II. EXPERIMENTS IN LOBSTER REARING.

By George H. Sherwood.

Under normal conditions the eggs of the lobster are laid in July and August, and, attached to the swimmerets along the lower side of the abdomen, are carried by the female until they hatch, the period being usually ten or eleven months, but depending somewhat upon the temperature of the water. The hatching season at Woods Hole is ordinarily from the middle of May until the 1st of July; on the Maine coast it is a week or two later. Not all the eggs develop with the same rapidity, so that the young are probably widely distributed as the mother moves about.

Immediately after hatching the fry are free-swimming, but, as has been many times described, they undergo a metamorphosis and become in the course of three or four weeks full-fledged lobsterlings, possessing pinching claws, a hard shell, and other anatomical characters of the adult. At this stage there is a remarkable transformation in their disposition and habits. They become combative and pugnacious if disturbed, but retreat from danger, hiding in the seaweed, under stones, or even burrowing in the sand, their color harmonizing with their surroundings; their movements are active and vigorous, and in many respects they are capable of taking care of themselves.

Each of the three stages of early development is completed with the molting or shedding of the skin or shell. This process continues throughout the life of the lobster, becoming more infrequent, however, with increased age. During the larval stages, especially, it is a severe drain on the vitality, for a time leaving the fry exhausted and almost entirely helpless. These early metamorphoses are the most critical period in the life of the lobster, and the mortality at this time limits the effectiveness of planting newly hatched fry; moreover, it is during this enfeebled condition that the natural enemies are most active.

When the young lobster emerges from the egg it bears little resemblance to the adult either in external form or in habit. It swims aimlessly or floats at the surface of the water, occasionally seizes a particle of food, but apparently has no sense of danger. Its bright colors and activity render it conspicuous to the numerous predatory fishes, and currents carry it far from its native waters. It is safe to say that not more than one in a thousand reaches maturity. If the fry are retained in artificial inclosures some of the natural enemies are eliminated, but new agents of destruction arise.

Many years ago the cannibalistic tendencies of confined larvæ were noted, and were found to be especially strong during the molting periods. The young possess an almost insatiable appetite, and devour all weaker brethren within reach. From the exhaustion incident to molting, they settle to the bottom of the inclosure, collecting in masses at the lowest points, and the mortality from cannibalism and suffocation is astonishing. This loss is also materially increased by the attack of a vegetable growth (diatomaceous) which infests even the most vigorous and healthy fry. They are so thickly coated with these diatoms as to look like balls of chenille; they become logy and inactive, refuse food, and eventually settle to the bottom and die.

It is evident, then, that the mere hatching and distributing of a large number of fry can have little if any effect toward reestablishing the waning lobster industry. If, however, it were possible to carry the young lobsters through the critical larval periods to the stage when they assume the habits of the adult, and thus are able to protect themselves, there is reason to believe that a much larger percentage would reach maturity. It was, then, to the difficult problem of rearing the fry through three molts to the lobsterling stage that the special commission first turned its attention. In 1898 Doctor Bumpus began a series of experiments which covered a period of two years, and considerable preliminary work had been done when the special commission took up the problem. The difficulties referred to above were thoroughly understood. It should be remembered, also, that the hatching season covers at most a period of only eight weeks, and frequently three weeks' time or more is necessary to test the practicability of any experiments. Two failures mean the loss of a season.

In the experiments of 1898 and 1899 a variety of inclosures was tried—cars of wood and cars of wire netting, some with gravel bottom and some containing sand, glass aquaria and aquaria of stone, balanced aquaria and aquaria with automatic plungers, deep and shallow dishes of earthenware and glass, cars made of scrim cloth and deeply submerged, others of scrim and floating, and natural pools, both large and small, in which the tide rose and fell. These various receptacles were located in many places in the vicinity of Woods Hole; some were placed in the hatchery and fed by water from the pumps, others were placed in the "pools" and waters adjacent to the station, some in Eel Pond, some near Ram Island, and some even at Hadley Harbor, where there could be no question of the purity of the water. Neither the nature nor location of the receptacle, however, nor the kind of food, changed the course and outcome of the experiments. The fry seemed to thrive until about the time for the first molt; then there was a heavy mortality, which occurred again at the second and third molts. Rarely could more than half a dozen lobsterlings be obtained, whether the original number of fry was a score or a thousand.

Toward the close of 1899 there was a receptacle devised which promised more satisfactory results than all the others. This was a rectangular bag 8 feet long, 4 feet wide, and 4 feet deep, made of cotton scrim. The top of the bag was attached to a wooden frame floating on the surface of the water, while the bottom was kept submerged by means of sinkers. Since the bag was merely suspended in the frame, and its sides were not rigid, the fluctuations in the currents, due to tide or wind, kept the sides waving continuously back and forth with a kind of undulating motion. This motion of the bag created circulation and prevented the fry from sinking to the bottom. With only three of these bags about 100 lobsterlings were reared in 1899.

THE FIRST SEASON'S WORK (1900).

It had frequently been suggested, and the repeated failures in previous years seemed to indicate, that the environmental conditions at Woods Hole were not at all favorable for the development of young lobsters. To test the correctness of this view and to discover if possible a locality better suited to the needs of the fry, it was decided to try experiments with the same apparatus at various other localities on the New England coast as well as Woods Hole. The places selected were Orrs Island, on the Maine coast; Annisquam River, near Gloucester, Mass., and Wickford, R. I., on Narragansett Bay.

EXPERIMENTS AT WOODS HOLE.

Since the floating scrim bag had proved the most practical inclosure and promised interesting results, the special commission decided to adopt it for the first investigations in 1900, and early in May preparation for the work was begun at the Woods Hole station. Several large floats or rafts were constructed of heavy planking and buoyed with casks. Each float was about 16 by 12 feet, and was capable of holding 6 bags of the standard size (8 by 4 by 4 feet). Later larger bags were tried, some 8 by 6 by 4 feet and others 16 by 12 by 4 feet, but on the whole the small bags gave the most satisfaction. All the bags were made of the coarsely woven cotton scrim above mentioned.

The first experiment was started May 23, when 950 young (the first of the season) were taken from the hatchery and placed in the bag moored in the inner basin at the station. These were fed twice a day for five days with surface towings, which consisted mostly of copepods.[a] This did not prove a practical food, however, as it was often

[a] It was believed from the work in 1899 that the plankton was the natural food of the young lobster, and that it was the solution of the food question.

impossible to procure sufficient quantities. After the failure of the plankton supply, lobster liver was used as food and continued until the close of the experiments.

The fry began to molt on May 28, and on June 1, or ten days from date of hatching, the majority of those alive were in the second stage; but the mortality was considerable, only 486, or about one-half the original number, having survived. On June 5, 1 had reached the third stage, but it was sixteen days from the date of hatching before a majority had passed the second molt, and even greater mortality occurred during this period than during the first, only 36 passing successfully. Of these, 19, or 2 per cent of the original number, reached the fourth stage, their age at this time being twenty-five days. This percentage, small as it is, was encouraging, although it was the largest percentage secured at Woods Hole by the methods of 1900.

TABLE I.—*Details of lobster-rearing experiments at Woods Hole in 1900.* [a]

Experiment No.	Date of hatching.	Date of beginning of experiment.	Number of fry received.	Location of experiment.	Food.	Condition of fry when received.	First of second stage appeared.	Majority of second stage appeared.	First of third stage appeared.	Majority of third stage appeared.	First of fourth stage appeared.	Majority of fourth stage appeared.	Duration of first 3 stages.	Average temperature between hatching and fourth stage.	Total number reaching fourth stage.	Remarks.
													Days.	°*F.*		
1	May 20-23.	May 23	[b]950	Basin, Woods Hole Station.	Plankton and lobster liver.	Good..	May 28	June 1	June 5	June 7	June 12	(?)	25	60.	19	486 became IIs; 36 became IIIs.
2	May 25....	May 25	[c]10,000	Hadley Harbor.	.....do	...do...	June 4	June 6	June 8	June 10	(?)	June 20	25	59.7	15	Diatoms became very abundant. On June 7 there were 25 Is, 236 IIs, by actual count.
3	May 26-27.	May 28	30,000	Basin, Woods Hole Station.	Lobster liver.	...do...	...do...	...do...	June 9	(?)	(?)	(?)	(?)	(?)	(?)	On June 9 there were only 105 IIs and 5 IIIs, by actual count.
4	May 29....	May 30	[c]2,000	.....do	.....do	...do...	June 5	...do...	...do...	(?)	(?)	June 18	21	59.5	50	Diatoms abundant; 350 lobsters alive June 9.
5	....do.....	May 31	[c]2,500	Hadley Harbor.	.....do	Fair...	June 4	...do...	(?)	(?)	(?)	June 20	23	59.8	3	All IIs on June 9. Not visited from June 10 to 19.
6	June 6....	June 7	[b]1,000	.....do	.....do	Picked fry.	(?)	(?)	(?)	(?)	(?)	(?)	(?)	(?)	(?)	Fed only once. Not visited from June 10 to 19. Not one in bag on June 20.
7	June 1....	June 2	[b]1,000	Basin, Woods Hole Station.	Plankton only.	...do...	June 7	June 9	(?)	(?)	(?)	(?)	(?)	(?)	(?)	June 8, 150 alive—about half IIs. June 9, 73 alive; all IIs. June 11, experiment discontinued.
8	....do.....	...do...	[b]1,000	.....do	Lobster liver only.	...do...	...do...	...do...	(?)	(?)	(?)	(?)	(?)	(?)	(?)	June 8, 200 alive; about half IIs. June 9, 100 alive; all IIs. June 11, experiment discontinued.

[a] In the laboratory the fry in these various stages have been designated by the Roman numerals I, II, III, and IV, or as first, second, third, and fourth stages.
[b] Counted. [c] Estimated.

Average time from hatching to fourth stage=23+days.

From the foregoing table it will be seen that although the floating scrim bags were in many respects superior to other inclosures, they did not yield results of particular importance. It was proved, however, that as long as there was a current in the water the bags worked well, though at slack water or during calm weather, when the sides of the bag were motionless, the fry sank to the bottom, collected in masses, and perished by the thousand. Calms of only a few hours' duration were sufficient to cause the failure of many experiments.

EXPERIMENTS AT ORRS ISLAND, ME.

The work on the Maine coast was in immediate charge of Dr. W. C. Kendall, who began his work at Orrs Island, in Casco Bay, in the latter part of June. Floats were constructed and equipped with scrim bags like those used at Woods Hole. They were anchored in a "gutter" between Orrs Island and Baileys Island, where the rising tide brought in cold clear water from the open sea. It was believed that this would prove an admirable place for lobster culture, as the water was free from all contamination.

On June 23 a shipment of 500,000 fry was received through Capt. E. E. Hahn from the Gloucester hatchery. They were transported from Gloucester in the well of the schooner *Grampus* and arrived in good condition. The fry were distributed to three small bags and regularly fed with finely chopped lobster liver. Only 20 became lobsterlings. A second shipment of 500,000 was received about the middle of the season. They were nursed in one of the large bags (16 by 12 feet), and 59 finally reached the fourth stage. The work was closed August 6.

The history of these experiments is practically a repetition of that at Woods Hole. The fry seemed to do very well for a few days, then died in great numbers. In one bag containing 1,245 lobsters, actually counted, 75 per cent died the first week. Diatoms were abundant and infested all the young.

EXPERIMENTS AT ANNISQUAM, MASS.

A plant consisting of a float and large bag was constructed on the Annisquam River near Annisquam, and on July 6 about 100,000 fry were brought from the Gloucester hatchery in transportation cans. Both clam and lobster liver were used as food. During a gale on July 11 the bag was blown out of the water and most of the lobsters were lost, but with the few that were saved the experiment was continued until July 14.

The death rate was about the same as in the other localities, but diatoms were less abundant. The growth of the fry was more rapid than at either Orrs Island or Woods Hole. The first second-stage lobster appeared on the fifth day from date of hatching, and three reached the lobsterling stage on the tenth day.

The water at Annisquam is very shallow and is much warmer than in the open ocean. The temperature during the experiments ranged from 64° to 76° F.

EXPERIMENTS AT WICKFORD, R. I.

The Rhode Island Commission of Inland Fisheries generously accorded the use of its new floating laboratory at Wickford, R. I., for experiments at this point, and Dr. A. D. Mead, biologist of the State commission, gave special attention to the work. Much credit is due Doctor Mead for his energy and interest in the investigations and for the magnificent results obtained.

All the lobster fry used were transported on the steamer *Phalarope* from the hatchery at Woods Hole. The apparatus employed in rearing was the same as at Woods Hole and elsewhere—namely, scrim bags and floats. The first shipment, estimated at 2,000 fry, was received from the Woods Hole hatchery on June 1 and placed in small bags. They were fed with lobster liver and soft parts of clam, and grew rapidly. Although many died during a calm on June 3, 320 reached the fourth stage. The average interval before the appearance of the lobsterling in this experiment was 16 days, while at Woods Hole the average time was never less than 22 days.

TABLE II.—*Details of lobster-rearing experiments at Wickford in 1900.*

Experiment number.	Date of hatching.	Date received.	Number received.[a]	Food.	Condition when received.	First of second stage appeared.	Majority in second stage appeared.	First in third stage appeared.	Majority in third stage appeared.	First in fourth stage appeared.	Majority in fourth stage appeared.	Average time from hatching to fourth stage.	Average temperature between hatching and fourth stage.	Total number of fourth stage.	Remarks.
													°F.		
1	May 31	June 1	2,000	Lobster liver, clams.	Good	....	June 6	June 9	....	June 13	June 16	16 days	65	320	Calm on June 3. Bags changed at third stage; killed many.
2	June 8	June 9	2,000	Clams	.....do.....	....	June 14?	....	June 19?	June 21	June 23	15 days	66	212	On June 21, 230 in third and 77 in fourth stage.
3	June 10	June 11	30,000?	.....do	Fair	....	....	....	.....do..	June 22	June 24	13 days	68	598	Many dead when received. Last of third stage molted June 26—16 days.
4	....	June 14	50,000?	.....do	Many dead	....	June 19	June 21[b]	....	June 26[c]	June 27	....do..	68	186	Brought from Woods Hole packed in ice.
5	....	June 18	70,000?	.....do	Very poor .	June 21	....	....	June 24[d]	June 27	July 2	....do..	69	522	On June 24 big bag was very foul, and 1,420 of second and third stages were put in fresh small bag. These yielded 339 at fourth stage.
6	June 22	June 22	5,000	Lobster liver, clams.	Excellent .	....	....	....	....	July 2	....	10 days	70	2	On June 23 estimated 1,000 dead from stagnation. On July 2 nearly all dead.
7	....	June 25	20,000?	Clams	Good	....	June 29	....	July 4	July 5	July 8	12 days	72	119	Those put in big bag nearly all died. Only 2 reached fourth stage.
8	....	June 27	15,000	.....do	....	....	....	....	.....do..	....	July 9	....do..	72	350	Injured by violent wind, June 28.
9	....	July 2	....	....	....	....	....	....	....	July 9	July 12	10 days	72	748	On July 11—9 days—there were 165 at fourth stage. Stirred constantly from July 6 to July 12. First of fourth stage in 7 days.
10	....	July 5	....	Clams	Poor......	....	....	....	July 10[e]	July 11	July 14	9 days	72	319	All those in car died from crowding together. Bags stirred continuously. Hole in one bag let many out.
11	....	July 11	....	.....do	Very poor[f]	....	....	....	July 16	July 4	July 23	11 days	73	49	This set was very poor, and received little care.

[a] Estimate. [b] 10 per cent. [c] 25 per cent. [d] Fresh bag. [e] Very clean. [f] Mostly dead.

Average time from hatching to fourth stage = 12 + days.
Total number of fourth stage = 3,425.

The short season allowed time enough for only eleven experiments, but with the interesting result that 3,425 fry were reared to the lobsterling stage. Compared with the meager results of other experiments, the aggregate of which was less than 400 lobsterlings, these figures were most satisfactory.

Many of the usual difficulties of the problem were encountered at Wickford, but in a lesser degree. The mortality at the molting time, particularly the first and second molt, was considerable. Cannibalism was noticeable, especially where large numbers were confined in small inclosures. The majority of the fry became infested with a profuse growth of diatoms, and it was necessary to change and clean the bags frequently, sometimes as often as two or three times in a week. Nevertheless, the facilities of the Wickford station, together with the physical and biological conditions, seemed to render the place especially suitable for lobster culture. The floating laboratory of the State commission was equipped not only with scientific instruments and work tables, but with sleeping quarters for two or three persons. Thus, by separating the men into watches, it was possible to keep the fry under continuous observation, the importance of which was later proved. The natural condition of the water was also favorable to the young lobsters. Mill Cove, where the plant was located, is a small inlet on the west side of Narragansett Bay, about 9 miles from Newport and the open sea. It is practically landlocked, and the severest storms have little effect. The water is considerably warmer, and its density somewhat lower, than in the vicinity of Woods Hole. This higher temperature of the water, together with its protected location, makes Mill Cove and many other portions of Narragansett Bay natural nurseries and feeding grounds for hosts of marine organisms, and at certain seasons of the year the waters are literally alive with millions of larvæ and eggs of clams, oysters, starfish, etc. As such organisms probably constitute the natural food of young lobsters, the importance of a rich plankton is readily understood.

Doctor Mead's continued observation of the fry led him to the conclusion that the secret of rearing young lobsters was constant agitation of the water, so that the fry could not gather on the bottom. In the scrim bags this condition existed only when there was a light wind or gentle current. High winds frequently blew the bags out of the water, and a strong current usually forced the fry against the sides or bottom of the bag, and the results were as disastrous as during the calm.

To test the correctness of his conclusion Doctor Mead decided to stir the water continuously and note the result. For this purpose the working force in the laboratory was divided into watches, and from July 6 to July 12 the water in experiments No. 9 and No. 12, Table II, was stirred with an oar day and night. The results were convincing, experiment No. 9 alone yielding 748 lobsters, or more than had been reared in the combined efforts at all other localities. Unfortunately the close of the season interrupted further experiments along this line.

SUMMARY OF THE RESULTS OF THE WORK OF 1900.

The first year's work of the special commission developed the following facts:

1. Conditions at Woods Hole, whether near the hatchery or at Hadley Harbor, were unfavorble, and the floating scrim bags proved in this locality as inadequate for practical lobster culture as other inclosures had proved.

2. Environmental conditions at Orrs Island and Gloucester were not more suitable for the growth of young lobsters than at Woods Hole.

3. Lobster fry thrive much better at Wickford than at Woods Hole, Orrs Island, or Gloucester; just why is not fully known, but there can be little doubt that the higher temperature of the water, its relative calmness, and the great abundance of natural food were prime factors. The rate of growth also is a matter of great importance, for, other things being equal, the shorter the critical period the greater the chance of survival. For example, and as already stated, at all the stations the fry became covered with diatoms, which are both directly and indirectly responsible for a great amount of the mortality. When the shell or skin is shed, the fry get rid of this pest, and are clean until a second infection. Hence if the young lobsters grow rapidly they shed before the diatoms become a serious incumbrance. This was demonstrated at Wickford, where the average time required for a young lobster to reach the lobsterling stage was 12 days instead of 22, as at Woods Hole.

4. The temperature of the water, as is to be expected, has a marked influence on the rate of growth. The coldest water was found at Orrs Island, ranging from 57° to 63° F., and the critical period was from 25 to 26 days. The temperature at Woods Hole was only slightly higher, and the fry developed in from 22 to 25 days. At Wickford the water averaged 5° to 10° higher than at Woods Hole, and the average developmental period was only 12 days. In the first experiments the duration of the first three stages was 16 days, average temperature 65° F.; in experiment No. 10, with an average temperature of 72° F., it was 9 days. (See Table II.) At Annisquam the water was very warm, sometimes reaching 76°, and lobsterlings were obtained in 10 days.

5. Proper food and feeding is a problem in itself. Naturally the lobster liver used in the Woods Hole, Orrs Island, and Annisquam experiments was not practicable, and although the fry seemed to thrive on the soft clam, this food sank to the bottom, where it decayed and

fouled the water. The subject of food and the method of feeding will be discussed later.

6. Constant agitation of the water is the most important factor in lobster rearing, and Doctor Mead's fortunate discovery of this fact marked the course of future experiments.

WORK DURING 1901.

Since it appeared from the investigations of 1900 that young lobsters thrive better at Wickford than at other localities in New England, the special commission decided to abandon for the season its other stations and concentrate its energies at Wickford. Again the Rhode Island Commission of Inland Fisheries most cordially cooperated with the government, offered the use of its floating laboratory with its equipment, and facilitated the carrying out of the experiments in every way possible.

The application of the most important result of the preceding year (1900) was the first consideration. Constant agitation of the water, very different, however, from that obtained in the McDonald hatching jar, was a prime necessity, and the commission decided to provide some mechanical device to replace the laborious and unsatisfactory method of stirring used in the test experiments.

The last week in April the writer went to Wickford for the purpose of devising and constructing an apparatus suitable for the work. Some of the mechanical difficulties were peculiar, and of the devices suggested some modification of a propeller movement seemed most feasible. The floating laboratory or house boat proved an admirable place for constructing the apparatus. The house boat, with a house at each end, was a kind of catamaran, consisting of two large pontoons, 58 feet long and 4 feet wide, placed 8 feet apart. The pontoons and the two houses inclose a "well" 8 feet wide and about 25 feet long. The boat possessed the necessary rigidity to protect the apparatus from the effects of storm or wind, while the houses furnished shelter for the engine and attendants.

The rearing device, a detailed description of which is given below, consisted of a series of cylindrical scrim bags supported in a wooden frame. In each bag, near the bottom, was placed a two-bladed fan or propeller, the vertical shaft of which was connected with a horizontal shaft on the deck of the house boat. This shaft was geared to a gasoline engine, which furnished the power. Rotation of the fans created a current of water from the bottom of the bag toward the top.

The apparatus may be described as consisting of two parts:

(*a*) The car or bag for holding the fry, with its supporting framework;

(*b*) The mechanism (propeller, belts, shafting, etc.) for stirring the water.

(A) THE CAR OR BAG.

The requirements for the inclosure were as follows:

1. It should allow for abundant circulation of the water from the outside.
2. It should have as few corners and pockets as possible.
3. It should be fastened so that it could be readily changed and cleaned.
4. It should be rigid enough to keep its walls out of the propeller.

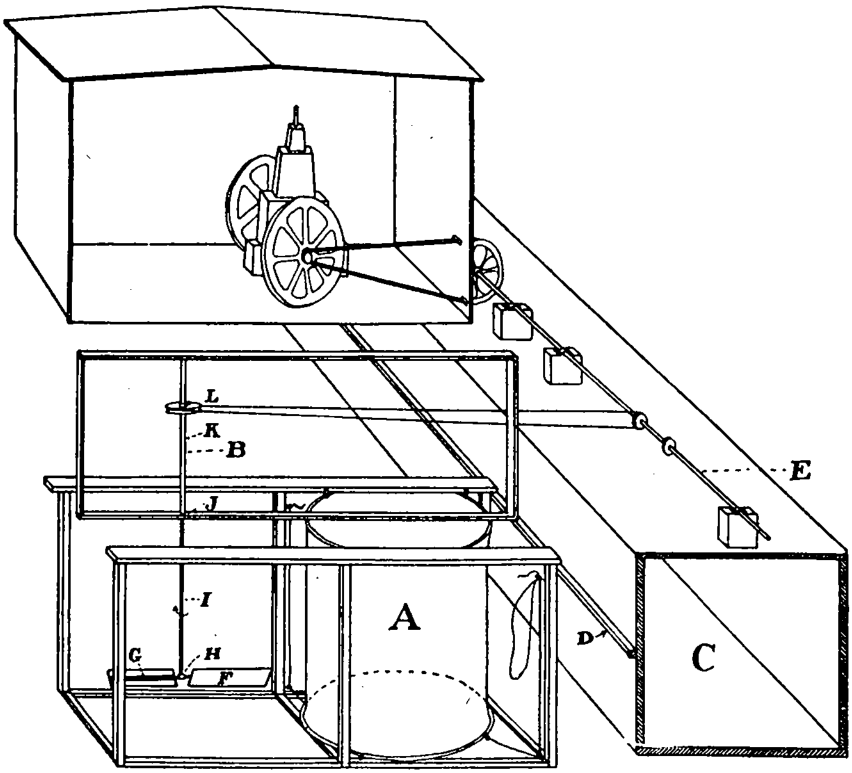
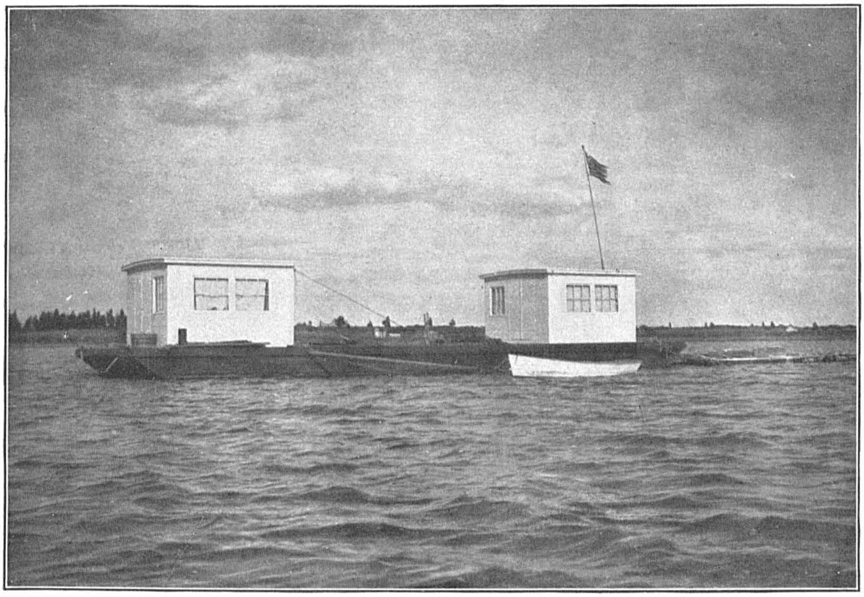
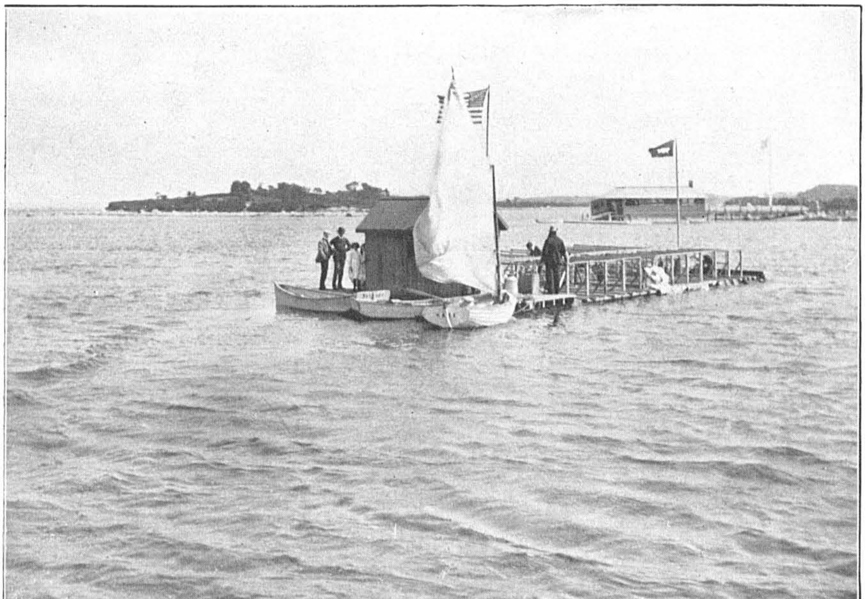


Diagram of apparatus used in hatching and rearing lobsters.

Material.—Galvanized-wire netting was first suggested as the most suitable material for the car. This was soon abandoned because of its tendency to break, and because it was feared that the current of water might carry the young lobsters against the rigid metal and fatally injure them. The cotton scrim, such as was used in the experiments of last year, was considered more serviceable, as it would permit free circulation, was comparatively inexpensive, and could be easily cleaned. The only difficulty connected with its use was keeping the cloth free from the propeller blade.



FLOATING LABORATORY OF THE RHODE ISLAND COMMISSION OF INLAND FISHERIES AT WICKFORD, R. I., WHERE EXPERIMENTS OF 1901 WERE CONDUCTED.



REARING PLANT USED IN EXPERIMENTS IN 1902, AT WOODS HOLE.

Size and shape of bag.—From this material was made a cylindrical bag, a little more than 3 feet in diameter and 40 inches deep, the latter being the width of the goods as it comes from the factory. By making a sack this size, it was necessary to have only two seams, one up the side, the other around the bottom of the bag. This did away with the pockets and corners which were so troublesome in the square bags the year before. Along the bottom seam on the outside of the bag was sewed a piece of drilling 4 inches wide, and this was turned over a wooden hoop (child's rolling hoop), which was a little greater in diameter than the diameter of the bag. The hoop kept the bottom taut, and also furnished a strong attachment for the ropes necessary to hold the bag in place. In a like manner another hoop kept the mouth of the bag open.

The support of the bag.—A cleat runs lengthwise on the inside wall of each pontoon 6 inches above the water, and at intervals of 4 feet on the cleats 2 by 6 inch planks were laid across the well and securely fastened. To the under side of each plank were nailed three posts 4 feet long, one at each end and one in the middle (see diagram). To make the frame still stronger, the submerged free ends of the posts hanging from consecutive planks were joined together by scantling pieces. Brass screw eyes were fixed in the bottom of each post.

The bag was held in the frame just as the bowl or pocket of a fish pound is secured. The top was fastened with strings to the planks above (see diagram). The bottom was drawn down and the sides of the bag stretched by means of "down-hauls", or ropes, which roved through the screw eyes in the post. In this manner the bag was held so securely that there was little danger of the wind or tide carrying the cloth into the propeller, which was suspended in it. At the same time it was a very simple matter to remove the bag whenever desired.

(B) THE STIRRING MECHANISM.

To keep the fry from settling to the bottom of the bag, a simple two-bladed fan, similar to those so often seen in restaurants for circulating air, was suspended in the bag and revolved slowly. The blades, F, of the fan (see diagram) were 14 inches long and 5 inches wide, made of cypress, and screwed firmly to a piece of maple, G, one end of which fitted snugly into the ⅜-inch tee, H. The blades were then set at angles and opposite each other. The shaft of the fan was made of two pieces of galvanized gas pipe 3 feet long and of different sizes. One end of the lower half (⅜-inch pipe) was screwed into the tee and the other was joined to the upper half (¾-inch pipe) by a reducing coupling. The whole was then suspended in the bag by means of some 2 by 3 inch pieces, as shown in the diagram, the reducing coupling serving as the bearing for the shaft. To make the fan turn more easily, an iron washer was sunk in the frame, and the coupling revolved on this. When the fan was in position, the blades were about 6 inches from the bottom and about the same distance from the sides of the bag. An 8-inch galvanized sheave, L, was put on the upper end of the shaft and fastened with a set screw. A belt from the main power shaft, E, on one of the pontoons, to this wheel transmitted the power for revolving the shaft. It was found that the strength of the current could easily be controlled by changing the angle of the blades.

The power for rotating the fan was supplied by a Fairbanks & Morse gasoline engine of 2½ horsepower, which was placed in one of the houses of the boat and connected by a belt with a large driving wheel on the main power shaft. This shaft was set up on the deck of one pontoon and extended the length of the well. At intervals on the shaft corresponding to the positions of the fans, small 3½-inch wheels were fastened with set screws. Each of these wheels was connected with the driving wheel of the fan by a rope belt.

The most troublesome part of the mechanism was the belting. All the machinery except the engine was exposed to the weather. No belting was found that would stand the weather and not stretch and shrink, and finally a loose-laid 1-inch rope called "Russia purse line" was used, as this seemed least affected by dampness. The annoyance from the slacking and shrinking was overcome in two ways. The belts could be lengthened or shortened several inches by moving the sheave up or down on the shaft of the fan; when this was not sufficient they were run over spools which were fastened to the supporting posts and which acted as third pulley. The fans revolved at the rate of 15 to 20 turns per minute, and produced a current which took all the material from the bottom, but still allowed comparatively uniform distribution of the fry in the upper part of the bag.

OBJECT OF THE WORK.

The chief object of the investigations in 1901 was not to see how large a number of lobsterlings could be reared, but to determine how large a percentage could be carried through successfully to the fourth stage by means of stirring the water. From the data thus secured the value of the principle could be judged and the wisdom of its application on a large scale determined. Observations were also continued on the habits of the fry in the several stages, the effect of temperature and light, food, and the best method of feeding.

Fourteen experiments were made in all, of which two were total or partial failures through accidents to the apparatus, while in the last experiment the stirring was not continued after the fifth day. The complete data of the experiments are given in Table III. Nearly 9,000 lobsterlings were obtained and either released in the adjacent waters or kept in jars for future observation. In no instance, excluding the experiments interrupted by accident, was the percentage of fry reaching the lobsterling stage less than 16.32, while in one experiment it was 50.60. The average percentage was 27.25.

TABLE III.—*Details of lobster-rearing experiments in 1901.*

Experiment No.	Date of hatching.	Date of beginning experiment.	Number placed in bag.	Age when first fourth stage appeared.	Average age when fourth stage appeared.	Number in fourth stage.	Reared to fourth stage.	Remarks.
							Per cent.	
1	June 12....	June 14	....	11 days.	12 days...	1,418	....	These were not counted in the early stage, the lot being stock for other experiments.
2	.....do.....	June 12	5,000	....	12-13 days	1,110	20.22	Fry taken from lot No. 1.
3	June 13....	June 13	....	....	13 days...	1,336	....	
4	June 10....	June 11	1,000	13 days.	15 days...	347	34.70	Hatched at Woods Hole and transferred.
5	June 13-15.	June 14	2,500	...do...	.....do....	408	16.32	
6	.....do.....	June 15	2,500	...do...	.....do....	436	17.44	
7	.....do.....	June 17	2,500	...do...	.....do....	1,004	40.16	These were from 2 to 3 days old when experiment began.
8	June 20....	June 24	5,000	....	....	....	....	Experiment interrupted by an accident.
9	.....do.....	....do...	5,000	10 days.	11 days...	971	19.42	These were 4 days old when experiment began; the percentage would have been higher if IVs had been promptly removed as soon as hatched.
10	.....do.....	June 25	5,000	...do...	.....do....	947	18.94	These were 5 days old when experiment began.
11	June 26 or 27	June 28	....	....	....	476	....	From Woods Hole.
12	June 26....	....do...	2,500	9 days..	10 days...	19	.76	The experiment a failure through accident to bag.
13	.....do.....	....do...	1,000	...do...	.....do....	506	50.60	From Woods Hole.
14	July 1 (?)..	July 2	1,134	....	....	95	8.38	As this was the last lot and in poor condition, the agitation was not continued after the first 5 days.
	Total.	....	....	....	....	8,974		

With the exception of experiments No. 4, 11, and 13, all of the fry were hatched at Wickford.

The figures given in Table III are based on actual count. Compared with the experiments of 1900, which represent the best previous efforts, the results of the stirring apparatus were certainly satisfactory. If with this comparatively simple and inexpensive device it is possible to plant as lobsterlings 20 per cent of the product of the hatchery, there is every reason to believe that much could be accomplished for a declining industry.

When the season's work was planned, it was the intention to transport fry for the experiments from the Woods Hole hatchery by boat, as had been done in 1900. Circumstances prevented the detail of a proper boat for this work, however, and it was necessary to ship the fry in tin transportation cans by rail, a journey which occupied five or six hours and left the fry which survived the trip in a weakened and precarious condition. Transportation thus became a serious question, and it was decided to collect egg-bearing female lobsters and attempt hatching in the rearing apparatus. Several "berried lobsters" were brought from Newport, the eggs stripped in the usual manner and placed in one of the scrim cylinders, and the propeller was adjusted to create a current strong enough to lift the eggs from the bottom.

The results surpassed our expectations, for although constructed primarily for rearing and brooding the fry, the stirring apparatus proved admirably adapted for hatching the eggs, and as a hatching device merely was decidedly superior to the McDonald hatching jar. In the latter the eggs and young lobsters are subjected to a protracted mauling. If examined under a microscope, many are found to be mutilated, appendages are missing, a gill torn off, or an eye indented. Such a lobster must be seriously handicapped from the very beginning. The fry hatched in the bags are not subject to such violent treatment, are probably stronger and more healthy, and their chances of living are materially increased. The bags were of a convenient size and could easily be removed and cleaned. To separate the fry from the eggs all that was necessary was to stop the fan, when the eggs sank quickly to the bottom, leaving the active fry swimming near the surface. These could be easily removed, and expeditiously transferred to the rearing bags.

SUMMARY OF RESULTS OF THE WORK OF 1901.

1. The value of artificial agitation of the water was established.
2. It was proved by experiments that from 16 to 50 per cent of the fry could be carried through three molts.
3. It was shown that apparatus of large capacity could be built and maintained at small expense.
4. The rearing apparatus was found to be also a most efficient hatching apparatus, far superior to the McDonald or Chester jars.
5. Data for guidance of future experiments were secured:

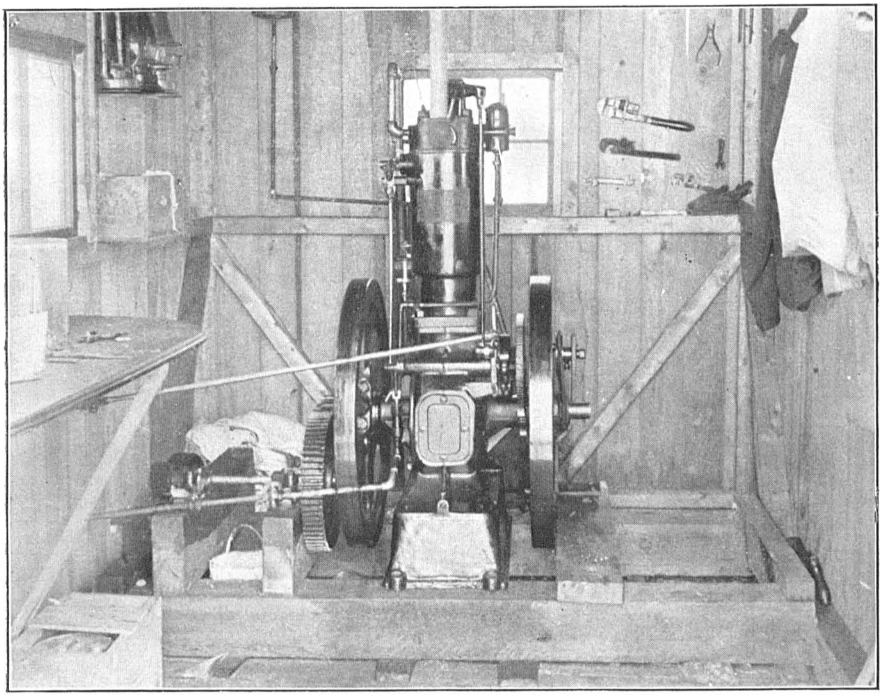
(*a*) It is important to remove the lobsterlings from the brooding bags as fast as they appear. Overcrowding the bags with fry does not give good results.

(*b*) Careful attention must be given to the kind and amount of food.

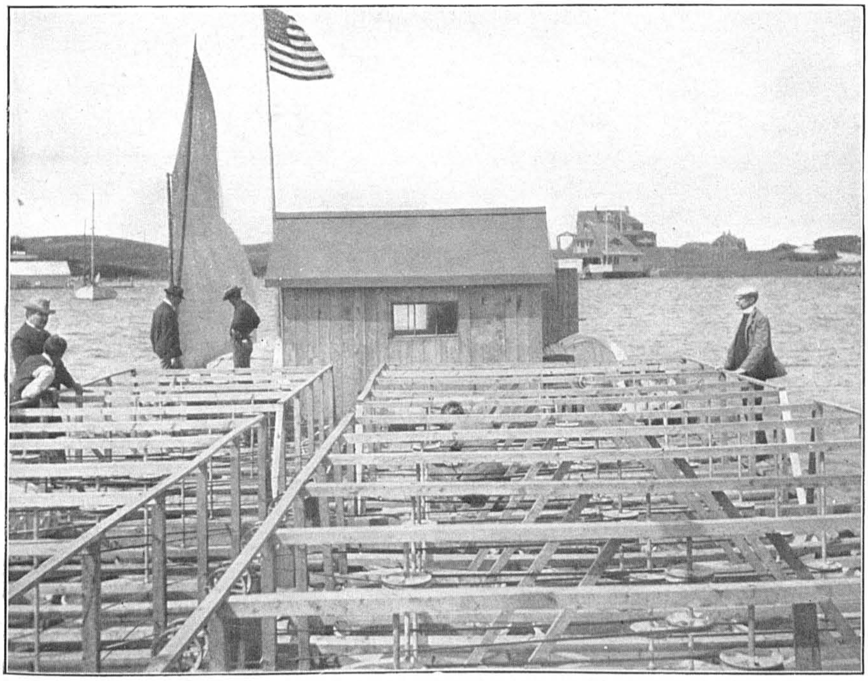
WORK DURING 1902.

Before closing its work, the special commission wished to learn, if possible, whether agitation of the water would prove equally successful in other localities. It was also desired to make experiments on a larger scale in order to test the adaptability of the apparatus.

Although, on account of the greater abundance of lobsters, several places on the Maine coast or near the Gloucester hatchery seemed more favorable for the location of a plant, it was decided to establish it at Woods Hole, for the following reasons: (1) Owing to the prox-



INTERIOR OF ENGINE ROOM OF PLANT USED IN 1902, AT WOODS HOLE.



VIEW OF REARING PLANT AT WOODS HOLE, SHOWING METHOD OF TRANSMITTING POWER TO THE FANS.

imity of the machine shops and scientific laboratory of the Woods Hole station, the cost of construction and maintenance would be less than elsewhere. (2) The physical conditions were better understood there than elsewhere. (3) It seemed probable that the temperature conditions would more nearly approach those at Wickford than would be the case farther north. (4) It was desirable to compare the results of these experiments directly with results obtained in earlier experiments. (5) It seemed desirable to test what several investigators had frequently claimed, and what our previous experiments seemed to indicate, namely, that the biological conditions at Woods Hole were extremely unfavorable for the development of young lobsters.

The investigations of 1902 were placed in charge of the writer, who began the work of constructing apparatus the last week of April.

THE APPARATUS.

In order that the comparison of results might be more satisfactory, it was decided to employ essentially the same stirring mechanism and bags as were used at Wickford in 1901.

The plant consisted of a strong raft or float supporting 60 cylindrical scrim bags, in which were suspended two-bladed propellers, as at Wickford, and these were rotated by a small gasoline engine. On the stern of the raft was built a small house which protected the engine and served as a laboratory and shelter for the attendants.

The construction of the bag and the propellers was the same as in the Wickford experiments. The raft was made by fastening together two spars 50 feet long and 2 feet in diameter, with four 6 by 6 timbers 25 feet long. To give added strength and buoyancy, a third spar was securely bolted between and parallel to the others, but a little to one side of the center of the raft.

Thus the three spars, the platform, and the forward timber inclosed two "wells" of unequal size, one 40 feet by 7½ feet, the other 40 feet by 11½ feet. These wells were cut up into a number of smaller ones by planks placed across the spars at intervals of 3½ feet. To the under side of these planks were nailed two posts of 2 by 3 stock 4 feet in length, and a third piece of 2 by 3 as long as the width of the "well," connected the lower ends of the posts. The planks and posts were securely spiked to the spars and formed a firm and rigid support for the bag. There was space for 60 bags, or five times as many as had been used at Wickford. Across the stern of the raft was built a plank platform 25 by 10 feet, which served for support of the engines and the house.

The power for rotating the fans was furnished by a Fairbanks & Morse 2½-horsepower gasoline engine, as at Wickford, and was transmitted to the main shaft, which ran the length of the middle spar of the raft, by a system of gears which reduced the speed to the required revolutions. From the main shaft the power was distributed to the individual fans by belts, in a manner not materially different from that described for the Wickford apparatus.

The rearing plant completed, the engine was started June 3, and continued to run day and night until the close of the experiments on July 19. In order to have water free from contamination, the plant was removed from the "pool" at the station and anchored in the edge of the tide near Devils Foot Island. The depth of the water was 15 feet, and it was thought that the current through the Hole would bring a large amount of natural food into the bag. The current was too strong, however, and the dirt and débris suspended in the water were deposited on the bag and soon prevented circulation. Therefore, on June 9 the plant was towed to the head of Great Harbor and anchored in 8 or 10 feet of water. The conditions proving more favorable here, where they more nearly approached those at Wickford, the apparatus was kept at this place until the close of the season.

The efforts to rear and plant a large number of lobsters were not as successful as had been hoped; nevertheless, fully 4,000 were brought to the fourth stage, and though the number seems small, and could doubtless be considerably enlarged during a second season, from present experience and observation upon the habits of the young, and in view of the enfeebled condition in which they ordinarily leave the McDonald jar, the claim is unhesitatingly made that 4,000 lobsterlings have the replenishing value of many million fry. The combined previous efforts in rearing at Woods Hole had resulted in raising not more than 500 lobsterlings. Compared with this, the results of these experiments are magnificent.

TABLE IV.—*Details of lobster-rearing experiments at Woods Hole in 1902.*

Experiment No.	Date of hatching.	Date of beginning of experiment.	Number of fry.	Source of fry.	Age of first IVs.	Experiment closed.	Number of IVs.	Percentage.	Food.	Remarks.
1	May 16-19	May 19	3,000	Woods Hole hatchery.	25 days.	(?)	11	0.36	Lobster liver and clam	Occasionally stirred. On May 26 3,000 in bag. First II on ninth day. Diatoms abundant. Retained in pool until June 4.
2	May 23-27		(?)	....do	(?)	June 14	38	(?)	....do	Miscellaneous lot. Kept in bags during construction of raft. Diatoms very abundant.
3	June 4	June 6	2,500	....do	(?)	July 1	39	(?)	....do	
4	June 5-6	...do	2,500	Hatched in bag	(?)	(?)	0	(?)	Lobster liver	On June 16, 341 IIs, badly infested with diatoms.
5	June 3	...do	(?)	Woods Hole hatchery.	17 days.	June 23	118	(?)	Clam, menhaden	
6	June 4	...do	a14,000	....do	(?)	(?)	125	(?)	Clam	
7	June 5	...do	(?)	....do	(?)	June 24	46	(?)	....do	Fed irregularly and scantily.
8	June 6	June 7	a148,000	....do	17 days.	June 23	47	(?)	Clam and lobster liver	Poorly fed. Many diatoms.
9	June 7	...do	(?)	....do	(?)	June 25	83	(?)	Lobster liver	On June 25, about 200 IIIs put in with miscellaneous lot.
10	....do	June 8	1,000	Rearing bags	(?)	(?)	0	(?)	Clam and lobster liver	Poorly fed.
11	June 8-9	June 10	2,500	....do	14 days.	June 26	302	12.08	Clam and menhaden	Light excluded. Well fed.
12	June 9-10	...do	2,500	Woods Hole hatchery.	12 days.	June 28	200	8.00	Lobster liver, clam, menhaden.	Do.
13	....do	...do	a10,000	....do	...do	June 29	725	(?)	Clam, menhaden	Do.
14	....do	...do	a2,500	....do	12-14 d'ys	June 28	525	21.00	....do	Do.
15	....do	...do	2,500	....do	...do	June 27	306	12.24	....do	Do.
16	June 10	June 11	(?)	....do	14 days.	July 1	60	(?)	....do	
17	....do	...do	a2,500	Rearing bags	(?)	June 24	144	(?)	....do	Fry badly infested with diatoms at beginning of experiment.
18	....do	...do	a2,500	....do	(?)	June 28	35	(?)	....do	
19	June 11	June 12	(?)	Woods Hole hatchery.	(?)	June 25	0	(?)	Clam	A bad lot. Many diatoms. Poorly fed.
20	June 12	June 13	a2,500	....do	16 days.	June 30	82	(?)	Clam, menhaden	
21	....do	...do	(?)	....do	12 days.	July 2	334	(?)	Clam	Many lost during storm of June 26.
22	(?)	(?)	(?)	(?)	(?)	June 21	65	(?)	(?)	Many lost during storm of June 26.
23	June 12-14	June 15	a5,000	Rearing bags	10 days.	June 30	136	(?)	Clam, menhaden	
24	June 12-15	June 16	(?)	....do	...do	June 25	75	(?)	Menhaden, clam	
25	(?)	...do	(?)	....do	10-12 d'ys	June 28	76	(?)	Menhaden	
26	June 17	June 18	(?)	Woods Hole Hatchery.	(?)	(?)	(?)	(?)	(?)	Failure through storm of June 26.
27	....do	...do	(?)	(?)	10 days.	July 3	141	(?)	Menhaden	Many lost in storm of June 26.
28	June 16-20	June 20	(?)	Rearing bags	(?)	July 1	6	(?)	....do	Do.
29	....do	...do	2,500	....do	12 days.	July 4	2	(?)	....do	Well fed. Carefully handled.
30	July 12-19	...do	a2,500	....do	(?)	(?)	(?)	(?)	(?)	A killifish entered the bag and ate the fry.
31	June 20	June 21	a300,000	Woods Hole Hatchery.	(?)	(?)	(?)	(?)	(?)	Light excluded. Many reached third stage and then died. Very few diatoms.

a Estimated.

TABLE IV.—*Details of lobster-rearing experiments at Woods Hole in 1902*—Continued.

Experiment No.	Date of hatching.	Date of beginning of experiment.	Number of fry.	Source of fry.	Age of first IVs.	Experiment closed.	Number of IVs.	Per centage.	Food.	Remarks.
32	(?)	June 22	(?)	(?)	(?)	June 29	1	(?)	Menhaden	Diatoms abundant. Fry well fed.
33	(?)	(?)	[a]3,500	Rearing bags	(?)	(?)	0		do	Failure through storm of June 26.
34	June 20	June 21	[a]8,000	do	(?)	July 4	5	(?)	do	Well fed.
35	(?)	(?)	[a]3,000	do	(?)	June 30	21	(?)	do	This bag used for miscellaneous lot.
36	June 22	June 23	3,000	do			1	(?)	do	Failure through storm of June 26.
37	June 21-23	June 24	[a]7,500	do	(?)	(?)	0	(?)	do	A very few became IIs. Failure through storm of June 26.
38	(?)	(?)	3,000	do			0	(?)	do	Fry were in fine condition. Well fed, but none became IIs.
39	June 25-26	June 27	5,000	do			0	(?)	do	A few alive July 4, mostly IIs, with "mold" spots.
40	do	June 26	2,500	do	(?)	(?)	0	(?)	do	Well fed. No diatoms. Some reached third stage. All died.
41	June 25	June 27	3,000	Woods Hole Hatchery.	(?)	July 8	0	(?)	do	

[a] Estimated.

From Table IV it will be seen that the results of the experiments varied greatly during the season. First was a period of partial failure, followed about the middle of the season by one of success, while practically all the experiments from June 25 to the close were total failures. It should not be forgotten, however, that in the early experiments at Woods Hole it was unusual to rear more than 1 per cent of a given number of lobster fry to the fourth stage, no matter what kind of inclosure was used or where the experiment was located. In the experiments of 1902, 10, 12, and even 20 per cent of the original number of fry were successfully carried to the lobsterling stage, and these figures are based on actually counted fry, not on estimates.

One cause attending at least the early unsatisfactory results of these experiments was the lack of sufficient food. Great difficulty was experienced in finding a food which the fry would eat and which could be obtained in sufficient quantities to make it practicable. Until the solution of this problem (which is discussed fully elsewhere), the young lobsters were poorly nourished, growth was retarded, parasites flourished; and these conditions were aggravated by moving the plant from place to place. For two or three weeks after the time the food supply became plentiful, the fry in all the experiments grew rapidly and were strong and healthy. In one week more than 2,000 lobsterlings were taken from six bags, one bag alone yielding 725.

The experiments of the latter part of the season, however, were most disappointing. Awnings had been stretched over the bags, and it was found that by excluding the direct sunlight the diatoms were greatly reduced in numbers, but even the disappearance of this enemy apparently had no effect in decreasing the mortality. The development of the fry was different from that heretofore observed. They grew well, and reached the third stage in an apparently strong and healthy condition; they were free of diatoms, were vigorous and active, and fed well; but within a day or two all had died, and the cause of this mortality could not be determined. It was noticed that many of the dead lobsters, and occasionally living ones, had white spots on their bodies. Professor Gorham, who was studying the diatoms, examined many of these spots and found them to be colonies of a mold which had ramified through and through the tissues. Whether this was the primary cause of death Professor Gorham was unable to determine. After its appearance, however, it was almost impossible to raise a single lobsterling. Frequent changing of the bags, exclusion or presence of direct sunlight, or changes in quantity and kind of food made no apparent difference.

That bag experiments like those of 1901 would not have been more successful in 1902, was proved by experiment before the completion of the rearing plant. Fry were placed in one of the cylindrical bags and occasionally stirred. They were regularly fed and had excellent care for the first two weeks, but in spite of careful attention they did no better than in former years. Although the number received from the hatchery was estimated at 30,000, at the end of the first week only 3,000 were alive. Diatoms infested them, they became inactive, and metamorphosis was retarded. None reached the second stage until the ninth day. Even after the plant was completed, and with the water constantly stirred, only the most vigorous rallied, and but 11 reached the fourth stage after more than 25 days. Thus it would seem that the physical and biological conditions were not more favorable than in other years. The temperature and density of the water were at an average, the plankton was not especially rich, and the natural enemies were present in great abundance. In the past five years diatoms had never been seen so abundant or their growth so rapid.

EXPERIMENTS IN HATCHING EGGS.

Several experiments were made to test the efficiency of the bags as a hatching device, and also for comparison with fry from the hatcheries. According to the hatchery records, about 5,000,000 eggs from the Woods Hole Station and 2,000,000 from Gloucester were turned over to us for this purpose. Although there was no method of determining what percentage hatched, large numbers of fry from these eggs were used in the rearing experiments. The eggs collected from southern New England waters seemed to hatch more quickly and better than those received from Gloucester, and the fry were more hardy. This can be accounted for in part by the fact that Woods Hole and Noank eggs are further developed when collected than Gloucester eggs. Very few of the Gloucester fry became lobsterlings, but as those eggs did not begin to hatch until about the time that all the experiments seemed to prove futile, the results are not especially significant. A comparison of the habits, rate of growth, and vitality of fry from the hatchery and those hatched in the bags did not show any appreciable differences.

The most serious objection to the apparatus as a hatchery is that the diatoms multiply very rapidly, completely coating the unhatched eggs and possibly killing them. This may not prove serious. By excluding direct sunlight the diatoms may be eliminated.

SUMMARY OF RESULTS AND CONCLUSIONS FROM THE WORK FOR 1902.

1. The physical and biological conditions of the water at Woods Hole, at least during the years 1898, 1899, 1900, 1901, and 1902, were extremely unfavorable for the growth of lobster fry. Future experiments in lobster culture should be tried in other localities.

2. The value of a gentle agitation of the water, such as is obtained with this stirring device, was again demonstrated and under most

adverse circumstances. Formerly, no matter what device was used, less than 1 per cent of the fry could be reared to the lobsterling stage. With this apparatus, in an environment so unfavorable for the work as exists at Woods Hole, it is possible to rear 10 or 12 per cent.

3. At Woods Hole eggs hatch very satisfactorily in the bags, and probably as successfully as in the McDonald hatching jars. The fry are strong and active and grow well.

4. Although the diatoms multiply with great rapidity in the bags at Woods Hole, and therefore endanger successful lobster culture, it is probable that exclusion of direct sunlight will prevent their growth.

5. Ground menhaden flesh was found to be a practical food for the young lobsters.

DISCUSSION OF CERTAIN PHASES OF THE LOBSTER PROBLEM.

FOOD OF LARVÆ.

The young lobster comes into the world with a ravenous appetite which is rarely satisfied during the larval period. In spite of this, however, he is something of an epicure. The kinds of food which appeal to him are very few, and on this account the food supply has frequently been a serious question in the course of these investigations. The natural food consists chiefly of the minute organisms—copepods, fish eggs, very young fish, etc.—so abundant near the surface of the ocean, especially in sheltered bays and inlets. All our efforts to nourish the fry in confinement with this food, however, have been unsuccessful, because of lack of constancy in the supply. It is necessary to provide suitable artificial food.

In the experiments of 1898 and 1899 Doctor Bumpus gave much attention to the question of nourishment. Finely chopped fish, such as tautog, cunner, flounder, etc., settled to the bottom, and even when floating was not relished by the fry. Shredded codfish, as purchased at the stores, was more buoyant, but was refused by the lobsters. Flesh and eggs of spider crabs and other crustaceans were little better. The one food which the fry seemed to prefer above all others was the so-called lobster liver or digestive gland of the adult. This gland is composed of numerous small tubules which can be easily chopped into fine particles, and the oil contained keeps the bit of food in suspension for some time. The young lobsters, especially in the first stage, eat this food with great avidity, and a single liver is sufficient to feed many thousand. Lobster liver was used quite extensively as food in some of the early experiments, but it could not be used on a large scale, because it would necessitate the destruction of many lobsters nearly mature.

A more practical food was found in the investigations at Wickford during 1900. Here the fry were fed almost entirely upon the soft parts of the common clam (*Mya arenaria*), on which they thrived, and as the clam is comparatively abundant in Narragansett Bay, this was the staple food for the experiments at Wickford in both 1900 and 1901. Clams were so scarce in the vicinity of Woods Hole, however, and the difficulty of procuring them from other localities was so great, that an economical substitute was sought. The digestive glands of starfish, soft parts of sea-urchins, the common mussels, and several kinds of fish were tried, but all were refused by the fry. At last was discovered a food which attracted them—the oily flesh of the menhaden—and as these fish were caught in the traps in great numbers in 1902, the food supply was practically unlimited for the rest of the season. The flesh of the menhaden is so saturated with oil that it does not sink quickly. The fish were run through an ordinary meat grinder, still further triturated by a vigorous stirring, and then poured into the bags. This was the staple food throughout the season.

The amount of food is an important item, and should receive careful attention. As stated above, it is necessary to put in the bag more food than can actually be eaten. In the earlier experiments this excess sank to the bottom of the inclosure, quickly decomposed, and fouled the water. The introduction of the stirring device, however, corrected this, and greatly facilitated the feeding of the fry. The current of water lifted the food, as well as the lobsters, from the bottom, and kept them in constant circulation.

During 1902 the fry were fed twice a day (morning and night), a small teacupful of the shredded menhaden being given to each bag, i. e., to about 5,000 fry. As the fry develop they need proportionally more food. There is little danger of overfeeding.

ENEMIES OF THE YOUNG.

It would seem at first glance that the hatching and releasing annually of so many millions of lobster fry must accomplish a great deal toward restocking our waters. No doubt such would be the case if it were not for the many dangers to which the young lobster is subjected, particularly during its larval existence.

The most destructive natural enemies are the small fish, such as cunners, minnows, tautog, etc., which are so numerous along our shores. The light-colored newly hatched larva is a tempting morsel to these fishes, and they doubtless are responsible for the immediate destruction of thousands of fry liberated by the hatcheries. To be convinced of this it is only necessary to observe when a few thousand are released at Woods Hole, for instance. During 1902, frequently 30 to 50 minnows and cunners were counted around a single bag that was being emptied, and the fish were quick to pick up the living fry before touching the dead. In one instance, a single mummichog entered one of the bags through a hole, and devoured 2,500 fry in a single night.

In addition to the destruction by living enemies the young lobster is also likely to be stranded on the shore by the wind and receding tide.

In confinement, although the fry are protected more or less completely from natural enemies, others equally destructive are encountered and have proved serious obstacles in successful lobster culture, but the experiments encourage the belief that in due time all these difficulties will be removed.

RATE OF GROWTH.

The growth oi the lobster, especially during the larval period, is dependent on two factors, namely, temperature of the water and food supply. Other things being equal, the colder the water the slower the development, and vice versa. This is shown by a comparison of the experiments at the various stations, and also of experiments at the beginning and near the close of the season. For example, at Orrs Island in 1900, when the temperature of the water averaged 60°, it took 25 to 26 days for the fry to reach the lobsterling stage. At Wickford at the same time, with the water at 72°, the fry were only 10 to 12 days in passing through the same metamorphoses. In the one experiment at Annisquam, where the water temperature reached 76° F., the lobsterling stage was reached in 10 days. In the same locality development is slower at the beginning of the season than toward the close. At Woods Hole in the early part of the season, 20 to 25 days were required for the fry to pass through the larval stages, while later 12 to 14 days were sufficient. The same holds true at Wickford, although not so noticeably, since the difference in temperature is not so great. Sixteen days' time was necessary for the fry to become lobsterlings in the first experiment in 1900. Later in the season only 9 or 10 days were needed.

The amount of food the lobster receives is also of importance. Fry which are poorly nourished, if they live for any considerable length of time, will remain in the first stage for as much as 3 or 4 weeks.

To obtain an environment which will encourage a rapid growth is the all-important factor in rearing the fry. The shorter the critical period the greater the chance of surviving it.

POSSIBILITY OF ECONOMIC LOBSTER CULTURE.

The results of these investigations lead to the belief that it is not only feasible to retain the lobsterlings in inclosures until they reach a marketable size, but that such an undertaking might be made a profitable industry. The special commission confined its attention chiefly to the observation of the larval lobsters and gave only incidental attention to later stages, but Dr. A. D. Mead has made some interesting and suggestive observations on the rate of growth from the lobsterling stage onward, and has valuable data bearing upon comparative mortality. He has retained the young for more than two years, and by direct observation has ascertained many facts of interest. The length of the lobster is not a criterion of age. Although at the end of the first year the average length of the young was 2⅛ inches, he shows that six months later, while some have grown but little, others are fully 5 inches in length. The average rate of growth, however, is so slow that at least three years, and possibly five, must be allowed for the animal to reach a marketable size. Doctor Mead's experiments prove that it is possible to retain the young for an indefinite period, and that the mortality after the lobsterling stage is reached is very small.

A more conclusive demonstration of the possibility of rearing lobsters for market is perhaps required by the lobster men before they can be persuaded to invest in the enterprise, but that such a scheme can ultimately be made financially profitable is convincingly shown. A simple method would be for the government to cooperate with some lobstermen who control a suitable pound, preferably on the Maine coast, and release there a large number of lobsterlings. It would not be possible to judge of the results for three or four years, but in this way the practical value of artificial rearing could be determined.

Thus far the apparatus used for stirring the water has been crude, and obviously several changes should be made before constructing a permanent plant. Larger bags of more durable material should be used for rearing purposes, though the small bags are good for hatching the eggs, and the annoying and unsatisfactory system of belts for transmitting power should be replaced by a series of gears and worms.