Notes on *Haliotis tuberculata*. I.

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I. INTRODUCTION.

Haliotis tuberculata, the "ormer" (from *oreille de mer*) of the Channel Islands, is, as is well known, used as an article of food, both in those islands and elsewhere. Of recent years a marked decrease in its numbers has been observed in Guernsey, and in order to devise suitable legislation for checking this decrease, the States of Guernsey undertook to finance a short investigation of the mollusc during the summer of 1923. I undertook this investigation, and spent three months in Guernsey in connection with it. I must here record thanks not only to many helpers in Guernsey, and to the States of Guernsey for the facilities placed at my disposal, but also to Prof. Watson for the loan of apparatus, and to Dr. Orton and Prof. Fleure for advice. In addition I wish to acknowledge help in the actual work given by my wife, which made it possible to get through far more in the time.

It was impossible, of course, to make more than an outline-investigation in so short a time, but we aimed at clearing the ground. If the investigation should be continued later, the notes offered here could be largely

extended; and we hope ourselves to add to them later, especially by working out the life-history of *Haliotis* in detail, for which purpose material has been preserved. But as further work must be postponed for the time being, the present paper aims at adding something to our general knowledge of the bionomics of an interesting species.

In addition to the shortness of the time, we were necessarily somewhat incompletely equipped, since *Haliotis* is an animal which cannot be kept in captivity save under conditions available only at a biological station.

There seems to be no doubt about the actual diminution of *Haliotis* in Guernsey (although it is not by any means dying out yet), and the diminution seems to have been quite marked. Estimates of the period which it has covered, however, vary from ten to about thirty-five years, the mean estimate being over twenty years. M. Joubin, of the Museum d'Histoire Naturelle, who has studied *Haliotis* in France, tells me he has heard of no such diminution in Brittany.

II. BREEDING-TIME AND AGE, ETC.

Sizes of the Young Ones. *Patella* and *Crepidula* can attain a length of 2 cm. in a year, and in special circumstances much more (Orton). If *Haliotis* were a winter breeder, one would expect specimens a few *millimetres* long to occur during the summer, on the analogy of these other molluscs; if it were a summer breeder, the next summer one might expect specimens 2–3 *centimetres* long. On our collecting expeditions we searched carefully for any very minute ormers; but although minute animals of other sorts were clearly visible, we never found an ormer smaller than 9 millimetres long, and this was exceptional. We measured nearly 100 young specimens, ranging from ·9 to 3·95 cm. in length. This in itself suggests that summer is the breeding time, and that these are mostly one-year-olds. The majority would be between 1·5 and 3·5 cm. and a good many under 3 cm. The few tow-nettings we were able to take did not help much in fixing on the breeding-time; at any rate, we obtained no young *Haliotis* we could certify as such, though a few of the veligers may have belonged to it.

Development of the Gonad. In determining the sex of young ormers, it was found that females are recognisable from a gonad sample at as small a size as 1·85 cm., the young eggs being very clear; the youngest male we were able to determine was 2·8 cm. long. Sometimes samples from a young specimen would be indecisive as to sex. It does not follow that a specimen, the sex of which can be determined by a sample, has a gonad sufficiently developed to be visible as a whole to the eye. In fact, the smallest female with a gonad visible as such was 2·55 cm. long; the smallest male with visible gonad being ca. 3·3 cm. long.

If the shell is removed from a young ormer, there is often no visible gonad at all; but a more or less distinct tinge of green or yellow on the

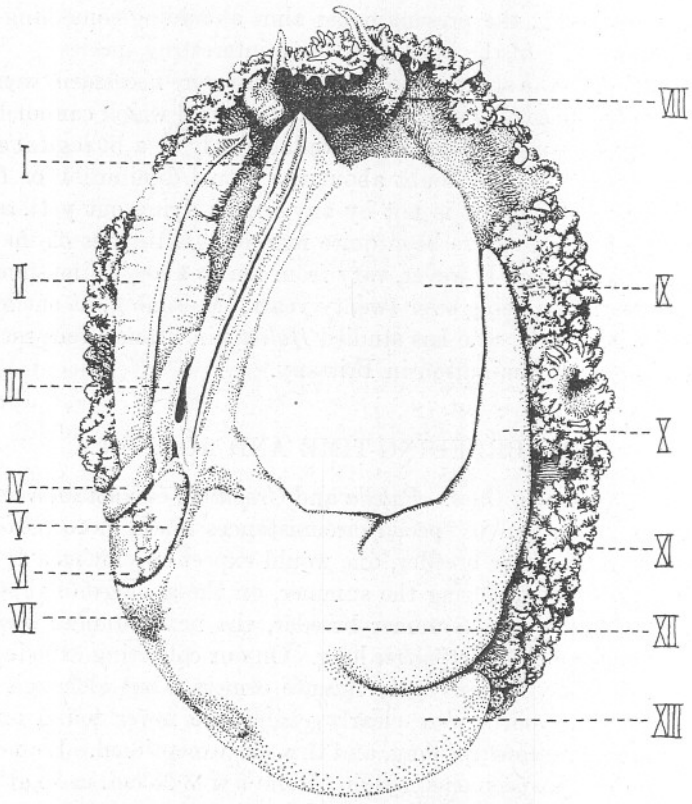

FIG. 1.—A preserved specimen of *Haliotis*, slightly dissected, to show general arrangement of parts. The roof of the branchial cavity has been removed, so as to expose the gills, rectum, and left kidney. The roof of the pericardium is also removed, and so are parts of the mantle.

I: Right gill. II: Left gill. III: Rectum. IV: Left kidney. V: Right auricle. VI: Left auricle (the two auricles cover and hide the ventricle in their present state of dilation). VII: A small portion of the liver, which is not covered up, as most of it is, by gonad. VIII: Head, with two pairs of tentacles, the eyes borne on the hinder pair. IX: Large shell-muscle. X: The conical cæcum of the visceral hump, containing a core of liver surrounded by gonad. XI: Epipodium. XII: Gonad (covering most of the surface of the visceral hump). XIII: The part of the visceral hump, which is lodged in the spiral tip of the shell.

conical cæcum* of the visceral hump, or at its base, or on the cæcum and neighbouring parts, often suggests the beginning of the gonad: this tinge is not invariably present. In sufficiently developed specimens

* "Conical cæcum"—the conical extension of the visceral hump which stretches forward on the right-hand side of the large shell muscle (see Text Fig. 1). It contains a core of liver surrounded by a layer of gonad, in the adult.

the actual gonad is just visible as a thin creamy or greenish film, which may be uneven in thickness, and may cover about half the upper surface of the visceral hump, or more, and may be thickest on the conical cæcum; one specimen had a slight creamy film on the conical cæcum only.

It is difficult to estimate the time which these specimens with just-visible gonads would need for the ripening of their sex-products. A female 3·3 cm. long on June 16th had some of its eggs reaching small medium size and getting opaque; one, 3·95 cm. long, on July 1st had also some of them beginning to be opaque. But judging from older specimens, it would take individuals of this sort a good while to ripen; perhaps one could not expect it for another year, when they might be two years old. It is certain, however, that a female 5·55 cm. long can spawn, since we actually witnessed it (see below)—this at an estimated age of two or three years. A male can have active sperms at as small a length as 2·8 cm., when it is presumably about a year old; and could probably effect a fertilisation during its second summer of life, if not before, in some cases at any rate.

Summarising, one may say that in the female the sexual products may be clearly differentiated before the animal is 2 cm. long, and the gonad visible before it is 3 cm. long; and that it can spawn at 5·55 cm. It is probable that the gonad becomes visible during the second summer of life and that maturity is reached the third or fourth summer, i.e. at two or three years old. In the male the gonad may be differentiated before the animal is 3 cm. long, visible before it is 4 cm. long, and certainly ripe at 5·5 cm. (we saw one spawn at this length) if not before; and a male could perhaps spawn at a year, almost certainly at two or three. For comparison, *Patella* can breed as a male certainly at an age of a year, and as a female almost certainly, in many cases, at two years (Orton).

Progress of the Gonads. Gonads and gonad samples were examined at intervals during June and July, with a view to finding out when ripeness occurs. The following notes apply to "adult" specimens, i.e. specimens over 4 cm. long.

Females. None of the specimens examined in June seemed to be ripe or very near to ripeness. Eggs in several stages would be present in the samples: the eggs were inclined to be irregular in shape (and though some would be round and regular they were perhaps under size), the large ones especially tending to be crushed looking. Not many eggs would wash out in water, and samples would be murky and apt to contain a good deal of tissue. In July a fair number of specimens were judged to be approaching ripeness, though there would be others still far from ripe. There would be more free eggs in the samples, and less tissue, and in the best

cases plenty of free eggs washing out easily, clean, round and regular in shape, and little tissue. The gonad of a fully ripe female exhibits a perfectly characteristic appearance with even, regular, loose eggs of uniform size. Artificial fertilisations were made (twenty-seven attempts) as a control, from the beginning of June onwards. In June no results were gained or expected ; the same is true of July, although there seemed more chance of results then ; but on August 1st a small proportion of embryos were obtained from the eggs of females sampled the day before ; on August 2nd a female laid eggs in formalin while being preserved ; and on August 3rd a male and female spawned of their own accord, in observation vessels. Notes of the actual extent of the gonads, made from June 18th onwards, show that in the great majority of cases the gonad spreads over three-quarters (or oftener more than three-quarters) of the area of the upper side of the visceral hump, at this time of year. Sections taken through the conical cæcum, at the same time, about half an inch from the tip, showed that the layer of gonad in that region was usually thick, so thick sometimes that the cæcum consisted of almost solid gonad. The gonad would often be extremely plump.

Males. In all males examined after June 18th, the gonad was similar in distribution to that of the female. The gonad would usually run milky when cut, though sometimes very slightly. In every living male examined during the summer *active* sperms were present.

Conclusion. These observations are not enough in themselves to fix the extent of the breeding-time in detail, and are of the kind which need confirmation by observations made at other times of year. But as far as they go, they suggest that the eggs are ripening gradually during June and July, and prove at any rate that the beginning of August falls within the breeding-time. Taken together with the sizes of the young specimens collected, they render it probable that *Haliotis* is a late-summer breeder ; and there is no indication so far of a second breeding period in early spring, such as would leave young specimens a few millimetres long behind it, during the summer. These conclusions are further strengthened by a later observation. Nine ormers sent by post from Guernsey were examined on December 13th, 1923. They varied in length from 4·1 to 5·2 cm. In these the gonads were in a reduced condition as compared with those examined in the summer, having become thin and patchy, and not even opaque save at certain spots in given cases ; sometimes barely visible at all. They seemed to be gonads which had died down after spawning.

Sex-change. We had not time to get any evidence as to whether sex-change occurs in *Haliotis*. No *very* young specimens were available. All that can be said is that young ones estimated as last year's spat are often females.

III. METHOD OF SPAWNING: FERTILISATION: DEVELOPMENT.

Method of Spawning. The actual process of spawning was witnessed in both a male and a female, during the evening of August 3. A male 5·5 cm. long, which was alone in a glass jar, began puffing out clouds of sperm through the holes in its shell. At about 7·15 p.m., while the male was still discharging, a female, 5·55 cm. long, alone in another glass jar, shot out a cloud of eggs from the holes in its shell; they quickly sank to the bottom, and made a pale green carpet there. The eggs are perfectly circular, pale green, each enclosed in a transparent shell. The gonads of these two ormers were examined afterwards; that of the female was yellowish, and looked speckled by reason of ripe eggs, with transparent patches where eggs had gone; the male gonad looked much as usual, but rather patchy, and ran very milky when cut. The age of these specimens, as far as the data we have will allow us to estimate, would be two or three years. On August 2nd a female laid eggs in formalin as she was pickled. We find it difficult to reconcile these details with the account given by Mr. Sinel (Guernsey *Star*, May 7th, 1923) of some data collected by a naturalist in Herm about 1890. According to this account a female ormer was obtained in the act of depositing the eggs, of which about 1000 were laid, and they were deposited in a thin gelatinous mass in May or early June. In the case we witnessed there was no question of any gelatinous mass. Our specimen probably laid something like 10,000 eggs at one puff, all free from one another. It is not impossible that in the case recorded by Mr. Sinel, the accidental proximity of an ormer and the egg-mass of another mollusc may have led to a mistake.

Fertilisation. In the case of the two individuals which spawned on August 3 some of the details of fertilisation were seen. Sperms were introduced into the vessels containing the eggs (some of which had been removed into finger-bowls from the original jar) at 7.35 p.m. In samples examined just afterwards many sperms could be seen with their heads up against the egg-shell, the long axis of the head being at right angles to the surface of the shell; they were quite motionless as far as one could see, but the tails were not visible. Sometimes a single sperm could be seen apparently penetrating the egg-shell, and sometimes a single sperm within the shell which seemed to be entering the egg. The birth of a polar body was witnessed in one case, and polar bodies were visible in other cases.

Development. To follow up the fertilisations made on August 3, from the spawning individuals, first—at fourteen to fifteen hours after the introduction of sperm, there were large numbers of active young ones,

at an early trochophore stage with a clearly visible prototroch, some of them revolving in the egg-shell. We were unfortunately unable to make prolonged examinations of the young at any point, because they were developing just as we were obliged to make preparations for leaving the island; but a number were preserved, and we hope to work them out later. At forty-four to forty-six hours after introduction of sperm, a considerable number of larvæ had escaped from the egg-shell, and were swimming actively about at various levels in the water, other embryos being still within their shells at the bottom. The swimmers were plainly visible to the naked eye. These larvæ were much more advanced than at fourteen to fifteen hours, and from the condition of oval masses with a belt of comparatively short cilia, had changed to a stage with a body and a prototrochal crown separated from it by a constriction. The cilia of the crown were very numerous, long and powerful, and seemed to be held typically in such a way that some projected upwards and others curved down over the edge of the crown, which had a narrow transparent rim outlining its denser central portion. At sixty to sixty-two hours after introduction of sperm the larvæ seemed little different in general form from those at forty-four to forty-six hours, and further than this our observations could not be carried, as we were obliged to leave.

Apart from the larvæ just described, the first fertilisations which produced any result were made on July 31st, in the morning, from eggs and sperm extracted from living gonads. In the evening a few two-cell stages were seen. Samples examined during the next two days showed a certain number of segmentations, though the majority did not develop. Two- and four-cell stages were to be seen, as well as stages with a distinction of cells into macro- and micromeres, but nothing further; and even these embryos gave the impression that they were developing rather abnormally.

In the supposed case of *Haliotis* development mentioned above, and recorded by Mr. Sinel, hatching occurred in seven to twelve days, and the veligers began to swim then. L. Boutan (*Arch. de Zool.*, VII, 1899, p. 270) has given an illustrated account of the young stages of *Haliotis*, but has not been able to determine at what age the swimming larvæ begin to creep. The larvæ doubtless swim in the sea as they do in captivity. In confirmation of this there is a note of Mr. Sinel's, to the effect that he has found ormers in pools nearly at high-tide limit, on a reef near St. Heliers; a locality where larvæ might settle but which adults would be less likely to seek out. Dr. Orton has also found ormers in pools high up.

In our attempts at rearing *Haliotis* and certain other mollusc eggs which we got as far as veligers, we used the finger-bowl method and also a plunger jar. The sterilisation of vessels and instruments, and the

filtering of the water, had to be less meticulous than we could have wished, because of the conditions under which we were working ; but we gained the impression that apart from this, *Haliotis* larvæ may need a better water supply than these methods give, if they are to be reared all the way through.

IV. METHOD OF FEEDING.

Samples of stomach-contents from twenty-two living *Haliotis* gave a certain amount of information as to its food materials. The things most clearly recognisable were, a good many chips of coarse brown weeds, some of them of considerable size (e.g. 5·5 mm. long) ; remains of small crustacea ; sand, sometimes a good deal of it ; spicules and parts of spicules, including triradiates and presumably belonging, many of them, to sponges ; diatoms ; foraminifera ; remains of polyzoa ; and filaments of confervæ. A good deal of the refuse seemed to be of a vegetable nature, and much of it one could not identify.

Boutan (*Ann. des Sci. Nat., Zool.*, VI, 1923, p. 59, etc.), in speaking of *Haliotis*, states that it is herbivorous, and that if kept in glass aquaria with small green algæ lining the sides, it makes these its food, and browses with the radula in such a way as to leave sinuous tracks devoid of algæ on the glass.

We witnessed the feeding-process more than once. In one case a specimen fixed on to the vertical side of a glass jar began feeding at about 6 p.m., everything being clearly visible through the glass, by aid of a lens. The end of the snout was spread out either very close to or actually pressed against the glass, and was rounded in outline. On the opening of the slit-like mouth in the centre of this area, the end of the radula came out, with curled-in edges, licking the glass like a tongue. Bits of dirt and slime, stuck to the glass, were licked off and swallowed. The animal did not walk very straight up the vertical side of its jar, it would go from side to side or even turn round and go down again. A piece of *Fucus* held near the mouth was seized by wrapping the snout round it, and several pieces were bitten out of the edge of it. Carmine and plankton were placed just in front of the mouth, and portions of both were swallowed when they came within pull of the lips and tongue, but the animal did not seem to seek out the plankton provided, if anything the reverse, eating it only if it came his way.

A number of experiments were made in the hope of finding out whether *Haliotis* gains part of its food supply from plankton, after the manner of *Crepidula*.

If the shell be removed from a living *Haliotis*, and it be pinned out under water, it will often settle down quite well and expand, the heart

beating actively and the tentacles waving. (It can live for months after shell removal, see p. 490). If carmine (or plankton) be then scattered on the gills, it passes off them by ciliary action, to a groove along the right side of the left gill, whence it follows a definite diagonal track* across the back of the head and into another groove formed by the right half of the epipodium. Ultimately it floats or falls off the edge of the epipodium quite close to the mouth. This experiment was repeated a good many times, and always the particles (apparently tangled in a cord of slime) followed the same route, sometimes moving steadily and rapidly. The direction they follow is the general direction of the row of holes in

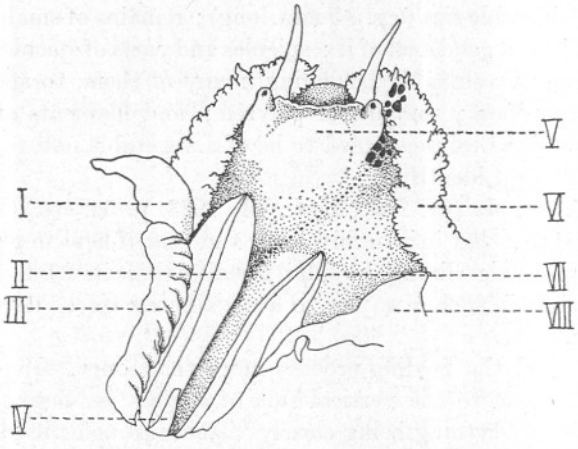

FIG. 2.—Diagram of the fore part of *Haliotis*, sketched from a living specimen after removal of shell. To show the direction of the track followed by particles of carmine, plankton, etc., when scattered on the gills. This track is dotted in heavily, and masses which have collected at its front end are shown on the right side of the head. I, VIII: Flaps of the mantle curled back. II: Left gill. III: Left mucous-gland curled back. IV: Rectum. V: Head. VI: Epipodium. VII: Right gill.

the shell. Sometimes odd particles will fall of their own weight into convenient crevices, but this track is the normal direction taken by the bulk of them. In no case did the animal make any attempt to eat the plankton thus provided, although it could have reached it. Sometimes it would get rather excited and feel about with snout and tentacles, or would simply jerk about, when the foreign matter reached the edge of the epipodium. Waste from the rectum was seen to follow the same path.

In other cases plankton or carmine were introduced into the branchial cavity of a *Haliotis* with the shell still on. In these cases the plankton would come out in a worm, fairly rapidly from under the edge of the shell;

* The direction of this track may be understood from Text Fig. 2.

but there was no attempt to eat it. Some of the looser particles would be puffed out, via the holes in the shell sometimes, before the main stream came out from under its edge.

Another experiment was made by leaving ormers in baskets sunk in the sea in a place inhabited by other ormers, but providing them with no food save what could be extracted from the water. After six weeks the baskets were recovered, and although they were tightly tied and all the lashings were intact, some of the ormers had escaped, despite the absence of any visible crevice or mesh of the baskets through which they could have done so. It was possible, however, to identify those remaining accurately, to the best of our belief ; and not one showed any measurable increase in size whatever. Inside the baskets were trochi, young crabs, and in particular young scallops had settled there and had attained a length of about half an inch in the six weeks—so there must have been a supply of food in the water for animals which could use it. The *Haliotis* were quite healthy.

These experiments were unfortunately not conclusive. But at least they suggest that Haliotis does not use plankton much ; so far as they go they give no sign of it. The ciliated track in branchial cavity can be understood in connection with the normal removal of the heavier part of the rectal waste, and perhaps also of sand which must sometimes intrude. It is at least definitely proved that *Haliotis* is a browser, can eat fairly coarse as well as fine materials, and is fairly omnivorous.

V. GENERAL NOTES.

During the summer about 250 living specimens passed through our hands altogether (estimated), and the sizes of those measured varied between 9 mm. and 12·3 cm. Of 127 examined for sex, 50 were males, 71 females and 6 (young ones) did not give decisive information, in the absence of sections. The male gonad is usually white or cream, greenish white or greenish cream, rarely pale yellow or salmon. The female gonad may be bright or dull green, various shades of grey-green, grey, fawn and brownish ; it may be creamy when very young ; in a specimen which had just spawned the spent gonad was yellowish. The sex of an ormer can usually be determined without making any incision or removing the shell, if the animal is not too small (but the observations above recorded are made after removal of shell and sampling the gonad). The underside of visceral hump and conical cæcum are visible at the back end of the animal, if foot and epipodium be turned down ; the gonad colour is then usually perceptible through the skin at a given point on the inner side of the curve and close to the large shell-muscle, although partially masked by pigment in the covering skin.

Occurrence. *Haliotis tuberculata* occurs on the coast of France from Barfleur southward, as well as in the Channel Islands. We collected it in Herm and several parts of Guernsey and received specimens from Sark. In our experience it occurs chiefly beneath stones not embedded in sand, in clean places. It is found typically only in the Laminarian zone (and is only available in quantity at low spring tides), but occurs at higher levels in a certain number of pools and lagoons which never dry. The species tends to occur in colonies, and chooses its localities with some exactness ; for instance, one small shallow bay in an off-shore reef which we visited, was known locally as a special resort of young ormers ; and certainly we found more of them there than elsewhere. The depth-range of the species is uncertain ; according to M. Joubin it extends only " some few metres " below low water of spring tides. A diver working from St. Peter Port obtained two ormers from a rock at a depth of not more than about 35 feet of water at low water of springs. Probably the main home of the species is in fairly shallow water close to low-water mark of spring tides.

Habits. *Haliotis* is probably not a homing mollusc like *Patella*. It is difficult to watch a marked specimen, because the creature is so active. It walks very rapidly, surprisingly so—Sinel estimates the pace at not less than 5 or 6 yards a minute, and we have seen it go at a similar rate. It adheres very firmly to its stone (so that sometimes the shell will come off rather than the animal) ; but if one fails to remove it at the first pull, it does not necessarily adhere all the faster for an indefinite time, like a limpet ; often after a minute or two it runs away, if left alone. Again, when an ormer is removed from a stone, so far as we have seen it never leaves behind it a distinctly marked-off area as a limpet often does ; the surface from which it was detached is quite indistinguishable from the rest of the stone ; the ormer may have been covering anything, for instance an incrusting animal, and the foot may bring away some of the incrustation with it. Three ormers which had settled in our tank one evening were noticed and all had gone elsewhere by morning ; we believe this to be usual. These things are only hints, but do not suggest a homing habit.

When *Haliotis* is healthy the foot is very active, strong and mobile. If the animal is laid on its back it can, at best, pick itself up wonderfully quickly by attaching the tip of its tail and rearing itself up vertically thereon. The foot is pale yellowish or creamy on its underside, and very conspicuous ; but can fold up longitudinally, so that the upper side is exposed, and this is of dull greenish and greyish shades, dark and inconspicuous.

If the shell be removed from *Haliotis*, the animal remains quite lively and creeps about as usual. Boutan has kept *Haliotis* for months after

shell removal (see *Ann. des Sci. Nat., Zool.*, VI, 1923, p. 59, etc., and *Comptes Rendus de l'Acad. des Sci.*, 127, 1898, p. 828), and finds that the shell is regenerated; but the new shell is abnormal and falls off very easily, after which yet another will be secreted. Boutan has also succeeded in producing pearls in *Haliotis* by the introduction of foreign bodies in a suitable manner.

According to Sinel, *Haliotis* is nocturnal in habits.

Conditions demanded by Haliotis. It is evident from the works of Boutan that *Haliotis* can be kept for long periods in captivity, and will acclimatise themselves easily, provided they can be supplied with well-aerated water in sufficient quantity. But the grade of aeration required is high, and involves a supply of water under pressure from a reservoir. In Guernsey we were unable to obtain these conditions, and found it almost impossible to keep ormers in a tank or other vessel of still water, even by changing some or all of the water each day; although the water was aerated also in some degree and was kept clean; and we had to keep our stock of specimens floating in the sea in a basket, which keeps them lively, but is inconvenient. Sometimes specimens would live a few days in a tank, and a few small ones lived as long as a month; but these were exceptions and usually one dare not leave them in a tank even overnight. Many animals could have been kept in health easily with the facilities at our disposal. An old experiment by Beudant (see Flattely and Walton, *The Biology of the Seashore*, p. 81), in 1816, showed that *Haliotis* will not stand lowering of the salinity of its water as well as some other animals. All this makes it clear that *Haliotis* demands high conditions; and sometimes even if kept in a tank with new sea water flowing constantly through it, will not live long, to judge from Mr. Sinel's experience.

VI. *HALIOTIS* FROM AN ECONOMIC STANDPOINT.

It does not seem suitable to give an extensive account here, of the various possibilities which have to be considered in connection with the shortage of *Haliotis* in the Channel Islands, but a summary of the question may be of interest. A fuller report has been sent to Guernsey.

It was not possible within three months to follow up the various lines of inquiry laid before us, in much detail. We think it fair to say, however, that if legislation can check the disappearance of *Haliotis*, suitable regulations can probably be made on the basis of the knowledge now at our disposal. They could be modified as time goes on should further investigation make it needful.

In trying to find out the cause of the shortage, we were naturally obliged to rely partly upon information gained by word of mouth in the

island. There are a good many ideas current about the shortage. The outstanding points may be summarised as follows :—

1. There is universal agreement as to the actual diminution in the number of ormers available. Reliable estimates give former catches at as much as ten to fourteen dozen per head, now three dozen is reckoned a good catch for one man. The quality of the ormers is not thought to have deteriorated. The decrease has been going on for some years, the mean estimate being over twenty.

2. During our work we have found the ormers apparently in excellent health. They are clean, plump and active, showing no obvious signs of disease or parasitisation. "Sick" ormers are known, though we did not actually see any; they occur, however, in very small proportion. We examined 100 shells, but found nothing to suggest that these were suffering enough from outside attacks to affect the general health of the animals. Seventy per cent of them were practically perfect.

3. *Natural Enemies.* It seems established that octopus, starfish and oyster-catchers will attack *Haliotis*. There is evidence that the ormer forms, at any rate, a small part of the normal food of *Octopus*. There is nothing to show that any steady increase in the numbers of starfish or octopus has occurred recently, comparable to the decrease in ormers. *Octopus* is nevertheless regarded in some quarters as the villain of the piece. The extent to which any one of these enemies can account for ormers is not clear. Beyond the possibility that a heavy octopus year (octopus varies much from *year to year*) and a poor ormer year may coincide, there is no sign that natural enemies have anything to do with the ormer scarcity as a main cause.

4. *Climatic conditions.* It was suggested that some kind of change in the Gulf Stream had taken place and had led to a local cooling of the water, and this to fatalities among the ormers. An enquiry has been made into this question, but is not yet complete. It promises to be interesting, but any change involved would be very slight, and the effect of it on the ormers difficult to estimate. The Channel Islands, however, are the northern limit of the species, and there if anywhere a very slight temperature change might affect it. In any case this question would not affect corrective legislation, since the temperature of the sea is uncontrollable !

5. *Contamination, etc.* So far there has been no evidence pointing to contamination from oil, petrol or sewage forming any serious source of trouble. Nor does there seem to have been silting-up of suitable habitats upon any large scale ; certain temporary silting has been noticed.

6. *Frost.* It is said that "all that is needed to bring the ormers up is a good frost," the shortage being put down to lack of such. The details collected in connection with this idea certainly do not lead to the conclusion that there is any explanation of shortage here.

7. *Food supply and overfishing.* As far as our study has enabled us to judge, we think the main answer to the question lies here. It is evident that the ormers' food supply forms a low growth on rocks and stones, in the main, unless it can strain out plankton from the water also, which so far seems doubtful. A certain proportion of this food supply, perhaps a large proportion, is the growth found underneath clean stones and boulders which are not embedded in sand—and where the ormers themselves are mainly found. Some section of this part of the food supply is very easily upset. During ormering the stones and boulders will get turned over to an enormous extent, with the result that a good deal of animal food (polyzoa, sponges, larvæ, eggs, etc.) is doomed to die of exposure. These boulders cannot be expected to recover a growth as rich as they originally had for some time, perhaps for a year or so. It is clear that if the beaches get disturbed on a wholesale scale too often, this could interfere with the food supply in the disturbed area, apart from the taking of too many ormers and of too small ones, which would help to spoil the fishery. If this did nothing else, it might in time place the upper limit of the zone inhabited by ormers a little lower down than before, and this would make them no longer available for fishing, since they cannot be got at in more than a few feet of water.

It is not easy to find out whether more people actually go after ormers than formerly; opinions are very conflicting. The most widely held view is that the number of those who fish has increased very much; and it is significant that the population of the island of Guernsey is now nearly twice what it was one hundred years ago. Jersey has to be considered separately in this matter of ormers; the conditions there may be different; but Guernsey is the headquarters of the species, with its neighbouring islands of Sark and Herm.

8. *Conclusions.* If ormers are more fished than formerly, and the beaches consequently more disturbed (and it is possible to disturb them very badly), we need probably look no farther for a main cause of shortage. It does not follow that there are not other subsidiary causes. If this is *not* the cause, it may well be a matter of natural fluctuation spread over a period of years, and possibly reversible. If it is due to overfishing, suitable legislation may hope to check it; if to natural fluctuation, that would be revealed by the failure of legislation. Natural fluctuation would be connected with some cause or causes not yet evident, and possibly involving some connection with changes in food supply not

brought about by man, or with temperature. We suggested a total suspension of the fishery for two years, followed by further biological investigation. After the two-year period a detailed set of more permanent regulations can be worked out. The two-year period of suspension has been adopted by the States of Guernsey. The question of artificial breeding of ormers has been considered, but it is difficult to see how it could be made a sound scheme economically. The difficulties of keeping the active *Haliotis* captive and of supplying it with sufficiently extensive browsing grounds, make it a problem very different from that of the sedentary current-feeding oyster.

SUMMARY.

1. Eggs may be clearly differentiated in a female specimen of *Haliotis* before a length of 2 cm. is reached by the animal, and the female gonad visible before 3 cm. is reached. The female may spawn at 5·5 cm. In the male, active sperms with tails may be differentiated before a length of 3 cm. is attained, and the gonad visible before 4 cm. is reached. The male may spawn at 5·5 cm., if not before.

2. It is estimated that specimens up to about 3·5 cm. long are a year old or less. If so, male and female can both spawn at three years old at any rate, more likely at two years.

3. The first week in August certainly lies within the breeding season. The range of that season is not known, but evidence points to its being late summer.

4. The male gonad is typically white or cream-coloured, or with a tinge of green in addition ; rarely salmon or pale yellow. The female gonad varies more, various shades of green, grey-green, brownish grey, etc., are found. These data refer to specimens observed in June and July.

5. Of 127 specimens examined for sex, 50 were males, 71 females, 6 young ones not giving decisive evidence.

6. A male and female were seen spawning. The male puffed out successive clouds of sperms. The female puffed out one cloud of eggs through the holes in the shell, perhaps 10,000 of them. They sank rapidly. They were visible to the naked eye, pale green and quite free from one another. Each was enclosed in a transparent shell.

7. Fertilisation took place after the eggs were laid. The young had reached an early trochophore stage at fourteen to fifteen hours after introduction of sperm. At forty-four to forty-six hours many had left the egg shell and were swimming actively, being then at a decidedly more advanced trochophore stage. How long it is before they settle down and end the larval stage is not known.

8. The food supply consists of algæ (both coarse ones and confervæ, also diatoms), polyzoa, sponges, small crustacea, foraminifera, etc. A good deal of sand is taken in with it.

9. *Haliotis* is certainly a browser and uses the radula as a licking tongue. Experiments were made to ascertain whether it can extract plankton from the water as part of its food as *Crepidula* does. The results were interesting (see p. 487), but not conclusive, pointing to inability to use plankton.

10. There is no evidence to show that *Haliotis* is a homing mollusc like *Patella*, what there is pointing the other way. It is an exceedingly active species.

11. *Haliotis* demands the highest possible conditions of aeration in its water. Given these it is hardy, and will even live for months after removal of its shell, secreting one or more new ones (Boutan).

12. In the attempt to find out why *Haliotis* is getting scarcer in Guernsey and the neighbouring islands (leaving Jersey out of account), it was concluded that this could probably be brought about by overfishing, and by a too ruthless disturbance of the beaches, leading to a certain diminution of the food supply over the area within which *Haliotis* is available for fishing. If this is not the main cause, some kind of natural fluctuation may account for it; contamination, natural enemies, etc., not appearing to be main factors. The fishing of *Haliotis* in Guernsey has consequently been totally suspended by the States for a period of two years. At the end of that time more permanent regulations will be devised.