12.—THE HABITS AND DEVELOPMENT OF THE LOBSTER, AND THEIR BEARING UPON ITS ARTIFICIAL PROPAGATION.

BY FRANCIS H. HERRICK,

Professor of Biology in Adelbert College.

Wanton destruction has exterminated the wild buffalo of the plains, and indiscriminate slaughter is threatening the fur-seal of the Pacific with a like fate. The oyster beds of the Chesapeake, among the richest in the world, have been brought to the verge of ruin by a lack of foresight and a blind trust in the resources of nature. The same evil has overtaken the lobster, and to-day the fishery is declining. It has already ceased to be profitable in many places, and the size of the lobsters has diminished. Too late, the lesson is being learned, that we can not forever reap the wild harvests which we have not sown. "Where I could catch 500 lobsters in a day twenty-five years ago," writes a lobsterman from Maine, "75 per day is now a large catch." The same complaint is heard from nearly every point on the coast. Fishermen are not inclined to look beyond the demands of the present hour, and men in general regard the ocean as inexhaustible in its animal life, as it is apparently limitless in extent and fathomless in depth, forgetting that marine animals may be as restricted in their distribution as terrestrial forms, and as nicely adjusted to their environment.

Before we can deal intelligently with the problem of protecting an animal from destruction, or of increasing its numbers, it is of the first importance that we become thoroughly acquainted with the habits of the animal in question, with its distribution, with the sources of its food at all seasons, with its method of breeding, with the development of the young, and their habits from the time they leave the egg until they are themselves able to propagate their kind.

Until recently, the lobster, our largest and most important crustacean, economically considered, has been singularly neglected by naturalists, and a review of the various measures which have been suggested or adopted for its protection in different States points very clearly to the value of accurate knowledge. The fact that so important a question as the breeding habits of the lobster should have remained for so long a time a matter of guesswork, emphasizes the need of a thorough investigation of its habits and development.

At the invitation of Hon. Marshall McDonald, U. S. Commissioner of Fisheries, I undertook such a work four years ago, and have since given to it all the time which could be spared from professional duties. During the summers I have enjoyed the excellent facilities for research which are afforded by the U. S. Fish Commission station at Woods Holl, Mass., and in August and September of this year I have been able to extend my observations in the field to the coast of Maine, from Portland to Eastport. There is only time to lay before the Congress some of the most significant and interesting facts in the life of the lobster, and to point out what seems to me the most promising method of directing our energies in the work of its artificial propagation.*

The American lobster (*Homarus americanus* Milne-Edwards) is confined, in its adult state, to a comparatively small strip of the Atlantic Ocean, stretching from Delaware on the south to Labrador on the north, and extending in breadth from the coast line out to a depth of 60 to 100 fathoms.

The adult lobster lives and feeds exclusively upon the sea bottom, which it never leaves of its own accord to any appreciable degree. It does not undertake periodic littoral migrations up and down the coast, like the truly migratory fish, such as the mackerel and cod, but is far more sedentary in its habits. In the spring, however, about the first of May, when the temperature of the sea water approaches 55° F., it begins to move from deeper water towards the shore, and in fall, about October, it retires to deeper waters again when a similar temperature has been established; but these semiannual impulses do not affect the entire number of lobsters in a given locality, since some individuals remain in shallow water in winter and in deep water in summer. Goode believes that the extensive northward and southward migrations of the mackerel are carried on in connection with movements to and from deep water. The same causes, of which the change of temperature is the most potent, probably determine the migrations of both fish and crustacean. It is further possible that in the case of the latter these short migrations are secondarily influenced by the occurrence of the molting and reproductive periods. It is certain, at least, that in most cases the eggs are laid and hatched while the lobster is in shallow water.

As a rule lobsters are taken at a depth of from 1 to 10 or 12 fathoms, from the last of April or first of May until October or November. During the rest of the year they are mostly found in water of from 35 to 50 or 60 fathoms, and some stray out to even greater depths. They seem to move back and forth more or less in a body, though it is by no means certain that this is the case.

The lobster must be regarded, as we have seen, as a relatively sedentary animal, and the fact that it is steadily decreasing at most points on the coast, and that the decrease is the most marked where the fishing has been conducted with greatest persistence, points to the truth of this conclusion. The once famous Cape Cod fishery, which dates back to the beginning of the century, and formerly supplied a large proportion of the lobsters sent to New York City, is now practically extinct. The region is depleted, and it will probably be many years before it can be restocked under natural conditions. Indiscriminate and persistent fishing is certain to end in the destruction of such a sedentary species as the lobster, and it is illogical, in the face of an efficient cause for its decrease, to seek for other causes which are neither known nor understood.

The principal food of the lobster consists of fish, either living or dead, and of clams and mollusks of various kinds. Fish which live upon the sea bottom, like the flounder, doubtless fall a prey to their powerful claws, and I have known the lob-

* The detailed work on the Life-History of the Lobster will probably be completed by the end of the coming summer. It will contain a full presentation and discussion of all the facts that are known concerning the habits and general life-history of the adult lobster, the habits of the larvæ, and of the young during their long period of immaturity, and the structure and development of the reproductive organs. The development or metamorphosis of the larvæ from the time of hatching, and their subsequent growth, will be fully described, and the development of the embryo will also be reviewed. The paper will be illustrated with upwards of thirty-five plates.

ster while confined in an aquarium to catch and devour the sea-robin. Lobsters feed chiefly by night, when they are far more active than in the day. They are quite sensitive to strong sunlight, and are often found in the daytime under stones or bunches of seaweed, or lying at the mouths of their burrows. The lobster not only digs up the bottom in its search for shellfish and covers itself with mud in cold weather, but burrows, under some conditions at least, as extensively as the muskrat or prairie dog. This is certainly true of lobsters kept in pounds, where the mud banks are sometimes so extensively tunneled by them from below as to afford but insecure footing to a man. They dig horizontally into the bank to a distance of from 3 to 5 feet, and during the day may be seen lying in their burrows with their long sensitive "feelers," or antennæ, outstretched, ready to warn them of the approach of an enemy, and with their large claws ready to strike a blow should the opportunity arise. If the hole is exposed at low tide they will leave it in summer, but are not so careful to do this in winter, when they are far less active.

Next to reproducing its kind, the act of molting is the most important in the life of this animal. The whole body is covered by a chitinous shell, in which salts of lime are deposited, giving to parts of it the hardness of stone. When once formed the shell admits of no increase in size, since it is a dead structure, excreted by the skin below it, and when it is outgrown it must be cast off and replaced by a new and larger shell. The new shell is gradually excreted under the old one, and when the latter is discarded the new shell is soft and flexible, and is easily distended to meet the requirements of growth. The growth of the lobster, and of every arthropod, thus takes place, from infancy to old age, by a series of stages, characterized by the shedding of the outgrown old shell, a sudden increase in size, and the gradual hardening of the shell newly formed. Not only is the external skeleton cast off in the molt and the linings of the masticatory stomach, the œsophagus and intestine, but also the internal skeleton, which consists for the most part of a complicated linkwork of hard tendons. This is rendered possible from the fact that all these structures are derived from infolded portions of the skin, and in molting they are simply drawn out of their original folds or pockets. It is thus easy to see why the molting period is a critical one.

It requires from two to three weeks to form a tolerably hard shell, and from two to three months to produce one which is quite as hard as that cast off. Since the process of molting involves a long series of changes it is not surprising that a number of names have been applied to lobsters while undergoing them. The terms "black shell," "crack back," or "shedder" are used to designate a lobster which is nearly ready to molt. "Soft shell," "buckle shell," or "paper shell" apply to one which has recently shed, the shell being easily compressed by the fingers. A "hard shell" or "old shell" lobster is one in which the shell has attained, or nearly attained, its maximum weight and strength.

In the final act of molting, which lasted in one case which I witnessed exactly five minutes, the lobster lies on its side, and bending its body, distends the membrane between the "tail" and the shell of the back. This membrane finally bursts, and the front part of the body, the large claws, and other appendages are gradually withdrawn from their old armor, the "tail" coming out last. To aid this process, the lime salts have been absorbed from some of the joints of the legs which carry the large claws, so that the investing shell can be distended to an unusual size, and absorption also takes place along the median line of the back. Notwithstanding this, the tissues of the large claw are stretched out like a stick of candy, and are drawn through an opening at the base of the second joint, the area of which is less than one-fourth that of a cross section through the largest part of the claw. The shell of the back, or carapace, comes off entire, as a rule, but occasionally it is split along the line of absorption and is thus partially separated into two halves.

At the time of shedding a considerable store of lime has been laid down in the walls of the stomach, probably for the rapid hardening of the lining of this organ or of the shell. It is in the form of two glistening white masses, one on either side, and each about the size of a small filbert. These gastroliths, better known in the crayfish as "crayfishes' eyes," figured prominently in the pharmacopœia of the ancients, being much esteemed as remedies for a great variety of disorders. They are largely composed of carbonate and phosphate of calcium, and when the sacs in which they are formed are opened each mass separates into several hundred snow-white rods or columns.

A curious habit which I have lately observed in the case of small lobsters (3 to 5 inches long) which have recently molted, is that of stuffing the stomach with fragments of calcareous matter, such as weather-worn pieces of shells of mollusks. The examination of the stomachs of hard-shelled lobsters of similar size has not shown any such remarkable assortment of calcareous materials, and it is possible that in the absence of gastroliths these are swallowed by the young lobster after each molt to furnish the growing cuticular skeleton with lime. It has not yet been determined at what particular period in the life-history of the lobster the gastroliths make their first appearance.

After shedding, the lobster is, for the most part, helpless, except in so far as it is able to elude capture by hiding in seaweed or under stones, and must often fall a prey to fish. One would suppose that they would resort to their burrows at such times, but I have seen no evidence of their doing so. As shedding is the result of growth, which is dependent upon a variety of conditions, molting lobsters are found at nearly all times of the year. For the majority, however, the period of ecdysis is the summer and fall, varying in different localities and in different years. In the eastern districts of the Maine coast the greatest number of soft-shelled lobsters is taken in September; in the western, in July and August. Some are occasionally caught in winter, but are very rarely taken in March, April, and May. Lobsters thus, as a rule, molt in shallow water, but "shedders" and "soft shells" have been occasionally taken from the stomachs of codfish caught in deep water outside. The adult lobster increases its length at each molt by about 12 per cent; that is, by 1 to 1½ inches.

There is no definite limit as to age or size when this process can not take place, since we find adult lobsters of all sizes from the smallest to those weighing upwards of 30 pounds. I have recently examined the large claw of a lobster, said to have weighed when alive 39 pounds, and which must have actually weighed 28 to 30 pounds. It is evident from the thinness of the shell of the claw that it belonged to an individual which had molted within two months from the time of its capture. The claw was 13 inches long and 17½ inches in girth, while its total weight was only 16¾ ounces, including the third joint.

Female lobsters reach sexual maturity when 8 to 12 inches long, possibly a very few when even smaller, a larger number at the length of 9 inches, and the majority when measuring 10 to 12 inches.

Over 100 dissections were made in the summer of 1890 (June 28 to August 19) to determine the period at which female lobsters mature, and to follow out the development of the reproductive organs; out of this number, 25 lobsters, from 9.31 to 12 inches in length, had never spawned; 5 of these were between 10 and 11 inches long, and 6 between 11 and 12 inches. In many cases it was demonstrable that the ovaries of these lobsters could not have become mature in less than two years. It is therefore obvious that the lengths of 9, 10, and 10½ inches, which have been adopted in different States as standards below which no lobsters are allowed to be sold, should be raised, if these animals are to receive the fullest benefit from this kind of legislation.

The eggs of the greater number are laid at a definite period and are attached by a gluey secretion, coming from cement glands* in the legs of the "tail," to the long hairs which garnish these appendages and to the under side of the "tail" itself. They are thus carried about by the female, and protected for a period of from ten to eleven months, when they hatch, and the young which then leave the mother lead an independent, free-swimming life, near the surface of the water.

The number of eggs laid varies with the size of the animal producing them, from 3,000 to 9,000, in the case of a female 8 inches long, to 85,000 in one measuring 16½ inches. This is the largest egg-bearing female of which I have any record. Lobsters 10½ inches long, from Vineyard Sound, produce, on the average, 11,000 eggs.

The law of production may be stated as follows: *The numbers of eggs produced by female lobsters vary in a geometrical series, while the lengths of the lobsters producing*

---

* The cement glands, which are responsible for the viscous secretion in which the eggs are bathed at the time they are laid, and by means of which they are afterwards firmly secured to the body, are of microscopical size and occur in very great numbers. They are most numerous on the hinder faces of the second to fifth pair of swimmerets of the female. Each consists of a spherical cluster of upwards of a hundred large glandular cells, which terminate in a central rosette (a peculiar, reticulate structure whose nature I have not determined). In the center of this rosette a small lumen or empty cavity is usually seen. The lumen communicates with the exterior by a very delicate chitinous tube, the duct of the gland. This thread-like duct penetrates the chitinous covering of the swimmeret and opens at the surface by a minute pore. Each gland has a large, nearly central, ganglion-cell, which is connected with the rosette and with the nerve which supplies the gland. Organs of very similar structure occur in great numbers in the appendages about the mouth, particularly in the mandibles, maxillæ, the upper and lower lips (labrum and metastoma), and seem, from physiological experiments, to be sense organs, probably of a gustatory nature. These two kinds of organs, cement-gland and appendicular sense-organ, while agreeing in general structure, give an entirely different micro-chemical reaction. This analysis shows that the organs of the swimming-feet are undoubtedly glandular in their nature, and we must infer either that both kinds of organs are really glands, or that there is a close relation between glands and sense-organs of this particular type.

The cement glands, like the mammary glands of some mammals, are capable of active secretion only at definite reproductive periods, namely, at the time of egg-laying in the case of the lobster. The liquid secretion is probably poured out very slowly, and trickles down the sides of the swimmerets upon their hairs and into the pouch or cavity formed by the folding of the "tail," where we know, by observations made on other crustacea, that the eggs are stirred up by the movements of the swimmerets until they become effectually "varnished" and fixed in place by the cement substance. This is not viscous at first, and it is probably some hours before it becomes very tenacious. An interesting case of a lobster which had laid her eggs in the well of a fishing smack came to my notice this summer at Rockland, Me. The lobster was taken out of the well and laid on deck, when the newly laid eggs began to flow out from under the "tail." The crayfish has often been found with the eggs in a similar condition. After a longer contact with sea water the liquid cement becomes, as is well known, very tough and inelastic, resembling chitin in its general appearance and properties.

these eggs vary in an arithmetical series. According to this law we should have the following:

Lengths (in inches)	8	10	12	14	16
Numbers of eggs	5,000	10,000	20,000	40,000	80,000

An examination of nearly a thousand cases shows that the first three terms of these series express very closely what actually occurs in nature. The data are not sufficient for carefully testing the fourth and fifth terms, but the largest number of eggs obtained suggests that there is a tendency to maintain this high standard of production, even at an advanced stage of sexual life. I believe that the law formulated above expresses very nearly the propagative powers of the lobster during the height of its sexual activity, though it is not to be supposed that the latter conforms uniformly to any arithmetical standard.

Fertilization is effected on the outside of the body of the females by means of sperm cells which the male discharges during copulation into a seminal receptacle. This is situated on the under surface of the female, on the middle line, between the basal segments of the third pair of walking legs (fourth pair of pereiopods) and may be opened with a knife by pressing the elastic sides of its median aperture. The peculiar grooved legs of the first segment of the tail of the male are probably inserted into this pouch in copulation, but nothing is definitely known of the process. The spermatozoa are discharged in masses, embedded in a translucent jelly, which is secreted in the glandular section of the seminal duct (by spermatophoral glands). These packages of sperm cells are the spermatophores. The sperm cells of the lobster, when they leave the testis, are provided with three long, slender processes, which radiate from the constricted neck of the cell and are perfectly rigid. It is possible that the function of these processes is to hold the sperm cells together in masses, in the spermatophores, until they are deposited in the seminal receptacle. Here the spermatophores become disorganized, and the sperm may then be easily pressed out in a semifluid, grayish mass. The rigid processes, which would be an impediment to the translation of the sperm, have become relaxed, bent up, and in some cases have disappeared. The way in which the spermatozoa reach and penetrate the eggshell and coöperate in fertilization is unknown.

A female lobster, which laid her eggs July 1, 1890, was kept under observation at the Fish Commission station at Woods Holl 335 days, until June 1, 1891, when the eggs had begun to hatch. The hatching of the eggs begins there in May and extends into July, but the greatest number are invariably hatched in June. I am informed by Mr. Nielsen, superintendent of fisheries in Newfoundland, that the eggs are laid there from the first week in August to the latter part of September,* and that the greater number are hatched from the 15th or 20th of July to the 20th of August. He also states that he has hatched some eggs in floating incubators as late as November.

On the southern section of the coast of Massachusetts the eggs are laid in June, July, and August. In some seasons the greater number are extruded during the latter part of June and the first part of July, in others in the last of July and the first of

*In the Annual Report of the Newfoundland Fisheries Commission for 1892, Mr. Nielsen states that "the principal spawning time of the lobster, in Newfoundland waters, extends over a period of from 25 to 30 days, from the 20th and 25th of July to the 20th of August," and also that "the ova on the majority of the berried lobsters do not begin to hatch in any considerable numbers before the first week in August."

August, and in others again in August. On the eastern coast of Maine the period of egg-laying probably extends into the first part of September and in Newfoundland and Labrador possibly even later. The exact determination of this period for different sections can only be made after more material has been collected. *

Development can be hastened by artificially raising the temperature of the water, but it is not yet known if any advantage would attend this practice. Bumpus has suggested in his paper on the embryology of the lobster (Journ. of Morphology, vol. V) that if the young were hatched by artificially raising the temperature of the water during the cold months of the year, and were then liberated into the ocean, they would be certain to escape the attacks of many summer enemies. It is almost equally certain, however, that the young lobsters would find new enemies in winter, and that the indiscriminate destruction by storms, which must be very great at all times, would then be enhanced.

The female protects her eggs to the best of her ability, and aërates them by her natural movements in the water, and also by the fanning motions of the legs of the "tail" to which they are fixed. When creeping over the bottom she is careful to keep her "tail" well folded. Owing to the unequal development of the individual eggs the hatching of a brood occupies upwards of a week. After hatching, the young receive no fosterage, but are immediately set adrift.

At the time of hatching, the embryo not only gets clear of the egg membranes, but molts and enters upon the first stage of its larval life. This first molting, which occurs at the time of hatching or shortly after it, is very critical, and the failure to accomplish it successfully is the cause of death to a considerable number which are hatched artificially at the Woods Holl Station. The young lobster, just hatched, is about one-third of an inch long. It differs in habits and structure from the adult, but like the latter its growth is characterized by a series of well-marked stages or molts. With each molt it casts off its old shell and assumes new characters until the fourth stage is reached, when the adult characteristics are fairly established. It still, however, swims at the surface, which it continues to do to some extent in the next stage. Its food consists of microscopical organisms which float in the water, and, as at earlier

---

* Since this was written, I have obtained some new facts which throw light upon the breeding habits of the lobster. Mr. V. N. Edwards sent me some lobsters from Woods Holl, Mass., December 4, 1893, and among these was an egg-bearing female, 12½ inches long, with eggs of a peculiar light yellowish green color. They were in the stage of development which closely follows the egg-nauplius, and probably had been laid about November 1. I have also recently received, through the kindness of Mr. F. W. Collins, a number of specimens of the eggs of the lobster from Maine, which establish beyond question the late breeding of the lobster on the coast of this State. In one individual from York Island, November 15, the eggs were but two or three days old, and in another specimen taken at Cranberry Isle, November 25, the egg-nauplius is barely outlined. In the latter case the eggs were probably extruded about November 10.

The breeding season of the lobster may now be said with certainty, to extend from June to November, and it is possible that it covers even a larger part of the year. This important subject is being carefully investigated, in order to ascertain what proportion of lobsters breed outside the months of June, July, and August, when, without doubt, the greatest number of eggs are laid.

This late breeding of the lobster undoubtedly accounts for much of the obscurity which has hung over its reproductive habits and may also explain the cases of the occasional hatching of lobsters out of season, which have been recorded. Statements have been formerly made that lobsters have been taken with freshly laid eggs in the fall and winter, but they could never be received, because they were not supported by a microscopical examination.

stages, it falls an easy prey to surface-feeding fish. The pugnacious instinct of the young larvæ, and their remarkable activity in killing and devouring each other, invariably attracts the notice of every one who watches them, and is an insurmountable barrier to the successful raising of them in small aquaria.

The young larvæ are markedly heliotropic. If the vessel of water containing them is placed in direct sunlight they immediately retreat to the opposite side of the dish, that is, in the direction of the light rays or away from the source of light. If the vessel is rotated through an angle of 180° the larvæ beat a similar retreat, and this may be repeated a great many times. It is thus possible that the young free-swimming stages of the lobster belong to that class of larvæ which leave the surface under the influence of sunlight and swim down to a considerable depth in the ocean, rising to the surface again at night, but it is not known if this is the case, and it may turn out that the young lobster both shuns and seeks the light, under different conditions. This is a point for future experiment to decide.* During the past five summers which I have spent at the U. S. Fish Commission station at Woods Holl we have used the towing net in various parts of Vineyard Sound on bright days, but have never succeeded in capturing the first and second free-swimming stages. It should also be added that but very few of these larvæ were taken at night, and that little towing was done after dusk.

I believe that the scarcity of the young larvæ of the lobster in the surface waters of Vineyard Sound during the summer is due to the fact that they are eaten up or otherwise destroyed. The survival of the young is probably much greater in outside waters than in those sheltered by the land, which are so often the haunts of surface-feeding fish. If this is the case, we may look upon the long free-swimming period of the larvæ as a means not only of securing a wide distribution, but also of a transport from the shore. On the other hand, it is probable that the young lobster, after its metamorphosis is finished, tends to move towards the shore, where it can find a secure hiding-place among the rocks in shallow water.

The fourth larva does not show the same kind of sensibility to light, and is frequently taken at the surface on bright days. I have also dipped from the surface in the daytime a few individuals in the third larval stage. At the fourth stage the larvæ have attained a length of about one-half inch, and have been taken in Vineyard Sound as early as June 29 and as late as August 12, but the majority reach this stage in from fifteen to twenty days. Larvæ have, however, been reared to the fourth stage in the laboratory in eleven days.

Larvæ are never taken at the surface after the fifth stage, from which we infer that they go to the bottom during this period and assume the habits of the adult. At this time the difference between the large claws is not marked, and the first pair of legs of the "tail" is represented only by miscroscopical buds. These and the remaining adult characteristics are gradually assumed during successive molts.

Very little has been known about the habits of young lobsters from 1½ to 3 inches long. I am indebted to Mr. M. B. Spinney for a valuable collection of small lobsters from the shores of Casco Bay and Small Point Harbor, Maine, which he has very carefully explored. Lobsters 3½ to 4 inches long were found quite often under rocks, where at *extreme* low tide there would be an inch or two of water, but it was only in

*See the paper by Dr. Loeb in this volume, pp. 65 to 68.

the rock piles, where the rocks were several tiers deep, that the smallest lobsters were found. The smallest which Mr. Spinney sent me were taken in Small Point Harbor, October 9 to 19, and measured 1·56 to 1·62 inches; they were all found deep among the rock piles, where no enemy could reach them, and were about four months old. When the lobsters attain a length of 3 to 4 inches they leave the stone piles and take refuge under rocks, where they dig a small hole, in which they lie concealed when an enemy approaches.

Yearling lobsters attain a length of at least 2 and possibly as great as 3 inches. The increase in length of individual larvæ at each molt is subject to considerable variation, as we should expect, but the average increase is strikingly similar to that seen in the adults. In either case the average increase in length at molting is from 12 to 13 per cent.

Placing the length of the lobster one year old at 2 inches, and knowing the average length of the larva at the time of hatching to be about one-third of an inch, or more accurately 8·5 mm., we can estimate the number of the molts the young must pass through during the first year of its life. Calculated on the basis of an increase at each molt of 13 per cent, the lobster, when it is 2 inches long must have molted sixteen times, and a 10½-inch lobster would have molted thirty times. This estimate is undoubtedly too great. It is, however, certain that during the first four months of its life the young lobster molts at least ten times. Beyond this period, I have not followed individual larvæ.

After reaching sexual maturity the female lobster does not, as a rule, molt oftener than once in two years. This is shown to be the case by the following facts. New-egg lobsters, taken in summer, are almost invariably hard-shelled, and since the majority of all lobsters molt in July, August, and September, the last shedding of such lobsters must have taken place ten months or a year before the time of egg extrusion. Furthermore, the eggs are carried for a period of at least ten months, during which, molting is out of the question. After the young are hatched, however, a molt follows in the course of a few weeks. When the ovary of a female which has hatched her young is examined, it is seen that the growing ova are in a very immature condition, and if their growth is studied at different times of the year it will be evident that they can not be extruded until the summer following the hatching of the last brood. We may therefore conclude that the sexual female lobster lays eggs and molts at intervals of two years, and that these biennial periods are one year apart.

I have known of only four or five cases of lobsters which have molted just before spawning. New egg lobsters with soft shells are, in fact, so rare that many intelligent lobstermen who have fished for a quarter of a century have never seen one.

As the lobster increases in age the molting period is undoubtedly lengthened, but it still takes place in individuals of extraordinary size, when one might suppose that the time of senescence had arrived.

The artificial propagation of the lobster is attended by difficulties which are not met with in dealing with the same problem in fish. The ripe eggs can not be pressed from the body and artificially fertilized and reared. They must be taken in a fertile and growing condition, when attached to the outside of the body of the female. The best incubator for her eggs is undoubtedly the lobster, and it would be better policy to leave matters with her, if she could be trusted in the hands of her greatest enemy, man. Unfortunately this is not the case, and a wanton destruction of lobsters "in berry" has taken place for many years. The eggs are illegally scraped off with a mitten or with the fingers, and thus allowed to perish by the millions, in order to send a few more lobsters to market.

The only ways open to secure an increase of the species are to protect the spawn lobsters, or to protect the immature until they have a chance to reproduce, or to take the eggs and rear them artificially. I will speak only of the latter expedient.

We have seen that the eggs are carried and carefully protected by the female for the space of ten or eleven months, and that the young receive no protection or fosterage from either parent, but swim near the surface, where they drift helplessly about, subject to indiscriminate destruction from storms and other causes. To maintain the species nature has made use of the common resource of producing a vastly greater number of young than can possibly survive under natural conditions. In order to keep the species at an equilibrium it would be only necessary for each pair to produce in the natural term of their life two adults to take the place of the parents. Since sexual females of the average size of 10½ inches produce 11,000 eggs at each reproductive period, there must be, in nature, a destruction of nearly the entire product. The survival of 2 in 10,000 would probably more than maintain the species at an equilibrium, and as the animal is markedly on the decrease the actual survival must be less than this.

It should be borne in mind that the number of eggs produced by lobsters exceeding 10½ inches in length increases very rapidly in proportion to the increase in length, according to the law already stated. A lobster 12½ inches long produces upwards of 20,000 eggs and a lobster 16 inches in length four times this number.

The length of 10½ inches is taken as about the average length of reproductive females at the beginning of their sexual maturity. The average length of mature females is undoubtedly much greater than this. Furthermore, every female which has reached sexual maturity reproduces once in two years. A large number, however, are destroyed before they have succeeded in rearing a single brood.

Taking these facts into consideration, and also the fact that the species as a whole does not appear to be maintained at present at an equilibrium, but rather to be actually on the decline, a little reflection will convince anyone that the destruction of the young of this species in nature must be much greater than that entailed by the survival of 2 in 10,000. Whatever survival there is under nature is a result of all the conditions of the environment, whether adverse or favorable, so that as long as the existing conditions remain the same, such as the persistency with which the fishery is conducted, the temperature changes, and those conditions which affect the supply of food, we may be sure that it is only necessary for each female in the course of her term of life, be it long or short, to bring two young ones to maturity in order to maintain the species at a uniform level.

We can readily see how even a slightly greater survival than this would be rapidly felt. Thus, let us suppose that there are at the present moment 50,000,000 lobsters in the waters of the Atlantic Ocean off the eastern coast of North America, and that the sexes are evenly divided. If each pair were to produce a pair to take their places, as the result of their sexual activity, or what is the same thing, if each female should produce two sexual individuals, there would be neither increase nor falling off in numbers. If every female were to produce three instead of two to take their places, the total number of individuals would be increased to 75,000,000, and if four were the product of each pair, the original number of lobsters would be doubled. If a similar increase were to take place in the human species famine and starvation would undoubtedly follow in many places, but so far as abundance of food is concerned it is certain that the lobsters could maintain themselves in far greater numbers than at present.

Reproduction is an expensive process, and the birth-rate among animals is therefore kept down to a minimum, which will provide against extinction by discriminate and indiscriminate causes. A high birth-rate is bad for the individual, but is good for the race, and is only resorted to when the chance of survival becomes very small. When the parents foster and protect the young, as is the case with birds and mammals, a very low birth-rate will suffice to maintain the species, but when these conditions are not present and the chances of reaching maturity are less and less assured, the birth-rate has in many animals been more and more increased, until in extreme cases the number of eggs produced amounts to tens or hundreds of millions.

The number of eggs or young produced by an animal is thus directly related to the habits of the animal in its early and adult stages. This is well shown within the group of the crustacea by a comparison of the common edible blue crab (*Callinectes hastatus*), or the lobster, with a deep-sea shrimp (*Parapasiphaë sulcatifrons*). The shrimp lays from 15 to 19 eggs, each one of which, according to Prof. S. I. Smith, measures 4·2 mm. (about one-sixth of an inch) in diameter, and is "approximately equal to a hundredth of the bulk of the animal producing it—a case in which the egg is relatively nearly as large as in many birds." The blue crab is said to lay 4,500,000 eggs, each of which measures only 0·28 mm. in diameter. We must infer that this shrimp has a short larval period; probably it hatches from the egg with all the external characters and habits of the adults. The blue crabs, on the other hand, or the young lobsters, leave the egg as immature forms, or larvæ, and have a number of weeks of free-swimming life, during which time they are subject to innumerable chances of destruction.

In the tapeworm we have an example of an animal which produces an extraordinary number of eggs, possibly reaching to tens or hundreds of millions. In some species the body is composed of as many as 3,000 segments, each of which is really an hermaphrodite individual which produces thousands of eggs. In order that any of this vast progeny may come to maturity, the eggs or embryos must be eaten by an herbivorous or carnivorous animal, and the flesh of this animal containing the encysted parasite must be eaten by still a second animal of a particular species, which forms the second host. It is thus evident that if the number of these eggs were few there would probably be no survival at all.

The production of a large number of embryos invariably means destruction to all but a very few, and if, in our attempts at artificial propagation, we place the young on the same footing which they would acquire in the ordinary course of nature, we can not expect that nature will treat them with any partiality.

The hatching and immediate liberation of the young of the lobster can be easily accomplished by the methods now in use, but it is clear that in order to sensibly affect the total supply, such a method must be conducted upon a very large scale. Allowing the survival of 2 individuals out of every 10,000 hatched, we would have to hatch 1,000,000 eggs to produce 200 adults, and 1,000,000,000 to produce 200,000. Since hundreds of thousands of lobsters are captured every month during the best part of the fishing season, it is evident that the annual supply can not be appreciably affected by this method when conducted upon its present scale.

If there were a loss of half or more of the product of eggs during the ten or eleven months while they are carried by the female, then we should increase the supply if we were able to take the eggs at an early day and secure the hatching of the entire number. As a matter of fact, however, unless the lobster is destroyed outright, she manages to preserve her eggs with remarkable success, and a very large proportion of the number originally laid are almost invariably hatched. In the case of many fish, on the contrary, which extrude their eggs into the water and leave them a prey to the elements and to enemies of all kinds, it will obviously tend to increase the species if we take the eggs, artificially fertilize them, and tide them over this early danger-period, as is now commonly done.

It is something to makê one blade of grass grow where none has grown before, and it is well to use every means in adding, in however small a degree, to the supply of lobsters on our coast, but what I wish to point out is that we may deceive ourselves in regard to the success of our efforts. The placing of free-swimming crustacean larvæ in the ocean is a very different thing from placing young fish in a pond or stream, since the lobster, while restricted in its adult state, in its larval stage is at the mercy of the winds and currents and surface-feeding animals, and subject to distribution over very wide areas. This arises from the fact that while in this condition it lives near the surface of the water.

If we could save 100 instead of 2 out of every 10,000 hatched, every million young would give us 10,000 adults, and every billion would yield 10,000,000 lobsters, capable of reproduction. If we could preserve 1,000 out of every 10,000 eggs hatched (which is, of course, far too much to expect), every million young would yield 100,000 adults.

In view of these facts, it seems to me that, before liberating the young lobsters, an attempt should be made to rear them until they have passed their free-swimming stages, that is to say, until they have molted five times, and are from three to six weeks old. One hundred lobsters in the fifth or sixth larval stage would be of more value than many thousands of the youngest forms, since, like the adults, they then live upon the bottom and are able, in a great measure, to protect themselves.

Whether such an attempt would be successful or not, could be decided only after very careful experiments. Some of the conditions necessary for success can be outlined now, such as (1) the need of relatively large inclosures, where overcrowding, which inevitably results in destruction to the young, can be avoided; (2) a supply of pure sea water, as free from sediment as possible; (3) a means of regulating the light admitted to the inclosures (possibly a needless precaution); (4) a means of retaining the young without injury, so they will not have access to the water outside until the proper time.

The first step to be taken is to study the habits of the young in ponds, or places where they can be watched during the day and night, and to ascertain how near the surface they maintain themselves at such times.

While we can not say with certainty that, in the present state of our knowledge, such experiments would suceed, I believe that enough is known to encourage us to make an attempt in this direction.