil, and these were attached to the egg-capsule by silk thread, which had previously been immersed in liquid paraffin wax. This precaution is necessary owing to the decomposing effect of sea water and to the injurious action of bacteria. Marking with waterproof Indian ink on the flat portion of the shell between the long horns is just as efficient.

The mortality in the eggs was high, and this may be explained largely by rough handling of the adult fish and by artificial extraction of the capsule and the resultant jar on the yolk, even allowing for the possible use of the thick albuminous layer as a "buffer." A small percentage of perfectly formed, undamaged egg-capsules contained some albumen but no yolk, and these had evidently been closed before the eggs had passed down from the upper reaches of the oviduct. There were also a few very abnormal egg-capsules, obviously too small to receive fertilised eggs, and yet in two cases (*R. clavata*) contained yolk about the size of a pea. Unfortunately, the adult fish from which these eggs were taken were not secured for examination. In two species only were sufficient numbers of capsules obtained for a reliable percentage of successes. *R. clavata* gave 13% out of a total of 240 capsules, and *R. brachyura* 15% out of 127.

One must not lose sight of the fact that these eggs were reared under conditions more or less abnormal, where the temperatures and salinities were, on the average, a good deal higher than in natural conditions. The

results, however, are interesting and show that rearing under artificial conditions is quite possible. They show quite definitely that fertilisation is effected before the egg is enclosed in its shell. There are a few facts to look out for in the process. After about two months (the period varies with the species and with temperature and salinity conditions) in sea water, the albumen of the egg is absorbed, the slits at the base of the horns are then open, and it is dangerous to remove the eggs from the sea water. Bubbles of air collect inside the capsule and these prove fatal to development.

Capsules of *Raia clavata* were found to be quite easy to rear, and as the development covers only a few months, it is suggested that they would be more convenient for developmental studies than a larger form like *R. batis*, in which development is slower.

It was found to be more convenient to pull off the attachment filaments from those egg-capsules which had them, as they collected bubbles of air, which seemed to disturb the equilibrium of the shell.

## SPECIES OCCURRING AT PLYMOUTH.

1. Raia clavata Linn. Thornback.
2. R. maculata Montagu. Homelyn.
3. R. brachyura Lafont. Blonde.
   syn. *R. blanda* Holt & Calderwood.
4. R. microcellata Montagu. Small-eyed Ray.
5. R. undulata Lacépède. Painted Ray (non. Couch).
   syn. *R. picta* Lacépède.
6. R. nævus Müller & Henle. Cuckoo Ray.
7. R. circularis Couch. Sandy Ray (Couch).
8. R. fullonica Linn. Shagreen Ray (Skate).
9. R. batis Linn. Blue or Grey Skate.
10. R. marginata Lacépède. White-bellied Skate. Bordered Ray (Young).
    syn. *R. alba* Lacépède. (Bottlenose Skate.)
11. R. vomer Fries. Long-nosed Skate.

Numbers 1, 2, 3, 4, 6, 8, 9 are of frequent occurrence in the neighbourhood and are taken at all stages.

Numbers 5, 7, 10, 11 are periodic in their appearance, but the young of 5 and 10 occur commonly on the Outer Grounds.

Numbers 7, 10, and 11 increase in frequency with deeper water towards the western entrance to the Channel.

The commercial distinction between Rays and Skates is not very well defined at Plymouth. All the white-bellied forms are grouped as Rays, while the blue or dark-bellied forms, even in the immature stage, are known as Skates.

They are gutted and " winged " and find a ready market. The lateral jaw muscles of the large skate are often extracted as " knobs " and sold commercially as food.

## ORIENTATION OF EGG-CAPSULE IN THE UTERUS.

The long horns are directed towards the cloaca and the more convex face of the capsule towards the dorsal side of the fish. This is the normal orientation, and has been determined in situ in several hundred examples. Vaillant made the same observation in 1885. The embryo emerges at hatching between the long horns. In Dogfish, the blind end of the capsule is the first to appear at the cloaca, and the future open end is the last to be " presented."

## DEPOSITION OF EGG-CAPSULES.

A large female Blonde (*Raia brachyura*) was caught by otter trawl on the inner Eddystone fishing grounds on 5th April, 1922, and was transferred alive to one of the large tanks in the Aquarium. The bottom of this tank had a thick covering of gravel and pebbles. The other occupants of the tank were a large Cod (*Gadus morrhua*), several flat fish (Turbot, Plaice, and Dab), and a few immature Rays (*R. clavata, maculata,* and *brachyura*). All male Rays were transferred to another tank, to obviate the risk of vitiating the experiment. Egg-capsules began to be deposited on 12th April, 1922, and continued to be extruded singly at, more or less, regular intervals. At the beginning of the experiment, capsules periodically became visible in the cloaca of the fish, but disappeared rather strangely. It was supposed that the Cod was responsible for their disappearance, but on raking up the bottom of the tank, they were discovered completely buried in the " sand." With a few exceptions, this method of depositing the eggs was adopted by the fish, which extruded twenty-five capsules up to May 31st, 1922. The fish was then still alive, and the process of egg-laying was being continued. The actual method of deposition was not observed.

The capsules, as they appeared in the cloaca of the fish, were marked with string, which was attached to one of the protruding long horns. By this means, more definite information was obtained as to the time occupied in getting rid of the capsule and the period which elapsed before another made its appearance. This point also had an important bearing on the fertilisation of the egg and the degree of development of the germinal disc. Occasionally a capsule would be hung up for a few days in the

cloaca of the fish, but generally one capsule would be followed immediately by another, when a short period of rest would intervene, about twenty-four hours, before the process would be repeated. This appearance of eggs, spawned in pairs, as it were, is in keeping with the maturation of a single ovum from each ovary.

Dean, in "Fishes Living and Fossil," remarked that the eggs of oviparous skates were said to be deposited on sand-flats near the mark of low water, and he gave an observation by Mr. V. N. Edwards, Woods Holl, who believed that they were implanted vertically in the sand. From the occurrence of beds of skate eggs, the latter supposed that the fishes were singularly local in their places of spawning.

Williamson (1913) recorded the capture of skate eggs in considerable numbers on ground sixteen miles S.S.E. of Aberdeen by the trawl towing off the shoal water on Aberdeen bank, but records of living egg-capsules, after deposition, are extremely few. They have probably escaped capture, because of the inaccessibility or the roughness of the grounds on which they have been deposited. The occurrence of spawning fish and the young stages in shallow water tends towards accepting the view that spawning, in most of the species, takes place close inshore.

A few capsules with living embryos have been dredged in Plymouth Sound in water from five to six fathoms. The capsules were those of *R. brachyura* and *R. clavata* and the attachment filaments on the more convex face of the shell were not attached to living seaweeds or rocks in situ, but were firmly fixed to a mass of debris, which included pieces of dead mollusc shells, loose algal fronds, sand, and gravel. The capsules, which were spawned in the Aquarium, quickly picked up loose foreign objects, such as broken pieces of shells and small pebbles, immediately after deposition.

## FERTILISATION OF THE EGG.

The large female *Raia brachyura*, which was kept alive and which spawned in the Aquarium, afforded an excellent opportunity for testing the fertility of the eggs. As has already been stated, no males were kept in the same tank, so that all possibility of impregnation since being placed in the tank was eliminated. The fish was captured on 5th April, 1922, and transferred alive to the Aquarium on the same day. One egg was deposited on board ship. Capsules began to be extruded on April 12th and have continued to be deposited up to the time of writing, when a total of twenty-five capsules has been recorded. On 17th May, 1922, more than a month after the extrusion of the first egg in the tank, eight capsules were opened and examined. The series was so arranged that it should include stages from the appearance of the capsule in the cloaca to the full period of thirty-five days after deposition. All these eggs

were fertilised, the oldest having embryos from 5 to 6 mm. in length. Six other capsules were extracted as soon as they appeared in the cloaca of the fish, and the eggs were examined. All showed the circular white halo of the germinal disc, the early cleavage stage as figured by Balfour, Plate 6, Fig. 2. It is worthy of note that all the capsules were perfectly formed. A few capsules, which were taken from the cloaca of adult fish as they were landed on the fish quay, were also opened and showed the same halo condition of the germinal disc. In most cases, it occurred at the long horn end of the yolk and was comparatively of large diameter, ca. 5 mm. On being fixed with osmic acid and corrosive sublimate, it lost the circular shape and became more oval. Undoubtedly, the egg is fertilised just before it is enclosed in its capsule, and the further process of completion and extrusion of the egg-capsule must be fairly rapid. Fertilisation, in this case, must be effected by the sperm, which are stored somewhere, probably in the upper reaches of the oviduct, and which in some way become functional when the ovum matures and passes down to be enveloped by its shell.* Dean, in "Fishes Living and Fossil," notes the appearance of sperm in the upper reaches of the oviduct in Chimæra.

The alternative suggestion of a simultaneous fertilisation of ripe ova in the ovary must be ruled out, as there is nothing to suggest retardation of development after fertilisation.

Lo Bianco found the same thing at Naples, where the eggs of *R. asterias* and *R. undulata*, which were spawned in the tanks, were nearly all fertilised. He suggested the same two alternatives, and laid stress on the greater possibility of a receptaculum seminis. The question is one that may lead to great possibilities and is well worth following up.

## EGG-CAPSULES.

### STRUCTURE AND COMPOSITION.

The egg-capsules of Rays and Skates have been frequently described and figured. They differ considerably in shape and in size in the various species, but their structure and composition are identical. The chemical composition of the shell has been determined by Hussakof and Welker as resembling Keratin. It consists of several layers of closely packed fibres, which show definite longitudinal striation. The shape is more or less rectangular with the corners prolonged into hollow tubes or horns. These horns may be drawn out into fine points, but the tendril formation of the dogfish capsules is absent entirely. Each horn, as a rule, is provided with a definite slit, which is closed in the early stages by a thick

* Storage of sperm is a common phenomenon amongst invertebrates, but has not been observed very often in vertebrates. Schmidt (1920) describes an interesting case in the viviparous teleost, *Lebistes reticulatus*.

plug of albumen, or by a delicate membrane. These slits vary in position according to the type of capsule. There are always two long and two short horns. The embryo emerges normally on hatching between the long horns, and this is the end which is oriented towards the cloaca of the fish. Authors are far from agreeing as to the naming of each end of the shell, and the term inferior or posterior as used by some for the long horn end is rather confusing. This is the end which is oriented towards the cloaca of the adult, but it is also the end from which the embryo emerges. Thus it may be defined as posterior in relation to the fish or apical in reference to the embryo.

The shell, after being exposed to the action of sea water, becomes brittle. Osmosis undoubtedly takes place, and, as Peyrega's experiments show, a definite equilibrium is reached, both ways, between the outside medium and the internal fluid. As development of the embryo proceeds, the albumen disappears or is absorbed and the capsule is aerated through the open slits on the horns. A certain amount of weathering takes place, chiefly between the long horns, as the embryo gets ready for hatching. The shell at this stage is easily opened and more easily broken in handling. Its life corresponds with the period of incubation of the embryo.

## AERATION OF THE EGG-CAPSULE.

Opinions are divided in regard to this interesting feature in the life of the capsule. One school represents the view that there is an inward and outward flow of water through slits on the tubular horns, and the other, with modifications, that such a current is impossible. Wyman (1867) gave definite observations on older capsules of *Raia batis*, a species which has since been determined as *Raia diaphanes* Mitchill. He stated that the outer edge of each horn was the more rounded, and near the free end had an oblong slit for the inward and outward flow of the water which passed through the egg during incubation. He admitted that there might have been an albuminous covering at an earlier period and that this had been absorbed. Owen (1866) had the same opinion when he remarked that in the oviparous sharks the branchial filaments reacted on the streams of water admitted into the egg by the apertures.

On the other hand, Beard (1890) had no hesitation in stating that such an inward and outward current was non-existent, and that there was no mechanism present in the egg which would cause such a current to flow. His explanation was that the ordinary laws of endosmosis and exosmosis were quite sufficient to account for the presence of sea water in the egg-capsule and to provide for its aeration. His opinion of the function of the slits was that they were intended to counteract the effects of pressure. Dumeril (1865) and Moreau (1881) held that the slits were closed by an

excessively thin membrane and that the yolk and embryo were separated from the shell by a thick layer of albumen. Nordgaard (1917), in describing the capsules of *Raia radiata*, was unable to find the tube fissures, and remarked that the gelatinous mass would prevent any ingress of water.

In all the capsules which the writer has examined, *Raia batis* probably excepted, the longitudinal slits are definitely marked and easily recognised in capsules before and after deposition. At first, these fissures are tightly closed by albumen, which may or may not have a delicate covering membrane. Capsules taken from the cloaca of a fish show, when cut open, a thick gelatinous mass of albumen, which is in close contact with the whole of the shell and fills the tubular horns. In the middle of the central cavity a liquid fluid surrounds the yolk. After the capsule is deposited and has been in sea water for some time, the albumen begins to disappear. This disappearance coincides with the growth of the embryo, and especially with the development of the vascular system and the specialised branchial filaments. There is reason to suppose that the branchial filaments may help in the absorption of albumen. With the growth and expansion of the pectorals and their junction with the snout, the albumen has practically vanished. The slits are now open, and on lifting the capsule, at this stage, out of the tank, the internal fluid rapidly drains off. When replaced, the capsule floats on the surface of the water, and unless care be taken to expel every particle of air, it results in the death of the embryo. Experiments with finely powdered carmine grains were made on capsules with well-developed embryos, and a definite current was found to move away generally from one of the long horns. On the capsules being opened, after being submitted to the experiment for a few minutes, carmine grains were found inside the shell and on the spiracles of the embryo. Observations on a living embryo of *Raia nævus*, whose capsule is transparent, showed the use of the elongated caudal fin in expelling the enclosed water.

General osmosis undoubtedly occurs, but it can hardly be accepted as providing for the needs of a growing embryo, whose period of incubation may extend over several months. The slits are probably a supplementary adaptation for aiding in the respiration of the embryo, and are analogous to the respiratory perforations on the shell of Chimæra, cf. Dean (1902).

## ORIENTATION OF THE EMBRYO IN THE CAPSULE.

References are given in the present paper to observations on particular embryos at different periods of growth, but the material examined has not been sufficiently large to draw definite conclusions, except in regard to the orientation of the embryo just before hatching. Egg-capsules

of *R. nævus* (Cuckoo Ray) and of *R. marginata* (White-bellied Skate or Bottlenose) were periodically examined in the living condition up to the time of hatching of the embryo. The capsule of *R. nævus*, being transparent, was examined without being disturbed, but in the large skate capsule, observation windows were cut in the shell. In both cases, the embryo had its head end generally facing the short horns of the capsule for the period of development preceding the curling of the outer pectoral angles and the tail, a curling which takes place as growth in width and in length exceeds the dimensions of the central cavity. The embryo, however, was observed to undergo complete turning movements on the horizontal plane, but preserved a constant dorso-ventral position. The embryo emerged normally head first between the long horns. One example, however, of *Raia clavata* proved an exception by emerging between the short horns, which end, as a rule, is firmly closed. The dorso-ventral aspect of the embryo in relation to the flat or the convex side of the capsule, varied considerably, but there appeared a greater tendency, especially in capsules with hooked short horns, for the dorsal side of the embryo to face the more convex side of the shell, cf. Nordgaard (1917), for capsules of *R. radiata*. The orientation of the embryo seemed to bear a definite relation to the position assumed by the capsule after deposition.

## PERIOD OF INCUBATION OF THE EMBRYO.

| Species. | Average Period in months. | Range in days. | No. of Specimens. | Months. | Years. |
|---|---|---|---|---|---|
| Raia clavata | $4\frac{1}{2}$ | 121–154 | 22 | IV–X | 1921 |
| | $5\frac{1}{2}$ | 167–168 | 2 | VI–XI | 1920 |
| R. nævus | 8 | 212 | 1 | VI–II | 1920–1 |
| R. maculata | 5 | 145–172 | 5 | V–X | 1921 |
| R. brachyura | 7 | 189–219 | 4 | VI–II | 1921–22 |
| R. microcellata | ca. 7 | 240 | 1 | VI–I | 1921–22 |
| R. marginata | $14\frac{3}{4}$ | 449 | 1 | IV–VII | 1921–22 |

The period of incubation refers to embryos which were reared under artificial conditions in the Laboratory tanks. Newly hatched young, approximately the same size, and with similar characters, were secured by trawl in shallow water off Plymouth, about the same time as these tank specimens hatched out. The following table shows the range in width of disc for each of the monthly captures. The number of fish captured is here neglected. The figures represent the range in width of disc in millimetres, while those in thick-faced type show the width of disc of the artificially hatched fish as they occurred.

Examination of the following table gives a good index in regard to the period of spawning at Plymouth of the three species: *R. clavata*,

RECORDS OF SIZES OF EARLY YOUNG FISH CAUGHT IN TRAWL (PLYMOUTH) DURING THE YEARS 1920, 1921, AND 1922, ARRANGED MONTHLY.

| *Months.* | I. | II. | III. | IV. | V. | VI. | VII. | VIII. | IX. | X. | XI. | XII. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R. clavata | 84–99 | 86–100 | 80–100 | 82–100 | 83 | 80–100 | 80+ | 90+ | ***75–83*** | ***71–86*** | 79–90 | 88–94 |
| R. maculata | 99 | 90 | 78–95 | 81–88 | — | 70–90 | — | 100 | — | ***71–79*** | — | — |
| R. brachyura | ***103–106*** | ***115***–151 | 117–157 | 130–139 | — | — | 100–150 | 110–150 | 120–150 | 124 | — | ***100*** |
| R. nævus | — | ***62*** | 63–88 | — | — | — | 70–74 | — | 70–86 | — | — | — |
| R. microcellata | ***86*** | — | 110 | — | — | 80 | — | — | — | — | — | — |
| R. marginata | — | — | 266–276 | 253–265 | — | ***190*** | — | — | — | — | 240 | — |

*R. maculata*, and *R. brachyura*. From the small sizes which were caught practically in all the months of the year, from the known period of incubation of the embryo and from the occurrence of the eggs, one arrives at the conclusion, which seems justifiable, that the spawning for these species is prolonged for the greater part of the year. Similar observations of a prolonged spawning period have been recorded by Beard for the common Skate (*R. batis*) and the Cuckoo Ray (*R. nævus*) in the North Sea, by Borcea for the Cuckoo Ray at Roscoff and by Lo Bianco for *R. punctata* (syn. *R. asterias* Delaroche) in the Mediterranean.

The following table gives the record of the occurrence of egg-capsules at Plymouth during the period of the present investigation. It will be noted that the maximum months for the more frequently occurring species were April, May, and June. This is probably the true state of things, but it must be understood that these months represent the period of intensive fishing for Rays and Skates at Plymouth. It coincides with the season for boulter or long-line fishing, which fills in the gap between the winter herring and the summer mackerel fisheries. The numbers tabulated are the frequency numbers and represent the capsules examined during the years 1920, 1921, and part of 1922.

OCCURRENCE OF EGG-CAPSULES AT PLYMOUTH.

| *Months.* | I. | II. | III. | IV. | V. | VI. | VII. | VIII. | IX. | X. | XI. | XII. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Raia nævus | — | 3 | 10 | 10 | 19 | 2 | — | — | — | — | — | — |
| R. undulata | — | — | — | — | — | — | 2 | — | — | — | — | — |
| R. microcellata | — | — | — | 2 | 4 | 3 | 3 | 2 | — | — | — | — |
| R. brachyura | — | 1 | 15 | 32 | 43 | 79 | 34 | — | — | — | — | — |
| R. clavata | — | — | 1 | 15 | 44 | 159 | 51 | — | — | — | — | — |
| R. batis | — | — | — | 1 | 1 | — | — | — | — | — | — | — |
| R. circularis | — | — | — | 1 | 4 | — | — | — | — | — | — | — |
| R. vomer | — | — | — | — | — | — | — | — | 2 | — | — | — |
| R. marginata | — | — | — | 4 | — | 2 | — | — | — | — | — | — |
| R. maculata | — | — | — | 6 | 21 | 5 | 1 | — | — | — | — | — |

AVERAGE SIZES OF EGG-CAPSULES SECURED AT PLYMOUTH.

Measurements in mm.

| Species. | No. of capsules. | Length (without horns) along the median line. | Width (greatest). |
|---|---|---|---|
| Raia nævus | 28 | 63·4 | 36·8 |
| R. undulata | 2 | 81·5 | 52·0 |
| R. microcellata | 15 | 90·8 | 57·2 |
| R. brachyura | 177 | 128·4 | 78·5 |
| R. clavata | 255 | 74·9 | 57·1 |
| R. batis | 2 | 143·5 | 80·8 |
| R. circularis | 3 | 89·3 | 50·3 |
| R. vomer | 2 | 133 | 79·5 |
| R. marginata | 6 | 180·3 | 138·6 |
| R. maculata | 24 | 70·7 | 41·8 |

The foregoing table gives the average sizes of the capsules of ten species, all of which were secured from the Plymouth area. It is interesting to compare these sizes with those recorded by Lo Bianco for Mediterranean forms. The method of measurement is the same in both cases.

SPECIES RECORDED BY LO BIANCO AT NAPLES.

| | Length (without horns). | Width (greatest). |
|---|---|---|
| R. asterias Rond. | 105 | 60 |
| R. clavata Rond. (*R. petrosa*) | 60 | 45 |
| R. maculata Mont. | 65 | 35 |
| R. oxyrhynchus L. (*R. monaca*) | 140 | 115 |
| R. punctata Risso (*R. d'arena*) | 45 | 30 |
| R. undulata Lacep. | 90 | 45 |

Considerable variation is apparent in these Mediterranean capsules from the Plymouth specimens. There is the strong suggestion that the mature fish of the same species are of smaller size in the Mediterranean, as Borcea (1905–6) has also remarked, but there is an alternative suggestion that we are dealing with different species. With *R. asterias* Rondelet, the writer is not familiar and cannot give its true synonym until specimens have been examined. *R. oxyrhynchus* L. seems to be distinct from *R. vomer* Fries, to which it is closely allied. *R. punctata* Risso is identical with *R. asterias* Delaroche, which is a definite species, and probably confined to the Mediterranean.

The size of the egg-capsules from the same fish shows considerable variation. Twenty-nine capsules from a female *R. brachyura* which spawned in Plymouth Aquarium supplied the following data :—

| | | |
|---|---|---|
| Arithmetic means | Length (without horns) | 130·5 mm. |
| | Width (greatest) | 77 mm. |
| Variations from the means | Length | +12·5 |
| | | − 6·5 |
| | Width | +11·0 |
| | | − 3·0 |

Nordgaard (1917) remarks that the eggs from the same fish need not be of the same size.

## BRANCHIAL FILAMENTS.

The term, branchial filaments, here applies to those temporary external embryonic structures, the elongations of the gill-lamellæ, cf. Goodrich (1909). The name, however, is still open to question as their function has not been definitely determined. As Southwell and Prashad (1919) remark, the name is less open to confusion than external gills or gill-filaments, which would denote homology with true external gills, or trophonematous filaments, a name which Alcock and Wood Mason (1891) applied to the uterine villiform papillæ of certain viviparous Elasmobranchs. In the Rays, they arise from five-gill arches, being absent from the spiracle. They are extremely delicate and are highly vascular. It seems feasible in oviparous Elasmobranchs to believe that they may assist in the absorption of albumen, but it is more difficult to accept the view that they absorb nutriment from the yolk sac, which pours its secretion into the spiral valve through the medium of an internal yolk sac. They are present also in viviparous Elasmobranchs, and are there supposed to be of use for the absorption of nutriment.

In the living eggs which the writer examined, they were observed to decrease in length with the growth of the broad flat pectorals, the consequent ventral position of the gill-clefts and the overgrowth of the anterior part of the gill-arch. They do not quite disappear even at the end of the embryonic period, though they are more or less invisible on the surface of the cleft, but are pushed outwards to the outer margin of the gill-arch with the development of the permanent gills. At the end of the embryonic period, one or more may be seen to extrude, generally from the last gill-cleft. Further investigation appears to be necessary to determine their true function.

## TEMPERATURE OF LABORATORY TANKS.

The temperatures of the sea water in the experimental tanks in the Laboratory have been recorded daily since the beginning of 1920. Readings are taken generally about 10 a.m. and 5 p.m., and the thermometers are weighted so as to register the temperatures at the bottom of the tanks. The work was begun by Dr. J. H. Orton, and has been continued by Mr. A. J. Smith, who has been responsible for the daily readings. It will be seen from the times of observation and from the absence of self-recording instruments that the temperatures are only approximate, that they do not record the actual minimum, but are probably nearer the true maximum. The figures are tabulated in the above table and represent the monthly averages for five of the tanks during the periods of incubation of the egg-capsules. The incubation period for eggs of the same species was successfully obtained for *Raia clavata* in separate years. Two

## TEMPERATURE OF LABORATORY TANKS.

Average Monthly Temperatures of five Laboratory Tanks in degrees Centigrade.

| *Months.* Year. | I. | II. | III. | IV. | V. | VI. | VII. | VIII. | IX. | X. | XI. | XII. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1920. | — | — | — | — | — | 14·8 | 14·9 | 14·8 | 14·8 | 14·4 | 12·2 | 10·3 |
| 1921. | 11·5 | 10·9 | 11·1 | 12·1 | 13·4 | 15·6 | 18·0 | 16·6 | 16·6 | 15·4 | 12·7 | 11·8 |
| 1922. | 10·6 | 9·9 | 10·1 | 10·0 | 13·6 | — | — | — | — | — | — | — |
| | | | | | Average Surface Temperatures at Stations L. 1 and L. 2. | | | | | | | |
| 1921. | — | — | — | — | 12·9 | — | — | 15·7 | — | 15·9 | 12·3 | 11·0 |
| 1922. | 10·0 | 8·5 | 8·4 | — | 13·7 | — | — | — | — | — | — | — |
| | | | | | Average Surface Temperatures at Stations L. 3, L. 4, L. 5. | | | | | | | |
| 1921. | — | — | — | — | 12·0 | — | — | 15·4 | — | 15·9 | 14·2 | 12·2 |
| 1922. | 10·5 | 9·2 | 8·9 | — | 12·7 | — | — | — | — | — | — | — |
| | | | | | Average Surface Temperatures at L. 6 and E. 1. | | | | | | | |
| 1921. | — | — | — | 10·1 | 13·4 | — | 14·7 | 15·6 | 15·8 | 15·6 | 14·4 | 12·8 |
| 1922. | 11·2 | 9·9 | 9·4 | — | 12·7 | — | — | — | — | — | — | — |
| | | | | | Average Bottom Temperatures at Station E. 1. | | | | | | | |
| 1921. | — | — | — | 9·8 | 10·7 | — | 12·5 | 13·2 | 13·8 | 15·3 | 14·9 | 13·1 |
| 1922. | 11·3 | 10·5 | 9·6 | — | 10·0 | — | — | — | — | — | — | — |

embryos were incubated from June to November, 1920, and twenty-two embryos in 1921 from April to September. The temperatures for 1920 were lower than those for 1921, though the average for the period showed only a difference of 1 degree Centigrade. The rate of development in the 1920 embryos was correspondingly slower, being one to two months longer than in 1921. Experiments, however, on a larger scale are required before making any definite deductions.

The average temperatures of the sea in the immediate neighbourhood of Plymouth at fixed Hydrographical Stations have been added for comparison. Stations L. 1 and L. 2 are taken together, L. 1 being below the Laboratory and L. 2 at the western end of Plymouth Breakwater. Stations L. 3, L. 4, and L. 5 occur at equal distances from L. 2 to the Eddystone rocks, and thus represent the area involved as the Inner Eddystone fishing-grounds. Stations L. 6 and E. 1 are outside the Eddystone rocks, and have been taken to represent the Outer Eddystone fishing-grounds. Only surface temperatures at Stations L. 1 to L. 5 were obtained, but there is probably not a great deal of difference from temperatures on the bottom, as the water is more or less homogeneous. A general comparison between the tank temperatures and those of the sea shows that the former are higher from March to September (inclusive) and lower from October to March, except in the case of L. 1 and L. 2, which are lower throughout the year than the Laboratory tanks. This is probably what one might expect to happen.

The correlation of these sets of temperatures distinctly shows that the tank temperatures differ very little from those of the Sound and of the Inner Eddystone grounds, which represent the conditions for the normal habitat of the eggs of the fish which are here recorded.

Salinity observations, unfortunately, have not been obtained. These might have brought out some interesting facts, for the water circulation in the Laboratory, owing to the periodicity in fresh supplies, develops an abnormally high degree of saltness.

### Raia clavata Linnæus.

Common Names.—Thornback, Roker.

#### Egg-capsule (Fig. 1).

The egg-capsule of the Thornback, Fig. 1, is reproduced approximately ¾ actual size. The tips of the four horns end as delicate fibrillæ. One side is decidedly more convex than the other, which has a tendency to become almost flat. The more convex side appears ventrally in relation to the enclosed embryo in the figure. This is the side of the capsule which is oriented towards the dorsal side of the adult fish. It is covered with a tight-fitting felty mass of fibres, which become looser at each end of

the shell. The side margin of the shell is projected horizontally for most of its length as a flattened keel, from which springs a mass of loose fibres, which serve undoubtedly as attachment processes. This felty mass was present in all the specimens examined, but became much reduced with

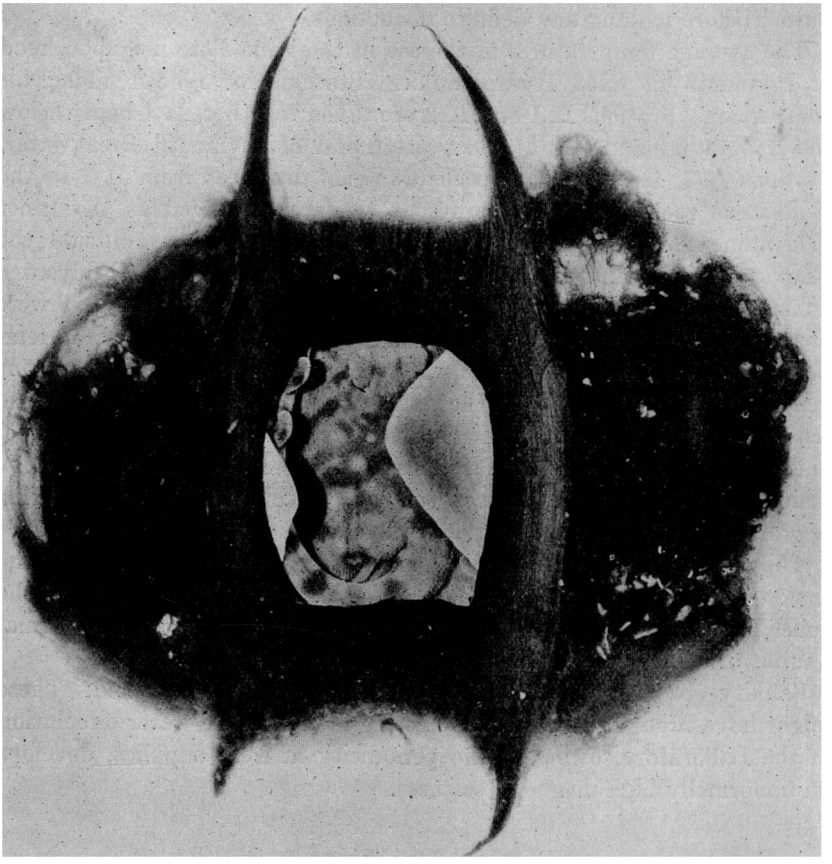

*Photo. R.S.C.*

FIG. 1.—EGG-CAPSULE OF RAIA CLAVATA L.
Length (without horns) 80 mm. Width (greatest), without attachment threads, 62·5 mm. Typical orientation of embryo just before hatching.

long exposure in sea water. Each horn has a slit near its tip on the outer side, not on the inner base of the horn, as has so often been assumed. These slits help in the aeration of the egg, but are closed with a thick plug of albumen during the early stages.

The number of capsules examined amounted to 300. The average

sizes were 74·9 mm. in length along the median line of the capsule, and 57·1 mm. in width (greatest). The length ranged from 63 to 90 mm., and the greatest width from 49 to 68·5 mm.

A few abnormal capsules were obtained, which were badly twisted, and had the central cavity so much reduced that the reception of a normal egg was impossible. Unfortunately, the adult fish could not be secured for examination. Their measurements were as follows :—

| | Length (without horns). | Width (greatest). |
|---|---|---|
| 1. | 48 mm. | 55 |
| 2. | 45 | 59 |
| 3. | 51 | 55 |
| 4. | 46 | 41 |
| 5. | 47 | 43 |

Fig. 1 shows the embryo in situ just before hatching. The orientation is normal, with the head of the embryo pointing diagonally towards the long horns, the end from which it would finally have emerged. The writer, however, has one example of an embryo of this species which hatched from the short horn end, which, as a rule, is tightly closed.

The dorsal side of the embryo faces the flat side of the capsule, but several examples show the reverse orientation. The embryo is capable of considerable movement within the capsule, as the writer has observed repeatedly, but the position assumed by the capsule may have a definite bearing on the final orientation of the embryo, cf, Beard and Nordgaard.

As the embryo increases in size, it becomes too big for the cavity of the capsule and it adopts the overlapping of the angles of the pectoral fins, while the tail curls round towards the head. The writer has not observed the embryo actually in the process of emerging from the capsule, but he has a strong suspicion that the curl of the tail is used as a fulcrum against the short horn end of the cavity in spasmodic efforts to force the head end out between the long horns.

## Post-embryonic Stages.

### Stage 1. (Fig. 2).

The period of incubation of the embryos ranged under artificial conditions in the Laboratory tanks from 4 to 5½ months. Temperature seemed to be an important factor, but the periodic high salinities of the Laboratory circulation might have had a deleterious effect. Twenty-three embryos were hatched, of which 15 were females and 8 males. The mean sizes of these at hatching, or soon after hatching, were 125·9 mm. in length and 79·5 mm. in width of disc, with a range round the mean from −7·9 mm. to +10·6 mm. in length, and −8·5 mm. to +6·5 mm. in width.

The means of 8 males were 126·9 mm. in length and 79·1 mm. in width, and of 15 females 125·4 mm. in length and 79·7 mm. in width.

Fig. 2 shows a male a few days old. The claspers are well defined.

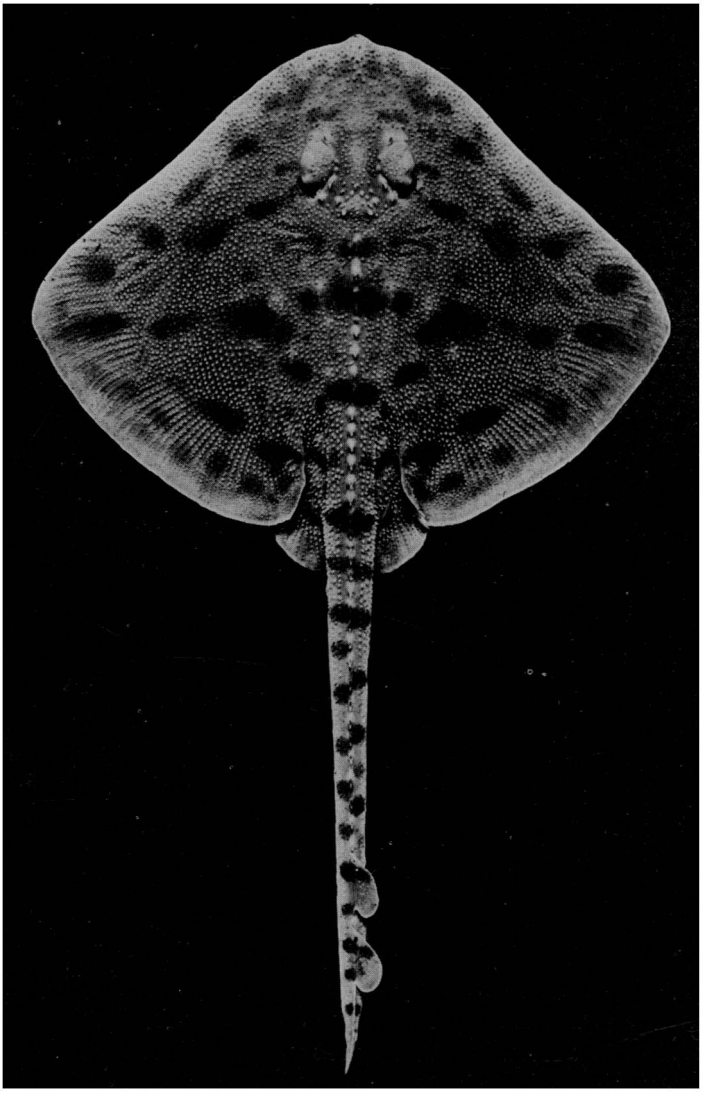

*Photo. R.S.C.*

FIG. 2.—RAIA CLAVATA L.

Newly hatched. Sex ♂. Period of incubation 155 days. Tota Length 133·5 mm. Width of Disc 82 mm.

The external yolk is fully absorbed, and only the flattened remains of the sac, ca. 1 mm. in diameter, can be seen. The internal yolk sac is still very large and occupies more than half the space of the body cavity. The spiral valve has been pushed to the left side of the fish and overlies the stomach. The date of hatching was 30th September, 1921, and the egg-capsule was taken from the adult fish and placed under circulation on 29th April, 1921. The period of incubation was thus 155 days.

STAGE 1 (Fig. 2).

Measurements are in mm.—on preserved specimen.

| | |
|---|---|
| Total length. . . . . | 133·5 |
| Length of disc . . . . . | 62·5 |
| Width of disc . . . . . | 82·0 |
| Snout . . . . . | 14·0 |
| Interorbit . . . . . | 6·0 |
| Snout to tip of ventrals . . . . | 69·0 |
| Tail . . . . . | 70·0 |
| Præoral . . . . . | 17·0 |
| Internasal . . . . . | 10·5 |
| Prænasal . . . . . | 12·0 |
| Width of mouth . . . . . | 10·0 |
| 2nd dorsal to tip of tail . . . . . | 12·5 |

Teeth in upper jaw very irregular, both in shape and in position. There are less than forty rows, but these are difficult to define in vertical series. They are quite flat and embryonic, but a few show a short point posteriorly.

Upper surface entirely spinulose, except for a narrow bare longitudinal space on each side of the median ridge of spines. Thirty-five median spines on the body and tail, of which two only are in front of the shoulder and one between the dorsals. There are two præ-orbital and three post-orbital spines and two smaller inner orbital spines on each side. The two endolymphatic canals are open and appear as short tubes behind the head, in front of the first large median spine. There is one spine on each shoulder. The side margins of the tail are spinulose. Colour of upper surface approximates to Klinksieck and Valette, code No. 134, with small irregularly shaped dark patches scattered over the disc and tail, and a few cream spots more or less circular in shape near the central area of the body. The lower surface is entirely smooth and white except for a margin of grey round the angle of the pectorals and along the posterior border of the disc and pelvics. The tip of the tail is darker brown.

There is a considerable amount of variation in spinulation. In sixty-one specimens the variation in the total number of median spines ranged from twenty-six to thirty-eight, with a mean of thirty-one.

Pigmentation is very unstable. Some are more or less uniform, others have dark and light spots, others have a black bar on each wing, cf. Figs. 3 and 4.

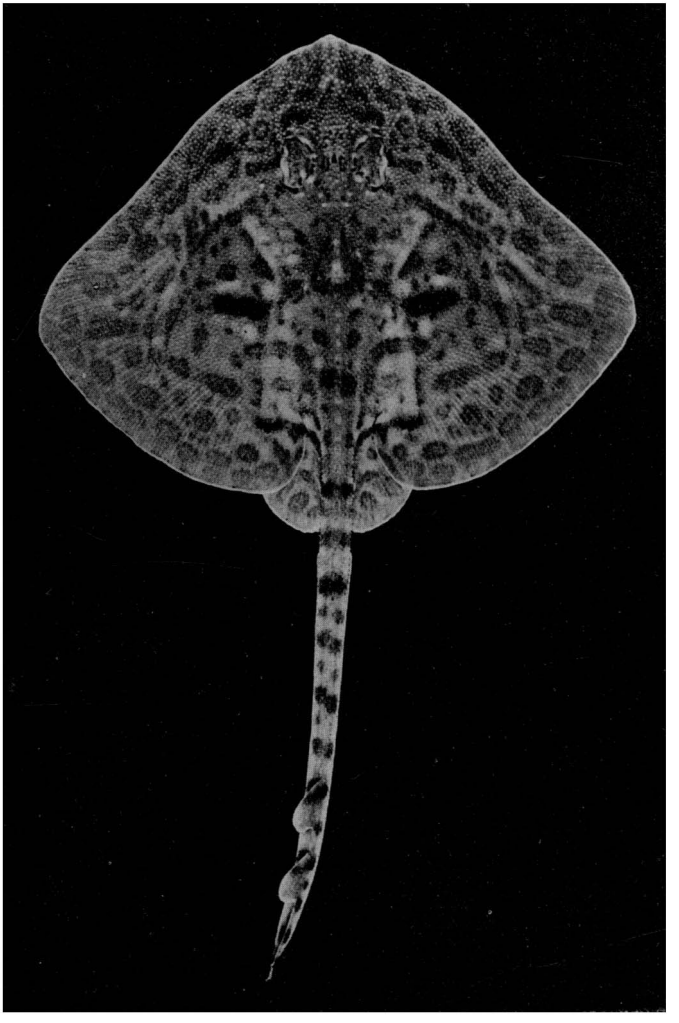

*Photo. R.C.S.*

FIG. 3.—RAIA CLAVATA L.

Age, after hatching, 4 months. Sex ♂. Reared in Laboratory Tank. Total Length 121 mm. Width of Disc 75 mm.

### Stage 2 (Fig. 3).

Fig. 3 represents a male Thornback, age four months. It was hatched in October, 1921, and lived till 12th February, 1922.

| Measurements in mm. | |
|---|---|
| Total length | 121 |
| Length of disc | 57·5 |
| Width of disc | 75 |
| Snout | 13·5 |
| Interorbit | 5·5 |
| Snout to tip of ventrals | 62·5 |
| Snout to vent | 48 |
| Tail | 63 |
| 2nd dorsal to tip of tail | 11 |
| Præoral | 15·5 |
| Internasal | 10 |
| Prænasal | 12 |
| Width of mouth | 10 |
| Teeth in upper jaw | ca. 40 rows. |

Upper surface entirely spinulose. A narrow bare patch along each side of the median row of spines. Total number of median spines thirty-two, of which two are in front of scapula and two between the dorsal fins. Two præ-orbital and three post-orbital spines, with two smaller inner orbitals. Endolymphatic tubes prominent and open. A narrow projecting margin of skin along the greater part of the tail. Colour of upper surface mottled, as the figure shows, with two pairs of dark spots transversely elongate, one larger pair near the middle of the body, the other pair smaller and narrower near the base of the disc. A narrow white border surrounds the disc, snout and ventrals. The lower surface is smooth and white, with a darker margin round the angle and posterior border of the disc and ventrals. The teeth are still irregular in shape and position, but the middle rows show a tendency towards a sharp posterior point.

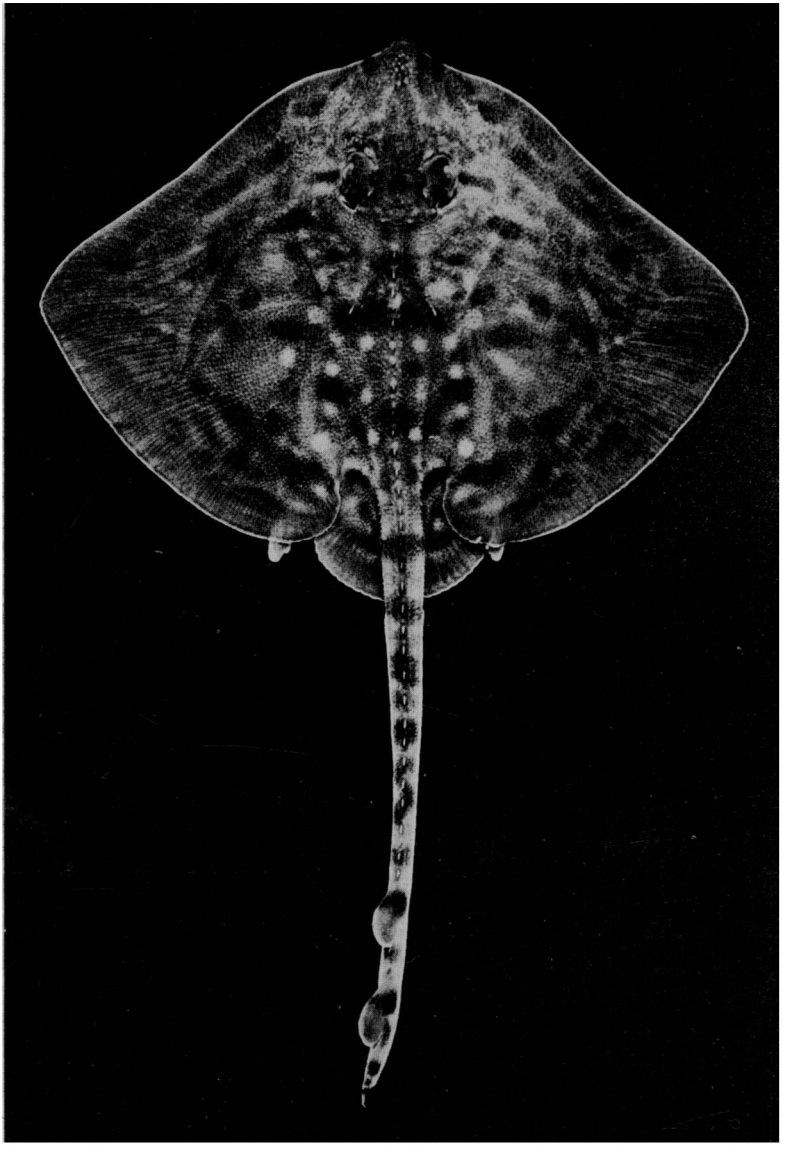

*Photo. R.S.C.*

FIG. 4.—RAIA CLAVATA L.

Age, after hatching, ca. 4 months. Sex ♀. Reared in Laboratory Tank. Total Length 146 mm. Width of Disc 95 mm.

STAGE 2 (Fig. 4).

Fig. 4 represents a female Thornback, also about four months old. It was hatched in October, 1921, and killed on 6th February, 1922.

Measurements in mm.

| | |
|---|---|
| Total length | 146 |
| Length of disc | 69 |
| Width of disc | 95 |
| Snout | 16·5 |
| Interorbit | 6 |
| Snout to tip of ventrals | 77 |
| Snout to vent | 59 |
| Tail | 75 |
| 2nd dorsal to tip of tail | 10·5 |
| Præoral | 19 |
| Internasal | 12 |
| Prænasal | 13 |
| Width of mouth | 12 |
| Teeth in rows in upper jaw | ca. 44 |

This fish was observed to feed freely on Amphipods which were placed in the tank. It shows the typical shape and characters of the young Thornback. The disc is broad, tail long, dorsals widely separated, upper surface entirely spinulose. There are thirty-six median spines on the body and tail, of which three are præ-scapular.

The anterior margin of the disc is slightly undulated. The pigmentation scheme is less pronounced than in Fig. 3, and the dark bars are absent. The circular cream white spots are more pronounced near the middle of the body. The tip of the caudal is much reduced. Otherwise, the characters are the same as in the preceding.

RAIA MACULATA Montagu.

Common Names.—Homelyn, Spotted Ray.

EGG-CAPSULE (Fig. 5).

The egg-capsule, Fig. 5, is narrower in proportion to its length than that of the Thornback, which is shown in Fig. 1. The general characters are identical, but the texture of the shell is much more delicate and the mass of attachment threads much smaller. The capsule more nearly

resembles that of *Raia undulata*, Fig. 18, but is of much smaller size. Both sides of the shell are convex, the side which is dorsal in relation to the adult fish being covered with a close-fitting network of fibres, and the ventral side being perfectly smooth. Each horn has a definite longitudinal slit on its outer side and near its distal end, in the region of the bend of the tube. There is no lateral horizontal prolongation of the

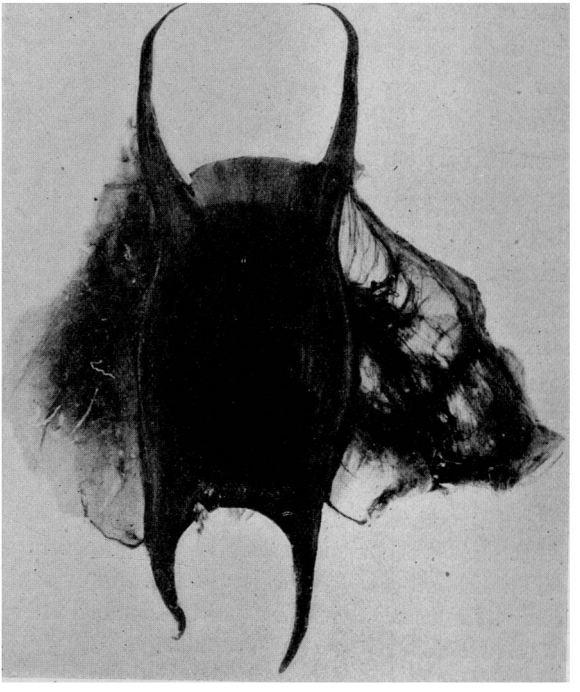

*Photo. R.S.C.*

FIG. 5.—EGG-CAPSULE OF RAIA MACULATA Montagu. Length (without horns) 69 mm. Width (without attachment threads) 42 mm.

capsule into a flattened keel as in the Thornback. The figure reproduced by Holt and Calderwood belongs to this species, but appears rather broad in relation to its length. Beard could find no difference between the eggs of the Thornback and the Homelyn, but this is not convincing. The average sizes for twenty-four capsules were 70·7 mm. in length without horns, and 41·8 mm. in greatest width. Mediterranean examples, according to Lo Bianco, are much smaller, the length being given as 65 mm. and the width 35 mm.

## Post-embryonic Stages.

### Stage 1 (Fig. 6).

The following are the measurements in mm. of the young Homelyn, reproduced in Fig. 6, which has just emerged from its capsule :—

| | |
|---|---|
| Total length | 116 |
| Length of disc | 54·5 |
| Width of disc | 67·5 |
| Snout | 11·75 |
| Interorbit | 6 |
| Snout to tip of ventrals | 61 |
| Snout to vent | 47·5 |
| Length of vent | 3 |
| Præoral | 14·5 |
| Internasal | 8·5 |
| Prænasal | 10 |
| Width of mouth | 9 |
| Tail | 60 |
| 2nd dorsal to tip of tail | 11 |
| Teeth in upper jaw | ca. 40 |

The period of incubation in five examples ranged from 145 to 172 days, from May to October, 1921. Of the five examples, two were males and three females. The average total length of these fish was 127·2 mm. and width of disc 75 mm. The upper surface is smooth, except for the characteristic median row of spines and a narrow border of spinulæ on the anterior margin of the disc. There are a few small spines on the rostrum and on the interorbit, two præ-orbital and two post-orbital spines and one smaller inner orbital. Twenty-eight median spines extended from the neck region to the dorsal fins, and of these two only were in front of the shoulder and one between the dorsals. A single spine is present on each side of the shoulder. The tail is also provided on each side with a single row of marginal spines, which are less pronounced than the median series. The colour is light fawn with black spots, which do not extend on to the edge of the disc. A narrow line, white in colour, surrounds the outer margins of the disc and ventrals, while the tail has a horizontal prolongation of the skin as a flattened keel, which extends longitudinally or most of its length.

The mucous canals are well shown in the figure. The endolymphatics occur as short open tubes behind the head. The characteristic feature of this newly hatched fish is the long caudal tip behind the second dorsal

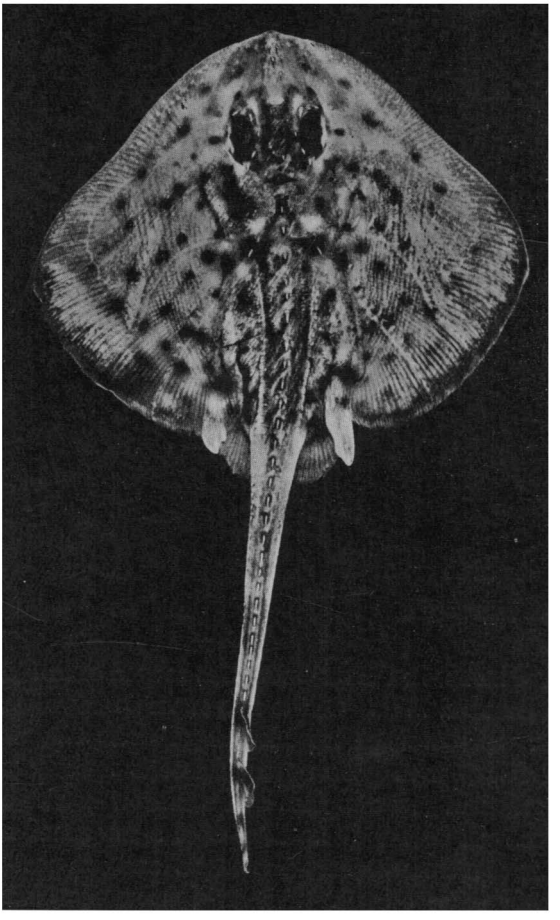

*Photo. R.S.C.*

FIG. 6.—RAIA MACULATA Montagu.
Newly hatched. Sex ♂. Period of incubation 172 days. Total Length 116 mm. Width of Disc 67·5 mm.

fin. The extreme tip has begun to show signs of shrinkage. The lower surface is entirely smooth and white, except for the usual border of pigment round the angle and the posterior margins of the disc and ventrals. The internal yolk sac is still la ge.

STAGE 2 (Fig. 7).

Measurements in mm. of fish reproduced in Fig. 7.

| | |
|---|---|
| Total length | 126 |
| Length of disc | 65 |
| Width of disc | 86·5 |
| Snout | 16 |
| Interorbit | 6 |
| Snout to tip of ventrals | 72 |
| Snout to vent | 51·5 |
| Tail | 63·5 |
| 2nd dorsal to tip of tail | 6·5 |
| Præoral | 18·5 |
| Internasal | 10 |
| Prænasal | 13·5 |
| Width of mouth | 9·75 |
| Teeth in upper jaw | ca. 40 |

This specimen was hatched on 17th October, 1921, and lived till 16th March, 1922. Its length on hatching was 132 mm. and width of disc 79 mm., and the distance from the end of the 2nd dorsal to the tip of caudal fin was 6·5 mm. The reduction in length of the caudal is a pronounced feature of all these post-embryonic Rays. It begins to shorten before the end of embryonic life, and the process of absorption is carried on for some time after hatching. It shows a wrinkled appearance, while the extreme tip curls and shrivels up, cf. Figs. 6 and 7. The fish, Fig. 7, has undergone considerable changes. The snout has been pushed out and now projects slightly beyond the margin of the disc. The pigmentation is intensified, and an ocellus on each pectoral is beginning to show more prominently, as a circular cream-coloured spot, surrounded by a few irregularly shaped black spots. The general shape of the fish approximates more to the adult condition, but the characters are still more or less embryonic.

The upper surface shows the same spinulation as in the younger stage. There is a median row of thirty spines, of which two are præ-scapular. No spine is as yet developed between the dorsals, which are separate. The inner orbital spine is absent, but spinulæ are more frequent on the interorbit. The upper surface is covered with irregularly shaped black spots, which are large in comparison with the size of the fish. The cream-

coloured spots are circular and very prominent near the middle of the body. The tail has a definite lateral keel.

The lower surface is entirely smooth and white except for a greyish border round the angle and posterior margin of the disc and ventrals.

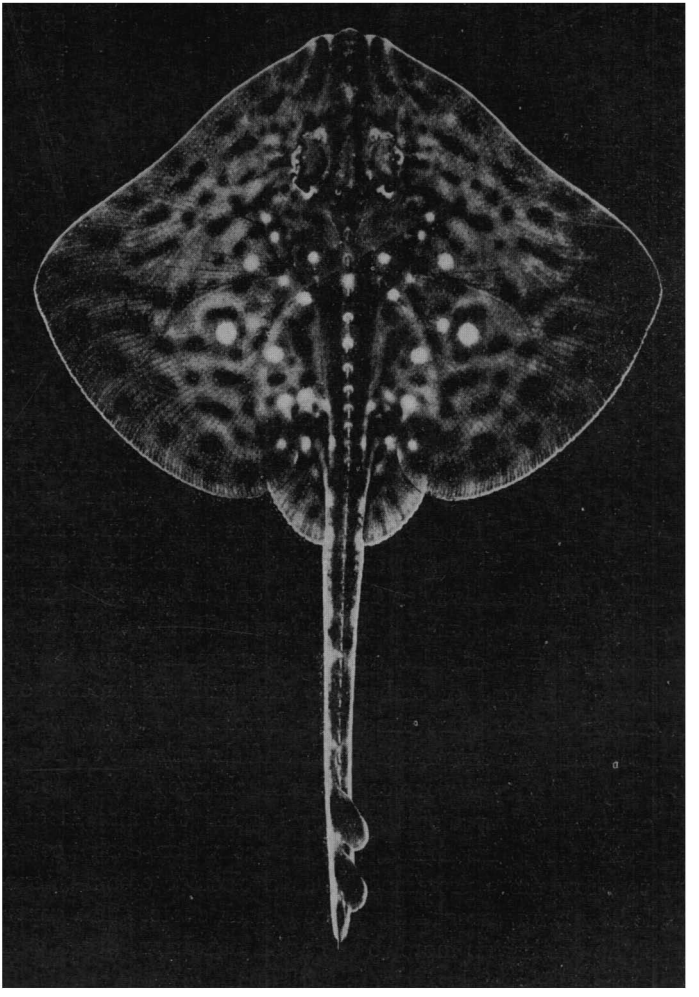

*Photo. R.S.C.*

FIG. 7.—RAIA MACULATA Montagu.
Age, after hatching, 5 months. Sex ♀. Reared in Laboratory Tank.
Total Length 126 mm. Width of Disc 86·5 mm.

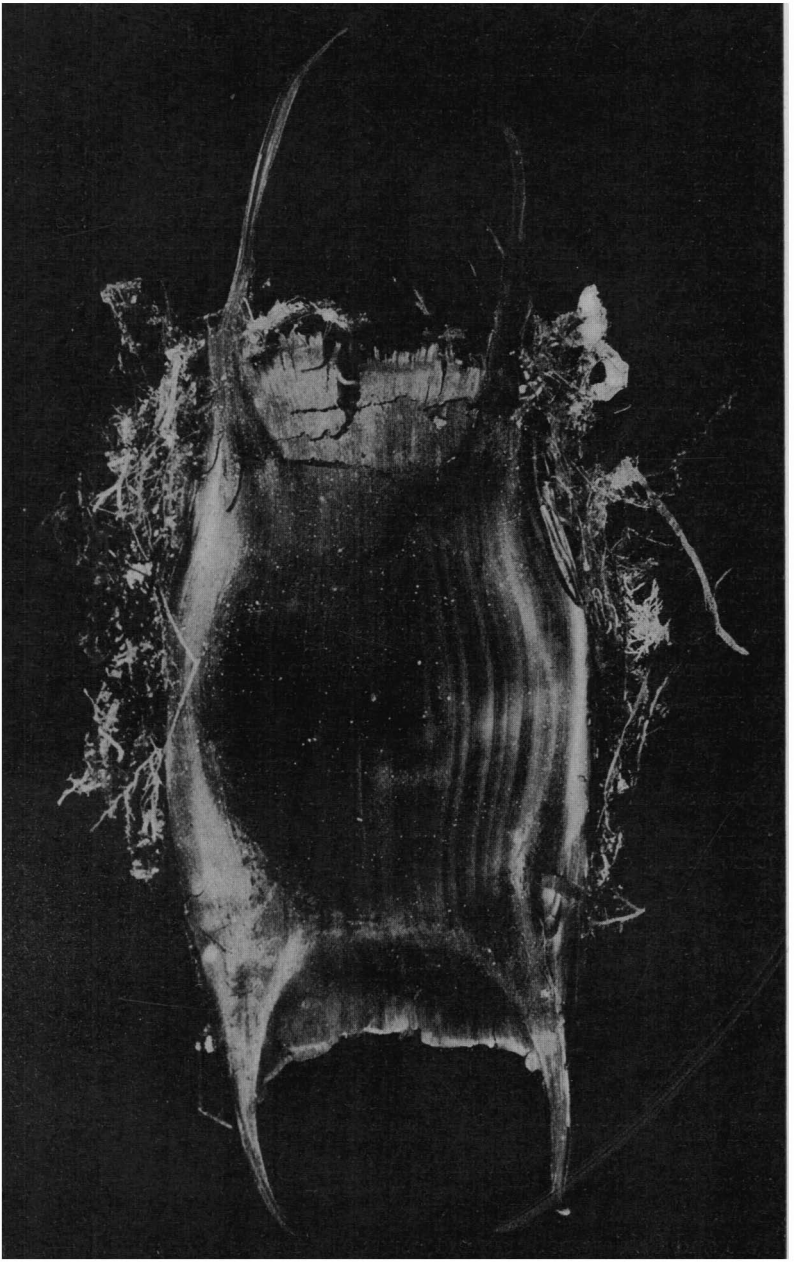

*Photo. R.S.C.*

FIG. 8.—EGG-CAPSULE OF RAIA BRACHYURA Lafont.
Length (without horns) 121 mm. Width (without attachments) 79 mm.

RAIA BRACHYURA Lafont.

syn. *R. blanda* Holt and Calderwood.

Common Name.—Blonde.

EGG-CAPSULE (Fig. 8).

The empty egg-capsule, here figured, was secured by Otter Trawl on the Inner Eddystone grounds on 20th December, 1921. It shows conclusively the use of the felty mass of fibres attached to the margins and all over the more convex side, which are firmly entwined round a mass of debris, including small empty mollusc shells and seaweeds, encrusted with Polyzoa. The weathering process is very apparent at the long horn end, where the embryo had escaped. The long horns are broken and have lost the short filamentous tip. Capsules from which embryos have hatched are very brittle and easily broken. They are evidently adapted, as Dean has remarked for Chimæra, to withstand wear and tear and the chemical action of sea water, and their life corresponds with the duration of the embryo's period of incubation. Reference has already been made to Rays burying their eggs on deposition. They are seldom taken n trawls, and only occasionally in dredges on rougher grounds. It is significant also to record that nearly all the eggs secured at Plymouth have been taken from Rays which were caught by long lining or hand-lining on rough ground. Some fish were also secured in Ray nets, which were worked on rocky bottom.

An egg-capsule of this species, containing a living embryo, was dredged on the New Grounds in Plymouth Sound from a depth of five fathoms on December 12th, 1911. The attachment threads had picked up the following material, which was undoubtedly a mass of debris, and had become firmly entangled round it.

| | | |
|---|---|---|
| Algæ. | Fucoideæ | Fucus serratus. |
| | Florideæ | Rhodymenia palmata with encrustation of the Polyzoan, Membranipora pilosa. |
| | | Gigartina stellata. |
| | | Nitophyllum sp. |
| | | Delesseria sanguinea. |
| | | Dasya coccinea. |
| Hydroids | | Eudendrium ramosum (stalks). |
| | | Antennularia (stumps). |
| | | Halecium ,, |

Holt and Calderwood figure a capsule of *Raia blanda*, 136 by 76 mm., which is identical, except that the attachment fibres are not shown.

The average of 177 capsules gave a length of 128·4 mm. without horns, and a greatest width of 78·5 mm.

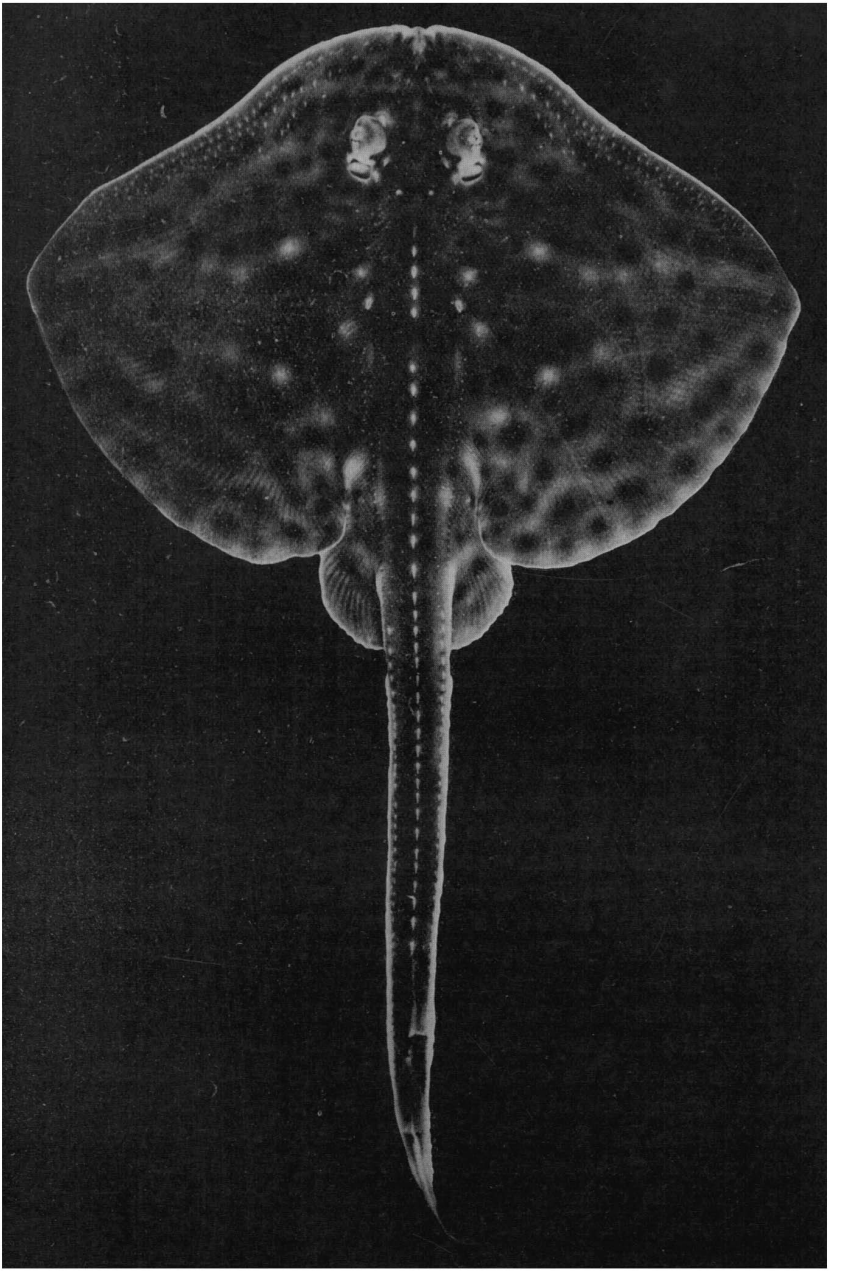

*Photo. R.S.C.*

FIG. 9.—RAIA BRACHYURA Lafont

Newly hatched. Sex ♂. Period of incubation 218 days. Total Length 187·5 mm. Width of disc 115·5 mm.

## Post-embryonic Stages.

### Stage 1 (Fig. 9).

The following table gives a few measurements in millimetres at fixed dates on the same fish which hatched out on 3rd February, 1922, after an incubation period since July 1st, 1921, and after having been kept alive till 20th March, 1922. The fish is shown in Fig. 9 immediately after hatching.

Table of Measurements showing Absorption of the Caudal Tip.

| | 4 Feb., '22. | 26 Feb., '22. | 22 Mar., '22. |
|---|---|---|---|
| Total length . . . . | 187·5 | 188·5 | 186 |
| Width of disc . . . | 115·5 | 123 | 122·5 |
| Tail . . . . . | 103 | 94 | 93 |
| Snout to tip of ventrals . . | 95 | 102 | 90·5 |
| 2nd dorsal to tip of caudal . | 22 | 13·5 | 14 |

The February measurements may not be too reliable as they were taken on the live fish, but they are near enough for general use. The March measurement was taken two days after the fish had been killed and preserved. The inconsistency in the last measurements may also be due to regressive development, due to lack of feeding and artificial conditions.

The embryonic characters are well shown in the backward position of the tip of the snout and the elongated caudal. The spines and spinules, as in all those newly hatched specimens, are for the most part through the epidermis. Spinulation is quite characteristic and shows very little difference from that which occurs in the smaller species, *Raia maculata*. The border of asperities extends further out to the angle than in the latter species, and there are always three or more median spines in front of the shoulder. In *R. maculata* there are two only. In the fish here figured, there are thirty-six median spines, with a short blank space behind the shoulder, arranged as follows: three in front of and two on the shoulder medianly and one on each side: thirty to the first dorsal and one between the dorsals. A single series of less prominent spines appears on each side of the tail. There are two præ-orbital and two post-orbital spines, but the interorbit is bare. A few spines are present along each margin of the rostrum. The body and tail are otherwise entirely smooth. The colour is a rich fawn with numerous black irregularly shaped spots, which extend right to the margin of the disc. A few oval or circular cream spots occur on the disc, generally near the middle of the body. They have no definite marginal outline, but blend imper-

ceptibly with the ground colour. There is a narrow white border line round the disc, and a soft white keeled expansion on each side of the tail, extending longitudinally from near the tip of the ventrals to a point just behind the second dorsal fin. The tip of the tail in these early stages is generally reabsorbed to this point.

The arrangement of the mucous canals is well shown in the figure, where the ends appear as white dots. A pair of endolymphatics occurs as short open tubes in front of the first median spine. They are shown as white dots. The lower surface is entirely smooth and is white except for the usual marginal band round the angle and posterior disc and pelvics.

### Stage 2 (Fig. 10).

A few measurements are recorded for this fish, which was kept alive from 21st December, 1921, the date of hatching, to 21st February, 1922. The period of incubation was ca. 7 months. The external yolk sac after the embryo hatched out had a diameter of 6 mm., but very little yolk was left. The internal yolk sac could be seen through the skin and occupied most of the body cavity. In the majority of cases, the external yolk sac is reduced to the size of a pin's head at the time of hatching, but occasionally it was found a few millimetres in diameter. In the above fish the spasmodic movement of the long caudal end was observed at intervals, after the fish had left the egg-capsule.

Measurements in mm. of the same fish at regular intervals.

| Date of measurements | 24.12.21. | 22.1.22. | 5.2.22. | 21.2.22 |
|---|---|---|---|---|
| Total length | 175 | 181 | 184 | 187 |
| Width of disc | 100 | 116 | 122 | 122 |
| Length of disc | — | 88 | — | — |
| Tail | — | 92 | — | 95 |
| 2nd dorsal to tip of tail | 22·5 | 14 | 13 | 12·5 |
| Snout to tip of ventrals | — | 98 | 101 | 102 |

Growth appeared to be about normal. The reduction in the distance from the base of the second dorsal to tip of caudal is very pronounced. This is shown clearly in the figure. The table proves, if another were needed, that the tip of the caudal is absorbed. It confirms Jensen's opinion that the embryonic tail end behind the horizontal skin fold at each side of the tail is the part that is reduced. This is one of the most interesting features in the present investigation, and has occurred definitely in all the species which have so far been examined. Another post-embryonic change occurs in the snout region. The newly hatched fish, vide Fig. 9, shows the tip of the snout a little behind the anterior margin

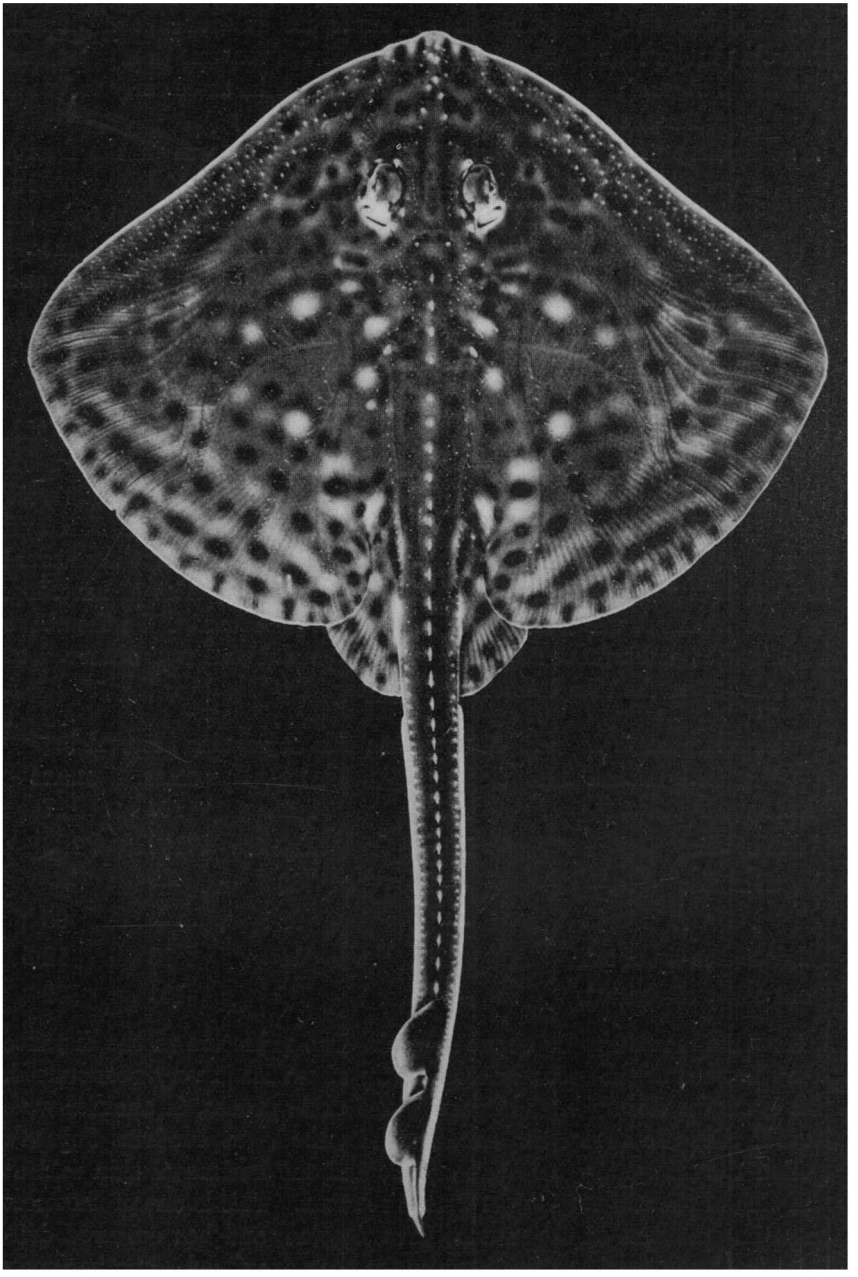

*Photo. R.S.C.*

FIG. 10.—RAIA BRACHYURA Lafont.
Age, after hatching, 2 months. Reared in Laboratory Tank. Sex ♀. Total Length 187 mm. Width of Disc 122 mm.

of the disc in a small gap, but, with growth, the snout soon projects beyond the disc and assumes the adult shape. The teeth are the last to assume the adult condition, the median series being the first to show change. Internally, the embryonic structures show a rapid change. At first the internal yolk sac is very large, but is quickly absorbed with the functioning of the stomach. Young specimens have been examined with the internal yolk sac still persisting, though much reduced, and with the stomach full of small Crustacea—Amphipods and Crangonids. With the reduction of the internal yolk sac, which communicates directly with the top of the spiral valve, the latter gradually assumes the normal position on the right-hand side of the fish. The life of those Rays which were hatched and reared in the Laboratory tanks averaged from two to seven months, the older fish surviving with additional food. The difficulty has been not so much to get the required food, but to get the fish to feed under artificial conditions.

Measurements in mm. of the fish reproduced in Fig. 10.

| | |
|---|---|
| Total length | 187 |
| Length of disc | 93 |
| Width of disc | 122 |
| Snout | 21·5 |
| Interorbit | 8 |
| Snout to tip of ventrals | 102 |
| Snout to vent | 74·5 |
| Length of vent | 4·5 |
| Præoral | 25 |
| Internasal | 12 |
| Prænasal | 17·5 |
| Width of mouth | 14·5 |
| Teeth in upper jaw | ca. 60 |
| 2nd dorsal to tip of tail | 12·5 |
| Tail | 95 |

Teeth irregularly placed, flat, and embryonic.

Fig. 10 requires little by way of description. The characters are similar to those of the newly hatched fish, with the exceptions already noted. The general scheme of spinulation is the same, variation occurring in the number of median spines which are here 33. In the newly hatched stage of the same fish the spine between the dorsal fins was absent. In 22 fish, early stages with width of disc ranging from 117 to 179 mm.,

the total number of median spines ranged from 30 to 36. There were never less than 3 in front of the shoulder, while between the dorsals the range was 0 to 3. In slightly larger fish the spines immediately behind the shoulder are the first to disappear.

The ground colour of the upper surface approximates to Klinksieck

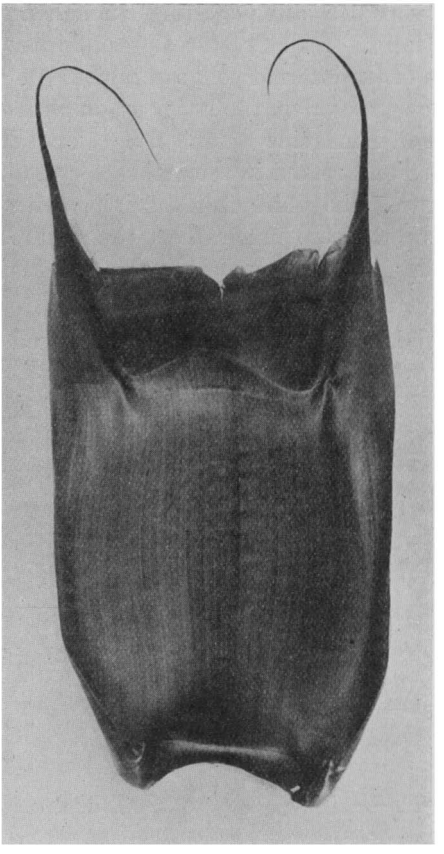

*Photo. R.S.C.*

FIG. 11.—EGG-CAPSULE OF RAIA MICROCELLATA Montagu.
Length (without horns) 93 mm. Width (greatest) 56 mm.

and Valette, Code Nos. 134 and 135. The disc is covered with black spots, while there are a few lighter spots near the middle of the body. The upper surface is quite smooth, except for the spinules on rostrum and anterior margin of disc, the median spines on the body and tail, the marginal row on the tail, two præ-orbital and two post-orbital spines, and one small inner orbital. The horizontal skin fold on the margin of the tail is very pronounced, and is white in colour.

### Raia microcellata Montagu.

Common Name.—Small-eyed Ray.

#### Egg-capsule (Fig. 11).

The capsules of this species are smooth and without attachment filaments. One side is considerably more convex than the other, the more convex side being the dorsal in relation to the adult fish. Both sets of horns tend to curve away from the dorsal side of the capsule, and give the egg the appearance of curving longitudinally. The long horns are elongated into thin tubes, while the others are very short and strongly hooked. The widest part of the capsule is across the base of the long horns. The hooks in the short horns may probably serve as anchors. The lateral margin of the shell is produced horizontally into a keeled flange. The average sizes of fifteen capsules were 90·8 mm. in length along the median line and 57·2 mm. in greatest width. Slits are present on the outer edge of the long horns, near the base of the exposed part where the lateral keel shows as a spur. They open alternately, one towards the dorsal side, the other towards the ventral aspect of the capsule. The slits in the short horns are more median in position and open longitudinally for almost their whole length, one on each face of the shell. The ventral opening on the long horn coincides with the ventral opening on the short horn.

#### Post-embryonic Stages.

##### Stage 2 (Fig. 12).

The stage figured (Fig. 12) corresponds to Stage 2 of the general scheme adopted in the present report. The patchy effect of the figure is due to the post-mortem sloughing of mucus, which carried the pigment with it when an attempt was made to clear the fish. Unfortunately, it was the only available example of this species. It was first observed on 31st January, 1922, in a tank, where there were also several newly hatched young of *Raia clavata*, but it had obviously been hatched for some time. As proof of this, one may instance the shortening of the caudal tip, the advanced development of the spinulation and the disappearance of the internal yolk sac. The period from the date of placing the egg-capsule under circulation to the date of observation amounted to eight months, so that one may assume the period of incubation for this embryo to be about seven months.

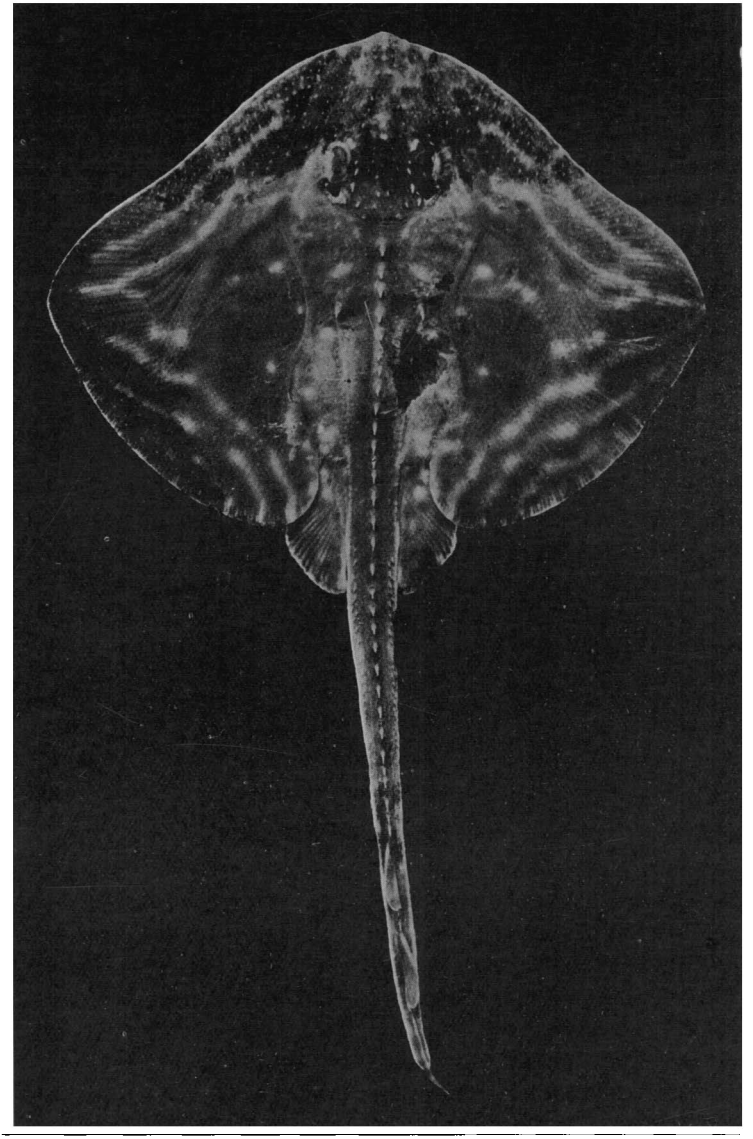

*Photo. R.S.C.*

FIG. 12.—RAIA MICROCELLATA Montagu.
A few weeks after hatching. Reared in Laboratory Tank. Sex ♀. Total Length 144 mm. Width of Disc 86 mm.

Fig. 12. Stage 2. Measurements in mm.

| | |
|---|---|
| Total length | 144 |
| Length of disc | 66 |
| Width of disc | 86 |
| Snout | 16 |
| Interorbit | 7 |
| Snout to tip of ventrals | 75 |
| Snout to vent | 57 |
| Tail | 75 |
| 2nd dorsal to tip of tail | 13·5 |
| Præoral | 18·5 |
| Internasal | 10·5 |
| Prænasal | 14 |
| Width of mouth | 12 |
| Teeth in rows in upper jaw | ca. 42 |

The spinulation of the upper surface is much the same as occurs in *Raia brachyura*, except that there is a definite and prominent triangular patch of densely packed spinulæ across the snout and anterior region of the pectorals, including the interorbit. The base of the triangle may be taken as a line drawn across the eyes and extending outwards to the margins of the disc at right angles to the main longitudinal axis of the fish. There are thirty-three median spines on the body and tail, of which three are in front of the shoulder and two between the dorsals. There are two præ-, three post-, and two inner orbital spines, and one on each side of the shoulder. The tail is furnished with a lateral row of smaller spines, which is irregularly double on the proximal half of its length.

The colour of the upper surface approximates to Klinksieck and Valette, Code Nos. 130, 135, with a few white spots and long narrow white bands which follow the outlines of the disc, both anteriorly and posteriorly. The tail has a narrow, white, longitudinal keel.

The lower surface is entirely smooth and white except for a margin of grey round the angle and the posterior border of the disc and ventrals.

RAIA NÆVUS Müller und Henle.

Common Name.—Cuckoo Ray.

EGG-CAPSULE (FIG. 13).

The egg-capsule of this species has been figured by Holt and Calderwood as *Raia circularis* (Günther). It is definitely the egg of the Cuckoo Ray. The capsule is relatively very small, and so far as can be gathered from

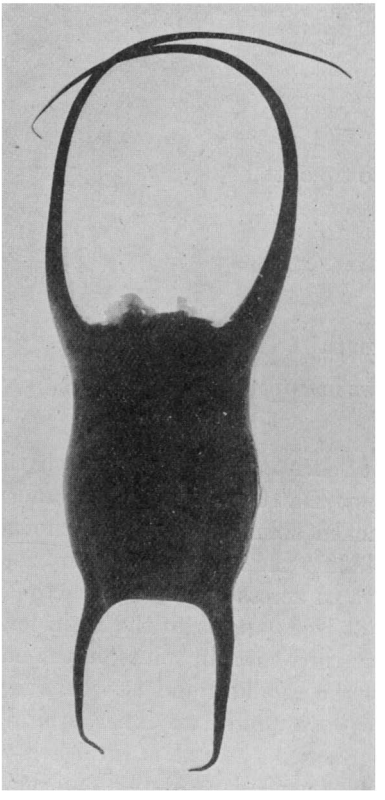

*Photo. R.S.C.*

FIG. 13.—EGG-CAPSULE OF RAIA NÆVUS M. und H.
Length (without horns) 60·5 mm. Width (greatest) 36 mm.

the number examined, is devoid of any loose threads. The shell is more or less transparent and a convenient one in which to watch the development of the embryo, though the whole structure is delicate and requires careful handling. Both sides of the capsule are convex, the short horns projecting outwards from one side, the ventral in relation to the adult

fish, and the long horns tending towards the opposite direction. The short horns have their tips curled almost in hook fashion, while the long horns nearly always cross one another. The slits occur on the outer margins near the tip of each horn, generally where the tube bends. The slits on the short horns are on the ventral side of the capsule. The end between the short horns is tightly closed and almost concave, but the long horn end is convex and easily opened. This is the end from which the embryo escapes on hatching.

The average sizes of twenty-eight egg-capsules were 63·4 mm. in length and 36·8 in breadth.

## Post-embryonic Stages.

### Stage 1 (Fig. 14).

The period of incubation for a single record was 243 days. The following observations were made on the developing embryo. The egg was taken from the cloaca of an adult fish on 5th June, 1920, and placed in a tank under circulation in the Laboratory. It was suspended from a glass rod at the crossing of the long horns. The outer surface of the capsule retained its fresh glossy appearance throughout development, showing only a darkening in colour from a yellowish brown to a dark reddish brown. The yolk lay at the short horn end of the inner cavity, while the embryo, as it developed, became suspended above the yolk sac near the long horn end. The external branchial filaments developed from five gill arches, being absent from the spiracular cleft. They increased in length enormously and seemed to hang in close contact with the yolk sac. As development proceeded, the embryo lay suspended by its yolk stalk, head downwards diagonally across the cavity towards the yolk sac, while the tail end moved freely upwards towards the base of one of the long horns. The movement was lateral and rhythmic along the whole length of the embryo, but more apparent in the tail region, whose length was considerable. As the embryo increased in length, the elongated caudal region entered the base of the long horn and continued its rhythmic movement. At this period the slits were found to be open and not obstructed by albumen, as on lifting the capsule out of the water the internal fluid was seen to drain off from the slits at the tips of the horns. There seems no doubt that the phenomenon observed was an adaptation to secure aeration of the egg. As this happened to be the only successful attempt to rear the embryo of this species, the capsule was not disturbed, as it was thought equally important to hatch out the fish to secure the definite characters of this species for systematic purposes. A capsule, however, of *Raia clavata*, with a well-developed embryo, was placed in a dish of water and treated experimentally with powdered carmine grains.

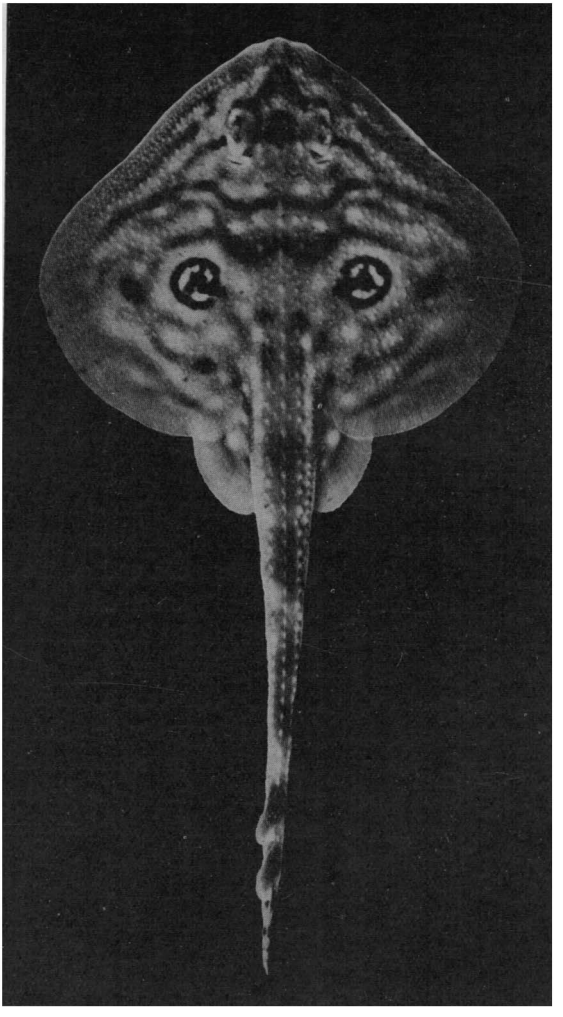

*Photo. R.S.C.*

FIG. 14.—RAIA NÆVUS M. und H.
Newly hatched. Sex ♂. Period of incubation 243 days.
Total Length 119 mm. Width of Disc 62 mm.

A definite current was found to move away from one of the long horns, but no other movement was visible. After a few minutes, the capsule was opened and carmine grains were found on the spiracle, on the inner lining of the shell cavity, and were also forcibly ejected from the gill clefts. Observations were interrupted in September, October, and part of November, but were continued at the end of the last month. The embryo had now assumed the definite form of a Ray, with broad flat pectorals. As these increased in size and became too large for the narrow cavity, the outer angles of the pectorals curled over on the dorsal side of the embryo, while the tail was stowed away round the left side of the embryo and with its tip towards the long horn end. The embryo thus became definitely oriented with the snout pointing diagonally towards the long horn end. The external yolk sac was greatly reduced. Pigment was gradually acquired on the dorsal side, and the ocelli could be seen as rings of black dots near the middle of the disc. The egg case showed signs of weathering between the long horns and to a small extent along the sides. Pigmentation was well developed before the embryo hatched out on 3rd February, 1921. Immediately after hatching, the external yolk sac was reduced to the size of a pin head, but the abdominal region was greatly distended by the internal yolk. The points of the larger median spines had penetrated the skin, but the tips of the spinulæ were just beginning to show through. This explains to some extent the poor definition of the photograph.

Fig. 14 shows the characteristic scheme of pigmentation. The general ground colour is light fawn with bands of sepia. There are also a few lighter coloured patches and some smaller oval to circular spots. A large ocellus, in the form almost of a simple spiral, occurs near the middle of each pectoral. The outer ring and the core are dark brown to black, while the intervening space is cream coloured.

The upper surface is entirely spinulose, with the median series of spines on the body and tail prominent. There are thirty-three median spines, of which three are in front of the scapula. A lateral row of less prominent spines extends from the shoulder to the dorsal fins, and is supplemented on the tail proximally for part of its length by another series. There is a triangular patch of spines in front of the shoulder with the apex of the triangle pointing anteriorly. The dorsal fins are almost confluent.

### Stage 2 (Fig. 15).

The newly hatched embryo, Fig. 14, was kept alive for three months, and the following measurements were taken, at intervals, the last on 8th May, 1921, after the fish had been a short time in preservative :—

Measurements in millimetres.

| | 4 Feb., '21. | 7 Mar., '21. | 10 April, '21. | 8 May, '21. |
|---|---|---|---|---|
| Total length . . | 119 | 125 | 125 | 122·5 |
| Length of disc . . | 50 | 58 | — | 58·5 |
| Width of disc . . | 62 | 65 | 67 | 66 |
| Snout . . . | 8 | — | — | 12 |
| Interorbit . . | 5 | — | — | 5 |
| Snout to tip of ventrals | 59 | 66 | — | 66·5 |
| Snout to vent . . | — | — | — | 50 |
| Tail . . . . | 64·5 | 63 | — | 62 |
| 2nd dorsal to tip of tail | 13 | 9 | 7 | 4·5 |
| Præoral . . . | — | — | — | 19 |
| Internasal . . | — | — | — | 9 |
| Prænasal . . . | — | — | — | 12 |
| Width of mouth. . | — | — | — | 9 |
| Teeth in rows in upper jaw . . | — | — | — | ca. 44 |

Growth was maintained probably entirely at the expense of the internal yolk sac for about two months, as the fish was not observed to feed. The shrinkage of the caudal area is well seen in the above measurements.

The upper surface is entirely spinulose, except for a narrow margin on the posterior edge of the disc and pelvics. There are thirty-four median spines on the body and tail, but none between the dorsals, which are practically confluent. A single small spine is present on each side opposite the meeting of the dorsals. A triangular patch of large spines occurs on the shoulder, which includes three medium spines in front of and one on the shoulder, and two on each side. The first spine behind the shoulder is minute. The median series of spines on the body and tail is very prominent, but later, as the fish reaches maturity, these spines entirely disappear and the lateral series becomes more pronounced. A row of spines extends along each side of the median series on the body and tail. On the proximal half of the tail, there is an additional outer row. A ring of spines is present on the inner orbit. All the large spines are hooked.

The colour of the upper surface approximates to Klinksieck and Valette, Code No. 574, with narrow transverse bands of a dark brown colour on the snout, disc, and tail. There are also a few whitish spots on the disc, but these have no definite outline. The colour of the fish

was lost in preservative, and is not fully represented in the figure. A prominent marbled ocellus, dark brown to black and creamy white, occurs on each wing.

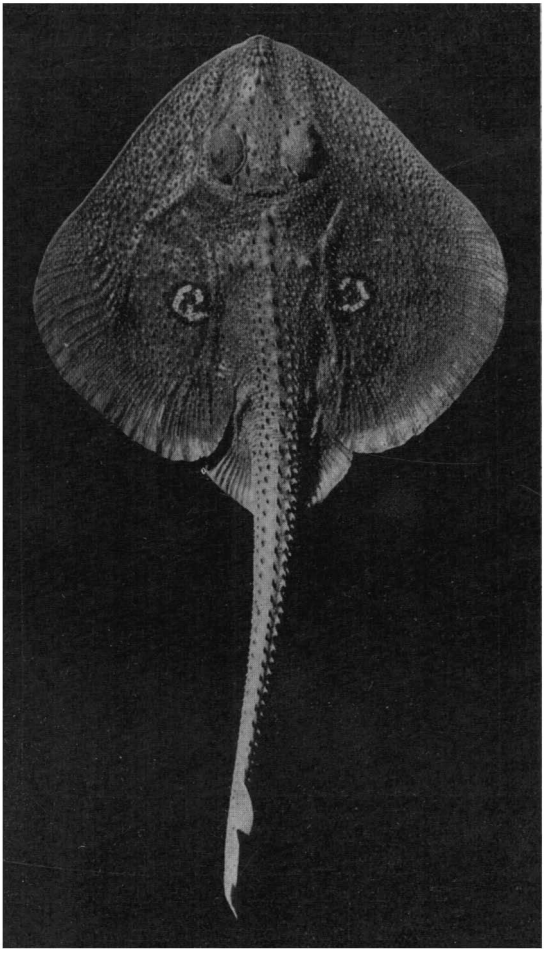

*Photo. R.S.C.*

FIG. 15.—RAIA NÆVUS M. und H.
Age, after hatching, ca. 3 months. Reared in Laboratory Tank.
Total Length 122·5 mm. Width of Disc 66 mm.

The lower surface is entirely smooth and white. A narrow greyish margin is present on the outer angle and along the posterior border of the disc and ventrals. There are a few grey patches on the tail.

## Raia fyllæ Lütken.

### Post-embryonic Stages.

### Stage A (Fig. 16).

Three small specimens of this rare deep-water species were kindly lent to the writer by Dr. A. Bowman. Two of these are very small, but they have distinct post-embryonic characters, which prove that they had been hatched out for some time. The external yolk sac had entirely disappeared, there was no trace of an internal yolk sac, the spiral valve was in its normal position on the right side of the fish, and the stomach

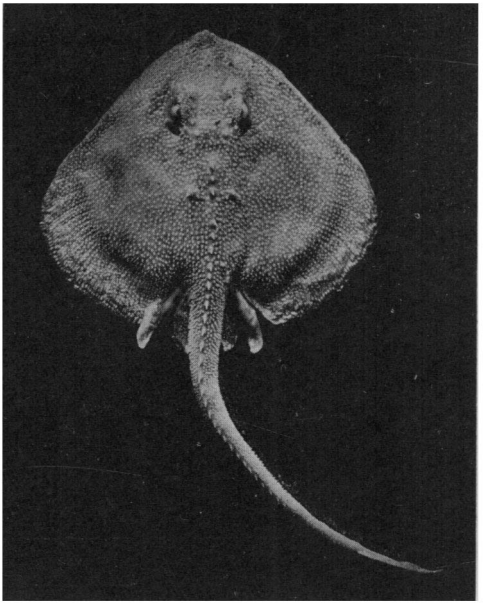

*Photo. R.S.C.*

Fig. 16.—Raia fyllæ Lütken.
Sex ♀. Total Length 80 mm. Width of Disc 40·5 mm.

contained small crustacean food—Copepods, Amphipods, and Schizopods. They are the smallest post-embryonic Rays which the writer has seen, smaller even than the diminutive Starry Ray, *Raia radiata*. The egg case, or its cavity, at least, must be of very small size.

There is a suggestive resemblance in the shape of these young fish to the young of *Raia nævus*. From Lütken's descriptions of *Raia fyllæ* adult No. 1 and young No. 2, the writer has provisionally ascribed the present series to the same species.*

* Pigmentation and spinulation strongly suggest a specific difference between Stages A and B, but more material is necessary for verification.

The two smallest fish are very thin and delicate, especially round the margin of the disc. On the anterior margin of the disc near the snout there is a tendency, in these preserved specimens, for the skin to curl ventrally, and thus to give the figure a slightly sharper appearance than it really has. There is distinct sinuation, as Lütken has remarked, though no definite notch. Lütken, it is presumed, had in his mind the deep sharp notch of the adult, of which he gives, in the same report, an excellent figure of a mature male. Maturity in this species is reached at a very small size. The measurements of the two smaller fish are given here in millimetres. One was a female, the other a male. Both were captured with a small trawl on 23rd August, 1910, at a depth of 1448 metres in Latitude 58° 43′ N. and Longitude 9° 6′ W.

| | Sex ♀ | Sex ♂ |
|---|---|---|
| Total length | 80 | 72·5 |
| Length of disc | 34·5 | 32·5 |
| Width of disc | 40·5 | 39·5 |
| Snout | 8 | 7 |
| Interorbit | 4·5 | 4 |
| Eye | 4 | 4 |
| Eye+spiracle | 5 | 5 |
| Snout to tip of ventrals | 38·5 | 34 |
| Snout to vent | 30·5 | 27·5 |
| Tail | 44·5 | 40·5 |
| 2nd dorsal to tip of tail | ca. 3·5 | ca. 4 |
| Præoral | 9·75 | 8·5 |
| Internasal | 5·75 | 5·5 |
| Prænasal | 7 | 6·5 |
| Width of mouth | 6 | 6 |
| No. of median spines | 35 | 37 |

Fig. 16 represents the larger of the two specimens, which is a female. The upper surface is entirely spinulose, the spinulæ having a very sharp delicate point. Larger spines stand out prominently on the orbit, scapula, and median line of the body and tail to the first dorsal. The dorsal fins are practically confluent and are small and delicate structures. There are two præ- and three post-orbital spines, one to three spines on each side of the shoulder, two in front and one on the shoulder. The anterior lobe of the pelvics is long.

Colour of upper surface is uniform (in formalin), and approximates to Klinksieck and Valette, Code No. 128 C. Lower surface a dirty white.

The lower surface is smooth except the margins of the tail, which are spinulose for most of the length.

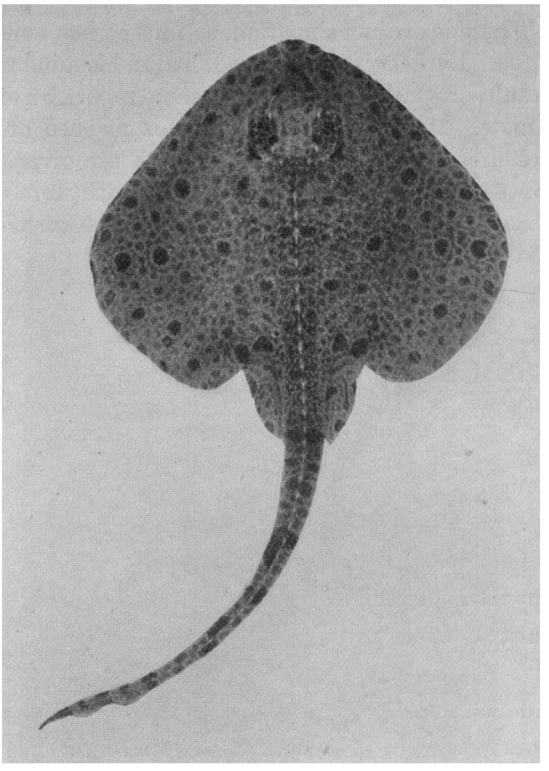

*Photo. R.S.C.*

FIG. 17.—RAIA FYLLÆ Lütken.
Sex ♀. Total Length 104·5 mm. Width of Disc 53 mm.

## STAGE B (FIG. 17).

The third specimen, a female, is represented in Fig. 17. It was captured by small trawl at Scottish Station 13 A, on 9th July, 1913, at a depth of 630 metres. It is obviously much older. The following are the measurements in millimetres :—

| | |
|---|---|
| Total length | 104·5 |
| Length of disc | 44·5 |
| Width of disc | 53 |
| Snout | 9·5 |
| Interorbit | 4·5 |

| | |
|---|---|
| Eye | 5 |
| Eye+spiracle | 6 |
| Snout to tip of ventrals | 52 |
| Tail | 57 |
| 2nd dorsal to tip of tail | 4 |
| Præoral | 12 |
| Internasal | 7 |
| Prænasal | 9 |
| Width of mouth | 7·25 |
| Teeth in rows in upper jaw | ca. 26 |
| No. of median spines | 34 |

The general ground colour, in formalin, corresponds to Klinksieck and Valette, Code Nos. 133 and 138, while the round or oval spots are darker brown and correspond to Code No. 143. The larger oval spots have a distinct halo of lighter colour round them. The whole of the upper surface except a narrow margin on the posterior edges of the disc and ventrals is covered with spinulæ, which have a very sharp point. There are two præ- and three post-orbital spines and one inner orbital. Of the thirty-four median body and tail spines, two are in front of and one on the shoulder. A group of three spines is present on each side of the shoulder. There are no spines between the dorsals, which are closely set. The rows of spinulæ on the sides of the tail are beginning to enlarge, the outer row being the largest. All the spines are hooked, and the median series most prominent.

The lower surface is of uniform dirty white colour and is smooth, except for a few spinulæ on the margins of the tail near its base.

### Raia undulata Lacépède.

Syn. *R. picta* Lacépède.

Common Name.—Painted Ray (non Couch).

#### Egg-capsule (Fig. 18).

The capsule of this species is very similar to that of *Raia maculata*, but is much larger and more robust. The filamentous attachments are well shown in Fig. 18. They arise from a horizontal flattened keel at the margin of the shell. The capsule is convex on both sides and there is little difference in the degree of convexity. However, one side is definitely smoother than the other, which is covered with a close felty mass of loose fibres. At both ends of the median line of the capsule these fibres are set more loosely and more thickly. Each of the horns

bears a longitudinal slit. It is present nearer the tip of each horn, occurring on the outer side near the bend of the long horns and near the middle of the short horns on the same face as the smooth surface of the capsule. Only two capsules have come under observation at Plymouth.

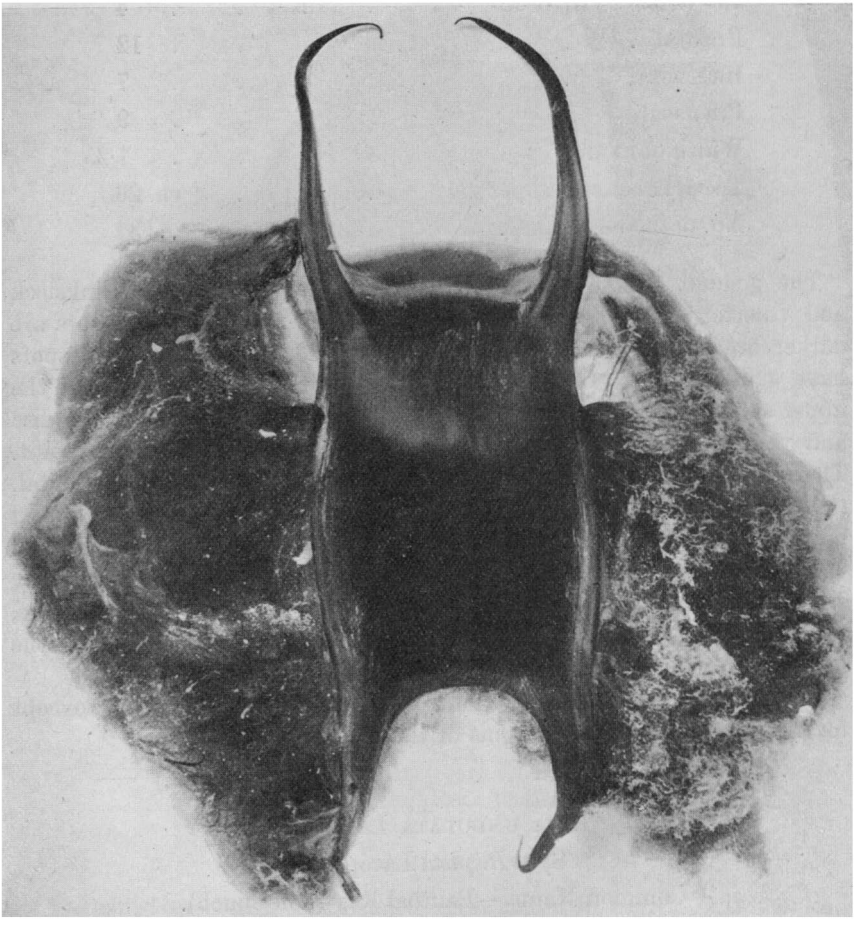

*Photo. R.S.C.*

FIG. 18.—EGG-CAPSULE OF RAIA UNDULATA Lacép.
Length (without horns) 81 mm. Width (without attachment filaments) 52 mm.

The species is not uncommon in the outer fishing-grounds of the Channel, and these capsules were secured on 15th July, 1920. The average sizes of these two capsules were 81·5 mm. in length (without horns), and 52 mm. in breadth (greatest). The size of this capsule agrees closely with that for Mediterranean specimens, for which Lo Bianco gives 90 mm. by 45 mm.

## RAIA BATIS Linnæus.

Common Names.—Skate, Blue Skate, Grey Skate.

### EGG-CAPSULE (FIG. 19).

Fig. 19 represents a capsule which was sent, with five others, to the writer by Mr. B. Storrow, of the Cullercoats Marine Laboratory. These were secured from the adult fish on North Shields fish quay on 18th February, 1922, and were kept in the Laboratory tanks for more than a week, when they were despatched to Plymouth and arrived on 4th March, 1922. Five of these eggs did not develop, but the sixth, represented in the above figure, was opened on 25th May, 1922, and showed a well-developed embryo with a length of 39·5 mm. The branchial filaments were well developed, being longer than the head, and showed the red blood circulation streaming round the loop of the filaments. Albumen still closed up the capsule, but a watery liquid surrounded the yolk and embryo in the central cavity. No trace of slits could be found on the horns, but the hollow tube could be traced out to the tip, with a delicate thin membrane on the upper and lower face of the horn, through which the albumen penetrated with a little pressure. It seems suggestive that this membrane slits at a later period in the age of the capsule. Beard described the slits as occurring at the extremity of the horns on the inner side. Along each side of the capsule the outermost layer of the shell projects horizontally, showing a central longitudinal furrow. Near the base of the long horns a patch of very long attachment filaments arises. These become twisted in rope fashion for most of their length, and end in an expanded mass of very fine filaments. The weight of this wet knotted end when lifted out of water is considerable, and it has the property of fastening on to any solid object.

The average sizes of these six capsules were length 159 mm. along the median line, without the horns, and greatest width 80·5 mm. The averages of two Plymouth specimens were 143·5 mm. in length and 81 mm. in width. The length of the attachment filaments in these last two specimens was about 200 mm. The tips of all the horns end as very thin delicate filaments, and are easily broken off. The capsule is biconvex and thicker towards the short horn end. The whole of the shell is covered with a felty mass of tightly packed fibres. Strengthening is given to the margins by a solid inner rod, triangular in cross section, running longitudinally along each margin of the shell. The walls of the capsule are formed of several layers, most of which are membranous, except the outermost, where the fibres are more loose. All the layers have definite longitudinal striation.

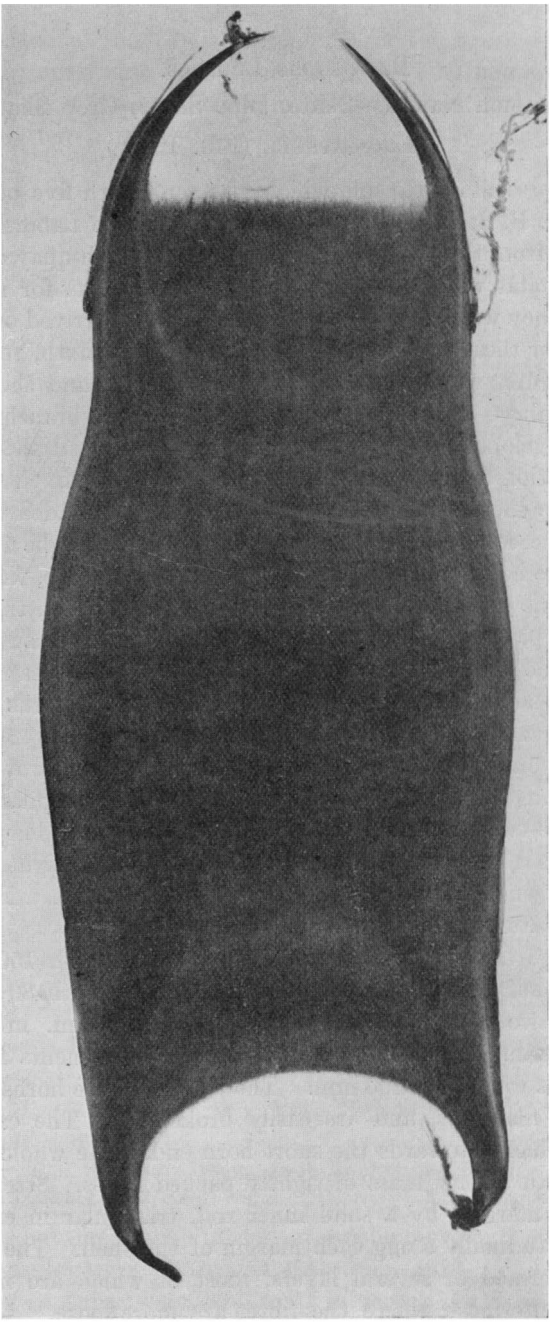

*Photo. R.S.C.*

FIG. 19.—EGG-CAPSULE OF RAIA BATIS L.
Length (without horns) 163 mm. Width (greatest) 82 mm.

## Young Stages.

No early post-embryonic stages have been hatched at Plymouth, but the following description is based upon sixteen young stages, ranging in width of disc from 219 to 394 mm. These were caught by trawl in the immediate neighbourhood of Plymouth.

Disc broader than long. The ratio, width to length of disc averaged 1·31, with a range from 1·26 to 1·39. Anterior margins of disc emarginate, with very slight undulation. Outer angles rounded. Snout blunt and obtusely rounded, its length 4·06 in width of disc (range 3·85 to 4·42). Interorbital width 3·8 in length of snout (range 3·42 to 4·29). Internasal width 2·28 in præoral length. Teeth close set, flat, broader than long, with short obtusely pointed posterior cusp. Forty-five to fifty-four rows in upper jaw.

Upper surface smooth. One præorbital spine, sometimes 2, 0–2 postorbital spines. No other spines on the body. Tail, beginning at the junction of the pelvics, with thirteen to twenty median spines, of which there may be 0–3 between the dorsals. Only one specimen had marginal tail spines, and these were limited to three on right and three on left side near the dorsals. Colour of upper surface varies considerably in different fish. The general ground colour approximates to a mixture of Code Nos. 65, 120, 154, and 155 (Klinksieck and Valette), with or without oval or circular spots, Code Nos. 153 and 162. A large oval ocellus may or may not be present, but it is very faint in colour and with no prominent margin. It appears generally in fresh specimens as a yellow halo round a light brown centre, but it is by no means a constant feature. The pigment both of upper and lower surfaces has a tendency to rub off very easily. This is even a more pronounced feature in the young of *Raia vomer* Fries, where the dark grey pigment sloughs off with mucus as a greyish black ink.

Black ends of mucous pores show a definite arrangement on the upper surface. They occur as a single line—duplicated at points—along the anterior margin of the snout and disc and for some distance round the angle : scattered dots along the outer edges of the rostrum : a densely packed aggregation just outside the præ-orbit and extending along the junction line of the disc and snout to the anterior edge : a small semicircular area on each side of the shoulder and a few scattered dots along the sides of the median line on to the base of the tail.

Lower surface entirely smooth in the youngest fish ; but later, with a narrow band of spinulæ round the anterior snout and margin of the disc, extending about half-way out to the angle. Colour, K. and V., Code Nos. 69, 120, 474, and 475, with scattered black dots—the ends of the

mucous pores. A broad band round the angle and posterior margins of the disc and ventrals free from black dots. Short black streaks show through the skin. These are the pigmented sections of the ends of the mucous canals.

### RAIA MARGINATA Lacépède.

Syn. *R. alba* Lacépède.

Common Names.—White Skate, Bottlenose Skate, Bordered Ray (young).

#### EGG-CAPSULE (FIG. 20).

Holt has given a description of the capsule of the Bottlenose Ray, but without any illustration. Emphasis was laid on the beaded structure of the capsule as a ready method of identification. This beaded character, however, is a misnomer, except in the newly spawned condition. The surface of the capsule becomes later a honeycombed mass, with the longitudinal ridges and transverse crests as the walls of the pits. This honeycombing disappears on the lateral strengthened keels, which are striated longitudinally. The capsule has one side distinctly more convex, the side which faces the dorsal aspect of the adult fish before extrusion, and with the curling of the horns away from this side, gives the other side a flattened effect at least near the base of the long horns. The slits are present in the middle of the short horns on the more convex side and in the middle of the long horns on the opposite side. They extend along the horns for most of their length. There are no accessory attachment fibres on the capsule, and anchorage, if one may suggest such a thing, may be effected by the strongly hooked short horns. The long horns are ribbon-shaped.

Le Danois gives an outline figure of the same capsule under the name of *Raia batis*. The average sizes for six capsules were length 180·3 mm. along the median line (exclusive of horns), and greatest width 138·6 mm. Four of these eggs were secured on Plymouth fish quay in April and two in June, 1921. It is the largest Skate capsule which has come under observation.

Out of six eggs, one has been reared successfully almost to the hatching stage. It was placed in a Laboratory tank under circulation on 14th April, 1921, the date on which it was taken from the cloaca of the fish on Plymouth fish quay. A small window was cut open on the capsule on 27th February, 1922, to watch the further development of the embryo. At that time the embryo was well developed and had the pectorals and snout united. The head end pointed towards the short horns, and the expanse of the pectorals did not occupy the full width of the cavity. It was then capable of turning round inside the capsule cavity, for at a subsequent date the snout became oriented towards the long horn end.

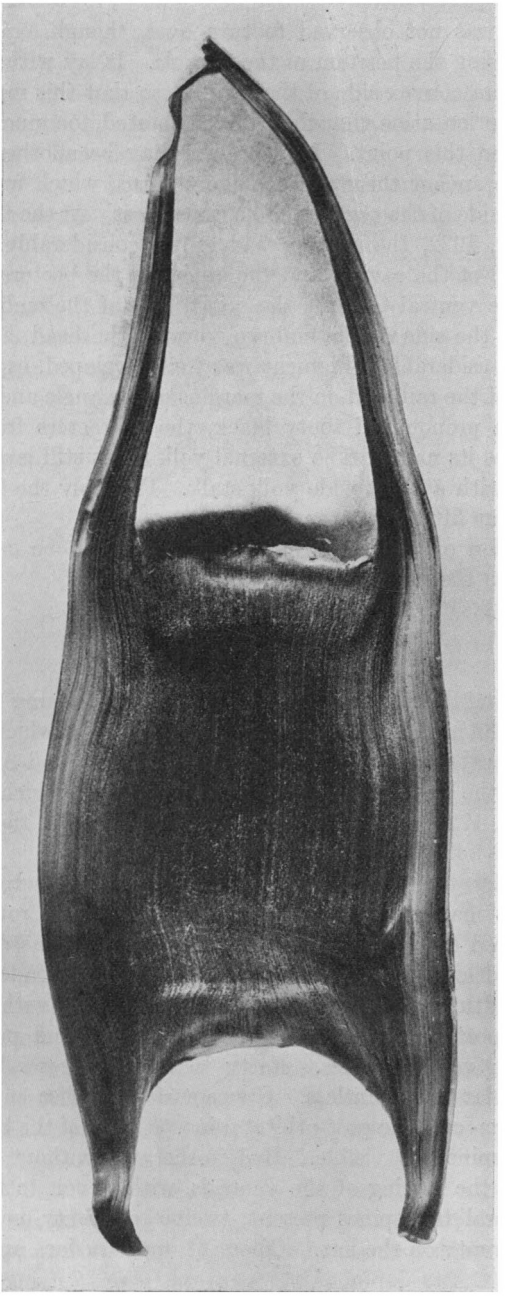

*Photo. R.S.C.*

FIG. 20.—EGG-CAPSULE OF RAIA MARGINATA Lacép.
Length (with horns) ca. 390 mm.; (without horns) 176 mm.
Width (greatest) 131 mm.

The embryo was not observed to turn over, though experiments were tried in reversing the position of the capsule. It lay with its dorsal side facing the more convex side of the capsule, so that this may be assumed as its normal orientation, though, as already stated, too much stress should not be laid on this point. It, however, may be another argument in favour of the anchor theory of the short horns, which would cause the more convex side of the egg case to lie uppermost. At the time of writing, on 25th May, 1922, the embryo had grown considerably. It occupied the full width of the cavity, and the angles of the pectorals were curled over from the ventral towards the dorsal side of the embryo. The tail curled round the side of the embryo towards the head, and the caudal length was considerable. Pigment was well developed, especially on the ventral side of the tail, and on the margins of the angle and posterior disc which were a pronounced sooty black, the characters from which this species derives its name. The external yolk sac is still large, ca. an inch in diameter with a short wide yolk stalk. Probably the full incubation period is about fifteen months.

A description of this fish will be given if it can be carried through successfully to the hatching stage.*

## Young Stages.

The following description is based on a series of young stages ranging from 238 to 389 mm. in width of disc, the youngest of which are probably not many months old. These were taken in March and April, 1921 and 1922, except the smallest, 238 mm. in width of disc, which was captured in November, 1921. All were taken by Otter Trawl in the Outer Eddystone grounds off Plymouth.

Disc broader than long. Its length contained 1·3 to 1·4 times in breadth. Its margin undulated, outer angles slightly rounded. Snout acutely pointed and projecting considerably beyond the disc, its length 4 to 4·3 in width of disc. Interorbital width 3·2 to 3·5 in length of snout. Internasal width 2·1 to 2·2 in præoral length. Teeth with base rounded and with a posterior conical cusp, which is long and pointed. Rows closely set in vertical series. Forty to forty-six rows in upper jaw. Outer series flat and pointless. Upper surface of disc entirely smooth, except one præ- and one post-orbital spine. Traces of the base of another post-orbital spine are visible. Body otherwise without spines. Tail, beginning at the joining of the ventrals, with eleven to fifteen median spines. Lateral tail spines present, twelve to twenty-one on the right and ten to twenty on the left. Colour of upper surface approximates to

* This embryo hatched out on July 6th, 1922. Total length 292 mm., and width of disc 190 mm.

Klinksieck and Valette, Code Nos. 129, 130, 154, with or without oval or round spots of a light colour, Code No. 153 D. No ocellus.

Lower surface with the præoral area strongly spinulose. A narrower margin of spinules along the anterior edge of the disc half-way out to the angle. Body and tail smooth. Colour of lower surface white, with a broad margin of sooty black round the angle, along the posterior edge of the disc, narrower on the ventrals and covering most of the tail.

## FOOD OF THE EARLY YOUNG OF FOUR SPECIES OF RAIA.

| Number of fish examined | 100 | | 50 | | 27 | | 32 | |
|---|---|---|---|---|---|---|---|---|
| Range in width of disc in mm. | 79–119 | | 78–360 | | 117–336 | | 63–254 | |
| Species. | Clavata. | | Maculata. | | Brachyura. | | Nævus. | |
| Stomach contents. | No. in which present. | % | No. in which present. | % | No. in which present. | % | No. in which present. | % |
| Polychæta | 7 | 7 | 11 | 22 | — | — | 8 | 25 |
| Crustacea— | | | | | | | | |
| Amphipod | 69 | *69* | 42 | *84* | 16 | *59* | 16 | *50* |
| Isopod | — | — | 3 | 6 | 1 | 3 | — | — |
| Cumacea | 5 | 5 | 3 | 6 | — | — | — | — |
| Schizopod | 8 | 8 | 3 | 6 | 10 | 37 | 7 | 21 |
| Crangonid | 47 | *47* | 32 | *64* | 17 | *62* | 12 | *37* |
| Nika edulis | 3 | 3 | 3 | 6 | 1 | 3 | 1 | 3 |
| Galathea sp. | 4 | 4 | 3 | 6 | — | — | — | — |
| Upogebia sp. | 4 | 4 | 1 | 2 | — | — | — | — |
| Hippolyte sp. | 1 | 1 | 1 | 2 | 1 | 3 | — | — |
| Pandalus sp. | 1 | 1 | 3 | 6 | — | — | 1 | 3 |
| Portunus sp. | — | — | 4 | 8 | — | — | — | — |
| Mollusca | 1 | 1 | 7 | 14 | — | — | — | — |
| Cephalopoda— | | | | | | | | |
| Sepiola sp. | 2 | 2 | — | — | — | — | — | — |
| Pisces | 2 | 2 | 1 | 2 | 8 | 29 | 9 | 28 |
| Empty | 10 | 10 | — | — | 2 | 7 | 5 | 15 |

The above table shows the predominant types of food of the early young of four species of Rays. It will be seen that Amphipods and Crangonids form a very high percentage in all the species. Examination was also made of a few available stomachs of the following six species: *R. radiata*, *microcellata*, *fyllæ*, *fullonica*, *batis*, and *marginata*, and the results were more or less similar, except that in the Skate species, *R. fullonica*, *batis*, and *marginata*, small fish and the larger crustacean types, Galathea and Portunus, occurred more frequently than in the smaller Ray species. In the youngest stages, where the internal yolk sac still persisted, or had just been absorbed, the food consisted, almost without exception, of small Amphipods and Crangonids, with the occasional occurrence of Isopods, Cumaceans, or Schizopods. As the young fish

increased in size, the food consisted more frequently of the larger Crustacean types and of small fish.

The specific identification of the stomach contents was a matter of considerable difficulty, owing to the immaturity of the specimens and their consequent decomposition. The commonest Amphipods were *Nototropis vedlomensis* (Sp. Bate) (syn. *Ampelisca spinipes* Bœck), which were identified for the writer by Mrs. E. W. Sexton. A large percentage of the specimens was ovigerous. The Crangonids caused considerable trouble, as they were nearly all immature forms. The most frequently occurring species were *Pontophilus spinosus* (Leach), *Crangon vulgaris* Linn., *Philocheras trispinosus* (Hailstone), and *Philocheras sculptus* (Bell). The nomenclature is that of Kemp, in Decapoda Natantia of the coasts of Ireland. The fish belonged to three types, of which the following were easily determined :—

*Gobius jeffreysii* and *G. minutus.*

*Arnoglossus laterna*—post-larval and early bottom forms.

*Callionymus lyra*—young specimens.

## RECORDS OF EGG-CAPSULES IN THE STOMACHS OF OTHER FISH.

Jensen, in his report on the Selachians of Greenland, p. 19, states, under *R. radiata*, that the egg-capsules were frequently taken in the stomachs of other fishes (especially Halibut). Again, on p. 25, a footnote says that some egg-capsules of *R. hyperborea* have been taken from the stomachs of other fishes (Greenland shark) which had swallowed them. These are the only records which the writer has, so far, been able to obtain.

## SUMMARY.

Eleven species of the genus Raia are landed by fishermen at Plymouth. Seven of these occur frequently, and are known to spawn in the immediate neighbourhood.

The species are all oviparous, and the eggs are enclosed in rectangular horny capsules. The capsules vary in size in different species.

Capsules spawned by the same fish show also considerable variation in size.

Egg-capsules have a definite orientation in relation to the adult fish.

Spawning extends over a considerable part of the year, but the maximum probably occurs during the early summer months.

Eggs appear to be deposited in " beds " and the fishes may be local in their places of spawning.

There is a strong suggestion that the eggs are buried in sand on deposition, or that the fish selects sheltered spots between rocks.

The eggs are fertilised in the upper reaches of the oviduct, and the egg-capsule passes rapidly down the oviduct to be extruded from the cloaca.

A single experiment has shown that sperm may be stored for the fertilisation of ripe ova as they pass down to be enclosed in the shell.

The egg-capsule is aerated by general osmosis and by the special adaptation of slits on the horns. The aeration is greatly assisted by a rhythmical lateral movement of the whole body, and especially of the tip of the elongated tail.

Temporary external branchial filaments are developed by the embryo. They are highly vascular, but may also be used for the absorption of nutriment.

The period of incubation of the embryo has been determined for six species under artificial conditions from four to ca. fifteen months.

The newly hatched fish differs considerably in character and in shape from the adult, and undergoes definite post-embryonic changes.

The tip of the tail behind the second dorsal fin is gradually reabsorbed about the end of the period of incubation, and more quickly after the embryo has hatched out.

The embryo absorbs the yolk from the external yolk sac through the medium of an internal yolk sac which opens directly into the anterior end of the spiral valve.

The food of the early post-embryonic stages consists almost entirely of small Crustaceans, Amphipods and Crangonids, which are supplemented, soon after the fish hatches, by a reserve store of yolk from the internal yolk sac.

## SUMMARY OF SPECIFIC CHARACTERS OF EGG-CAPSULES AND POST-EMBRYONIC STAGES.

### Egg-capsules.

*R. clavata.* Capsule medium, average 74×57 mm. range 63 to 90×49 to 68. Shell stout and rough, being more or less covered with loose fibres. One side more convex, the other almost flat. Lateral horizontal keel pronounced.

*R. maculata.* Capsule small. Narrow in proportion to length. Average 70×41 mm. No horizontal keel. Loose fibres not voluminous. The less convex side smooth. Similar to *R. undulata*, but smaller.

*R. brachyura.* Capsule large. Average 128×78 mm. Thick mass of loose fibres on convex side and on lateral margins. Other side smooth and nearly flat.

*R. microcellata.* Capsule medium 90×51 mm., curved longitudinally and much narrower at base of short horns, which are stumpy and hooked. Long horns filamentous. Shell almost transparent.

*R. nævus.* Capsule small, average 63×36 mm. No loose fibres. Shell entirely smooth and transparent. Long horns curved and greatly prolonged. Bi-convex.

*R. undulata.* Capsule medium. Similar to *R. maculata*, but much larger, 81×52 mm. Lateral fibres voluminous. Outside smooth and slightly rounded, the other more convex with felty mass of fibres.

*R. batis.* Capsule large. Velvety texture. Loose fibres confined to one spot at the base of the long horns, extremely elongated, being longer than the capsule. Golden yellow colour when spawned. Average 143×80 mm.

*R. marginata.* Very large capsule. Average 180×138 mm. Beaded structure when spawned. Honeycombed and pitted on long exposure in sea water. Short horns stumpy and hooked. Long horns flat and ribbon shape.

## POST-EMBRYOS.

*R. clavata.* Width of disc in newly hatched young, 71–86 mm. Upper surface entirely spinulose. Median spines 26–38, of which two are in front of the shoulder. Colour of upper surface, K. and V., Code No. 134, with scattered dark patches or a few circular cream-coloured spots. Dark bars present or absent. Teeth ca. 40 in vertical series in upper jaw. Tail long, dorsals far apart.

*R. maculata.* Width of disc in newly hatched young 71–79 mm. Upper surface smooth, except for a narrow border of asperities on anterior margin of disc, præ-orbital and post-orbital spines, spinules on the interorbit, a median series of body and tail spines, twenty-eight to thirty in number, one spine on each shoulder and a single series of smaller spines on each tail margin. Two spines only on the median line in front of shoulder. Upper surface fawn colour with scattered black and some circular cream-coloured spots. Older specimens show a definite ocellus, with light-coloured centre, and surrounded by a few irregularly shaped black spots. Teeth ca. 40 in vertical series in upper jaw.

*R. brachyura.* Width of disc in newly hatched young 100–115 mm. Spinulation of upper surface with the same pattern as in *R. maculata.* Median series of 30–36 spines. Never less than three spines in front of the shoulder. Interorbit smooth. Colour of upper surface light fawn, with black spots extending close to the margins of the disc, and with lighter coloured spots showing no definite margin but an imperceptible blending with the general ground colour. No ocellus. Snout very blunt in newly hatched stage and more obtuse in later stages than in *R. maculata.* A single row of less prominent spines on each side of the tail. Teeth ca. 60 in vertical series in upper jaw.

*R. microcellata.* Width of disc ca. 80 mm. in newly hatched young. A large triangular patch of spines on the snout area, including the interorbit, and extending right across the disc to a line passing through the middle of the orbits. Body otherwise smooth. A median series of about thirty-three spines, of which three are in front of the shoulder. Tail with a double row of spines near the base on each side of the proximal half. Colour of upper surface, K. and V., Code Nos. 130, 135, with white lines parallel to the outer margins of each side of the disc and with a few indefinite white spots. Teeth ca. 42 rows in vertical series in upper jaw.

*R. nævus.* Width of disc in newly hatched young ca. 60 mm. Upper surface entirely spinulose. A triangular patch of spines on the shoulder. Tail with one or more marginal rows on each side of the proximal half. Colour of upper surface light fawn with wavy bands of sepia colour. Also lighter patches and a few smaller oval or circular light spots. A large marbled ocellus on each wing. Teeth ca. 44 rows in vertical series in upper jaw. Dorsal fins practically confluent.

*R. fyllæ.* An extremely small fish. Width of disc 39 to 40 mm. Upper surface entirely spinulose. Spinulæ with needle-shaped points. A group of one to three large spines on each shoulder, and a median series of thirty-four to thirty-seven retrorse spines. Dorsals small and practically confluent. Colour of upper surface marbled in later young stages, with oval or circular brown spots surrounded by a light margin. Teeth ca. 26 rows in vertical series in upper jaw.

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