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State of Rhode Island and Providence Plantations.

REVISED EDITION

OF THE

METHODS OF PROTECTING AND PROPAGATING THE LOBSTER, ⁴⁵⁹
963

WITH

A BRIEF OUTLINE OF ITS NATURAL HISTORY.

PLATES IV.—XXIV.

EARNEST W. BARNES,

Superintendent of the Wickford Experiment Station.

1910.

Reprinted from the Forty-First Annual Report of the Commissioners of the
Inland Fisheries of Rhode Island.

PROVIDENCE:

E. L. FREEMAN COMPANY, PRINTERS TO THE STATE.

1911.

APPENDIX A.

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PREFACE TO THE REVISED EDITION.

Since publishing the original article which appeared in the Annual Report of the Commissioners of Inland Fisheries for the year 1906, the lobster rearing at the Wickford Experiment Station has continued under the writer's personal superintendence. The changes in apparatus and methods, which have been almost without exception the results of his own devising, have been so considerable that it has been thought best to bring them together. As it is necessary, in order to make the subject more easily understood, to give a rather detailed account of the process of rearing lobsters at Wickford, it has been decided to follow the plan of the original paper, incorporating into it the changes and successes which have attended the work since 1906.

The principal changes in apparatus and methods to be noted since the previous article are:—

The substitution of durable wooden boxes to replace the unreliable canvas bags, and the necessary devices attendant upon this change.

The adoption of a unit system of raft structure, which makes a great extension of the apparatus possible.

Changes in the gearing and shaft arrangement which greatly reduce the loss of power in the long lateral extensions.

Devices for easily and quickly handling the rearing boxes.

A method of handling the hen lobsters while they are hatching their eggs, which very closely follows natural conditions and gives uniform and excellent results in the rearing cars.

Extending the rearing beyond the fourth stage.

A more effectual method of liberation.

An economical and practical mechanical feeding device.

The adoption of a most practical and economical food—hen's eggs.

Many slight changes, including shade adjustment, copper painting the cars, and other factors of importance in the economy of rearing.

EARNEST W. BARNES,

Superintendent of the Wickford Experiment Station.

INTRODUCTION.

The success in lobster culture attained by the Commission of Inland Fisheries, at their experiment station, at Wickford, is one of those few remarkable successes in artificial marine culture which have been reached through a long course of slow and, at times, disheartening experiments. The ordinary method employed in the artificial propagation of fishes, the mere hatching the eggs, has been of little avail in the case of the lobster. Its failure may be stated, briefly, as due to two causes: The first, and most important of these, is the slow growth of the lobster, which greatly lengthens the time required to reach maturity and propagate itself naturally; the second is the prolonged period of larval helplessness.

If we leave out of consideration the helpless larval period we find that the lobster, in its natural state, is not materially handicapped in its struggle for maintenance, except in the particular fact of its slow growth. With reference to the natural advantages it might be stated that its life on the sea bottom, together with the instinct of hiding in burrows in the mud or under rocks, affords much better protection than fishes seem to possess. Besides, there is perhaps no external part, unless it is the eye, which can be lost or injured without the lobster being able to replace it. The loss of a fin or the upturning of a few scales, will often be sufficient cause for the death of a fish. The lobster also has the advantage of having its eggs more surely fertilized and afterwards cared for by the parent until hatched. The eggs of most fishes are thrown into the water, and depend on chance fertilization and favorable circumstances for their fostering. But against the human foe the lobster is powerless, and there has been a rapid decrease in its abundance since there was a demand for it in the market.

Because the lobster possesses, in a high degree, natural advantages for protecting itself, except its larval helplessness, it seemed necessary to adopt some measure of rearing them through this latter period. For more than a quarter of a century experiments were pushed with vigor by the various States, the United States Government, and also by European governments. The many difficulties, however, prevented success till 1900, when the honor of having offered the first and, up to the present time, the only solution of the problem was won by the Rhode Island Commissioners of Inland Fisheries, at Wickford. It took, nevertheless, after the discovery of the principle, five years of slow and tedious experiments to develop the scheme to the point where it was practical and economical, even on a small scale. However, during the past five years the methods have been so much improved that it is not only much more economical and practical, but it has also become possible to extend the plant to almost any desired limit.

Furthermore, the results have been very satisfactory. Seventy per cent. in round numbers (69 per cent. actually) have been reared from the first to the fourth stage from a counted lot of 10,000. It is in this stage that the fry commence to burrow and are, therefore, more able to care for themselves. These figures will be appreciated when it is recalled that the best result in Europe was 6.6 per cent. starting with 1,500 fry in the second stage; and in this country, 21 per cent., from an estimated 3,000 fry in the first stage at the U. S. Bureau of Fisheries, at Woods Hole, Mass.

But it was soon discovered that it was not sufficient to successfully rear the lobster fry to the fourth stage. In the first place, while it is true that at this stage the lobsterlings do go to the bottom, and also true that they are immensely more capable of surviving than when in the first three larval stages, yet the swimming habit is not completely abandoned and therefore it was considered desirable to rear the young lobster to a later stage—fifth or sixth stage. Furthermore, as important as it is to be able to rear them successfully to the “bottom” stages, it is of equal importance to get them safely established in the ocean bottom.

In both these directions the efforts of the Commission have met with great success, and while each year will undoubtedly see further improvements in methods and results, yet it may safely be said that the future changes will be in the nature of increased efficiency in detail of the work and also in the ability to rear to still later stages, if not to the adult stage. This is, without doubt, the ultimate goal of lobster rearing, and indeed a more successful solution of the problem of lobster supply can scarcely be thought of than the making it possible for a lobster dealer to raise his own lobsters. The productivity of the lobster is so great (from 8,000 to over 150,000 eggs per lobster) that could a plan of rearing to the adult size be proven to be successful, the future supply would be at once assured.

For the benefit of those who are interested in the practical side of lobster culture, and who may not have followed the development of the plan as given in previous reports, a brief consideration of the lobster culture work is here given, which, while it does not pretend to be more than an outline of the subject, yet will go somewhat into detail concerning the methods use at Wickford.

I. NATURAL HISTORY OF THE LOBSTER.

1. DISTRIBUTION.

The American lobster is found along the Atlantic coast from Labrador to Delaware. It attains its largest size and is most abundant in the northern half of this range (Nova Scotia and Maine.) It is found in all depths up to 100 fathoms. In deeper water than this it is very rarely found, though sometimes reported from fishing banks farther off shore.

In Rhode Island waters the northern limits of the lobster-producing territory are Mount Hope Point on the east side of Narragansett Bay and Patience Island on the west side. Off-shore the lobster fishing is carried on as far as 8 to 14 miles off Block Island. The usual maximum depth of water in which pots are set, ranges from 12 to 14 fathoms, but occasionally in fishing some distance off-shore, the pots are set in water from 16 to 19 fathoms deep.

2. NATURAL HOME AND MIGRATIONS.

The character of the shores where the lobster lives varies from rocky and precipitous to sandy or muddy. During the winter the lobsters probably retreat to deeper water and burrow in the mud, since the fishermen find it necessary to gradually move their traps farther off shore with the approaching winter. This migration to deep water is not common to all lobsters, as we find some in holes along the shores which are exposed by extreme low tides during the winter months.

With the return of spring and early summer, the lobstermen move their pots nearer shore. This movement of the lobsters to and from shore is probably the whole extent of their migrations, and therefore the restocking of the shores of a particular locality is possible. Efforts are being made to get more exact data on migrations by liberating tagged lobsters. Female lobsters, with eggs ready to hatch, are most often caught on rocky bottoms, and lobsters ready to shed, or those that have just done so, are most abundant on sandy or muddy shores. Dutch Island Harbor in Narragansett Bay seems to be a great shedding ground.

In Rhode Island waters, as a result of long experience, the following seasonal changes are made in setting lobster pots:

From April 15 to the last of June the pots are set in shoal water among the rocks. On this kind of bottom, and apparently on no other kind, the female lobsters with "ripe eggs" (*i. e.* hatching) are found.

Between the above time and the latter part of August, the experienced lobstermen set their gear on smooth bottom—such as sandy bottoms or bottoms covered with small gravel or mussels. At this time of year, the lobsters which have hatched their eggs are molting, and other female lobsters are beginning to extrude their eggs. The absence of chogsetts and tautog from this sort of bottom, renders it particularly favorable for molting and spawning.

From the early part of September to the end of season (Nov. 15) fishing is again renewed on rocky bottoms but need not be carried on

in as shoal water as in the spring. Here in quite deep water green egg lobsters are so abundant as to merit the name of "school egg lobsters"—often comprising more than half of the entire catch.

Often near the close of the lobster season (Nov. 15), lobsters may be readily caught within Narragansett Bay on muddy bottom.

3. FOOD.

Although lobsters are called the "scavengers of the sea" and do undoubtedly feed on dead fish, yet they seem to prefer recently killed food. Rotten fish, while it probably attracts hungry lobsters, is found to remain untouched, or is even pushed aside, by lobsters in cars, which have been reasonably well fed. Lobsters in their natural homes undoubtedly have long intervals between meals, and eat ravenously when any food is found. This will account for the ease with which they are caught in pots. The food of the lobster includes nearly all kinds of fish; whatever shellfish it can find, crabs, and other invertebrates. Pieces of shell and pebbles are also found in their stomachs. The material for the hardening of the shell is probably obtained from the former. The lobster does not hesitate to eat another lobster which has been weakened by molting or injury. This cannibalism is most marked in the larvæ, where it is a most serious obstacle to rearing.

The following list of articles are used in *Rhode Island* for baiting lobster pots:—(these are given in order of preference.)

Halibut heads, bluefish heads, menhaden (this kind is used chiefly when fishing on smooth bottom because it is a soft fish. On rocky bottom, the chogsetts would steal the bait), sculpin, sea-robins, whiting (the last three are used mostly in the spring), flounders, herring, and small fish used in net bags.

4. LENGTH OF LIFE.

The age of a lobster can only be told with a moderate degree of accuracy. Size may be an indication, but frequently, among those reared in cars, some will be found four or five times the length of

others of the same age. (Plate IV.) From accounts of early days, there seems to be no limit to the size which lobsters may attain; but in recent years no lobster of over 25 pounds (21 inches in length) has been authentically recorded. From the slow growth which we know lobsters have, this specimen could not have been under 20 years old, and many considerations would point to a greater age. (Plate V.)

The following table, giving the probable rate of growth of the lobster from time of hatching to largest size known, was compiled by Dr. P. B. Hadley, in 1906, while at the experiment station at Wickford:

PLATE IV.—Two lobsters of the same age, illustrating differences in rate of growth.
Life size; age, 1 year and 4 months. (Photographed from life.)

PLATE V.—A very old male lobster. (Photographed from life.) Length, $19\frac{1}{2}$ inches; weight, 19 pounds.

An Estimate of the Rate of Growth of the American Lobster from Time of Hatching to Attainment of Greatest Known Size.

STAGE.	Approximate. Age.	LENGTH. Inches.	INCREASE. Per cent.	Sex.
No. 1.....	.....	.32	.....	M.-F.
No. 2.....	3 days.....	.38	18	"
No. 3.....	7 days.....	.45	18	"
No. 4.....	12 days.....	.54	18	"
No. 5.....	24 days.....	.64	18	"
No. 6.....	35 days.....	.74	18	"
No. 7.....	7 weeks.....	.84	18	"
No. 8.....	9 weeks.....	1.1 ¹ ₂	18	"
No. 9.....	3 months.....	1.1 ¹ ₂	18	"
No. 10.....	5 months.....	1.1 ¹ ₂	18	"
No. 11.....	9 months.....	1.1 ¹ ₂	18	"
No. 12.....	1 year.....	2.2 ¹ ₂	18	"
No. 13.....	1 yr., 1 mo.....	2.2 ¹ ₂	18	"
No. 14.....	1 yr., 3 mos.....	2.2 ¹ ₂	18	"
No. 15.....	1 yr., 6 mos.....	3.1 ¹ ₂	18	"
No. 16.....	2 yrs.....	4.1 ¹ ₂	18	"
No. 17.....	2 yrs., 3 mos.....	4.1 ¹ ₂	18	"
No. 17.....	2 yrs., 3 mos.....	4.1 ¹ ₂	18	"
No. 18.....	2 yrs., 6 mos.....	5.1 ¹ ₂	16	"
No. 19.....	3 yrs.....	6.1 ¹ ₂	15	"
No. 20.....	3 yrs., 6 mos.....	7.1 ¹ ₂	11	"
No. 21.....	4 yrs.....	8.1 ¹ ₂	11	"
No. 22.....	4 yrs., 6 mos.....	8.1 ¹ ₂	11	M.
No. 22.....	4 yrs., 6 mos.....	8.1 ¹ ₂	11*	F.
No. 23.....	5 yrs.....	9.1 ¹ ₂	11	M.
No. 23.....	6 yrs., 5 mos†.....	9.1 ¹ ₂	11	F.
No. 24.....	6 yrs.....	11	11	M.
No. 24.....	8 yrs., 4 mos.....	11	11	F.
No. 25.....	7 yrs.....	12	9	M.
No. 25.....	10 yrs., 4 mos.....	12	9	F.
No. 26†.....	8 yrs.....	13.1 ¹ ₂	9	M.
No. 26†.....	12 yrs., 4 mos.....	13.1 ¹ ₂	9	F.
No. 27.....	9 yrs.....	14.1 ¹ ₂	9	M.
No. 27.....	14 yrs., 4 mos.....	14.1 ¹ ₂	9	F.
No. 28.....	10 yrs.....	15.1 ¹ ₂	7	M.
No. 28.....	16 yrs., 4 mos.....	15.1 ¹ ₂	7	F.
No. 29.....	12 yrs.....	16.1 ¹ ₂	7	M.
No. 29.....	18 yrs., 4 mos.....	16.1 ¹ ₂	7	F.
No. 30.....	14 yrs.....	17.1 ¹ ₂	6	M.
No. 30.....	20 yrs., 4 mos.....	17.1 ¹ ₂	6	F.
No. 31.....	17 yrs.....	18.1 ¹ ₂	6	M.
No. 32.....	20 yrs.....	19.1 ¹ ₂	5	M.
No. 33.....	23 yrs.....	20.1 ¹ ₂	5	M.
No. 34.....	26 yrs.....	21	4	M.
No. 35.....	29 yrs.....	21.7 ¹ ₂	4	M.
No. 36.....	33 yrs.....	22.3 ¹ ₂	4	M.

*For female lobsters bearing eggs, there can naturally be no molt during the period that the external eggs are carried; this is at least for 11 or 12 months.

†Because of the great lack of data on the molting periods of stages 26 to 35 the following estimate must be, to a high degree, speculative. It can not, however, fall far from actual conditions.

‡It is uncertain at just what time the spring or early summer molt for female lobsters not bearing external eggs is first omitted, but it is probably near this stage.

5. MOLTING AND GROWTH.

Covered by a hard shell, the only means which the lobster has of becoming larger is by casting off its old shell; that is, by molting. Growth has already taken place within, rendering the animal more compact, so that when the lobster sheds it immediately expands through the absorption of water. (Plate VI.) The new shell, at first as soft as wet paper, becomes hardened in a few days and prevents further expansion. The lobster in the first year, molts about 14 or 15 times. Each successive year it molts less often until lobsters between 8 and 9 inches long shed no more than 2 or 3 times a year. Concerning the molting periods of larger lobsters, scarcely anything is known.

It is known, however, that—

1. When regeneration of various parts is taking place, the molting period and presumably the growth will very often be retarded.
2. Excessive light (as rearing in cars without covers), will lessen the percentage of gain at each molt, and perhaps of the periods.
3. Abundance of food will increase the percentage of gain and perhaps hasten the molt.

6. REGENERATION.

If a claw or any appendage is lost the lobster has the power of growing it again (regeneration). (Plate VII.) Should the loss occur within a certain period, too near an approaching molt, the molting occurs regularly without anything being done in the way of repair. If, however, the loss happens a considerable length of time before the molt, this period will be delayed somewhat, and, in place of the lost limb, a bud will grow out. When the molt occurs the lost limb will come out fully formed, but about one-half size. When the next molt occurs it will be full size. This is true, with some variation, of all external organs unless it is the eye. This has never been observed to regenerate at the experiment station. Closely related to this

PLATE VI.—A young, newly-molted lobster (right), together with its old shell.

PLATE VII.—Regenerating appendages on the same lobster. (Photographed from life.)

Fig. I.—Just before molting. Shows regenerating bud of left claw-limb (1).

Fig. II.—Same lobster after molting. Shows the regenerated limb (1).

PLATE VIII.—An adult female lobster bearing egg-clusters.

power of regeneration is the habit which the lobster has of throwing off a claw, when it is crushed or injured (autotomy).

7. SEXUAL MATURITY.

Since it is impossible to tell how old a lobster is, we can not tell at what age it reaches sexual maturity. Observation on several thousand egg lobsters received at the experiment station during several years seems to indicate that, in Narragansett Bay, lobsters may become sexually mature when from $8\frac{1}{4}$ to 9 inches long. In the past ten years, only about twenty egg lobsters under 9 inches in length, have been received, though a considerable number have been just 9 inches. This would indicate that in Narragansett Bay very few lobsters under 9 inches have become sexually mature, although 9 inches is a good average. Herrick places the range in length of the Massachusetts lobster, at the time of sexual maturity at from 8 to 12 inches, and thinks that $10\frac{1}{2}$ inches is the average length at sexual maturity.

8. SPAWNING HABITS.

The female lobsters spawns once in two years. (Plate VIII.) The eggs, as a rule, are laid in August, but some few lobsters lay them in July and some later in the fall or winter. Hatching occurs the following summer at a time determined by the temperature of the water to which the eggs have been subjected during the period in which they have been carried. In Narragansett Bay it usually takes place from the first of May to the end of July.

The lobster therefore carries its eggs for a period of 10 or 11 months before they hatch. The number of eggs carried by a lobster varies according to the size of the lobster; thus, according to Herrick, assuming that an 8-inch lobster has on the average, 5,000 eggs, a 10-inch lobster would have 10,000, a 12-inch lobster, 20,000, etc. A lobster about 16 inches long would thus lay about 80,000 eggs. This is, however, a low average. Lobsters 16 inches in length, may have

100,000 eggs. When the female lobster is bearing eggs, she usually frequents some rocky shore where she can better protect herself.

As was mentioned in Section 2, "Natural Home and Migrations," female lobsters when extruding their eggs are most often caught upon sandy or smooth bottom.

9. LARVAL STAGES.

During the first two or three weeks which follow hatching, the lobster passes through a larval period, during which it molts 3 times before it takes on the general external appearance of the adult. In each period it differs in form and habits as well as size. The main characteristics are as follows:

First Stage. (Plate IX.) In this stage the lobster swims rather feebly at the surface by the use of the outer branches of the thoracic appendages. The last segment of the abdomen bears one piece which is cleft like a fish's tail. The abdominal swimmerets are lacking, and the limbs that usually bear the big claws are of the same size as the walking limbs. In this, as in the second and third stages, the fry are ravenous feeders.

The average number of days that the fry continue in this stage at Wickford is five.

Second Stage. (Plate X.) After the first molt the lobster's claws become a little larger than the other limbs, but remain hanging down. The abdominal swimmerets appears, although the thoracic swimming organs are used almost entirely in swimming. The tail lacks those outer segments which cause it to be characterized later as the "tail-fan."

The average number of days in this stage at Wickford is three.

Third Stage. (Plate XI.) The lobster, after the second molt, has proportionally still larger claws than the larvæ of the second stage, but they still droop. The abdominal swimmerets become fringed with short hairs, and the outer blades of the "tail-fan" make their appearance. Swimming is still by use of the thoracic

PLATE IX.—First Stage Lobster. (Drawn from life by P. B. Hadley.)
Enlarged about 18X.

PLATE X.—Second Stage Lobster. (Drawn from life by P. B. Hadley.)
Enlarged about 14X.

PLATE XI.—Third Stage Lobster. (Drawn from life by P. B. Hadley.)
Enlarged about 12X.

PLATE XII.—Fourth Stage Lobster. (Drawn from life by P. B. Hadley.)
Enlarged about 5X.

appendages. The greater size and more vigorous swimming causes this stage to be easily distinguished from the preceding stages.

Four days is the average duration of this stage at Wickford.

Fourth Stage. (Plate XII.) The lobster at this stage becomes shaped like the adult. The claws are carried in front while swimming. The thoracic swimming appendages become reduced and functionless, and in general the unmistakable resemblance to the adult easily determines this stage from the preceding ones. The swimming is now very vigorous, and, when swimming in the rearing ear, it always heads toward the current. Burrowing is begun to a certain extent in this period.

The average number of days required at Wickford to reach this stage from the time of hatching is thirteen.

10. ADOLESCENT PERIOD.

Later stages develop other structural changes, although more gradually. At the seventh stage the appendages on the first abdominal segment appear as buds, and by the eighth stage they have developed sufficiently to enable the sex to be told. Beyond this stage the changes consist merely in the gradual assumption of the mature form and structure.

11. SOME PECULIAR MEANS OF SELF-PRESERVATION.

Any one who has handled lobsters under 3 inches in length is familiar with the fact that the little fellows, when handled, will straighten out and to every appearance seem to be dead. The rigidity does not cease immediately when replaced in the water. This *death-feigning habit* is gradually outgrown, and perhaps is never found among adult lobsters. It is supposed to be useful to the animal in protecting itself against fishes which prefer live food.

Autotomy, the voluntary shedding of an appendage, is another habit which is more easily seen to be self-preservative. If a lobster's claw is held too tightly or crushed, it is almost always quickly dropped

off. As it can again be regenerated the lobster is only maimed for a short time, while the loss of the claw may prevent the lobster from getting pulled out of its burrow and destroyed.

12. SENSIBILITY TO LIGHT.

The adult lobster is negatively heliotropic, *i. e.*, it will endeavor to get away from the light. This is not, however, characteristic of all stages. In the first three larval stages the fry seem to seek the lighted area (positively heliotropic). The fourth stage also has this peculiarity till near the end of the stage, when it seems to anticipate the later stages and becomes negatively heliotropic. This negative heliotropism is perhaps the explanation of the fact that at this time also the lobster leaves the surface and begins to burrow at the bottom.

It is an interesting fact, also, that the fry when confined in one of the rearing cars, though closely crowded together, and carried rapidly around by the current, will avoid, and keep some little distance away from, any white object, such as a white stick or a paddle blade thrust in among them.

13. THE ENEMIES OF THE LOBSTER.

From the moment of hatching until death, the lobster is beset with enemies. The amount of harm which these can do, however, decreases as the lobster becomes larger. Some of these enemies are particularly antagonistic while the lobster is *in the larval stages*. In this period the natural mode of life of the lobster fry renders them helpless. Their efforts at swimming are little more than "treading water." They are powerless against the slightest current of water, and are an easy prey to even the smallest fishes. Shrimp and tautog, as they frequent the places where the fry are found, are particularly dangerous foes. But perhaps the lobsters are their own worst enemies. A lobster larvæ is just as willing to pounce upon a weaker neighbor as upon the choicest morsel of food.

After the larval period is past the lobster's enemies do not lessen, but the lobster can better protect itself by burrowing among the

rocks. Herriek says that "every predaceous fish which feeds upon the bottom, may be looked upon in general as an enemy to the lobster." Among these the cod, the sea eel, and the dogfish are particularly effective. So frequently are lobsters found in the stomachs of these fishes that fishermen are not loath to state that the lobster is their principal diet. The most important foe of the adult lobster, however, is man, and his attacks are so successful that the lobster unaided can not hold his own against them.

14. DECREASE IN ABUNDANCE OF LOBSTERS.

From consideration of the many enemies it is not wonderful that the supply of lobsters all along the coast should become less. All of the facts as given above are, to some extent, responsible for this depletion, but excessive fishing is the most important.

So strenuously is the lobster fishing followed up and with such good success that often those who are best informed in regard to the industry are deceived by the large and, either constant or increasing, number of lobsters caught and argue that the supply in this or that locality is not decreasing. This deception is accomplished either by an increase in the number of lobster pots or by shifting the gear to grounds which have not been fished so extensively, or by both. The demands of the market are certain to be supplied if human ingenuity can find a way, and, as has been said before, lobsters are very easily trapped. The items that should be taken into account in the consideration of the status of the lobster industry are the extent of the area fished, the number of pots actually set, the thoroughness with which they are cared for, and the number of pounds, but also the number of lobsters, caught. Furthermore, these statistics, to be of real value, should extend over a period of at least five years. With the above variables in mind it will be readily seen from any table of statistics that everywhere along the Atlantic coast the abundance of lobsters has decreased since the establishment of a market for them.

II. METHODS EMPLOYED TO PREVENT EXTERMINATION.

As early as the decrease in the number of lobsters was observed, some 80 years ago, various States and the general government began to contrive means to prevent the decrease and, if possible, to increase the supply of this "king of crustacea." Naturally the methods which had proved satisfactory in the case of fishes were first used for the lobster, *i. e.*, legal restricting of the fishing and artificial hatching of the eggs. These two methods will be considered briefly, and then will follow a somewhat detailed description of the scheme of hatching and rearing so successfully developed by the Rhode Island Commission of Inland Fisheries.

A. LEGAL RESTRICTIONS.

1. *Protection of Egg Lobsters.* One of the first laws enacted for the protection of the lobster is that which imposes a fine on any one retaining or destroying lobsters bearing spawn. The value of the principle upon which this law is based is apparent to any one, especially considering the fact that lobsters carry their eggs for eleven months before hatching. Unfortunately this law can be quite easily evaded by scraping off the eggs. Furthermore, when it is remembered that the female carries its eggs only 10 months in every two years, and in the remaining fourteen months may be caught and sold, the value of the law decreases perceptibly. It should be added that *the purchasing of egg lobsters* by the various States and the federal government prevents many from being scraped by taking away the incentive and is therefore a valuable addition to the lobster legislation.

2. *Protection of Immature Lobsters.* An equally early law of easily recognized value is known as the "short lobster law." A fine is placed upon the retention of lobsters under a certain length. The idea in the framing of this law was to enable the lobster to reach maturity and spawn at least once before it was lawful to capture it. The legal length in various States ranges from 9 to 10½ inches. As was

seen in the paragraph on sexual maturity, the lobster in Narragansett Bay in all probability is 9 inches, or slightly over, when it becomes sexually mature. In Massachusetts, Herrick found the average to be $10\frac{1}{2}$ inches, and perhaps in the colder water of the State of Maine, it may be still greater. It is to be regretted that a uniform law has not been established. The fact that often the lobsters do not mature until they have passed the legal length, and the proportionately small number of eggs which the first spawning produces, tends to diminish the value of this law. In the light of our present knowledge of the biology of the lobster, the most valuable feature of such a law is seen to be the fact that protection is given to the lobster where it is most harassed by its enemies, and is most receptive to the attacks because of its frequent molting.

3. *Protection of Large Lobsters.* For a few years there has been agitated a change in the laws, so as to prevent the capture of lobsters over a certain length. In this way protection would be given the large lobsters instead of the small ones. It is argued in favor of this scheme that:

(1) Lobsters bear eggs in geometrical proportion to their length: 8-inch lobsters, 5,000; 10-inch, 10,000; 12-inch, 20,000, etc. If these old ones are saved, more spawn will be hatched, and the greater the number of eggs hatched, the greater number of lobsters will result. ✓

(2) The larger the lobster becomes, the more immune it is from its enemies; and since, barring accidents, there seems to be no limit to the size which it may attain, there will always be spawners to keep up the supply.

(3) It will be easy to enforce a law of this kind, since pots may be required to have an opening under a certain size. This will prevent the big lobsters from entering.

(4) The older ones are not so tender meated, and thus the least possible damage will be done to the fisheries.

It is argued on the opposing side that, if the young ones were caught where would the old ones come from, and also that protection should be given the lobster during the period which is most critical. This

latter contention is a strong one, but in regard to the former, it is a well-known fact that all the lobsters of a certain size are not caught.

4. *A Double Limit.* There are certainly good points on both sides of the argument presented in the last section, and it would be impossible to give judgment in favor of either. The wisest plan, in view of the depleted condition of the lobster fishery, would be to adopt both. Laws could be enacted preventing the legal capture of those under $8\frac{1}{2}$ inches and over 13 inches. As a help to the enforcement of such a law the pots might be required to have an entrance small enough to prevent those over 14 inches from entering. The value of such a law cannot be too strongly stated, especially when there is coupled with it laws penalizing the retention of egg lobsters except to sell them to the State for propagation purposes.

5. *Close Time.* The State of Rhode Island has passed laws making the setting of pots and the taking of lobsters between the 15th of November and the 15th of April unlawful. There might be some question also, whether these particular dates are the best, as every month in the year has been included in the close season in some State or other. Some restriction of this sort is certainly needed, but there should be co-operation between all the States interested in the lobster fishery.

6. *Prevention of Mutilation.* In order to avoid the consequences of retaining short lobsters, the fishermen have recourse to breaking the lobsters in two. This makes it impossible to tell the length of the lobster, especially when the parts of many lobsters were mixed together. To prevent this infringement, and also to prevent the use of short lobsters for bait, laws have been passed in most of the lobster-producing States, imposing a fine for possessing the mutilated remains of uncooked lobsters. The canning industry was dealt a severe blow by these laws, but in one State (Maine) special legislation was made in regard to these factories.

7. *Further Regulations.* In Rhode Island and some other states, non-residents are prevented from engaging in lobster fishing and the

residents themselves must be licensed. Further, certain States require that all cars, traps, and other contrivances used in catching or handling lobsters shall be branded with the owner's name, and in order to give protection to the lobstermen, unauthorized meddling with lobster gear is heavily fined.

8. *Tabulation of Lobster Laws.* The following table gives the main laws of various states regarding the lobster fishery:

Table of Lobster Laws in the Various States, 1910.

STATE.	Egg lobsters. Penalty for not liberating.	State Pur- chasing egg lobsters.	SHORT LOBSTERS.			Un- cooked multi- lated. remains. Penalty.	Not marking gear. Penalty.	CLOSE TIME.		Unauthorized. interference with gear. Penalty.	Non- residents fishing, and penalty.
			Minimum Size.		Penalty.						
			Alive.	Cooked.							
Maine.....	\$10.00 each.	May pur- chase.	4½ in. body measure.	4½ in. body measure.	\$1.00 each.	\$20.00.	Cars, \$10.00; traps, \$5.00.	.....	.....	\$20.00 to \$50.00.	.....
New Hampshire..	\$10.00 each.	.....	10½ in. entire length.	.....	\$10.00 each.	.....	Marking is nec- essary in order to bring suits for damages.	.....	.....	\$50.00.	.....
Massachusetts....	For each offence, \$10.00 to \$100.00 or one to three months' im- prisonment.	May give entire length. permit.	9 in. entire length.	8½ in.	\$5.00 each.	\$5.00 each.	\$10.00 to \$100.00.	.....	.....	First offence, \$5.00 to \$25.00, and 30 days; subsequent \$20.00 to \$30.00, and 60 days.	Must be an inhabitant for one year, or \$20.00 fine.
Rhode Island.....	\$5.00.	Shall pur- chase.	4½ in. body measure.	4½ in. body measure.	\$5.00 each.	\$5.00.	Confiscation; \$20.00, or 30 days' im- prisonment.	Nov. 15 to April 15.	\$20.00, or 30 days' im- prison- ment.	\$10.00.	Shall be a citizen for one year, and licensed; \$20.00 fine and 30 days.
Connecticut.....	Not to exceed \$25.00.	May pur- chase.	4½ in. body measure.	4½ in. body measure.	Not to exceed \$25.00.	.....	Confiscation; fine not to ex- ceed \$25.00.	.....	.....	.....	Non- residence and aliens licensed.
New York.....	No restriction.	.....	9 in. entire length.	.....	Deter- mined by court as misde- meanor.	.....	.....	.....	.....	.....	.....

It would be safe to assume that, even with well-enforced and uniform laws in the various States, the abundance of lobsters would not be sufficient to keep pace with the increased demands of the market. Some means of artificial propagation must be resorted to.

B. ARTIFICIAL HATCHING AT THE STATIONS OF THE UNITED STATES BUREAU OF FISHERIES.

As artificial hatching had been successful, in the case of fishes, it was naturally the first method to be tried with lobsters. When the lobsters are received at these stations, the eggs are scraped off and placed in jars to hatch. The MacDonald jar, well known through its use in the hatching of shad, has been, till quite recently, the one made use of, and has been quite successful, only a small percentage of eggs failing to hatch. Within the past few years the station at Woods Hole has used, with good results, the Downing jar instead of the MacDonald.

It was, however, pointed out long ago that few, perhaps not over 1 in 1,000 of the fry thus hatched ever reached the fourth stage. Furthermore, hatching the eggs artificially possesses no advantage over the natural method. It is safe to say that the egg lobster hatches practically all the eggs that will hatch. No artificial method can do as well. Even though the hatching can be perfected to such an extent that the percentage very closely approximates the natural method, there will be a great mortality before the fry can be liberated. This would not occur in the natural state, because the eggs of a lobster do not all hatch at one time, and consequently, in moving about over the bottom, the egg lobster would scatter its fry over a wider area. Furthermore, when the fry are liberated from the artificial hatchery, the cloud which results from pouring out the thousands of larvæ must undoubtedly attract the attention of fishes, while the few which would hatch at one time from the natural method might escape notice.

Perhaps the principal thing which can be said in favor of artificial hatching is that the practice of buying egg lobsters, usually at a pre-

mium, discourages the fishermen from scraping off the immature eggs in order to evade the law.

C. HATCHING AND REARING AS DEVELOPED BY THE RHODE ISLAND COMMISSION.

1. INTRODUCTION.

In view of the decided disadvantage with which the recently hatched larvæ commence life, and the very slight advantage, if any, which hatching them artificially has over the natural methods, it has been clearly recognized for a number of years that some further protection must be given the young lobster if artificial methods are to make any appreciable difference in the lobster supply. Herrick, in whose charge the United States Bureau of Fisheries placed the investigation of the entire lobster problem, said, in 1895, "The problem of artificial propagation of the lobster will be solved when means are devised by which larvæ, after hatching, can be reared in enclosures until the fifth or sixth stage, when they are able to take care of themselves."

This idea of rearing the larvæ until they are able to care for themselves has been before the Rhode Island Commission since 1898. But instead of rearing them to the fifth and sixth stages it has been the policy until quite recently to rear them only to the fourth stage, when, as has been seen, the lobsters assume the general form of the adult and to some extent its habits. It is true that the lobster does not entirely give up its swimming habits till it reaches the fifth stage, and occasionally not until the sixth stage is reached. But since, as will be shown later, the fourth stage lobster does burrow and, if liberated with care at favorable localities, will hide at the bottom among the stones and eel-grass, and also on account of the great space required, it has been until lately impractical to retain them until a later stage. With the continual enlargement of the plant and with improvements in methods to such an extent that less space is required for the fry, we have been able to rear many thousands to the fifth and

PLATE XIII.—Raft units attached to the houseboat. (End View.)

PLATE XIV.—Raft units attached to the houseboat. (Side view.)

sixth stages. It is quite probable in the near future that only to avoid excessive crowding will any lobsters be liberated at the fourth stage.

The successful method of rearing the lobsters through the free-swimming stage was the result of many painstaking experiments. Since the idea was hit upon in 1900, it has taken ten years of continued experiments in order to bring the work up to its present condition. It can now be truly said that the scheme, as now operated, is entirely practical and successful. The chief obstacles which had to be overcome in reaching success were the serious cannibalism of the larvæ, the necessity of crowding them together in order to rear large numbers, the difficulty of supplying them with sufficient food, the parasitic growths of diatoms and protozoa which infect the early stages, and the determination of an optimum current of water by correct adjustment of the angle of the paddle.

The main feature of the scheme used in rearing consists in keeping the fry in constant motion. This is accomplished by confining the fry in large wooden boxes or tanks which are suspended in the water, and provided with windows of fine mesh wire netting or perforated metal. A two-bladed paddle, not unlike a restaurant fan, is kept revolving slowly in each box at a rate of 9 revolutions per minute. Through their motion the water is kept fresh and the fry are prevented from settling to the bottom. The current of water is made just strong enough to keep them separated, thus preventing them from feeding upon one another, and yet of sufficient strength to keep their food in circulation near them. The proper adjustment of the paddle is one of the most important elements in successful rearing.

A three horse-power gasoline engine supplies the power for operating the paddles. This power is transmitted by means of steel shafting, and mitred gears from the houseboat (Plates XIII, XIV), in which the engine is located, to the floats attached to the sides of the houseboat. There are two of these floats which are fastened to the houseboat, one on each side, and are composed of a number of raft units bolted together and floated by barrels. The units are construct-

ed of 6 x 6 spruce, and each one contains two rearing cars. These cars or boxes are ten feet square and four feet deep and are made of matched spruce. Four carefully screened windows, two in the bottom and one on each of two opposite sides, are set in the cars and provide for the necessary circulation of water. More detailed account of the various constructions and operations is given in the following paragraphs.

2. STRUCTURE OF THE FLOATS.

Reference to Plates XV, XVI will give an idea of the manner in which a raft unit is constructed. In brief, it is a skeleton raft, with two alleyways running the length of the float, one on either side, for the supporting barrels. Between the alleyways are two open pools, 12 feet square, in which the rearing cars are placed. At the corners of each pool are uprights which are connected across the top by cross beams. Running the full length of the raft and supported by these cross beams is a beam which crosses the center of each pool and furnishes support for the shafting and gears. Two sets of these units are employed, one on each side of the houseboat.

3. ENGINES AND GEARING.

A three horse-power engine of the Fairbanks-Morse Vertical Type, located in the houseboat, furnishes the power necessary to operate the 28 nine-foot paddles now in use. Because of the distance from repair shops, and also because a stop of an hour's duration would result in considerable loss, we have installed two of these engines in the houseboat. These are arranged so that they may be used independently. That this size engine is capable of doing the work required of it and even more is shown by the fact that this past season (1910) one was used day and night for over two months before it became necessary to shut it down for slight repairs. The other engine has been in use for eight years and is still capable of carrying the entire load. It is further to be remembered that the constant bending of the floats by the motion of the water makes necessary the transmis-

PLATE XV.—A raft unit with rearing carts raised as for washing and drying.

PLATE XVI.—A raft unit with the rearing cars removed.

SPECIAL APPARATUS USED AT WICKFORD.

PLATE XVII.—Universal joint and sliding sleeve.

PLATE XVIII.—Paddle gear (2), and bushing (1).

PLATE XIX.—Hoisting apparatus.

sion of more power than is necessary for the mere turning of the paddles. In addition to this, the gears are protected in no way from the weather. Under all these conditions, however, there was ample power in the engine to provide for all emergencies.

The speed of the engine, 320 revolutions per minute, is reduced, by means of belt pulleys situated within the engine-house, to forty revolutions. This speed is transmitted by means of a belt to a main transverse shaft of 1½-inch steel running across the houseboat.

From this main shaft two transmissions are made to 1-inch shafting running transversely on the two floats. The constant change in level between the houseboat and the floats, caused by the motion of the water, made necessary the adoption of universal joints (Plate XVII) invented especially for this purpose, to connect the shaft on the houseboat with the shafts on the floats. These universal joints consist of a pair of toggle-joints (Fig. 2) united by means of a sleeve (Fig. 5) in which two pieces of square shafting slide (Figs. 3, 7). The toggle-joints make possible the transmission of power at any angle, and the square shafting, sliding in the sleeve, allows for the lengthening or shortening of the distance between the houseboat and the floats. From the transverse shafts on each float, which of course have the same speed as the main transverse shaft on the houseboat, connection is made, by sets of mitred gears, to longitudinal shafts running the length of the centers of the floats. The speed of the longitudinal shafts is reduced by the gears to twenty revolutions per minute.

From these two longitudinal shafts, connection is made, by means of mitred gears, to the vertical paddle shafts. (Plate XX, figs. 4-9.) In these the speed is reduced by the gears to nine revolutions. The paddle shafts are composed of two parts. The upper part, which is above the water, consists of one-inch square shafting. The lower part, which enters the water and upon which the paddle blades are attached, consists of galvanized iron piping except at the extreme upper end, where there is a short piece of one-inch square shafting. This piece of square shaft enables the power to be transmitted from

the upper to the lower portions of the paddle shaft by means of a sliding sleeve, which is pinned to the upper shaft through a slot. When the sleeve is raised up the paddle is disengaged. Thus each paddle may be operated separately without interfering with the entire machinery.

With the exception of the paddle shaft and the transverse shaft running across the houseboat, the entire shafting in use consists of one-inch round steel shafting supported by ordinary babbitted shaft-hangers and pillow blocks. It is very necessary to use shaft as light as one-inch because in the long drives (at present about 530 feet—250 feet on each side of the houseboat) and the constant bending of the long floats, caused by the motion of the waves, a heavier shaft because of its rigidity, would pull out the hangers. The one-inch shafting readily bends with the float and the low speed (18 R. P. M. in the longitudinal shafts) is not materially interfered with.

Between each raft unit the shafting is connected by a sleeve coupling so devised that by sliding it back the shafting on the farther unit is disengaged. In this way the power on each unit raft can be stopped independently. Furthermore, since these couplings are loose on the shafts, they permit the shafts of two adjacent units to slightly pull apart or come together under stress of the bending caused by the waves without materially interfering with the alignment of the shaft or the transmitted power.

The constant bending of the rafts led to an attempt to install electric motors on each unit. In such an arrangement, each unit would be independent of all others, and slack wires would easily take up all changes in length between rafts due to this motion. A practical method of installing a motor was easily found and tried out, but under present conditions proved to be too expensive.

4. CONSTRUCTION AND CARE OF THE REARING BOXES.

Previous to 1908, large bags made of canvas or scrim were used in rearing lobsters. Since this time wooden boxes have been substituted and have been found to be more satisfactory in every way. Even at their best the canvas bags were not as efficient as the cars,

PLATE XX.—A lobster rearing car or box, showing paddle and windows.

and when we consider the durability, ease with which they may be handled, and the certainty with which they retain the fry, we see that the boxes far surpass the bags. Furthermore, the current in the cars differs greatly from that in the bags. In the latter the current is a sort of an ascending spiral and is in a measure continuous in direction. In the wooden boxes, because of the square corners, the current "doubles on itself," as it were, in each corner. This, if not allowed to be too strong, is of great advantage to the fry, often enabling a weaker one to escape the pursuit of its stronger neighbor. The food also tends to be scattered more widely through the box.

The wooden rearing boxes (Plate XX) are 10 feet square and 4 feet deep. They are built throughout of matched spruce strengthened by 2 by 3 timbers and in form are like ordinary boxes. The inside corners or angles may be truncated or not, just as desired, by wide boards carefully fitted in. (There is perhaps a slight advantage in truncating the corners but it is by no means very important.) In the bottom and on two sides of the rearing boxes are windows. The frames of these are made of furring (figs. 1, 2, and 3) and are covered on the outside with a heavy galvanized screening (from 4 to 8 meshes to the inch) designed to keep out the fish and also to protect the inside screen, which is usually a bronze wire netting (16 inches to the inch) and therefore quite light. This inside screening may be of various materials—such as wire netting of copper, bronze, or galvanized iron, or may be made of perforated metal. Bronze wire is used at present because it is inexpensive, and with care will last an entire season or longer. Furthermore, the gauge of the wire is small and therefore interferes very little with the circulation of water.

The rearing cars are sunk into the pools of the rafts about three quarters of their depth and are held down by 2 x 8 spruce planks, which are notched to fit over the projecting 2 x 3 posts in each corner of the car (Plate XX, fig. 10) and are clamped down to the rafts by iron hasps. A toothed hoisting-drum (Plate XIX) is located on the 4 x 6 uprights at each corner of the pools and enables these cars to be easily raised whenever desired.

As soon as the fry in a rearing car have reached the fourth stage,

they are removed and the rearing box raised and thoroughly washed. (Plate XV.) The insides of the boxes are covered with a thin coating of copper paint in order to prevent them from becoming overgrown. This is quite an important matter because the fry often become contaminated from contact with the foul sides of the car. Care in seeing that there are no holes with a diameter greater than $\frac{1}{16}$ of an inch in the cars, and then guarding against their becoming foul, are the two most essential points in the care of the cars.

5. CONSTRUCTION AND ADJUSTMENT OF THE PADDLES.

The paddles used at Wickford are two-bladed, not unlike those used overhead in restaurants. (Plate XX.) Each blade is made of one-inch cypress and is 8 inches wide at the end nearest the paddle shaft, and tapers to about 4 inches at the outer end. The blades are fastened by clamps to a piece of $\frac{3}{4}$ -inch galvanized iron pipe, which is placed on the under side. (figs. 4,5.) Between the two blades there is a cross coupling, into one opening of which a short vertical galvanized iron pipe is screwed (fig. 6) which sets over a stud-bearing in the bottom of the rearing car. (fig. 7) In the opposite opening of the cross coupling is a long vertical galvanized pipe (fig. 8) which is used as a shaft for that part of the paddle which is under water, and connects with the shafting and gears as described in section 3, page 110. The paddle used at present is broadly beveled on each side, though the double beveling is unnecessary. The length of the paddle should be sufficient to clear the sides of the box by about 3 inches when revolving, and should be raised about the same distance above the bottom. The blades of the paddle should, furthermore, be painted white so that the lobsters will avoid them.

Too great care can not be exercised in the proper adjustment of the paddle. With a paddle of the above width and length, a little less than ten revolutions per minute are sufficient. The angle which the paddle should oppose to the water is a matter which requires experience to determine. It is, however, a very important factor. Many times in two lots of larvæ, under apparently similar conditions,

one of them will appear clean and healthy while the other will be covered with growths. In one a large percentage will survive, while in the other the mortality will be high. The main cause will be the difference in the current of water.

By the angle of the paddle the amount of current is determined, and the current determines the amount of food which is accessible to the lobster, the extent of cannibalism, the ease with which they molt, the amount of diatoms and other parasitic growths on the fry, and those undeterminable factors which go to make up conditions of health and vigor.

That the proper amount of current should affect the accessibility of the food, and to a certain extent prevent their eating one another, is easily seen. That it should have an influence on the ease of molting is also apparent. When the lobster molts it is, for a short time, more or less helpless. A strong current throws it against the sides of the box or forces it against the screenings. These conditions naturally do not favor molting. On the other hand, if the current is very weak, while it may be sufficient to keep an active larva moving, yet when the molting period arrives the larva will sink to the bottom and be rolled along with whatever food, silt, diatoms, and fungus spores have collected there. The current must be so adjusted as to prevent both of these difficulties. Why it should affect the parasitic growths on the fry is not so easily seen. Because of the current continually running in the boxes, a considerable number of diatoms, etc., will collect on the inside of the box, and consequently there will be in the water within the boxes. The number in the water within the boxes, however, cannot be much greater than in the water outside; at least not enough greater to explain the abundant growths of diatoms which sometimes occur. The probability is that the fry are infected with these organisms by their contact with the sides of the boxes. With a current great enough to continually throw the fry against the sides of the boxes, the opportunity for their infection would be very great; while with a current of less intensity the natural instinct of the fry to shun any object would prevent this to a great extent. That this

is actually the case is shown by the fact that frequently two lots of fry, under exactly similar conditions as regards cleanliness of the boxes, etc., will, with different strengths of current, turn out, one clean and healthy and with a low mortality, the other covered with diatoms, etc., weak, and with a high mortality.

Other unfavorable circumstances attend a strong current. Experiments with fry of all stages, conducted carefully in jars, showed that all through the larval period the lobster is negatively rheotropic, *i. e.*, will endeavor to swim in opposition to the current. Efforts to oppose the current are more marked the stronger the current. In a very feeble current the lobster will, to a certain extent, act as if in quiet water; when the current is strong, but not too strong, it will oppose it, provided other things, such as the pursuit of food, reaction to light, etc., do not interfere. Of course in a too strong current the larvæ will be prevented by the mere force of the current from swimming against it. This reaction to current is most pronounced in the fourth stage, as in that stage the fry are very strong swimmers. The first, second, and third stages swim very feebly, and are naturally turned over and over by a strong current. They will continue to struggle against it, however, though without avail. This certainly can not be favorable for their development. When turned over and over by a too strong current it is impossible for them to secure food, and starvation results.

Although from what has been said, it will be seen how important a matter the proper adjustment of the current is, yet the selection of the most favorable current can be made only after one has gained experience by actual experiment.

6. OBTAINING THE EGG LOBSTERS.

At Wickford, previous to 1910, the egg lobsters were purchased only in the spring from the lobstermen who were paid the regular retail price. But this past year the egg lobsters were bought throughout the entire year. These were retained in cars until the commencement of the close season (Nov. 15) when all but 400 were liberated.

PLATE XXI.—A towing car for transporting lobsters and fish.

The remainder were kept through the winter in floating cars which were 4 feet deep. If proper care can be given the egg lobsters, the method of buying the year around is preferable, as it creates a market for the egg lobsters and takes away the incentive to scrape off the green eggs; also, since the time in which they may be collected is longer, a greater number of egg lobsters can be secured. In transporting and handling the egg lobsters considerable care should be exercised, especially when the eggs are nearly ripe. The extremes of heat and cold, fresh water, and exposure to the air for any length of time, are the things to be most guarded against. Whenever they are to be shipped any distance it is preferable to have them contained in the well of a boat where abundant circulation of water can be had. Where a boat's well is not available a towing car like the one in Plate XXI may be used. This is constructed of two barrels ballasted with Portland cement to keep them right-side up, and connected together with strips of furring. On the bottom, between these strips, cracks are left wide enough to allow abundant circulation of water, and on the upper side canvas flaps are provided to protect the lobsters from the hot sun. The front end of the forward barrel is built out and covered with tightly stretched canvas, in order that the car may tow easier. Lobsters have been carried long distances in excellent condition in this towing car. Wherever the lobsters must be shipped in barrels, care should be taken not to allow the ice to come in contact with the lobsters, as the fresh water from the melting ice will kill most of the eggs. If it is necessary to use ice in shipment, it should be so arranged that neither the ice nor the fresh water come in contact with the lobsters or with the eggs. This is readily accomplished by placing in the center of the barrels long cans above five inches in diameter to contain the ice. These should be covered with sacking to keep the lobster eggs from the extremely cold cans.

The lobsters, however obtained, should be confined in covered cars which provide for abundant circulation of water. As the lobsters are more or less crowded together, it is often necessary to secure their claws in some way, to prevent fighting, which may result in their

killing or mutilating one another, or at least in scraping off the eggs. Tying their claws with string or wire, winding with canvas bandages, or putting on mittens made of some cheap cloth, and plugging the claws with wooden plugs have all been tried. The surest way is to insert wooden plugs just outside of the movable jaw of their claws. This at first was avoided, for fear of injuring the lobsters, but it was found that very little, if any, injury was caused by this plugging. The use of the claw is very quickly restored after the plug is removed, and the lobster seems to be none the worse for it. This practice is employed by lobstermen everywhere, where lobsters are kept in cars.

As the season progresses, usually about the first of May, the lobsters are looked over. One who has had experience can tell at a glance about how soon the eggs of a lobster will hatch. The lobsters that will hatch their eggs about the same time are put in compartments together. Too much care cannot be exercised in keeping them picked over.

7. HATCHING THE EGGS.

As soon as a lobster's eggs reach the point where they will hatch in two or three hours, the lobsters are transferred to the rearing box, where the paddle is started and they are allowed to roam over the bottom and hatch their eggs in a perfectly natural manner. The paddle in this car should be sufficiently high from the bottom of the car to keep from striking the hen lobsters, and also prevent crowding them into the corners. As many as 100 hen lobsters may be put into one car, but care should be taken not to overcrowd them, because in overcrowded cars the hen lobsters cannot properly care for the eggs, which consequently are apt to spoil. Only enough should be put in to insure the filling of the car with fry in a few hours. Naturally this is a very important factor, because of the cannibalistic habits of the fry, for if lobster fry of varying ages are in the same car the danger of their devouring one another is much greater than as if they are all of the same age, even though this danger is reduced to a minimum in the rearing boxes. The rearing cars containing the egg lobsters should be carefully screened, because the bright light tends to

PLATE XXII.—Feeding the lobster fry by hand.

weaken the lobsters, and furthermore, the uniform shade in the covered cars keeps the hen lobsters scattered about instead of remaining crowded together in the corners.

As soon as a sufficient number of fry has hatched to reasonably fill the rearing car, the hen lobsters are taken out and examined. Those that still have eggs are immediately put into the next rearing box, and so on until the eggs are all hatched.

8. FEEDING.

Feeding is another operation which requires much attention. (Plate XXII.) The lobster fry in all stages eat ravenously and without much selection of food. Almost anything in the way of animal food will serve them for a meal. Their cannibalistic habits have been referred to. In confinement in the rearing cars the food item becomes of tremendous importance. Molting three times in from 10 to 14 days, while in each molt important structural changes occur, the lobsters demand regular and almost continual feeding. Their feeding apparently does not take place chiefly at night as in the adult, but on the contrary they seem to feed most frequently during the day. The warmth of the water and the bright sun seem to favor their growth, or at least the rapidity of molting. Lobster fry very often, when taken from the rearing bag and placed in a shallow dish for observation, will molt in a very short time if it is a bright sunny day. This occurs so often as to lead one to conclude that the warmer temperature of the water in the dish hastens the molting. Since the conditions of temperature favor growth, they must undoubtedly encourage more abundant feeding in order to supply proper material for growth. But we are not to conclude that the lobster does not feed during the night. Flash lights thrown on the water in the rearing boxes at night have shown fry eating pieces of food. The fact that the proportion of those feeding was not as great as in the daytime must not be taken as an indication that the lobsters feed principally by day, for a sudden light greatly excites them and may have caused the dropping of food.

The practice of feeding the fry as frequently during the night as during the day, *i. e.*, every two hours, has been carried on at Wickford. The kind of food used is determined, not so much by the preference of the lobster, as by the requirements of the scheme of rearing. The fry feed quite as readily on one kind of food as another. The articles which may be used as food, in order of their value, are hens eggs, soft shell clams, beef (cooked and raw), liver, fish, fly larvæ, mussels, shredded codfish, copepods, etc. .

Hens eggs, fried without grease and finely pulverized, is the best and most economical food that has been found at present. Its light color attracts the fry, and the fact that immediately after feeding them, particles of egg can be seen through the transparent shell of nearly every lobster, is evidence of how readily they eat it. It is not necessary to obtain fresh eggs and we have used quite satisfactorily the "broken out" eggs, which are sold by the gallon. This past season (1910) it was found most economical to buy the second grade cold storage eggs by the case. In the first and second stages the fry were fed eggs exclusively, but in the later stages it was the practice to mix cooked beef and liver with the eggs.

Soft-shelled clams, when available seem to be a very good food. The advantages are lightness (requiring little current to keep it up in the water), absence of oil, and less likelihood of decay. The fry eat it very readily. The preparation of the clams consist in cutting them from the shells and chopping them finely with a meat chopper. The whole clam is usually employed, not even discarding the tough snout, as the lobsters seem to pounce upon a piece of this almost as quickly as upon the softer parts. Clam, however, is not as good nor as economical as hens' eggs.

Fish, perhaps, is as much preferred by the fry as anything; but it is very oily and fills the water with grease. This interferes with observation, and is unfavorable to a healthy condition of the fry. Moreover, those particles which fall to the bottom of the ear rapidly decay and foul the water.

It is the custom at Wickford to feed the fry every two hours

throughout the twenty-four, and this seems to be very satisfactory. However, the practice of keeping the fry continually supplied with food should be considered of more importance than regular feeding periods.

A *mechanical feeder* was used this last year which promises to be very satisfactory. It consists of an ordinary flour sieve which is suspended in the water and so arranged that the handle is slightly turned at each revolution of the paddle. The finely ground food is placed in this sieve and at each turn of the paddle a little of it is scraped out into the car, where the current of water quickly spreads it.

9. LENGTH OF TIME REQUIRED TO REACH THE FOURTH STAGE.

The length of time required to reach the fourth stage from the time of hatching varies at Wickford from 10 to 21 days. The temperature of the water is, in a great measure, responsible for this variation, but careful records kept during 1905 seem to show that, while it is the most important, it is not the only factor. It will be necessary to experiment further in order to fully establish the importance of the various factors, yet it may be said that the following certainly do exert considerable influence on the duration of the first three stages. In the order of apparent importance they are temperature, food, current, density, and light. The effects of temperature, food, and current have already been described. Of the influence of the density of the water little is known; after a warm rain, however, molting seems to progress more rapidly. The importance of the light factor is as yet undetermined. It has been the practice this past year (1910) to rear the fry unscreened from the sunlight, until they have reached the third stage after which they were kept screened. Good results were obtained from this method.

10. LIBERATION OF THE LOBSTERLINGS.

The proper liberation of the young lobsters is a matter equally as important as the successful rearing of them to the bottom stages and great care must be taken, otherwise the results so hardily won in

rearing will be lost. Three methods will be spoken of: the liberation of the fourth stage lobsters along the shore, the liberation of fifth and later stages, and the liberation by means of specially devised cars.

LIBERATION OF THE FOURTH STAGE LOBSTER ALONG THE SHORE.

By this method as fast as the fry reach the fourth stage they are dipped out and put by themselves in a retaining car. As soon as a sufficient number has been collected they are transported to the place where they are to be liberated, in large galvanized iron cans with a loose cover over the top. A suitable shore, one composed of rocks, with a growth of short eel-grass or seaweed of some sort, is selected, and the young lobsters poured out just at the water's edge. (Plate XXIII.) The morning is the best time for transporting and liberating them. If the time during transportation is long, a tight can with ice may be suspended in the can containing the lobsters; but where there is to be only one or two hours confinement in the can, care in keeping it from the sun and frequently aeration of the water by stirring, is all that will be necessary.

The above plan is the result of experience. At first the lobsters were liberated at the surface of rather deep water, over a rocky ledge. The fry, when poured out, would sink for some distance, and then the greater part would rise and swim about. Just how long this swimming was continued is not known. But instances occurred where individual lobsters, which had some distinguishing mark, as the absence of a claw or a peculiar tuft of diatomaceous growth, have been liberated by accident near the houseboat, and have been observed for several days, swimming from one beam of the float to another, though the bottom was only from six to ten feet distant. It is hardly needful to comment on this method of liberation. *Tautog* abounding around such ledges would scarcely allow such an opportunity to go by without taking advantages of it. Perhaps few lobsterlings would ever become established in safe retreats.

Profiting by this experience, the idea of liberating on the shore was tried. Here another distinction between favorable and unfavor-

PLATE XXIII.—Liberating lobsterlings along the shore.

able places was found. If the lobsterlings were poured out at the edge of the water where the shore was composed of white or light colored rocks, the majority of them would swim out from the shore while still near the surface, and apparently the result would be similar to liberating in deep water. If the shore, however, afforded a dark background, especially if this was occasioned by eel-grass, algæ, or seaweed of some sort, the lobsters would disappear, and close scrutiny would reveal most of them lodging in the branches of the weeds and following the stems down to the bottom. Some fry, of course, would swim out, due mostly to the reaction from being in confinement. Most of them, however, would soon go to the bottom.

LIBERATION OF FIFTH AND LATER STAGES.

As has already been shown, the exact time when the lobster fry leave off swimming, except when disturbed, varies somewhat. The majority of lobsters in the fourth stage, when confined in cars, do build burrows, and perhaps swim about only when in search of food or upon some other stimulus; many will, however, keep swimming about on the sides of the car near the surface, but it is not long, usually near the commencement of the fifth stage, before these too have taken up the habits of bottom life. From the above considerations it would seem that the lobsters may, if care is taken, be liberated successfully after the first three or four days of the fourth stage are past. But a later stage is preferred, and as many stages later as may be will further insure the lives of the lobsters liberated. The chief difficulty in the way of rearing these later stages is the great space required. However, it is hoped that in the future a large majority of our lobsters will be reared to the fifth stage or beyond.

LIBERATION IN SPECIALLY DEvised CARS.

Two devices for liberating in deep water have been tried out this past year. One of these is a covered box weighted with stones, and with numerous large holes bored in the sides near the bottom. On the outside of the box strips of wood wider than the diameter of the

holes are nailed over the holes in such a way as to leave a crack on the lower side of the strip large enough for the lobsters to get through and yet too narrow to allow fish to get in. As these strips are nailed only on the outside, the holes are left the entire size on the inside, and thus can readily be found by the young lobsters. The lobsters are then placed in the box, which is covered, sunk to the bottom, and left for a day or two. In this length of time the lobsters have gradually worked out of the box through the numerous holes.

The second and better method is to construct a wooden box with a tight cover and with the bottom made of galvanized screening eight meshes to the inch. This screen is fastened three inches up from the lower edges of the sides. This allows the sides to project three inches below the bottom of the car and consequently the car may sink a little way into a soft bottom and still leave the screen a little higher than the mud. The mesh of the screen is then spread open in a number of places so as to leave holes large enough to permit the lobsters to crawl out. In lowering the car the inrush of water keeps the lobsters away from the holes and when the car rests on the bottom an inclosed place is formed under the screen between the projecting sides. Within this inclosure the lobsters, after they crawl out, can burrow in the ocean bed unmolested by fish. The car can usually be removed at the end of twenty-four hours.

11. LIBERATION OF THE EGG LOBSTERS.

After the eggs are hatched from the hen lobsters a copper tag with a serial number and the words "Return to the R. I. Fish Commission" is often fastened securely with fine wire to the lobster's beak. (Plate XXIV.) Then, after the length and other data of interest have been recorded, they are liberated at various places in the Bay. The tags of those caught are returned by the lobstermen, with a record of the date and place captured. Considerable information is thus collected in regard to the migration of the lobsters, and, since the lobster in molting casts off the tag together with the old shell, some data is

PLATE XXIV.—Method of tagging a lobster.

obtained in regard to the length of time after the eggs are hatched before molting.

Another way in which liberated lobsters have been marked at Wickford has been to punch holes in one or more flippers of the tail. As there are five flippers the lobsters may be marked in a large number of different ways.

12. CONDITIONS MOST ESSENTIAL FOR THE LOCATION OF A REARING PLANT.

The experience of the past ten seasons in the operation of the plant at Wickford has made it evident that for the proper location of a station for rearing lobsters, two conditions especially must be sought. These conditions are quiet water and warm water. It is not essential in the least to have the station near the place where egg lobsters are obtained most abundantly, for the lobsters may be shipped with little injury. Shelter from storms and ocean swells is obviously a very important factor.

The plant described above, though evidently but a skeleton structure, is nevertheless capable of withstanding quite a heavy sea. It has been subjected to some of the worst storms for years along the coast and rode them out uninjured. The paddles ran in good order, until in the midst of the storm the engine was shut down as a measure of precaution. The seas often ran so high that many fry were swept out of the cars. The greater the protection afforded by the location however, the less danger will there be of accident.

The temperature of the water is of paramount importance in order to obtain the best results. Although it is possible to rear lobsters with some success in cold water, the best results will be obtained with water at a temperature of 65° to 75° F. This higher temperature results in a more rapid development of the lobsters. This more rapid development results, first, in a reduction of the expenses of operating the plant, because of the less time required; and second, in a greater proportion of fry reared to the fourth stage, because in the

shorter time there is less chance for death from cannibalism, parasites, and injury.

13. COST OF A REARING PLANT.

The estimated cost of the simplest possible plant, consisting of 24 rearing boxes, capable of turning out 600,000 lobsterlings, is follows:

3. H. P. Engine.....	\$180
Scow.....	200
4 floats.....	300
Gearing.....	700
Rearing boxes.....	320
Miscellaneous fixtures.....	100
<hr/>	
Total.....	\$1,800

In some localities this might vary from the above more or less, according to the advantage for securing the material.

The running expenses of such a plant in a favorable locality would not be far from \$3 per thousand lobsterlings reared; this includes gasoline, food for the fry, and labor; but does not include the cost of egg lobsters. The cost of operation in 1910, at Wickford, was less than \$2 per thousand.

14. RESULTS OBTAINED.

A number of good results have been obtained at Wickford by the use of the method described above. Among these may be mentioned:

From a counted lot of 10,000 fry less than one day old, 6,946 fourth stage lobsters were reared. Very often a percentage as high as forty or forty-eight per cent. has been obtained. In nature probably not more than one in a thousand reaches this stage.

From the eggs of one egg lobster 7,465 fourth stage lobsters were reared. This corresponds closely to 40 per cent. of the number of the eggs.

Total Number of Fourth and Fifth Stage Lobsters Reared Each Year Since 1900.

	IV.	V.
1900.....	*3,425	.....
1901.....	8,974	.....
1902.....	27,300	.....
1903.....	13,500	.....
1905.....	103,572	.....
1906.....	189,384	24,800
1907.....	294,896	4,900
1908.....	322,672	5,481
1909.....	178,542	.....
1910.....	511,274	28,372
Total.....	1,704,136	63,553

*All of the figures were obtained by actual count and were not estimated.

APPENDIX C.

TITLES OF SPECIAL PAPERS PUBLISHED IN THE ANNUAL REPORTS OF THE COMMISSIONERS OF INLAND FISHERIES OF THE STATE OF RHODE ISLAND.

1. MEAD, A. D. The Starfish. (First paper.) Twenty-eighth Annual Report. 1898.
2. MEAD, A. D. The Starfish. (Second paper.) Twenty-ninth Annual Report. 1899.
3. TOWER, R. W. Improvements in the Methods of Preparation of Fish for Shipment. Twenty-ninth Annual Report. 1899.
4. BUMPUS, H. C. The Extension of the Commercial Fisheries of the State. Twenty-ninth Annual Report. 1899.
5. KELLOG, J. L. The Life History of the Common Clam. Twenty-ninth Annual Report. 1899.
6. MASON, N. R. A List of the Diatoms Found in the Water over the Clam, Mussel, and Oyster Beds in Narragansett Bay. Thirtieth Annual Report. 1900.
7. MEAD, A. D. Observations on the Soft-shell Clam. Thirtieth Annual Report. 1900.
8. MEAD, A. D. Observations on the Soft-shell Clam. (Second paper.) Thirty-first Annual Report. 1901.
9. RISSER, J. R. H. Habits and Life History of the Scallop. Thirty-first Annual Report. 1901.
10. MEAD, A. D. Habits and Growth of Young Lobsters and Experiments in Lobster Culture. Thirty-first Annual Report. 1901.
11. MEAD, A. D. Observations on the Soft-shell Clam. (Third paper.) Thirty-second Annual Report. 1902.
12. MEAD, A. D. Habits and Growth of Young Lobsters and Experiments in Lobster Cultures (Second paper.) Thirty-second Annual Report. 1902.
13. MEAD, A. D. and WILLIAMS, L. W. Habits and Growth of the Lobster and Experiment. in Lobster Culture. (Third paper.) Thirty-third Annual Report. 1903.
14. MEAD, A. D. and BARNES, E. W. Observations on the Soft-shelled Clam. (Fourth paper.) Thirty-third Annual Report. 1903.
15. MEAD, A. D. and BARNES, E. W. Observations on the Soft-shell Clam. (Fifth paper.) Thirty-fourth Annual Report. 1904.
16. BARNES, E. W. Preliminary Inquiry into the Natural History of the Paddler Crab (*Callinectes hastatus*) with Remarks on the Soft-shell Crab Industry of Rhode Island. Thirty-fourth Annual Report. 1904.
17. MEAD, A. D. Experiments in Lobster Culture. (Fourth paper.) Thirty-fourth Annual Report. 1904.
18. MEAD, A. D. Experiments in Lobster Culture. (Fifth paper.) Thirty-fifth Annual Report. 1905.
19. HADLEY, P. B. Changes in Form and Color in Successive Stages of the American Lobster. Thirty-fifth Annual Report. 1905.
20. EMMEL, V. E. The Regeneration of Lost Parts in the Lobster. Thirty-fifth Annual Report. 1905.
21. TRACY, H. C. A List of the Fishes of Rhode Island. Plates I-XII. Thirty-sixth Annual Report. 1906.
22. TRACY, H. C. The Common Fishes of the Herring Family. Plates VII-XII. Thirty-sixth Annual Report. 1906.

23. BARNES, E. W. Methods of Protecting and Propagating the Lobster, with a Brief Outline of its Natural History. Plates XIII-XXVI and XXVIII, XXXI, XXXII, XXXVI. Thirty-sixth Annual Report. 1906.
24. HADLEY, P. B. Regarding the Rate of Growth of the American Lobster. Plates XXVI-XXXVII, and XL. Thirty-sixth Annual Report. 1906.
25. HADLEY, P. B. Observations on Some Influences of Light upon the Larval and Early Adolescent Stages of *Homarus Americanus*. Plates XXXVIII-XL. Thirty-sixth Annual Report. 1906.
27. EMMEL, V. E. The Relation of Regeneration to the Molting Process in the Lobster. Plates XL-XLI. Thirty-sixth Annual Report. 1906.
28. TRACY, H. C. The Fishes of Rhode Island, III. The Fishes of the Mackerel Family. Thirty-seventh Annual Report.
29. TRACY, H. C. A List of Rare Fishes taken in Rhode Island in the year 1906. Thirty-seventh Annual Report.
30. WILLIAMS, DR. LEONARD W. List of the Rhode Island Copepoda, Phyllopoda, and Ostracoda, with new species of Copepoda. Thirty-seventh Annual Report.
31. EMMEL, V. E. Regenerated and Abnormal Appendages in the Lobster. Thirty-seventh Annual Report.
32. WILLIAMS, L. W. The Stomach of the Lobster and the Food of Larval Lobsters. Thirty-seventh Annual Report.
33. HADLEY, P. B. Regarding the Behavior of the Larval and Early Adolescent Stages of the American Lobster. Thirty-seventh Annual Report.
34. BARNES, E. W. Lobster Culture at Wickford, Rhode Island, in 1906. Thirty-seventh Annual Report.
35. BARNES, E. W. Lobster Culture at Wickford, Rhode Island in 1907. Thirty-eighth Annual Report, 1907.
36. TRACY, H. C. The Fishes of Rhode Island V. The Flatfishes. Thirty-eighth Annual Report, 1907.
37. TRACY, H. C. The Fishes of Rhode Island VI. A Description of two young Specimens of Squiteague (*Cynoscion regalis*) with Notes on the Rate of their Growth. Thirty-eighth Annual Report, 1907.
38. EMMEL, VICTOR E. The Problem of Feeding in Artificial Lobster Culture. Thirty-eighth Annual Report, 1907.
39. TRACY, H. C. The Fishes of Rhode Island VII. The Life History of the Common Eel. Thirty-ninth Annual Report 1908.
40. SULLIVAN, W. E. Notes on the Crabs Found in Narragansett Bay. Thirty-ninth Annual Report, 1908.
41. MEAD, A. D. A Method of Fish Culture and of Transporting Live Fishes. Thirty-ninth Annual Report, 1908. (Paper Presented Before the Fourth International Fishery Congress, Washington, 1908, and Awarded Prize of Two Hundred Dollars in Gold.)
42. MEAD, A. D. A Method of Lobster Culture. Thirty-ninth Annual Report, 1908. (Paper Presented Before the International Fishery Congress Washington, 1908, and Awarded Prize of One Hundred Dollars in Gold.)
43. TRACY, H. C. Annotated List of Fishes Known to Inhabit the Waters of Rhode Island. Fortieth Annual Report, 1909.
44. BARNES, E. W. Notes on the Spring and Summer Fishing in Deep Water off Newport, During the Years 1905-1909. Fortieth Annual Report, 1909.
45. BARNES, E. W. The Plague of Sea Clams at Easton's Beach, Newport. Fortieth Annual Report, 1909.
46. HADLEY, P. B. Additional Notes Upon the Development of the Lobster. Fortieth Annual Report, 1909.
47. BARNES, E. W. Revised Edition of Methods of Protecting and Propagating the Lobster, with a Brief Outline of its Natural History. Plates IV-XXIV. Forty-first Annual Report, 1910.

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