Shelve: Annual Report of the Commissioners of Inland Fisheries, RI

State of Rhode Island and Providence Plantations.

THIRTY-SIXTH ANNUAL REPORT

OF THE

COMMISSIONERS OF INLAND FISHERIES,

MADE TO THE

GENERAL ASSEMBLY

AT ITS

JANUARY SESSION, 1906.

PROVIDENCE:
E. L. FREEMAN & SONS, STATE PRINTERS.
1906.

COMMISSIONERS OF INLAND FISHERIES OF RHODE ISLAND.

HENRY T. ROOT, *President, Treasurer, and Auditor*........Providence, R. I.

J. M. K. SOUTHWICK, *Vice-President*......................Newport, R. I.

Wm. P. MORTON, *Secretary*...............P. O. Box 966, Providence, R. I.

CHAS. W. WILLARD.................................Westerly, R. I.

ALBERT D. MEAD.................................Brown University.

ADELBERT D. ROBERTS................P. O. Box 264, Woonsocket, R. I.

Wm. H. BOARDMAN.................................Central Falls, R. I.

REPORT.

To the Honorable the General Assembly of the State of Rhode Island and Providence Plantations, at its January Session, 1906:

The Commissioners of Inland Fisheries herewith present their annual report for the year 1905:

As heretofore, the policy of your Commission has been to purchase such yearling trout and black bass as were required to stock favorable waters in the state. The beneficial results of such stocking of suitable streams and ponds is unquestioned. Without this annual restocking it would be but a matter of time before these valuable fish would disappear from our waters. Anglers throughout the state have become interested in the efforts of your Commission, and have given their co-operation in maintaining the close season and in the prevention of illegal fishing. Without their co-operation much of the restocking would be in vain, as it is obviously impossible for your Commissioners to maintain any suitable patrol of the widely scattered fishing-waters.

Several times the question has arisen as to whether it would be practicable and feasible for the Commission to establish a hatchery within the state for the purpose of providing fry and yearlings to be used in stocking the waters of the state. This method is followed by many other states with considerable success. It must be remembered, however, that most other states have larger areas to restock, requiring many more fish, and that their fishery interests are many times more important than our own. There seems to be no doubt, as it is evidenced by reports from fishermen in all parts of the state, that we are securing excellent results by the method now followed, and that, too, at no very great expense. As long as we can secure fish for stocking purposes near by, and in good condition and at a fair price, there seems to be no need of setting up a hatchery, which would require a considerable amount of experimentation before successfully established, and which would also be a considerable expense.

The policy of your Commission in planting yearling trout instead of fry seems to be a good one. There is no doubt that a larger proportion of adult fish is secured by this means than would be if fry were planted. Although in some states the practice of planting fry is still followed, yet it seems to be the general policy to abandon this practice and to use yearlings only. The chances of a fish surviving the many dangers to which trout are exposed increase proportionately with the size of the fish. The yearling fish, therefore, stands a much better chance than the smaller fry. And the advantage derived is not only in securing larger fish at an earlier period, but is also in securing a larger number of fish of lawful size in the streams for a given expenditure of money.

Your Commission, as usual, made application to the U. S. Bureau of Fisheries for a supply of shad fry, but this year, owing to the exceedingly backward season, was unable to secure any. It is hoped that in future years it will be possible to investigate more fully the habits and requirements of the shad and to make more intelligent efforts to secure the return of this valuable fish to our waters.

At the Wickford laboratory of the Commission steady progress has been made in the rearing and planting of lobsters. The past summer 103,572 lobster fry were reared to the fourth stage and distributed in the waters of Narragansett Bay. It is interesting to compare this total with the numbers reared in previous years. In 1899, at Woods Hole, Dr. Bumpus succeeded in rearing about 100 lobsterlings to the fourth stage. In 1900 at Wickford, 3,425 fry were reared to the lobsterling stage. In 1901 the number reached 8,974; in 1902, 27,300; in 1903, 13,500; in 1904, 50,597; making an entire total for all previous years at Wickford of 103,796, or only

224 more than were reared during this one season of 1905. There seems to be no reason why, with the increased knowledge coming from each season's experience, this number might not still further be increased, while using the same apparatus, and with no extra expense.

The practical results of this planting of young lobsters is unquestioned. Reports from the lobster fishermen show that more small lobsters were present in the localities where the fry were liberated than have been seen before for many years. It will be but a few years before these small lobsters will be of marketable size, and then the expense of developing the lobster rearing plant of the Commission will be returned to the inhabitants of the state many times over.

Such results as these are very gratifying, especially when we consider that nowhere else in the world have any such results been obtained. Indeed, nowhere else has it been possible to rear lobster fry at all successfully, and the results of your Commission's work have attracted the attention of those interested in promoting the fishery interests in all parts of the world.

In this country our work has been watched by the United States Bureau of Fisheries and the commissioners of other maritime states, and now that our efforts are crowned with success both the national Bureau and the commissioners of other states are ready to follow our example. Indeed, the neighboring State of Connecticut has already appropriated $10,000 to establish a hatchery, and a committee has visited our laboratory at Wickford to secure the information necessary to begin operations in their own waters.

With each year the efforts of your Commission to enforce the laws regarding the capture of short lobsters or lobsters bearing eggs meet with better success. Two deputies have continued to safeguard the interests of the lobster fishery, and have succeeded in prosecuting three offenders under the short-lobster law. They have seized and liberated in the waters of the bay 5,170 short lobsters imported into the state contrary to law. The fishermen are coming to recognize, more and more, that the efforts of the Commission are for their own good, and that they are being protected against the illegal competition of those who willfully disregard the laws which have been created to preserve for them an important industry.

Work in connection with the propagation of the clam has not been neglected. A careful watch has been kept on the shores of the bay in order to determine the location of the new set, so that they might be distributed in favorable localities, and the survey of the shore to determine the location of favorable localities for planting clams has been continued. In other states the planting of clams has been commenced along the lines worked out by this Commission.

Along scientific lines much progress was made last summer at the Wickford laboratory in determining the rate of growth of the lobster, in studying his ability to repair injury, and his migratory propensities. Some of these facts will receive special treatment in the latter part of the report. The continued study of the physical and biological conditions of the bay was also carried well forward, especially along the lines of a survey of the shores to determine the location of favorable localities for planting clams, quahaugs, lobster fry, etc., and the determination of the distribution and numbers of food and other fishes in the waters of the bay.

Your Commission again undertook the preparation of an exhibit at the fair of the Washington County Agricultural Society at Kingston. In co-operation with Hon. Rowland G. Hazard, of Peace Dale, and Mr. George A. Griffin, of Wakefield, an exhibit pertaining to sea farming was installed in a building provided for the purpose by authorities of the fair. Six large tanks of sea water were used for an exhibit of the more common food fishes of the Bay and many of the more rare or curious forms. Through the courtesy of the New York Aquarium several specimens of Blue Angels, a beautiful Bermudan fish, were secured and kept alive through the fair. Another tank of fresh-water fish and a collection of shell-fish, lobsters in various stages, models of nets and traps and other fishing utensils, were exhibited. Many thousands of persons were thus acquainted with the efforts of the state in studying the problems and opportunities connected with the fishery interests.

Your Commission wishes to record the fact that, whatever success has been obtained in preserving or restoring to the waters of the state any of the industries connected with the fisheries has only been secured because of the continued support of your honorable body. In all of this work it is not one year that counts, but continuous study and experiments carried through a series of years. Much has been done, but much remains to be done. The success which has been attained in the clam and lobster work should be extended to other lines, such as the propagation of food fish, crabs, scallops, quahaugs, etc. There can be no doubt but what the money expended for this work will return many times over, not only to those directly concerned with the fisheries, but to all the inhabitants of the state and to other states and other countries.

In the absence from the country of the biologist of the Commission during the summer, the scientific work was carried on under the efficient direction of Prof. F. P. Gorham.

There follows the statement of the expenses of the Commission for the year.

State of Rhode Island in account with Commissioners of Inland Fisheries.

1905.		Dr.	
Oct.	12.	To paid for 40,000 yearling trout, distribution of same, and 700 black bass	$1,308 83
Dec.	31.	To expenses and salary of deputy commissioners under lobster law	1,940 77
		To expenses at laboratory investigating lobster, clam, and other fish culture	3,745 52
		To expenses of commissioners	587 93
			$7,583 05
1905.		Cr.	
Jan.	6.	By received from State Treasurer	$61 99
	18.	" " " "	20 50
	27.	" " " "	82 40

1905.			
Jan.	27.	By received from State Treasurer	$84 80
Feb.	4.	" " " "	14 50
	18.	" " " "	50 00
		" " " "	82 53
	28.	" " " "	2 00
		" " " "	46 00
		" " " "	72 20
Mar.	9.	" " " "	50 00
		" " " "	5 00
	29.	" " " "	8 10
		" " " "	44 55
	31.	" " " "	62 00
		" " " "	79 90
		" " " "	68 60
		" " " "	2 00
April	5.	" " " "	4 75
	12.	" " " "	37 44
		" " " "	31 95
	13.	" " " "	4 75
	19.	" " " "	5 00
	21.	" " " "	114 71
	26.	" " " "	41 33
		" " " "	12 02
	28.	" " " "	78 15
		" " " "	60 75
		" " " "	2 00
May	2.	" " " "	10 50
	5.	" " " "	50 00
		" " " "	3 31
	17.	" " " "	1 25
		" " " "	22 35
	24.	" " " "	27 13
	31.	" " " "	60 00
		" " " "	38 00
		" " " "	27 00
		" " " "	24 93
		" " " "	13 50
		" " " "	107 00
		" " " "	86 55

1905.			
May	31.	By received from State Treasurer	$72 90
		" " " "	4 30
		" " " "	25 00
June	6.	" " " "	40 00
	9.	" " " "	279 25
		" " " "	5 60
	14.	" " " "	12 63
		" " " "	6 88
		" " " "	4 00
	21.	" " " "	362 77
		" " " "	30 00
		" " " "	23 00
		" " " "	20 00
	30.	" " " "	2 50
		" " " "	71 70
		" " " "	87 55
		" " " "	40 00
		" " " "	40 00
		" " " "	30 00
		" " " "	14 66
		" " " "	18 66
		" " " "	6 66
July	5.	" " " "	40
		" " " "	31 65
		" " " "	1 50
		" " " "	2 00
		" " " "	1 35
	7.	" " " "	5 00
Aug.	2.	" " " "	229 89
		" " " "	47 08
		" " " "	60 00
		" " " "	40 00
		" " " "	40 00
		" " " "	40 00
		" " " "	40 00
		" " " "	20 00
		" " " "	90 95
		" " " "	73 50
		" " " "	2 60

1905.			
Aug.	4.	By received from State Treasurer	$69 73
		" " " "	83 07
	9.	" " " "	10 00
	16.	" " " "	94 73
	18.	" " " "	30 00
		" " " "	20 00
		" " " "	20 00
		" " " "	20 00
	30.	" " " "	398 81
Sept.	1.	" " " "	90 20
		" " " "	76 35
	6.	" " " "	30 00
		" " " "	20 00
		" " " "	20 00
		" " " "	20 00
		" " " "	80 60
	14.	" " " "	21 75
		" " " "	4 00
	27.	" " " "	86 00
		" " " "	73 60
Oct.	4.	" " " "	30 00
		" " " "	20 00
		" " " "	20 00
		" " " "	20 00
		" " " "	2 00
		" " " "	30 00
	12.	" " " "	1,000 00
	18.	" " " "	30 00
		" " " "	338 01
	27.	" " " "	89 60
		" " " "	78 80
		" " " "	2 20
Nov.	1.	" " " "	42 45
		" " " "	5 82
		" " " "	30 00
	15.	" " " "	30 00
	17.	" " " "	32 95
		" " " "	11 27
	29.	" " " "	87 65

1905.		
Nov. 29.	By received from State Treasurer	$73 77
	" " " "	21 20
	" " " "	25 00
	" " " "	21 28
	" " " "	36 05
	" " " "	22 56
	" " " "	28 28
	" " " "	19 60
	" " " "	100 04
Dec. 1.	" " " "	30 00
6.	" " " "	61 87
14.	" " " "	38 49
	" " " "	41 67
15.	" " " "	45 06
20.	" " " "	48 27
27.	" " " "	10 20
	" " " "	10 40
	" " " "	84 50
	" " " "	69 80
		$7,583 05

The remainder of the report includes an account of the work undertaken by the Commissioners during the past year, which may be tabulated as follows:

First. The stocking of our ponds and streams with suitable fresh-water fish, through the distribution of fry. Page 13.

Second. The collection of data and statistics relating to the commercial fisheries. Page 15.

Third. The location of fish-traps within the waters of Narragansett Bay, and the collection of data bearing upon their ownership. Page 21.

Fourth. The continued examination of the physical and biological conditions of the waters of the Bay, begun in 1898. Page 29.

Fifth. A continuance of the survey of the shores of the Bay, for the purpose of determining those portions which are most productive of seed-clams, those most favorable for the planting of clams and for the distribution of lobster fry. Page 103.

Sixth. The continued investigation of the life-history of the clam. Methods of artificial propagation and cultivation. Page 105.

Seventh. The efforts to prevent the illegal taking of short lobsters Page 110.

Eighth. The propagation of lobster fry for the purpose of increasing the supply of lobsters in the waters of the state. Methods of artificial propagation and cultivation. Page 111.

Ninth. The continued investigation of the life-history of the lobster. Page 153.

The list of members of the Fisheries Commissions or Departments of the United States and the several states and territories, compiled by the United States Bureau of Fisheries, is submitted in Appendix A, and a copy of the fisheries laws of Rhode Island is given in Appendix B.

Respectfully submitted,

Wm. P. MORTON, *Secretary.*

December 31, 1905.

I. The Stocking of our Ponds and Streams with Suitable Fresh-water Fish, Through the Distribution of Fry.

Trout.

Your Commission has purchased 48,300 yearling trout, and these have been placed in suitable streams throughout the state. The distribution of these fish in the northern part of the state was in charge of Messrs. Roberts and Boardman; in the central part, of Messrs. Root and Morton; while Newport county and the southern part of the state were cared for by Messrs. Southwick and Willard, respectively.

Bass.

During the year 1905 we again received, through the kindness of the Bureau of Fisheries of the Department of Commerce and Labor, a consignment of black bass. In all 700 small-mouth black bass and 300 large-mouth black bass were distributed in such ponds as are known to be suitable for the propagation of these fish. This number is slightly larger than the number received last year.

Pickerel.

A slight addition to the General Laws of the state was made by the General Assembly at its last session, to make the taking of pickerel under 10 inches illegal. A copy of the law follows:

CHAPTER 1125.

An Act for the Protection of Pickerel and in Addition to Chapter 171 of the General Laws, Entitled "Of Certain Fisheries."

Section 1. Every person who catches or takes from any of the waters of this state or has in his or her possession any pickerel less than 10 inches in length, shall be fined five dollars for each such offence; but any person catching or taking any pickerel less than 10 inches in length from any of the waters of this state and immediately returning the same alive to the water from which taken, shall not be subject to such fine. The possession of any such pickerel not of the prescribed length shall be *prima facie* evidence to convict.

SEC. 2. This act shall take effect upon and after its passage.

II. The Collection of Data and Statistics Relating to the Commercial Fisheries.

It would be impossible to estimate at all accurately the total amount of fish caught in the waters of the state. The nearest to accurate data that can be obtained are those derived from the books of the transportation companies. The tables here submitted show the amount of shipments and the yearly variation in shipments from the city of Newport by regular transportation lines, but are no indication of the total amount of fish caught.

Table Showing the Number of Barrels of Fish, Lobsters, Crabs, Clams, Sounds and Roe Shipped out of the State from Newport by Regular Transportation Lines. Also the Number of Swordfish, Horse-Mackerel, Sturgeons, and Sharks for Each Month During the Year 1905.

	Barrels of Fish.	Barrels of Lobsters.	Barrels of Crabs.	Barrels of Clams.	Barrels of Sounds.	Barrelsof Roe.	Number of Swordfish.	Number of Horse-mackerel.	Number of Sturgeon.	Number of Sharks and Porpoises,
January.....	1,264	202	....	....	....	2	....	....	....	....
February....	393	122	....	....	....	....	....	....	....	....
March.......	417	104	....	3	....	....	....	....	....	....
April........	449	72	....	....	....	....	....	....	....	....
May.........	10,467	122	....	3	....	1	....	....	14	....
June........	16,064	105	18	3	....	....	67	6	3	1 Porpoise.
July.........	3,961	91	52	10	....	....	611	80	3	1 Shark.
August......	5,104	104	34	30	....	....	22	1	....	....
September...	3,559	7	15	24	17	....	3	4	....	....
October.....	4,087	2	2	....	6	....	18	....	2	....
November...	2,762	....	1	6	....	....	2	....	4	....
December....	1,600	46	....	1	....	....	....	....	....	....
Total......	50,127	977	122	80	23	3	723	91	26	....

Table of Fish, Lobsters, etc., Shipped from Newport by Regular Transportation Lines Out of the State for the Past 18 *Years.*

YEAR.	Barrels of Fish	Barrels of Lobsters.	Barrels of Eels.	Barrels of Crabs.	Barrels of Clams.	Barrels of Sounds.	Barrels of Roe.	Number of Swordfish.	Number of Horse-mackerel.	Number of Sturgeon.	Number of Porposies.	Number of Sharks.
1887.....	16,657	834	....	....	....	....	....	....	....	....	....	....
1888.....	15,033	1,161	....	....	....	....	....	....	....	....	....	....
1889.....	19,306	2,047	....	....	....	....	....	....	....	....	....	....
1890.....	8,933	2,650	....	....	....	....	....	....	....	....	....	....
1891.....	18,032	2,204	....	....	....	....	....	....	....	....	....	....
1892.....	26,832	2,123	....	....	....	....	....	....	....	....	....	....
1893.....	24,452	1,399	....	....	....	....	....	....	....	....	....	....
1894.....	17,769	2,392	....	....	....	....	....	....	....	....	....	....
1895.....	24,622	2,119	....	....	....	....	....	....	....	....	....	....
1896.....	20,425	1,728	....	....	....	....	....	143	....	....	....	....
1897.....	25,098	2,039	....	....	....	....	....	45	....	....	....	....
1898.....	34,065	1,163	....	....	....	....	....	74	....	....	....	....
1899.....	34,917	4,143	....	....	....	....	....	162	....	....	....	....
1900.....	38,184	4,793	....	....	....	....	....	166	....	....	....	....
1901.....	50,500	4,393	....	....	....	....	....	21	....	....	....	....
1902.....	53,986	4,342	....	1	....	....	....	179	....	....	....	....
1903.....	54,384	1,474	....	84	....	....	....	164	79	11	....	....
1904.....	62,106	1,921	18	45	8	....	....	554	336	....	....	....
1905.....	50,127	977	....	122	80	23	3	723	91	26	1	1
Total..	595,428	43,902	18	252	88	23	3	2,231	506	37	1	1

One or two facts are noticeable in these tables. First, the number of barrels of fish shipped in 1905 is less than for any year since 1900. This does not necessarily indicate any particular scarcity of fish, but merely that changes are taking place in regard to the transportation lines made use of by the fishermen in shipping their catch. From the somewhat scanty data at hand there can be no doubt that the amount of fish caught has not appreciably decreased in the last ten years. The gradual development of the crab industry is also noticeable. The market for crabs is becoming better every year. Your Commission believes that, as the lobster experiments are now on a firm foundation, attention should be paid to the crab question, which in the future is destined to become more and more important. Another striking fact is the rapid increase in the shipment of swordfish. Each year finds more boats engaged in this lucrative fishery, and the fishes were more abundant this year than usual. The market for horse-mackerel, which are still abundant in offshore traps, and sturgeon, is also developing, and it is only a question of time when the demand for sharks and dogfish also will become insistent enough to attract the attention of enterprising fishermen.

It seems strange that, as yet, no one has undertaken the capture and marketing of the tilefish. In these days, when everything that comes to the hook is game or food, the neglect of this abundant supply of fine food fishes right at our doors is surprising. The work of Dr. Bumpus, formerly of this Commission and of the United States Bureau of Fisheries, showing that there is an abundant market for this fish and that it can easily be secured by fishermen from this state, which was fully described in the 29th Annual Report of this Commission for 1898, seems to have attracted scarcely any attention.

The codfish season was better than usual this year. The scup season was poor. The scup season at Block Island lasted several days later than along the shore. This may be accounted for by the later season this year, or perhaps because of the large run of pollock which occurred offshore from Brenton Reef to Sakonnet about May 15th. This was the largest run of pollock for years. The flatfish season was also very late, extending into May.

On the whole, the line fishing in the bay was good; tautog, squeteague, scup, and flatfish were fairly abundant, and, for the first time in several years, bluefish were taken in the upper waters of the Bay.

The menhaden season was a poor one. The factories could not pay dividends. The epidemic among these fishes during the summer of 1904 may be to blame for this scarcity. Plans were made to continue the study of the disease this year. It was expected that it would recur again, but these expectations were not realized. With the exception of a few dead fish found in the head waters of the Bay and one or two living fish showing symptoms of the disease seen in the neighborhood of Pawtuxet on June 9th, and one at Wickford on June 15th, no cases were observed. At any rate, menhaden were not nearly so abundant in the bay in 1905, and this fact lends credence to the belief that the epidemic was but the result of overpopulation, the effort of nature to regulate the overabundance of this particular fish, and was only indirectly due to pollution of the water.

The scallop fishery this year was again practically a negative quantity. There were no scallops in the bay. It will be recalled that in 1901 the set was so thick that, in the late fall the shores were actually lined with the shells of those which had been exposed by the tide and then chilled by the cold. These, of course, would not have been of marketable size until the next fall, since the seed scallops are protected by law. Unfortunately, for some unknown reason, there was not much of a set in the summer of 1902, except in Greenwich Bay. In the fall of this same year the scallop fishing ended two months after the beginning of the open season, because the scallops were practically exterminated. The winters of 1903 and 1904 were unusually severe, and seemed to still further decrease the supply of scallops. This season there has been no scallop fishing whatever in the Bay. Only one place has been reported where more than one bushel has been taken, and that was near Fogland Point in the Sakonnet River. The winter up to February has been unusually mild and the men along shore report the occasional finding of considerable numbers of scallops, which have worked out from some unobserved spot in the eel-grass. This seems to indicate that enough are left to replenish the waters of the Bay if given an opportunity.

It may be that the previous two winters have been mainly responsible for the great reduction in the number of these shell-fish. It is our opinion, however, that unrestricted fishing has been the real trouble. Such an important industry and such a valuable food animal should not be allowed to pass away without some efforts to prevent it. A few close seasons would undoubtedly enable them to gain a foothold again, and then, with proper regulation of the fishing, they could be protected from complete extermination. Your Commission has made some efforts toward planting scallops in favorable places in the Bay, but as long as fishing is permitted to such an extent that all opportunities for breeding are destroyed, it will be impossible to get results.

The following table indicates the amount of the lobster catch for the year 1905, as far as can be estimated from the reports of market-men and wholesale dealers. It will be noticed that the amount of lobsters has increased 122,296 pounds over last year.

Number of Pounds of Lobsters Caught in Rhode Island Waters for the Season of 1904 *and* 1905.

Fish Markets.	1904.	1905.
Burlingame & Carey	12,000 Pounds.	8,079 Pounds.
Toliefson & Dewitt	10,000 "	15,000 "
Lawton	6,000 "	8,000 "
Wyat	9,000 "	8,004 "
Ring	800 "	550 "
Smith	9,500 "	10,000 "
Easterbrooks	5,000 "	6,525 "
Ash	15,000 "	20,636 "
Lancaster	5,000 "	....
Crowly	500 "	....
C. B. Anderson	34,074 "	31,965 Pounds.
H. McGinn	113,430 "	147,484 "
Saloons and Restaurants	6,700 "	45,436 "
Sakonnet, Block Island, Watch Hill, Narragansett Pier, about	150,000 "	....
Sakonnet		97,641 Pounds.
Block Island, Watch Hill, Narragansett Pier,		100,000 "
Total	377,004 Pounds.	499,300 Pounds.

Number of Boats Engaged in Lobster Fishing in this State for the Years 1904 *and* 1905.

	Sailboats.		Rowboats.		Pots.	
	1904.	1905.	1904.	1905.	1904.	1905.
Newport	36	36	35	30	5,000	6,050
Narragansett	3	2	3	2	400	350
Saunderstown	1	1	2	1	150	100
Sakonnet	1	1	5	5	250	250
East River	3	4	0	2	185	260
Warren	2	1	0	2	180	200
Green Hill	0	0	1	1	70	70
Watch Hill	1	2	4	4	400	400
Block Island	8	8	0	2	1,200	1,200
Jamestown	0	0	3	3	100	100
Point Judith	0	0	0	3	......	200
Total	55	55	53	55	7,935	9,180

Lobsters Received from Nova Scotia from December 19, 1904, *to June,* 1905.

	Crates.	Pounds.	Shorts.*	Egg.
December	271	47,395	647	22
January	395	68,775	1,110	50
February	153	26,775	627	6
March	320	56,600	800	10
April	161	28,175	330	8
May	262	45,850	1,421	58
June	194	33,950	235	58
Total, 1905	1,756	307,520	5,170	212
Total, 1904	2,209	386,565	4,577	116

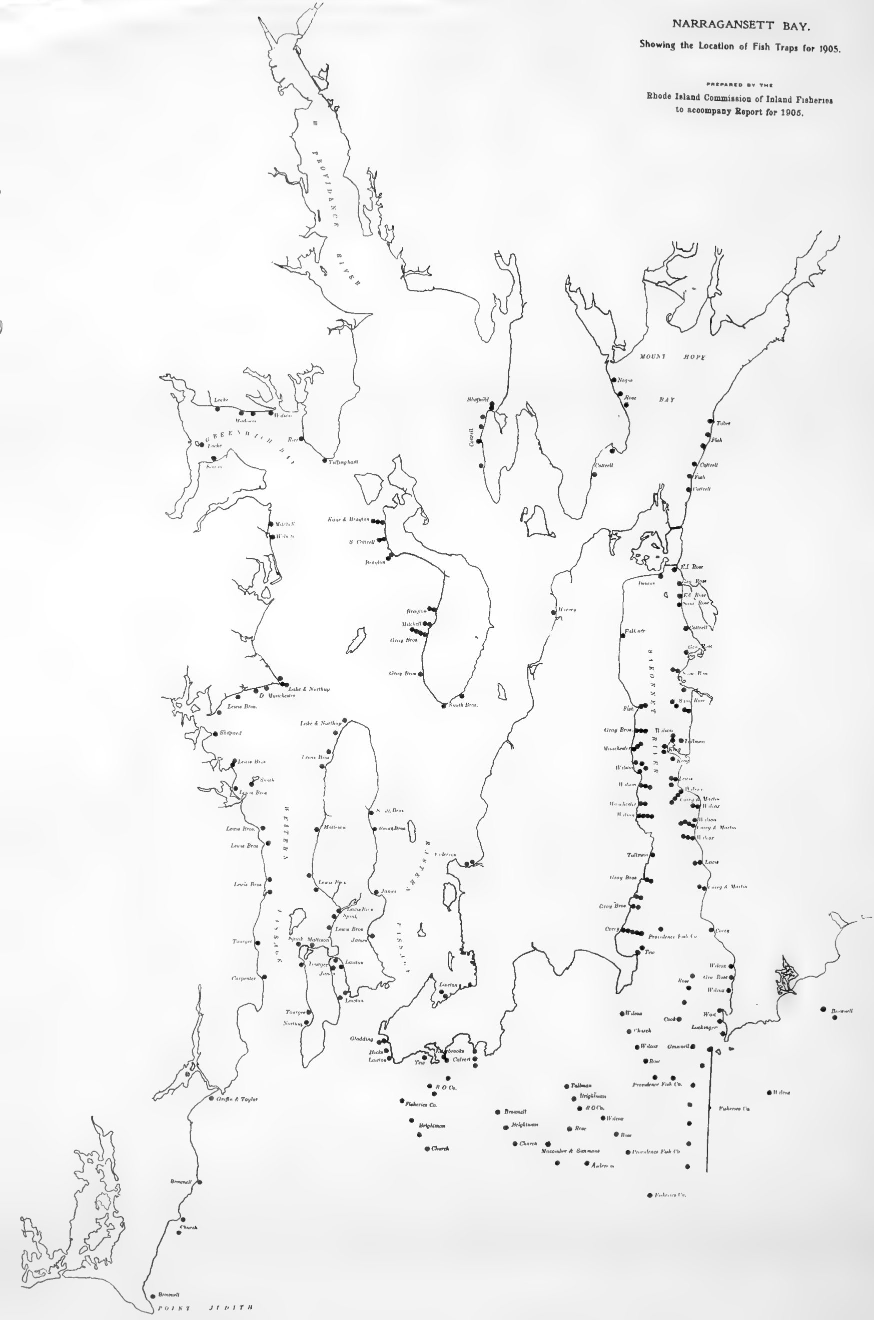
* The short lobsters in the above shipments were seized by the deputies and liberated in Rhode Island waters.

NARRAGANSETT BAY.

Showing the Location of Fish Traps for 1905.

PREPARED BY THE

Rhode Island Commission of Inland Fisheries to accompany Report for 1905.



Nı

Ne
Na
Saı
Sal
Eas
Wa
Gre
Wa
Blo
Jan
Poi

L

Dec
Jan
Feb
Mar
Apr
May
June

T

T

*T
Rhoc

III. The Location of Fish-Traps within the Waters of Narragansett Bay, and the Collection of Data Bearing upon Their Ownership.

A glance at the table giving the number of traps for each year since 1898, which is appended, shows that there has been a steady increase in the number of traps in Narragansett Bay and vicinity. Whereas in 1898 there were 119 traps, in 1905 there are 240. Subtracting from the latter the 6 which were set off Block Island, and were not included in the earlier reports, we see that in the past eight years the number of traps lacks only four of having doubled itself.

The depletion in the amount of fish caught, which it was feared would be the outcome of extensive trap fishing, does not seem to have taken place. It should be remembered that the amount of fish caught this past year can not, with any approach to accuracy, be compared with years more than a decade ago. For the earlier years we are mostly dependent on the memory of the fishermen and not on any reliable records. Allowing for fluctuations from year to year, there can be little doubt that the amount of fish has not appreciably decreased during the past ten years.

The distance which the traps have been placed from shore has increased very markedly. The immense traps of the Fisheries Company last season extended in an unbroken line for a distance of three miles from Sakonnet Light, and the results of the past season's fishing have caused the fishermen to decide to still further extend their traps in the coming year. Offshore fishing has also been carried on later in the fall with good success.

The principal items in regard to the past season's fishing are the lateness of the season, both in time of commencement and length of run, and the unusual abundance of pollock and horse-mackerel. It might also be stated here that the impounding of scup which has taken place for the last few years seems to be of benefit to the scup fisheries in an unlooked-for manner. The scup which are thus impounded are full of spawn and, being retained for some time, are compelled to discharge their spawn in Rhode Island waters, the traps often swarming with fry. It is the accepted belief of fish culturists that fry hatched in one place tend to return each year to that particular place. If this is true the impounding is greatly beneficial to the scup industry in our state.

The location of the traps is shown in the two accompanying charts. (Charts I and II.)

Table showing Number and General Distribution of Fish-Traps since 1898.

The following arbitrary divisions have been made for the sake of convenience:

I. *Providence River.*—South to a line joining Warwick Point and Popasquash Point.

II. *Greenwich Bay.*—South of Providence River division in west passage to a line drawn east and west touching southern part of Hope Island.

III. *West Passage.*—The west passage south of Greenwich Bay region to a line drawn due west from Beaver Tail and west of line connecting the east end of Greenwich Bay boundary and North Point.

IV. *Mount Hope Bay.*—North of railroad bridge, Tiverton, and a line connecting Bristol Ferry and Muscle Shoal Light.

V. *East Passage.*—South of Providence and Mount Hope Bay divisions and north of a line from Beaver Tail to Brenton's Point.

VI. *Sakonnet River.*—The Sakonnet River south of railroad bridge to line connecting Flint Point and the breakwater.

VII. *Off Shore.*—Traps south of above divisions and not including Block Island.

VIII. *Block Island.*

YEAR.	Providence River.	East Greenwich.	West Passage.	Mount Hope Bay.	Sakonnet River.	East Passage.	Off-shore.	Block Island.	Total.
1898.....	4	6	26	9	34	15	25	.....	119
1899.....	3	10	23	11	35	15	24	.....	121
1900.....	4	16	24	16	34	12	29	.....	135
1901.....	7	15	24	13	52	14	26	.....	151
1902.....	6	22	27	13	52	14	27	.....	161
1903.....	7	21	32	13	72	16	30	.....	195
1904.....	6	27	33	7	78	14	49	6	220
1905.....	6	26	33	11	82	20	56	6	240

1905.

Off-Shore Traps.

Anderson, C. .... South Cormorant Rock.
Brightman, W. (00)* .... Seal Ledge.
Brightman, W .... Below Bull Rock.
Brightman, W .... Below Cormorant Co.
Brownell, James .... Lower Pier.
Brownell, James .... North Point Judith.
Brownell, James .... Coggeshall's Ledge.
Brownell, James (00) .... Halfway Rock.
Calvert, G. (000) .... Spouting Rock.
Church, J. .... Lower Pier.
Church, J. .... South Lower Pier.
Church, J .... Coggeshall's Ledge.
Church, J. .... Coggeshall's Ledge.
Church, J .... Cormorant Rock.
Cook, G. (00) .... North Sakonnet Light.
Easterbrooks, C. (00) .... Price's Neck.
Fisheries Company .... Coggeshall's Ledge.
Fisheries Company (00000000) .... Sakonnet Light.

*The ciphers indicate the number of traps set in line on one string of leaders.

Griffin & Taylor.................................Narrow River.
Grinnel & Gray................................Sakonnet Light.
Lockinger, H.............................South Breakwater.
Lockinger, H..................................Sakonnet Point.
Macomber & Simmons (00)..............Below Coggeshall's Ledge.
Providence Fish Co.......................South Cormorant Rock.
Providence Fish Co (00)......................West Sakonnet Light.
Rose, W............................Below Cormorant Rock.
Rose, W............................West Cormorant Rock.
Rose, W............................South Cormorant Rock.
Rose, Geo. (00).........................North Sakonnet River.
Sakonnet Oyster Co.....................Below Cormorant Rock.
Sakonnet Oyster Co...............................Seal Rock.
Sakonnet Oyster Co. (00)........................Below Seal Rock.
Tallman, B...........................South Cormorant Rock.
Tew, R................................West Price's Neck.
Wait, B.......................................Breakwater.
Wilcox, H. (00)........................East Cormorant Rock.
Wilcox, H.............................South Cormorant Rock.
Wilcox, H..............................South Warren's Point.

Other Traps.

Anderson, C. B...........................Coddington Cove.
Anderson, C. B...........................Coddington Cove.
Brayton, G. (00).......................North Prudence Park.
Brayton, G..................................Pine Hill Point.
Carpenter, George..............................South Ferry.
Corey, Ed. (00000)............Lower West Shore, Sakonnet River.
Corey, Ed.................................Church's Cove.
Corey & Martin (00).........................High Hill Point.
Corey & Martin (0000)....................North Brown's Point.
Corey & Martin (00)......................South Brown's Point.
Cottrell, S..........................West Popasquash Neck.
Cottrell, S..........................West Popasquash Neck.


SANDY POINT
Sheffield
SACHEM
POND
GREAT
SALT
POND
BLOCK ISLAND.
Showing the Location of Fish Traps for 1905.
Ball
Littlefield
Dunn
Willis
Dunn
Lewis

Cottrell, S. . . . . West Popasquash Neck.
Cottrell, S. . . . . West Popasquash Neck.
Cottrell, S. . . . . Mount Hope Point.
Cottrell, S. . . . . South Mount Hope Point.
Cottrell, S. . . . . Upper East Sakonnet River.
Cottrell, S. . . . . North Pine Hill Point.
Cottrell, W. . . . . North Tiverton.
Cottrell, W. . . . . North Tiverton.
Dennis, M. . . . . Island Park.
Falkner, G. . . . . South Portsmouth.
Fish, Clinton . . . . . North Tiverton.
Fish, Clinton . . . . . North Tiverton.
Fish, Clinton . . . . . North Tiverton.
Fish, Clinton (00) . . . . . McCurry's Point.
Gladding, A. B. (00) . . . . . Castle Hill, South.
Gray Bros. (00) . . . . . North Wood's Castle.
Gray Bros. (00) . . . . . North Wood's Castle.
Gray Bros. (00) . . . . . North Wood's Castle.
Gray Bros. (000) . . . . . South McCurry's Point.
Gray Bros. (0000) . . . . . West Prudence Island.
Gray Bros . . . . . Southwest Prudence Island.
Harvey, Charles. . . . . South Coal Mines, West Shore Rhode Island.
Hicks, O. G . . . . . Castle Hill, South.
James, Arnold . . . . . Taylor's Point.
James, Arnold. . . . . Jamestown.
James, Arnold. . . . . Mackerel Cove.
Kays & Brayton. . . . . North Pine Hill Point.
King, Charles . . . . . Fogland Point.
King, Charles . . . . . Fogland Point.
King, Charles . . . . . Fogland Point.
Lake & Northup . . . . . Hull's Ledge.
Lake & Northup. . . . . Conanicut.
Lake & Northup (00). . . . . Quonset Point.
Lake & Northup. . . . . Clark's Point.

Lawton, Ed	Mackerel Cove.
Lawton, Ed	Mackerel Cove.
Lawton, F	Mackerel Cove.
Lawton, F. (00)	Brenton's Cove.
Lawton, F	Mackerel Cove.
Lawton, F	Castle Hill.
Lewis Brothers	Scragg Rock.
Lewis Brothers	Scragg Rock.
Lewis Brothers	North Old Ferry.
Lewis Brothers	Packard's Rocks.
Lewis Brothers (00)	Wild Goose Point.
Lewis Brothers	West Vial's Creek.
Lewis Brothers	Dutch Island Harbor.
Lewis Brothers	North Dutch Island Harbor.
Lewis Brothers	The Hummocks.
Lewis Brothers	Sandy Point.
Lewis Brothers	Sandy Point.
Lewis Brothers	Fowler Rocks.
Lewis, Will (000)	South Fogland Point.
Lewis, Will (00)	North Brown's Point.
Locke, Moses	Buttonwoods.
Locke, Moses	Chepiwanoxet.
Madison, Peter	Buttonwoods.
Madison, Peter	Buttonwoods.
Manchester, A. (00)	South Sandy Point.
Manchester, A. (000)	North Sandy Point.
Manchester, D	Quonset Point.
Manchester, D	Vial's Creek.
Matteson, C	Fox Hill.
Matteson, C	Conanicut.
Mitchell, E. (00)	North Prudence Park.
Mitchell, E	South Pojac Point.
Negus Brothers	North Mount Hope Point.
Northup & Co	Austin's Hollow.

Providence Fish Co	Wood's Castle.
Rice, H. H	Warwick Neck.
Rose, George	Upper East Shore, Sakonnet River.
Rose, George	Upper East Shore, Sakonnet River.
Rose, George	North Breakwater.
Rose, George	North Mount Hope Point.
Rose, George	North Mount Hope Point.
Rose, Ed	Upper East Shore, Sakonnet River.
Rose, Ed	South Stone Bridge.
Rose, Sam	Upper East Shore, Sakonnet River.
Rose, Sam (00)	North Sapowet Point.
Rose, Sam	South Sapowet Point.
Rose, Sam (0000)	South Sapowet Point.
Shepard, J. (00)	North Point.
Shepard, St. John	Poplar Point.
Sisson,———	South Greenwich Bay.
Smith Brothers	S. E. Point, Prudence.
Smith Brothers	S. W. Point, Prudence.
Smith Brothers	East Shore, Conanicut.
Smith Brothers	East Shore, Conanicut.
Smith, John	Fox Island.
Spink, J. W	Dutch Island Harbor.
Spink, J. W	Fox Hill, North.
Taber, J	North Tiverton.
Tallman, B	Corey Wharf.
Tallman, B	South Black Point.
Tew, G	Flint Point.
Tillinghast, G	Warwick Point.
Tourgee, P	Austin's Hollow.
Tourgee, P	Beaver Head.
Tourgee, P	South Saunderstown.
Wilcox, H. (00)	South High Hill Point.
Wilcox, H. (000)	South High Hill Point.
Wilcox, H	Church's Cove.

Wilcox, H. Lower East Shore, Sakonnet River.
Wilson, Al. . . . . Pojac Point.
Wilson, Al . . . . Buttonwoods.
Wilson, W. (00) . . . . Fogland Point.
Wilson, W. (00) . . . . High Hill Point.
Wilson, W. (000) . . . . Sandy Point.
Wilson, W. (0000). . . . . North Black Point.
Wilson, W. (000) . . . . South Sandy Point.
Wilson, W . . . . Sandy Point.
Wilson, W . . . . South High Hill Point.

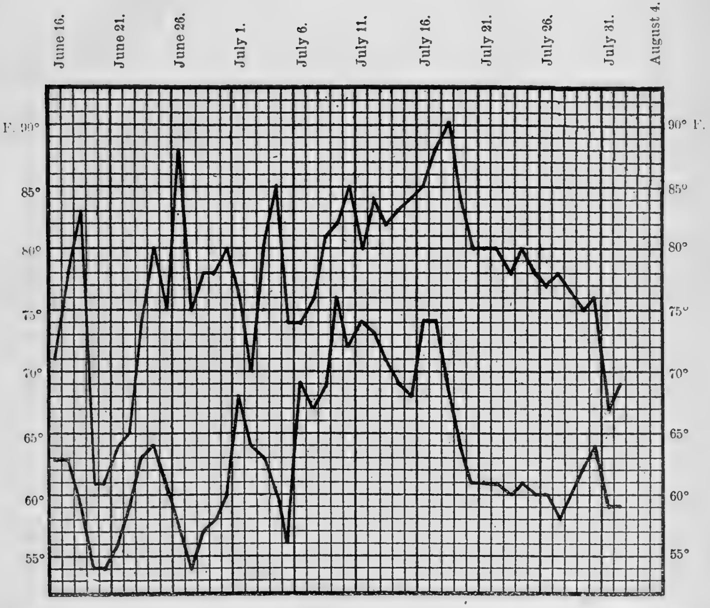


CHART III.—Showing the maximum and minimum air temperature at the Wickford Laboratory of the Rhode Island Commission of Inland Fisheries from June 16 to August 1, 1905.

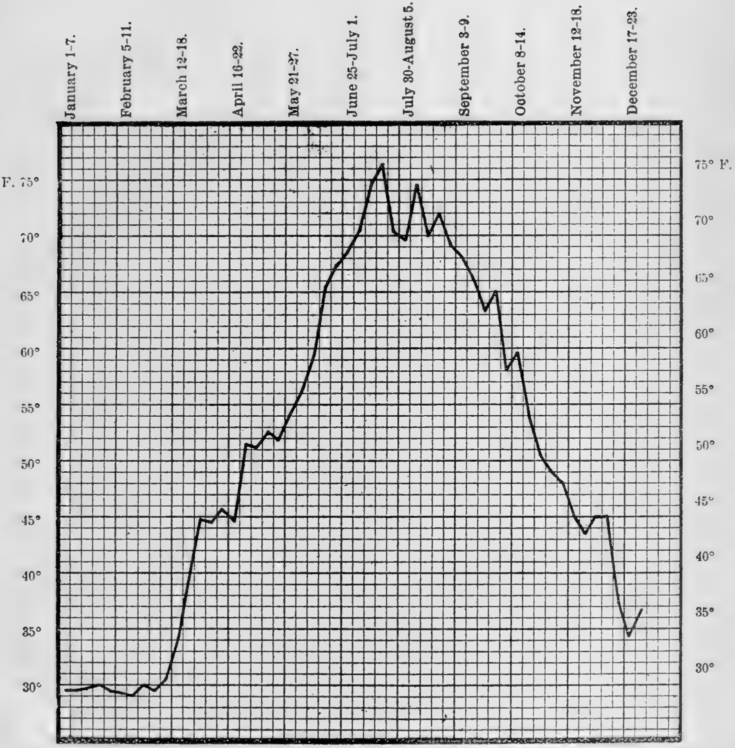


CHART IV.—Showing the average temperature of the sea-water at the Wickford Laboratory of the Rhode Island Commission of Inland Fisheries for each week in 1905.

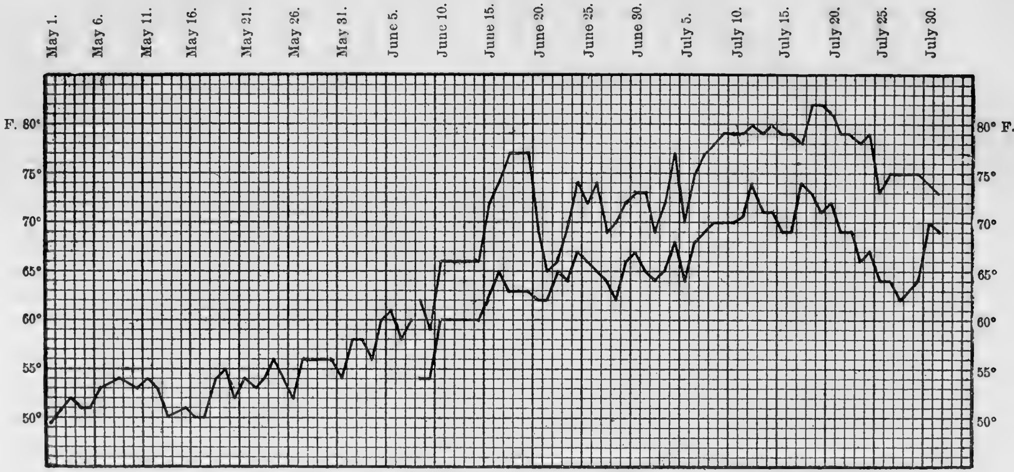


CHART V.—Showing the mean daily temperature of the sea-water at the Wickford Laboratory of the Rhode Island Commission of Inland Fisheries from May 1 to June 7, 1905, and the maximum and minimum daily temperatures from June 8 to July 31, 1905.

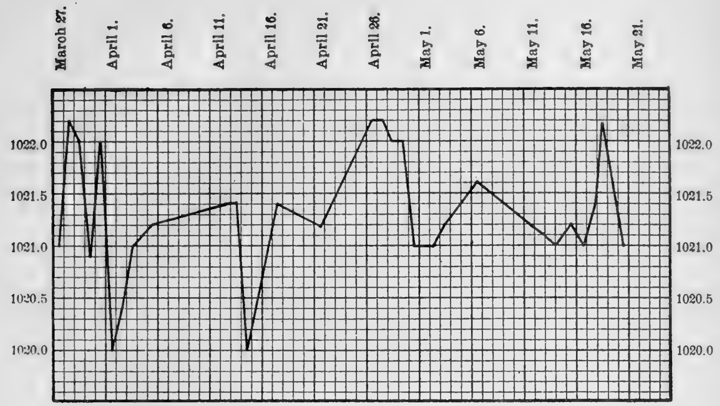


CHART VI.—Showing the specific gravity of the sea-water at the Wickford Laboratory of the Rhode Island Commission of Inland Fisheries from March 27 to May 20, 1905.

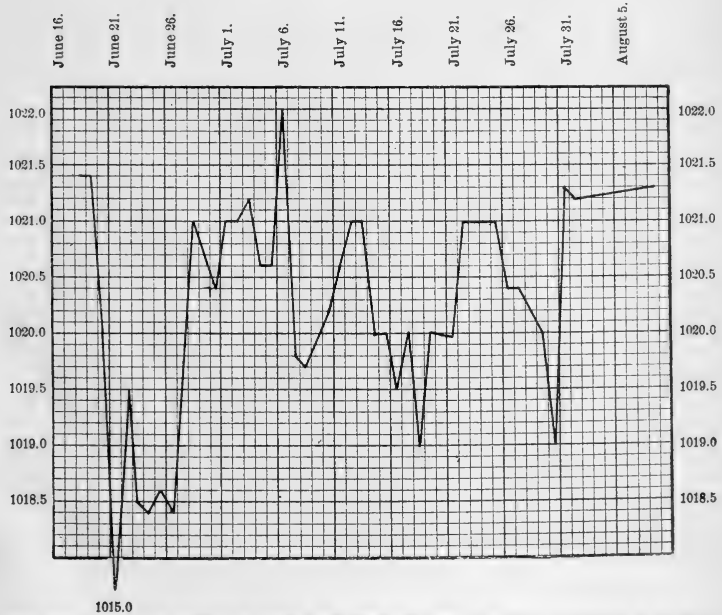


CHART VII.—Showing the specific gravity of the sea-water at the Wickford Laboratory of the Rhode Island Commission of Inland Fisheries from June 18 to August 8, 1905.

IV. The Continued Examination of the Physical and Biological Conditions of the Waters of the Bay, Begun in 1898.

The following charts represent the observations made during the past year of the air and water temperature and the water density. Some of them cover only the months during which the lobster hatching was going on, while the observations of water temperature extend over the entire year. (Charts III, IV, V, VI and VII.)

As a beginning of the report of the examination of the biological condition of the Bay, two lists are appended, one of the shell-fish or mollusca which have been found in the Bay, and the other of the fishes which occur in Rhode Island waters.

The lists have been prepared by collecting all authentic observations found in the literature and adding to these all data in the hands of the Commission.

The list of mollusca was prepared by Mr. E. W. Barnes and the list of fishes by Mr. H. C. Tracy. To the list of fishes is added a short illustrated description of the Herring Family, a group of fishes in which there exists considerable confusion as regards the names in use by fishermen.

A PRELIMINARY LIST OF THE MARINE MOLLUSCA OF RHODE ISLAND.

BY ERNEST W. BARNES,

ASSISTANT SUPERINTENDENT AT THE WICKFORD LABORATORY.

I. CEPHALOPODA.

DIBRANCHIATA.

DECAPODA.

Spirula peronii, Lamarck.
Loligo peallii, LeSueur.
Omnastrephes illecebrosa, LeSueur.

II. GASTEROPODA.

PULMONATA.

BASOMMATOPHORA.

Alexia myosotis, Draper.
Melampus bidentatus, Say.

OPISTHOBRANCHIATA.

NUDIBRANCHIATA.

Aeolis papillosa, Lovén.
Dendronotus arborescens, Ald. & Hancock.
Doto coronota, Lovén.
Polycera lessonii, D'Orbigny.
Tergipes despectus, Adams.

TECTIBRANCHIATA.

Cylichna alba, Brown.
Cylichna oryza, Totten.

Tornatella puncto-striata, Adams.
Diaphana debilis, Gould.
Uriculus canaliculatus, Say.

PROSOBRANCHIATA.

RACHIGLOSSA.

Turbinellidæ.

Fulgur carica, Gmelin.
Sycotypus canaliculatus, Linnæus.
Turbinella elegans, Verrill.
Turbinella interrupta, Adams.

Buccinidæ.

Sipho stimpsonii, Mörch.
Sipho pygmaeus, Gould.
Astyris rosacea, H. & A. Adams.
Neptunea curta, Verrill.

Nassidæ.

Phrontis vibex, Say.
Tritia trivittata, Say.
Ilyanassa obsoleta, Say.

Columbellidæ.

Anachis avara, Say.
Anachis diaphana, Verrill.
Anachis pura, Verrill.
Anachis rosacea, Gould.
Columbella lunata, Say.
Columbella dissimilis, Stimpson.

Muricidæ.

Eupleura caudata, Say.
Urosalpinx cinera, Say.
Purpura lapillus, Linnæus.

TAENIOGLOSSA.

Cerithiidæ.

Triforis nigrocinctus, Adams.

Bittium nigrum, Stimpson.
Bittium greenii, Adams.
Cerithiopsis terebralis, Adams.
Cerithiopsis emersonii, Adams.

Littorinidæ.

Lacuna divaricata, Fabricius.
Littorina irrorata, Say.
Littorina littorea, Linnaeus.
Littorina palliata, Say.
Littorina tenebrosa, Mont.

Vermetidæ.

Vermetus radicula, Stimpson.

Cœcidæ.

Cœcum cooperi, Smith.
Cœcum pulchellum, Stimpson.

Rissoidæ.

Littorinella aculeus, Gould.
Littorinella exarata, Stimpson.
Littorinella minuta, Totten.

Hydrobiidæ.

Amnicola limosa, Say.

Skeneidæ.

Skenea planorbis, Fabicius.

Carpulidæ.

Crepidula convexa, Say.
Crepidula fornicata, Say.
Crepidula, plana, Say.
Crucibulum striata, Say.

Naticidæ.

Lunatia heros, Say.
Lunatia triserrata, Say.
Natica pusilla, Say.
Neverita duplicata, Say.
Mamma immaculata, Totten.

Ptenoglossa.

Scalariidæ.

Scalaria lineata, Say.

Scalaria grœnlandica, Chemnitz.

Scalaria multistriata, Say.

Ianthinidæ.

Ianthina fragilis, Deshayes.

Gymnoglossa.

Pyramidellidæ.

Odostomia bisuturalis, Say.

Odostomia dealbata, Stimpson.

Odostomia fusca, Adams.

Odostomia seminuda, Adams.

Odostomia trifida, Totten.

Odostomia producta, Adams.

Rhiphidoglossa.

Trochidæ.

Margarita helicina, Fabricius.

Margarita obscura, Couthouy.

Docoglossa.

Acmæidæ.

Acmæa testudinalis, Müller.

III. SCAPHOPODA.

IV. PELECYPODA.

EULAMELLIBRANCHIATA.

Anatinacea.

Anatinidæ.

Anatina papyracea, Say.

Cochlodesma leana, Conrad.

Thracia conradii, Couthouy.
Thracia truncata, Mighels & Adams.

Pandoridæ.
Clidiophora trilineata, Say.

Lyonsiidæ.
Lyonsia hyalina, Conrad.

PHOLADACEA.

Pholadidæ.
Pholas costata, Linnæus.
Pholas truncata, Say.
Zirphæa crispata, Linnæus.

Teredinidæ.
Teredo navalis, Linnæus.

MYACEA.

Myidæ.
Corbula contracta, Say.
Mya arenaria, Linnæus.

Glycimeridæ.
Saxicava rugosa, Linnæus.

Solenidæ.
Siliqua costata, Say.
Solecurtus gibbus, Spengl.
Ensatella americana, Gould.
Solen viridis, Say.

Psammobiidæ.
Macoma sabulosa, Mörch.
Macoma fusca, Say.

CARDIACEA.

Cardiidæ.
Cardium pinnulatum, Conrad.
Lævicardium mortonii, Conrad.

VENERACEA.

Veneridæ.

Cytherea matracea, Linsley.
Venus mercenaria, Linnæus.
Callista sayii, Conrad.
Tottenia gemma, Totten.
Callista convexa, Adams.
Turtonia minuta, Stimpson.

Petricolidæ.

Petricola pholadiformis, Lamarck.

TELLINACEA.

Tellinidæ.

Angulus tenera, Say.
Tellina tenta, Say.

Mactridæ.

Mactra solidissima, Chemnitz.
Mulinea lateralis, Say.
Ceronia arctata, Conrad.

SUBMYTILACEA.

Astartidæ.

Astarte castanea, Say.
Astarte quadrans, Gould.
Astarte undata, Gould.

Cyrenidæ.

Cyclas dentata, Wood.

Carditidæ.

Clyclocardia borealis, Conrad.

Cyprinidæ.

Cyprina islandica, Linnæus.

Erycinidæ.

Kellia panulata, Stimpson.
Lepton fabagella, Conrad.

Lucinidæ.

Lucina filosa, Stimpson.

Cryptodon gouldii, Adams.

Cryptodon obsesus, Verrill.

PSEUDOLAMELLIBRANCHIATA.

Ostreidæ.

Ostrea borealis, Lamarck.

Ostrea virginica, Lamarck.

Pectinidæ.

Pecten irradians, Lamarck.

Pecten tenuicostatus, Mighels & Adams.

FILIBRANCHIATA.

ARCACEA.

Arcadæ.

Argina pexata, Say.

Scapharca transversa, Say.

MYTILACEA.

Mytilidæ.

Crenella grandula, Totten.

Modiola hamatus, Say.

Modiola modolius, Linnæus.

Modiola plicatula, Linnæus.

Mytilus edulis, Linnæus.

Modiolaria discors, Linnæus.

ANOMIACEA.

Anomiidæ.

Anomia aculeata, Gmelin.

Anomia glabra, Verrill.

PROTOBRANCHIATA.

Nuculidæ.

Nucula delphinodonta, Mighels.

Nucula proxima, Say.

Leda tenuisulcata, Stimpson.

Yoldia obesa, Stimpson.

Yoldia limatula, Say.

Yoldia sapotila, Gould.

Solenomyidæ.

Solenomya borealis, Totten.

Solenomya velum, Say.

V. AMPHINEURA.

CHITONES REGULARES.

Ischnoidea.

Chastopleura apiculatus, Say.

Trachydermon ruber, Lowe.

A LIST OF THE FISHES OF RHODE ISLAND.

PLATES I TO XII.

BY HENRY C. TRACY, A. M.,

BROWN UNIVERSITY, PROVIDENCE, R. I.

In the year 1898 the Commission of Inland Fisheries began a "systematic examination of the physical and biological conditions of Narragansett Bay." The importance of the study of the fish fauna, as a part of this investigation, is obvious from a practical as well as from a scientific point of view. Such a knowledge of the fishes of Rhode Island waters as would be given by a thorough investigation of their distribution, times of occurrence, food, diseases, enemies, etc., would furnish a body of facts in themselves of very great value to the scientist, to the sportsman, and to the man practically interested in the commercial aspect of the fisheries; and, furthermore, it is only by the possession of such facts that important problems regarding the life history and life conditions of any species can be solved.

Since the biological study of Rhode Island waters was begun, numerous isolated facts regarding the fishes of these waters have come into the possession of the Commission, some of which have been included from time to time in its annual reports. But the only systematic contribution to this investigation which has been published heretofore is the "List of Fishes of Narragansett Bay," by Dr. H. C. Bumpus, which was contained in the report of the Commissioners of Inland Fisheries for 1900. This was a bare list of fishes, as the title indicates, with no notes or information regarding any of the species included. The report for 1901 contained a further contribution to this subject, under the title "Additions to the List of Fishes Known to Inhabit Narragansett Bay, with Remarks on Rare Species Recently Caught."

It is the purpose of this present paper to complete and extend as far as possible the list of fishes above referred to, and also to include under the name of each species in the list such notes as will contain whatever information is in the possession of the Commission regarding its abundance, time of occurrence, habits, etc. It seems best to bring these notes together at this time as a matter of permanent record, although they are necessarily of a fragmentary and incomplete nature. They are intended rather as a basis of investigation which may result in a future comprehensive paper than as any important contribution to our knowledge of the fishes mentioned.

The original list was intended to contain only those fishes which were known to inhabit Narragansett Bay. But it is impossible to adequately understand the life history of many of our important food fishes, most of which are pelagic and migratory in their habits during a considerable portion of their existence, unless the fish fauna of the open water is included in our investigation. Furthermore, the offshore fisheries between Newport and Sakonnet and those of Block Island are of great importance to the citizens of Rhode Island; and the rich variety of rare species already known to have been taken in those waters is of great scientific interest. For these reasons it has seemed best to extend the list so as to include every fish which has been known to be present in the waters of Rhode Island, using that term broadly to include, besides Narragansett Bay, the fresh water streams of the state, and the open waters of the ocean bordering on the southern shores of the state and of Block Island.

The material used in the preparation of this list has been derived from the following sources:

1. The "List of Fishes in Narragansett Bay," by Dr. H. C. Bumpus, referred to above.

2. Data gradually acquired by the Fish Commission in years past.

3. Data furnished by Mr. E. W. Barnes, of Wickford, R. I., Superintendent of the Experiment Station. The data secured by Mr. Barnes has been very valuable, especially that portion of it relating to the more important food fishes.

4. Statements regarding time of occurrence, abundance, etc., of various fishes, made by fishermen and others practically interested. I am under special obligations to the Lewis Brothers, of Wickford, for information of this kind and for other favors, for which I here make acknowledgment.

5. Collections made at various times in the past, particularly by the late Prof. J. W. P. Jenks, and by Mr. J. M. K. Southwick, of Newport, Vice-president of the Commission.

6. Collections and personal observations made by the writer, chiefly during the year 1905. Visits were made to the fish-traps with the fishermen at various times throughout the season; at each haul specimens were taken, and records were made of the date, species present, abundance, size, and any other data which seemed desirable. The seine was also used in securing the young of many fishes and the smaller shore fishes.

I should add, further, that in several cases references of the isolated occurrence of certain rare species in Rhode Island waters have been found in various works on ichthyology or in special papers. I have made use of these sources also, as a matter of record, giving the proper reference under each particular species.

The material for the notes on the food of the various species, in addition to data obtained by personal observation, has been taken from a variety of sources. The observations on the stomach contents of fishes made by Dr. Edwin Linton, and published in the Bulletin of the United States Fish Commission for the year 1899, have been largely used. It has seemed scarcely necessary to give authorities for statements as to the food of the different fishes in cases in which there is general agreement.

The experiences of the past suggest the following as profitable lines of future work:

1. *Frequent and systematic visits to the traps with the fishermen.* A great variety of information can be obtained in this way which it is difficult to secure otherwise. It is possible by this means to get almost any kind of data desired, on such points as the distribution of the fishes, their times of arrival and departure, abundance, sizes, food, spawning, enemies, etc. Reference to the list of fish-traps and their locations, contained in this report, shows that 240 traps are in operation in Rhode Island waters, and that they are scattered all the way from Point Judith to Providence River, from Providence River to Newport, out in the open water from Brenton's Reef to Sakonnet Point, up and down Sakonnet River, and off the exposed shore of Block Island. These traps, being scattered over such a distance, where the conditions are so very different, afford a most excellent opportunity of obtaining very reliable data by systematically following trap fishing in a few chosen typical localities.

2. *Young fishes should be carefully studied.* Very little work has been done in this line anywhere. Narragansett Bay, which is a favorite spawning ground of so many fishes, affords a great opportunity for original work in this line. The discovery of means of identification of young fishes of different species is a great desideratum.

3. *The different sizes of fishes caught in the traps at different times should be accurately ascertained and compared.* This will throw light on such questions as the rate of growth, the age of sexually mature individuals, the movements of schools, etc.

4. *Study of the parasites of the fishes.* These may frequently furnish clues to their migrations.

5. *Study of the diseases of the fishes by microscopical and bacteriological examination of pathological specimens.*

6. *Careful observations of the condition of the reproductive organs of the fishes at different times to determine their breeding season.*

7. *Examination of the stomach contents of the fishes to determine their food.*

8. *Use of the tow-net and dredge in the spring and early summer for the securing of spawn.* The location of favorite spawning grounds and means of identifying the spawn of different species are important points to be ascertained.

9. *Study of the fresh-water fishes.*

10. *The special study of the fishes of Block Island.* This island is located so near the boundaries between the northern and southern division of the Atlantic coast fauna, and is so near deep water that it undoubtedly has a fauna of great richness and variety. There is every reason to suppose that it is as favorably situated in these respects as Wood's Hole, where about 250 different species of fishes are recorded. Fishermen say that frequently in these offshore waters they take fish which are new to them, and that they see even whole schools of unfamiliar species.

Above are indicated some of the lines of work which will be followed in the future as far as time and circumstances allow.*

A collection of fishes is also being made which is intended to contain, eventually, a specimen of every species known to inhabit Rhode Island waters.†

A proper record of the results of future study and observation has been provided for in the form of a card catalogue of the species of fishes. This form of record admits of indefinite expansion and modification for the accommodation of new material, and makes it possible to have all the known data regarding any particular species readily accessible at a moment's notice.

An appendix to the list of fishes is given which contains the names of certain species, most of which were taken by the United

---

*Any information regarding any phase of this subject, whatever, will be gladly received from any one interested. Any facts relating to the time and places of spawning of different fishes, and their movements and migrations, are particularly desired.

†Fresh or preserved specimens of rare and unusual fishes will be gratefully received from fishermen or others. They should be sent to the R. I. Fish Commission at Brown University, Providence. Record of the date and place of capture should be sent at the same time.

States Fish Commission while investigating the extent of the tilefish grounds. These grounds include an area between 69° and 73° west longitude and 40° 20′ and 39° 47′ north latitude, and are situated on the edge of the Gulf Stream, directly to the south of the Rhode Island coast. A complete discussion of the tilefish, which is the most important of the fishes taken in that region, will be found in the R. I. Fish Commission reports for 1899 and 1900, and in the Bulletin of the United States Fish Commission for 1898, page 321. If any apology is necessary for mentioning the fishes taken in waters at such a distance from Rhode Island, it may be said that a knowledge of the fish fauna of the Gulf Stream at that particular point helps to explain the occurrence of so great a number of tropical species in our coast waters, and also that, if the tilefish should become of any commercial importance, the location of the area in which it is taken is such that it would be more readily accessible to the Rhode Island fishermen than to those of any other state. With a few exceptions, the species mentioned in this appendix are surface forms. A complete enumeration of the deep-water fishes of this region would unduly extend the list by the inclusion of a large number of forms which have a closer relation to the deep-sea fauna than to the fauna of Rhode Island.

Following the list of fishes is a short article on "The Common Fishes of the Herring Family." This has been added in the hope that it may aid in clearing up the confusion prevalent in this locality regarding the identity of some of the species of that family. Plates have been inserted to supplement the descriptions of the fishes mentioned.

In order to make the identification of certain forms easier, plates are presented to show a few of our occasional visitors from southern waters, and also to illustrate the two species of the sturgeons which are common in the waters of Rhode Island. These plates have been reproduced from Goode's "Natural History of Aquatic Animals," except Plate VI, which was taken from Jordan's "Guide to the Study of Fishes."

I. Annotated List of Fishes Known to Inhabit the Waters of Rhode Island.

In the following list there are arranged in systematic order, by families, all species of fishes known to have been found in the waters of Rhode Island. In nomenclature and sequence of species, "The Fishes of North America," Bull. U. S. Nat. Mus. No. 47, by Jordan and Evermann, has been followed. The fishes enumerated represent 84 families, 149 genera, and 177 species. Of these about 30 are important food fishes; about 65 may be said to be rare, as far as the present records go; of these latter about 25 have been taken but once, as far as is known. The type specimens of 6, or perhaps of 7, species were taken in Rhode Island waters.

PETROMYZONIDÆ. The Lampreys.

1. **Petromyzon marinus** (Linnæus). *Great Sea Lamprey; Lamprey Eel.*

Geog. Dist.: Atlantic coast of Europe and America, south to Chesapeake Bay.

Migrations: Ascends fresh water streams in spring to spawn.

Season in R. I.: Rare, sometimes caught in traps in Narragansett Bay, a few in Taunton River in spring. De Kay in 1842 described specimens from Providence. (De Kay, New York Fauna, Fishes, 1842, 381.)

Reproduction: Spawns in fresh water in spring, dying after the process. (Jordan, Guide to the Study of Fishes. I. 498.)

Food: Parasitic on other fishes.

GALEIDÆ. The Requiem Sharks.

2. **Mustelus canis** (Mitchill). *Smooth Dogfish; Switchtail.*

Geog. Dist.: Cape Cod to Cuba, southern Europe.

Season in R. I.: May to November.

Food: Crabs usually, also lobsters, squids, annelids and fishes.

Size: Small specimens one foot long caught August 23, 1905; this size is common the remainder of the season.

3. Carcharhinus obscurus (Le Sueur). *Dusky Shark; Shovel-nose.*

GEOG. DIST.: The middle Atlantic.

SEASON IN R. I.: Very common from May to November in outside waters, and occasionally in Narragansett Bay.

HABITAT: Surface of the open water.

FOOD: Fishes. Stomach contents have shown skates, squeteague, young mackerel, menhaden.

SIZE: Eight to 14 feet.

4. Carcharhinus milberti (Müller & Henle). *Blue Shark.*

GEOG. DIST.: Cape Cod to Florida.

DeKay describes a specimen 7 feet, 4 inches long, weighing 160 pounds, taken at Brenton's Reef September, 1842. (DeKay, New York Fauna, Fishes, 1842, 354.)

FOOD: Fishes.

SPHYRNIDÆ. The Hammer-Headed Sharks.

5. Sphyrna zygæna (Linnæus) *Hammer-head.*

GEOG. DIST.: All warm seas. From Cape Cod and Pt. Conception southward.

SEASON IN R. I.: Not common but occasionally occurring from June to October. In 1905 a specimen taken August 2, and another reported about two weeks later.

FOOD: Fishes, especially menhaden; squids.

SIZE: Average 4 feet, the largest reaching 7 and 8 feet; the smallest 1½ feet.

ALOPIDÆ. The Thresher Sharks.

6. Alopias vulpes (Gmelin). *Swing-tail; Whip-tail; Thresher.*

GEOG. DIST.: Abounds in all warm seas, especially in the Atlantic and Mediterranean. Frequent on Pacific coast.

SEASON IN R. I.: Rare in Narragansett Bay, but the most common shark in outside waters, especially after the scup season. It is a great nuisance to fishermen.

FOOD: Fishes, which the animal is said to kill by blows of its long flexible tail.

SIZE: Sometimes as large as 300 pounds.

CARCHARIDÆ. The Sand Sharks.

7. **Carcharias littoralis** (Mitchill). *Sand Shark.*

GEOG. DIST.: Atlantic coast, Cape Cod to Cape Hatteras.

SEASON IN R. I.: From May to November it is common, but is less so than the dogfish.

FOOD: Fishes, such as flatfish, menhaden, squeteague, butterfish, scup. Also crabs and squids.

SIZE: Average 4½ to 5 feet long, largest 12 feet long.

LAMNIDÆ. The Mackerel Sharks.

8. **Isurus dekayi** (Gill). *Mackerel Shark.*

GEOG. DIST.: Cape Cod to West Indies.

SEASON IN R. I.: Said to be more common of late years, but not abundant. Rare in Narragansett Bay.

FOOD: Small fishes, squids, mackerel, conger eel.

SIZE: They average 4 or 5 feet, the largest 10 feet, weighing up to 400 pounds.

9. **Lamna cornubica** (Gmelin). *Blue Shark; Mackerel Shark.*

GEOG. DIST.: Newfoundland to West Indies. Common on Massachusetts coast during mackerel season.

SEASON IN R. I.: Said by the fishermen to be more common than the mackerel shark (Isurus dekayi), but this species is probably confused with others.

FOOD: Small fishes, especially mackerel. Squids.

SIZE: Ten feet.

SQUALIDÆ. The Dog-Fishes.

10. **Squalus acanthias** (Linnæus). *Dogfish; Spiny Dogfish.*

GEOG. DIST.: Atlantic south to Cuba and from the North Cape to the Mediterranean.

MIGRATIONS: Probably moves northward in spring a little after the mackerel, returning from September to November.

SEASON IN R. I.: The last of April or first of May to November. Rare in the Bay, but so common outside as to be a nuisance to the fishermen. Follows the schools of scup in spring.

HABITAT: Open water, following schools of pelagic fishes.

REPRODUCTION: Viviparous.

FOOD: Fishes, especially herring, mackerel, and scup. Also crustacea and jelly fishes.

SIZE: Two to 3 feet.

RAJIDÆ. The Skates.

11. Raja erinacea (Mitchill). *Summer Skate; Old Maid.*

GEOG. DIST.: Virginia to Maine.

SEASON IN R. I.: Very abundant everywhere from May to November.

REPRODUCTION: Eggs common in August and September.

FOOD: Usually crustacea and annelids, but bivalve molluscs, squids, and small fishes are frequently found in the stomach.

SIZE: Average 1 to 2 feet. One young specimen, 2 inches long, taken in trap in the Bay, October 9, 1905.

12. Raja ocellata (Mitchill). *Big Skate; Winter Skate.*

GEOG. DIST.: Atlantic coast northward from New York.

SEASON IN R. I.: Very rare in summer. Scattering specimens taken in the Bay in the fall.

FOOD: Squids, annelids, crustacea.

SIZE: Average, 3 feet.

13. Raja lævis (Mitchill). *Barndoor Skate.*

GEOG. DIST.: New England to Florida.

SEASON IN R. I.: Rare in summer when it is probably in deep water, but common in spring and from August to October.

REPRODUCTION: Eggs found occasionally in September.

FOOD: Crustacea. Lobsters have frequently been found in their stomachs.

SIZE: Four feet.

NARCOBATIDÆ. The Electric Rays.

14. Tetranarce occidentalis (Storer). *Torpedo; Crampfish.*

GEOG. DIST.: Cape Cod to Cuba.

SEASON IN R. I.: Caught off Sakonnet not uncommonly in midsummer, where it has become rather common in the last four or five years. They run through July and August, coming one or two at a time.

FOOD: Fishes. The walls of the alimentary canal in this fish are very thick and possess great digestive power.

SIZE: Two to 5 feet long. Maximum weight 300 pounds; average, 150 pounds; small ones infrequent.

DASYATIDÆ. The Sting Rays.

15. Dasyatis centrura (Mitchill). *Sting Ray.*

GEOG. DIST.: Coast of Maine to Cape Hatteras.

SEASON IN R. I.: Said to have been very common formerly and as large as a foot thick, but are small and few at the present time. Most abundant the last part of July and through August and September.

FOOD: Large species of invertebrates such as crabs, squid, clams, sea snails. Sometimes small fishes and annelids.

SIZE: Reaches a length of 10 or 12 feet.

16. Dasyatis hastata (Dekay).

GEOG. DIST.: West Indies north to Rhode Island.

The type specimen originally described by DeKay in 1842 was a female captured in September off the Rhode Island coast. (DeKay, New York *Fauna*, Fishes, 1842, 373.)

17. Pteroplatea maclura (LeSueur). *Butterfly Ray; Angel-fish.*

GEOG. DIST.: Wood's Hole to Brazil.

SEASON IN R. I.: Rare. The type specimen of this species described by LeSueur was taken in 1817. (LeSueur, Jour. Ac. Nat. Sci. Phila., 1817, 41.) In July, 1900, a specimen 23 inches long was taken in the southern part of Narragansett Bay by the Lewis Brothers of Wickford.

FOOD: Fishes, shrimp, lamellibranchs, annelids.

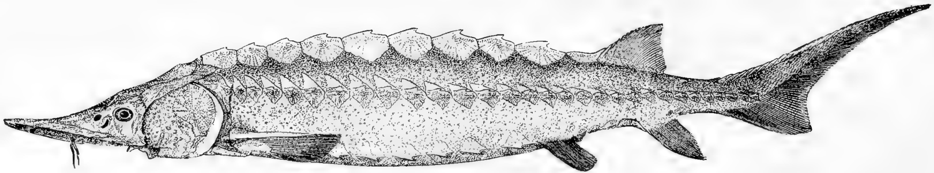
MYLIOBATIDÆ. The Eagle Rays.

18. Myliobatis freminvillei (LeSueur). *Sharp-headed Ray; Sting Ray.*

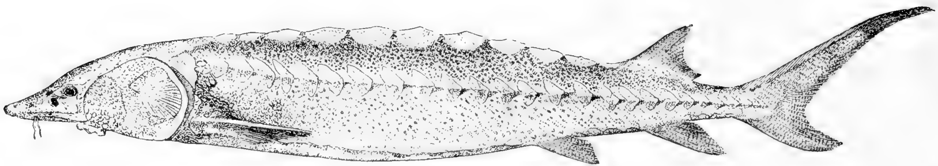
GEOG. DIST.: Cape Cod to Brazil.

SEASON IN R. I.: Not very common. The original type specimen described by LeSueur was taken in 1824 from Rhode Island. (LeSueur, Jour. Ac. Nat. Sci. Phila., IV, 1824.) DeKay mentions specimens from Rhode Island. (DeKay, New York Fauna, Fishes, 1842, 376.) Mr. John O. Lewis of Wickford says several have been taken in traps near Saunderstown, Narragansett Bay.

FOOD: Chiefly molluscs, which they crush with their large grinding teeth.



The Common Sturgeon
(Acipenser sturio).



The Short-Nosed Sturgeon
(Acipenser brevirostrum).

Plate I.

19. Rhinoptera bonasus (Mitchill). *Cow-nosed Ray; Sting Ray.*

GEOG. DIST.: Cape Cod to Florida.

SEASON IN R. I.: An immense school of these fishes once seen off Block Island by Capt. Mason, of Tiverton. Said to have been more common formerly.

REPRODUCTION: Viviparous, breeding season lasting over five or six months.

FOOD: Chiefly molluscs; also crustacea, crabs, and lobsters.

ACIPENSERIDÆ. The Sturgeons.

20. Acipenser sturio (Linnæus). *Sturgeon.* (Plate I.)

GEOG. DIST.: Ascends rivers of Atlantic coasts of Europe and America.

SEASON IN R. I.: Rather common in traps off Sakonnet from May to November. Said to have been more common formerly; 20 years ago 5 or 6 were caught in traps at a time. Rare in the upper part of Narragansett Bay. One caught off Quonset, June, 1905. Common at Block Island. The young are said to be common in Taunton river.

REPRODUCTION: Ascends rivers to spawn in spring and summer.

FOOD: Molluscs and crustacea, which it obtains by grubbing in the mud.

SIZE: Five to 12 feet, weighing 50 to 300 pounds.

21. Acipenser brevirostrum (LeSueur). *Short-nosed Sturgeon.* (Plate I.)

GEOG. DIST.: Cape Cod to Florida.

SEASON IN R. I.: Occurs in company with the common sturgeon but is said by the fishermen to be more numerous.

SILURIDÆ. The Cat-Fishes.

22. Felichthys felis (Linnæus). *Sea Catfish; Gaff-topsail Catfish.*

GEOG. DIST.: Cape Cod to Texas.

SEASON IN R. I.: Specimen taken at Brenton's Reef lightship September 16, 1898.

23. Galeichthys milberti (Cuvier). *Sea Catfish.*

GEOG. DIST.: Cape Cod to Texas.

24. Ameiurus nebulosus (LeSueur). *Horned Pout; Bullhead.*

GEOG. DIST.: Great Lakes, Ohio Valley, to Maine, Florida and Texas.

HABITAT: Fresh water ponds and streams.

SIZE: Up to 18 inches.

CATOSTOMIDÆ. The Suckers.

25. Catostomus commersonii (Lacépède). *Common Sucker; Brook Sucker.*

GEOG. DIST.: Quebec and the Great Lakes to Montana, Colorado, Missouri, and Georgia.

HABITAT: Fresh water streams and ponds.

26. Erimyzon suceta (Lacépède). *Chub Sucker.*

GEOG. DIST.: Great Lakes and Mississippi Valley, eastward.

HABITAT: Very abundant in lakes and lowland streams.

SIZE: About 10 inches.

CYPRINIDÆ. The Carps.

27. Abramis crysoleucas (Mitchill). *Golden Shiner; Roach; Dace.*

GEOG. DIST.: Nova Scotia and Maryland to Dakota and Texas.

HABITAT: Fresh water. Sluggish fish, frequenting ponds and cutoffs, preferring those where the bottom is covered with aquatic plants.

28. Notropis cornutus (Mitchill). *Shiner; Red-fin.*

GEOG. DIST.: Entire region east of Rocky Mountains, except the South Atlantic States and Texas.

HABITAT: Small streams.

SIZE: Five to 8 inches.

29. Rhinichthys atronasus (Mitchill). *Black-nosed Dace.*

GEOG. DIST.: New England to Minnesota, Northern Alabama, and Virginia.

HABITAT: Fresh water. Abundant in clear brooks and mountain streams.

ANGUILLIDÆ. The True Eels.

30. Anguilla chrysypa (Rafinesque). *Eel.*

GEOG. DIST.: Maine to Mexico. Ascends rivers east of Rockies and south of Canada.

MIGRATIONS: Adults move from fresh water into salt in the autumn to spawn. The young move from salt water into fresh in spring.

SEASON IN R. I.: Abundant throughout the year, but are most numerous in the autumn when the females are descending the rivers. About April 15, 1905, the eels in Greenwich Bay, R. I., for a period of about three weeks, died in great numbers. They rose to the surface of the water, swam slowly around until dead; they floated up in immense numbers on the surface and drifted on the shores.

REPRODUCTION: Breeding takes place in winter time in salt water. The females with mature ovaries are taken through the ice.

FOOD: The eel is an excellent scavenger, eating all kinds of dead animal matter. It also feeds on small fishes, shrimp, crabs, molluscs, worms, etc.

SIZE: Four or 5 feet. Young taken when ice breaks up in the spring 1 to 1½ inches long. Prof. Jenks found specimens 2¼ inches long on April 19th.

LEPTOCEPHALIDÆ. The Conger Eels.

31. **Leptocephalus conger** (Linnæus). *Conger Eel.*

GEOG. DIST.: Cosmopolitan, except not found in eastern Pacific.

MIGRATIONS: Moves into deep water for spawning; does not run into fresh water.

SEASON IN R. I.: Scattering specimens in spring and summer, common from August to November. In the U. S. Museum are casts of 2 specimens taken at Block Island by the U. S. Fish Commission, September 26, 1874. One of these weighed 11 pounds.

HABITAT: Salt and brackish water.

REPRODUCTION: Takes place in the depths of the ocean.

FOOD: Fishes, snails, shrimp, worms.

SIZE: Average, 4 to 6 feet. Smallest observed at Woods Hole are 15 to 20 inches long.

ELOPIDÆ. The Tarpons.

32. **Tarpon atlanticus** (Cuvier & Valenciennes). *Tarpon.*

GEOG. DIST.: Cape Cod to Brazil.

SEASON IN R. I.: Rare. Stragglers are reported by fishermen.

Specimen taken in August, 1874, at Newport by Mr. Samuel Powell (Photograph No. 398 in U. S. Nat. Mus.) Mr. J. M. K. Knowles, of Wakefield, is authority for the statement that a tarpon 5 feet long and weighing 30 pounds was taken near Dutch Island Harbor, Narragansett Bay, in 1900.

HABITAT: Tropical waters; ascends streams in pursuit of small fry.

REPRODUCTION: Does not breed north of Cuba.

FOOD: Schools of small fry.

SIZE: Six feet; weighs sometimes 150 pounds.

33. **Elops saurus** (Linnæus). *Ten-pounder; Big-eyed Herring.* (Plate II.)

GEOG. DIST.: Tropical seas to Carolina, straying north to Cape Cod.

SEASON IN R. I.: So rare that it is not usually recognized by fishermen. Specimen 14 inches long, taken in trap at Dutch Island Harbor, Narragansett Bay, October 29, 1905.

HABITAT: Open seas.

FOOD: Shrimp.

SIZE: Three feet.

ALBULIDÆ. The Lady-Fishes.

34. **Albula vulpes** (Linnæus). *Lady-fish.*

GEOG. DIST.: Tropical seas on sandy coasts, north to Woods Hole.

Specimens are reported by fishermen. A specimen from Newport is in the U. S. National Museum. (Proc. U. S. Nat. Mus., 1880, 107.)

CLUPEIDÆ. The Herrings.*

35. **Etrumeus sadina** (Mitchill). *Round Herring.*

GEOG. DIST.: Cape Cod to Gulf of Mexico, on sandy shores; not rare southward.

Specimen in U. S. National Museum taken at Newport by Mr. Samuel Powell. (Bull, U. S. Nat. Mus., 1879, 59.)

36. **Clupea harengus** (Linnæus). *Sea Herring; Herring; Blue Back.* (Plate VII.)

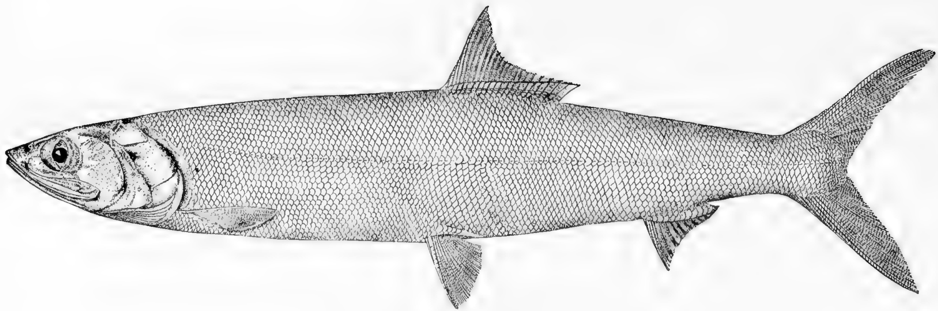
GEOG. DIST.: North Atlantic ocean, Europe and America. South to Cape Hatteras, but not abundant south of Cape Cod.

SEASON IN R. I.: Winter herring arrive in October or November and remain until very cold weather. The spring run arrives in May, and the fishes of that run are larger and more numerous. Young specimens, 2 inches long, taken June 6, 1893. (Prof. Jenks.)

HABITAT: Surface of open water.

---

* Plates illustrating the common species of this family will be found at the end of the article on "The Common Fishes of the Herring Family." Page 102.



THE TEN POUNDER
(Elops saurus).

PLATE II.

REPRODUCTION: Some schools spawn in the spring and others in the autumn. The fall schools spawn to west of Bay of Fundy; spring schools to the east of that point. Spawning takes place in Penobscot Bay, September and October; at Wood Island after middle of September; along the coast of Massachusetts about October 1; at No Man's Land, for 3 or 4 weeks beginning October 15; at Block Island, November. Spawning takes place at a temperature between 47° and 57°F, in the open coast waters not deeper than 30 fathoms. (H. F. Moore, Report U. S. Fish Commission, 1896, 40.)

FOOD: Microscopic animal life.

37. Pomolobus mediocris (Mitchill). *Hickory Shad.* (Plate VIII.)

GEOG. DIST.: Florida to Bay of Fundy.

SEASON IN R. I.: Probably arrives in the spring, but specimens are common from August 1 to November.

REPRODUCTION: The location of the breeding grounds is uncertain. Some authorities say that it does not ascend rivers to spawn; other claim that it spawns in fresh water under same conditions as shad.

FOOD.: Small fishes, crustacea, squids.

SIZE: Maximum, 24 inches.

38. Pomolobus pseudoharengus (Wilson). *Alewife; Branch Herring; River Herring; Buckie.* (Plate IX.)

GEOG. DIST.: Atlantic coast of the United States.

MIGRATIONS: Arrives off Virginia and Maryland about March 1. Said to arrive at Cape Cod about April 1, a month before the scup.

SEASON IN R. I.: This is one of the first fish to arrive in the spring, the traps at that time sometimes being full of them. Comes in March, running up into fresh water through March, April, and the first of May. After that, in May and June, a few spent stragglers are taken on their way back to salt water. The dates of their arrival in Taunton River, kept by Mr. Elisha Slade, from 1871 to 1883, show that their earliest appearance during that time was February 28, 1880, and the latest March 28, 1875.

REPRODUCTION: During March and April in fresh water.

FOOD: Minute free-swimming crustacea. Sometimes young squids and small shrimp.

SIZE: One-half pound. The young, hatched from the eggs in the spring, become 2 or 3 inches long before winter.

39. Pomolobus æstivalis (Mitchill). *Glut Herring; Blackback.* (Plate X.)

Geog. Dist.: Coast waters United States north to Maine.

Migrations: Similar to the alewife (P. pseudoharengus), except that it appears later and remains in fresh water for a shorter time.

Season in R. I.: It appears from two weeks to a month later than the alewife.

Reproduction: Similar to the alewife, but about two weeks later; the spawning grounds are probably confined to brackish water in ponds, and in large streams not far above tide water.

Food: Free-swimming crustacea.

40. Alosa sapidissima (Wilson). *Shad.* (Plate XI.)

Geog. Dist.: From Alabama along the whole Atlantic coast. Introduced by the U. S. Fish Commission into rivers of Pacifie coast.

Migrations: Probably lives in deep water in winter or near Gulf Stream, coming into shore waters when the temperature reaches 60°F., running up rivers to spawn. When this process is completed they probably return to salt water. The young, when hatched, remain in rivers till autumn, then move into salt water.

Season in R. I.: Arrives last of March and runs for about 6 weeks. A large specimen taken August 3, 1905, at Rumstick Point. Specimen 3 inches long, taken October 29, 1905, at Dutch Island Harbor; this was probably hatched from spawn of the previous spring, and was then on its way to salt water. Dates of arrival in Taunton River from 1871 to 1883 range from March 10 in 1880 to April 5 in 1883.

Reproduction: Spawning takes place in fresh water in April and May.

Food: Like the other members of this family, its chief food supply consists of minute free-swimming crustacea.

Size: Maximum, 2½ feet. It reaches its full size in four years.

41. Opisthonema oglinum (LeSueur). *Thread Herring.*

Geog. Dist.: West Indian fauna, straying north to Cape Cod. The type specimen described in 1817 by LeSueur was taken at Newport. (Jour. Ac. Nat. Sci. Phila., I, 1817, 359.) In the U. S. National Museum is a specimen taken at Newport by the U. S. Fish Commission. (Bull. U. S. Nat. Mus., 1879, 60.) A few have been taken very rarely since.

42. **Brevoortia tyrannus** (Latrobe). *Menhaden; Pogy; Bony Fish.* (Plate XII.)

GEOG. DIST.: Nova Scotia to Brazil.

MIGRATIONS: The migrations of the menhaden are largely determined directly by the water temperature; they enter the coast waters in the spring when the average harbor temperature reaches about 50°F, and leave in the autumn when the temperature falls below that point.

The approximate times of the arrival of the first schools is given as follows by G. Brown Goode: Chesapeake Bay, March and April; New Jersey, April and early May; south coast of New England, late April and May; Cape Ann, middle of May; Gulf of Maine, last of May and June. They leave the Maine coast in September and October; Massachusetts, in October, November, and December; Long Island Sound, November and December; Chesapeake Bay, December; Cape Hatteras, January; further south they remain throughout the year. It will be seen that they arrive somewhat later than the shad and alewife, about the same time as scup, and in advance of the squeteague and bluefish, and remain longer in the autumn than any of these, except possibly the two last-named species. This order of appearance is what would naturally be expected in view of the fact that the squeteague and bluefish are both carnivorous and feed largely upon the schools of the menhaden.

SEASON IN R. I.: They appear last of April or first of May and are present throughout the summer and fall. Most abundant in May when first arriving and in October when the falling temperature is driving them away from northern shores. They finally leave in November and December.

REPRODUCTION: Spawns in December, probably, and in May and June; the location of the spawning grounds is at present uncertain.

FOOD: The whole food supply of this fish is obtained by filtering out from the surface stratum of water the organic life there suspended. The arrangement of the gill rakers forms a very effective filter of the water which the fish takes in by swimming actively in circles through the water with widely opened mouth and expanded gillcovers. The stomach generally appears comparatively empty, but usually has a small quantity of what appears to be a dark greenish or brownish mud, with a variable quantity of copepods and small crustacea intermixed. This may be demonstrated by observing the habits of the living fish, by the study of the gill rakers, and by collecting on a filter the organic matter suspended in a given quantity of surface water and by comparing the matter thus filtered out with the stomach contents of the menhaden. The following animals have been found: a few small annelids, a few rotifers, the smaller crustacea, like Gammarus and young shrimp, Zoea larva, Nauplius larva, copepods. But the great majority of organisms were Glenodinium, Peridinium, Infusoria and unicellular plants like diatoms, algal swarm spores, bacterial masses. (On the Food of the Menhaden, by J. H. Peck, Ph. D., Bull. U. S. Fish Commission, 1893. 113.)

SIZE: Schools arriving at New England in midsummer from 2 to 5 inches long are hatched from the spawning of the previous fall and spring. The 7 to 10-inch fishes are 2 years old; the 12 to 14-inch size, 3 years old; adults are the large fish 15 to 18 inches.

ENGRAULIDIDÆ. The Anchovies.

43. **Stolephorus brownii** (Gmelin). *Striped Anchovy; Anchovy.*

GEOG. DIST.: Cape Cod to Brazil. Abundant southward.

SEASON IN R. I.: Specimen 1½ inch long, dredged by the *Fish Hawk* in Narragansett Bay, November, 1898. Larger than S. mitchilli, but not so common.

FOOD: Annelids, copepods, sometimes univalve molluscs, foramenifera.

SIZE: Four to 6 inches.

44. **Stolephorus mitchilli** (Cuvier & Valenciennes). *Anchovy.*

GEOG. DIST.: Cape Cod to Texas.

SEASON IN R. I.: Common in late summer. Forms an important part of the so-called "white bait."

HABITAT: Sandy shores, entering rivers.

SIZE: Two and a half inches.

SALMONIDÆ. The Salmon Family.

45. **Salmo salar** (Linnæus). *Salmon.*

GEOG. DIST.: North Atlantic, ascending rivers between Cape Cod and Hudson Bay. Formerly south to Hudson River.

SEASON IN R. I.: Small fish, weighing 2 to 3 pounds, have been taken in Sakonnet River in the spring.

46. **Salvelinus fontinalis** (Mitchill). *Brook Trout; Speckled Trout.*

GEOG. DIST.: East of the Mississippi, Savannah to Labrador.

SEASON IN R. I.: Common in fresh-water streams. In fall, where communication exists, enters salt water, remaining there through the winter.

HABITAT: Clear, swift, cold, fresh-water streams.

ARGENTINIDÆ. The Smelts.

47. **Osmerus mordax** (Mitchill). *Smelt.*

GEOG. DIST.: The Atlantic coast, Virginia to the Gulf of St. Lawrence.

SEASON IN R. I.: Common from October to May. Caught in large numbers in Narrow River, but not as important commercially here as further north, especially in Maine and New Brunswick.

REPRODUCTION: Spawns in February and March.

FOOD: Shrimp and other small crustacea.

SIZE: Maximum, 14 inches.

SYNODONTIDÆ. The Lizard-Fishes.

48. **Synodus fœtens** (Linnæus). *Lizard-fish.*

GEOG. DIST.: Cape Cod to Brazil, common from South Carolina southward.

LUCIIDÆ. The Pikes.

49. **Lucius americanus** (Gmelin). *Banded Pickerel.*

GEOG. DIST.: Massachusetts to Florida, east of the Allegheny Mountains.

HABITAT: Fresh water, in lowland streams and swamps.

PŒCILIIDÆ. The Killifishes.

50. **Fundulus majalis** (Walbaum). *Mayfish; Killifish.*

GEOG. DIST.: Cape Cod to Florida.

SEASON IN R. I.: Common through the summer from April and May until late in the fall.

HABITAT: Along shores, especially sandy beaches.

REPRODUCTION: Spawns in June and July.

FOOD: Small crustacea, especially shrimp and copepods; molluscs and annelids.

SIZE: Four to 6 inches.

51. Fundulus heteroclitus (Linnæus). *Mummichog; Common Killifish.*

GEOG. DIST.: From Maine to the Rio Grande.

SEASON IN R. I.: Most abundant of the mummichogs, and very common at all seasons.

HABITAT: Shores and brackish waters, in eelgrass and on muddy bottoms, especially at the mouth of fresh-water streams.

REPRODUCTION: Spawns in June and July.

FOOD: Shrimp and other small crustacea. Stomach is sometimes filled with a green mud consisting of vegetable debris, diatoms, and foraminifera.

51 a. Fundulus heteroclitus macrolepidotus (Walbaum).

This is a variety of the preceding. Very common everywhere in brackish waters from Maine to Virginia. Specimens from Newport described by LeSueur. (Jour. Ac. Nat. Sci. Phila., I, 1817, 133.)

52. Fundulus diaphanus (LeSueur). *Spring Minnow; Killifish.*

GEOG. DIST.: From Maine to Cape Hatteras.

SEASON IN R. I.: Found throughout the year, but not so common as the other species of this family.

HABITAT: Around shores fed directly by fresh-water streams.

ESOCIDÆ. The Needle-Fishes and Garfishes.

53. Tylosurus marinus (Walbaum). *Garfish; Billfish.*

GEOG. DIST.: From Cape Cod to Texas.

Common from June to October.

SEASON IN R. I.: July 20, 1905, young specimens 3 inches long were taken from the seine at Cold Spring Beach, Wickford. August 28, 1905, several large ones were taken at the same place.

REPRODUCTION: Breeds in fresh water.

FOOD: Fishes, especially small silversides; crustacea, shrimp, amphipods; annelids.

SIZE: Three or 4 feet. The young, 3 to 8 inches long, taken along shores in summer.

HEMIRAMPHIDÆ. The Halfbeaks.

54. Hyporhamphus roberti (Cuvier & Valenciennes). *Halfbeak; Skipper.*

GEOG. DIST.: Coasts of America on sandy shores.

Season in R. I.: Rather common in summer and early fall. The first specimen from Rhode Island was taken by Samuel Powell at Newport and described by Gill in 1862.

Habitat: Sandy shores.

Food: Almost exclusively algæ.

55. Euleptorhamphus velox (Poey).

Geog. Dist.: West Indies, occasionally northward in the Gulf Stream to Massachusetts. Rare.

Specimen in the U. S. National Museum, taken at Newport by Mr. Brown. (Bull. U. S. Nat. Museum., 1879, 55.)

SCOMBERESOCIDÆ. The Sauries.

56. Scomberesox saurus (Walbaum). *Saury; Billfish.*

Geog. Dist.: Common in schools in open seas north of Cape Cod and of France.

Season in R. I.: Very rare. One specimen is in possession of the Commission, presented by Mr. J. M. K. Southwick, of Newport, and dated 1899.

EXOCŒTIDÆ. The Flying-Fishes.

57. Parexocœtus mesogaster (Bloch).

Geog. Dist.: Tropical seas, common in the East Indies and West Indies, and in the Hawaiian Islands. North in the Gulf Stream to Newport.

A specimen 5½ inches long, from Newport, is in the Museum of the Academy of National Sciences at Philadelphia. (Jordan and Meek, Proc. U. S. Nat. Mus., 1885, 47.)

58. Exocœtus volitans (Linnæus). *Black-winged Flying-fish.*

Geog. Dist.: Open seas, north to the Grand Banks, southern Europe and Hawaiian Islands.

Specimen in U. S. National Museum, taken at Block Island by the U. S. Fish Commission, August, 1874

59. Cypsilurus furcatus (Mitchill).

Geog. Dist.: Common in warm seas, north to Cape Cod and Mediterranean.

Two specimens from Newport, one 5½ inches, the other 6 inches in length, are in the Museum of the Academy of Natural Sciences at Philadelphia. (Proc. U. S. Nat. Mus., 1885, 61.) These are apparently the specimens described by Jordan and Evermann, in "The Fishes of North America."

60. Cypsilurus gibbifrons (Cuvier & Valenciennes).

Two specimens only are known; one, the type specimen in the Museum d'Histoire Naturelle at Paris, the other, a young specimen 8 inches long, taken by Mr. Samuel Powell at Newport, R. I., and described by Jordan in 1886. (Proc. U. S. Nat. Mus., 1886, 528.)

GASTEROSTEIDÆ. The Sticklebacks.

61. Gasterosteus bispinosus (Walbaum). *Two-spined Stickleback.*

Geog. Dist.: From Labrador to New Jersey.

Season in R. I.: Very common at all seasons.

Reproduction: During July and August it spawns in nests guarded by the male.

62. Apeltes quadracus (Mitchill). *Four-spined Stickleback.*

Geog. Dist.: From Maine to New Jersey.

Season in R. I.: Common at all seasons.

Food: Copepods.

FISTULARIIDÆ. The Cornet-Fishes.

63. Fistularia tabacaria (Linnæus). *Trumpet-fish.*

Geog. Dist.: West Indies north to Woods Hole.

SYNGNATHIDÆ. The Pipe-Fishes.

64. Siphostoma fuscum (Storer). *Pipe-fish.*

Geog. Dist.: The Atlantic coast of the United States, Cape Ann to Virginia.

Season in R. I.: Common throughout the summer in the eelgrass along the shores and in salt ponds. Two specimens were taken in offshore waters in purse seines with menhaden in July, 1904.

Reproduction: Females with eggs and young were taken in Narragansett Bay March 22, 1897. (Dr. H. C. Bumpus, Science, 1898, 485.)

Food: Small crustacea, amphipods and copepods.

65. Hippocampus hudsonius (DeKay). *Sea-horse.*

GEOG. DIST.: Atlantic coast, Cape Cod to Charleston, S. C.

SEASON IN R. I.: Not common. Rarely found floating in gulfweed and rockweed.

ATHERINIDÆ. The Silversides.

66. Menidia gracilis (Günther). *Silverside.*

GEOG. DIST.: Woods Hole to Albemarle Sound, common in brackish waters.

SEASON IN R. I.: Very common through summer.

67. Menidia menidia notata (Mitchill). *Silverside; Brit.*

GEOG. DIST.: Atlantic coast northward, south to Florida.

SEASON IN R. I.: Very abundant everywhere from April to December, especially along sandy shores, where bushels of them can be taken in the seine almost unmixed with other fish. Used to a great extent as bait for eel pots.

REPRODUCTION: Spawns in June and early July.

FOOD: Small crustacea, shrimp, univalve molluscs, and sometimes vegetable material and diatoms.

SIZE: Five inches.

MUGILIDÆ. The Mullets.

68. Mugil cephalus (Linnæus). *Striped Mullet; Jumping Mullet.*

GEOG. DIST.: Atlantic coast, Cape Cod to Brazil. Pacific coast, Monterey to Chili.

SEASON IN R. I.: October and November. This species, in company with the white mullet, is sometimes very abundant. In the middle of October, 1904, 500 barrels were taken at one haul off Newport. A specimen from Newport is in the U. S. National Museum. (Proc. U. S. Nat. Mus., 1880, 120.)

FOOD: Stomach contents show a greenish mud containing large numbers of diatoms, green algæ, copepods.

69. Mugil curema (Cuvier & Valenciennes). *White Mullet; Jumping Mullet.*

GEOG. DIST.: Cape Cod to Brazil, Magdalena Bay to Chili.

SEASON IN R. I.: Same as the preceding species.

FOOD: Same as the preceding.

SIZE: About 5 inches.

SPHYRÆNIDÆ. The Barracudas.

70. Sphyræna guachancho (Cuvier & Valenciennes). *Barracuda.*

GEOG. DIST.: West Indies to Pensacola, straying north to Woods Hole.

SEASON IN R. I.: Rare. A young specimen, 8 inches long, taken in seine at Willow Beach, near Wickford, on July 17, 1905.

AMMODYTIDÆ. The Sand Launces.

71. Ammodytes americanus (DeKay). *Sand Launce; Lant; Sand Eel.*

GEOG. DIST.: Newfoundland to Cape Hatteras.

SEASON IN R. I.: Said to appear at all seasons; sometimes in summer is so abundant as to fill the traps.

FOOD: Worms and small fry. This species is important as the food of cod, halibut, and mackerel.

SIZE: Largest grow to 16 inches, but are generally much smaller, seldom over 5 or 6 inches.

HOLOCENTRIDÆ. The Squirrel-Fishes.

72. Holocentrus ascensionis (Osbeck). *Squirrel-fish.*

GEOG. DIST.: West Indies about rocks and reefs; accidental on the coast. This species has been taken at Newport. (Bull. U. S. Nat. Mus., 1879, 44.)

SCOMBRIDÆ. The Mackerels.

73. Scomber scombrus (Linnæus). *Common Mackerel.*

GEOG. DIST.: North Atlantic, abundant on both coasts. North to Norway and Labrador, south to Spain and Cape Hatteras.

MIGRATIONS: Appear in the spring when the water reaches 45° F. At sea, off Cape Hatteras, March 20 to April 25; Norfolk, March 2 to April 30; the Capes of Delaware, April 15 to May 1; Barnegat and Sandy Hook, May 5 to May 25; appear at the same date along the whole coast of New England and Nova Scotia; Gulf of St. Lawrence, May and early June. These are probably coastwise movements for the most part, as they can be followed by the fishing boats from southern waters to the north. On their return they probably head out into deep water. In 1898 they appeared at Sakonnet, Chatham, Mass., and Yarmouth, N. S., on the same day, May 3. In 1901 they reached Chatham on April 29, and the next day were taken at Cuttyhunk and Menemsha Bight.

Season in R. I.: Usually arrive at Rhode Island about May 1. In 1905 they first appeared in Sakonnet River on April 28. The first catch was on May 2 in the scup traps off Sakonnet. June 3 they appeared off the Cape Cod shore. June 5 at Newport marked the beginning of the big run of the season, which culminated June 19. The season closed there June 28. On June 22 was the best catch off Block Island. Scattering fishes are present all summer. On September 6 and 7, 1905, there was a very big run of "tinkers" at Newport, the harbor being full of them. A similar run usually occurs about this time, though it was exceptionally large this year. Mackerel finally leave in November. February 1, 1906, a single specimen taken in a tide-water pond, Sakonnet River.

Reproduction: Spawns the middle of May and June, in deep water along the coast from Long Island to the Gulf of St. Lawrence.

Food: The mackerel strains the sea-water through its gill rakers as it swims open-mouthed through the water, taking in all kinds of small crustacea and the larvæ of marine invertebrates. They also feed on young fishes, especially in the latter part of the summer when these are abundant.

Size: Reach a length of 2 inches in 30 days from hatching, 4 inches in 45 days, 7 inches before the autumn migration. The "blinks" are 2 years old, the "tinkers" 3 years, and the adult size of 17 or 18 inches is reached in the fourth year. (Report U. S. Fish Com., 1879, 32.)

74. Scomber colias (Gmelin). *Chub Mackerel; Bull's-eye Mackerel.*

Geog. Dist.: Atlantic and Pacific, widely distributed, north to England, Maine, and San Francisco. Appears irregularly on our Atlantic coast.

Season in R. I.: This species must be present in Rhode Island waters, though beyond vague reports of fishermen, no definite data are available. Dr. Seth E. Meek describes a peculiar fish taken at Block Island, September 16, year not given, which was supposed to be a hybrid between this species and the common mackerel. (Jordan and Evermann, "The Fishes of North America, 866.)

75. Auxis thazard (Lacépède). *Frigate Mackerel; Bonito; Tunny.*

Geog. Dist.: All warm seas, wandering northward to Cape Cod.

Season in R. I.: This species has been abundant in some years, but is usually rare or absent. On August 23, 1880, 28 barrels were taken in a mackerel seine ten miles east of Block Island. Immense schools were reported that year between Montauk Point and George's Banks. (Proc. U. S. Nat. Mus., 1880.) One was reported taken at the mouth of Narragansett Bay in the autumn of 1904.

76. Thunnus thynnus (Linnæus). *Horse-Mackerel; Tunny.*

GEOG. DIST.: Pelagic on all warm coasts. North to England, Newfoundland, San Francisco, and Japan.

SEASON IN R. I.: Plentiful some years; rare others. Taken in autumn around Newport and Narragansett Pier, but more abundantly at Point Judith. More rare formerly, but of late becoming more common. Forty to 60 have been taken in one trap at one time. Present in Rhode Island waters from June to November, but most numerous in July. Mr. Brownell of Tiverton says that, in the autumn of 1904, he ran through an immense school of this species, extending for 10 miles.

FOOD: Menhaden chiefly. (Goode.)

SIZE: The largest ever taken weighed 1,500 pounds; the largest on record from Rhode Island, caught by Mr. Brownell, weighed 750 pounds.

77. Sarda sarda (Bloch). *Bonito.*

GEOG. DIST.: Atlantic Ocean of both coasts, north to Cape Cod.

SEASON IN R. I.: Seen occasionally in the autumn. It is not distinguished by the fishermen from other species of this family.

HABITAT: The open ocean, approaching shores for food and spawning.

FOOD: Stomach contents have shown fishes, squids, small crustacea.

SIZE: Maximum, 2½ feet.

78. Scomberomorus maculatus (Mitchill). *Spanish Mackerel.*

GEOG. DIST.: Both coasts of North America; appears in irregular schools in the Gulf of Mexico and off the Carolina coast. Ranges north to Cape Ann and south to Brazil.

SEASON IN R. I.: Not very common. A few dozen specimens taken this season (1905) between the middle of August and October, in Narragansett Bay. Fifty large ones taken in a trap by Mr. Easterbrook at Price's Neck, Newport, August 15, 1905.

FOOD: Fishes, squids, and crustacea.

79. Scomberomorus regalis (Bloch). *Cereen; Kingfish.*

GEOG. DIST.: Cape Cod to Brazil, abundant at Cuba.

SEASON IN R. I.: Rare in Narragansett Bay, taken usually in the autumn.

FOOD: Small fishes.

SIZE: Maximum, 5 to 6 feet

TRICHIURIDÆ. The Cutlas-Fishes.

80. Trichiurus lepturus (Linnæus). *Cutlas-fish; Scabbard-fish.*

Geog. Dist.: Warm seas, chiefly of western Atlantic; north to Cape Cod.

Season in R. I.: A few stragglers taken nearly every year. Specimen taken by Mr. J. M. K. Southwick, Newport, November 16, 1899. Specimen 3 feet 8 inches long caught in a trap at Newport, 1901. This is the largest specimen recorded from New England waters. Several smaller specimens taken in the Bay the same year. Several specimens have been taken by the Lewis Brothers in their traps in Narragansett Bay at various times.

ISTIOPHORIDÆ. The Sail-Fishes.

81. Tetrapturus imperator (Bloch & Schneider). *Spearfish.*

Geog. Dist.: West Indies north to Cape Cod.

Season in R. I.: Very rare.

XIPHIIDÆ. The Sword-Fishes.

82. Xiphias gladius (Linnæus). *Swordfish.*

Geog. Dist.: Atlantic Ocean on both coasts, most abundant between Cuba and Cape Breton. Common off Cape Cod and Newfoundland Banks. Common off Southern Europe and found in the Pacific.

Season in R. I.: In 1905 they began to reach George's Banks about June 16. Twenty-two were taken in one day, 61 in a week. Began to reach Block Island June 26, when 13 were taken. One seen off Sakonnet Point July 18. Leave Rhode Island waters in September. Abundant in 1905, and extremely so in 1904.

Food: Contents of the stomach show fishes like cod, hake, and squids.

CARANGIDÆ. The Pompanos, Amber-Fishes, etc.

83. Oligoplites saurus (Bloch & Schneider). *Leather-jacket.*

Geog. Dist.: Both coasts of tropical America, common in West Indies, north to Woods Hole.

Season in R. I.: Very rare. Only one specimen is on record from Rhode Island waters; taken September 10, 1886, at Newport.

84. Naucrates ductor (Linnæus). *Pilot-fish.*

GEOG. DIST.: Pelagic fish found in all warm seas. Occasional on our Atlantic coast from West Indies to Cape Cod.

SEASON IN R. I.: Occasionally taken from July to October.

85. Seriola zonata (Mitchill). *Rudder-fish; Pilot-fish; Shark-pilot.*

GEOG. DIST.: Cape Cod to Cape Hatteras.

SEASON IN R. I.: Single specimens occasionally taken from July to October. A specimen in possession of the Commission is dated 1899. Three specimens from Newport are in the U. S. National Museum. (Proc. U. S. Nat. Mus., 1880, 91.)

FOOD: Stomach of one individual contained fragments of a butter fish.

86. Seriola lalandi (Cuvier & Valenciennes). *Amber-fish.*

GEOG. DIST.: Brazil to Cape Cod.

SEASON IN R. I.: Rare. Taken in traps occasionally during summer months.

87. Decapterus punctatus (Agassiz). *Scad; Round Robin; Cigar-fish.*

GEOG. DIST.: Cape Cod to Brazil.

88. Decapterus macarellus (Cuvier & Valenciennes). *Mackerel Scad.*

GEOG. DIST.: Warm parts of Atlantic north to Cape Cod.

SEASON IN R. I.: Occasional in October. Prof. Jenks is authority for the statement that none are ever taken over 6 inches long. Specimen in the U. S. National Museum, taken at Newport by Mr. Samuel Powell. (Bull. U. S. Nat. Mus., 1879, 42.)

FOOD: Copepods and annelids.

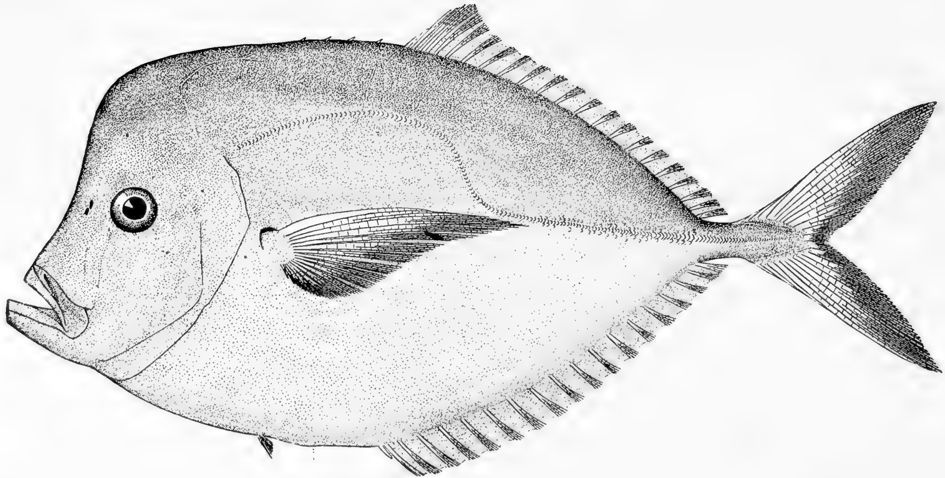
89. Trachurus trachurus (Linnæus). *Saurel; Gascon.*

GEOG. DIST.: North Atlantic, chiefly on coast of Europe, south to Spain and Naples. Taken also at Newport; Pensacola; Cape San Lucas. Only 4 American specimens are known.

SEASON IN R. I.: Goode describes specimens from Newport. (Proc. U. S. Nat. Mus. 1882. 269.)

90. Trachurops crumenophthalmus (Bloch). *Big-eyed Scad; Goggler.*

GEOG. DIST.: Both coasts of tropical America, north to Cape Cod.



The Pug-Nosed Shiner
(Vomer setipennis).

Plate III.

Season in R. I.: Common in October and November. (Prof. Jenks.) Specimen from Newport in the U. S. National Museum. (Proc. U. S. Nat. Mus., 1880, 84.)

Food: Annelids.

91. Caranx hippos (Linnæus). *Crevallè; Jack.*

Geog. Dist.: Warm seas, both coasts of tropical America, north to Gulf of California and Cape Cod, also found in East Indies.

Season in R. I.: Occasionally taken from July to December. Specimen from Newport in U. S. National Museum. (Proc. U. S. Nat. Mus., 1880, 90.)

Food: Fishes and crustacea.

Size: Largest are 2 feet long. Young 1 inch long are taken at Woods Hole about July 1st.

92. Caranx crysos (Mitchill). *Hardtail; Yellow Crevallè.*

Geog. Dist.: Cape Cod to Brazil.

Season in R. I.: Not uncommon from August 1 to November. Most of those caught in traps are small, about 8 to 10 inches long, but one very large specimen, about 18 inches long, taken in trap near Saunderstown, Narragansett Bay, August 10, 1905. Specimen from Newport in the U. S. National Museum. (Proc. U. S. Nat. Mus., 1880, 90.)

Food: Crustacea.

93. Alectis ciliaris (Bloch). *Cobbler-fish; Threadfish.*

Geog. Dist.: Tropical America on both coasts, ranging north to Cape Cod.

Season in R. I.: Rare. From June to November. The Commission is in possession of a specimen 3½ inches long from Newport. Specimens from Newport are in the U. S. National Museum. (Proc. U. S. Nat. Mus., 1880, 90.)

94. Vomer setipinnis (Mitchill). *Pug-nosed Shiner; Dollar-fish.* (Plate III.)

Geog. Dist.: Tropical America, both coasts. Common south, young occurring north in Gulf Stream.

Season in R. I.: Not common. Adults very rare. Occasional specimens in August, September, and October. The first recorded of this species from Rhode Island was a young specimen described by Cope in 1870. (Proc. Amer. Philos. Soc. Phila. 1870, 119.) Specimens from Newport are in the U. S. National Museum. (Proc. U. S. Nat. Mus., 1880, 89.)

An adult specimen taken in Narragansett Bay at Newport by Mr. J. M. K. Southwick in 1899. Young specimens taken August 23 and October 9, 1905.

95. Selene vomer (Linnæus). *Lookdown; Dollar-fish.*

GEOG. DIST.: Tropical seas.

FOOD: Small crustacea. Shrimp, gasteropods, lamellibranchs.

96. Trachinotus falcatus (Linnæus). *Round Pompano.*

GEOG. DIST.: Cape Cod to Brazil.

97. Trachinotus carolinus (Linnæus). *Common Pompano.*

GEOG. DIST.: South Atlantic and gulf coasts of United States, straying to Brazil and Cape Cod.

FOOD: Stomach contents: Fishes, small crustacea, amphipods, lamellibranch shells, diatoms, and vegetable debris.

POMATOMIDÆ. The Bluefishes.

98. Pomatomus saltatrix (Linnæus). *Bluefish.*

GEOG. DIST.: Atlantic and Indian Oceans.

MIGRATIONS: Its migrations are probably more influenced by the presence of food than by temperature. They move along the coast from the south toward the north in the spring, following schools of menhaden. Immense schools appear off the Carolina coast in March and April; reaching the Jersey coast in the early part of May; Newport, middle of May to first week in June. In October they leave the northern coasts and appear off the coast of Carolina about the middle of November, where a very extensive fishery exists until late in December. Their presence off the Carolina coast in autumn is preceded by schools of menhaden and marked by flocks of birds. (Prof. Baird, Report U. S. Fish Commission, 1873.)

SEASON IN R. I.: Common but not abundant. They arrive about June 1, and remain until the last of November. These fishes are 12 to 14 inches in length. On August 27, 1905, many young of this species, 4 to 6 inches long, were found gilled in the meshes of the traps. These had probably been present for some time, but had before been too small to be held in the nets. These increased to about 9 inches in length before the end of the season.

REPRODUCTION: Little is known about this. It is possible that they spawn in early spring or winter in deep water or along more southerly coasts. Then the young, under the influence of migratory instinct, move northward along the coast, growing rapidly as they proceed. This explains the presence of the young fishes 4 to 6 inches in length in August. Well developed spawn is found in a small proportion of the bluefish when they first arrive. (Smith, The Fishes of Woods Hole, Bull. U. S. Fish Commission, 1897, 98.)

FOOD: A very voracious, carnivorous fish, feeding particularly on menhaden and squeteague. Stomachs also sometimes contain herring, cunners, squid, scup, butter-fish, marine worms, and crustacea.

SIZE: They reach a length of 5 inches in the middle of August; 6 or 7 inches in September; 9 inches in November; and at a year old are from 12 to 14 inches in length.

NOMEIDÆ. The Nomeids.

99. Nomeus gronovii (Gmelin). *Portuguese Man-of-war-fish.*

GEOG. DIST.: Tropical parts of the Atlantic and Indian Oceans in rather deep water, swimming near the surface, very abundant in the Sargasso Sea, common north to Florida and Bermuda, straying to Panama and Woods Hole.

SEASON IN R. I.: Found living under Portuguese man-of-war.

STROMATEIDÆ. The Butter-Fishes.

100. Palinurichthys perciformis (Mitchill). *Rudder-fish; Pole-fish.*

GEOG. DIST.: Atlantic coast of North America from Cape Hatteras to Maine.

SEASON IN R. I.: Specimen from Newport in U. S. National Museum. (Proc. U. S. Nat. Mus., 1886, 91.)

FOOD: Small squids, snails, crustacea.

101. Peprilus paru (Linnæus). *Harvest-fish.*

GEOG. DIST.: Cape Cod to Jamaica.

SEASON IN R. I.: Rare, only a few appearing each season in June or July with the butter-fishes. A large specimen taken July 24, 1905.

102. Poronotus tricanthus (Peck). *Butter-fish.*

GEOG. DIST.: Maine to Florida, rare south of Cape Hatteras.

MIGRATIONS: Appears early in April off the Jersey coast.

SEASON IN R. I.: Appears toward the last of May a little later than the scup. In 1905 first appeared May 22. The height of the spring run is during the first two or three weeks in June. A few are present throughout the summer. In October occurs the fall run. They finally leave in November. Young, 3 to 5 inches long, are common in October.

REPRODUCTION: Spawns in June. Young frequently found in summer, living under the protection of stringers of the jellyfishes.

FOOD: Small fishes, small free-swimming crustacea, annelids.

SIZE: Maximum, 10 inches.

CENTRARCHIDÆ. The Sunfishes.

103. Lepomis auritus (Linnæus). *Long-eared Sunfish.*

GEOG. DIST.: Maine to Louisiana, east of the Alleghenies.

HABITAT: Abundant in all fresh-water streams.

SIZE: Eight inches.

104. Eupomotis gibbosus (Linnæus). *Sunfish.*

GEOG. DIST.: Great Lake region to Maine, and southward east of the Alleghenies to Florida. Occurs only in the northern part of the Mississippi Valley.

HABITAT: Clear brooks and ponds.

105. Micropterus dolomieu (Lacépède). *Small-mouthed Black Bass.*

GEOG. DIST.: From Lake Champlain to Manitoba and southward on both sides of the mountains from James River to South Carolina and Arkansas.

HABITAT: Clear cold waters of running streams.

PERCIDÆ. The Perches.

106. Boleosoma nigrum olmstedi (Storer). *Darter.*

GEOG. DIST.: Lake Ontario to Massachusetts, south to Virginia.

HABITAT: Among weeds of clear streams.

SIZE: Three and a half inches.

CHEILODIPTERIDÆ. The Cardinal Fishes.

107. Apogon imberbis (Linnæus). *King of the Mullets.*

GEOG. DIST.: Mediterranean and neighboring waters; Florida, West Indies, and Brazil.

A specimen taken at Newport was described by Cope in 1870. (Proc. Ac. Nat. Sci. Phila., 1870, 120.)

SERRANIDÆ. The Sea Basses.

108. Roccus lineatus (Bloch). *Striped Bass; Rockfish.*

GEOG. DIST.: Atlantic coast of United States, New Brunswick to Florida. Most common from Cape Cod to Cape May.

MIGRATIONS: It is said not to be migratory but present along our coast in winter as well as in summer. Taken through the ice in Long Island and Block Island Sounds in December. (Goode, Nat. Hist. of Aquatic Animals, 425.)

SEASON IN R. I.: Arrives the last of March with the shad. The dates of arrival in Taunton River from 1871 to 1883 range from March 15 in 1880, to April 6, in 1883. (Bull. U. S. Fish Commisison, 1883, 478.)

REPRODUCTION: Spawns in rivers in the spring.

FOOD: Voracious feeders, eating fishes and crustacea. (Goode, loc. cit.)

SIZE: Largest ever taken weighed 112 pounds.

109. Morone americana (Gmelin). *White Perch.*

GEOG. DIST.: Atlantic coast, South Carolina to Nova Scotia.

SEASON IN R. I.: Present the year round. Taken in traps in the Bay in October.

HABITAT: Shallow shore waters, brackish and fresh water of rivers and ponds connected with salt water. Sometimes land-locked.

REPRODUCTION: Spawns in May in fresh water. (Goode, Hist. of Aquatic Animals, 432.)

FOOD: Shrimp, fish spawn, insects, crabs, small fishes, and eels.

SIZE: Eight inches.

110. Epinephelus niveatus (Cuvier & Valenciennes). *Snowy Grouper.*

GEOG. DIST.: Brazil to West Indies, often straying north to Cape Cod.

SEASON IN R. I.: Two young specimens, 2 inches long, taken by Samuel Powell at Newport, 1860. (Proc. Ac. Nat. Sci. Phila., 1861, 98.) Drs. Goode and Bean report the capture of another specimen at the same place in 1877. (Amer. Jour. Sci. & Arts, XVII, 1879, 545.) Also, three other specimens of this species from Rhode Island are in the U. S. National Museum; one 2½ inches long is from Tiverton, the other two, 3 and 3¼ inches long, taken at Point Judith. The first specimens recorded from Woods Hole were taken in 1895; 8 or 10 other specimens taken in the vicinity in the same year; 2 of these were 2¾ and 1¼ inches long.

111. Centropristes striatus (Linnæus). *Sea Bass; Black Bass.*

GEOG. DIST.: Atlantic coast, Casco Bay to Northern Florida.

MIGRATIONS: Probably spends the winter in a torpid state around rocky bottoms without extensive migrations. (Goode.) Appears on the Jersey coast in April.

SEASON IN R. I.: Arrives in May and is then most abundant. Leaves in October.

HABITAT: Rocky bottom in cavities and under stones.

REPRODUCTION: Spawns in June. Sexual differences are very marked, especially during the breeding season.

FOOD: The various crustacea are its most important food; crabs, lobsters, shrimp; also squids, molluscs, small fishes.

112. Rypticus bistrispinus (Mitchill).

GEOG. DIST.: South Altantic coast of the United States in rather deep water, straying north to Newport, R. I.

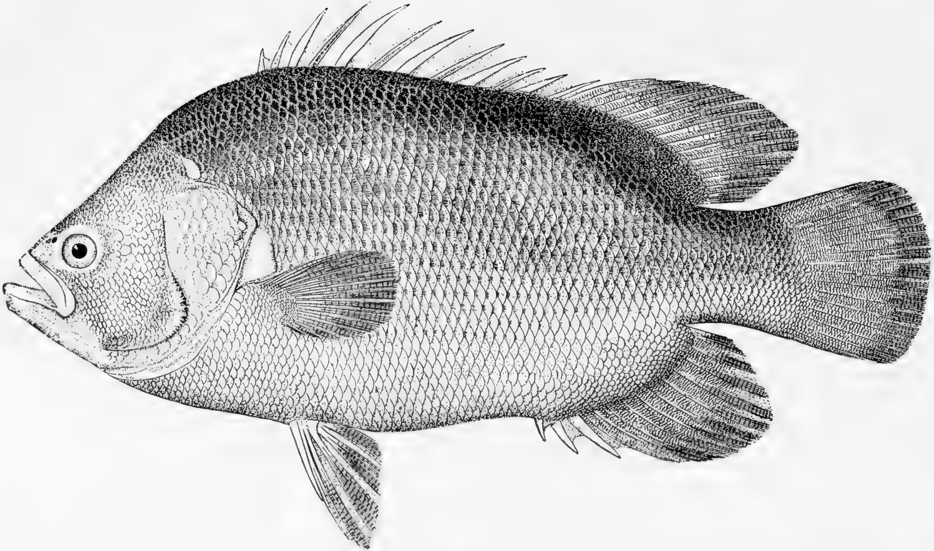
SEASON IN R. I.: One specimen was taken at Newport by Samuel Powell and described by Cope in 1870. (Proc. Ac. Nat. Sci. Phila., 1870, 119.)

LOBOTIDÆ. The Triple-Tails.

113. Lobotes surinamensis (Bloch). *Triple-tail; Flasher.* (Plate IV.)

GEOG. DIST.: All warm seas, Cape Cod to Panama.

SEASON IN R. I.: The rarity of this species is shown by the fact that, according to the Report of U. S. Fish Commission, 1901, only 6 specimens had been recorded in northern waters in twenty years. September 10, 1901, a specimen weighing 6 pounds and 22 inches long was caught in a trap off



The Triple-Tail
(Lobotes surinamensis).

Plate IV.

Prudence Island. A specimen 18 inches long was taken in a trap August 20, 1905, near Saunderstown. Another was reported by a fisherman in the upper part of Narragansett Bay about two weeks later.

HABITAT: A bottom fish of sluggish habits.

REPRODUCTION: Probably spawns in brackish water in the spring, as young 3 inches long were found in August in the eelgrass in Tuckahoe River, New Jersey. (Goode.)

FOOD: Small fishes, muscles, shrimp.

SIZE: Three feet.

PRIACANTHIDÆ. Catalufas.

114. Pseudopriacanthus altus (Gill). *Big-eye.*

GEOG. DIST.: West Indies in rather deep water, north to Cape Cod.

SEASON IN R. I.: Very rare. A few have been taken at Woods Hole and vicinity. The type of this species described by Gill was a very young specimen taken in Narragansett Bay near Conanicut Ferry in September, 1860. (Proc. Ac. Nat. Sci. Phila., 1870, 120.)

LUTIANIDÆ. The Snappers.

115. Neomænis griseus (Linnæus). *Gray Snapper; Mangrove Snapper.*

GEOG. DIST.: West Indies, ranging from New Jersey to Brazil, straying northward to Woods Hole.

SEASON IN R. I.: A snapper was taken in 1896 at Newport which was probably this species. A few others have been taken at Woods Hole in September. (H. M. Smith, The Fishes of Woods Hole, Bull. U. S. Fish Commission, 1897, 100.)

SPARIDÆ. The Porgies.

116. Stenotomus chrysops (Linnæus). *Scup; Porgy; Scuppaug.*

GEOG. DIST.: Most abundant on south coast of New England. Ranges from Casco Bay, Maine, to South Carolina.

MIGRATIONS: They strike directly on the southern New England coast from their winter habitat in warmer water; they begin to leave about the middle of October. Cod have been taken on Nantucket shoals, in late November, filled with small scup.

Season in R. I.: The first stragglers appear about the last of April. The first large run comes early in May, and consists of large breeding fish. The second or summer run comes after the breeders and is composed of small fishes without spawn. They are said to come in from the west and south. They are very abundant in May and June; stragglers remain all summer; they finally leave the last of October. In 1900 the first arrival was April 21, reaching Cuttyhunk April 26, Woods Hole on May 1. In 1901 the first arrival was April 26. The dates of arrival of the scup in Taunton River from 1871 to 1883 range from May 27 in 1880 to June 1 in 1882. The earliest recorded appearance in Rhode Island is probably April 15 in 1871. The greatest abundance of that year in Newport was on the 15th of May. In 1905, Capt. Church of Tiverton caught a single scup on May 1st at Newport. On May 11th the sea fowl appeared outside Newport Harbor, the usual sign of the approach of the schools. First good catch was made on May 16; small catches were made until June 4, when for a few days the largest hauls of the season were made. The season ended June 25 in the Bay, while at Block Island it lasted until after June 27. The season this year was poorer than usual, due perhaps to the fact that on May 16 and a few days following there was an exceptionally large run of pollock along the whole shore from Brenton's Reef to Sakonnet Point.

Reproduction: The first runs consist of large breeding fish filled with spawn. The eggs are deposited on eelgrass and sandy shores; they sink to the bottom and adhere to solid objects. Fishermen say that the scup spawn in the pounds when being confined there. The eggs hatch in a very few days, and the young can often be seen swimming around on the surface with the yolk sac visible. As they grow older they continue to remain in and around the pounds, apparently for protection. Spawning season is over not long after June 1, as is shown by the taking of spent fishes and by the fact that, about this time, the scup begin to take the hook.

Enemies: Bluefish, cod, halibut, shark, squeteague.

Food: Invertebrates chiefly, though small fishes are sometimes found in the stomachs of large specimens. Molluscs, crustacea, annelids, squids, hydroids, crepidulæ. Stomachs of small specimens usually contain chiefly copepods and other small crustacea.

Size: The young 4 or 5 inches long are sometimes taken in the seine in September and October on sandy shores. The young reach ½ to 3 inches long in July. (Smith, Fishes of Woods Hole, loc. cit.)

117. Lagodon rhomboides (Linnæus). *Sailor's Choice; Shiny Scup.*

Geog. Dist.: Abundant from Cape Hatteras southward, straying north to Cape Cod.

Season in R. I.: Not common. Specimen from Newport, collected by Mr. J. M. K. Southwick in 1899.

Reproduction: Spawns in the south in winter or early spring.

Food: Small fishes, small crustacea.

118. Archosargus probatocephalus (Walbaum). *Sheepshead.*

Geog. Dist.: Cape Cod to Mexico, abundant in the south.

Season in R. I.: Said to have been common formerly, but now rare north of Long Island. Sometimes taken at Newport. (Mr. Southwick).

Reproduction: Spawns in bays and mouths of rivers in March and April.

Habitat: Bottom fish.

Food: Barnacles, shell-fish.

Size: Maximum, 3 pounds.

KYPHOSIDÆ. The Rudder-Fishes.

119. Kyphosus sectatrix (Linnæus). *Rudder-fish.*

Geog. Dist.: Common in West Indies and Key West, and east to the Canary Islands; straying to Cape Cod.

Specimen in U. S. National Museum, taken at Newport by Mr. Samuel Powell. (Bull. U. S. Nat. Mus., 1879, 46.)

SCIÆNIDÆ. The Drums.

120. Cynoscion regalis (Bloch & Schneider). *Squeteague; Weakfish.*

Geog. Dist.: Abundant from Cape Cod to Florida, straying on the Gulf coast to Mobile, north to Bay of Fundy.

Migrations: Taken on the Jersey coast in April. The temperature of the water at the time of their arrival is about 50°F., though their movements may depend more on the presence of schools of menhaden and butter-fish, on which they feed, than on the temperature.

Season in R. I.: Scattering individuals are taken the middle or last of May, but the large run does not come until about June 10. Very abundant through the remainder of the season and is the most important food fish of the State after the end of the scup season. They decrease considerably in numbers the latter part of July and August; they increase again the latter part of August and September, and finally disappear in October. The first runs are composed of adults fishes of uniform size, some having ripe spawn. About August 20 a new school arrives, composed of smaller fishes about 12 to 14 inches in length. These remain throughout the season. The first specimen taken in Providence River in 1905 was at Gaspee Point on June 16th. A catch of 70,000 pounds was made June 16, 1905, by a Gloucester schooner off Block Island.

HABITAT: Coast and still-water fish, running up tidal waters. Immense schools on surface have often been seen. (Goode.)

REPRODUCTION: Many of the fishes have ripe spawn when they first arrive; this indicates the spawning season about June 1. Spawns around bays and inlets and at the mouths of rivers in certain localities; Providence River is a favorite spawning ground. The eggs are buoyant.

FOOD: Fishes, especially menhaden and butter-fish, are its staple articles of diet. Herring, scup, squids, shrimp. The young live exclusively on shrimp and young fishes. (J. H. Peck, Ph. D., The Sources of Marine Food, Bull., U. S. Fish Commission, 1895, 351.)

SIZE: August 5, 1901, young squeteague abundant at Red Bridge, Providence River, 1.25 to 2.25 inches in length. (Eigenmann, Investigations into the History of the Young Squeteague, Bull., U. S. Fish Commission, 1901, 45.)

121. Leiostomus xanthurus (Lacépède). *Spot; Goody.*

GEOG. DIST.: Cape Cod to Texas; abundant south.

MIGRATIONS: Jersey coast at Sea Isle City in July; north Jersey coast in August; Woods Hole in autumn; remaining through October until the temperature falls below 45° F.

SEASON IN R. I.: Sometimes taken at Newport. (Mr. Southwick.)

HABITAT: Bottom fish.

REPRODUCTION: Spawns in the south in bays and inlets in November and December.

FOOD: Small molluscs and crustacea, annelids.

SIZE: Three or 4 inches on south Jersey coast, Woods Hole specimens about 6 inches.

122. Menticirrhus saxatilis (Bloch & Schneider). *Kingfish; Sea-mink.*

GEOG. DIST.: Cape Ann to Pensacola.

MIGRATIONS: Reaches Jersey coast in April, most abundant in May.

SEASON IN R. I.: First appears in May. A few are present throughout the season until October.

REPRODUCTION: Spawns in June. (Smith, Fishes of Woods Hole.)

HABITAT: Deep channels, sandy bottoms. Occurs singly, not in schools.

FOOD: Bottom feeders. Small crustacea, annelids, sometimes young fishes.

SIZE: At Woods Hole the young one inch long appear in the middle of July on sandy beaches. These become 4 or 5 inches long in October. (Smith, loc. cit.)

123. Pogonias cromis (Linnæus). *Drum.*

GEOG. DIST.: Abundant on South Atlantic and Gulf coasts, rare north to Provincetown.

SEASON IN R. I.: Very rare.

HABITAT: Sluggish swimmers, living on the bottom.

FOOD: Bottom-dwelling invertebrates. This fish is especially destructive to oysters.

SIZE: Average, 20 pounds, maximum, 80 pounds. Young specimens much unlike adults.

POMACENTRIDÆ. The Demoiselles.

124. Abudefduf saxatilis (Linnæus). *Pintano; Cow-pilot.*

GEOG. DIST.: Tropical America on both coasts, abundant in West Indies.

Gill in 1870 mentioned a specimen of this species from Rhode Island. (Proc. Ac. Nat. Sci. Phila., 1870, 120.)

FOOD: Free-swimming crustacea.

LABRIDÆ. The Wrasse-Fishes.

125. Tautogolabrus adspersus (Walbaum). *Cunner; Chogset.*

GEOG. DIST.: Labrador to Sandy Hook.

SEASON IN R. I.: Extremely abundant the year round; hibernates in the eelgrass during the winter.

HABITAT: Shoal water around shores and wharves.

REPRODUCTION: Spawns in June and July.

FOOD: Like that of the tautog. Browses around wharves, piles, and similar places, eating fishes, tunicates, hydroids, annelids, small crustacea, univalve molluscs; an important scavenger of harbors, feeding on all kinds of dead animal matter.

SIZE: Ten inches. Young 1 inch long appear August 1. (Smith, loc. cit.)

126. Tautoga onitis (Linnæus). *Tautog; Blackfish.*

GEOG. DIST.: Atlantic coast, New Brunswick to Charleston.

SEASON IN R. I.: Abundant from May to November, but taken in the greatest numbers from the middle of May till the middle of June. In winter they seek deeper water and probably hibernate among the rocks. A few have been taken in Rhode Island in midwinter with lines and in lobster pots. (Goode.) There are instances of their death in great numbers during very cold winters. In February, 1857, after a very cold season, hundreds of tons of tautog drifted on the shores of Block Island; in 1841 the same thing occurred on the southern shores of Massachusetts and Rhode Island. (Goode.) In 1900 the first specimen taken at Pawtuxet was on April 26.

HABITAT: Shallow water on exposed shores about rocks and seaweed.

REPRODUCTION: Spawns from May through July, probably in eelgrass. The young appear about August 1.

FOOD: Hard-shelled molluscs and crustacea.

SIZE: The largest one on record was taken at New York, July 1876, and measured 36½ inches.

EPHIPPIDÆ. The Angel-Fishes.

127. Chætodipterus faber (Broussonet). *Spadefish; Angel-fish; Moon-fish.*

GEOG. DIST.: Cape Cod to Rio Janeiro, very abundant on our south Atlantic coast.

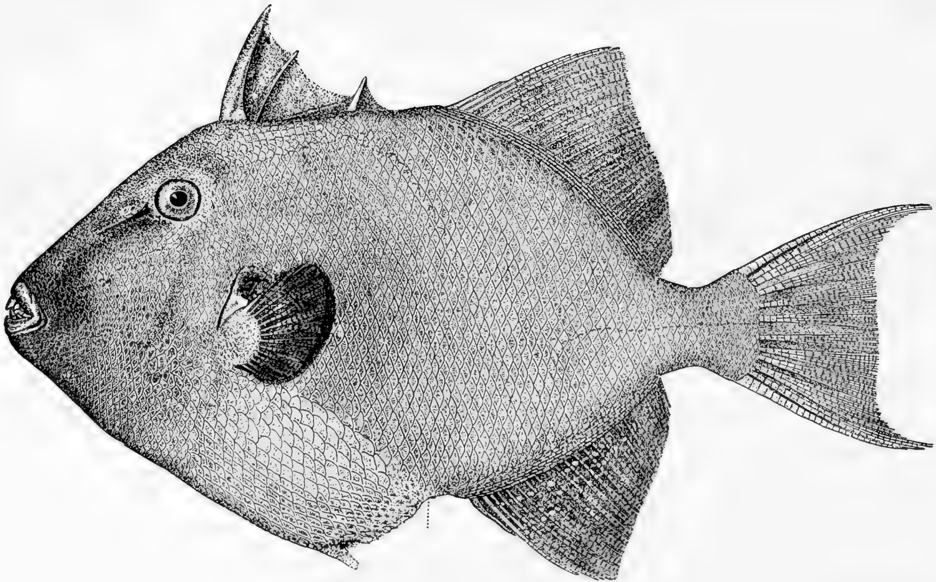
SEASON IN R. I.: Very rare. One specimen, 17 inches long, is in possession of the Commission, taken in Narragansett Bay, date uncertain.

FOOD: Shrimp, annelids, foramenifera, diatoms.

CHÆTODONTIDÆ. The Butterfly Fishes.

128. Chætodon ocellatus (Bloch). *Parché.*

GEOG. DIST.: Common at West Indies, the young straying northward to New Jersey, Rhode Island, and Cape Cod.



THE TRIGGER FISH
(Balistes carolinensis).

PLATE V.

Season in R. I.: Gill describes a young specimen 1 inch long from Newport. (Proc. Ac. Nat. Sci. Phila., 1861, 99.)

BALISTIDÆ. The Trigger-Fishes.

129. Balistes forcipatus (Gmelin). *Powell's Filefish.*

Geog. Dist.: Africa, occasionally straying to American coasts.

This species has been identified with Balistes powelli. (Jordan and Evermann, Fishes of North America, 1702.) Only one specimen has ever been recorded from northern waters; this was a young individual taken in September, 1867, at Newport by Samuel Powell and described by Cope. (Proc. Ac. Nat. Sci. Phila., 1870, 120.)

130. Balistes carolinensis (Gmelin). *Trigger-fish; Leather-jacket.* (Plate V.)

Geog. Dist.: Tropical parts of the Atlantic north in the Gulf Stream to England and Cape Cod.

Season in R. I.: Somewhat rare, but generally a few are taken each year. One specimen, taken in a trap in the West Passage, Narragansett Bay, August 1, 1905, and another October 9, 1905, with tautog, near the north end of Conanicut Island. Specimen from Newport in the U. S. National Museum. (Proc. U. S. Nat. Mus., 1880, 77.)

Reproduction: Supposed to spawn in deep water.

Food: Molluscs, crustacea.

MONACANTHIDÆ. The Filefishes.

131. Monacanthus hispidus (Linnæus). *Foolfish; Filefish.*

Geog. Dist.: Cape Cod to Cuba, through the West Indies to Brazil.

Season in R. I.: A few specimens taken in Rhode Island waters, the maximum size being 5 or 6 inches. A specimen from Newport in the U. S. National Museum. (Proc. U. S. Nat. Mus., 1880, 76.)

Food: Small crustacea, annelids, lamellibranchs, small gasteropods.

Size: Adults, 10 inches; only the young found north.

132. Ceratacanthus schœpfii (Walbaum). *Foolfish; Filefish.*

Geog. Dist.: Cape Cod to Florida and Texas.

Season in R. I.: Occasionally taken in August and September. Specimen from Newport in the U. S. National Museum. (Proc. U. S. Nat. Mus., 1880, 76.) Four taken in the traps in Narragansett Bay during August, 1905. One young specimen, 4 inches long, taken in trap at Goose Neck, near Wickford, October 9, 1905. Young, 1 to 4 inches long, common under gulfweed in summer.

REPRODUCTION: Probably spawns in mid-ocean. (Goode.)

FOOD: Small crustacea, jelly-fishes, ctenophores, hydroids.

OSTRACIIDÆ. The Trunkfishes.

133. Lactophrys trigonus (Linnæus). *Trunkfish; Shell-fish.*

GEOG. DIST.: West Indies, north to Woods Hole.

SIZE: Young specimens 1 inch long are common from July to October at Woods Hole in eelgrass and around wharves. (Smith.)

TETRAODONTIDÆ. The Puffers.

134. Lagocephalus lævigatus (Linnæus). *Smooth Puffer; Puffer.*

GEOG. DIST.: Cape Cod to Brazil.

SEASON IN R. I.: Somewhat rare. One specimen taken in Narragansett Bay, July 22, 1887. Three were taken in the year 1900, the largest weighing 10 pounds, caught October 4 at Tiverton; one at Newport, collected by Mr. J. M. K. Southwick, and a third taken in a purse-net near Point Judith, September 28. Specimen 4½ inches long taken in early August, 1905. This is an interesting specimen in view of the fact that Smith says that those of this species taken at Woods Hole are all about 11 or 12 inches long, small ones never being observed.

REPRODUCTION: Said to breed near Pensacola in June and July.

SIZE: Average, 2 feet.

135. Spheroides maculatus (Bloch & Schneider). *Swellfish; Puffer.*

GEOG. DIST.: Atlantic coast of United States from Cape Ann to Florida.

SEASON IN R. I.: Very common from May to October. Many young specimens, an inch long and upwards, are taken in the seines on the sandy beaches through July and August.

REPRODUCTION: Spawns from June 1 to 10. (Smith.)

FOOD: Bottom invertebrates; small crabs, hermit crabs, shrimp, molluscs, crepidulæ, annelids.

136. Spheroides testudineus (Linnæus).

Geog. Dist.: West Indies north to Newport.

Season in R. I.: Has been taken at Newport. (Cope, Proc. Ac. Nat. Sci. Phila., 1870, 120.)

137. Spheroides trichocephalus (Cope).

This species is known only from Cope's description of a small specimen 4 inches long taken by Samuel Powell in the Gulf Stream off Newport. Possibly the young of *Spheroides pachygaster*. (Cope, Proc. Ac. Nat. Sci. Phila., 1870, 120.)

DIODONTIDÆ. The Porcupine-Fishes.

138. Chilomycterus schœpfi (Walbaum). *Swell-toad; Puffer; Porcupine-fish.*

Geog. Dist.: Cape Cod to Florida, abundant south in shallow water.

Season in R. I.: Two specimens from Rhode Island are in the U. S. National Museum; one was taken at Newport, (Proc. U. S. Nat. Mus., 1880, 75); the other was taken at Watch Hill by the U. S. Fish Commission, September 18, 1874. (Bull. U. S. Nat. Mus., 1879, 24.) In 1903 Mr. Fowler, of Wickford, took a specimen in a dredge in Narragansett Bay opposite Hamilton.

Food: Crustacea, molluscs.

Size: Six to 10 inches.

MOLIDÆ. The Head-Fishes.

139. Mola mola (Linnæus). *Sunfish.*

Geog. Dist.: Tropical seas, north to San Francisco, Cape Cod, and England.

Season in R. I.: Occasionally taken at Block Island in late summer.

Habitat: Surface of the open water.

Reproduction: Nothing is known about its breeding habits, but the young are sometimes taken in mid-ocean.

Food: Fishes, crustacea, ctenophores, jelly-fishes.

Size: Largest on record was taken at California, 8 feet, 2 inches long, weighing 1,800 pounds.

SCORPÆNIDÆ. The Rock-Fishes.

140. Helicolenus dactylopterus (De la Roche).

Geog. Dist.: Narragansett and Chesapeake Bays, in deep water. Common in the Mediterranean.

Season in R. I.: First discovered in America in 1880 off Narragansett Bay, by the *Fish Hawk.* (Goode and Bean, Oceanic Ichthyology, 1896, 249.)

COTTIDÆ. The Sculpins.

141. Myoxocephalus æneus (Mitchill). *Little Sculpin; Grubby.*

Geog. Dist.: Coast of southern New England and New York.

Season in R. I.: Common throughout the year.

Reproduction: Spawns in March; the eggs at that time may be seen sticking to nets and seaweed.

Food: Bottom invertebrates; annelids, copepods, shrimp, young flounders.

Size: Maximum, 6 to 8 inches. Specimen 3 inches long taken in seine at Willow Beach near Wickford, July 17, 1905.

142. Myoxocephalus grœnlandicus (Cuvier & Valenciennes). *Daddy Sculpin; Sculpin.*

Geog. Dist.: New York to Greenland.

Season in R. I.: Common in October and November.

Reproduction: Spawns in November and December.

Food: Fishes, crustacea, worms.

Size: Maximum, 25 inches.

143. Myoxocephalus octodecimspinosus (Mitchill). *Eighteen-spined Sculpin; Sculpin.*

Geog. Dist.: Labrador to Virginia, common about Cape Cod.

Season in R. I.: Common in October and November. Specimen taken May 29, 1905, off Brenton's Reef, Newport.

Reproduction: Spawns in November and December.

Size: About a foot long.

144. Hemitripterus americanus (Gmelin). *Sea-raven; Red Sculpin.*

Geog. Dist.: Atlantic coast, New York to Labrador.

SEASON IN R. I.: Occasionally taken in October and November. Two specimens from Newport are in the U. S. National Museum. (Proc. U. S. Nat. Mus., 1880, 86.) October 9, 1905, a specimen taken at the north end of Conanicut Island.

FOOD.: All bottoms invertebrates; molluscs, crustacea, sea urchins, worms. Useful scavengers.

CYCLOPTERIDÆ. The Lump-Suckers.

145. Cyclopterus lumpus (Linnæus). *Lumpfish.*

GEOG. DIST.: North Atlantic, south to France and Cape Cod.

SEASON IN R. I.: Fairly common in April, May, and June. Specimen from Newport in the U. S. National Museum. (Proc. U. S. Nat. Mus., 1880, 83.)

HABITAT: Rocky shores.

REPRODUCTION: Spawns in April and May near the shore. "The female then retires to deep water, leaving the male to watch the eggs which hatch among seaweed and eelgrass." (Garman.) The young are sometimes taken in the summer under drifting seaweed.

FOOD: Ctenophores, small jelly-fishes.

SIZE: Sometimes reaches 20 inches, but generally less.

LIPARIDIDÆ. The Sea-Snails.

146. Liparis liparis (Linnæus). *Sea-snail; Sucker.*

GEOG. DIST.: North Atlantic on both shores, north to Spitzbergen, south to Connecticut and France. Most abundant in North Europe.

SEASON IN R. I.: In the U. S. National Museum is a specimen taken by the U. S. Fish Commission at Watch Hill Reef, August, 1874. Small specimen taken in September, 1874, off Block Island, from the shell of a large species of scallop, *Pecten tenuicostatus.* (Goode, Nat. Hist. of Aquatic Animals, 234.) Common in winter on rocky bottoms. (Smith.)

HABITAT: Parasitic, living within the shells of large scallops, in company with a small crab.

REPRODUCTION: Found full of spawn in December and January. (Smith.)

TRIGLIDÆ. The Gurnards.

147. Prionotus carolinus (Linnæus). *Common Gurnard; Sea-robin.*

Geog. Dist.: Cape Cod to South Carolina. But in 1896, between July 4 and 14, over 25 specimens were taken in Casco Bay, Maine.

Season in R. I.: Appears in May, and is common until October. Two specimens from Newport in the U. S. National Museum.

Reproduction: Spawns in June.

Food: Fishes, one specimen had four winter flounders in the stomach. Also young clams, squids, molluscs, shrimp, annelids.

148. Prionotus strigatus (Cuvier & Valenciennes). *Sea-robin; Red Sculpin.*

Geog. Dist.: Atlantic coast, Cape Cod to Virginia.

Season in R. I.: Common in shallow water in summer.

Reproduction: Spawns in summer. (Smith.)

CEPHALACANTHIDÆ. The Flying Gurnard.

149. Cephalacanthus volitans (Linnæus). *Flying Robin; Flying Gurnard.*

Geog. Dist.: Atlantic Ocean, on both coasts.

ECHENEIDIDÆ. The Remoras.

150. Echeneis naucrates (Linnæus). *Shark Sucker; Remora.*

Geog. Dist.: Warm seas, universally distributed, north to Cape Cod and San Francisco.

Season in R. I.: In the warmer part of the summer they are occasionally found swimming around in the traps or attached to almost any fish.

Habitat: Very common in the tropics, attached to turtles or any large fish.

151. Echeneis naucrateoides (Zuieuw). *Sucker.*

Geog. Dist.: The same as the above species.

Season in R. I.: Specimen from Newport in U. S. National Museum. (Proc. U. S. Nat. Mus., 1880, 102.) One taken in a trap in Dutch Island Harbor, Narragansett Bay, October 2, 1905.

152. Rhombochirus osteochir (Cuvier). *Spearfish Remora.*

Geog. Dist.: West Indies north to Cape Cod. Rare.

Habitat: Parasitic on spearfish (*Tetrapturus*).

BATRACHOIDIDÆ. The Toadfishes.

153. Opsanus tau (Linnæus). *Toadfish; Toad-grunter.*

GEOG. DIST.: Cape Cod to Cuba.

SEASON IN R. I.: Common throughout the year in shallow water under stones and eelgrass.

HABITAT: Among rocks and weeds close to the shore.

REPRODUCTION: Spawns in June, the eggs being attached to the under sides of sticks and stones.

FOOD: Young fishes and all kinds of bottom invertebrates.

SIZE: Maximum, 15 inches.

BLENNIIDÆ. The Blennies.

154. Pholis gunnellus (Linnæus). *Butter-fish; Rock Eel.*

GEOG. DIST.: North Atlantic, Labrador to Rhode Island, Norway to France.

SEASON IN R. I.: Occurring rarely in spring.

HABITAT: Rocky shores among algæ, in deep water in winter.

SIZE: Twelve inches.

ANARHICHADIDÆ. The Wolf-Fishes.

155. Anarhichas lupus (Linnæus). *Wolf-fish; Catfish.*

GEOG. DIST.: North Atlantic south to Rhode Island and France.

SEASON IN R. I.: In the U. S. National Museum is a cast of a specimen taken by the U. S. Fish Commission at Coxswain's Lodge, R. I., July 25, 1875. (Bull. U. S. Nat. Mus., 1879, 32.)

SIZE: Three or 4 feet.

ZOARCIDÆ. The Eel-Pouts.

156. Zoarces anguillaris (Peck). *Eel-pout; Sea Eel.*

GEOG. DIST.: Delaware to Labrador.

SEASON IN R. I.: Offshore waters in the autumn.

HABITAT: Deep water.

SIZE. Twenty inches.

157. Lycodes reticulatus (Reinhardt). *Eel-pout.*

GEOG. DIST.: North Atlantic, south to Narragansett Bay.

SEASON IN R. I.: The National Museum contains two specimens taken by the *Fish Hawk* in Narragansett Bay in 17 fathoms, September, 1880. (Goode and Bean, Oceanic Ichthyology, 1896, 305.)

HABITAT: Deep water, 17 to 140 fathoms.

SIZE: Fourteen inches.

MERLUCCIIDÆ. The Hakes.

158. Merluccius bilinearis (Mitchill). *Silver Hake; Whiting; Frost-fish.*

GEOG. DIST.: Coast of New England, northward to Straits of Belle Isle; south in deep water to the Bahamas.

SEASON IN R. I.: A few taken in May in offshore waters. Common in Narragansett Bay in October.

REPRODUCTION: In September and October, 1880, while exploring the ocean bottom off Newport and at the edge of the Gulf Stream, immense numbers of the young of this species, from ½ inch to 3 inches in length, were taken on the bottom, in water 150 to 487 fathoms deep; with them were taken many adults, 12 to 18 inches in length, apparently in the act of spawning, some with ripe or nearly ripe ova, others which were evidently spent fish. The largest of these young must have been hatched from eggs shed in July. Thus the spawning season must be somewhat extended, lasting well into the fall. In September an adult taken at Halifax, N. S., was full of nearly ripe spawn. (Goode, Nat. Hist. of Aquatic Animals 242.)

FOOD: This species is a fish of prey, coming to the surface to capture herring and other small fishes. Also feeds upon crabs and small crustacea.

GADIDÆ. The Cods.

159. Pollachius virens (Linnæus). *Pollock.*

GEOG. DIST.: North Atlantic, south on both coasts to New Jersey and France.

MIGRATIONS: Like the cod, appearing in New England shore waters in cool weather, leaving when temperature reaches 60° or 65°F. Reach Nantucket early in April.

Season in R. I.: Not common in Narragansett Bay. A large run arrives in offshore waters in the middle of May, probably leaving in June. Comes in again in September and October and are present through the winter. A small specimen, 14 inches long, taken September 11, 1905, Dutch Island Harbor, Narragansett Bay. On May 15, 1905, and during the few following days a large run of pollock took place all along the shore from Brenton's Reef to Sakonnet. This was the largest run for years, and made havoc among the scup schools.

Reproduction: Like the cod, spawning takes place in winter in the open water. The eggs are buoyant, but smaller than those of the cod.

Habitat: Like the cod; a bottom and deep-water fish. But it is more often seen on the surface than the cod, congregating in large schools which roam from place to place preying on fishes of all sorts.

Food: Fishes of all kinds; scup, young codfish.

Size: Ten or 12 pounds. Schools of young at Woods Hole in April, 1 to 1½ inches long; these are 4 inches long in June. In September there is a run of pollock 7 or 8 inches long.

160. Microgadus tomcod (Walbaum). *Tomcod; Frostfish.*

Geog. Dist.: Virginia to Labrador.

Season in R. I.: Present along the coast the year round; common in streams and near shores in winter.

Reproduction: Spawns in shore waters in December.

Food: Annelids, shrimp, amphipods, and other small crustacea.

Size: Rarely over 12 inches.

161. Gadus callarias (Linnæus). *Cod.*

Geog. Dist.: North Atlantic, south to Virginia and France.

Migrations: Prefers a temperature of 35° to 42°F., therefore it remains on the offshore banks during summer along the New England coast, keeping out in the cold Labrador current, which extends south inside the Gulf Stream, coming into more shallow water in the winter.

Season in R. I.: Appears in October; height of season November 1; present all winter. A spring run takes place in April.

Reproduction: The extreme length of the spawning period is from September to May. The spawning of each fish probably continues through a period of two months. The eggs are buoyant.

FOOD: Feeds on all marine animals smaller than itself. Many specimens of lobsters have been found in the stomach of cods; a 5-inch lobster was found in the stomach of a cod taken off Nantucket November 1, 1900. The very young feed exclusively on copepods.

SIZE: At Woods Hole young, ½ to 1 inch in length, are seined in March. These leave about June 15, 3 or 4 inches in length.

162. Melanogrammus æglifinus (Linnæus). *Haddock.*

GEOG. DIST.: North Atlantic, south to France and North Carolina; in deep water to Cape Hatteras.

REPRODUCTION: Spawning season in April, May, and June.

FOOD: Like that of the cod, but more largely of invertebrates. (Goode.)

163. Urophycis regius (Walbaum). *King Hake; Codling.*

GEOG. DIST.: Nova Scotia to Cape Hatteras, but nowhere common except in the neighborhood of Long Island.

SEASON IN R. I.: From September to November; not common. Rare in Narragansett Bay. Specimens taken in 155 fathoms of water off Newport by the *Fish Hawk*, September, 1880.

HABITAT: Deep water.

SIZE: Average about 10 inches.

164. Urophycis tenuis (Mitchill). *White Hake; Hake; Squirrel Hake.*

GEOG. DIST.: Banks of Newfoundland to Cape Hatteras, abundant northward in deep water, reaching a depth of 304 fathoms.

SEASON IN R. I.: April to November; not so common as the Red Hake (*Urophycis chuss*).

REPRODUCTION: Probably spawns in spring and early summer. Young specimens found in the shells of *Pecten tenuicostatus*, off Watch Hill, September, 1874. (Goode.)

FOOD: Bottom feeding; fishes and crustacea.

SIZE: One to 2 pounds.

165. Urophycis chuss (Walbaum). *Hake; Red Hake.*

GEOG. DIST.: Atlantic coast, Gulf of St. Lawrence to Virginia.

Common northward, reaching a depth of 300 fathoms.

SEASON IN R. I.: Comes in about May 1 and is very common through May and June, but absent through the summer. Comes in again about October 1 and is abundant until December.

HABITAT: Bottom fish.

REPRODUCTION: They are said by the fishermen to be full of spawn when they first arrive, breeding season lasting through June and July.

FOOD: Crustacea and small fry.

SIZE: Two to 5 pounds.

166. Brosme brosme (Müller). *Cusk; Ling.*

GEOG. DIST.: North Atlantic, south to Long Island and Denmark, north to Iceland and Spitzbergen. Rare south of Cape Cod.

SEASON IN R. I.: Specimen taken off Newport November, 1898.

HABITAT: Deep water, inhabiting rocky ledges.

REPRODUCTION: Said to spawn during April and May.

PLEURONECTIDÆ. The Flounders.

167. Hippoglossus hippoglossus (Linnæus). *Halibut.*

GEOG. DIST.: In all northern seas. In water of moderate depth in North Atlantic, North Pacific and Behring Sea; south in deep water to France, Sandy Hook, and San Francisco.

SEASON IN R. I.: In February, 1876, a few were taken about eight miles from the southeast point of Block Island. On May 1, 1876, off Watch Hill an 80-pound halibut was taken, the first in that vicinity for many years. On April 16, 1900, a 100-pound halibut was brought to Newport; it was taken with others off Block Island by a cod fisherman. It was formerly quite common around Block Island and Vineyard Sound.

HABITAT: Cod banks of northern seas in water 32° to 45° F., from shoal water down to 250 fathoms or more.

REPRODUCTION: Spawning season probably lasts from the latter part of the summer through the fall. (Goode.)

FOOD: Molluscs and crustacea, and fishes of all sorts.

SIZE: Up to 400 pounds.

168. Hippoglossoides platessoides (Fabricius). *Sand-dab; Rough-dab; Rusty Flounder.*

GEOG. DIST.: North Atlantic, common in deep water south to southern New England and the coast of England and Scandinavia.

SEASON IN R. I.: Not unusual in deep water off southern Massachusetts and Rhode Island, approaching the coast in winter. (Proc. U. S. Nat. Mus., 1880, 471.)

169. Paralichthys dentatus (Linnæus). *Summer Flounder; Flounder; Fluke.*

GEOG. DIST.: Atlantic coast, Cape Cod to Florida.

MIGRATIONS: They are found northward in 2 to 20 fathoms; in winter they move out into deeper water.

SEASON IN R. I.: May to the end of October. More abundant in summer than the winter flounder.

HABITAT: Sandy bottoms.

FOOD: Small fishes, especially butter-fish and scup, crsutacea, molluscs, squid, sand dollars.

170. Paralichthys oblongus (Mitchill). *Four-spotted Flounder; Flounder.*

GEOG. DIST.: Coasts of New England and New York, inhabiting deeper water than the other species of this genus. Common on the coast of Cape Cod, rare in other places.

SEASON IN R. I.: Common in May and June in the outside waters. Not common in Narragansett Bay. Specimens were taken off the Rhode Island coast by the *Fish Hawk*, in September, 1880, at a depth of 100 fathoms.

REPRODUCTION: Spawns in May. The eggs are buoyant, 1-26 inch in diameter and hatch in 8 days in water of 51° to 56°F.

FOOD: Crustacea, annelids, molluscs, small fishes.

SIZE: Twelve inches.

171. Limanda ferruginea (Storer). *Rusty Flatfish.*

GEOG. DIST.: Atlantic coast, Labrador to New York.

SEASON IN R. I.: Common through the year in deep water.

FOOD: Crustacea, molluscs, annelids, small fishes.

172. Pseudopleuronectes americanus (Walbaum). *Flatfish; Winter Flounder.*

GEOG. DIST.: Atlantic coast, Labrador to Chesapeake Bay.

MIGRATIONS: Moves very little with change of season, but goes out into somewhat deeper water during the hot summer months.

SEASON IN R. I.: Present the year round. More abundant in late winter and spring while spawning, and in October. A few are taken in traps in the summer, but it is not so common at that time as the summer flounder (*Paralichthys dentatus*). A specimen 5 inches long was seined at Willow Beach near Wickford, July 17, 1905. A dark bellied variety appeared in Greenwich Bay in 1897; apparently these have since disappeared. (Bulletin U. S. Fish Commission, 19, 1899, 305.)

HABITAT: Grassy and muddy bottoms.

REPRODUCTION: Spawns from February to April. The eggs are 1-30 of an inch in diameter and very glutinous. The average number of eggs in a single individual is 500,000. The eggs hatch in 17 or 18 days in water 37° or 38°F. (Smith.)

FOOD: Small fishes, shrimp and other small crustacea, molluscs, annelids.

173. Lophosettal maculata (Mitchill). *Window-pane; Sand-dab.*

GEOG. DIST.: Atlantic coast of United States, Casco Bay to South Carolina.

SEASON IN m. I.: Very common from April to October.

REPRODUCTION: Spawns about June 1. The eggs are buoyant, non-adhesive, 1-24 of an inch in diameter; they hatch in 8 days in water 51° to 56° F.

FOOD: Fishes and crustacea.

SIZE: Ten to 12 inches in length. Specimen 3 inches long, taken at Willow Beach, Wickford, July 17, 1905.

SOLEIDÆ. The Soles.

174. Achirus fasciatus (Lacépède). *Sole; Hog-choker; Black Flatfish.*

GEOG. DIST.: Coasts of the Atlantic and the Gulf of Mexico north to Cape Ann. Common south of Susquehanna River.

SEASON IN R. I.: Not very common in Narragansett Bay. Specimens from Providence and from Newport are in the U. S. National Museum. Specimen taken August 14, 1905, in a trap in the West Passage.

FOOD: Eight specimens examined by Dr. Linton in 1899 had only vegetable debris (*Fucus* and eel-grass) in the alimentary canal.

LOPHIIDÆ. The Fishing-Frogs.

175. Lophius piscatorius (Linnæus). *Goosefish; Bellows-fish; Angler.*

GEOG. DIST.: North Atlantic, common on both coasts. Ranges southward along the shore to Cape Hatteras; in deep water as far as The Barbadoes in 209 fathoms, and to the Cape of Good Hope. North to Norway and Nova Scotia.

SEASON IN R. I.: Very common from April to July; apparently absent in summer, probably going out into deeper water; common in shallow water again in October. In September, 1880, three specimens were taken in the tilefish area at depths of 120 to 365 fathoms. (Proc. U. S. Nat. Mus., 1880, 461.)

HABITAT: A sluggish, bottom-loving fish. It probably hibernates in deep water in winter. In the winter of 1904–1905 many of this species, about a foot in length, were frequently seen dead in Narragansett Bay and thrown up on the shores. This was probably caused by the excessive cold of that season.

REPRODUCTION: Probably spawns in July and August in deep water. The eggs are buoyant, enclosed in a ribbon-shaped gelatinous mass about a foot wide and 30 or 40 feet long. Young specimens have been found only at considerable depths.

FOOD: Extremely voracious in its feeding habits, swallowing all kinds of fishes, including large numbers of its own species. It has been known to swallow live water fowl, whence its common name. Dr. Linton found specimens whose stomachs contained large quantities of mud full of mollusca, small crustacea, and annelids.

ANTENNARIIDÆ. The Frog-Fishes.

176. Pterophryne histrio (Linnæus). *Marbled Angler; Sargassum Fish.* (Plate VI.)

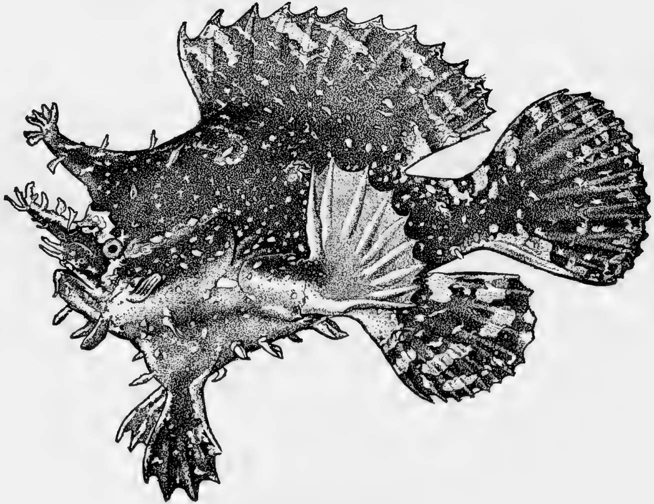
GEOG. DIST.: Tropical parts of the Atlantic, north to Cape Cod in floating masses of gulf weed. A specimen has been taken in Norway from seaweed floating in the Gulf Stream. A number of specimens have been taken at different times at Woods Hole and Nantucket Shoals.

SEASON IN R. I.: Two specimens were taken in 1904 at the mouth of the Sakonnet River, one on September 6, the other about a week later.

HABITAT: Surface of tropical waters, chiefly under floating masses of gulf-weed.

REPRODUCTION: Several specimens in an aquarium at Woods Hole spawned in August. The eggs were in long bands like those of the goosefish.

This is one of the most interesting of our visitors from southern waters. It is usually found swimming under the bits of gulfweed which sometimes



THE MARBLED ANGLER
(*Pterophryne histrio*).

PLATE VI.

drift in from the Gulf Stream in summer and autumn during long east and southeast blows. This fish furnishes an interesting example of protective resemblance. Reference to the illustration given in Plate VI shows the mottling of its body and the numerous filamentous appendages attached to its skin. This gives them such a resemblance to the gulfweed in which they float that they must be very effectively hidden from their enemies. With regard to their habits, Smith (The Fishes of Wood's Hole), speaking of some specimens in an aquarium at Wood's Hole, says: "While clumsy in their movements they were adepts at approaching and capturing other fishes. They are quite cannibalistic and one 6 inches long swallowed another 4 inches long, and they frequently bit off the fleshy dermal appendages of their fellows."

As far as is known the two specimens above referred to are the only members of this species ever taken in Rhode Island waters. Their presence here at that particular time is explained by the following data which has been kindly furnished by Mr. W. L. Day, Observer, Weather Bureau, Block Island. The direction of the wind during the two weeks previous to September 6, 1904, was prevailingly southwest for five days, east for three days, south for three days, northwest for three days. The mean velocity, moreover, for the two weeks under consideration was greater than the average by a difference amounting to about five miles an hour, the normal hourly velocity for August and September being 13 miles, and the average hourly velocity for the two weeks being 18. Remembering the general trend of the Atlantic coast and bearing in mind the fact that Cape Cod is less than 100 miles distant from the western edge of the Gulf Stream, it is easily seen that the drift of the Gulf Stream and the winds of the direction and velocity noted above would unite to form a resultant acting on the floating masses of gulfweed so as to drive them northward and into the huge "pocket" formed by the configuration of the southern New England coast.

OGCOCEPHALIDÆ. The Bat Fishes.

177. Dibranchus atlanticus (Peters).

Geog. Dist.: Deep waters of the Atlantic; very abundant in about 300 fathoms; north in the Gulf Stream to Rhode Island.

Season in R. I.: Very many specimens have been taken in the tile-fish area at depths ranging from 100 to 500 fathoms. A single specimen was captured off Block Island in 1880. (Goode and Bean, Oceanic Ichthyology, 1896, 501.)

APPENDIX.

A PARTIAL LIST OF FISHES OBTAINED IN THE GULF STREAM SOUTH OF RHODE ISLAND.

1. Psenes edwardsii (Eigenmann).

A single specimen, 90 mm. in length, was taken for the first time about July 28, 1900, by the schooner *Grampus* from under a Medusa 30 miles south of Newport. (Bull. U. S. Fish Commission, 21, 1901, 35.)

2. Lopholatilus chamæleonticeps (Goode & Bean). *Tilefish.*

GEOG. DIST.: Deep water of western Atlantic. Taken in water not less than 55 fathoms in depth directly to the south of Rhode Island, in the area between 69° and 73° W. longitude and 40° 20′ to 39° 47′ N. latitude. (Bull. U. S. Fish Commission, 1898, 321.)

FOOD: Preëminently a crab eater; there have also been found, in the stomach of many specimens, squids, molluscs, holothurians, spiny dogfish, eels, and fish bones.

The following fishes were dredged off the southern coast of New England, by the U. S. Fish Commission steamer *Fish Hawk*, September 1, 1899, 40° N. latitude, 70° W. longitude. (Bull. U. S. Fish Commission, 19, 1899, 240.) Those marked with a * have already been mentioned in the list of Rhode Island fishes given above. It is interesting to note their occurrence in the Gulf Stream, as it in part explains their occasional presence in Rhode Island waters nearer shore.

3. Seriola fasciata (Bloch). Range, West Indies to Charleston, S. C. One specimen.

4. *Trachurops crumenophthalmus (Bloch). Range, Atlantic coast of United States. Two specimens.

5. *Caranx crysos (Mitchill). *Hard-tail.* Range, Cape Cod to Brazil. One specimen.

6. **Glossamia pandionis** (Goode & Bean). Range, deep water off Chesapeake Bay. One specimen.

7. ***Abudefduf saxatilis**(Linnæus). Range, both coasts of tropical America. One specimen.

8. **Balistes vetula** (Linnæus). *Trigger-fish.* Range, tropical parts of the Atlantic, Gulf Stream to Woods Hole. One specimen.

9. ***Monacanthus hispidus** (Linnæus). *File-fish.* Range, Cape Cod to Brazil. Several specimens.

10. **Lycenchelys verrilli** (Goode & Bean). Range, coast of Massachusetts and northward. One specimen.

11. ***Merluccius bilinearis** (Mitchill). *Whiting or Silver Hake.* Range, coast of New England and northward. Two specimens.

12. ***Helicolenus maderensis** (Goode & Bean). Range, deep waters of Atlantic coast from New York to Florida. One specimen.

13. **Raja eglanteria** (Bosc). *Skate.* Range, Cape Cod, southward to Florida. One specimen.

14. ***Dibranchus atlanticus** (Peters). Range, Gulf Stream. Several specimens.

Note : The following should be added to the List of Rhode Island Fishes:

178. **Lucius reticulatus** (Le Seur). *Pickerel; Green Pike.*
179. **Pygosteus pungitius** (Linnæus). *Nine-spined Stickleback.*
180. **Sphyræna borealis** (De Kay). *Northern Barracuda.*
181. **Micropterus salmoides** (Lacépède). *Large-Mouthed Black Bass.*
182. **Perca flavesceus** (Mitchill). *Yellow Perch.*

INDEX

OF THE COMMON AND SCIENTIFIC NAMES OF ALL FISHES IN THE PRECEDING LISTS.

P.

R.

S.

THE COMMON FISHES OF THE HERRING FAMILY.

PLATES VII TO XII.

HENRY C. TRACY, A. M.

BROWN UNIVERSITY, PROVIDENCE, R. I.

The fishes of the herring family common in Rhode Island waters are the herring, the hickory shad, the alewife, the glut herring, the shad, and the menhaden. The shad (Plate XI) and the menhaden (Plate XII) are so well known as to require no description, but I have found by conversations with fishermen and others that considerable uncertainty exists as to the identity of some of the other more closely related species. The reason why the herring is not better known is doubtless due to the fact that its numbers in Rhode Island waters are so small that its capture is of little importance. The alewives are generally properly distinguished, but the fact that there are two distinct species of them does not seem to be generally known. This is due, probably, to the fact that the two species are so very much alike that special care is necessary to separate them; and as the market is good for both under the name "alewife," there is no necessity for distinguishing them. The following description of these species is given in order to make clear the differences between them.

The true herring (Plate VII), sometimes called the sea herring or English herring, is probably the most important of all food fishes. It ranges along the North Atlantic coasts of both Europe and America in immense schools covering many square miles, and from which are captured every year thousands of millions of fishes. Its southward limit of range on the American coast is Cape Hatteras, though its numbers south of Cape Cod are so far diminished as to make its capture in these waters of little importance. At Eastport, Me., the young are canned in oil and sold under the name of "sardines." The true sardines, however, come only from France and are the young of the "pilchard," another member of the herring family which does not occur on our coast.

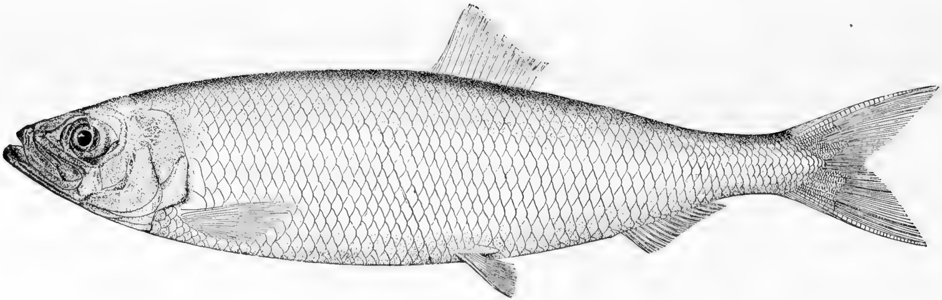
The true herring never spawns in rivers, but in shoal water in certain localities along the Atlantic coast from Newfoundland to Block Island, when the water reaches temperatures between 47° and 57°F. Some schools spawn in the spring, others in the fall; but the spring schools spawn almost exclusively to the east of the Bay of Fundy, and the fall schools entirely to the west of that place.

It is readily distinguished from the other members of the herring family by the following points: Its body is long and slender, and compressed; it has teeth on the roof of the mouth and *no sharp saw-tooth-like edge on the ridge of the belly;* the distance from the pectoral fins to the ventral fins is greater than the distance from the ventral fins to the anal fin.

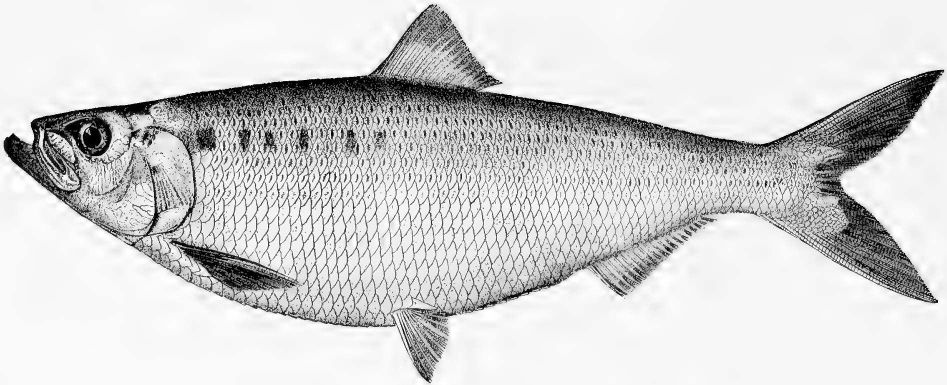
The other three species of the herring family under consideration, namely, the hickory shad (Plate VIII), the alewife (Plate IX), and the glut herring (Plate X), differ from the true herring and agree with each other with regard to the following points: Their bodies are not elongated, but are somewhat oval in shape; they have no teeth on the roof of the mouth; *they have a very sharp saw-tooth edge on the ridge of the belly;* and the distance between the pectoral fins and ventral fins is about equal or less than the distance between the ventral fins and the anal fin. This difference in distance between the fins will be easily seen by reference to the plates.

The hickory shad (Plate VIII) is distinguished from the alewife and the glut herring as follows: The form of its body is nearly oval and less heavy forward than is the case with the two other species; its head is longer and more slender; its lower jaw is also more projecting. *There is a row of large dark spots on the upper forward part of the* *body*, as will be seen by reference to the illustration. The alewife and glut herring both have short thick heads, and their bodies are heavier forward. They are very similar to each other, and can best be distinguished by cutting open the body cavity; the lining membrane in case of the alewife is *pale or gray in color*, while it is *black* in the case of the glut herring. The fins are lower, also, in the glut herring, *the eyes are smaller*, and the body more elongated.

Other names for the alewife (Plate IX) are the "river herring," the "buckie," and the "branch herring." Both the alewife and the glut herring run up the rivers in the spring to spawn like the shad. The herring never does so, and the hickory shad probably does not. The glut herring appears two or three weeks later than the alewife, coming in great numbers all at once. This fact, because of its "glutting" the markets, probably is the reason of its name. Its run does not last as long as that of the alewife. It is supposed not to go as far up the river, probably spawning not far above tide water.

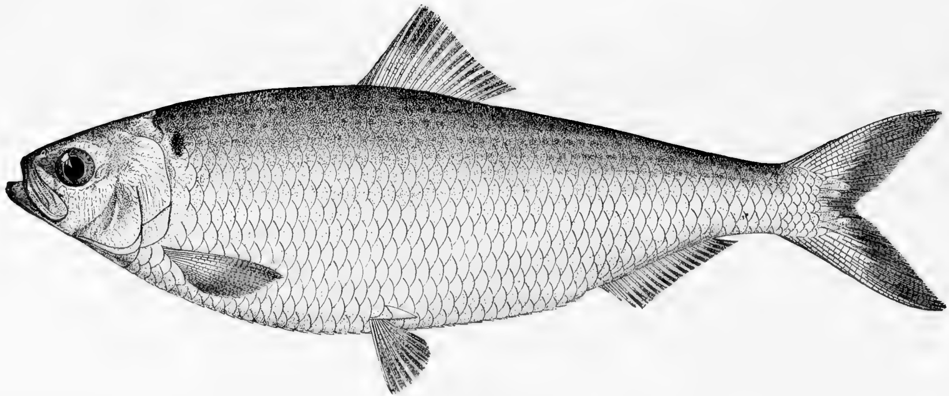


The Herring
(Clupea harengus).
Plate VII.



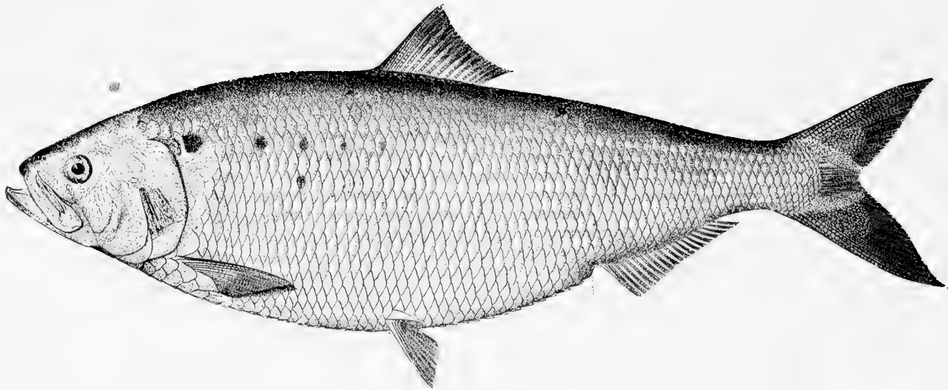
THE HICKORY SHAD
(Pomolobus mediocris).

PLATE VIII.

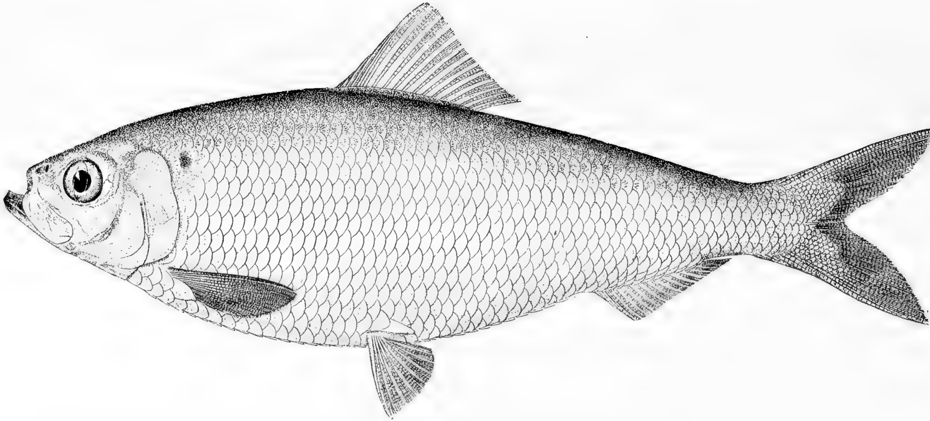


The Alewife
(Pomolobus pseudoharengus).

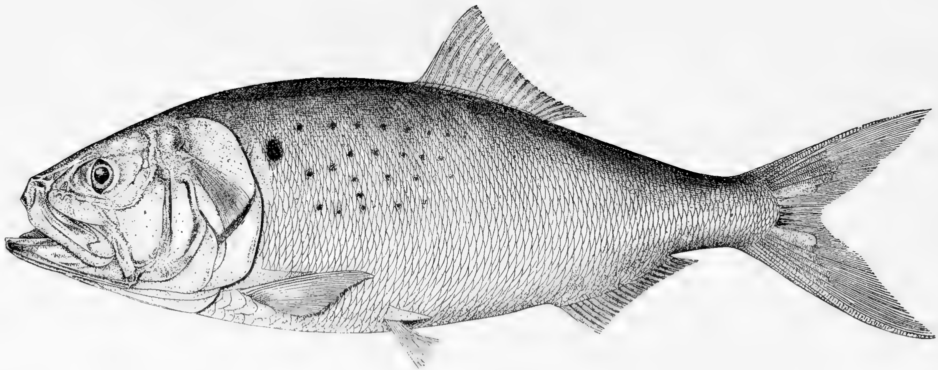
Plate IX.



THE GLUT HERRING
(*Pomolobus æstivalis*)
PLATE X.



THE SHAD
(Alosa sapidissima)
PLATE XI.



The Menhaden
(*Brevoortia tyrannus*).
Plate XII.

V. A Continuance of the Survey of the Shores of the Bay, for the Purpose of Determining those Portions Which are Most Productive of Seed Clams, Those Most Favorable for the Planting of Clams and for the Distribution of Lobster Fry.

Considerable progress was made during the past year in collecting data regarding the character of the shores of Narragansett Bay. A systematic survey was begun, charts of selected portions of the shore-line were made, on which were indicated all data regarding the character of the shore and facts regarding the presence of animal and plant life. Records of the water temperature and density were made in each section, and offshore dredgings and the collection of tow were systematically carried out. These charts were put on file and will be worked into a permanent chart of the whole Bay. The notes made and the specimens collected will be worked up as time allows, and will form the basis of a complete biological survey of the waters of the Bay, parts of which are already appearing in the previous section of this report.

It will require considerable time to cover in such a thorough manner the extensive and varied shore-line of Narragansett Bay, especially when we consider the limited amount of time which can be spared from the other routine work for this purpose. The value of the work, however, is evident. Already there have been many species of animals found which were not known to occur in Rhode Island waters. The data regarding the distribution of the clam and the clam set, which were collected at the same time, are alone worth the trouble and expense of the undertaking.

The following shores were thoroughly investigated this summer:

Mill Cove (including shores of Cornelius and Rabbit Islands).
Fishing Cove.
The shore from Sauga Point to Quonset Point.

Quonset Point north to Allen's Harbor.
Rocky Point to Conimicut Point.
Conimicut Point to Pawtuxet (including Greene's Island).
Bullock's Point to Nayatt Point.
Prudence Island.
Patience Island.
Kickemuit River.
East shore Sakonnet River south to Sapowet Point.
Upper west shore of Conanicut Island.

Places dredged in addition to above:

Wickford Harbor.
Poplar Point, Cold Spring Beach.
Off Vial's Creek.
Plum Beach Shoal.
Dutch Island Harbor.

VI. The Continued Investigation of the Life History of the Clam. Methods of Artifical Propagation and Cultivation.

During the season of 1905 little was attempted in the artificial propagation of the soft-shell clam, owing to the remarkable abundance of the natural supply. The number of clams on the shores of the Bay has not been so great for many years. Whereas in past years the distribution of the clams has been uneven, some localities being thickly set while others close by were practically barren, this year the entire shores of the Bay are covered with clams. Places which were good clam territory in the memory of the oldest inhabitant, but which for many years have been barren, have taken part in this general revival. Owing to the great abundance of clams everywhere, the size attained was not very great. The clams were so crowded together that they could not attain full size. This fact necessitated, in spite of the great abundance of clams on our own shores, the shipment of clams from other States to supply the great demands of our shore resorts.

These abundant native clams are mostly from the set of 1904, which, as described in the report for that year, were so abundant that in one locality 4,264 were found in an area of one square foot. This year the search for new set was thoroughly conducted, but, as will be seen in the table at the end of this section, with practically no result. Clam set was unusually scarce this year.

Owing to the great abundance of clams it was a common sight to see a number of diggers come week after week to the same piece of shore and carry away anywhere from two bushels to a barrel each. The result of this continual digging over of the shores in one spot was forced upon our attention continually, and brings up the question of the effect of digging on the size and number of clams.

It is the common opinion of the clammers that digging over the clams stimulates growth. The idea which they seem to have is that the loosening of the earth about the clams is as good for them as it is for a hill of corn or potatoes. The fallacy in this argument is in the supposition that the clam draws its nourishment from the soil in which it grows, as is the case with the corn or potatoes. As a matter of fact the food of the clams is the microscopic life in the water, and can be secured only when the clam bed is covered with water.

In reality the effect of digging over the clams is many-sided. To illustrate, by two examples: On Cornelius Island, in Wickford Harbor, the clams set extremely thick in 1904. A portion of the shore was set aside by the Commission for purposes of experiment, and was not dug over at all. Alongside this protected area the shore has been visited almost daily by the clammers. In the protected area the clams were so thick at the time of setting that there was not room for the growth of all of them, and so, as they increased in size, many were forced out upon the surface, so that in a short while the ground was thick with shells. The ice carried off many of the small clams in winter, and the gulls and black ducks destroyed many more; but still they were so abundant that there was no opportunity for growth, and their size has increased but little, averaging now but a little over an inch.

In the area alongside, where the clammers have been digging almost daily, the clams are two or three inches in length, and many barrels have been taken out of this rather limited area. The soil is similar in the two localities, the currents of water striking the two about equal in strength; the only difference has been that in one the soil has been dug over continually, in the other not at all. In this case certainly the advantage is with the well-dug-over area. And yet, on the other hand, the new set of the present year is found among the thickly populated area of the protected portion, and hardly at all in the portion disturbed by digging. In the latter locality the young clams were unable to set because the upper layers were made so loose and shifting by the continual digging, or if they did set, they were immediately covered over so deeply by the diggers that they were destroyed.

Another case in point was observed at Greene's Island. On the east shore of this island is a long flat which in 1901 was set so thickly with clams that 7,910 were counted in a single shovelful. In 1902 and 1903 the clams from this set were abundant, and the shore was dug over continually by clammers. In 1904 the clam set was good on this area, though less abundant. In 1905, however, there were a few large clams, but not a single clam from the set of 1904, which was so abundant, as noted above, on every other shore in the Bay. The cause of this is not difficult to see. The constant digging had not only buried the young clams so deeply that they were destroyed, but had left the upper layers of soil loose and shifting, and no clams can set under these conditions. In this case, then, the constant digging has practically exterminated the clams.

So we must be careful about concluding as to the results of digging over a clam bed. It will be recalled that almost every shore has a good set occasionally, and then for a few years there seems to be no new set. When the clams become quite scarce again, and digging ceases for a while, the set appears again.

Summing up, then, the apparent conditions caused by digging over the clams, we find that continual digging may be beneficial to a clam bed by thinning out a too thickly set area and thus promoting more rapid growth in those that are left; but that, on the contrary, continual digging is prejudicial to a new set of clams. A sort of rotation of areas, then, would seem to provide the ideal condition, allowing certain undisturbed shores to start a good set, while others are being dug over; and then, by changing the areas, provide for a new set on the exhausted territory. That the conditions maintained above seem to hold throughout the Bay is shown by the facts brought out in the table below:

CONDITION OF CLAM GROUNDS VISITED IN AUGUST AND SEPTEMBER, 1905.

LOCALITY.	The Abundance of Clam Set in		The Size and Adundance of the Set of 1904, as Observed in 1905.	
	1904.	1905.	Size.	Abundance.
Academy Cove, Wickford	Extremely thick	Scant	Small	Thick.
Bullock's Point	Very good	None	Undersized	Thick.
Buttonwood's Shore	Poor			
Conanicut, west shore	Good	Few	Undersized	Good.
Cold Spring Beach	Fair	Few	Fair	Good.
Cornelius Is. (S.W. Pt.)	Extremely thick	Few	Very small	Extremely thick.
Cornelius Is. (elsewhere)	Thick	None	Fair	Good.
Duck Cove	Good	Few	Fair	Good.
Fishing Cove	Good	Scattering	Fair	Good.
Greene's Is. (east shore)	None	None		None.
Kickemuit (west bend)	Very good	Scattering	Undersized	Very good.
Kickemuit (elsewhere)	Meagre	Scattering	Good	Fair.
Little Tree Pt. to Scragg Rock	Occasionally good	Few	Fair	Occasionally good.
Mill Cove, south shore, Wickford	Very good	Few	Fair	Good.
Mill Cove, west shore, Wickford	Fair	Scattering	Good	Fair.
Mill Cove, north shore, Wickford	Good	Few	Fair	Good.
Poplar Point	Good	Few	Good	Good.
Prudence Is. (east shore)		None	Undersized	Good.
Prudence Is. (west shore)	Good	None	Undersized	Good.
Patience Is. (east shore)		Few	Undersized	Good.
Pawtuxet	Good			
Quonset Pt. to Greenwich Bay	Good	None	Small	Good.
Rumstick Pt. (west)	Poor			
Sakonnet River (upper east shore)		Few	Fair	Good.
Sauga Point	Good	Few	Good.	Good.
Sheep Pen Cove	Good	Few	Rather small	Good.
Vial's Creek	Good			
Village Cove, Wickford	Good			

Your Commission is continually called upon to give information and instruction as to the methods worked out by them of successfully propagating clams on a commercial scale. Although, owing to the peculiar conditions regarding shore rights, it is impossible for individuals in this State to secure land for this purpose, yet in other States this is possible, and several such attempts are at present in progress. These will be reported on more fully at some later time.

VII. The Efforts to Prevent the Illegal Taking of Short Lobsters.

Two deputies are still employed by your Commission to enforce the lobster laws. Even though it is impossible to detect and punish every offender, yet the results obtained entirely justify the efforts in this direction. Undoubtedly the influence of this line of endeavor has resulted in saving great numbers of short lobsters and egg lobsters. Out of the large number of lobsters received from Nova Scotia during the year, 5,170 short lobsters were seized and liberated in Rhode Island waters.

The following table indicates the prosecutions and fines made under the Lobster Law in 1904 and 1905.

Date.	Name.	Location.	Shorts.	Eggs.	Unmarked cars.	Case.	Amount.
Total. 1904....	....	....	.. 66	9	....	Settled.....	$175
1905. May 23...	G. Franks......	Narragansett Pier.......	9	.....	Unmarked cars..	Settled....	$65
May 23...	R. G. Burdick..	Narragansett Pier.......	......	.....	Unmarked cars..	Settled....	20
July 7....	....	....	75	.....	....	Not settled.	375
July 16...	J. Parris.......	Jamestown ..	18	.....	....	Settled....	90
Total. 1905....	....	....	102*	.....	....	....	$550*

*One case involving 75 short lobsters and a fine of $375 is not yet settled.

VIII. The Propagation of Lobster Fry for the Purpose of Increasing the Supply of Lobsters in the Waters of the State. Methods of Artificial Propagation and Cultivation.

LOBSTER CULTURE IN 1905.

BY EARNEST W. BARNES,

ASSISTANT SUPERINTENDENT OF THE WICKFORD EXPERIMENT STATION.

The first mature lobster eggs were scraped into a hatching bag about noon on the 21st of May, and by 1 P. M. of the same day nearly all had hatched. These eggs were obtained from one egg lobster, and no more lobsters with mature eggs were found till the 24th. The hatching then proceeded quite rapidly. The last lot of eggs was hatched on the 21st of July. By August 1st all the fry had reached the fourth stage, except a few weak undersized ones. Consequently, after a continuous run of 71 days, the engine was shut down and the season closed. The work usually closes by the middle or last of July, and it is quite remarkable that the season should last till the first of August.

The weather conditions throughout the season were very good. The absence of any bad storms and the many bright warm days made the season one of the best the station has had.

Among the improvements which were installed this year are the following:

WINDOW IMPROVEMENTS.

Instead of covering the windows with scrim, a copper wire netting of twenty meshes to the inch was used. To prevent its becoming broken by the frequent bending which is apt to occur in the handling of the bag, it was mounted in a wooden frame, and this was fastened to the edge of the canvas about the window. The screening was a decided improvement over the scrim windows used in 1904, as it allowed better circulation and was not so overgrown with diatoms. It is probable that the fry obtained much of their fuzzy growths from the overgrown scrim windows.

ADJUSTMENT OF THE REARING BAGS.

Improvements were further made in the handling of the canvas bags. The vertical gas pipes which kept the bags down in the water in previous years were discarded, and a haul-down post of 4 x 4 hard pine was bolted into the corners of each pool. A hole was gouged out in the lower end and a rope run through and spliced so as to leave a free end. This end was fastened to the corner of the outer square bottom-frame, which was of gas pipe as before. The top of the bag was held up by ropes passed through the corners and the middle of the sides. The bottom was pulled down by the haul-down ropes. This method proved very satisfactory.

A small float for washing the bags was made, which was very convenient and useful. (Plates XIX, XX, XXI.)

PLUGGING THE LOBSTERS.

Various methods were tried for preventing the egg lobsters, when placed in cars, from fighting. Plugging, as commonly employed by the fishermen, was found to be the best method, and the injury caused the lobster was of no importance. The plugs were removed when the lobsters were liberated.

BREAKWATER.

The idea of using deep lobster cars for a breakwater to the hatching bags was tried and proved very successful. Most all waves and swells were effectually broken by them.

HATCHING CRATES.

Very few eggs were scraped from the lobsters this year. The hatching of the eggs while still on the mother can not be improved upon by artificial means; therefore it was found more satisfactory to confine the lobsters whose eggs were ready to hatch in flat crates, three feet square and four inches deep, made of lathes about one inch apart (Plate XXII). These were then placed in the rearing bags and removed as soon as a sufficient number of fry was obtained in the bag. The injury caused to the fry from being thrown by the current against the crates was prevented by allowing the crates to float with the current. They were, however, loosely fastened around the paddle shaft so as to prevent them from knocking against the sides of the bags. The hatching crates were used for two different purposes. First to prevent the loss from eggs collecting in a mass at the bottom and spoiling; second, to keep the age of the fry in a bag within a certain limit, depending on the length of time the crates are kept in the bag.

REGULATION OF THE CURRENT.

The use of the copper screening for the windows necessitated a different adjustment of the angle of the paddle in order to produce a proper current. A current just sufficient to keep the food and the lobsters suspended in the water was found to be best. It was further observed that the proper adjustment of the paddle, and consequently the current, kept the fry reasonably free from growths of diatoms, fungi, etc., prevented the windows from becoming clogged with food particles and lobster casts, and improved the condition of the bag in general.

SHADING THE BAGS.

Shading the rearing bags was also tried, but as yet no positive results have been reached. The records show a slight lengthening of the third stage in the lots shaded. This may not be caused, however, by the shading.

SUMMARY OF RESULTS.

To briefly summarize the results, it may be said that as many fourth stage lobsters were reared during the summer of 1905 as in all the previous years combined. Over 103,000 lobsterlings were counted out of the rearing bags. The estimation which is usually made, that one fourth stage lobster is equivalent to 1,000 in the first stage, would make the results of the season's work equal to turning over of 103 million newly hatched fry.

The percentage from individually counted lots carried through from the first to the fourth stage surpassed that of all other years for similar numbers. In 1901, 50 per cent. was obtained from a counted lot of 1,000 fry, all of which were at least two days old. This season 48.2 per cent. was obtained from 20,000 which were counted out just after they had hatched. A number of lots gave a percentage of over 40. These results were obtained in spite of the fact that a great deal of attention was turned from the regular work of rearing to various lines of experiment.

LIBERATION OF TAGGED LOBSTERS.

The total number of tagged lobsters (Plate XXV) liberated in 1905 was 385. Sixty-two of these were caught and the tags returned. Page 115 contains a table giving the data in regard to them. It is a rather significant fact that 13 of these were caught in the first seven days of freedom. One was caught within 24 hours, after having travelled a distance of four miles. Another lobster, liberated at the same time, travelled 11 miles in five days. It is further to be noted, because of its bearing on the question as to how soon the lobsters molt after their eggs hatch, that one tagged lobster was captured after having been free for 59 days. The egg lobsters retained in the cars at the Station do not, as a rule, begin to molt earlier than the last of August.

Records of Tagged Lobsters.

Tag Number.	Liberated.		Recaptured.		Number of Days Free.	Distance Travelled.	General Direction.
	Locality.	Date.	Locality.	Date.			
2021	Mill Cove, Wickford..........	June 13	Dutch Island Harbor...	July 1	18	6	S. E.
2023	" " "	" 13	Wickford Light........	June 20	7	1	S. E.
2026	" " "	" 13	Cold Spring Rock......	" 16	3	1½	S. E.
2029	" " "	" 13	Wickford Light........	" 20	7	1	S. E.
2048	" " "	" 13	Little Tree Point.......	" 22	9	2	S. E.
2052	" " "	" 13	Fox Island............	" 22	9	3	S. E.
2071	" " "	" 13	Narragansett Pier......	July 12	29	12	S. E.
2076	" " "	" 13	Two Brothers Rock....	June 24	11	1	E. S. E.
2078	" " "	" 13	Black Rock...........	July 25	12	2½	N. of E.
2079	" " "	" 13	" "	" 21	8	2½	N. of E.
2008	" " "	" 14	Fox Island............	June 20	6	3	S. E.
2020	" " "	" 14	Wickford Light........	" 16	2	1	S. E.
2039	" " "	" 14	Fox Island............	" 19	5	3	S. E.
2041	" " "	" 14	Little Tree Point.......	" 22	8	2	S. E.
2048	" " "	" 14	" " "	" 22	8	2	S. E.
2058	" " "	" 14	" " "	" 22	8	2	S. E.
2002	" " "	" 22	Wickford Light........	" 28	6	1	S. E.
2012	" " "	" 22	Poplar Point..........	July 1	9	1	S. E.
2022	" " "	" 22	Little Tree Point.......	June 28	6	2	S. E.
2176	" " "	" 22	Fox Island............	Aug. 3	42	3	S. E.
2183	" " "	" 22	Whale Rock...........	July 2	10	10½	S. E.
2090	" " "	" 22	Below Dutch Island....	Aug. 20	59	7	S. E.
2098	" " "	" 22	Narragansett Pier......	July 12	20	12	S. E.
2152	" " "	" 22	Poplar Point..........	" 2	10	1	S. E.
2096	" " "	" 22	Below Dutch Island.....	Aug. 20	59	7	S. E.
3068	Mount Hope Bay............	July 13	Bristol Ferry..........	Aug. 12	30	4	S. W.
3093	" " "............	" 13	" "	" 12	30	4	S. W.
3082	" " "............	" 13	" "	" 13	31	4	S. W.
3046	" " "............	" 13	S. W. Prudence Island..	July 20	7	8	S. W.
3043	" " "............	" 13	" " " ..	" 20	7	8	S. W.
3064	" " "............	" 13	Bristol Ferry..........	Aug. 3	20	4	S. W.

RECORDS OF TAGGED LOBSTERS.—Concluded.

Tag Number.	Liberated.		Recaptured.		Number of Days Free.	Distance Travelled.	General Direction.
	Locality.	Date.	Locality.	Date.			
3225	North of North Point.........	" 15	Plum Beach...........	July 16	1	4	S. W.
3199	" " " "	" 15	Below Dutch Island....	Aug. 20	36	6	S. W.
3152	" " " "	" 15	" " "	" 20	36	6	S. W.
3165	" " " "	" 15	" " "	" 20	36	6	S. W.
3157	" " " "	" 15	Rose Island............	July 22	7	6	S. E.
3222	" " " "	" 15	Narragansett Pier......	" 20	5	11	S. W.
3252	North of North Pt., Conanicut	" 15	Gould Island..........	" 27	12	4	S. E.
3239	" " " " "	" 15	" "	Aug. 2	18	4	S. E.
3097	" " " " "	" 15	Rose Island...........	" 3	19	6	S. E.
3111	" " " " "	" 15	Greene's Ledge, Hope Island............	" 1	17	1	N.
3166	" " " " "	" 15	Greene's Ledge, Hope Island............	" 1	17	1	N.
3312	" " " " "	" 26	Rose Island...........	" 3	8	6	S. E.
3236	" " " " "	" 26	Boat House Point......	" 5	10	4	S. E.
3301	Wickford Harbor............	" 26	Dutch Island..........	" 7	12	5½	S. E.
3253	" "	" 26	Plum Beach...........	" 9	14	4½	S. E.
3275	" "	" 26	" "	" 21	26	4½	S. E.
3221	" "	" 26	" "	" 12	17	4½	S. E.
3272	" "	" 26	Wickford Light........	" 17	22	½	S. E.

Number liberated..	385
Number tags returned with date of capture..........................	49
Number tags returned without date...............................	13
Number caught first day after liberation...........................	1
Number caught first week after liberation..........................	13
Greatest number of days free....................................	59
Fastest travel, No. 3225	4 miles in 1 day.

SHORT LOBSTERS.

There was a greater number of small lobsters caught last season than there has been before for a great many years. It is quite significant that this reported increase in number comes almost entirely from that part of the Bay where the Commission has liberated its fourth stage lobsters. Because of its nearness, the region about Conanicut Island has received the greater part of the output in the past years. Walter H. Munroe, who sets lobster pots along the west shore of Conanicut, reports that during the past year he very seldom pulled in his pots but that four or five small lobsters would slip out between the slats. At Dutch Island Harbor, somewhat near the central part of the island, the lobsters under nine inches are so numerous that the lobster deputies have had considerable difficulty in preventing their sale. It is the common opinion that, in spite of their vigilance, barrels of "shorts" have found their way into the market from this place. The two deputies are very much handicapped in their efforts by having such an extensive shore to cover, especially considering that their only means of getting to the pots is in what boats they can get on the nearest shore. The great number of small-sized lobsters looks very promising for the future supply of lobsters in Narragansett Bay, and extremely encouraging for the scheme of rearing used at Wickford.

RECORDS.

A careful record of each lot of lobsters, with conditions under which they were reared, was made and filed in a card catalogue. From this catalogue the following tables are taken:

LENGTH OF LARVAL STAGES IN 1905.*

Experiment Number.	Begun.	Ended.	Temperature.		Number of Days in Different Stages.			Age in Days when Fourth Stage was Reached
			Extremes.	Average.	First Stage.	Second Stage.	Third Stage.	
1	May 21.....	June 13.....	53–56	57.4	12	6	3	21
2	May 24.....	June 13.....	54–56	57.6	9	6	3	19
3	May 24.....	June 19.....	52–70	60.	9	6	4	19
5	May 26.....	June 23.....	52–70.5	61.3	7	7	4	18
8	June 5.....	June 19.....	54–77	63.3	7	4	4	15
9	June 5.....	June 27.....	54–77	64.8	7	5	5	17
10	June 7.....	June 26.....	54–77	65.	7	5	4	16
11	June 9.....	June 26.....	54–77	65.9	6	4	4	14
12	June 10.....	July 1.....	60–77	66.8	6	4	4	14
13	June 12.....	June 29.....	60–77	67.	5	4	4	13
14	June 16.....	July 1.....	62–77	68.	5	3	5	13
15	June 19.....	July 5.....	61–77	68.	4	3	5	12
16	June 21.....	July 7.....	61–77	69.	5	3	5	13
17	June 21.....	July 11.....	61–79	70.	4	4	6	14
18	June 25.....	July 6.....	61–77	69.	5	2	4	11
19	June 28.....	July 10.....	61–79	70.7	5	2	4	11
20	June 29.....	July 12.....	64–79	71.	5	3	5	13
21	June 29.....	July 13.....	64–79	71.2	5	2	4	11
22	June 29.....	July 13.....	64–79	71.4	5	2	4	11
25	July 5.....	July 19.....	66–82	74.4	5	2	5	12
26	July 7.....	July 19.....	69–82	75.	4	2	4	10
27	July 9.....	July 24.....	69–82	74.4	4	3	4	11
28	July 11.....	July 24.....	69–82	75.1	4	2	4	10

The aveage number of days in the first stage was 5 and ranged from 4 to 12.
The average number of days in the second stage was 3 and ranged from 2 to 6.
The average number of days in the third stage was 4 and ranged from 4 to 6.
The average number of days to reach fourth stage was 13.8 and ranged from 10 to 21.

*It must be borne in mind that the different lots were subjected to different conditions which may have had an equal or greater influence than the temperature in regulating the number of days in the various stages.

LIBERATION OF FOURTH STAGE LOBSTERS, 1905.

Date.	Locality.	Number.	Character of Shore.
June 13..	East Poplar Point..............	400	Rocky.
June 26..	Little Tree Point...............	3,000	Very rocky, abundance of rockweed.
June 27..	East Poplar Point...............	9,000	Rocky.
June 28..	Wickford Cove.................	200	Muddy bottom.
July 6....	Point Judith Pond, Billings' Cove.	15,000	Stony, light seaweed.
July 11...	Warwick Neck, below Rocky Point	10,000	Rocky.
July 13...	Portsmouth....................	10,000	Rocky, rockweed.
July 13...	Kickemuit River...............	15,000	Rocky, rockweed.
July 17...	Conanicut Island...............	12,000	Rocky ledge, rockweed below.
July 21...	Dutch Island Harbor............	20,000	Muddy bottom.
July 29...	Conanicut Island...............	6,000	Muddy bottom.
Total liberated......................		100,600	....
Used for experimental purposes, etc.........		2,972	....
Total counted out.................		103,572*	....

*This number is that of the fourth stage lobsters actually counted. In addition to these there were many first, second and third stage lobsters preserved for study, and some fourth lobsters were liberated in the cove by accident to the bags.

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

1900..................................	3,425
1901..................................	8,974
1902..................................	27,300
1903..................................	13,500
1904..................................	50,597
1905..................................	103,572
Total..................................	207,368

METHODS OF PROTECTING AND PROPAGATING THE LOBSTER, WITH A BRIEF OUTLINE OF ITS NATURAL HISTORY.

PLATES XIII TO XXIX AND XXXVI.

BY EARNEST W. BARNES.

ASSISTANT SUPERINTENDENT OF THE WICKFORD EXPERIMENT STATION.

TABLE OF CONTENTS.

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, the length of 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 their abundance since there was a demand for them in the market.

Because the lobster possesses, in a high degree, natural advantages for protecting itself, except in its larval helplessness, it seemed necessary to adopt some measure of rearing them through this latter

PLATE XIII.—An adult female lobster in "berry," so called, or bearing the egg-clusters under the tail. (Photograph from life.)

period. For more than a decade 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 Commission at Wickford. It has taken, nevertheless, since the discovery of the principle, five years of slow and tedious experiments to develop the scheme to the point where it is practical and economical.

Fifty per cent. in round numbers (48.2 per cent. actually) have been reared from the first to the fourth stage in lots of 20,000. 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 Woods Hole.

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 used 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.

2. *Natural Home and Migrations.*

The character of the shores where the lobster lives varies from rocky and precipitious 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.

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 traps. 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

PLATE XIV.—End view of houseboat and lobster-rearing floats.

Plate XV.—Side view of houseboat and lobster-rearing floats.

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.

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. 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.*

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 XXXVI.) 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 till lobsters between 8 and 9 inches long shed no more than 3 or 4 times a year. Concerning the molting periods of larger lobsters scarcely anything is known. It is known, however, that regeneration of various parts will very often retard the molting period and presumably the growth. Excessive light (as rearing in cars without covers)

*For a more complete discussion of the age and rate of growth of lobsters see article, Regarding the Rate of Growth of the American Lobster, by P. B. Hadley, Report of Rhode Island Commissioners of Inland Fisheries, made to the General Assembly at its January session, 1906.

will lessen the percentage of gain at each molt, if not the frequency of the periods.

6. *Regeneration.*

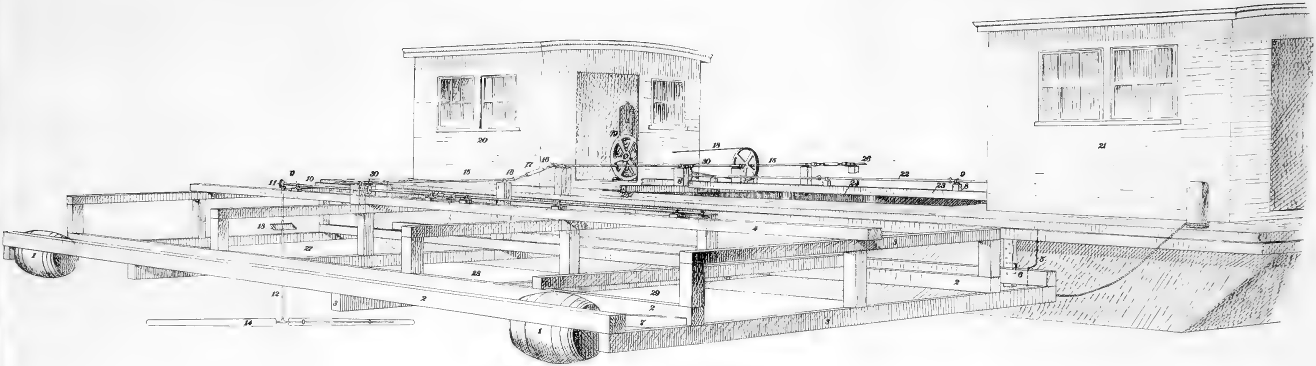
If a claw or any appendage is lost the lobster has the power of growing it again (regeneration). Should the loss occur within a certain period, too near an approaching molt, the molting occurs regularly without anything being done in the way of repair. If, however, the loss happens a considerable length 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 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 over one 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 five years only about a dozen 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

---

*For a more complete account of the matter of regeneration in lobsters see article, Regeneration of Lost Parts in the Lobster, by V. E. Emmel in the Report of Rhode Island Commissioners of Inland Fisheries, made to the General Assembly, 1905.



Showing the construction of one of the rearing floats

PLATE XVI

will l[illegible]
of th[illegible]

If [illegible]
growi[illegible]
certa[illegible]
regul[illegible]
howe[illegible]
molt, [illegible]
limb, [illegible]
come [illegible]
molt [illegible]
all ex[illegible]
to re[illegible]
powe[illegible]
off a [illegible]

Sin[illegible]
what [illegible]
thous[illegible]
sever[illegible]
may [illegible]
past f[illegible]
have [illegible]
inches[illegible]
lobste[illegible]
inches[illegible]
Massa[illegible]

*For [illegible]
eration [illegible]
mission[illegible]

12 inches, and thinks that 10½ inches is the average length at sexual maturity.

8. *Spawning Habits.*

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

9. *Larval Stages.*

During the first two 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 XXVI.) 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

*For a more complete account of the larval stages see article, Changes in Form and Color in Successive Stages of the American Lobster, by P. B. Hadley in the Report of Commissioners of Inland Fisheries of Rhode Island, made to the General Assembly, 1905.

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 state at Wickford is five.

Second Stage. (Plate XXVIII.) After the first molt the lobster's claws become a little larger than the other limbs, but remain hanging down. The abdominal swimmerets appear, 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 ~~XXVIII~~ XXXI.) 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 appendages. The greater size and more vigorous swimming causes this stage to be easily distinguished from the preceding stages. Four days is the average length.

Fourth Stage. (Plate ~~XXIX~~ XXXII.) 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 bag, 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 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

*See article, Observations on Some Influences of Light upon the Larval and Early Adolescent Stages of Homarus Americanus, by P. B. Hadley, in the Report of the Commissioners of Inland Fisheries of the State of Rhode Island made to the General Assembly at its January session, 1906.

of the rearing bags, though closely crowded together, while carried rapidly around by the current, will avoid, and keep some little distance away from, any white object, such as a 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 stage. 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 they 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. Herrick 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 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. The problem of lobster preservation, therefore, resolves itself into the protection of the lobster from its natural enemies at the critical periods of its life, and also in regulating and restricting the fishing.

II. Methods Employed to Prevent Extermination.

As early as the decerase in the number of lobsters was observed, some 70 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 Fish Commission.

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 this law 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.

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 paragragh on sexual maturity, the lobster in Narra-

gansett Bay in all probability is 9 inches, or slightly over, when it becomes sexually mature. In Massachusetts Herrick found the average to be 10½ 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.

3. *Protection of Large Lobsters.* Recently there has been considerable controversy about changing 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.

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. Perhaps the wise 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 9 inches and over 14 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, and the slats wide enough apart to allow those under 9 inches to escape.

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. Some restriction of this sort is certainly needed but there should be coöperation between all the states interested in the lobster fishery. There might be some question also, whether these particular dates are the best.

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 some 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 some states non-residents are prevented from engaging in lobster fishing. 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, 1906.

STATE.	Egg Lobsters, Penalty for Not Liberating.	Short Lobsters. Minimum Size. Alive.	Short Lobsters. Minimum Size. Cooked.	Short Lobsters. Penalty.	Uncooked mutilated remains. Penalty.	Not Marking Gear. Penalty.	Close Time. When.	Close Time. Penalty.	Unauthorized Interference with Gear. Penalty.	Non-residents Fishing, and Penalty.
Maine	$10 00 each	$10\frac{1}{2}$ in.	$10\frac{1}{2}$ in.	$1 00 each	$20 00	Cars, $10; traps, $5.	....	....	$20 00 to $50 00.	....
New Hampshire	$10 00 each	$10\frac{1}{2}$ in.	....	$10 00 each	....	Marking is necessary in order to bring suits for damages.	....	....	$50 00	....
Massachusetts	For each offence, $10 00 to $100 00, or one to three months' imprisonment.	$10\frac{1}{2}$ in.	$10\frac{1}{4}$ in.	$5 00 each	$5 00	....	....	....	First offence $5 to $25, and 30 days; subsequent, $20 to $50, and 60 days.	Must be an inhabitant for 1 year, or $20 fine.
Rhode Island	$5 00	9 in.	$8\frac{3}{4}$ in.	$5 00 each	$5 00	Confiscation; $20, or 30 days' imprisonment.	Nov. 15, to Apr. 15.	$20 00, or 30 days' imprisonment.	$10 00	Must have home and residence in state for 1 year. $20, and 30 days.
Connecticut	$10 00 to $50 00, 30 days' imprisonment.	9 in.	9 in.	$10 00 to $50 00, or 30 days imprisonment, or both.	....	....	....	....	....	....
New York	No restriction	9 in.	....	Determined by court as misdemeanor.	....	....	....	....	....	....

It would be safe to judge 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 two 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 attact 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 premium, 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 dozen years or more 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 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 among the stones and eel-grass, it has been thought impractical to retain them until a later 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 five years of con-

Plate XVII.—Showing the appearance of one of the side floats containing the bags for rearing the young lobsters. This plate shows, on the right, the universal joint, by means of which the power is transmitted to the shafting of the float from the houseboat.

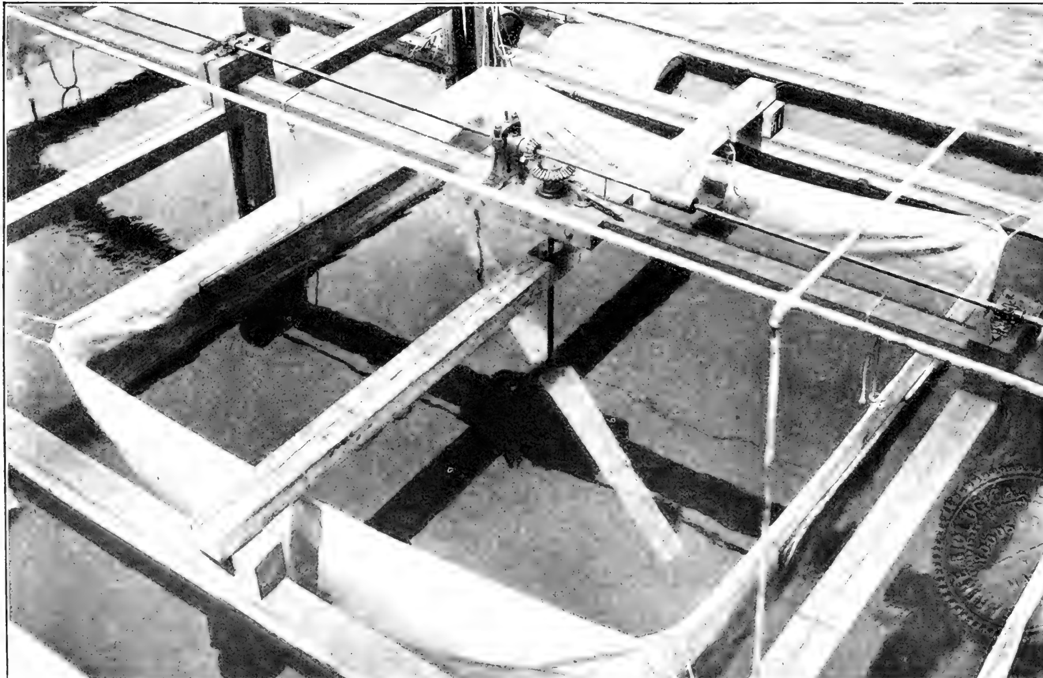


PLATE XVIII.—One of the rearing bags, showing method of supporting the bags and arrangement of gears for turning the paddle.

tinued 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, and the parasitic growths of diatoms and protozoa which infest the early stages.

The main feature of the scheme used in rearing consists in keeping the fry in constant circulation. This is accomplished by confining the fry in canvas bags which are suspended in the water and provided with windows of fine mesh copper wire netting. Two bladed paddles, not unlike restaurant fans, are kept revolving slowly in the bags at a rate of 10 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.

A 2½ horse power gasoline engine supplies the power for operating the paddles. This power is transmitted from the houseboat (Plates XIV and XV), in which the engine is located, to the floats ~~anchored~~ attached ~~by~~ to the side of the houseboat, by means of shafting and mitred gears. A specially constructed device is used for transmitting the power to the constantly moving floats, and consists in a pair of toggle-joints connected by a sleeve in which two pieces of square shafting slide. The two floats are fastened to the houseboat, one on each side, and are composed of a framework of 6 x 6 spruce, floated by barrels. Each one is capable of containing five rearing bags. These bags are made of canvas, eleven feet square and four feet deep, with three windows of copper netting, one in the bottom and one on each of two sides of the bags. More detailed account of the various constructions and operations will be given in the following paragraphs.

2. *Structure of the Floats.*

Reference to Plates XVI and XVII will give an idea of the manner in which a float 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. Occupying the center is a row of open pools, 12 feet 6 inches square, in which the rearing bags are placed. Running the length of the float, and crossing the center of each pool, is a beam which furnishes support for the shafting and gears. At each corner of the pool and projecting into the water is a 4 x 4 post, 5 feet long, extending 4 feet below the surface of the water. Each of these has a hole gouged out in the lower end, through which a rope is passed and spliced, so that one end hangs free. The bottom frame of the lobster bag is fastened to these free ends, and thus the bag may be lowered and raised by the ropes. Two of these floats are employed, one on each side of the houseboat.

3. *Engine and Gearing.*

The engine used for transmitting power to the paddles of the rearing bags is located on the houseboat. By means of shafts and gears the power is transmitted from the houseboat to the five paddles on each of the two floats and to the three paddles in the well of the houseboat. The gasoline engine is a Fairbanks-Morse of the vertical type, two and one-half horse power. That this engine is fully capable of doing the work required of it, or even more, is shown by the fact that, though it has been in use for three years, yet, during the past season, it ran day and night for seventy days without a breakdown. It is further to be remembered that the constant bending of the floats by the motion of the water makes necessary the transmission 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 1¼-inch steel running across the houseboat just outside the engine-house. From this main shaft three transmissions are made.

The first of these is by means of mitred gears to a 1-inch shaft running lengthwise of the well in the center of the houseboat. By means of the gears the speed in this is reduced to twenty revolutions per minute. The other 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 united by means of a sleeve in which two pieces of square shafting slide. 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 two transverse shafts on the two floats, 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 these shafts is also reduced by the gears to twenty revolutions per minute. These longitudinal shafts are of one-inch steel and are 53 feet long. It might further be said that the shafting used in this longitudinal drive of 53 feet is purposely of 1-inch stock because, with the constant bending of the long float, a heavier shaft, because of its rigidity, would pull out the hangers. The one-inch shafting readily bends with the floats, and the slow speed of twenty revolutions is not materially interfered with. The shafting is supported throughout by ordinary babbitted shaft-hangers.

From these two longitudinal shafts, and from the shaft running along the well of the houseboat, connection is made, by means of mitred gears, to the vertical paddle shafts. (Plate XVIII.) In these the speed is reduced by the gears to ten revolutions. Each paddle can be thrown out of gear independently by means of a lever. This enables each bag to be manipulated separately without shutting off the entire machinery.

4. *Construction and Care of the Rearing Bags.*

The canvas rearing bags (Plates XVIII and XXI) are 10 feet, 2 inches square, 4 feet deep, and made of 10-ounce duck. In the bottom and on two sides are windows. The frames of these are made of furring on the outside and a strip of lattice on the inside, the two being fastened together with brass screws, thus binding the edges of the canvas to the copper wire netting, 20 mesh to the inch, which forms the windows. A hem is made around the top of the bags, in which a rope is run. This hem is open at each corner, so that at those points loops of the rope can be put over line cleats, on the top of the haul-down posts, to support the corners of the bag. The sides are held up by ropes passed through grummet holes in the centers of the sides. A free edge is left around the outside bottom of the bag, with grummet holes at frequent intervals. Through these holes marlin or some light rope is passed and the bottom stretched quite taut over a square framework of one-half inch galvanized gas pipe which, for this purpose, is made a little larger than the bag. But however tight the canvas is drawn the upward current of water will pull up the center of the bag and endanger its being struck by the paddle. This is best remedied by placing two strips of furring, long enough to project over the sides of the framework, on the bottom of the bag underneath the framework. Then thin lattice strips, just the length of the inside bottom, are placed within the bag opposite the pieces of furring, and screwed down to the furring strips. Care of course should be exercised to round the edges of both lattice and furring strips so as to prevent them from cutting holes in the canvas when it is drawn up by the current.

PLATE XIX.—Small float used in cleaning the bags. Shows the method of scrubbing a bag.

PLATE XX.—Small float used in cleaning the bags. Shows the method of washing a bag.

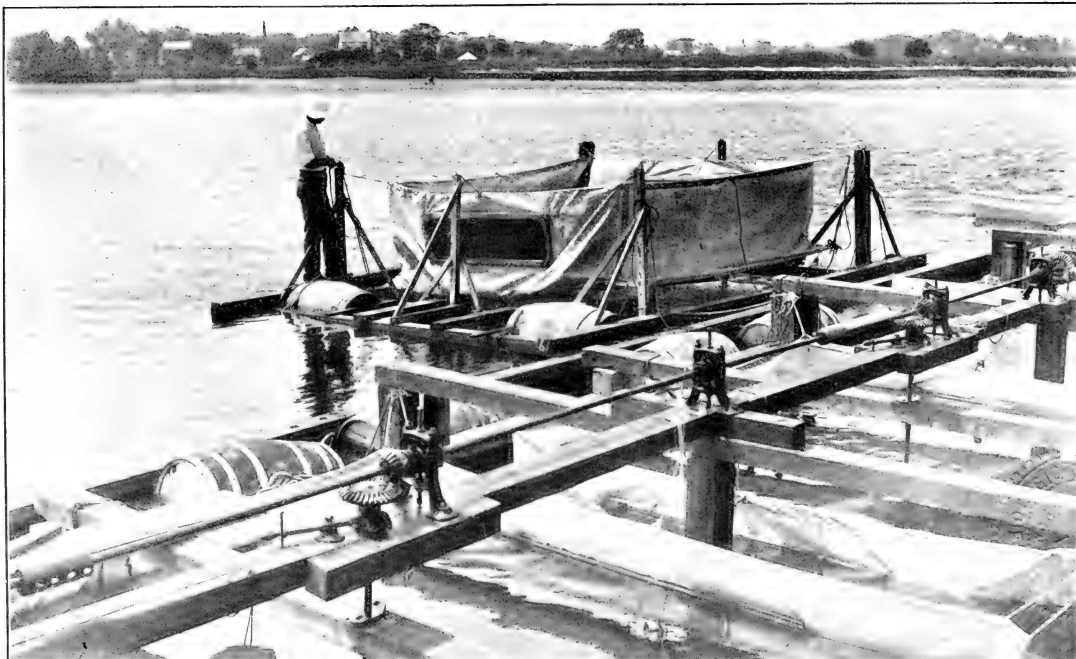


PLATE XXI.—Small float used in cleaning the bags. Shows the method of drying a bag.

As soon as the fry in a bag have reached the fourth stage and have been removed, or sooner if its condition requires, the bag is taken up and thoroughly cleaned. As we have seen, the bags in a short time become more or less foul. Most of the fouling occurs at the bottom, where the silt collects. This is the least dangerous to the lobster, as the current keeps them from the bottom, but of course the fouling tends to rot the canvas, and if the bags are left in the water with the filth from hatching still in them, the bottoms will soon rot out. If the sides of the bag become dirty, however, it is of the most serious consequence to the fry, as will be described later. As yet it is impossible to prevent this entirely. Soaking the canvas in a solution of Stockholm tar in gasoline preserves it and, in a measure, prevents the fouling. This is an excellent preparation for the bottoms, although it darkens the bag and interferes with observation. As regards the sides, it is another matter. Here the whiteness is of a decided advantage to the fry, for if white they tend to avoid it and consequently the current is not so likely to throw them against the sides and so infect them with the same growths that have fouled the bag.

Washing and drying the bags is the best expedient yet found for preserving them and keeping them in good condition. As soon as the bag commences to be foul, so that the lobsters become endangered, the fry should be removed and the bag taken up and washed. Usually, however, the bag will rear one set of larvæ before becoming foul.

Plates XIX, XX, and XXI show the process of washing and drying. A small float with a pool 12 feet square is used for the purpose. When the lobsters have been dipped out of the bag which is to be washed, this float is brought up alongside the rearing float; the dirty bag is then unfastened and floated under the outside barrel alley and up under the small float. The bag is fastened at the surface of the water, and the sides are scrubbed within and without with stiff brooms. The bag is then raised on an incline (Plate XIX), and the dirt scrubbed loose and washed out by water thrown on the bag.

(Plate XX.) It is sometimes necessary to turn the bag upside down and scrub, or even scrape, the underside of the bottom, as in the ten or twelve days that the bag has been in the water the sea squirts (Molgula) and barnacles may set thickly upon it. After the careful scrubbing and washing the bag is pulled up out of the water, the sides raised, and the bag left to dry (Plate XXI). The drying takes but two or three hours on a clear, warm summer day. The drying of the salt water tends to whiten the bags considerably.

5. *Construction and Adjustment of the Paddles.*

The paddles used at Wickford are two-bladed, not unlike those used overhead in restaurants. (Plate XVIII.) 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 ¾-inch galvanized iron pipe which is placed on the under side. Between the two blades is a T coupling, into which a vertical galvanized iron pipe is screwed. This vertical pipe is used as a shaft for that part of the paddle which is under water, and connects directly by a coupling to a short piece of one-inch shafting connecting with the gears. 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 bag by about 6 inches when revolving, and should be raised about the same distance above the bottom of the bag when this is drawn up by the current. 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 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 bag 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 bags, there can not help but be a considerable collection of diatoms, etc., on the inside of the canvas, and consequently in the water within the bags. The number in the water within the bags, 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 bags. With a current great enough to continually throw the fry against the sides of the bags, the opportunity for their infection would be very great; while with a current of less intensity the natural instinct of the fry to shun a white surface 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 bags, 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 i 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 some experience has been gained by actual experiment.

6. *Obtaining the Egg Lobsters.*

At Wickford the egg lobsters are purchased in the spring from the lobstermen at the regular retail price. It is the custom at some stations to buy the egg lobsters throughout the entire year, and retain them in pounds or cars. If a suitable place is at hand this is of course

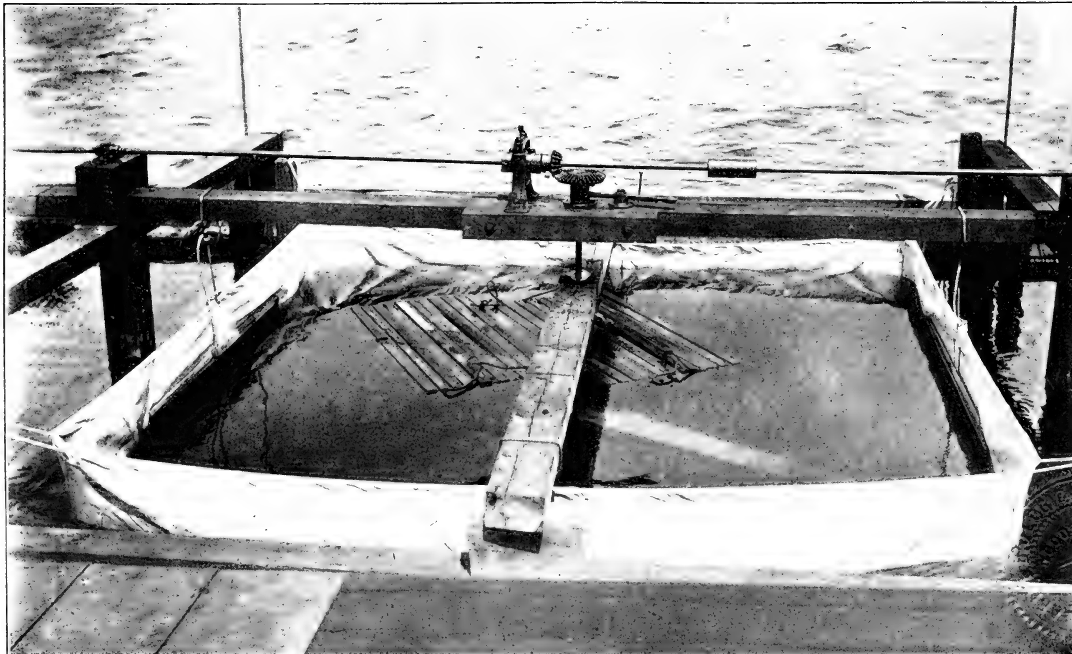


PLATE XXII.—Hatching-crate in position in one of the bags.

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 case the egg lobsters are shipped some distance, 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.

The lobsters obtained are confined in covered cars divided into two compartments, each five feet square, and with a water depth of two feet. As the lobsters which are to be put in these compartments are more or less crowded together, it is necessary to secure their claws in some way to prevent fighting, which may result in 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. Of these three the winding with canvas bandages is preferable; but the bandages invariably work off from one or two, and then the others are at their mercy. 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 can not 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 flat crates (three feet square and four inches deep) made of laths about an inch apart. These crates, which must float when filled with lobsters, are placed in the rearing bags and the paddle started. (Plate XXII.) Care should be taken not to permit the lobsters remaining so long in the retaining cars that hatching commences there, for if this occurs many fry will be lost. Yet at the same time only those whose eggs are on the point of hatching should be put into the bags, for this enables one to get a sufficient number of fry in the bag in a very few hours, and also all the fry are about the same age. Naturally this is a very important factor because of their cannibalistic habits, for if lobster fry of assorted sizes are in the same bag the danger of their devouring one another is much greater than as if they are all of the same age, although this danger is reduced to a minimum in the rearing bags.

The crate, also, to a certain extent, impedes the circulation of the water, and consequently the sooner removed the better. Besides this, the longer the egg lobsters remain in the crates the more unhatched eggs are scraped off into the bags, and though many of these are subsequently hatched, they stand no show against their older fellows. The crates should be allowed to float around with the current, as many fry would be lost by being dashed against a stationary crate. It is better, however, to fasten the crates loosely about the paddle shaft so that it can not damage the bag by striking against it.

8. *Feeding.*

Feeding is another operation which requires much attention. (Plate XXIII.) 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

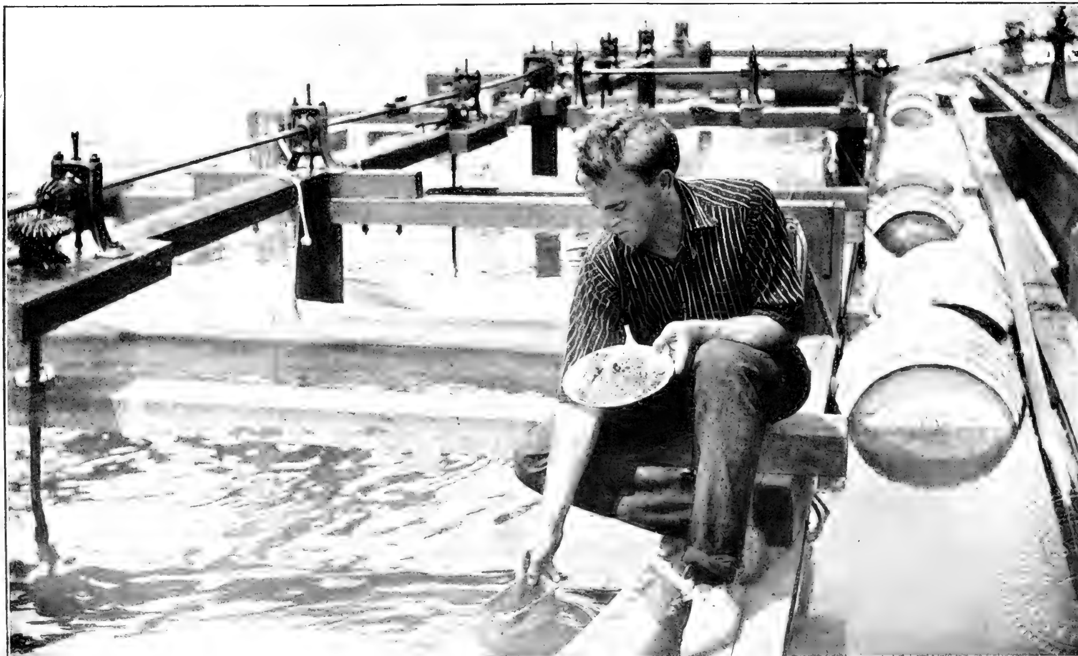


Plate XXIII.—Shows the method of feeding the lobster fry.

referred to. In confinement in the rearing bags 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 lobster demands regular and almost continuous 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 these 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 bags at night have shown fry eating pieces of clam. 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 lobster feeds principally by day, for a sudden light greatly excites the lobster and may have caused the dropping of food.

The practice of feeding the fry as frequently during the night as during the day 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. Fish, perhaps, is as much preferred 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 bag rapidly decay, fouling the water and rotting the bag. Soft-shell clams seem to be the best available food. The advantages are lightness, requiring little current to keep it up in the water, absence of oil, and are less likely to decay. The fry eat it very readily. The preparation of the clams consists 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 pieces of this almost as quickly as on the softer parts. In past years it has been the custom to sift the grindings through wire netting, and only use the very finest, such as would give a milky look to the water; but the past season all the grindings were used. In some instances the fry were seen to pass by the smaller particles and seize a larger fragment. Of course the particles must not be too large, otherwise they are not kept properly suspended by the current. In regard to the time of feeding, it was the practice last year to feed every three hours throughout the twenty-four. This seems to have been quite satisfactory. The practice of keeping the fry continually supplied with food should be considered of more importance than regular feeding periods.

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.

10. *Liberation of the Lobsterlings.*

As fast as the fry reach the fourth stage they are dipped out *in-*

PLATE XXIV.—Shows the method of planting lobster fry.

dividually and put by themselves in a retaining bag. As soon as a sufficient number has been collected in this bag 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 XXIV). 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 two or three hours' confinement in the can, care in keeping it from the sun and frequent 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 6 to 10 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 advantage 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 unfavorable 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 smiliar to liberating in deep water. If the shore, however, afforded a dark background, especially if this was occasioned by eelgrass, 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.

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; a minority will, however, either keep swimming about on the sides of the car near the surface; but it is not long 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 passed. To be sure a later stage is preferred, and as many stages later as may be will further insure the lives of the lobsters liberated; but for practical rearing purposes the fourth stage is probably sufficient.

11. *Liberation of the Egg Lobsters.*

After the eggs are scraped or hatched from the hen lobster, a copper tag with a serial number and the words "Return to the R. I. Fish Commission" is fastened securely with fine wire to the lobster's beak. (Plate XXV.) 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 obtained in regard to the length of time before molting after the eggs are hatched.

12. *Conditions Most Essential for the Location of a Rearing Plant.*

The experience of the past five seasons in the operation of the plant

PLATE XXV.—Adult lobster with copper tag attached to beak. Lobsters thus tagged are liberated at certain stations, and lobstermen are requested to return such tags, if retaken, to the Commission, giving date and place of capture. Valuable information on the movements of lobsters has been obtained by this method.

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. In the summer of 1903 it was subjected to one of the worst storms for years along the coast, and rode it out uninjured. The break-water then in use was light and was carried away. The rearing apparatus, however, was not damaged. 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 ran so high that many fry were swept out of the bags. 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 expense 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 20 rearing bags, capable of turning out 500,000 lobsterlings in a season, is as follows:

4 H. P. engine	$400 00
Houseboat	325 00
4 floats	350 00
Gearing	700 00
Bags	500 00
Miscellaneous fixtures	225 00
	$2,500 00

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

The running expenses of such a plant in a favorable locality would not be far from $3.00 per thousand lobsterlings reared; this includes gasolene, food for the fry, and labor; but does not include the cost of egg lobsters.

REGARDING THE RATE OF GROWTH OF THE AMERICAN LOBSTER,

(*HOMARUS AMERICANUS*).

PLATES XXVI TO XXXVII.

PHILIP B. HADLEY,

BROWN UNIVERSITY, PROVIDENCE, R. I.

CONTENTS.

I. Introduction.

At a time when artificial propagation is bidding fair to partially check the ever increasing depletion of many forms of marine animals whose economic value has long sustained a many-sided fishing industry, any facts which may bear directly or indirectly upon the life, habits, or development of such forms might seem to be of value. This fact is especially true in respect to the American lobster, a knowledge of whose development must influence not only methods of artificial propagation, but also legislation in determining the season and size at which the taking of lobsters shall be allowable.

It may here be noted that the life of the lobster from time of hatching until time of death is but a series of *stages* or *stage periods*, so-called, each one of which represents a period of its life between any two successive molts or castings of its shell. Of these stages, the first four are passed through rapidly, the young creature molting usually four times in the first twenty days of his existence. It is these first few stages, so quickly passed, that include the most important changes which the young lobster undergoes, and they are called the larval stages, denoting the successive emergence of one form from another. In each successive stage the lobster is larger than before;

thus we can say that *he grows by molting,* but (except for the gradual inter-articular expansion within the few days immediately following the molting process) *never between molts.* From the fourth stage on, however, each succeeding stage period is of longer interval and the changes which the adolescent lobster undergoes are correspondingly less distinct or significant, being characterized chiefly by those alterations in internal morphology which are concerned with the reproductive organs as the young lobster approximates to the adult structural and adult functional type. The slight changes in body form which the older lobsters experience are evident in the increasing "stockiness" of the body, the increasing relative size of the chelipeds, and (in the case of the secondary sexual characteristics) the broadening of the cephalothorax in the male, or the widening of the abdominal segments in the female for the better accommodation and protection of the eggs which are borne attached to the swimmerets on the under side of the "tail." The first three stages of the lobster are free-swimming stages, but all the activities are without co-ordination or aim. The fourth stage is also free-swimming, but in this case there is co-ordination in movement, and the young lobster swims with directness and purpose, usually at the surface, a phenomenon which is very likely determined by the general positive phototropic reactions evinced in this, but not in later, stages. Sometimes in the late fourth stage, but always in the fifth, the bottom-seeking and "hiding-habit" becomes prominent, and lobsters in all later stages manifest the characteristic habits of the adult species, namely, the tendency to shun the light and to seldom wander far from the rocky crevices which they select for their dwelling place. There appear to be, however, certain migrations of lobsters, some of which, according to Bumpus ('99), travel long distances in an incredibly short time. The migration may be general in its nature and characterized by a flux of lobsters into deep or shallow water at certain seasons of the year. These migrations seem to be influenced by water temperatures. There are, on the other hand, certain peculiar individual migrations, as mentioned above, when often a lobster may cover 15 or 16 miles in 3 or 4 days. For such as these there is no explanation available except the general tendency to wander restlessly about (a phenomenon observable in all the early stages) when once they have been removed from their habitual environs or when their habitation has been altered, removed, or destroyed.

This general absence of a migratory tendency (over great distances) which has also been proved to hold true for most of the tagged lobsters liberated in Narragansett Bay is a significant fact which bears upon the possibility of a depletion of lobsers in certain localities—a subject to be considered on a later page.

With these facts in mind, the writer has herewith attempted to offer a limited amount of new observations upon the rate of development of the American lobster and, recalling some observations of other writers, to make an estimate of the age of lobsters in different stages of development. A great number of the facts here reported have fallen under the writer's own observation while engaged in the work of artificial lobster propagation at the Experiment Station of the Rhode Island Fish Commission, at Wickford, R. I. He has, however, taken the liberty to make free use of data from several other reliable sources, as Herrick, Buckland, Boeck, G. O. Sars, Mead, Williams, Brook, Emmel, Goode, Dalyell, Bumpus, Packard, Gorham, Cobb, and others, each one of whom has presented facts which, when combined with the others, help to construct a somewhat fuller account of the rate of growth of *Homarus* than has yet been obtained from any single source.

II. Earlier Observations on the Rate of Growth.

1. *Amount of Increase at Molts.*

The question was raised by Herrick ('95), "How long does it take a lobster to attain marketable size?" (10½ inches in Massachusetts.) Herrick himself was the first to gather data, make an estimate, and to give a tentative answer. For this reason, before considering our own and other observations, it may be appropriate and of advantage to examine briefly the result of this writer's numerous and careful observations, made at the Woods Hole Station of the United States Fish Commission, upon the size and molting periods of lobsters in all of the earlier, and many of the later, stages of development. To show the average length of young lobsters in the first ten stages, Herrick presents the following table:

TABLE No. 1.

(Herrick's Table No. 25.) Actual length of lobsters during the first 10 stages at Woods Hole, Mass.

NUMBER OF MOLT OR STAGE.	Average length.	Extremes in length.	Number of lobsters examined.
	mm.	*mm.*	
1	7.84	7.5 to 8.03	15
2	9.2	8.3 to 10.2	47
3	11.1	10.0 to 12.0	79
4	12.6	11.0 to 14.0	64
5	14.2	13.4 to 15.0	15
6	16.1	15.0 to 17.0	12
7	18.6	18.0 to 19.5	4
8	21.03	19.0 to 22.0	5
9	24.5	24.0 to 25.0	2
10	28.03	26.6 to 29.5	3

Using as a basis this table, together with one other (Herrick's Table No. 35), we can formulate the following scheme, which briefly summarizes the results of Herrick's observations on the first ten stages, with reference to (1) average length, (2) increase in length at molts, (3) percentage of increase, and (4) average age of individuals in a single stage.

TABLE No. 2.

Summary of Herrick's statistics for first 10 stages of lobsters Raised at Woods Hole, Mass.

STAGE.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Average length (mm)	7.84	9.2	11.1	12.6	14.2	16.1	18.6	21.03	24.5	28.03
Increase in length (mm)	....	1.36	1.9	1.5	1.6	1.9	2.5	2.43	3.47	3.43
Increase per cent.*	....	17.3	20.6	13.5	12.7	13.4	15.5	12.5	16.5	14.00
Average age, (days)	....	.....	20	24	38	....	....	.....	.....	.....

*Average per cent. of increase for the 10 stages is about 15.2.

Estimating from this table, the average increase in length for the 10 stages will be found to be 15.2 per cent. In another group of 66 individuals, however, Herrick obtained an average increase of only 13 per cent. It will be observed, however, that, owing to the difficulties in maintaining the 7th, 8th, 9th, and 10th stages, the number of individuals in these stages examined is comparatively small; and since the variation in size in a single stage is great, a larger number of observations might perchance give more certain results. It will be observed from Table No. 2 that the percentage of increase undergoes no great variation between stages 1 and 10.

Other observations were made by Herrick upon lobsters of later stages, and the following table gives records of molts of eight lobsters varying in length from 5½ to 11¼ inches. The results demonstrate that, although the percentage of increase for these older lobsters varies between 6.66 and 18.18, the average per cent. of increase is 12.01 which, as will be noted, is not far from the per cent. of increase in length for the first 10 stages. (See Table No. 2.)

TABLE NO. 3.

(*Herrick's Table No. 24.*) *Increase in length of lobsters at time of molting.*

No.	Date.	Sex.	Length before Molt.	Length after Molt.	Increase in length.	Increase per cent.
			Inches.	*Inches.*	*Inches.*	
1	Oct. 22, 1890 ..	Female....	5½	6½	1	18.18
2	Oct. 29, 1890 ..	Male......	11	12	1	9.09
3	Nov. 6, 1890....	Male......	7¾	8½	¾	9.68
4	Nov. 10, 1890..	Male......	9	10½	1½	16.66
5	Nov. 11, 1890..	....	7½	8	½	6.66
6	June 8, 1891...	Male......	9 9/32	10½	1 7/32	13.13
7	July 13, 1891 ..	Male......	11¼	12½	1¼	11.11
8	............*	....	6½	7¼	¾	11.54
	Average......	....	....	....	....	12.01

*Recorded by Dr. A. S. Packard, "The Molting of the Lobster," Am. Nat., 1886, XX. 173.

Taking as a basis the observations presented in the foregoing tables, Herrick, having determined the average percentage of increase per molt as 15.3, and the average length of the first stage larva as 7.84 mm. constructs the following systematic scheme to show the probable lengths of lobsters in all the later stages from 1 to 30, a period of time which would represent the life of the lobster from time of hatching to the attainment of very great size:

TABLE No. 4.

(*Herrick's Table No. 26.*) *Estimated length of lobsters during the first 30 stages.*

Stage.	Length.	Stage.	Length.	Stage.	Length.
	mm.		*mm.*		*mm.*
1.........	7.84	11........	32.55	21........	135.17
2.........	9.04	12........	37.54	22........	155.86
3.........	10.42	13........	43.28	23........	179.70
4.........	12.02	14........	49.90	24........	207.20
5.........	13.86	15........	57.53	25........	*238.90
6.........	15.98	16........	66.34	26........	†275.45
7.........	18.42	17........	76.49	27........	317.59
8.........	21.24	18........	88.19	28........	366.16
9.........	24.49	19........	101.68	29........	422.21
10........	28.23	20........	117.24	30........	‡486.81

*9.5 inches. †11 inches. ‡19.1 inches.

2. *Frequency of the Molting Period.*

Next arises the question of the time interval between the successive molts. Herrick considers several cases of young lobsters which have fallen under his observation and concludes that a lobster one year old has molted 14 to 17 times and has attained an average length of from 2 to 3 inches. Regarding the molting period of larger lobsters, Herrick makes reference to Brook ('87). This observer kept a female lobster $6\frac{15}{16}$ inches long, for 506 days, during which time it gained $2\frac{7}{16}$ inches in 4 molts:

	?	$6\frac{15}{16}$
1.	July 1, 1883	$7\frac{3}{16}$
2.	December 25, 1883	8
3.	July 25, 1884	$8\frac{14}{16}$
4.	November 19, 1884	$9\frac{6}{16}$

In consequence Herrick assumes that if a lobster 6 or 7 inches long, kept in the unfavorable conditions of an aquarium, will gain $2\frac{1}{2}$ inches in 14 to 17 months, *a 6-inch lobster will attain a length of* 9 *to* 10 *inches in* 2 *years.* He further believes that 5 molts may elapse between the 3-inch stage and the 6-inch stage; and that these 5 molts can not take more than 2 years. As to the rate of growth of lobsters just under 3 inches, Herrick mentions a young female lobster which measured 51.8 mm. on the 10th of December. If it had lived, Herrick thought probable *that it would have molted* 3 *times before the following June;* and that by this date it would have attained a length of over 3 inches.

He considers that *the young lobster probably molts* 14 to 17 *times during the first year and in this time attains a length of* 2 *to* 3 *inches, which length may be greatly exceeded.* Putting all these facts together, Herrick finally concludes that *a lobster* $10\frac{1}{2}$ *inches long is between* $4\frac{1}{2}$ *and* 5 *years old, the higher degree of probability being in favor of the smaller number.*

Before considering the data in hand it may be well to examine briefly some facts concerning the development of the European lobster (*Homarus vulgaris*) which, though usually somewhat smaller, is very similar in other respects to *Homarus americanus*.

III. General Observations on the European Lobster (*Homarus vulgaris*).

There appears to be a wide variation in the reports concerning the development of the European lobster. As is the case with the American lobster, the early stages may be divided into two groups, the zoëa or free-swimming stages, and the megalops, the first stage in which the lobster assumes the form and, to some extent, the habits of the adult. Next, according to Williamson ('04), comes the *megalops*, which seems most comparable to the fourth stage of *Homarus americanus*, and then the "first-young" stage, so-called, which is represented by the fifth stage of the American lobster. Some writers, as R. Q. Couch ('43), have assumed the existence of a protozoëa stage. Chadwick ('05) also has published, according to Williamson, a description of a protozoëa stage, three zoëa stages, a megalops and a "first-young" stage. It would seem probable, however, that there may be reasonable doubt of the existence of this protozoëa stage, and that what the observers have actually seen is but an occasional variation which sometimes presents itself in the first zoëa stage and not a separate stage.

We note, on the other hand, that such observers as Appellôf ('99–'01) and Ehrenbaum ('03) make mention only of the stages which correspond very nearly with the first stages of *Homarus americanus* as described by Herrick ('95) and the writer ('05). Likewise in the reports of the duration of the early stage period of *Homarus vulgaris* there is wide variation.

Chadwick ('05) states, according to Williamson, that with the exception of the protozoëa stage, each of the first five stages of the European lobster lasts about a week. It seems hardly credible, however, that the length of the stage periods should be so nearly the same; and especially that the fifth should be no longer than the first. Appellôf ('99–'01) and Ehrenbaum ('03), as we shall see, give quite different reports regarding the stage periods of the European lobster.

The hatching period for the European lobster extends from the middle of July to the middle of September. The first stage lobster, according to most observers, is about 8 mm. in length. We have examined the drawings made (to scale) by Williamson ('04), and conclude that the lobsters examined by him on the west coast of Scotland were, in length, as follows:

First zoëa stage	8.0 mm.
Second zoëa stage	10.7 mm.
Third zoëa stage	12.2 mm.
Fourth zoëa stage	14.8 mm.
Megalops stage	15.0 mm.
First-young stage	17.4 mm.
Second-young stage	17.0 mm.
Third-young stage	20.0 mm.

The value of this estimate must, however, be lessened because of the manner in which it was deduced by the present writer. Accurate measurements of the lobsters themselves would, no doubt, have given somewhat different results. Concerning the exact length of some of these early stages, we can obtain more satisfactory data from Ehrenbaum ('03) and Appellôf ('99–'01). The latter observed that the first stage-period might be as short as five days, but averages six or seven days. The results of certain observations made by Appellôf and Ehrenbaum on the length and stage periods of *Homarus vulgaris* may be tabulated as follows:

TABLE No. 11.

Showing the rate of development of European lobsters in the early stages.

Stage.	Appellôf.		Ehrenbaum.	
	Stage period.	Length.	Stage period.	Length.
1	6–7 days	8 mm	4–5 days	8 mm.
2	9–10 days	*	3–5 days	
3	10–12 days (?)		10 days	12–14 mm.
4	23–28 days		17 days	16 mm.
5	37 and 62 days		24 days	17 mm.
6			26 days	18–20 mm.
7			30 days	21–22 mm.
8			3 mo. (?)†	24 mm.

*No accurate data on the length of Appellôf's lobsters are available at time of writing.

†These lobsters, four in number, mentioned by Ehrenbaum ('03) were kept in Aquaria in water whose temperature was relatively high. This probably accounts for the molting of these lobsters (one in February and three in March) during the winter months. As will be shown later, this is not usually the case.

It is here observed that not only are the stage periods of the European lobster very long, but the amount of increase in length at each molt is relatively small.*

The periods are so long, in fact, that Appellôf observed that the average number of his lobsters had passed through but five stages (and were in the sixth) when the on-coming cold weather and the consequent lowering of the prevailing temperature of the water put an end to their apparent growth. In December, however, Ehrenbaum's lobsters, raised in the warmer waters of Helgoland, were in the seventh stage, and Ehrenbaum concludes that if the young lobsters had been hatched earlier in the summer, they would have passed into the eighth stage before the cold winter months had come and put an end to the period of growth (Wachsthumsperiode).

Thus Ehrenbaum finally concludes that *the European lobster molts* 7 *or* 8 *times the first summer and autumn of its existence, and attains in this time an average length of* 22 to 25 *mm.*

Regarding the rate of growth of young lobsters over 8 months old, Appellôf observed a few individuals which molted 4 or 5 times during their second year of life. Making use of this, and other data, Ehrenbaum estimates in consequence that *a young lobster* 116 *mm.* (4⅔ *inches*) *in length, is three years old.* He formulates the following scheme to demonstrate the rate of development. The "periods" refer to the periods of growth (Wachsthumsperiode) *i. e.*, in this case, years:

First	period	8 to 25 mm.	Amount of increase,		17 mm.
Second	"	30 to 70 mm.	"	"	40 mm.
Third	"	70 to 120 mm.	"	"	50 mm.
Fourth	"	120 to 170 mm.	"	"	50 mm.
Fifth	"	170 to 210 mm.	"	"	40 mm.
Sixth	"	210 to 250 mm.	"	"	40 mm.

From the summation of these facts, we can (having already observed the data presented by Herrick, page 159 draw the conclusion. that the rate of growth of the average European lobster may be less

*These facts will be more evident when a comparison is made with the tables which appear on subsequent pages.

rapid than that of *Homarus americanus*. This hypothesis will permit of demonstration in the course of the succeeding pages.

IV. Observations at Wickford on the First Ten Stages of the Lobster.

The observations made at the Wickford Station of the Rhode Island Fish Commission by the writer and others, though differing to some extent from the results obtained by Herrick at Woods Hole, and from those of other investigators working with *Homarus vulgaris*, may serve to throw further light upon the rate of growth of lobsters under natural conditions of environment, and perhaps give some hint as to the value of a few of the conditions which appear to modify it. Attention may be first directed to Tables Nos. 25 and 26. The observations here recorded were made upon young lobsters in stages 1 to 12, whose approximate age and definite stage were known. Individual records were started immediately after the molt from the third to the fourth stage and carried through the following stages until the last of November. The records include observations upon individuals many of which did not live through the later stages because of inadequate methods of preservation during the winter months. A sufficient number, however, were brought to the twelfth stage to give some value to the data on the average size and usual duration of the stage periods at this time of life.

To determine precisely the rate of growth of lobsters in the first three stages, few special observations have been made. This is because of the fact that when these young lobsters are isolated in glass dishes or other receptacles, for particular observation, the rate of growth does not appear to be the same as under natural conditions, but somewhat decreased. For this reason the most valuable data on the rate of growth of lobsters in the first three stages are gained from observations upon large numbers of lobsters in these stages, which have been hatched at approximately the same time and develop under more natural conditions in the large hatching bags. In order, then, to represent the average rate of development in the first three stages at the Wickford hatchery, the following (Table No. 11a), compiled by Mr. E. W. Barnes, Assistant Superintendent of the Wickford Hatchery of the Rhode Island Commission of Inland Fisheries, is presented.

TABLE NO. 11a.

Length of Larval Stages in 1905.*

Experiment Number.	Begun.	Ended.	Temperature.		Number of Days in Different Stages.			Age in Days when Fourth Stage was Reached
			Extremes.	Average.	First Stage.	Second Stage.	Third Stage.	
1	May 21.....	June 13.....	53–56	57.4	12	6	3	21
2	May 24.....	June 13.....	54–56	57.6	9	6	3	19
3	May 24.....	June 19.....	52–70	60.	9	6	4	19
5	May 26.....	June 23.....	52–70.5	61.3	7	7	4	18
8	June 5.....	June 19.....	54–77	63.3	7	4	4	15
9	June 5.....	June 27.....	54–77	64.8	7	5	5	17
10	June 7.....	June 26.....	54–77	65.	7	5	4	16
11	June 9.....	June 26.....	54–77	65.9	6	4	4	14
12	June 10.....	July 1.....	60–77	66.8	6	4	4	14
13	June 12.....	June 29.....	60–77	67.	5	4	4	13
14	June 16.....	July 1.....	62–77	68.	5	3	5	13
15	June 19.....	July 5.....	61–77	68.	4	3	5	12
16	June 21.....	July 7.....	61–77	69.	5	3	5	13
17	June 21.....	July 11.....	61–79	70.	4	4	6	14
18	June 25.....	July 6.....	61–77	69.	5	2	4	11
19	June 28.....	July 10.....	61–79	70.7	5	2	4	11
20	June 29.....	July 12.....	64–79	71.	5	3	5	13
21	June 29.....	July 13.....	64–79	71.2	5	2	4	11
22	June 29.....	July 13.....	64–79	71.4	5	2	4	11
25	July 5.....	July 19.....	66–82	74.4	5	2	5	12
26	July 7.....	July 19.....	69–82	75.	4	2	4	10
27	July 9.....	July 24.....	69–82	74.4	4	3	4	11
28	July 11.....	July 24.....	69–82	75.1	4	2	4	10

The average number of days in the first stage was 5 and ranged from 4 to 12.
The average number of days in the second stage was 3 and ranged from 2 to 6.
The average number of days in the third stage was 4 and ranged from 4 to 6.
The average number of days to reach fourth stage was 13.8 and ranged from 10 to 21.

*It must be borne in mind that the different lots were subjected to different conditions which may have had an equal or greater influence than the temperature in regulating the number of days in the various stages.

Table No. 25 represents the result of a series of observations upon the early stages, conducted during the early summer of 1904 by Dr. A. D. Mead, and continued upon the later stages, during the latter part of the same summer, by the present writer. In this case the lobsters used for the experiment were taken at random from the large hatching bags or special cars in which they were confined, and represent the *normal average size* for the summer of 1904. Table No. 26 records observations made by the writer during the summer of 1905 at the Wickford Station. In this case, instead of taking the fourth stage lobsters at random, a selection was made of those lobsters upon which records were to be started; that is, the small and weak fourth stage lobsters were thrown out, while an attempt was made to secure those individuals which gave appearance of being larger and stronger. A comparison of these two tables reveals some differences which may be better brought out by the following tabulations:

TABLE No. 5.

Summary of observations on the rate of growth of the first 11 stages.

	Stage 1.		Stage 2.		Stage 3.		Stage 4.		Stage 5.		Stage 6.		Stage 7.		Stage 8.		Stage 9.		Stage 10.		Stage 11.	
	Size.	Stage-period.	Size.	Stage-period.	Size.	Stage-period.	Size.	Stage-period.	Size.	Stage-period.	Size.	Stage-period.	Size.	Stage-period.	Size.	Stage-period.	Size.	Stage-period.	Size.	Stage-period.	Size.	Stage-period.
	mm.	*da.*	*mm.*	*da.*	*mm.*	*da.*	*mm.*	*da.*	*mm.*	*da.*	*mm.*	*da.*	*mm.*	*da.*	*mm.*	*da.*	*mm.*	*da.*	*mm.*	*da.*	*mm.*	*da.*
Normal 1904 Average.	8.2	2.0	9.6	4.0	11.4	5.0	13.5	12.0	15.5	9.5§	18.6	12.7	22.5	14.3	26.5	16.0	32.1	....	37.9	....	42.9	....
Normal 1905 Selected.	....	....	....	....	....	....	14.4	11.7	17.0	11.2§	20.5	12.2	24.6	13.5	31.3	15.1	37.0	21.0	45.0	25.1	54.2	38.0
Mutilated 1905 Average.*	....	....	....	....	....	....	....	18.9	14.6	16.0	16.4	18.0	19.4	18.2	22.9	....	....	....	....	....	....	....
Herrick's Normals.	7.84	1–5	9.2	2–5	11.1	2–8	12.6	10–19	14.2	11–18	16.1	14.0	18.6	....	21.03	....	24.5	....	28.23	....	....	....
Normal 1905 Average.†	....	....	....	....	....	....	13.7	14.8	15.8	14.3†	18.4	15.7	22.2	17.5	25.5	....	....	....	....	....	....	....

*These represent individuals which had been mutilated for the purpose of making observations on regeneration. Data from Emmel ('05).

§It is a point worthy of notice that, as a rule, the fifth stage-period is shorter than the fourth. This is probably due to the fact that the lobsters observed happened to be passing through the fifth stage during the period of maximum water temperature, July 11 to 24. †Data from Emmel ('05).

TABLE No. 6.

Comparison of percentages of increase in length, per stage, for first 11 stages.

	Stage 1 to 2.	Stage 2 to 3.	Stage 3 to 4.	Stage 4 to 5.	Stage 5 to 6.	Stage 6 to 7.	Stage 7 to 8.	Stage 8 to 9.	Stage 9 to 10.	Stage 10 to 11.	Stage 11 to 12.
Normal 1904 Average.	17.0	19.2	18.6	15.0	20.0	21.0	17.0	21.0	17.0	14.0	18.9
Normal 1905 Selected.	......	......	......	18.0	20.6	20.	27.2	18.5	21.6	20.4	......
Mutilated 1905 Average.†	......	......	......	5.3*	12.3§	15.7§	20.5§	......	......	......	......
Herrick's Normals.	16.5	20.6	13.5	11.9	13.3	15.5	13.0	16.5	14.0	......	......
Normal 1905 Average.†	......	......	......	15.4†	16.3	20.6	15.7	......	......	......	......

*Mutilations took place early in the stage-period. Approximate.

§Mutilations took place late in the stage-period.

†Facts from Emmel ('05).

Reference to the foregoing tables demonstrates several important facts. First it will be observed that, though the stage periods of the lobsters observed in 1904 are for the most part longer than the stage periods of the selected lobsters (1905), the average size for the 1905 group is much greater. Furthermore it is observed that, while the total average increase for stages 4 to 12 in the 1904 group is 18.4 per cent., the average increase for these stages in the 1905 group is 20.9 per cent.; and that the increase in the case of Herrick's lobsters for the same stages is only about 14 per cent. In consequence it is evident that there may be great variation in the rate of development in different localities and under different conditions. Further, that there is a tendency manifested in those individuals which are slightly above the normal in size and strength to increase the advantage which they have already gained. This advantage in size of the fourth stage lobsters may be no more than a millimeter, but this slight gain, compounded through numerous successive stages, gives, even in the tenth and eleventh stages, a decided lead which may be observed in individuals recorded in Table No. 5 (1905 group). Through the courtesy of Mr. V. E. Emmel, the writer is able to append a table showing the result of observations upon a few stages of normal average lobsters in his keeping for the summer of 1905.

TABLE NO. 7.

Showing the size of some normal average lobsters in the summer of 1905.*

	Stage 4.	Stage 5.	Stage 6.	Stage 7.	Stage 8.	Stage 9.	Stage 10.
Average Size.	13.7 mm.	15.8 mm.	18.4 mm.	22.2 mm.	22.5 mm.	....	....
Average Stage-period.	14.8 da.	14.3 da.	15.7 da.	17.5 da.	17.5 da.		
Per cent. of Increase.	....	15.4%	16.3%	20.6%	15.7%	....	....

*Data from Mr. V. E. Emmel.

If this be compared with the relative stages given in Table No. 5 (1904 group) it will be observed that the average length per stage for the normal average of 1905 corresponds very closely with the normal average of 1904, although it is less than the average size of the selected normals for 1905. It is further evident, however, that the stage periods of the 1905 group are, in general, greater. It is difficult to assign a reason for this fact other than chance fluctuations in water temperatures or the possible effects of light. It has always been observed that the first four metamorphic changes in the young lobsters follow each other in more rapid succession and that in consequence, the individuals are larger and more healthy, when the temperature of the water is near its maximum. It is during a few weeks in the middle of the summer that all lobsters of whatever size experience their most rapid growth.*

On the other hand, as will be shown later, the effect of a strong light may exert a harmful influence on the development of the young lobsters. In the case of the group last mentioned (see Table No. 5, also Nos. 23 and 24) lobsters were kept in open wire cages and not protected from the sun's rays nearly as well as the lobsters which were confined in the covered wooden cars, and whose records are presented in brief in Tables Nos. 5 and 6 (1904 and 1905 groups). The difference in the lengths of the stage periods will be readily observed. A more detailed treatment of the influence of light upon rate of development is undertaken on a later page.

V. Possible Explanations of the Variations in the Rate of Growth of Lobsters Mentioned in the Foregoing Tables.

It is undoubtedly to such differences in the temperature of the water that such a variation as is noticeable in the rate of growth of the lobsters observed by Herrick at Woods Hole, and those of other groups considered in Tables Nos. 5 and 6 is partly due. It is readily noted that not only are the average first stage lobsters at Wickford

*See Tables Nos. 18, 19, 20, and 21.

larger than those recorded by Herrick, but that the percentage of increase for nearly all the early stages is greater in the case of the Wickford group. In experiments carried on at Orr's Island, Maine, where the prevailing summer temperature of the water was only 60°, the fourth stage was not attained short of 25 or 26 days ('03). This is over twice as long as the average time required at Wickford to reach the same stage when the prevailing water temperature has been 72°. These facts demonstrate how dependent the rate of growth of the lobster, at different points of the Atlantic coast, may be (at least during the early stages) upon the temperature of the water; hence the difficulty of drawing up any strict account of the rate of growth applicable to all regions. This subject will be considered again on a later page. (See p. 197.)

A second consideration appears from a glance at Tables Nos. 5, 6, 7, and 8. Through the investigations of Emmel ('05) on *Homarus* it is evident that mutilations of one or more appendages, contrary to the view of Zeleny ('05), exert great influence, not only in delaying the molting periods, but also in diminishing the normal percentage of increase in length in each successive molt. This is shown in the two following tables:*

*Whether or not the condition of mutilation and regeneration will decrease the percentage of gain in size at the coming molt seems to be more or less dependent upon the *time in the stage period, at which the mutilation takes place.* The experiments of Emmel ('05) would appear to indicate the fact that the condition of regeneration has less influence upon the rate of increase when the mutilation is performed in the early part of the stage period; and *vice versa;* that a mutilation performed in the middle of the stage period has a greater influence in diminishing the amount of increase in size at the following molt.

TABLE NO. 8.

Data on the molting period of lobsters having one or more regenerating appendages.§

Number.	4th Stage. Date.	Size.	Stage period.	5th Stage. Date.	Size.	Stage period.	6th Stage. Date.	Size.	Stage period.	7th Stage. Date.	Size.	Stage period.
1				July 26		11	Aug. 6					
2				July 24		13	Aug. 6					
3				July 27		10	Aug. 6					
4				July 28		12	Aug. 9					
5				July 27		13	Aug. 9					
6				July 27		13	Aug. 9					
7				July 27		13	Aug. 9		12	Aug. 21		
8				July 27		13	Aug. 9		14	Aug. 23		
9				July 27		13	Aug. 9		14	Aug. 23		
10				July 24		16	Aug. 9		18	Aug. 27		
11				July 27		13	Aug. 9		15	Aug. 24		
12				July 26		14	Aug. 9		28	Sept. 6		
13				July 26		13	Aug. 9		28	Sept. 6		
14				July 27		13	Aug. 9		18	Aug. 27		
15				July 27		13	Aug. 9		29	Sept. 7		
16				July 27		13	Aug. 7		13	Aug. 20		
				*Average		da. 12	*Average		da. 19			
17	July 12		16	July 28								
18	July 12		16	July 28		†12	Aug. 9					
19	July 12		20	Aug. 1								
20	July 12		15	July 27		†7	Aug. 3					
21	July 12		19	July 31		†9	Aug. 10					
22	July 12		15	July 27		†10	Aug. 6					
23	July 12		19	July 31								
24	July 12		16	July 28								
	Average		da. 17	†Average		da. 9½						

§Data from Emmel, ('04).

*In these sixteen lobsters it will be noticed that the molting period of the 5th and 6th stages was much longer than the normal period. See previous table.

The average duration of the normal 5th stage was 9½ days, and for the 6th stage 12.7 days, but in these regenerating lobsters the average period for the 5th stage was 12 days, and for the 6th stage 19 days.

†Lobsters 18, 20, 21, and 22 had regenerating appendages in the 4th stage, but had attained nearly normal condition during the 5th stage. In this latter stage it will be seen that the molting period had dropped back to the normal length of 9½ days.

VI. Observations on the Rate of Growth of Lobsters Past the Tenth Stage.

Before we turn to consider how these foregoing observations bear upon the probable normal rate of growth of the lobster, it may be well to examine data (Tables Nos. 9 and 10) compiled by Dr. A. D. Mead and Dr. L. W. Williams on the rate of growth of certain groups of lobsters in captivity at the Wickford Station of the Rhode Island Commission of Inland Fisheries.* From these observations we can gather many valuable points which serve to guide us in the estimation of the rate of growth of adolescent lobsters.

We find that, of 149 young lobsters hatched between June 1 and June 26, the average length on September 15 was 31.8 mm., the extremes being 44 mm. (hatched June 1) and 20 mm. (hatched June 26). Of these 149, about 10 months after hatching, 23 individuals gave an average length of 50 mm. while June 12, approximately one year after hatching, 79 gave an average length of 53.5 mm. A full list of the one-year-old lobsters examined stands as follows:

Group.	Number of individuals.	Average length.
1	4	43.0 mm.
2	22	48.2 mm.
3	28	52.7 mm.
4	19	56.0 mm.
5	6	67.0 mm.
Total Average,	79	53.5 mm.

*From time to time there have been attempts made at the Wickford Hatchery to raise lobsters to sexual maturity. These attempts have not been successful owing to the hard winters, the ice-packed harbor, and some insufficiencies in the construction or placing of the lobster cars for winter months. The attempt made by the writer during the winter of 1905–6 to keep lobsters in earthenware jars filled with salt water was a failure, owing either to poisoning from the jars or to unevenness in water temperature. The water may be cooled to such an extent that it freezes at the surface and no harm is done, but rapid changes appear to cause disastrous results. That lobsters kept in a cold and constant temperature require but a small amount of water, with infrequent changes, is shown by the fact that a few young lobsters which the writer entrusted for the winter to Mr. E. W. Barnes, and which he kept in a cold room in bottles, (whose width was scarcely greater than the length of the lobsters), passed the winter in safety. Of over fifty kept in this way but two died. The others were in good condition when again placed in their compartment cars in Wickford Cove about April 1, 1906.

TABLE No. 9.*

Measurements of lobsters hatched in 1900, showing growth during first summer.

(Each column represents a separate car).

Hatched May 31. Measured Sept. 15. Age 3½ months.		Hatched June 10. Measured Sept. 15. Age 3 months.		Hatched June 26. Measured Sept. 15. Age 2½ months.		Hatched between May 31 & June 26. Measured Sept. 15. Age ab't 3 months.		Hatched between May 31 & June 26. Measured Sept. 15. Age ab't 3 months.	
mm.	Inches.	mm.	Inches.	mm.	Inches.	mm.	Inches.	mm.	Inches.
26	1 1/16	21	13/16	20	13/16	19	3/4	20	1 13/16
30	1 3/16	22	7/8	21	13/16	20	13/16	22	7/8
30	1 3/16	22	7/8	23	15/16	21	13/16	23	15/16
30	1 3/16	25	1	24	15/16	22	7/8	23	15/16
31	1 1/4	27	1 1/16	25	1	22	7/8	23	15/16
33	1 5/16	27	1 1/16	25	1	22	7/8	24	15/16
33	1 5/16	30	1 3/16	26	1 1/16	24	15/16	24	1/16
33	1 5/16	30	1 3/16	26	1 1/16	24	15/16	27	1
35	1 3/8	30	1 3/16	27	1 1/16	24	15/16	25	1
36	1 3/8	30	1 3/16	27	1 1/16	25	1	26	1 1/16
37	1 7/16	32	1 1/4	27	1 1/16	25	1	26	1 1/16
38	1 1/2	32	1 1/4	29	1 1/8	25	1	27	1 1/16
38	1 1/2	32	1 1/4	30	1 3/16	25	1	28	1 1/8
39	1 9/16	32	1 1/4	30	1 3/16	25	1	28	1 1/8
44	1 13/16	33	1 5/16	31	1 1/4	26	1 1/16	28	1 1/8
44	1 13/16	35	1 3/8	31	1 1/4	26	1 1/16	29	1 1/8
		35	1 3/8	31	1 1/4	26	1 1/16	29	1 1/8
		37	1 7/16	32	1 1/4	26	1 1/16	30	1 3/16
		38	1 1/2	32	1 1/4	26	1 1/16	30	1 3/16
		38	1 1/2	33	1 5/16	26	1 1/16	31	1 1/4
		40	1 5/8	34	1 5/16	27	1 1/16	32	1 1/4
		40	1 5/8	34	1 5/16	27	1 1/16	34	1 5/16
		40	1 5/8	35	1 3/8	27	1 1/16	34	1 5/16
		42	1 5/8	35	1 3/8	27	1 1/16	34	1 5/16
		45	1 3/4	36	1 3/8	29	1 1/8	35	1 3/8
				37	1 7/16	30	1 3/16	35	1 3/8
				37	1 7/16	30	1 3/16	36	1 1/8
				40	1 5/8	32	1 1/4	37	1 7/16
				41	1 5/8	32	1 1/4	37	1 7/16
				42	1 5/8	33	1 5/16	37	1 7/16
				46	1 13/16	33	1 5/16	37	1 7/16
						34	1 5/16	37	1 7/16
						35	1 3/8	37	1 7/16
						38	1 1/2	38	1 1/2
						40	1 5/8	38	1 1/2
						40	1 5/8	39	1 9/16
						40	1 5/8		
						40	1 5/8		
						43	1 11/16		
						44	1 13/16		
Av. 34.7	1 5/16	Av. 32.6	1 1/4	Av. 29.9	1 3/16	Av. 30.1	1 3/16	Av. 31.8	1 1/4
Total No. 16.		Total No. 25.		Total No. 31.		Total No. 39.		Total No. 38.	

*Mead and Williams ('03).

TABLE No. 10.*

A — *Measurement of lobsters hatched in 1900, between May 31, and June 26, showing growth to November 7, 1901.*

B — *Measurement of lobsters hatched in 1900, between May 31, and June 26, showing growth to October 4, 1902.*

A: May 10. Approximate age 10 months.		A: June 12. Approximate age 1 year.		A: Aug. 22. Approximate age 14 months.		A: Nov. 7. Approximate age 17 months.		B: March 27. Approximate age 1 year 9 months.		B: May 31. Approximate age 2 years.		B: Sept. 10. Approximate age 2 years 3 months.		B: Oct. 4. Approximate age 2 years 4 months.	
mm.	Inches.	mm.	Inches.	mm.	Inches.	mm.	Inches.	mm.	Inches.	mm.	Inches.	mm.	Inches.	mm.	Inches.
40	1 5/8	41	1 5/8	49	2	69	2 3/4	69	2 3/4	85	3 3/8	106	4 3/16	106	4 3/16
41	1 5/8	42	1 5/8	55	2 1/8	73	2 7/8	73	2 7/8	88	3 1/2	106	4 3/16	106	4 3/16
41	1 5/8	42	1 5/8	57	2 1/4	79	3 1/8	76	3	88	3 1/2	108	4 1/4	108	4 1/4
42	1 5/8	44	1 3/4	57	2 1/4	79	3 1/8	79	3 1/8	95	3 3/4	108	4 1/4	108	4 1/4
43	1 5/8	47	1 7/8	60	2 3/8	82	3 1/4	79	3 1/8	95	3 3/4	108	4 1/4	108	4 1/4
44	1 3/4	47	1 7/8	62	2 1/2	82	3 1/4	82	3 1/4	98	3 7/8	117	4 3/4	117	4 3/4
45	1 3/4	47	1 7/8	65	2 1/2	85	3 3/8	82	3 1/4	98	3 7/8	123	4 7/8	123	4 7/8
45	1 3/4	49	2	65	2 1/2	85	3 3/8	85	3 3/8	e 106	4 3/16	e′ 123	4 7/8	123	4 7/8
47	1 7/8	49	2	68	2 3/4	88	3 1/2	88	3 1/2	d 114	4 1/2	d′ 128	5 1/16	128	5 1/16
47	1 7/8	49	2	69	2 3/4	95	3 3/4	95	3 3/4	127	5	c′ 149	5 7/8	149	5 7/8
48	1 7/8	50	2	70	2 3/4	95	3 3/4	98	3 15/16	c 127	5	159	6 1/4	159	6 1/4
48	1 7/8	50	2	70	2 3/4	98	3 7/8	b 107	4 1/4	b′ 130	5 1/8				
50	2	51	2	70	2 3/4	101	4	a 111	4 3/8	a′ 130	5 1/8				
50	2	52	2	70	2 3/4	107	4 1/4								
52	2	52	2	75	3	111	4 3/8								
53	2 1/8	52	2	80	3 1/8	111	4 3/8								
53	2 1/8	54	2 1/8	80	3 1/8	120	4 3/4								
53	2 1/8	55	2 1/8	81	3 1/8										
54	2 1/8	55	2 1/8	82	3 1/4										
55	2 1/8	56	2 1/4	82	3 1/4										
56	2 1/4	57	2 1/4	85	3 3/8										
58	2 1/4	57	2 1/4	86	3 3/8										
58	2 1/4	58	2 1/4	95	3 3/4										
		59	2 3/8	110	4 3/8										
		63	2 1/2												
		64	2 1/2												
		66	2 5/8												
		68	2 5/8												
Av. 50.5	2.0	Av. 52.7	2 1/6	Av. 72.6	2 13/16	Av. 87	3 1/2	Av. 87	3 1/2	Av. 107	4 1/2	Av. 122	4 7/8	Av. 122	4 7/8
Total No. 23.		Total No. 28.		Total No. 24.		Total No. 17.		Total No. 14.		Total No. 14.		Total No. 12.		Total No. 12.	

—Increase in average size in per cent.:
May 10 to June 12, 4.4 per cent.
June 12 to August 22, 38.4 per cent.
August 22 to November 7, 20.8 per cent.
May 10 to November 7, 72 per cent.

March 27 to May 31, 22.9 per cent.
May 31 to September 10, 14.0 per cent.
September 10 to October 4, 0 per cent.
March 27 to October 4, 40.2 per cent.
(Each column represents a separate car).

* Mead and Williams, ('03).

By examining Tables Nos. 25 and 26 it will be observed that the greater number of lobsters which were hatched between June 1 and June 26 (entering the fourth stage June 13 to August 9) were, by the first or middle of September, in the ninth stage, and that *the average length for the normal ninth stage lobster according to Table No. 21 is 32.1 mm.* If the average length of 79 individuals one year from hatching is 53.5 mm., it would seem (according to the normal average percentage of increase for all the earlier stages, 18 per cent.) that the yearling lobsters must be in the neighborhood of the twelfth stage. It is probable that the growth under these more natural conditions may be somewhat slower than when the individuals are carefully fed and kept in their own compartments (to be described later). Under the latter conditions we occasionally meet with lobsters which pass through the first twelve stages before December of the same year in which they are hatched. (See Table No. 26, Lobster No. 30.) Herrick believed that the normal rate of growth in natural environments was more rapid than that obtained in the case of his captive lobsters, which were kept in jars having water circulation. It is most probable that this is true. The difference is, however, probably less than one might expect, since the freedom from injury in aquaria must be of decided advantage. We know that the rate of growth of lobsters kept in their individual compartments is somewhat more rapid than the growth in the large storage cars. The reason for this may be the greater liability to injury when many lobsters are confined together, and the consequent retardation of the rate of growth—a state of affairs which would be in strict accordance with natural conditions where the probability of injury is at least equally as great.

The cars (Plate XXXV) in which the young lobsters were placed at entrance to the fourth stage, and in which all later observations on individual lobsters were carried on, were constructed as follows: Long troughs were built, about 10 feet long 10 inches wide, and 10 inches deep, having sides of No. 12 mesh galvanized iron wire screening. By means of board partitions the inner space was divided into 10 separate compartments in which the young lobsters were placed and through which (when sunk two-thirds their depth) the water made easy circulation by means of the screened sides. The cars were provided with hinged covers which served to protect the young lobsters from both the sun's rays and waves in periods of rough weather.

These storage cars, as described by Dr. Mead, were merely "large wooden boxes provided with sand, gravel, seaweed, etc., to simulate as closely as possible the natural environment. The sides were made of galvanized iron screening, which allowed free circulation of the water. During the summer the cars were suspended from the houseboat or from floats so that the water in them was about 18 inches deep. In the autumn they were provided with tight fitting covers and were sunk in the channel, in from 8 to 10 feet of water, and left undisturbed until spring. The lobsters were frequently fed during the summer, but in the winter no food was given them, although they may have obtained some from the water or from the animals which grew in the car. * * * The question at once arises, does the rate of growth of those lobsters kept in confinement fairly represent the rate of growth in their natural environment? It is impossible to answer this question definitely at the present time, but the following facts have a bearing upon it: The cars seemed to furnish a natural environment, for not only were the lobsters in a healthy condition, but seaweed, oysters, clams, shrimps, mussels, tunicates, barnacles, various specimens of marine worms and other animals, grew inside the cars as rapidly and as normally as in other places." *Mead* ('03).

Thus to summarize: *September finds the average lobster hatched the previous summer in the ninth stage of his existence, his length at this time being* 32 *mm. From observations on large numbers of adolescent lobsters we have deduced the probable average increase for stages* 4 *to* 12 *as* 18.4 *per cent. We know that the average size for* 79 *lobsters, aged approximately one year, is* 53.5 *mm. Applying our estimated per cent. of increase we deduce that a lobster one year old is generally in the twelfth stage.* The three molts between the ninth and the twelfth stage take place between the middle of September and the middle of the following May, for records of 23 lobsters show that they had attained at the latter date (when approximately 11 months old), $^{50}/_{53}$ of the year's growth. From these considerations it becomes evident that *the average lobster passes into the tenth stage in the latter part of September, and into the eleventh stage during the latter part of*

October or the first of November; furthermore, that it lies dormant through the months of December, January, February, and March, molting into the twelfth stage sometime in April or in the first part of May. It is entirely possible, however, that under certain conditions the young lobsters may enter the tenth stage in October or November and undergo two molts in the following spring; but this must be the exception rather than the rule. There are some instances (see Tables Nos. 25, 26) which have fallen under the writer's observation wherein certain individually cared for lobsters passed into even the twelfth stage before winter; but as has been said, these cases are exceptional. In any case, this view is rather in contradiction to Herrick's: *that a lobster under one year old may molt three times between December and the following June, and that a lobster one year old has molted from* 14 *to* 17 *times.*

VII. Observations on the Rate of Growth of Lobsters Over One Year Old.

We will now turn our attention to the rate of growth of lobsters over one year old. Herrick mentions the case of 16 young lobsters which were driven ashore at Woods Hole after a storm on January 16, and whose measurements were from 39 to 83.7 mm. Herrick thinks it possible that *all may have been hatched during the previous summer,* in which case none of them could have been over 8 months old. We know, however, that the young lobsters, at least in the earlier stages, grow more rapidly in Narragansett Bay than in the region of Woods Hole. Hence, since the largest of 79 lobsters *one year old* reared at Wickford was only 79 mm. in length, it is exceedingly doubtful that any of the shore-washed lobsters, recorded by Herrick as 83 mm. in length, could have been less than one year six months old. In this regard the writer would direct attention to records of two yearling lobsters raised from the egg, whose approximate age and stage were known.

TABLE No. 12.

Record of the rate of growth of two yearling lobsters raised at Wickford, R. I.*

Stage 12.			Stage 13.			Stage 14.			Stage 15.			Per cent. of increase for the 3 stages.
Date of molting to	Size.	Stage-period.	Date of molting to	Size.	Stage-period.	Date of molting to	Size.	Stage-period.	Date of molting to	Size.	Stage-period.	
May (?).......	..	..	July 20..	53	33	Aug. 23..	65	57	Oct. 19..	77	..	19.9
May (?).......	48	..	July 20..	61	30	Aug. 20..	70	65	Oct. 27..	84	..	21.9
Average......	..	..	....	57	..	....	67.5	..	....	80.5	..	20.9

*Had not molted again November 28.
†Rather smaller than the average size.

We observe from a study of Table No. 10A, that of 28 yearling lobsters (which as we have attempted to show were in the twelfth stage and which in this case had an average length of 52.7 mm. on June 12) 24 individuals, measured the last of August, had an average length of 72.6 mm. This would represent an average gain of 37 per cent., and we may infer that approximately 2 molts, each representing an increase of about 18 per cent., have taken place. It will be noted that the per cent. of gain corresponds very nearly with our average computed per cent. of increase, *i. e.*, 18.4 per cent., for the lower stages. Thus we assume that *the young lobster enters the thirteenth stage sometime in July, and the fourteenth stage perhaps in August.* Considering for a moment Table No. 12, we note that these deductions coincide very closely with the facts recorded regarding the rate of growth of the two yearling lobsters.

From Table No. 10A, we obtain the further data that of 24 lobsters averaging 73 mm. (and in all probability in the fourteenth stage the last of August) 17 individuals, when measured on November 7, had an average length of 87 mm. From this fact we conclude that *the passage into the fifteenth stage takes place sometime in October,* and note that the actual average increase in length over the fourteenth stage is in this case 21 per cent. By a consideration of Table No. 10A, however, it becomes apparent that several of the lobsters must have molted twice within the times of measurement. If we make allowance for this fact, the estimated average increase for this stage drops to 18 or 19 per cent. This deduction corresponds rather closely with the observations recorded in Table No. 12.

Now it is, that, when we consider the rate of growth during the winter months, an interesting fact is observed. In Table No. 10 it is shown that in the group of 17 lobsters (probably in the fifteenth stage and averaging 87 mm. November 7) 14 individuals which were measured the last of the following March had not increased a millimeter in length since the November measurement. This consideration must have great weight in emphasizing the fact that *young lobsters, at least those over one year old, do not, under natural conditions, molt during the last of November, December, January, February, or March; that is to say, the average lobster passes its second winter in its fifteenth stage, length* 86 *mm.* ($3\frac{3}{8}$ *inches*). During the months of April and May, however, it appears that the length of the 14 individuals last mentioned increased 18.3 per cent. This fact would signify that one molt has occurred and that *a young lobster two years old is in its sixteenth stage, having an average length of* 102 *mm.* ($4\frac{1}{12}$ *inches*).

VIII. Observations on the Rate of Growth of Lobsters over Two Years Old.

We come now to consider the rate of growth of lobsters over two years old. (Stage 16, length 102 mm.) We ascertain from Table No. 10B, that by September 10, after the third summer, the average length is 122 mm. ($4\frac{7}{8}$ inches), showing an increase of about 16 per cent. in the 12 individuals examined. Observations made October 4 reveal no further change in size. From this fact it seems safe to believe that *the average lobster, two years old, enters the seventeenth stage sometime in the late summer of its third year and probably molts again.*

before the winter months of the same year, into the eighteenth stage, experiencing no further change until the following April.

1. *Gradual Diminution in the Percentage of Increase at Molts.*

It is indeed possible, and perhaps probable, that, after the seventeenth or eighteenth stage, the percentage of increase in length for each successive stage undergoes a gradual, though slight, diminution. If we draw conclusions from observations on the rate of development of most of the marine invertebrates, we must believe that in all cases, as the size of the individual slowly approximates to the average growth limit of the species, the rapidity of development becomes gradually less. While among those forms which do not grow by means of an ecdysis, this fact is evinced by a gradual retardation of the growth process, among those animals which do grow by molting, *the change manifests itself as a gradually increasing period of time between successive molts and by a decreasing percentage of gain after each successive molt.* And without doubt this natural retardation in the rate of growth is somewhat accentuated by the average number of injuries to which animals with dispositions so pugnacious are always liable.

On the subject of the rate of growth of lobsters between 5 and 7 inches in length we are able to obtain valuable data from Table No. 10 B, and from other cases which have fallen under the writer's observation. In many instances it is to be regretted that the unfortunate and premature death of many very valuable individuals has placed some difficulties in the path of observation of certain molts, so that in several cases the deductions must appear to a degree speculative. It is most probable, however, that the majority of estimates, even in the instance of the very large lobsters, do not come far distant from the actual facts of the case. If attention be directed to Table No. 10 B, column 1, it appears that the individual lobsters under consideration did not molt more than once before May 31. Considering that lobsters designated a, b, c, d, e, and a′, b′, c′, d′, e′ are identical, we can construct the following table, which should give us some idea of the average per cent. of gain per stage for lobsters about 6 inches in length.

TABLE No. 13.

Data on rate of growth of lobsters between 5 and 6 inches raised at Wickford.

Specimen.	Before Molting.	After Molting.	Increase.	Increase per cent.
a–a′	107 mm.	130 mm.	23 mm.	21.5
b–b′	111	130	19	17.1
c–c′	127	149	22	17.3
d–d′	114	128	14	12.2
e–e′	106	123	17	15.0
g*	132	144	12	9.0
Average				15.4

*A lobster which had been measured for other purposes.

These observations would indicate that *the average per cent. of increase in length for 5 to 6 inch lobsters may be somewhat less than for lobsters in earlier stages* (1 *to* 17). In all probability the lobsters which gave an average of 122 mm. (Table No. 10 B, column No. 4) October 4, molted once more before the last of November. Unfortunately no further records of these lobsters were kept. We know, however, that normally they will not molt again until the following April. From these considerations it appears reasonable to conclude that *a young lobster passes its third winter in the eighteenth stage, length* 141 *mm.* (5⅝ *inches*), *molts again in the spring, probably in April, and by June* 1 (*when approximately three years old*) *is in its nineteenth stage and has an average length of* 162 *mm.* (6½ *inches*).

In the rate of growth of lobsters *over* 6 inches in length we may expect to find a still smaller percentage of increase at each molt. Our data in this case, however, is somewhat limited. Observations upon 15 young lobsters, whose length varied between 5⁵⁄₁₆ and 7¹⁰⁄₁₆ inches, gave results which are embodied in the following table:

TABLE No. 14.

Data on the rate of growth of mutilated "chicken" lobsters.†

Before Molting.	After Molting.	Average Increase.
$5\frac{5}{16}$	$5\frac{11}{16}$	
$6\frac{3}{8}$	$6\frac{15}{16}$	
$6\frac{3}{4}$	$7\frac{4}{16}$	
$7\frac{15}{16}$	$8\frac{7}{16}$	
$6\frac{12}{16}$	$7\frac{4}{16}$	
$8\frac{6}{16}$	$8\frac{15}{16}$	
$7\frac{2}{16}$	$7\frac{8}{16}$	
$7\frac{4}{16}$	$7\frac{10}{16}$	
$6\frac{12}{16}$	$7\frac{6}{16}$	
7*	$7\frac{11}{16}$	
$8\frac{9}{16}$	$9\frac{4}{16}$	
$6\frac{14}{16}$	$7\frac{4}{16}$	
$6\frac{10}{16}$*	$7\frac{5}{16}$	
$6\frac{14}{16}$	$7\frac{7}{16}$	
$7\frac{10}{16}$	$8\frac{3}{16}$	
		8.5 Per cent.

†Most of the individuals in this group of lobsters were intentionally or unintentionally injured, and were being made use of in the study of regeneration.

*Represent specimens which were the least injured.

The foregoing table demonstrates that in this group of lobsters the increase in length is only 8.3 per cent. This unexpectedly small percentage is no doubt partly due to the fact that the lobsters belonged to a set which was used in experiments in regeneration, and nearly every individual possessed two or more regenerating appendages; and this fact, as we have already noted in previous cases (Table No. 6), may reduce the normal percentage of increase, as was the case in the fifth stage, even to 5.3 per cent. We may, perhaps with fairness, estimate 10 to 12 per cent. as the actual rate of increase for normal lobsters of the size under consideration. It may, however, be of advantage to consider the cases of molting lobsters mentioned by Brook ('87). The facts in one instance may be tabulated as follows:

TABLE No. 15.

Showing rate of growth of Brook's lobster, No. 1.

No. of Molt.	Date of Molt.	Size after Molt.	Per cent. of Increase.
..1	(?)	$6\frac{5}{16}$ inches	
..2	July 1	$7\frac{3}{16}$ inches	8.0
..3	December 25	8 inches	11.3
..4	July 25	$8\frac{14}{16}$ inches	10.9
..5	November 19*	$9\frac{6}{16}$ inches	5.7
Average			9.0

*Period, 506 days.

The observations of Brooks, on another and larger lobster, were as follows:

TABLE No. 16.

Showing rate of growth of Brook's lobster, No. 2.

No. of Molt.	Date of Molt.	Size after Molt.	Per cent. of Increase.
1	(?)	$7\frac{3}{16}$ inches	
2	May 19	$7\frac{15}{16}$ inches	10.4
3	September 20	$8\frac{15}{16}$ inches	12.6
4	May 13	$9\frac{6}{16}$ inches	4.8
5	October 13*	$9\frac{12}{16}$ inches	4.3
Average			8.01

*Period, 414 days.

It would appear from the facts above outlined that the average percentage of increase in the length of these lobsters is very slightly greater than those already mentioned in Table No. 14. It must be stated, however, that the two lobsters above mentioned belonged to the European species (*Homarus vulgaris*), and since we know that this species is naturally smaller than the American species, we might reasonably expect a less rapid rate of growth; moreover the lobsters in question were kept in aquaria, where, as we have noted, the rate of growth would probably be a little slower than under natural conditions. Thus we must conclude that the percentage of increase in the case of Brook's lobsters is slightly less than the normal amount of increase for lobsters of the American species of the same size. Herrick probably approximates more closely to the actual conditions in the table here presented as Table No. 3, wherein he determines 12 per cent. as the average increase for lobsters between 5½ and 11½ inches in length. If we omit, however, the first, second, and seventh specimens, an average percentage for the remaining individuals (which represent more closely the size under consideration) drops to 11.4. This, without doubt, represents, with fair accuracy, the average percentage of increase in size for lobsters between 6 and 10 inches in length.

For lobsters over this size the percentage of increase appears to be further diminished. Two lobsters of the group mentioned in Table No. 3, which were over 11 inches in length, showed an average gain of 10.1 per cent. In three European lobsters mentioned by Williamson ('04), the amounts of increase were as follows:

12⅞ inches to 13 inches.
12½ inches to 12⅞ inches.
9½ inches to 10½ inches.

In all other cases of lobsters between 9½ and 12½ inches the amount of increase apparent directly after molting* varied between ¼ and ⅝ inches, showing that even the ultimate amount of gain must have been very slight, in all cases under 8 or 9 per cent. We know that the size of the European species is less than that of the American, and apparently the average percentage of gain in all stages is consequently diminished.

2. *Application of these Considerations to the Rate of Growth of Lobsters Beyond the Nineteenth Stage.*

Let us return now to the consideration of the average lobster which

*It usually happens that, if the lobster be measured directly after molting, there is found but a slight difference in length. It requires some little time, usually a week or more, before the lobster attains his full length.

we left with a length of 162 mm. (6½ inches) in June, at the beginning of his fourth year of life, and in the nineteenth stage. From our observations and those of Herrick and Brook it would appear that *a lobster over 6 inches in length does not molt oftener than twice a year; once in late spring or early summer and again in the autumn.* On this point the data of the following observation would seem to present some surprisingly clear evidence. Out of 48 "chicken" lobsters (6–8 inches) which were confined in cars during the summer months of 1904 at Wickford, it was a noteworthy fact that eleven lobsters from 6 to 7 inches in length molted between September 2 and October 4; that only one 6-inch lobster molted later in October, and not one in July or August. The lobsters were received early in July, and unfortunately it is not known exactly when the previous molt of the 6-inch lobsters took place, but it must have been in the early summer. The greater number of these lobsters were later more or less mutilated for experiments in regeneration, and the record of only 15 has been presented in Table No. 14. The *molting period,* however, was undoubtedly about normal, although, as already stated, the *percentage of increase* in size at each molt was somewhat less than what we must assume for normal. According to the above inferences, then, *the average lobster will enter the twentieth stage sometime in the autumn of his fourth year and at this molt will increase from* 162 *mm.* (6½ *inches*) *to* 180 *mm.* (7¼ *inches*). *In the late spring or early summer the young lobster, now approximately four years old, molts for the twentieth time and enters the twenty-first stage with a length of* 200 *mm.* (8 *inches*).

IX. Differences in the Rate of Growth of the Male and Female Lobster.

1. *Lobsters under Eleven Inches in Length.*

Except in the case of young female lobsters bearing eggs—and such are very seldom found in the 8-inch length—we may expect another molt the following autumn and *will find the lobster in the twenty-second stage with a length of 222 mm.* ($8\frac{7}{8}$ *inches*). From Mr. E. W. Barnes, the Superintendent of the Wickford Station of the Rhode Island Commission of Inland Fisheries, the writer has learned that out of many hundred female lobsters which he examined in the years 1902 to 1905, the smallest lobster which bore eggs was $8\frac{1}{4}$ inches long. There were very few lobsters under 9 inches long which were "in berry." Thus we may conclude that the molting periods for males and females remain about the same until they are past the 9-inch length. Therefore we may believe that *the entrance to the twenty-third stage, with the corresponding length of 247 mm.* ($9\frac{7}{8}$ *inches*), *takes place just before* (*or at any rate very soon after*) *the lobster becomes five years old.* According to statistics furnished by Mr. Barnes, there are few female lobsters which attain the 10-inch length that do not bear eggs; and thus *in the case of the females the rate of growth from this time on must be much diminished.*

It is a well-known fact that the female lobsters extrude their eggs but once in two years, and that the green or unripe eggs are carried about for a period of 11 or 12 months before hatching. Although there are a few cases in which the female lobster is said to have molted just before spawning, the greater number of observations point to the fact that, in general, the molting period of the mature female lobster is limited to a longer or shorter period of time directly following the hatching of the eggs. Consequently, since spawning occurs but once in two years, the molting process can not occur oftener than this; and the rate of growth is correspondingly diminished. This fact is quite in accord with what we know of the cessation of growth that is observable in many marine forms just previous to the spawning period. After the extrusion of the eggs growth again commences and continues until the approach of the next spawning period. The male lobster, on the other hand, maintains the former rate of development; so that, by the twenty-fourth stage, *the average male has attained the length of 275 mm.* (11 *inches*) *and must be at least* 6 *years of age; in the case of the female lobster which has borne eggs from the ninth* *stage, the 11-inch limit can not be reached before 8 years or more, the higher degree of probability being in favor of the larger estimate.**

2. *Lobsters over Eleven Inches in Length.*

This discrepancy in the relative rate of development of male and female lobsters makes itself more evident as a possible explanation of a phenomenon observable in the case of very large lobsters which have been caught from time to time in both European and American waters. In nearly all instances in which the sex has been observed, these "giant" lobsters have been males. Herrick makes note of this fact. Observations made by G. Browne Goode ('84), in 1880 on the length of lobsters in the region of Provincetown, Mass., revealed the fact that, while the largest male lobsters gave an average length of 18 to 22 inches, the females measured only from 15 to 16 inches. All the "giant" lobsters from Rhode Island waters which have come within the writer's observation have been of the male sex. From other localities also there are available numerous statistics to show that the largest lobsters caught have, with hardly an exception, been males. A list of these is presented on a later page. (Table No. 17.)

It is indeed probable that, in these days when the lobster fisheries are being driven to the uttermost, there are few female lobsters which are able to escape the pots during the course of the many years that are necessary for the growth of the female lobster even to a length of 16 inches. As Bumpus ('99) has observed, there are few chances for the continuance of the life of any lobsters over marketable size. This condition of affairs is doubly apparent when we note that of 479 tagged lobsters liberated in the neighborhood of Woods Hole during the summer of 1898, 76 individuals, and probably more,† were recaptured within a period of 4 months, and that in single instances

*We observe that Appellöf ('99) concludes that it requires 6 or 7 years for a lobster to reach sexual maturity ($8\frac{1}{4}$ inches) on the west coast of Norway, and that the number of molts which have been experienced to that time is 17 to 19. Meek ('04), on the other hand, concludes that a lobster 9 to 10 inches long is 4 or 5 years old.

†The facts that many tags were undoubtedly lost, either through accident or by the molting of the lobster, and that several fisherman failed to make any report of tagged lobsters which they had captured, make it extremely probable that more than the 76 lobsters bearing the tags fell into the hands of the lobster fisherman within the time scheduled.

even 20 to 30 per cent. of the liberated lobsters were recaught in less than 3 months.* When we seriously consider such facts as these, and realize that a female lobster which has had the rare good fortune to live to attain a length of 15 inches will produce on an average 7 times the number of eggs laid by a 9-inch lobster, it is a question whether State legislation should protect only the young and often sexually immature lobsters whose productivity is so much less than that of the older and larger individuals—individuals in whom life is cut short long before the period of maximum generative ability has been reached. It is not at all probable that the lobster problem will ever be solved by protecting the lobster in its earlier years alone; nor yet by protecting it only in its old age. Perhaps the time has come when there should be both a maximum and a minimum size limit between which lobsters may be taken. There seems to be no other method of legislation whereby it is possible to effectually combine the highest value of the lobster fisheries to man with the maximum advantage to the lobster itself.

X. Observations on "Giant" Lobsters.

Except the facts presented in the last section, concerning the very large or "giant" lobsters no accurate data regarding the rate of growth is at hand. We are at liberty to believe, however, that by the time a male lobster has attained a length of 10 inches, and perchance earlier, it does not molt oftener than once in a year; and after the 15-inch limit not oftener than once in two years.

This estimate of the frequency of molting is less than that accepted by most observers. Sars ('77) wrote concerning the European lobster, "The lobster changes its skin once a year as long as it grows; when it has ceased growing the changing does not occur so often." It is reasonable to believe, however, that the frequency of the molting period for all lobsters does not differ greatly from the frequency of molting in the case of other aged *macru-*

---

*In European waters it has been estimated, according to Ehrenbaum ('03), that of large number of lobsters liberated 40 per cent. were recaught within a period of 9 months; and that in 2½ years 65 per cent. of them had again come into the pots of the lobster fishermen.

rans, such as many of the larger species of *Palinurus*. Among the latter we find such instances as that of *Palinurus Lalandii* in whose deeply corrugated shell we observe the calcerous tubes of generations of tube dwelling worms. This is indicative of the fact that even in the more aged of these smaller *macrurans* the interval between the molting periods must be extremely long. Similar evidences are to be found in the examination of such forms as *Locorrhynchus crispatus* of the Pacific coast, whose shell forms the dwelling place of a host of marine animals.

It is needless to say that among the lobster fishermen themselves there are widely varying views on the subject of the age of lobsters. While some will maintain that a lobster attains a marketable size in two years, as many others will affirm, with equal sincerity, that at least a dozen years are necessary. The old records of the size of large lobsters are also exceedingly unreliable. As is the case with many marine forms, the few correct reports have become so modified by hearsay and generous repetition, and the few reliable observations have become so interwoven with early and uncertain tradition of monster lobsters, that our exact knowledge of "giant" lobsters is necessarily limited. We know that the European species is smaller than the American; yet according to Boeck ('69), Pontoppidans, the old Norwegian naturalist, records* a huge specimen from the Bay of Evien which was so large and fierce that nobody dared to attack it; and that between the claws it measured at least a fathom. Herrick repeats the tale of Olaus Magnus† regarding the lobsters that lived between the Orkneys and the Hebrides, so large that they could easily catch and squeeze in their claws strong swimmers. Such reports as these can be attributed only to superstitious belief which at all times has played havoc with reliable reports regarding the size and habits of many marine animals.

A lobster as large as the individual represented in Plate XXXIV can not be less than 14 years old and is, in all probability, more. The profusion of marine fauna and flora always found attached to the shells of aged lobsters bears testimony to a life of inactivity and is

*"Norges Naturlige Historie," Kopenhagen, 1753.

†Historia de Gentibus Septentrionalibus, Rome, 1555.

indicative of the fact that a great time must elapse between successive molts. It is true that vast colonies of barnacles and hydroids and algæ and tube-dwelling worms may be developed in a single season, but it is not probable that the excessive growth of these forms, found on the shells of huge lobsters and other aged macrurans, can be interpreted as the result of a single season's setting.

One of the largest lobsters of which accurate data is available is spoken of by Herrick. Its length was somewhat over 20 inches and its weight 23 pounds. In December, 1905, a huge specimen was captured in a fishing trawl outside of the mussel ridges of Rockland, Maine. This lobster is said to have measured 22½ inches and to have weighed 19½ pounds. The fishermen who saw this lobster believed that it was at least 50 years old. This is, with little doubt, an over-estimate, though it is entirely probable that its age was in the neighborhood of 30 years. The largest lobsters from Rhode Island waters which have come within the writer's personal observation were 18½ and 19½ inches long and weighed 11¾ and 19 pounds, respectively. This would seem to indicate that a very slight difference in the length of these large lobsters may be accompanied by a great difference in the weight, although the greater number of recorded lobsters over 20 inches long remain very close to a certain average weight. This fact is readily observed from most of the records which have been made of "giant" lobsters, as will be noted in Table No. 17. It is also apparent that, as Herrick has already suggested, the increase in the weight of the lobster is chiefly the result of gain in the size of the claws, while the body itself may experience but slight change in length. Ehrenbaum ('94) mentions the case of a lobster 42.2 cm. (16¾ inches) long, which gained scarcely a millimeter in length at a molt. Other cases of a similar nature are reported. Though our data on this point are too meagre to warrant far-reaching conclusions, it is fair to judge that the amount of increase for "giant" lobsters is not over 4 per cent. at the most, and that the molting process does not occur oftener than once in several years. According to this estimate, few of the lobsters mentioned in Table No. 17 can be less than 20 years old, and the majority must be much older.

TABLE No. 17.

Giving statistics concerning some of the "giant" lobsters of both European and American species.

Number.	Place Captured.	Date.	Length.	Weight.	Length of "Crushing" Claw.	Length of "Nipping" Claw.	Sex.
1	Salem, Mass.[3] . . .	1850	21¾ in.	20–22 lbs	12½ in.	12⅜ in.	Male.
2	Europe[1].	. . . .	19.4 in.	20–23 lbs.	13.1 in.	12.4 in.	Male.
3	Coast of Norway[2]	1850–56	18.73 in.	10 lbs.	10.23 in.	10.03in.	Male.
4	Boothbay, Me.[3] . .	1856	20¼ in.	20–22 lbs.	12½ in.	13¼ in.*	Male.
5	Belfast, Me.[3]	1891	20 in.	23 lbs.	13⅞ in.	14 in.*	Male.
6	Lubec, Me.	1892	20⅝ in.	20–22 lbs.	13⅛ in.	11½ in.*	Male.
7	Provincetown, Mass.[3]	1894.	20.21 in.	. . . .	. . . .	. . . .	Male.
8	Criehaven, Me.[5] . .	1898	25 in.	25 lbs.	. . . .	. . . .	Male.
9	Newport, R. I.[4] . .	1898	19½ in.	19 lbs.	11¾ in.	11⅞ in.	Male.
10	Mohegan Island, Me.[6]	1899	44 in.†	. . . .	. . . .	. . . .	. . . . . .
11	Narragansett Bay, R. I.	1903	18½ in.	11¾ lbs.	9½ in.	. . . .	Male.
12	Rockland, Me. . . .	1905	22½ in.	19½ lbs.	. . . .	. . . .	Male.

* Measurement from tip of spine near proximal end.

† Total length including claws. The body length must have been about 24 inches.

[1] This specimen is mentioned by Herrick, who also made an estimate of the weight. It is believed to be of the European species, and is now preserved in the Museum of the Academy of Natural Sciences of Philadelphia.

[2] Mentioned by Herrick, on the authority of Dr. Sounberg, of the University of Upsala. This specimen is now in the Bergen Museum.

[3] All mentioned by Herrick, in whose work on the American Lobster more detailed data in measurements may be secured. The Belfast lobster is now preserved in the Museum of Adelbert College, Cleveland, Ohio. The Provincetown lobster is now at the St. Nicholas Hotel, Boston, Mass.

[4] This specimen was caught entangled in a fish trap near Newport, and is now in the possession of the R. I. Commission of Inland Fisheries.

[5] This is a case mentioned by Cobb ('99) on the authority of R. F. Crie & Sons, of Criehaven, Maine. The specimen was caught in a hake trawl off Manticus Rock Light, Maine, in 60 fathoms of water.

[6] This lobster was seen by Cobb, at Peak Island, Maine, in 1899. It was caught off Mohegan Island, and the fisherman was drawing it about the country in a car, and charging a small fee for inspection.

XI. Summary of Facts Thus Far Considered.

In order to present in a clearer and more tangible form a summarized statement of the facts contained in the foregoing pages, the writer has made out the following table, which is based upon the observations already considered and, when they have been wanting, upon pure deduction. The very great variation in the size of lobsters, even of the same age and stage, renders it well-nigh impossible to tell off-hand, by any known means, the exact age of any adult lobster. On the other hand, the size of large numbers of individuals of a certain age must form a general average, on a basis of which, the age of a group of lobsters can be determined with a very fair degree of certainty. It is this average, together with the correlated age, which the writer attempts to formulate in the following table:

TABLE NO. 18.

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.		Increase.			Approximate Time of Molt.	Stage Period.	Sex.
		mm.	In.	mm.	In.	Per cent.			
No. 1	0	8.2	...	...	...	...	June	2.0 days	M. F.
No. 2	3 days	9.6	...	1.4	...	18	June	4.0 days	"
No. 3	7 days	11.4	...	1.8	...	18	June	5.0 days	"
No. 4	12 days	13.5	...	2.1	...	18	June	12.0 days	"
No. 5	24 days	16.0	$\frac{5}{8}$	2.5	...	18	July	11.0 days†	"
No. 6	35 days	18.8	$\frac{3}{4}$	2.8	...	18	July	12.5 days	"
No. 7	7 weeks	22.5	$\frac{7}{8}$	3.7	...	18	August	14.0 days	"
No. 8	9 weeks	26.5	$1\frac{1}{16}$	4.0	...	18	August	15.5 days	"
No. 9	3 months	32.0	$1\frac{1}{4}$	5.5	...	18‡	September	21.0 days	"
No. 10	5 months	37.9	$1\frac{1}{2}$	5.9	...	18	October or November	25.0 days	"
No. 11	9 months	45.0	$1\frac{3}{4}$	7.1	...	18	April	5.0 mos.	"
No. 12	1 year	53.0	$2\frac{1}{8}$	8.0	...	18	June	$1\frac{1}{2}$ mos.	"
No. 13	1 yr. 1 mo.	62.0	$2\frac{1}{2}$	9.0	...	18	July	33.0 days*	"
No. 14	1 yr. 3 mos.	73.0	$2\frac{7}{8}$	11.0	...	18	August or September	51.0 days	"
No. 15	1 yr. 6 mos.	86.0	$3\frac{3}{8}$	13.0	...	18	October or November	...	"
No. 16	2 yrs.	102.0	$4\frac{1}{16}$	16.0	...	18	April or May	...	"
No. 17	2 yrs. 3 mos.	121.0	$4\frac{3}{4}$	19.0	...	18	August	...	"
No. 18	2 yrs. 6 mos.	141.0	$5\frac{5}{8}$	20.0	...	16	November	...	"
No. 19	3 yrs.	162.0	$6\frac{3}{8}$	22.0	...	15	May	...	"
No. 20	3 yrs. 6 mos.	180.0	$7\frac{1}{4}$	18.0	...	11	Autumn[2]	...	"
No. 21	4 yrs.	200.0	8	20.0	...	11	Late Spring	...	"
No. 22	4 yrs. 6 mos.	222.0	$8\frac{7}{8}$	22.0	...	11	Autumn	...	M.
	4 yrs. 6 mos.	222.0	$8\frac{7}{8}$	22.0	...	11	Late Summer or Autumn	...	F.

No. 23	5 yrs.	247.0	$9\frac{7}{8}$	25.0	......	11	Summer	......	M.
	6 yrs. 5 mos.[1]	247.0	$9\frac{7}{8}$	25.0	......	11	Late Summer or Autumn	......	F.
No. 24	6 yrs.	275.0	11	28.0	......	11	Summer	......	M.
	8 yrs. 4 mos.	275.0	11	28.0	......	11	Autumn	......	F.
No. 25	7 yrs.	300.0	12	25.0	......	9	Summer	......	M.
	10 yrs. 4 mos.	300.0	12	25.0	......	9	Autumn	......	F.
No. 26§	8 yrs.	327.0	$13\frac{1}{12}$	27.0	......	9	Summer	......	M.
	12 yrs. 4 mos.	327.0	$13\frac{1}{12}$	27.0	......	9	Autumn	......	F.
No. 27	9 yrs.	356.0	$14\frac{1}{4}$	29.0	......	9	Summer	......	M.
	14 yrs. 4 mos.	356.0	$14\frac{1}{4}$	29.0	......	9	Autumn	......	F.
No. 28	10 yrs.	380.0	$15\frac{1}{4}$	24.0	......	7	Summer	......	M.
	16 yrs. 4 mos.	380.0	$15\frac{1}{4}$	24.0	......	7	Autumn	......	F.
No. 29	12 yrs.	406.0	$16\frac{1}{4}$	26.0	......	7	Summer	......	M.
	18 yrs. 4 mos.	406.0	$16\frac{1}{4}$	26.0	......	7	Autumn	......	F.
No. 30	14 yrs.	431.0	$17\frac{1}{4}$	25.0	......	6	Summer	......	M.
	20 yrs. 4 mos.	431.0	$17\frac{1}{4}$	25.0	......	6	Autumn	......	F.
No. 31	17 yrs.	457.0	$18\frac{1}{4}$	26.0	......	6	Summer	......	M.
No. 32	20 yrs.	480.0	$19\frac{1}{4}$	23.0	......	5	Summer	......	M.
No. 33	23 yrs.	505.0	$20\frac{1}{4}$	25.0	......	5	Summer	......	M.
No. 34	26 yrs.	525.0	21	20.0	......	4	Summer	......	M.
No. 35	29 yrs.	546.0	$21\frac{7}{8}$	21.0	......	4	Summer	......	M.
No. 36	33 yrs.	568.0	$22\frac{3}{4}$	21.0	......	4	Summer	......	M.

*The midsummer stage period is usually the shortest.

†The fifth stage period is generally shorter than the fourth; for explanation see text, p.200.

‡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.

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

[2]After the 18th stage it is very doubtful if the lobster molts oftener than twice in a year.

[3]Approximate.

XII. Influences Which Determine the Rate of Growth.

Inherited Physiological Condition.

Before leaving the subject it is not inappropriate to consider briefly the influences which may modify the rate of growth of the lobster under both artificial and natural conditions. Among these we may expect to find such factors as *temperature, light, food supply, parasites, injuries, and certain individual or group peculiarities which, as is the case with so many other forms, must be attributed to inherited physiological conditions;* for there are breeds of large and small lobsters just as truly as there are varieties of large and undersized individuals of the human race. These differences may be observed even in the egg, and can be traced through successive stages in which the characteristics in question are manifested either by producing large or small, regular or malformed, individuals.*

Provided that the food supply is adequate, *it is probable that water temperature is the influence which most modifies the rate of growth of young lobsters under both natural and artificial conditions.* This influence may produce a difference in the rate of growth, not only of small groups of lobsters at different times in the same season and in the same locality, but also of larger groups of lobsters in different localities where they are subjected to still greater differences in the prevailing water temperatures. The results of individual or group physiological constitution are no doubt partly due to hereditary causes, and are manifested in the difference in size and condition of lobsters when all other factors are equal. These results may, however, often be obscured by the influence of temperature, food, or, in the case of artificially reared lobsters, by other subtle influences, such as light or physical environment, etc. These facts are demonstrated by a comparison of Tables Nos. 25 and 26. That one of these groups of lobsters (Table

*Although we know that there is a great variation in the normal size of the mature egg, there still remains a question to be answered as to whether the prevailing temperature of the water shortly previous to the time of hatching may not exert an important influence in determining the size and condition of young lobsters directly after hatching.

No. 26) was made up of *selected* individuals enabled it to gain at once an advantage which was never again lost. On the other hand, many instances have fallen beneath the observation of the writer in which the majority of young larva, hatching from the eggs of certain lobsters, were peculiarly deformed, usually with respect to the thoracic appendages.

Among such lobsters are found great mortalities at the critical molting periods, and although the writer was successful in raising a few such individuals into the later stages, each successive molt was accompanied by greater discomfiture until most of the specimens died in later molting periods. Those that lived always remained weak and undersized. There were, however, many lobsters which, without showing any signs of malformation, were naturally small and stunted, and whose rate of growth was extremely slow throughout all stages upon which observations were made. This was true, moreover, not alone at times when the water temperature was low, but even when all conditions seemed most favorable to a full and rapid development. Leaving, for the time being, further consideration of the influences of injury and food supply, it is our intention to proceed directly to a brief discussion of the influence of temperature and light upon the rate of development of the young lobster.

XIII. The Influence of Temperature.

It may be said that the rate of development of the lobster from the beginning of embryonic life through the early adolescent stages is, provided the food supply be adequate, more fully determined by the prevailing temperature of the water than by any other one factor. It has been shown again and again that the eggs which mature during the colder part of the season and in cooler waters give rise to individuals which are distinctly undersized, and whose growth is correspondingly slow throughout the remainder of the season. As Mead ('02) has already clearly shown, the influence of the temperature is most effective upon lobsters in the larval stages. In this regard the following table is self-explanatory.

TABLE No. 19.

Showing the effect of variation of temperature upon the rate of development of lobster fry of the first three stages at Wickford, R. I.

Experiment.	Duration of the First Three Stages.	Average Temperature.
1	16 days	65° F.
2	15 days	66° F.
3	13 days	68° F.
4	13 days	68° F.
5	13 days	69° F.
6	10 days	70° F.
7	12 days	72° F.
8	12 days	72° F.
9	10 days	72° F.
10	9 days	72° F.
11	11 days	73° F.

The following table, compiled from data furnished by my friend V. E. Emmel, demonstrates readily the difference in the rates of growth of two groups of lobsters in the fourth stage at different periods of the summer. It is readily observed that the period of least rapid growth is contemporary with the time of lowest water temperature.

TABLE No. 20.

Showing the differences in the rate of development of two groups of fourth stage lobsters under different conditions of water temperature.

Group.	Number of Individuals.	Average Prevailing Temperature.	Maximum Temperature.	Minimum Temperature.	Date of Entrance to Fourth Stage.	Date of Entrance to Fifth Stage.	Duration of Stage Period.
1	42	71.1°	79°	68°	July 21.	Aug. 5.	15.4 days.
2	27	75.5°	82°	74°	July 8.	July 20.	12.0 days.

We would, in this connection, call attention to the very much less rapid development of lobsters in these same stages at the hatchery of the United States Fish Commission at Woods Hole, due to the much lower temperature of the water prevailing in the latter region. This fact is shown by the following table:

TABLE NO. 21.

Showing the effect of temperature upon the rate of development of lobsters in the first three stages at Woods Hole.

Experiment.	Duration of the First Three Stages.	Average Temperature.
1	25 days	60.0° F.
2	21 days	59.5° F.
3	25 days	60.0° F.
4	23 days	59.8° F.

Dannevig ('01) has found also, in his experience with the European lobster, that alterations in the temperature of the water make great differences in the frequency of the molting periods. From him we translate the following to demonstrate the influences of water temperature upon the rapidity of the first two molting processes during a period of 9 days:

Water at 8–10° C., no molts.
Water at 12° C., one molt completed.
Water at 14° C., second molt begun.
Water at 16–22° C., second molt completed.

The following table demonstrates the difference in the rate of growth of lobsters at different points on the Atlantic seaboard:

TABLE No. 22.*

Showing the effect of different prevailing temperatures at various points on the Atlantic coast.

Locality.	Temperature of Water.	Time Required for First Three Stages.
Orrs Island, Me.	57°–63° F.	25–26 days.
Woods Hole, Mass.	63°–65° F.	22–25 days.
Wickford, R. I.	65° F.	16 days.
Wickford, R. I.	72° F.	9 days.
Annisquam, R.I.	76° F.	10 days.

* Gorham ('03).

The temperature has a marked effect, not only upon the *frequency of molting,* but also upon the relative *increase in size* per molt. This result is reached, no doubt, by the stimulation or lack of stimulation of the general metabolic processes which seem to be checked by an unfavorably low temperature, as is the case during the cold winter months. A better conception of the outcome of these circumstances may be obtained by observing the data presented in Table No. 6, although all the facts which have been recorded to demonstrate the difference in size (stage for stage) of the Woods Hole and the Wickford lobsters have an important bearing in this connection. It is, moreover, often noticeable that one stage-period in the early development of the lobster may be briefer, instead of longer, than the stage-period preceding. This has usually been observed in connection with the fourth and fifth stage-periods. No reason has previously been given to account for this phenomenon. In these particular instances, however, it is clear that the unusually brief stage-periods are coincident with the period of maximum water temperature. For illustration attention may be directed to Tables Nos. 5, 6, and 25. Here it is seen that, though the fifth stage-period for the normal 1904 lobsters is 9.5 days, the fourth stage-period is 12 days. Records show that the highest prevailing temperature for the summer of that year occurred between July 11th and 23rd, which was the time when the majority of lobsters were passing through the fifth stage. We further notice in this regard that, while the average amount of increase for the fourth stage lobsters was 15 per cent., the gain in length for the fifth stage individuals was 20 per cent.; which again goes to show that the highest percentage of increase per molt may be coupled with the briefest stage-periods.

XIV. Regarding the Probable Difference in Age of Woods Hole and Wickford Lobsters at Maturity.

It is very probable that the lobsters in the region of Narragansett Bay, and other waters of a correspondingly high temperature, attain a marketable size somewhat sooner than along the coasts of Massachusetts or Maine (the so-called "home of the lobster"). Facts which would seem to warrant such a view may be obtained by examining the tables showing the rate of growth of Herrick's Woods Hole lobsters and by inferences which can be drawn from Table No. 22. In Herricks Woods Hole lobsters (stages 1 to 10)the average amount of increase per stage was approximately 14 per cent. We already know that, as a rule, the average percentage of gain in length, per stage, is never, in the later life of the lobster, greater than in the first 10 stages; and that on the other hand, there is, after the eighteenth stage, a gradual diminution in the rate of increase.*

If we conclude, as Herrick does, that 15.3 per cent. represents accurately the average amount of increase per stage for lobsters under natural conditions at Woods Hole, and if we assume that the facts stated in Table No. 18 regarding the *frequency* of molting are accurate, then we are forced to the conclusion that the average Woods Hole

*It might be inferred that the percentage of increase in length of the *older* Woods Hole lobsters would, as in the case of the early stages, be diminished as a result of the low temperature. It is most probable, however, that the rate of growth of lobsters beyond the eighteenth stage undergoes no great modification from the effect of water temperature. This influence is most effective in the summer months and for lobsters whose stage periods is relatively brief. Since we believe, as already stated, that groups of middle-aged lobsters in regions of different prevailing water temperatures correspond rather closely with one another as regards both the number and the periods of molting, and also as regards the increase in size at each molt, we may still interpret the time of successive molts of Woods Hole lobsters of later stages in the light of the estimates presented in Table No. 18.

or Maine lobster of the male sex which has attained the length of 11 inches, is in the neighborhood of 8 years old, and that the female lobster of this size is perhaps 11 or 12 years old.

If, however, we still accept 15.3 per cent. as the actual rate of increase in length for the earlier stages alone (as Herrick does), and, on the other hand (assuming that 28 mm. ($1\frac{1}{8}$ inches) as ascertained by Herrick, represents about the average size of the tenth stage Woods Hole lobsters), make allowance for the diminution which we know takes place in the rate of increase beyond the eighteenth stage, we arrive at the somewhat absurd conclusion that the Woods Hole lobsters of the male sex and 11 inches in length can be no less than 15 or 16 years old! Very apparently there is some flaw in our reasoning. Either Herrick started his experiments with undersized eggs (very improbable), or the normal rate of growth for Woods Hole lobsters, under natural conditions, is for some reason far greater than that deduced by Herrick from the study of his young lobsters confined in glass jars (very probable), or we have not correctly estimated the number of molts which (up to the twenty-sixth stage) occur within the length of time specified in Table No. 18 (improbable). There can be little doubt that the discrepancy lies in the second of the above mentioned hypotheses, namely, that 15.3 per cent. does not accurately represent the average rate of increase in length for lobsters in the first 18 stages, under natural conditions at Woods Hole; furthermore, that certainly 15.3 per cent. is an overestimate of the average rate of increase for lobsters past the eighteenth stage, in whatever locality they may be. The fact may here be emphasized that the most accurate possible data on the rate of growth of the lobster for *the first* 12 *or* 14 *stages* is absolutely necessary for any correct estimate of the size and age of adult lobsters; for it is upon these first stages, so quickly passed, that the influences of which we have been speaking have their greatest, perhaps their only, effect. Such data we now, for the first time, have in hand, and, as we have already shown, the rate of increase for Wickford lobsters in these earlier stages amounts to 18.4 per cent.

In view of the fact that there are no such data at hand to show the rate of growth of lobsters under natural conditions of environment at Woods Hole, we are unable to determine the actual percentage of increase for the average lobster in Massachusetts waters. The longer duration of the stage-periods in Woods Hole lobsters, however, would almost preclude the possibility of the amount of increase under natural conditions attaining 18.4 per cent. per stage, as at Wickford, for it appears to be a general rule that *the longer the stage-period the less will be the percentage of increase at the molt.* We are thus led to the conclusion that *the average male lobster of the Massachusetts or the Maine coast does not attain the* 11-*inch length before he is* 7 *years of age; and that the female lobster of this length is at least* 9 *years old; while, as we have seen, the Wickford lobster of the same size, if a male, is but* 6 *years old, and the female is not less than* 8.*

According to the foregoing view it might be inferred that lobsters would be more plentiful or larger at the present time in Rhode Island waters than in regions where the prevailing temperature is lower. And indeed this view would appear reasonable, did we not take into consideration, first, the great difference in the character of the coast in the case of Narragansett Bay shores and those of Maine; and secondly, the factor of lobster fishing, which is developed to a proportionately greater extent along the southern New England coast. The coast of Maine is more favorable to the carrying on of a great lobster fishery, not only because its rocky character provides greater protection for lobsters in the early stages, but also because its great extent furnishes a relatively wider field for the industry. The coast of southern New England, on the other hand, is generally characterized by sandy or pebbly beaches sloping gradually into the deeper water. Here also the shore line is more regular, not being frequently indented with the many inlets so characteristic of the northern

*In this regard it may be appropriate to say that it is not at all to be doubted that, under proper artificial conditions, wherein the food supply is adequate and the temperature at a maximum throughout the year, the rate of growth of the lobster might be so hastened that the marketable size (9 inches in Rhode Island) could be attained in a period of four years and perhaps less.

shores. To these differences is to be attributed the greater depletion of lobsters observable in the southern New England fishing grounds. In consideration of these facts it is not difficult to see the need of such means of artificial propagation as has been instituted and carried on so successfully by Dr. A. D. Mead of the Rhode Island Commission of Inland Fisheries.

XV. The Influence of Light.

Another point which must be touched upon is the influence of light upon the rapidity of development. The lobster is naturally a nocturnal animal, or at least he is an individual whose habits of life seldom lead him out of the twilight or darkness of his natural haunts. In captivity, at least, it appears that he is most active after dark. He naturally dwells in the cracks and crevices of the most rocky shores, seldom venturing forth except in search of food, which, when found nearby, will be dragged back into the retreat and there devoured. The stronger the light, the more cautious and seclusive becomes the lobster; and we have observed many cases of adolescent lobsters which would not, though in an apparently famished condition, take a morsel of clam while in the bright sunlight. That a strong light must exercise a disagreeable effect upon them is evinced (in all stages after the fourth) by their efforts to retreat from its rays. During exposure they wander nervously about their cars until they find a dark spot, when they at once cease their activity and remain quiet so long as undisturbed.* The presence of a stimulus which is able to produce such definite reactions as does light can not fail to be of decided advantage or disadvantage to the animal concerned. In consideration of these facts, believing that the intense midday light of midsummer must be disadvantageous to the young lobsters, covers were provided for all the cars in which experiments were being

*This subject of light influence upon the young lobsters has been treated more fully in special article, "Observations upon Some Influences of Light on the Larval and Early Adolescent Stages of the American Lobster," which will be found later on in this report, page 230, Hadley ('06); and also in an article in Science, Hadley ('05).

conducted, thus producing in each compartment the effect of twilight. There are no very definite data to show that this condition did actually create an advantageous influence upon the growth of the young lobsters. It is a noteworthy fact, however, that in the case of other lobsters from the same source, but which were confined in wire cages without covers, the stage-periods were, as a rule, longer and the percentage of increase correspondingly less. The results that have been obtained, though too few to warrant definite conclusions, are stated in the following tables:

TABLE No. 23.

Showing the effect of sunlight upon the duration of the stage-period of fourth stage lobsters.

In Sunlight.			In Twilight.		
Date of Molt to 4th Stage.	Date of Molt to 5th Stage.	Stage-Period.	Date of Molt to 4th Stage.	Date of Molt to 5th Stage.	Stage-Period.
July 23......	July 7....	14 days..	July 23.....	July (1).....	(8) days.
July 23......	July 7....	14 days..	July 23.....	July 5.....	12 days.
July 23......	July 8....	15 days..	July 23.....	July 3.....	10 days.
July 23......	July 9....	16 days..	July 23......	July 5.....	12 days.
July 23......	July 10....	17 days..	July 23.....	July 6.....	13 days.
July 23......	July 5....	12 days..	July 23.....	July 6.....	13 days.
July 23......	July 6....	13 days..	July 23......	July 5.....	12 days.
July 23......	July (15) ...	(22) days..	July 23.....	July 5.....	12 days.
July 23......	July 6....	13 days..	July 23.....	July 6.....	13 days.
July 23......	July 6....	13 days..	July 23.....	July 6.....	13 days.
July 23......	July 10....	17 days..	....	....	....
July 23......	July 8....	15 days..	....	....	....
July 23......	Juiy 10....	17 days..	....	....	....
July 23......	July 6....	13 days..	....	....	....
Average............		14.5 days.	Average............		12.2 days.

TABLE NO. 24.

**Showing the effect of sunlight upon the percentage of increase in size of fourth stage lobsters.*

In Sunlight.			In Twilight.[1]		
Fourth Stage.	Fifth Stage.	Gain per cent.	Fourth Stage.	Fifth Stage.	Gain per cent.
14.5 mm.	17.0 mm.	17.2	14.1 mm.	15.7 mm.	11.3
15.0 mm.	16.8 mm.	12.0	15.5 mm.	17.5 mm.	12.9
14.3 mm.	16.5 mm.	16.0	14.5 mm.	17.5 mm.	20.6
14.7 mm.	17.0 mm.	15.6	14.0 mm.	17.5 mm.	25.0
15.5 mm.	17.5 mm.	12.9	14.0 mm..	17.6 mm.	25.7
15.2 mm.	17.2 mm.	13.1	14.5 mm.	17.0 mm.	17.2
....	....	....	14.3 mm.	16.5 mm.	15.3
Average	....	14.4	Average	....	18.2

*All lobsters recorded passed from the third to the fourth stage on the same day, June 23, and were thus subjected to the same degree of water temperature whose variation, as we know, is able to make a great difference in the duration of the stage-period, as also in the amount of increase in size. Food conditions were also identical in the case of each group.

In this regard attention may be directed once more to Table No. 7. Here it is evident, when we note also the results given in Table No. 5, that the stage-periods of Emmel's normal 1905 lobsters are longer than the average; also that the percentage of increase in length is generally less. It is certainly worthy of notice that these lobsters, during the early stages, were confined in wire cages (Plate XL), and that the covering which was placed over them was insufficient to exclude all of the light; at least they were by no means as well protected as the young lobsters confined in the wooden compartment cars in which, as will be noted from Table No. 5, the duration of the stage-periods was less (1904 and 1905 group).

Not only may the influence of light act directly upon the metabolic activity, and thus upon the rate of development, but also indirectly by favoring the growth of various parasites on the body and appendages. This subject will be considered more appropriately in the following discussion.

XVI. The Influence of Parasites.

One other factor which is able, not only to modify the rate of growth of *Homarus* in the early stages, but even in some cases to cause a tremendous mortality, is the growth of diatoms, algæ, and protozoa. This is particularly true in the earlier stages, and of lobsters raised under artificial conditions. It is probable that this pest is of little harm to young lobsters under natural conditions of environment. The lobsters so attacked are designated as "fuzzy" lobsters, for their appearance is characterized by a heavy fringe of growth on all parts of the body, impeding their activities in both swimming and feeding; and, unless the molting period comes quickly enough, ultimately causing the death of the young lobsters.

Although the question is so often one of life or death to the lobsters attacked, the condition described has a marked effect upon the rate of development of those which do not succumb. The molting periods are delayed and the amount of increase in length for these lobsters is correspondingly small. This diminution in the rate of growth is probably, in this case, directly dependent upon the question of adequate food supply, the possibility of which is so often cut off by the excessive growth of protozoa, diatoms, and algæ. This growth is, in turn, partially dependent upon the conditions of light which surround the individuals. At the Wickford Hatchery it was distinctly observable that, of three groups of lobsters which were placed in dark cars, wire cylinders, and a shallow open box, respectively, the most profuse growth of diatoms and protozoa was upon those which were kept in the brightest light, while those confined in the dark were quite free.*

In the former case, the rate of growth was very slow, and though a

*Regarding the influence of light upon the abundance of growths on the lobsters, Williamson ('04) mentions an interesting fact. In each of two large concrete tanks were placed two female lobsters. In one tank a board shelf afforded protection from the sun so that only the antennæ of the lobsters were exposed to its rays. In the other tank there was no protection from the sun whatsoever. In the first case, after the summer season, the lobsters themselves were free from growth of all sorts, but the antennæ were covered. The bodies and appendages of the lobsters which were confined in the exposed tank were, however, quite hidden by the prolific growth of seaweeds, *Lammaria sp.*, young mussels, etc.

great majority of the individuals ultimately died, those that survived were much undersized. It is probable that half-shading is of little value in preventing the growth of these forms. In the interests of artificial propagation of marine crustaceans it would be highly desirable to determine more carefully the influence of light.*

XVII. The Influence of Food Supply and Injuries.

Although it has been demonstrated that lobsters which have been starved for a long time are materially smaller than the normals, it is not probable that conditions of food supply have much influence in producing differences in the rate of growth of lobsters under natural conditions of environment in different regions of the coast. In consideration of this problem the only question that might be raised is, Do lobsters which live in the neighborhood of large cities or settlements, where sewer outlets, refuse from fish factories, etc., are common, gain any advantage from the increased opportunity for food supply? A negative answer must be given, for the truth is that the lobsters seem generally to shun those portions of the coast where fresh water or sewage, or pollution of any sort, enters. Outside of these areas the distribution of food is so uniform that the question of its obtainment can have little or nothing to do with the differences in rate of growth of lobsters in different localities.

The question of the effect of injury upon the rate of growth has been already briefly considered in the earlier pages of this report. For fuller details on this subject, however, reference may be made to Emmel's ('05) recent publication dealing with the regeneration of lost parts in the lobster, and its relation to the molting process. It is

*It has been determined by Gorham ('03) that, among the diatoms which infest the young lobsters, the most common are *Licmophora tincta* Grunow, *Diatoma hyalinum* (Kützing) Grunow, and *Rhabdonema arcuatum* (Lygnby) Kützing. The first of these attacks the eggs and is most abundant in the larval stages. A certain green alga is also common. Of the protozoans the stalked *Ephelota coronata* is the most abundant both at Woods Hole and Wickford. At the latter station it has often been in greater abundance than the diatoms. Gorham has also isolated a fungus, supposed to be one of the *Hyphomycetacæ* whose life history is not yet known. This fungus, growing inside the body, caused considerable mortality among the young lobsters at Woods Hole. Williamson ('04) reports a disease which, it would appear from his description, may be of a similar nature.

TABLE No. 25.—DATA ON SIZE AND MOLTING PERIODS OF NORMAL AVERAGE LOBSTERS, (SEASON OF 1904) AT WICKFORD, R. I.

Number.	5th Stage. Date.	Size.	Stage Period.	6th Stage. Date.	Size.	Stage Period.	7th Stage. Date.	Size.	Stage Period.	8th Stage. Date.	Size.	Stage Period.	9th Stage. Date.	Size.	Stage Period.	10th Stage. Date.	Size.	Stage Period.	11th Stage. Date.	Size.	Stage Period.	12th Stage. Date.	Size	Stage Period
1	July 13		16	July 29	21.0	12	Aug. 10	23.0	14	Aug. 24	27.0	14	Sept. 10	33.0		**	40.0		**					
2	Aug. 1	15.0	15	Aug. 15																				
3	July 21		12	Aug. 2	19.0	14	Aug. 16	21.0	17	Sept. 20	24.5													
4	July 23	17.0	10	Aug. 2	18.5	14	Aug. 16	22.0	8	Aug. 24	26.0	15	Sept. 8	31.5			34.5							
5	July 23		10	Aug. 2	20.0																			
6	July	17.0	14	Aug. 1	19.5	10	Aug. 11	23.5	13	Aug. 24	29.0	15	Sept. 8	34.5			38.5							
7	July 27	17.0	19	Aug. 5	21.0	14	Aug. 19	25.0		Aug.	28.0													
8	July 26	17.0	21	Aug. 7	20.0																			
9	July 28		18	Aug. 5	19.0	14	Aug. 19	23.0	20	Sept. 8	28.0			33.0			39.0							
10	July 26	15.0		Aug.																				
11	Aug. 2	15.0		Aug.	18.0	18	Sept. 5																	
12	July 26	17.0	9	Aug. 4	20.0		Aug.	24.0		Aug. 23	28.5	18	Sept. 10	33.0										
13	July 28	15.0	9	Aug. 6	18.0	11	Aug. 17	21.0	14	Aug. 30	25.5	16	Sept. 15											
14	July 27	15.0	10	Aug. 6	17.0																			
15	July 30	15.0																						
16	July			Aug. 5	20.0																			
17	July 29	15.5	6	Aug. 4	19.0	15	Aug. 19	23.0	12	Sept. 1	28.0			32.0										
18	July			Aug. 6	18.0	10	Aug. 16	22.0	13	Aug. 29	25.5	19	Sept. 17											
19	July	[illegible]	[illegible]	Aug. [illegible]	[illegible]	[illegible]	Aug. [illegible]	24.0	[illegible]	Aug. [illegible]	[illegible]	[illegible]	[illegible]	[illegible]										
20	July	15.5		Aug. 3	18.5	12	Aug. 15	20.0	17	Sept. 5	22.0													
21	July	15.0		Aug. 7	18.0	14	Aug. 24	21.0	17	Sept. 10	24.5			29.0										
22	July 25		8	Aug. 2	19.0	10	Aug. 12	24.0	14	Aug. 26	28.5	19	Sept. 15	32.5										
23	July	16.0		Aug. 4	19.0	12	Aug. 16	24.0	11	Aug. 27	28.5	21	Sept. 18											
24	July 29	16.0	9	Aug. 7	19.5	13	Aug. 20	22.0	17	Sept. 5														
25	July 25	15.5	9	Aug. 3	19.0	10	Aug. 13	23.0	14	Aug. 27	28.0	18	Sept. 14											
26	July 28	15.5	9	Aug. 6	18.5	11	Aug. 17	22.0	15	Sept. 1														
27	July 29	13 8	9	Aug. 7	17.0	10	Aug. 17	20.0	14	Aug. 30	23.0													
28	July 27	16.0	8	Aug. 4	20.0	13	Aug. 17	23.0	15	Sept. 1														
29	July 25		8	Aug. 22	21.0	11	Aug. 13	25.0	14	Aug. 27	29.0	20	Sept. 16	34.0										
30	July 26	16.0	8	Aug. 3	19.0	11	Aug. 14	22.0	13	Aug. 27	25.0	14	Sept. 10	34.0										
31	July 28		7	Aug. 4	20.0	11	Aug. 15																	
32	July 26	15.5	8	Aug. 3	18.5	11	Aug. 15	22.0	12	Aug. 26	26.0	19	Sept. 14											
33	July 28	15.0	10	Aug. 7	18.0	14	Aug. 20	21.0	13	Sept. 2														
34	July 28		7	Aug. 4	19.5	14	Aug. 18	24.0	13	Aug. 31	28.0			31.5			40.0							
35	July 28	15 0	9	Aug. 6	18.0	12	Aug. 18	21.0	12	Aug. 30	23.0													
36	July 26		10	Aug. 5	20.0																			
37	Aug. 2	14 5	11	Aug. 13	18.0																			
38	Aug 1	15.2	11	Aug. 12		12	Aug. 24	21.5	14	Sept. 7	27.0	12	Sept. 19											
39	Aug. 2	16.2	10	Aug. 12	20 0	13	Aug. 15	23.0	15	Sept. 9														
40	July 30	16.0	9	Aug. 8	18.0	12	Aug. 20	22.0	20	Sept. 9	26.0													
41	July 29	15.0	8	Aug. 6	18.5	12	Aug. 18	22.0	13	Aug. 31														
42	July 27	15.0	8	Aug. 4	19.0	10	Aug. 14	20.0	13	Aug. 27	24.0	16	Sept. 9											
43	July 29	15.0	6	Aug. 4	19.0	10	Aug. 14	23.0																
44	July 29	14.0	19	Aug. 7	18.5	13	Aug. 20	22.0	10	Aug. 30	27.0	14	Sept. 13	32.0			38.0							
45	July 29	15.2	8	Aug. 6	18.5	10	Aug. 16	23.0	14	Aug. 30	26.0													
46	July 29	15.2	9	Aug. 7	18.5	13	Aug. 20	22.0	12	Sept. 1	28.5			31.5										
47	July 29	16.5	8	Aug. 6	20.0	10	Aug. 16	25.0	13	Aug. 29	29.5	16	Sept. 14	36.0			44.0							
48				Aug. 2	19.0	9	Aug. 11	24.0	15	Aug. 26	29.5		Sept.	33.5			40.0							
49	July 28	16.5	9	Aug. 6	19.0	12	Aug. 18	23.0		Sept.	30.0			33.0										
50	July 30	15.5	11	Aug. 10	18.5	12	Aug. 22	22.0	14	Sept. 5	26.0			32.0			38.0			43.0				
51	July 26	17.0	14	Aug. 9	20.0	13	Aug. 22	24.5	15	Sept. 6														
52	July 29	16.0	9	Aug. 7	19.0																			
53	July 29	17.0	7	Aug. 5	21.0	13	Aug. 18	24.5	19	Sept. 6														
54	July 29			Aug. 5	17.0	11	Aug. 16	20.0	18	Sept. 3	30.0			32.0										
55	July 29			Aug. 5	18.0	13	Aug. 18	22.0	13	Aug. 30	27.5	14	Sept. 13	29.5			33.0			39.0				
56	July 29	14.8	9	Aug. 7	18.5	14	Aug. 21	21.0	10	Aug. 30	24.5	15	Sept. 14	29.5			31.5							
57	July 30	14.8	9	Aug. 8	18.0	13	Aug. 21	22.0	13	Sept. 3														
58	July 30	15.0	14	Aug. 13	18.0	9	Aug. 22	22.0																
59	July 30	16.0	8	Aug. 7	20.0																			
60	July 30	15.0	7	Aug. 6	19.0	15	Aug.	22.5		Aug. 28	23.5	13	Sept. 10	29.0			31.5							
61	July 29	14.5	8	Aug. 6	17.0	9	Aug. 15	20.0																
62	July 28		8	Aug. 5	17.0	10	Aug. 15	20.0	14	Aug. 29		16	Sept. 14											
63	July 28	13.5	9	Aug. 6																				
64	July 29		7	Aug. 5	20.0	10	Aug. 15	25.0																
65	July 30	14.0	8	Aug. 7	17.0		Aug.	21.0		Aug. 27				30.0										
66	July 27		7	Aug. 3	20.0	10	Aug. 13	25.0	12	Aug. 25	32.*	15	Sept. 9	37.*			47.*							
67	July 27		8	Aug. 4	18.0	11	Aug. 15	22.5																
68	July 27	17.0	10	Aug. 6	21.0	19	Aug. 25	26.5	14	Sept. 8	30.0			37.0										
69	July 27		7	Aug. 3	20.0	10	Aug. 13	24.0	12	Aug. 25	30.0													
70	July 27		9	Aug. 5		14	Aug. 19																	
71	July 29	15.0	9	Aug. 7	21.8	15	Aug. 22	21.5																
72	July 27		11	Aug. 7	19.5	12	Aug. 19	21.0	15	Sept. 3														
73	July 27		7	Aug. 3	19.0	10	Aug. 13	22.0																
74	July 27		8	Aug. 4	19.5	13	Aug. 17	23.0	17	Sept. 3														
75	July [illegible]		[illegible]	Aug. 3	20.0	14	Aug. 17	25.0	21	Sept. 7	[illegible]													
76	July 27		8	Aug. 4	20.0	22	Aug. 26	17.0		Sept. 12														
77	July 26		9	Aug. 4	18.0	20	Aug. 24	22.0	15	Sept. 8	31.0													
78													Aug. 1	33.0			38.0			44.0			51.0	
79										Aug. 5	25.0	13	Aug. 18	30.0			34.0							
80										Aug. 6	25.0	13	Aug. 19	31.0										
81										Aug. 6	27.5	13	Aug. 19	31.0	19	Sept. 7	37.5							
82														30.0		Aug. 7	36.0							
83														33.0		Aug. 31	38.9			44.5				
84													Aug. 13	32.5	34	Sept. 16	36.5	25	Oct. 11	44.0				
		mm.	da.		mm.	da.		mm.	da.		mm.	da.		mm.	da.		mm.	da.		mm.	da.		mm.	da.
	Average.	15.5	9.5	Average.	18.6	12.7	Average.	22.5	14.3	Average.	20.5	16.0	Average.	32.1		Average.	37.9		Average.	42.9		Average.	51.0	

*Represents a specimen whose growth was much greater and more rapid than that of the average lobster. In the successive stages the gains in length are as follows:
- 5th to 6th stage, 25 %.
- 6th to 7th stage, 28 %.
- 7th to 8th stage, 15 %.
- 8th to 9th stage, 27 %.

It will also be noted in connection with this specimen that the successive stage-periods are much shorter than those of the average.

The normal percentage of gain in length for the successive stages are as follows:
- 5th to 6th stage, 22 %.
- 6th to 7th stage, 21 %.
- 7th to 8th stage, 17 %.
- 8th to 9th stage, 21 %.
- 9th to 10th stage, 17 %.
- 10th to 11th stage, 14 %.

Of the 12th stage lobsters, too few were examined to give valuable results by percentages.

**Unfortunately the difficulty in carrying on observations after September 15 prevented data on the stage-period of the 10th and 11th stage lobsters. The same difficulty prevented complete data for the 9th stage.

11th stage lobsters.

sufficient for us to state here that the conditions which favor the chance of mutilation in the lobster are, like the conditions of food supply, evenly distributed in all localities and can have no influence in causing variations in the rate of growth of groups of lobsters in different places, although in single instances their effect in retarding the rate of growth may be great.

Table No. 26.—DATA ON SIZE AND MOLTING PERIOD OF NORMAL SELECTED LOBSTERS, (SEASON OF 1905).

Number.	4th Stage.			5th Stage.			6th Stage.			7th Stage.			8th Stage.		
	Date of Molting.	Size.	Stage Period.	Date of Molting.	Size.	Stage Period.	Date of Molting.	Size.	Stage Period.	Date of Molting.	Size.	Stage Period.	Date of Molting.	Size.	Stage Period.
1	....	......	......	....	......	......	....	......	......	....	......	......	Aug. 22...	31.0	16
2	July 10...	14.0	10	July 20...	17.0	9	July 29...	......	15	Aug. 13...	25.7	14	Aug. 27...	31.0	14
3	July 10...	13.5	12	July 22...	15.0	13	Aug. 3...	19.6	13	Aug. 16...	23.0	......	N.§	......	......
4	July 10...	13.8	12	July 22...	......	14	Aug. 4...	20.6	13	Aug. 17...	......	......	N.	......	......
5	July 4...	13.9	13	July 17...	15.2	10	July 27...	17.8	11	Aug. 7...	22.0	14	Aug. 21...	25.0	15
6	July 4...	14.2	(18)	July 22...	17.0	16	Aug. 7...	......	10	Aug. 17...	28.1	13	Aug. 30...	35.0	19
7	July 4...	14.2	12	July 16...	16.9	9	July 25...	20.5	9	Aug. 3...	......	13	Aug. 16...	32.3	12
8	July 4...	......	(18)	July 22...	17.4	13	Aug. 4...	23.0	13	Aug. 17...	29.0	16	Sept. 2...	......	19
9	June 23...	14.1	8	July 1...	15.5	......	....	......	......	....	......	......	....	......	......
10	June 29...	14.7	11	July 10...	16.3	10	July 20...	19.6	15	Aug. 4...	26.0	15	Aug. 19...	33.0	......
11	July 4...	13.7	12	July 16...	16.0	10	July 26...	22.0	S.§	N.	25.1	......	Sept. 25...	30.0	15
12	July 12...	14.0	12	July 24...	17.5	13	Aug. 6...	......	11	Aug. 17...	29.0	12	Aug. 29...	34.7	19
13	July 10...	......	12	July 22...	......	12	Aug. 3...	19.0	16	Aug. 19...	22.3	......	N.	27.0	......
14	July 4...	14.0	11	July 15...	17.0	S	N.	19.0	......	Aug. 17...	22.0	15	Sept. 1...	31.0	......
15	July 10...	......	12	July 22...	17.0	16	Aug. 9...	22.5	12	Aug. 21...	29.0	14	Sept. 4...	38.0	14
16	July 4...	14.9	11	July 15...	17.9	9	July 24...	20.5	......	....	......	......	....	......	......
17	July 4...	14.8	14	July 18...	16.1	11	July 29...	......	......	N.	27.0	......	....	......	......
18	July 4...	13.8	14	July 18...	15.1	......	....	......	......	....	......	......	....	......	......
19	July 10...	......	11	July 21...	......	11	Aug. 2...	19.2	14	Aug. 16...	25.5	12	Aug. 28...	30.0	17

§ N=No record secured.

Table No. 26.—DATA ON SIZE AND MOLTING PERIOD OF NORMAL SELECTED LOBSTERS, (SEASON OF 1905).—Continued.

Number.	4th Stage.			5th Stage.			6th Stage.			7th Stage.			8th Stage.		
	Date of Molting.	Size.	Stage Period.	Date of Molting.	Size.	Stage Period.	Date of Molting.	Size.	Stage Period.	Date of Molting.	Size.	Stage Period.	Date of Molting.	Size.	Stage Period.
20	July 4...	14.0	12	July 16...	16.2	....	....	....	....	....	....	....	....	....	....
21	July 10...	14.2	13	July 23...	17.0	12	Aug. 4...	18.0	....	N.	20.0	....	Sept. 2...	26.0	13
22	June 15...	....	10	June 25...	14.0	....	....	....	....	....	....	....	....	....	....
23	July 4...	15.1	10	July 14...	17.2	....	....	....	....	....	....	....	....	....	....
24	July 4...	16.0	9	July 13...	18.0	8	July 21...	21.0	11	Aug. 2...	28.0	12	Aug. 16...	33.8	13
25	July 2...	14.3	9	July 11...	16.8	....	....	....	....	....	....	....	....	....	....
26	July 4...	14.3	11	July 15...	17.5	11	July 26...	21.3	....	N.	28.0	....	Aug. 15...	34.2	13
27	N.	....	....	July 4...	16.1	9	July 13...	20.0	9	July 21...	25.0	12	Aug. 2...	31.0	13
28	June 23...	....	12	July 5...	16.	10	July 15...	19.0	9	July 24...	23.0	11	Aug. 4...	28.0	13
29	June 15...	....	9	June 24...	17.5	14	July 8...	22.0	....	....	....	....	....	....	....
30	N.	....	....	N.	16.5	....	July 12...	20.0	9	July 21...	24.0	11	Aug. 2...	30.0	14
31	June 23...	....	10	July 3...	17.0	16	July 19...	20.9	10	July 29...	35.5	16	Aug. 14...	32.0	13
32	July 2...	....	11	July 13...	17.0	10	July 23...	20.7	12	Aug. 4...	24.0	18	Aug. 22...	30.0	....
33	July 2...	14.0	11	July 13...	....	....	N.	19.8	....	N.	23.0	....	....	....	....
34	July 4...	....	12	July 16...	17.1	13	July 29...	....	13	Aug. 11...	24.3	13	Aug. 24...	30.5	....
35	July 4...	15.0	12	July 16...	16.8	10	July 26...	....	13	Aug. 8...	26.0	13	Aug. 21...	31.0	15
36	N.	15.0	....	....	17.0	....	July 10...	19.6	9	July 19...	24.5	11	July 30...	31.0	17
37	July 4...	14.7	11	July 15...	17.1	13	July 28...	19.2	....	....	....	....	....	....	....
38	June 23...	13.5	12	July 5...	17.3	13	July 18...	19.5	....	N.	25.4	....	....	....	....

TABLE NO. 26. DATA ON SIZE AND MOLTING PERIOD OF NORMAL SELECTED LOBSTERS, (SEASON OF 1905).—Continued.

Number.	4th Stage.			5th Stage			6th Stage.			7th Stage.			8th Stage.		
	Date of Molting.	Size.	Stage Period.	Date of Molting.	Size.	Stage Period.	Date of Molting.	Size.	Stage Period.	Date of Molting.	Size.	Stage Period.	Date of Molting.	Size.	Stage Period.
39	N.	......	......	June 27...	16.5	10	July 7...	20.7	......	......	......	......	......	......	......
40	N.	14.0	......	June 29...	......	11	July 9...	20.3	S.	July 9...	24.0	14	July 23...	32.0	15
41	June 29...	......	13	July 12...	17.6	S.	N.	20.0	......	Aug. 7...	23.7	15	Aug. 22...	28.2	26
42	N.	......	......	N.	17.5	......	July 15...	21.5	11	July 26...	24.4	......	......	......	......
43	July 2...	14.3	10	July 12...	17.0	8	July 20...	21.0	12	Aug. 1...	26.0	14	Aug. 15...	33.5	13
44	June 23...	14.5	13	July 6...	17.5	13	July 19...	22.0	13	Aug. 1...	26.5	13	Aug. 14...	32.3	14
45	July 4...	14.0	11	July 15...	17.5	10	July 25...	22.2	11	Aug. 5...	27.0	12	Aug. 17...	32.4	......
46	July 4...	15.0	11	July 15...	17.4	......	......	......	......	......	......	......	......	......	......
47	June 23...	14.0	......	N.	17.5	......	July 20...	20.0	12	Aug. 1...	24.0	14	Aug. 15...	29.0	13
48	N.	......	......	N.	......	......	Aug. 2...	24.0	14	Aug. 16...	29.0	13	Aug. 29...	34.0	......
49	June 23...	14.0	13	July 6...	17.6	......	......	......	......	......	......	......	......	......	......
50	June 23...	......	12	July 5...	17.0	......	......	......	......	......	......	......	......	......	......
51	N.	......	......	N.	18.0	......	July 12...	21.0	13	July 25...	25.0	......	......	......	......
52	June 23...	14.5	12	July 5...	17.0	14	July 19...	23.2	......	......	......	......	......	......	......
53	June 23...	14.3	13	July 6...	16.5	......	......	20.0	......	......	......	......	......	......	......
54	June 23...	15.5	13	July 6...	17.5	......	......	......	......	......	......	......	......	......	......
		mm.	days.		mm.	days.		mm.	days.		mm.	days.		mm.	days.
	Average...	14.4	11.7	Average...	17.0	11.2	Average...	20.5	12.2	Average...	24.6	13.5	Average...	31.3	15.1

S=Lobster died or killed and substituted by another.

TABLE No. 26.—DATA ON SIZE AND MOLTING PERIOD OF NORMAL SELECTED LOBSTERS, (SEASON OF 1905).—Continued.

Number.	9TH STAGE.			10TH STAGE.			11TH STAGE.			12TH STAGE.			13TH STAGE.		
	Date of Molting.	Size.	Stage Period.	Date of Molting.	Size.	Stage Period.	Date of Molting.	Size.	Stage Period.	Date of Molting.	Size.	Stage Period.	Date of Molting.	Size.	Stage Period.
1	Sept. 7	38.0	16	Sept. 23	48.5										
2	Sept. 10	38.2	17	Sept. 27	46.3										
3	Sept. 4	32.0	16	Sept. 20	38.3										
4	N.	41.6													
5	Sept. 5	31.0		Sept. 21	36.0	27	Oct. 18	43.0							
6	Sept. 18	41.0	20	Oct. 8	50.0										
7	Aug. 28	38.0		Sept.	46.2										
8	Sept. 21	41.2	(32)	Oct. 23	51.0										
9															
10															
11	Oct. 10	37.0													
12	Sept. 17	43.5	34	Oct. 21	51.0										
13		33.0													
14															
15	Sept. 18	41.4													
16															
17															
18															
19	Sept. 14	37.2	35	Oct. 19	45.0										

TABLE NO. 26.—DATA ON SIZE AND MOLTING PERIOD OF NORMAL SELECTED LOBSTERS, (SEASON OF 1905).—Continued.

Number.	9th Stage.			10th Stage.			11th Stage.			12th Stage.			13th Stage.		
	Date of Molting.	Size.	Stage Period.	Date of Molting.	Size.	Stage Period.	Date of Molting.	Size.	Stage Period.	Date of Molting.	Size.	Stage Period.	Date of Molting.	Size.	Stage Period.
20															
21	Sept. 15	31.0	25	Oct. 10	38.5										
22															
23															
24	Aug. 29														
25															
26	Aug. 28	41.0	17	Sept. 14	49.4										
27	Aug. 15	37.2	14	Aug. 29	45.0	19	Sept. 17	55.6							
28	Aug. 17	35.2	19	Sept. 6	42.0	35	Oct. 11	51.0							
29															
30	Aug. 16	36.0	12	Aug. 28	43.5	21	Sept. 18	54.3	38	Oct. 26	59.0				
31	Aug. 27	37.0	16	Sept. 12	44.7	22	Nov. 4	54.0							
32	N.			Sept. 30	44.0										
33															
34	N.			Sept. 29	48.0										
35	Sept. 5	37.5	20	Sept. 25	46.7	29	Oct. 24	55.5							
36	Aug. 16	36.0	29	Sept. 14	42.5										
37															
38															

TABLE NO. 26.—DATA ON SIZE AND MOLTING PERIOD OF NORMAL SELECTED LOBSTERS, (SEASON OF 1905).—Concluded.

Number.	9th Stage.			10th Stage.			11th Stage.			12th Stage.			13th Stage.		
	Date of Molting.	Size.	Stage Period.	Date of Molting.	Size.	Stage Period.	Date of Molting.	Size.	Stage Period.	Date of Molting.	Size.	Stage Period.	Date of Molting.	Size.	Stage Period.
39															
40	Aug. 7	38.2	18	Aug. 25	47.0	20	Sept. 15	54.7							
41	Sept. 17	30.5	23	Oct. 10	38.0										
42															
43	Aug. 28	42.4	18	Sept. 15	52.2	24	Oct. 9	64.*							
44	Aug. 28	39.0	18	Sept. 15	44.0	34	Oct. 19	57.5							
45	N.			Sept. 26	46.0										
46															
47	Aug. 28	35.4	21	Sept. 18	43.3	20	Oct. 8	52.8							
48															
49															
50															
51															
52															
53															
54															
		mm.	days.		mm.	days.		mm.	days						
	Average	37.0	21	Average	45.0	25.1	Average	54.2	38.						

*Represents a specimen occasionally met with whose growth exceeds all others. In this case the increase in length is as follows: 4th to 5th stage, gain of 18.7 %; 5th to 6th stage, gain of 23.5 %; 6th to 7th stage, gain of 23.8 %; 7th to 8th stage, gain of 31.1 %; 8th to 9th stage, gain of 26.5 %; 9th to 10th stage, gain of 23.1 %; 10th to 11th stage, gain of 22.6 %.

As will also be observed in connection with this specimen, the stage periods are shorter than the average. A similar case is given in note to lobster No. 66 in Table No. 25.

XVIII. Summary.*

I. The Rate of Growth.

1. The rate of growth of the lobster is much less rapid than has been estimated by previous observers.

2. We find the average amount of increase at each molt to be 18.4 per cent. for the early stages; and this percentage undergoes a gradual diminution through later successive molts, so that the gain in large lobsters is very slight.

3. The average female lobster lays eggs for the first time in the summer of its sixth year, when in the twenty-third stage.

4. Beyond the twenty-second stage the male lobster grows more rapidly than the female. This explains the fact that nearly all the "giant" lobsters are of the male sex.

5. By the time the 9-inch length is reached the male lobster, in Rhode Island or other warm waters, is at least four and one-half years old; the female of the same length, if she has not borne eggs, is about the same age.

6. The lobsters in Narragansett Bay probably attain marketable size (9 inches in Rhode Island) a year sooner than do the Massachusetts or Maine lobsters.

II. Influences on the Rate of Growth.

1. The chief influences which modify the rate of growth of lobsters are water temperature, food supply, light, and injuries. They are most effective for the early stages.

2. Temperature is largely responsible for the differences in size of lobsters of the same age in different localities. This results from

*In addition to the above we would make reference to Table No. 18 which, together with the portions of the foregoing statement which have been printed in italics, embodies the most important facts considered in the exposition.

the influence upon (1) frequency of the molting process; (2) per cent. of increase in length of molts.

3. A decrease in food supply or the presence of injuries prolong the stage periods and diminish the rate of growth.

4. Excessive light may modify the rate of growth by (1) increasing the duration of the stage periods; (2) by decreasing the percentage of increase at each molt, and (3) indirectly, by favoring the growth of parasites.

The writer would take this opportunity to acknowledge his indebtedness to Dr. A. D. Mead and Prof. F. P. Gorham, of Brown University, for many helpful suggestions and references; to Mr. V. E. Emmel for valuable data on the effect of injury and regeneration upon the growth of the lobster, also to Mr. E. W. Barnes, Assistant Superintendent of the Wickford Experiment Station, for many kindnesses.

XIX. Bibliography.

'95. Allen—"The Reproduction of the Lobster." *Journal of the Marine Biological Association*, 1895–1897, N.S. IV, 60.

'99. Appellöf—"Mittheilungen aus der Lebensweise des Hummers." *Mittheil. d. Deutschen See fischerei-Vereins.* Berlin, 1899, Nr. 4.

'99–'01. Appellöf—Articles in *Selskabet for de norske fiskeriers fremme.* 1899, p. 37; 1900, p. 22; 1901, p. 44.

'69. Boeck, Alex.—"Om dets Norske Hummerfiske og dets Historie." Copenhagen, 1868–1869.

'87. Brook, George—"Notes on the Reproduction of Lost Parts in the Lobster (*Homarus vulgaris*)." *Proc. Roy. Physical Society of Edinburgh*, 1887, IX, 370.

'77. Buckland, Frank—Reports on the Crab and Lobster Fisheries of England and Wales, of Scotland and Ireland. London, 1877.

'99. Bumpus, H. C.—"On the Movements of Certain Lobsters Liberated at Woods Hole during the Summer of 1898." *U. S. Fish Commission Bulletin*, 1899, XIX, 225–230.

'05. Chadwick—"Experiments in Lobster Rearing." *Report for* 1904 *on Lancashire Sea-Fisheries Laboratory and Sea-Fish Hatchery at Piel.* Liverpool, 1905.

'99. Cobb—"The Lobster Fishery of Maine." *U. S. Fish Commission Bulletin*, 1899, XIX, No. 734.

'43. Couch, Jonathan—"On the Process of Exuviation and Growth in Crabs and Lobsters and other British Species of Stalk-Eyed Crustacean Animals." *The Eleventh Annual Report of the Royal Cornwall Polytechnic Society*, Falmouth, 1843.

'43. COUCH, R. Q.—"On the Metamorphosis of Decapod Crustacea." *Eleventh Annual Report of the Royal Cornwall Polytechnic Society*, Falmouth, 1843.

'97. CUNNINGHAM—"Lobster Rearing." Cornwall County Council Instruction Committee. *Report of the Lecturer on Fishery Subjects* for the years 1897–1898; 1899–1900.

'85. DANNEVIG, G. M.—"Beretning over Verksomheden ved Udkaeckningsanstalten for Saltvandfisk." Arendal, 1885; or a reprint entitled, "On Hummeravl in Dansk Fiskeritende," from A. Feddersen. 1886.

'01. DANNEVIG, G. M.—Various articles in *Selskabet for de norske fiskeriers fremme*. 1892 to 1901.

'94. EHRENBAUM, ERNST—"Der Helgolander Hummer, ein Gegenstand Deutsche Fischerei." *Wissensch. Meeresuntersuch. herausg. von der Kommission zur Untersuch. der deutschen Meere in Kiel u. der biologischen Anstalt auf Helgoland.* Kiel u. Leipsig, 1894, I, 277–300.

'03. EHRENBAUM, ERNST—"Neuere Untersuchungen über den Hummer," *Mittheilungen des Deutschen Seefischerei-Vereins*, 1903, Nr. 3, Helgoland.

'04. EMMEL, V. E.—"Regeneration of Lost Parts in the Lobster (*Homarus americanus*)." *Report of the Rhode Island Commission of Inland Fisheries, for* 1904. *Reprint*, 1905.

'05. EMMEL, V. E.—"The Relation of Regeneration to the Molting Process of the Lobster (*Homarus americanus*)." *Report of the Rhode Island Commission of Inland Fisheries* for 1905. *Reprint*, 1905.

'88. EWART AND FULTON—"The Scottish Lobster Fishery." *Sixth Annual Report of the Fishery Board for Scotland*, 1888.

'96. FULLARTON—"The European Lobster: Breeding and Development." *Fourteenth Annual Report of the Fishery Board for Scotland*, Pt. III. Edinburgh, 1896.

'84. GOODE, G. BROWNE—"The Fish and Fisheries Industries of the United States." Washington, D. C., 1884.

'03. GORHAM, F. P.—"Causes of death in artificially-reared lobster fry." *U. S. Fish Commission Report*, 1903, p. 139.

'05. HADLEY, P. B.—"The changes in form and color in successive stages of the American lobster." *Report of the Rhode Island Commission of Inland Fisheries for* 1904. *Reprint*, 1905.

'05. HADLEY, P. B.—"Phototropism in the larval and early adolescent stages of *Homarus americanus*." *Science*, 1905, XXII, 675.

'06. HADLEY, P. B.—"Observations upon some influences of light on the larval and early adolescent stages of the American lobster." *Report of the Rhode Island Commission of Inland Fisheries for* 1905. *Reprint*, 1906.

'95. HERRICK, F. H.—"The American Lobster; a Study of its Habits and Development." *U. S. Fish Commission Bulletin*, 1895, XV, 1–252.

'01. HERRICK, F. H.—"The Reproductive Period of the Lobster." *U. S. Fish Commission Bulletin*, 1901, XXI, 161.

'02. MEAD, A. D.—"Habits and Growth of Young Lobsters and Experiments in Lobster Culture." *Report of the Rhode Island Commission of Inland Fisheries for* 1902.

'03. MEAD, A. D., and WILLIAMS, L. W.—"Habits and Growth of the Lobster and Experiments in Lobster Culture." *Report of the Rhode Island Commission of Inland Fisheries for* 1903.

'04. MEEK—"The Crab and Lobster Fisheries of Northumberland." *Northumberland Sea-Fisheries Committee, Report on the Scientific Investigation for the year* 1904. Newcastle-on-Tyne.

'86. PACKARD, A. S.—"The Molting of the Lobster." *Am. Nat.*, 1886, XX, 173.

'97. PRINCE—"Natural History of the Lobster with special Reference to the Canadian Lobster Industry." *Twenty-ninth Annual Report of the Department of Marine and Fisheries, Fisheries Branch.* Ottawa, 1897.

'74. SARS, G. O.—"On Hummereus postembryonale Udvekling." *Selskabs Forhandlinger.* Christiana, 1874, p. 1–28.

'77. SARS, G. O.—Report made to the Department of the Interior of investigations of the salt water fisheries of Norway during the years 1874–1877. Also translation in *U. S. Fish Commission Report* for 1877.

'03. SHERWOOD, GEORGE H.—"Experiments in Lobster Rearing." *U. S. Fish Commission Report* for 1903. Also a reprint, *Report of the Special Commission for the Investigation of the Lobster and Soft-shell Clam.* Washington, 1903.

'03. SCOTT—"On the Spawning of the Common Lobster." *Report for* 1902 *on the Lancashire Sea-Fisheries Laboratory and Sea-Fish Hatchery at Piel,* No. XI, 1903, Liverpool.

'71. SMITH, S. I.—"The Early Stages of the American Lobster (*Homarus Americanus,* Edwards)." *Trans. Connecticut Academy of Arts and Sciences,* 1871–1873, II, 351.

'04. WILLIAMSON—"A Contribution to the Life History of the Lobster (*Homarus vulgaris.*)" *Twenty-third Annual Report to the Fishery Board for Scotland for the year* 1904. Aberdeen.

'05. ZELENY.—"Compensatory Regulation," "Regeneration in the Cray-fish." *Journ. of Exp. Zool.,* 1905, II, 1.

XX. List of Tables.

XXI. List of Plates.

EXPLANATION OF PLATES 26 AND 27.

First larval stage; length, 8 mm.; age, 3 days.

FIRST ANTENNÆ:

Project hardly to the end of the rostrum; endopodites have begun to bud off from the exopodites; the former are furnished with one long seta; the latter are tufted with four or five setæ. (The first antennæ are here described as if biramous.)

SECOND ANTENNÆ:

Exopodites and endopodites are about equal in length; edges of former are fringed with a variable number of long feathered setæ; the ends of the latter are tipped with several long setæ; the antennal segments are not yet visible.

EYES:

Very large and prominent; they contain in life a white iridescent pigment.

MAXILLIPEDS, SECOND AND THIRD PAIR:

These are furnished with exopodites.

CHELIPEDS:

These are furnished with exopodites or swimming appendages; the dactyl of the claw opens upward and outward.

AMBULATORY APPENDAGES:

The first two pairs have the rudiments of claws; the last two pairs have not. All are furnished with exopodites; gills (as also is the case with the maxillipeds and chelipeds) are attached beneath the carapace border to the first segment (coxopodite).

ABDOMINAL APPENDAGES:

These have not yet appeared, though they may often be seen in the first stage lobster as buds beneath the cuticle, on the under side of the abdomen.

TAIL:

Has the shape of a simple fan; the exopodites of the last abdominal segment have not yet appeared; the posterior margin is bordered with short, spine-like setæ.

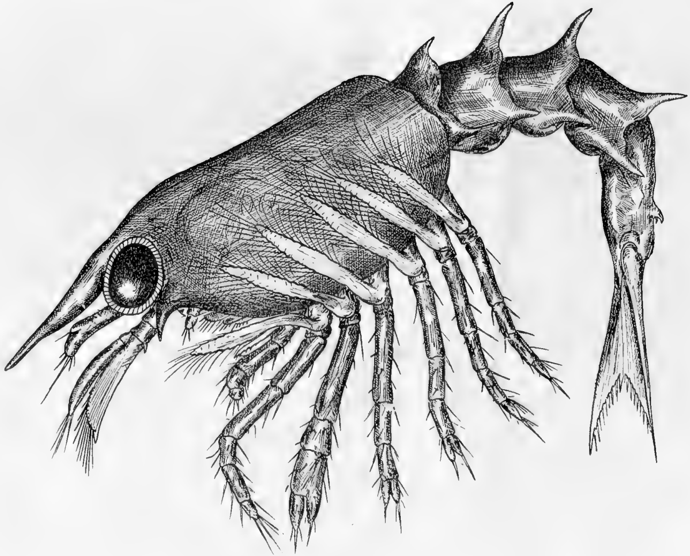


PLATE XXVI.
FIRST STAGE LOBSTER
DRAWN FROM LIFE BY PHILIP B. HADLEY, 1905.

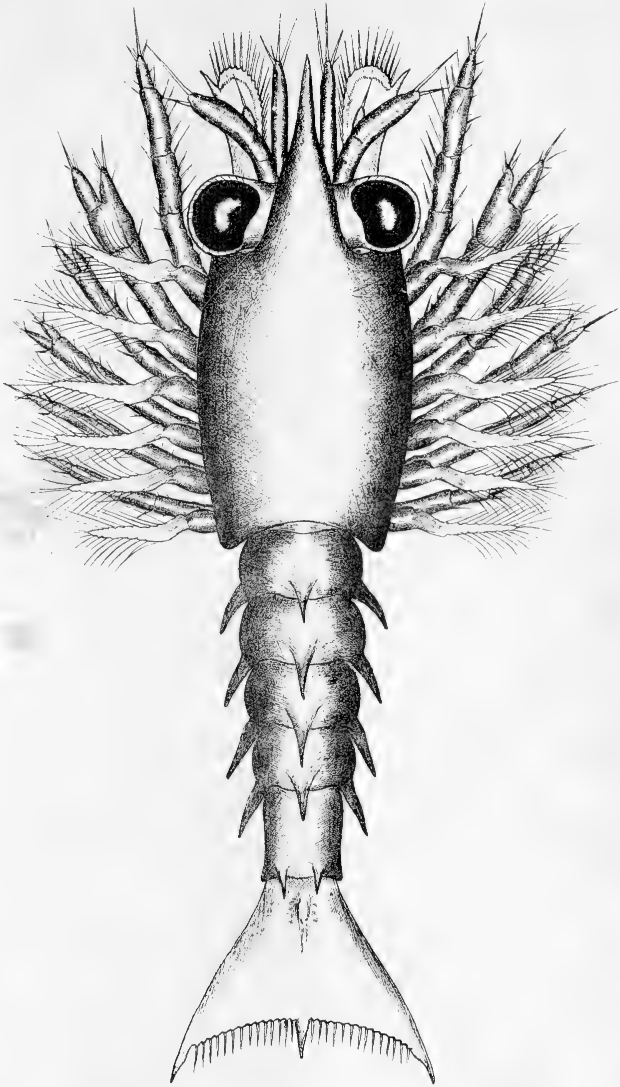


Plate XXVII

First Stage Lobster

Drawn from Life by Philip B. Hadley [illegible]

EXPLANATION OF PLATES 28 AND 29.

Second larval stage; length, 9.5 *mm.; age,* 6 *days.*

FIRST ANTENNÆ:

The endopodites have grown out over half the length of the expopodites; the latter extend nearly to the end of the rostrum; slight evidences of segmentation can now be observed on both endopodites and exopodites; the specialized olfactory setæ are present on the distal portion of the inner margin of the exopodites.

SECOND ANTENNÆ:

The endopodites now equal or excel in length the exopodites; traces of segmentation are now observable upon the endopodites.

EYES:

Still large and prominent, but less so than in the previous stage.

MAXILLIPEDS, CHELIPEDS, AMBULATORY APPENDAGES:

Very much as in first stage.

ABDOMINAL APPENDAGES:

The appendages of the second, third, fourth, and fifth abdominal segments have appeared but are not yet functional.

TAIL:

As in first stage.

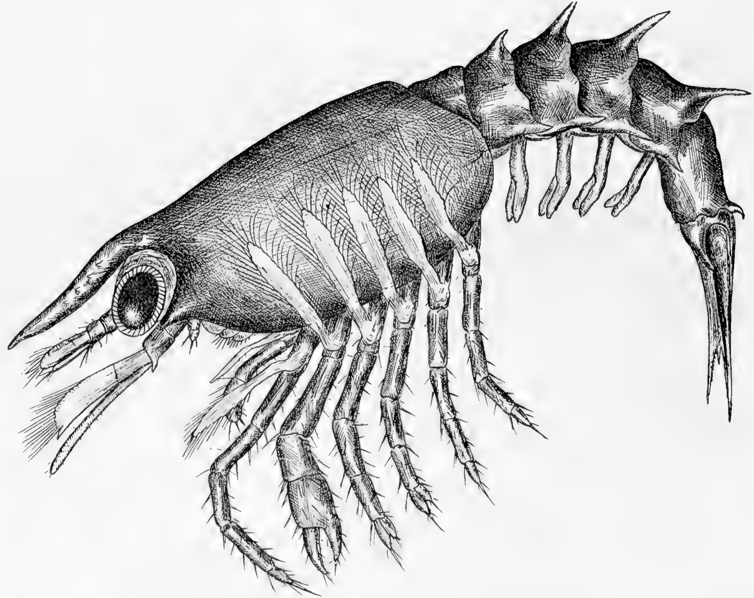


PLATE [illegible]

SECOND STAGE LOBSTER

DRAWN FROM LIFE BY PHILIP B. HADLEY [illegible]

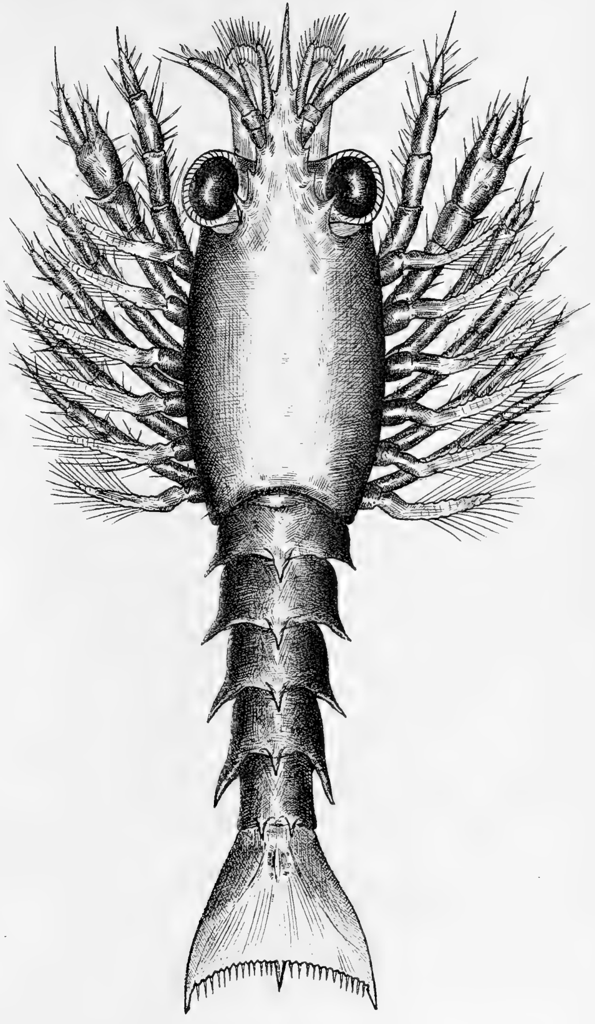


Plate XXIX.
Second Stage Lobster
Drawn from Life by Philip B. Hadley, 1905.

EXPLANATION OF PLATES 30 AND 31.

Third larval stage; length, 11.5 mm.; age, 9 days.

FIRST ANTENNÆ:

The endopodites have grown out to nearly the length of the exopodites; both are now as long or longer than the rostrum; the olfactory setæ are very distinct on distal portion of the inner margin of the exopodites; the segmentation of both exopodites and endopodites is clearly observable at this period.

SECOND ANTENNÆ:

The endopodites are now much longer than the exopodites; the latter still retain their leaf-like form and extend beyond the tip of the rostrum; the exopodites show definite traces of segmentation.

MAXILLIPEDS:

As in second stage.

CHELIPEDS:

The claw portion approximates more closely to the shape of the adult claw; owing to a gradual torsion of the limb from the carpopodite (fifth segment from base), the dactyl now opens upward and sometimes slightly inward.

AMBULATORY APPENDAGES:

Much as in the third stage, except that the claws on the first two pairs are more fully developed; the first segments of the last two pairs are tipped with spurs; the exopodites are still functional.

ABDOMINAL APPENDAGES:

These are now fringed with delicate setæ, but are not yet functional; the appendages of the sixth abdominal segment are now observable; they consist of exopodite and endopodite of about equal size, both of which are fringed with long setæ.

TAIL:

By the appearance of the appendages of the last abdominal segment the tail now resembles somewhat more closely that of the adult lobster; the telson is bordered with a fringe of setæ.

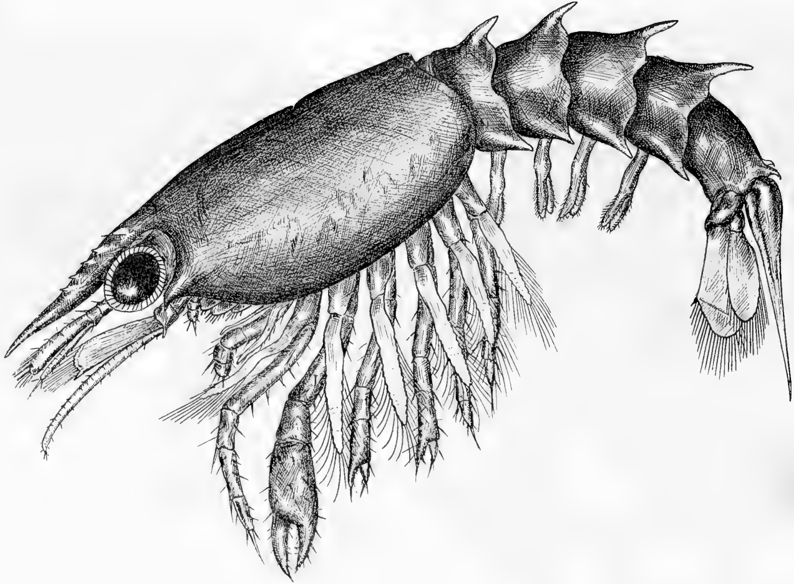


PLATE XXX
THIRD STAGE LOBSTER
DRAWN FROM LIFE BY PHILIP B. HADLEY, 1905.

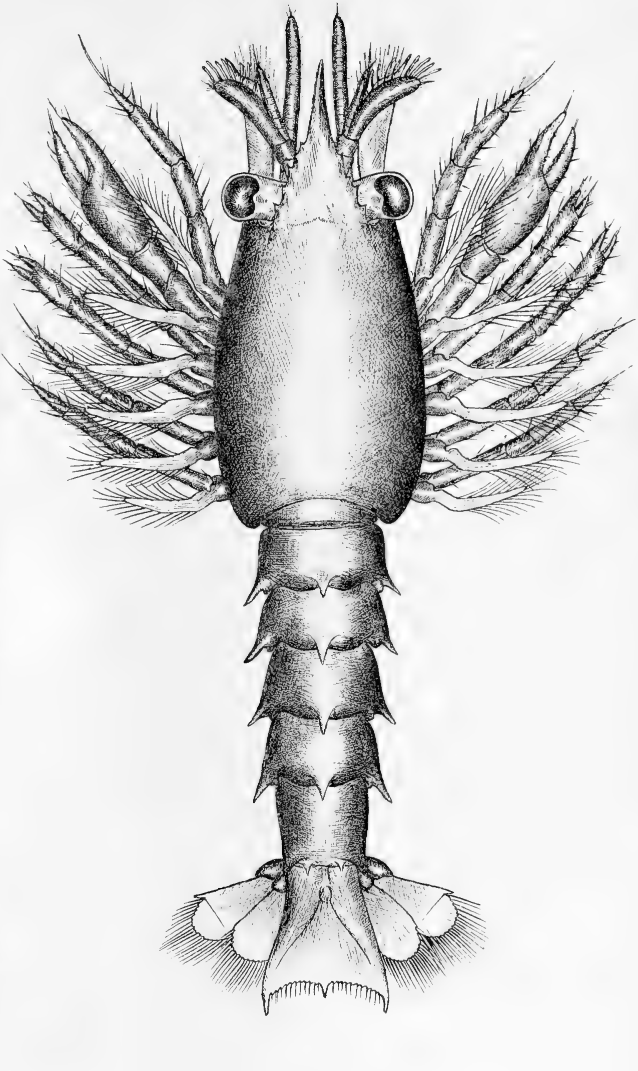


Plate XXXI

Third Stage Lobster

Drawn from Life by Philip B. Hadley, 1905.

EXPLANATION OF PLATE 32.

Fourth stage; length, 14.3 *mm.; age,* 14 *days. The greatest change in form which takes place (at any one molt) in the life of the lobster occurs in the transition from the third to the fourth stage.*

FIRST ANTENNÆ:

Both exopodites and endopodites are much elongated, and the segments are more distinct than in any previous stage; the olfactory setæ are very distinct.

SECOND ANTENNÆ:

The endopodites have, in a single molt, extended into long whip-like lashes, distinctly segmented and nearly two-thirds as long as the body; there has been no further development in the exopodites.

EYES:

These are relatively much smaller than in the previous stages.

MAXILLIPEDS:

These still retain the exopodites and they remain functional.,

CHELIPEDS:

These resemble more fully than in any previous stage the adult claw; right and left are similar; since the second stage a torsion has taken place (affecting, as Herrick has shown, the carpopodite or fifth joint) so that in the present position of the claw the dactyl opens inward; the exopodites have been lost in the recent molt.

AMBULATORY APPENDAGES:

These have lost, in the recent molt, the exopodites which, as is also the case in the chelipeds, have atrophied to functionless stumps (not shown in the drawing); no torsion has taken place in the first two pairs (the second and third chelate limbs), and the dactyls of the claws open upward and outward as before.

ABDOMINAL APPENDAGES:

These have become fringed with a border of delicate setæ; the exopodites and endopodites of each are clearly distinct and, for the first time, functional; the appendages of the last abdominal segment have increased in size and are now bordered by a fringe of long matted setæ; the appendages of the first segment have not appeared at this stage.

TAIL:

Owing to the changes in the appendages of the last abdominal segment, the tail now closely resembles that of the adult lobster.

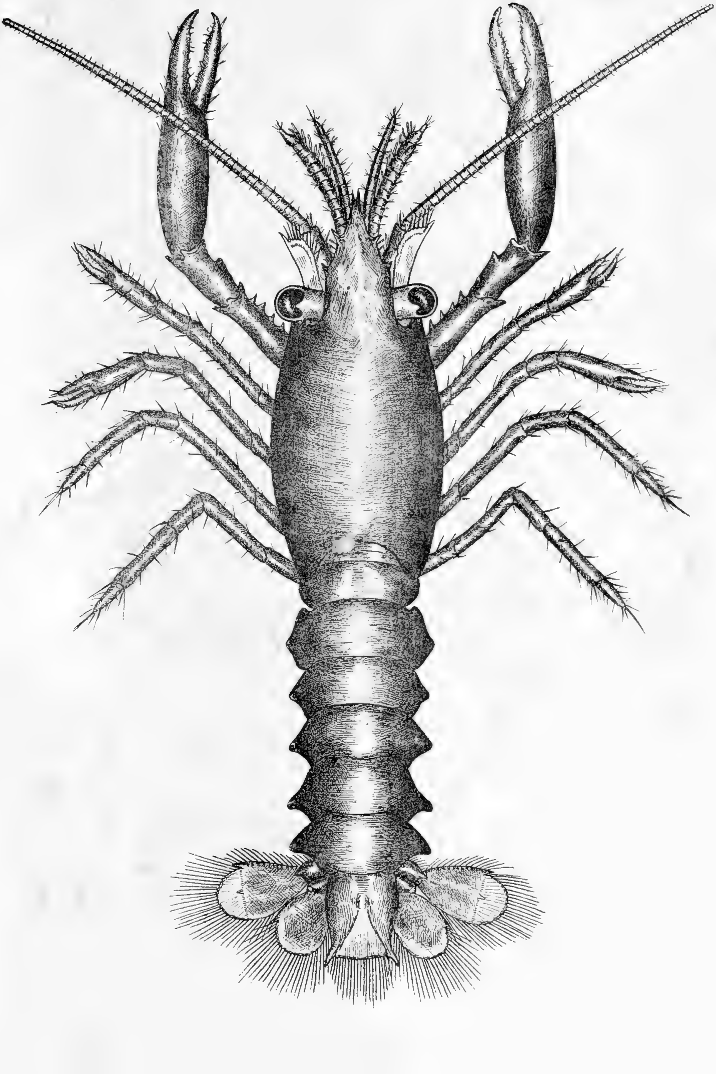


PLATE XXXII.
FOURTH STAGE LOBSTER
DRAWN FROM LIFE BY PHILIP B. HADLEY, 1905.

EXPLANATION OF PLATE 33.

Young male lobster; fourteenth stage; length, 65 *mm.; age, approximately* 14 *months.*

First antennæ:

These are relatively longer than in the fourth stage; the olfactory setæ are not distinct.

Second antennæ:

The endopodites have developed into long whip-like filaments longer than the whole body; the exopodites show no further development.

Eyes:

These are relatively smaller.

Chelipeds:

These are differentiated, after the sixth stage, into a "nipping" and a "crushing" claw; the tip of the dactyl often closes far past the tip of the propodos.

Ambulatory appendages:

As in the fourth stage; the atrophied stumps of the exopodites disappear after the fifth stage.

Abdominal appendages:

Much as in the fourth stage; the external reproductive organs (modified swimmerets in the case of the male) have appeared during the seventh or eighth stage, on the first abdominal segment.

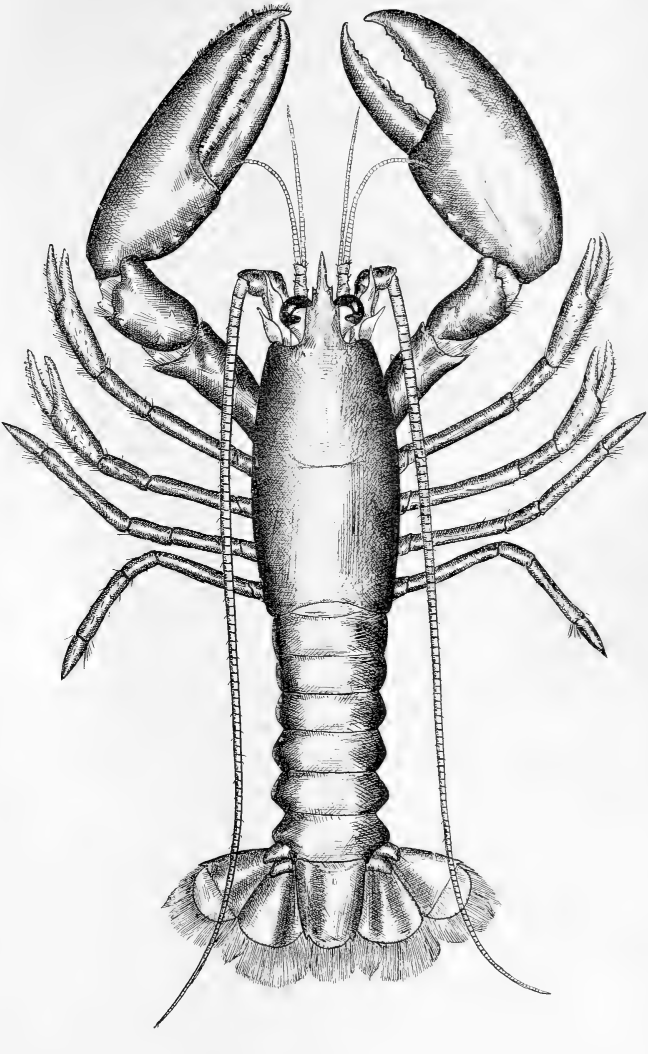


PLATE XXXIII.

YOUNG MALE LOBSTER

DRAWN FROM LIFE BY PHILIP B. HADLEY [illegible]

EXPLANATION OF PLATE 34.

This specimen, whose age can not be accurately estimated, but can not be less than sixteen or eighteen years, was taken from a fish trap in the southern part of Narragansett Bay, where it had become entangled in the meshes. The massive crushing claw was larger than the whole cephalo-thorax, and shows well the development of the two great tubercles which, in the case of aged lobsters, alone remain. The cephalo-thorax was broad, but the head portion narrow. The eyes were small, scarcely larger than shoe buttons. The appendages were all intact, but much worn and stubby. The exoskeleton was extremely thick and heavy, deeply scarred, and beset with barnacles and molluscs, several of which had grown into the articular membranes between the joints of the chelpeids.

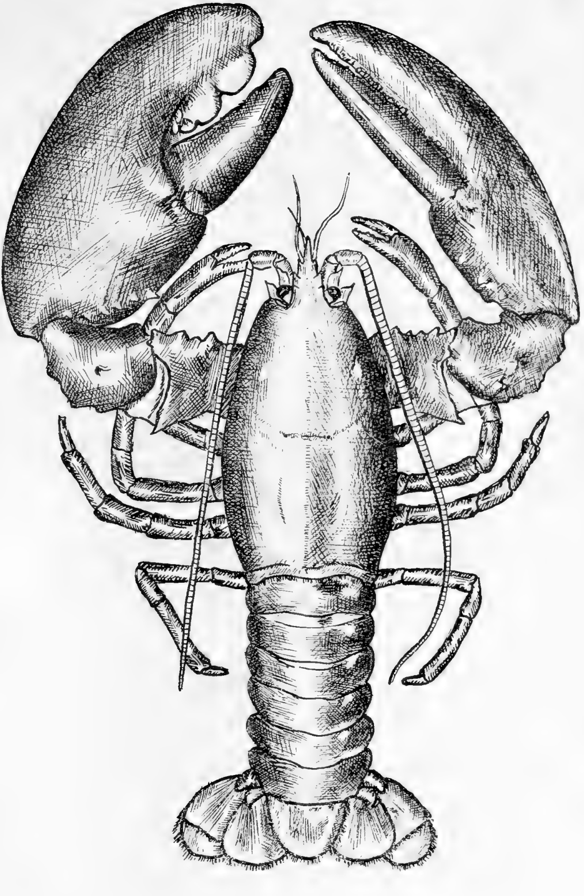


Plate XLIV.

Very Old Male Lobster

Drawn from Life by Philip B. Hadley

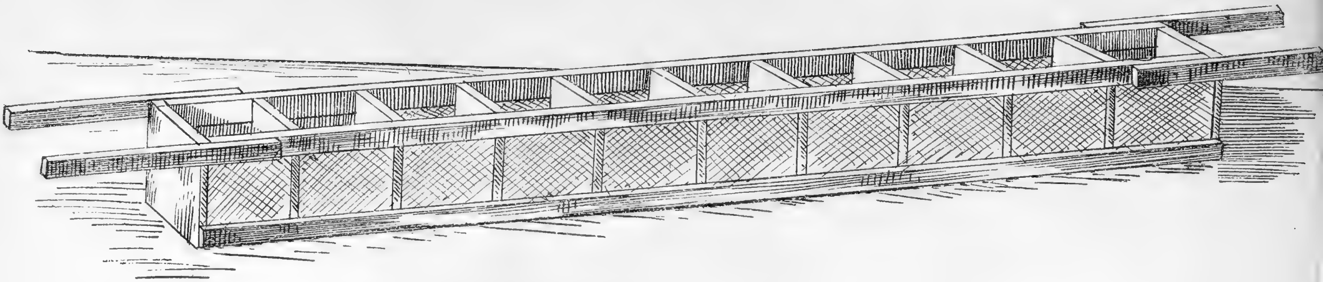


PLATE XXXV.—Showing the construction of the cars containing the separate compartments in which young lobsters are raised. (Designed by Mr. E. W. Barnes).

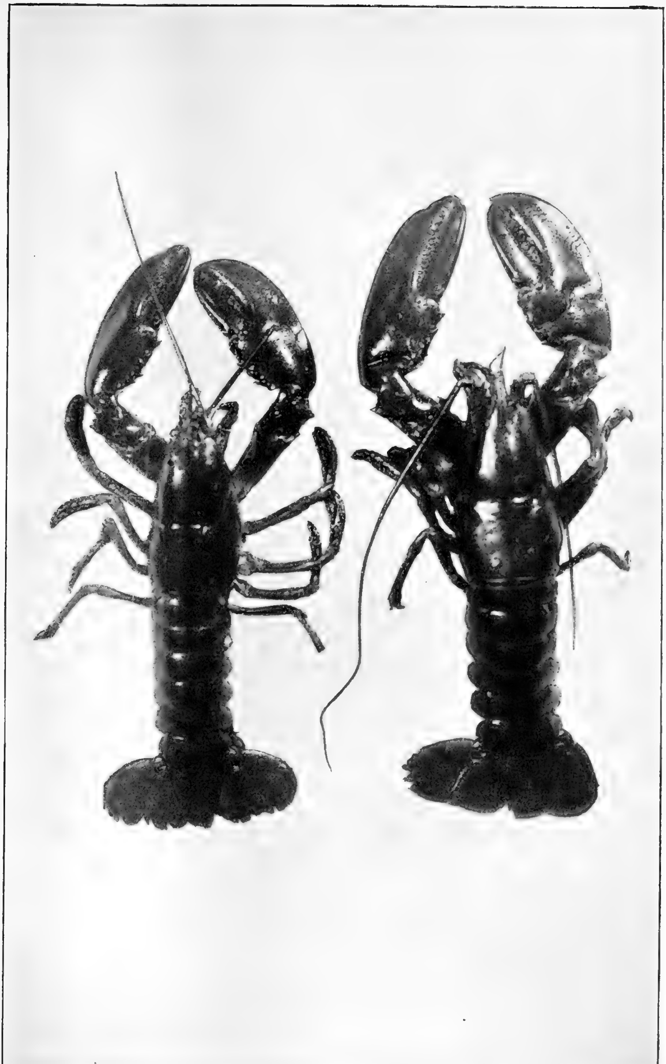


PLATE XXXVI.—Showing a young, newly-molted lobster (right), together with its old shell. Age, 2 yrs., 5 mos.; size, 5⅝ inches.

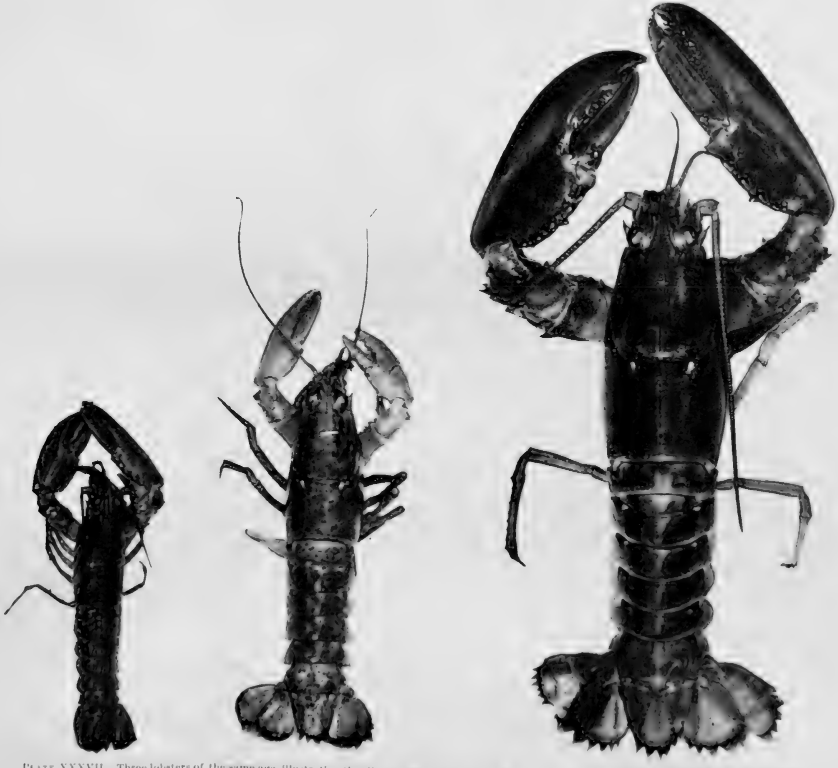


PLATE XXXVII.—Three lobsters of the same age, illustrating the differences in the rate of growth. They were hatched in the summer of 1901, and photographed alive October 23, 1902. Age about one year and four months. Life size

OBSERVATIONS ON SOME INFLUENCES OF LIGHT UPON THE LARVAL AND EARLY ADOLESCENT STAGES OF *HOMARUS AMERICANUS.*

PLATES XXXVIII TO XL.

PRELIMINARY REPORT.

PHILIP B. HADLEY,

BROWN UNIVERSITY, PROVIDENCE, R. I.

The study of the influence of light stimuli upon marine animals in general, and upon the group *Crustacea* in particular, has, during the past decade, proved a fertile field for investigation. The wide variation in the nature of the responses which may be called forth by the influence of light of different intensities, of different colors, and upon different backgrounds, has demonstrated the fact that the habits of life of many forms may be regulated by, and even to a great degree dependent upon, light changes; and, furthermore, that even questions of relative nutrition, bodily strength, and rate of development may be influenced, to no slight degree, by the light environment which surrounds the individuals.

With these facts in mind, and believing that further knowledge of the influence of light upon the early stages of the lobster would not only be of advantage to those engaged in the artificial propagation of marine crustacea, but would also form a further contribution to our data concerning the influence of light upon marine animals in general, we have, in a preliminary way, during the summer of 1905 at the Wickford hatchery, made a brief number of observations to which we hope to add at a later date.

The records of the experiments cover but a small part of the field of inquiry into the effects of light upon the lobster, inasmuch as they do not consider the subject of the influence of light upon chromatophore activity and pigment movement, but merely attempt to describe the reactions to light in the first five stages of *Homarus* when upon backgrounds of black or white; and then to consider briefly the possible influence of light on the rate of development of the lobster during its early life.

1. Photopathy in the Larval and Early Adolescent Stages.

In a previous paper (Science, 1905, XXII, 675) we have used somewhat ill-advisedly the term *phototropic* to indicate the tendency of organisms to move toward or away from a region of greater light intensity. Believing now, however, that the term *phototropism* should be used exclusively to represent a tendency on the part of organisms to *grow* toward the light or away from it, we have considered the terms *photopathy* and *photopathic* better adapted to express the nature of the greater number of reactions to be described in the following pages—that is, a tendency to move toward or from a region of greater light intensity. We shall also use, together with these terms, the terms *phototaxis* and *phototactic*, referring to the tendency of organisms to move in the direction of or opposite to the incident light rays. We consider these terms are here used more advisedly than the older terms *heliotropism* and *heliotropic* as used by Loeb, and which give no indication whether the response on the part of the organism concerned may be due to the intensity of the light or to the direction of the light rays, or both.

We do not assume, however (as does Loeb*), that such phototropic

---

*"Heliotropism of Animals," *The Decennial Publication of the University of Chicago, vol. I, p,* 84.

or heliotropic responses do not depend upon the specific characteristics of the nervous system. Later day investigations have pointed out that there may be wide differences between heliotropism in plants and in animals, and that, although instinctive action in the daily activities of the lower forms of life does, as Loeb argues, have its basis in the same laws which determine the behavior of matter in inanimate nature, still, in the light of these more recent investigations, it can not be denied that the behavior of these lower forms of life is modified and even determined by the effect of stimuli, primarily upon the nervous system.

First we are to discuss the results of experiments which were carried on under such conditions that there was no opportunity given for the young lobsters to manifest any reaction whatever by their efforts to swim in the direction of the incident light rays (phototaxis). The results, then, must indicate a "choice" on the part of the lobsters, of a specific degree of light intensity, light color (special rays), or both. We shall, however, on a later page make reference to experiments in which the phototactic responses (heliotropism in the sense used by Loeb in the greater number of his papers) are discussed.

The apparatus used for the experiments consisted of an oblong wooden box, 4 x 6 x 18 inches on the inside. The box was blackened and fitted with a light-tight cover, through one end of which protruded, to a length of 6 inches, a cardboard tube $1\frac{1}{2}$ inches in diameter; the function of this tube was to admit none but nearly parallel rays of light into one end of the box, thus distinctly localizing the light area (Plate XXXVIII). In experiments wherein a white background was required, the black interior of the box, as well as the under side of the light-tight cover, was covered with a heavy grade of white paper.*

The following description of the experiments, with some few changes, is taken from the previous paper of the writer, already referred to.

*The design of the box is based upon suggestions made by Keeble and Gamble. "*The Color Physiology of Higher Crustacea. Royal Society, London*, 1904.

The method of conducting a single experiment was essentially as follows: The box was filled with salt water to a depth of two inches, or thereabouts, and placed in a quiet and level position. The desired number of lobsters, together with sufficient salt water to make the total depth about three inches were added. When the water had quieted and the young lobsters had arranged themselves more or less uniformly in the water area, the cover was placed in position. At intervals, varying from five to fifteen minutes, the cover was removed and the position of the young lobsters was observed. After some of the observations the cover would be reversed in position, so that the illuminated area in the water would be changed to the opposite end of the box. After other observations, however, the cover would be left as in the first instance, or removed entirely until another uniform distribution of the young lobsters had been obtained. Whether the position of the cover was changed or not, the results, with few exceptions, agreed with great uniformity.

The light intensity was regulated by the time of day at which the observations were made, either at noon, mid-afternoon or nearly evening. In this way, without using artificial means, it was possible to regulate the degree of light intensity with a very fair precision. In the case of studying monochromatic lights (red and blue) sheets of glass were used, the plate being placed over the entrance of the tube. Without doubt, liquid filters would have been an advantage; but the experiments which were made with glass plates gave such definite reactions that they were judged satisfactory for preliminary work.

The counts were made by dividing the field into three areas, namely, the illuminated, the mid-area, and the dark. Owing to the fact, however, that the illumination in the mid-area must have been almost imperceptible, for practical results it might have been quite safe to include the mid-area counts with those of the dark area, but for sake of definiteness they have been considered as a separate area. In the greater number of cases it was an easy matter to count the number of individuals in each of the three areas before a change in position took place. Twenty individuals were, in most cases, used

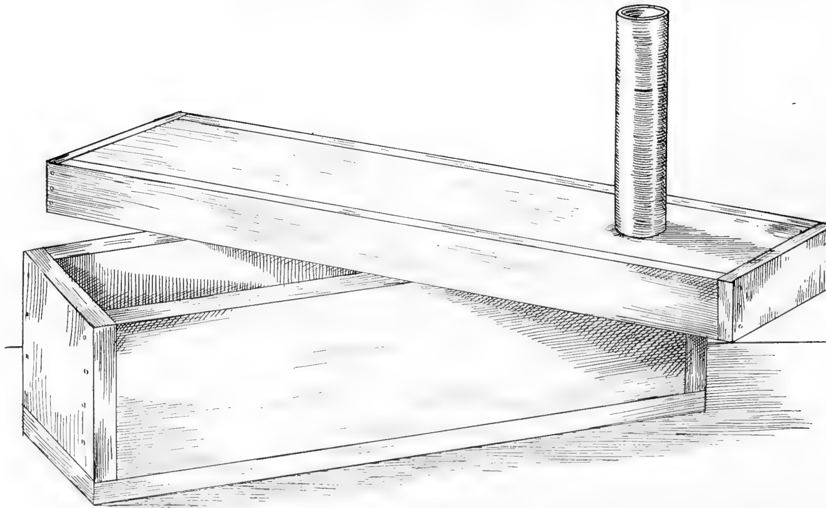


PLATE XXXVIII.—Showing the construction of the apparatus used in determining the reaction of young lobsters to different degrees of light intensity, and to special rays.

for experimentation, for so small a number distributed over three areas could be taken in at a glance, and furthermore twenty seemed a sufficient number to give representative results. In the following account are recorded experiments carried on with the first five stages. All the conditions of light and backgrounds were not brought to bear upon all five stages, and only a sufficient number of reports are here recorded to show the general drift of the results.

Experiment I.

Conditions: Black Background; Sunlight of Low Intensity; 20 First Stage Larvæ.

Test.	Light end.	Mid area.	Dark end.	Cover.
1	2	6	12	....
2	3	4	13	Reversed.
3	1	5	14	....
4	3	4	13	Reversed.

Similar results were obtained when a greater intensity of light was used.

Experiment II.

Conditions: White Background; Sunlight of Medium Intensity. 20 First Stage Larvæ.

Test.	Light end.	Mid-area.	Dark end.	Cover
1	2	5	13	....
2	2	2	16	Reversed.
3	2	3	15	Reversed.
4	1	5	14	....

Experiment III.

Conditions: White Background; Sunlight Bright; 20 First Stage Larvæ.

Test.	Light end.	Mid-area.	Dark end.	Cover.
1	22	4	4	....
2	18	7	5	Reversed.
3	20	7	3	....

These results seem to show that the first larval stage of *Homarus* is negatively photopathic on a black background, with weak, medium and bright light; but that, while on white backgrounds he is, under medium intensity, negatively photopathic, if the intensity of light is increased he becomes positively photophatic. Similar results were obtained with second and third stage larvæ under similar conditions of light and background. The reactions manifested under the conditions of white background and light of low intensity were, as a rule, not as definite as the others.

Experiment IV.

Conditions: White Background; Red Monochromatic Light; 20 First Stage Larvæ.

Test.	Light end.	Mid-area.	Dark end.	Cover.
1	2	1	17	....
2	2	3	15	....
3	3	4	13	Reversed.
4	6	2	12	....

Experiment V.

Conditions: White Background; Blue Monochromatic Light; 20 First Stage Larvæ.

Test.	Light end.	Mid-area.	Dark end.	Cover.
1	12	4	4	....
2	11	3	6	Reversed.
3	13	2	5	....

These two experiments indicate that in the case of a white background and red monochromatic light, the first stage lobsters are negatively photophathic, while in the case of a white background and a blue monochromatic light the same lobsters are positively photopathic. This was naturally somewhat unexpected, but in all the experiments involving similar conditions of light and background the second and third stage lobsters respond in a similar manner. In case, however, a black background is used with lobsters of the third stage, several experiments demonstrate a negative photopathy under the conditions of both red and blue light.

Experiment VI.

Conditions: Black Background; 20 Early Fourth Stage Lobsters; Sunlight Bright.

Test.	Light end.	Mid area.	Dark end.	Cover.
1	13	3	4	....
2	15	3	2	Reversed.
3	12	4	4	....
4	15	4	1	....

When experiments were tried with the fourth stage, however, a different reaction was found to occur. On black backgrounds and with white or blue lights of any intensity, the fourth stage lobsters, unlike the first three stages, were positively photopathic. The degree of light intensity made no change in the results, save in that instances where the light was the least intense the reaction was least marked; and when the light was most intense, as obtained by reflecting rays of light by means of a mirror into the tube, the definiteness of reaction was most evident.

When white backgrounds were used in connection with the fourth stage lobsters, it was found that in every case except with the monochromatic red light, a positive photopathic reaction resulted. The latter, which was also contrary to expectations, may be outlined as follows:

Experiment VII.

Conditions: White Background; Monochromatic Red Light; 20 Early Fourth Stage Lobsters.

Test.	Light end.	Mid area.	Dark end.	Cover.
1	8	5	6	....
2	1	6	13	Reversed.
3	1	10	9	Reversed.
4	4	5	11	....

These resulting reactions in the case of the early fourth stage lobster may offer an explanation of the fact that this stage is so frequently caught in tow-nets drawn over the surafce of any of our shore waters, while it has been a very unusual occurrence to secure in this manner either the earlier or the later stages. The same causes may also account for the reported facts that certain stages of the free-swimming larvæ of other forms of crustacea are found more frequently at the surface than are other larval stages of the same species, for it altogether probable that the presence of organisms in bright sunlight at the surface of the water may be indicative not of a positive phototactic or heliotropic reaction alone, but also of a positive photopathic response to the greater intensity of light in the surface waters.

It was a noteworthy fact, however, that old fourth stage lobsters would never manifest phototropic reactions with the same degree of certainty as those demonstrated in the case of younger fourth stage lobsters. Indeed, in a number of instances, fourth stage individuals which were due to molt within a period of one or two days manifested on black backgrounds a definite tendency towards a negative reaction. The negative photopathic response was assumed without exception after the lobsters had molted into the fifth stage, and this reaction was then manifested with any combination of light intensity, color, or background, except red and blue lights on a black background, in which case the resulting reactions were often either contradictory or obscure. The following tables show the reactions in the case of the late fourth and the fifth stage lobsters:

Experiment VIII.

Conditions: Black Background (Similar Results Were Seldom Obtained on a White Background); Sunlight Bright; 20 Late Fourth Stage Lobsters.

Test.	Light end.	Mid area.	Dark end.	Cover.
1	9	4	7	....
2	11	5	4	Reversed.
3	7	6	7	....
4	9	3	8	....

From the above experiments it appears that we have the probable explanation of the characteristic behavior of late fourth stage lobsters; *i. e.*, the tendency to seek the bottom and to hide under shells, rocks, or grass. It further appears that there is no good reason to attribute this manner of behavior, as do some writers, either to a negative heliotropism (phototaxis), or to contact irritability.

Experiment IX.

Conditions: Black Background; Medium Sunlight;
12 *Fifth Stage Lobsters.*

Test.	Light end.	Mid area.	Dark end.	Cover.
1	2	4	6	....
2	2	3	7	....
3	2	2	8	Reversed.
4	1	3	8	....

The results of these experiments may also explain, to a certain degree, the facts which appear through the observation of large numbers of the larval stages of *Homerus* when confined and exposed to different light conditions, and also interpret to some extent the behavior observed in the larval and early adolescent stages of lobsters under natural conditions of environment. The first three larval stages, when confined in the large twelve-foot white canvas bags in which they were observed, manifested at all times a marked tendency to sink toward the bottom—except perchance at night, when more active swimming is observed in all the stages. This tendency during the daytime could not be controlled in any way.

It seems entirely possible that this reaction may be explained upon the grounds of negative photopathy, for although it is certainly true that the young lobsters below the fifth stage are under certain conditions positively phototactic, still it may be that a certain intensity and background is required for the fullest manifestation of this response. For instance, at night, it was possible to evoke a seemingly positive photopathic reaction from any of the thousands of young larvæ in the large canvas bags. This was accomplished by means of an acetylene light so directed against a certain area of the white field of canvas that large numbers would at once group themselves thickly about the illuminated area, manifesting, in the case of the third and fourth stages, such an effort to come into the light area that they would often throw themselves partially out of water, causing thereby numerous surface ripples. Since, however, as has been stated, similar results could be obtained when a black background was employed with the acetylene rays, and since the results were not so definite when the incident rays struck the water perpendicularly as when they were thrown at an angle, it was assumed that these reactions were not manifestations of true photopathy, but were largely due to the effort on the part of the young lobsters to move in the direction of the incident light rays. This phenomenon was better observable in the fourth stage of *Homarus*, when the very definite rheotactic proclivity, first clearly observable in this stage, could be entirely broken up by introducing the incident rays either at right angles to or in opposition to the direction of the current. A diagrammatic representation of the effect of combining the opportunities for the manifestation of rheotaxis and phototaxis at the same moment is given in the figures of Plate XXXIX. In every observation made, whatever might be the direction in which the light rays were introduced, this effect was the same; the phenomenon of rheotaxis in the fourth stage lobsters was always lost in that area where the light rays had their full effect. A clearer view of the nature of this reaction may be obtained from the description accompanying the plate mentioned above.

The slight number of observations on the influence of light on the orientation and progressive movement of young lobsters does not, at the present time, warrant far-reaching deductions regarding the probable behavior of young lobsters under natural conditions or suggest aught that might be of value in methods of artificial propagation of lobsters. The writer, however, hopes to discuss this phase of the subject more in detail at a later date, and at that time to consider further the method of these reactions, and to determine to what extent the general behavior of the young lobsters may be dependent upon these responses to stimulation by light. In the meantime we may sum up the result of the observations thus far made by the following table and then briefly consider the probable influence of light on the general condition and rate of growth of the lobster as presented in the following section.

TABLE No. 1.

*Showing the nature of the photopathic reactions of lobsters in the first five stages on black and white backgrounds, and under the influence of white, red and blue light.**

STAGE.	On Black Backgrounds.					On White Backgrounds.				
	White Light.			Red Light.	Blue Light.	White Light.			Red Light.	Blue Light.
	Low Intensity.	Medium Intensity.	Greatest Intensity.			Low Intensity.	Medium Intensity.	Greatest Intensity.		
I	—	—	—	......	......	—	+	+	—	+
II	—	—	—	......	......	?	+	+	—	+
III	—	—	—	—	—	?	+	+	—	+
IV	—	+	+	?	+	?	+	+	—	+
V	—	—	—	?	?	—	—	—	—	—
VI	......	......	......	......	......	......	......	......	......	......

* In cases where the results were not certain, or not definite, or contradictory, the sign (?) has been placed. A positive reaction is indicated by the + sign; a negative reaction by the — sign.

Description of Plate XXXIX.

The current in every case was a continuous circular current created by a revolving paddle in a large canvas bag.

Fig. 1. Shows the normal rheotactic phenomenon when no disturbing influence is brought to bear.

Fig. 2. Shows the effect of introducing a pencil of light so that the rays proceed in an opposite direction to the current.

Fig. 3. Shows the result when the rays proceed in the direction of the current.

Fig. 4. Shows the effect of allowing the rays to fall vertically or at right angles to the direction of the current.

Fig. 6. Shows the effect of introducing the rays at a slight angle when no current is flowing in the bag.

Fig. 7. Shows the effect of withdrawing the source of the rays in a "serpentine" curve, in such a way that the direction of the rays is continually changing but at every point is tangent to the curve.

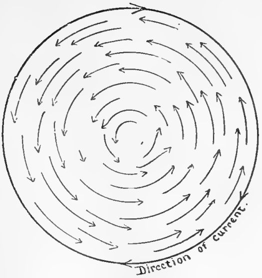


FIG. 1

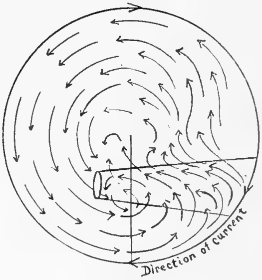


FIG. 2.

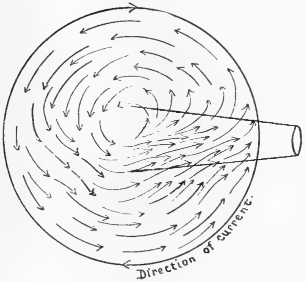


FIG. 3.

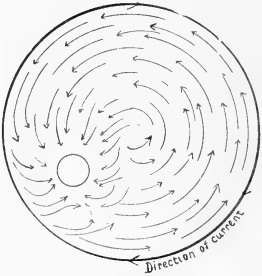


FIG. 4

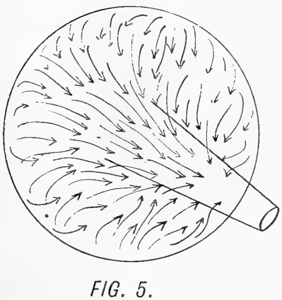


FIG. 5.

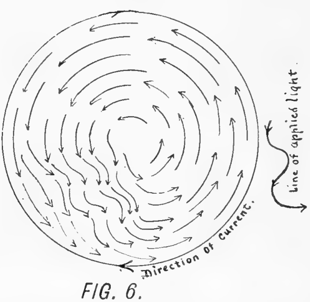


FIG. 6.

PLATE XXXIX.—Showing the effect produced when opportunity is given for both rheotactic and phototactic responses. Phototaxis is dominant.

II. The Influence of Light on the Rate of Development.

Insomuch as the writer has treated this subject in more detail in another paper* the present consideration will be brief. The question of the influence of light upon the rate of growth is, however, one of no little importance to the general problems of the artificial propagation of marine animals, and the writer hopes to be able at a later date to present the result of further investigations which shall better warrant the drawing of more far-reaching conclusions.

In the preliminary consideration of this problem, the first question which we may ask is, what influence do light and darkness appear to have upon the development of animal life in general; and, consequently, what effect might we expect it to have upon the young lobster? In answer to this query it may be said that, so far as investigations to the present are concerned, the following facts, which hold true both for vertebrates and for the lower forms of animals (many of them marine), are generally admitted.

1. *That development of animal life in general is more rapid in daylight (white light) than in absolute darkness.*

2. *That development in twilight is more rapid than in either (a) darkness or (b) daylight.*

3. *That development under the influence of certain monochromatic lights (blue or violet) is more rapid than in daylight, but, in most cases, less rapid than under the influence of twilight.*

4. *That the influence of white light may hasten destructive metabolism in many forms, but that the evil influence of the red rays contained in the white is not as detrimental to growth as the effect created by totally excluding the blue and violet rays which are also contained in the white, and from which, in many forms, the growth process derives a certain stimulation.*

The hypothetical conclusion to which, in view of the general facts,

*"Regarding the rate of growth of the American lobster," *Report of the Rhode Island Commission of Inland Fisheries for* 1905. *Reprint* 1906.

we might come, is that in all probability, full sunlight is detrimental to the development of the young lobster, but that weak sunlight or twilight exerts the most accelerating influence upon the rate of growth. We will now see what evidence there is to demonstrate the probable truth of this hypothesis.

We know first of all that the lobster is an individual whose habits of life seldom lead him beyond the twilight of his natural haunts. We know that when strong lights are brought to bear upon young adolescent lobsters they at once become restless, wander nervously about their cars, often refuse to touch food, and at all times manifest a definite effort to retreat from the light rays. Believing that the sunlight was unfavorable to the development of the lobsters, even after the fourth stage, the writer provided covers for most of the compartment cars in which the young lobsters were confined (Plate XXXV), thus producing in them the effect of twilight. Although the results obtained from these experiments do not justify far-reaching conclusions, they are nevertheless indicative of the fact that the condition of twilight does, for several reasons, actually prove beneficial to the developing lobsters; and that, on the other hand, broad sunlight is detrimental to their growth, first by increasing the length of time between each molting period, and second, by diminishing the amount of increase in length at each molt. The facts which lead to such a conclusion may be briefly presented in the tables which follow.

The lobsters in the groups indicated by the heading "in twilight" were raised from the third stage in the individual compartment cars already mentioned. They were quite protected from the light above by the broad covers with which the cars were supplied. The only light which was accessible entered through the wire screening of the sides, a large part of which was, in every instance, under water. In the case of those lobsters included under the heading "in sunlight," the compartments were in the form of wire cylinders, each containing in the bottom a saucer holding a small quantity of gravel. These cages were about 12 inches deep and 6 inches in diameter,* so that the bottom containing the saucer was, in most cases, 7 or 8 inches beneath the surface of the water. It is easy to perceive that the light was able to enter the cages from all sides and from the top.

Regarding the data presented in the tables, it should be borne in mind that all the lobsters whose records are given in a single table passed from the third to the fourth stage on the same night and were subsequently subjected to the same conditions of food supply and to the same degree of water temperature, both of which we know are able to cause so great a difference in the duration of the stage-periods when all other conditions are equal.

---

*See Plate XL.

TABLE No. 2.

*Showing the relative effects of sunlight and twilight upon the duration of the fourth stage-periods.**

In Sunlight.			In Twilight.		
Date of Molt to 4th Stage.	Date of Molt to 5th Stage.	Stage period.	Date of Molt to 4th Stage.	Date of Molt to 5th Stage.	Stage period.
July 23......	July 7.....	14 days..	July 23......	July (1)......	(8) days.
July 23......	July 7.....	14 days..	July 23......	July 5......	12 days.
July 23......	July 8.....	15 days..	July 23......	July 3......	10 days.
July 23......	July 9.....	16 days..	July 23......	July 5......	12 days.
July 23......	July 10.....	17 days..	July 23......	July 6......	13 days.
July 23......	July 5.....	12 days..	July 23......	July 6......	13 days.
July 23......	July 6.....	13 days..	July 23......	July 5......	12 days.
July 23......	July (15).....	(22) days..	July 23......	July 5......	12 days.
July 23......	July 6.....	13 days..	July 23......	July 6......	13 days.
July 23......	July 6.....	13 days..	July 23......	July 6......	13 days.
July 23......	July 10.....	17 days..	....	....	....
July 23......	July 8.....	15 days..	....	....	....
July 23......	July 10.....	17 days..	....	....	....
July 23......	July 6.....	13 days..	....	....	....
Average...	....	14.5 days..	Average....	....	12.2 days.

* See note to Table No. 3.

TABLE No. 3.

*Showing the relative effects of sunlight and twilight upon the increase in the size of lobsters molting from the fourth to the fifth stage.**

In Sunlight.			In Twilight.		
Fourth Stage.	Fifth Stage.	Gain Per cent.	Fourth Stage.	Fifth Stage.	Gain Per cent.
14.5 mm.	17.0 mm.	17.2	14.1 mm.	15.7 mm.	11.3
15.0 mm.	16.8 mm.	12.0	15.5 mm.	17.5 mm.	12.9
14.3 mm.	16.5 mm.	16.0	14.5 mm.	17.5 mm.	20.6
14.7 mm.	17.0 mm.	15.6	14.0 mm.	17.5 mm.	25.0
15.5 mm.	17.5 mm.	12.9	14.0 mm.	17.6 mm.	25.7
15.2 mm.	17.2 mm.	13.1	14.5 mm.	17.0 mm.	17.2
....	....	....	14.3 mm.	16.5 mm.	15.3
Average.....	....	14.4	Average....	....	18.2

* All lobsters recorded passed from the third to the fourth stage on the same day, June 23, and were thus subjected to the same degree of water temperature whose variation, as we know, is able to make a great difference in the duration of the stage-period, as also in the amount of increase in size. Food conditions were also identical in the case of each group.

Other observations from which we are able to determine a difference in the rate of growth are those from the experiments of Mr. V. E. Emmel, who kept many young lobsters through out the summer of 1905 in wire cylinders similar to those already described. In this case there was a partial protection afforded by stretching a framed canvas somewhat above the wire cages in which the lobsters in question were confined. Here, it is interesting to note, we find the duration of the fourth, fifth, sixth, and seventh stage periods from one to three days longer than in any other group of lobsters which were reared under different conditions during the same or during the previous summer.

TABLE No. 4.

Showing the average per cent. of increase for lobsters in the fifth, sixth, seventh, and eighth stages raised under different conditions of light.

	Stage 4 to 5.	Stage 5 to 6.	Stage 6 to 7.	Stage 7 to 8.
Group 1,* kept in weak sunlight.....	14.4	....	....	....
Group 2,† kept in subdued light.....	15.4	16.3	20.6	15.7
Group 3,‡ kept in semi-twilight.....	15.0	20.0	21.0	17.0
Group 4,§ kept in twilight..........	18.0	20.6	20.0	27.2

* This group was raised in wire cylinders in direct sunlight.

† Lobsters which were kept in wire cylinders, and protected by a framed canvas slightly above the cylinders.

‡ Lobsters which were kept in narrow compartment cars, which admitted no light on the sides and but little on the top.

§ Selected lobsters which were kept in wooden cars covered so that but little light was admitted from any direction.

If the influence of sunlight is able to cause such differences in the rate of development of lobsters in the fourth stage, it is not unreasonable to believe that the same influence may be, if anything, more detrimental to the development during the early larval stages.

One other factor which is commonly recognized as being able to greatly diminish the rapidity of growth, especially in the early stages, is the accumulation of diatoms, protozoa, and algæ which not infrequently gathers on the bodies of the young lobsters. There can be but little doubt that the profusion of this growth is, in a great measure, directly dependent upon the degree of light intensity to which the young animals are submitted. It is a recognized fact that the diatoms multiply most freely in regions of greater light intensity. This fact is apparent when observations are made upon several groups of lobsters under different conditions of light intensity. In relation to this point we have made observations upon three groups of lobsters in the fourth and fifth stages, confined under conditions of (1) semi-darkness or twilight, (2) very slightly subdued sunlight, and (3) full sunlight. It was very evident that the lobsters confined in an open car with practically no shade accumulated by far the most profuse growth of parasites, while the lobsters kept in twilight were, in every case, quite free. Those kept in slightly subdued sunlight had a more profuse growth than those maintained in the covered cars, but not nearly as great a growth as that on the lobsters in the open car.

After having made numerous observations on developing lobsters at Woods Hole, Gorham also believes that the abundance of parasitic growth is partially dependent upon the degree of light intensity to which the young lobsters are subjected.*

These few observations at least indicate the advisability of continuing this definite line of experimentation, not only upon the adolescent lobsters, but more especially upon the larval stages on which we know the variations in temperature and food supply have the greatest effect.

---

*F. P. Gorham, *U. S. Fish Commission Report for* 1903, p. 175.

THE RELATION OF REGENERATION TO THE MOLTING PROCESS OF THE LOBSTER.

BY VICTOR E. EMMEL,

BROWN UNIVERSITY, PROVIDENCE, R. I.

TABLE OF CONTENTS.

I.

Introduction and General Methods.

Both economic and scientific interests furnish incentives to a study of regeneration and its relations to the molting habits of the lobster.

The economic aspect of the subject is readily appreciated in view of the growing importance of the practical question of lobster culture. The recent noteworthy success of the Rhode Island Commission of Inland Fisheries, under the direction of Dr. A. D. Mead, in solving the difficulties involved in the problem of hatching and rearing lobster fry has given a new value to the study of the life history of this crustacean.

It is hardly necessary to emphasize the close relation existing between the growth of the lobster and its molting habits. It is well known that this animal increases in length, and to all appearances grows, only at certain periods. Indeed, this is so much the case that it is not at all impossible for a "short" lobster to grow from 8½ inches to 9 inches by the process of shedding the shell, during a single night; and thus rescue the fisherman from legal liabilities. However, of course, it is not true that this increase in size is due entirely to a rapid growth immediately after the molt; for the growth of the lobster, really, takes place more or less throughout the whole molting period. The growing tissue crowds against its shell, finally the animal sheds this shell, the compressed tissues expand and a rapid increase in size occurs. According to Herrick, this swelling out of the body after the molt "is due to the absorption of water through the new shell into the blood and tissues."*

This fact that the increase in size is correlated with the molting process, gives importance to the various factors which may influence the frequency of the molting period,—such as light, temperature, food, and the regeneration of injured structures.

From the scientific standpoint the subject of regeneration is full of interest. One of the most fundamental problems of biology at the present time is to determine the relation and interactions existing between different parts of the organism, and the phenomenon of regeneration furnishes an opportunity to study these relations by the experimental method. By disturbing the normal relations of the different parts of the organic system, and noting the resultant re-adjustments—as in the mutilation and regeneration of the appendages of the lobster—we may both demonstrate the existence, and learn something in regard to the nature, of these relations.

In the molting habit of the lobster we have a phenomenon in which the growing organism periodically reaches a climax and casts off its outer shell or exoskeleton. In approaching this climax the old tissue cells multiply and produce new tissue; the epithelial cells in the skin secrete a second shell underneath the old one; and finally these cell activities culminate in the act of molting.

On the other hand, when a limb has been removed from the lobster by mutilation, regeneration of that appendage occurs. In the process of forming this new structure a second series of cellular activities begins; which by multiplication and histological differentiation results in the reconstruction of a complete new appendage.

Accordingly, we have two distinct processes of cell activities. The one, *molting*, is going on regularly, and more or less contin-

---

*Herrick, Bulletin of U. S. Fish Commission, 1895, p. 81.

uously, throughout the period between molts; the other, *regeneration*, may be artificially introduced by mulitation at any point within this period. The interesting question arises as to what influences they may exert upon each other. Will the process of regeneration produce any effect upon the activities involved in molting, and *vice versa?*

Since it is evident that, in the molting process, a certain amount of energy is being regularly directed into the production of a greater mass of tissue, and the formation of a new shell to accommodate the increasing size of the growing organism; and since it is equally evident that a certain quantity of energy is necessary for the production and development of a mass of new tissue in the regeneration of a limb, the further question arises:—if the two processes do influnce each other, is the interaction of such a nature as to indicate that the energy normally involved in the cellular activities of molting may be diverted into the other series of cellular activities, regeneration?

The object of the present series of experiments is to study some of the relations existing between these two processes of regeneration and molting.

The present experiments and observations were made, during the summer of 1905, at the Experiment Station of the Rhode Island Commission of Inland Fisheries, Wickford, Rhode Island. The lobster hatchery at this station furnishes unsurpassed opportunities to obtain, from the thousands of young lobsters hatched during the months of June and July, material for experimental work.

The specimens selected for the experiments were young lobsters which had all molted to the *same stage on the same day.* By selecting a lobster pool in which the lobsters, perhaps 2,000 or more, were all known to be in a given stage, and by watching for the next molt, it was possible to obtain a large number of specimens which had molted to the same stage on the same day. Care was taken also to select only those individuals which were practically equal in size, and in a normal condition. The value of these specimens for comparative results becomes evident when it is considered that both the stage of the lobster and the season of the year greatly modify the length of the period between molts.

The specimens selected in this way were next separated into two groups. The specimens of one group were then mutilated, while the lobsters in the other group were kept in a normal condition as controls. The molting period of normal individuals thus served as a standard with which to compare any variations in the molting of the other specimens, caused by the mutilation and resulting regeneration.

The nature of the mutilations was also considered, for it is highly important, in comparing results, that the character and degree of injury be uniform. The requisite uniformity of the mutilations in the lobster is easily obtained. By means of a special structure at the base of the legs and chilipeds, these limbs, when injured, are always thrown off by the animal at this particular region or breaking plane, a process known as autotomy.* In the present experiments the mutilations were made by crushing the tip of the limb with forceps, and in every case the limb was dropped at the moment of injury. It is from the stump remaining after autotomy that another limb begins to bud and regenerate.

It was attempted to conduct the experiments under conditions as nearly normal as possible. Both mutilated and normal lobsters were kept in cylindrical boxes with earthenware saucers, six inches in diameter, at the bottom, and these were suspended in the water, as shown in Plate XL. Thus each cylinder provided a free circulation of water. The lobsters were fed on minced clams and fish. A canvas awning was placed over all the cylinders, and every precaution was taken to keep the specimens in as nearly a natural environment as possible.

Observations were made three times every day, morning, midday, and evening. A record was made of the date of molting for each

*See Emmel, "The Regeneration of Lost Parts in the Lobster." Report of R. I. Commission of Inland Fisheries, 1904, pp. 88–89.

individual. Occasionally a specimen would be engaged in the act of molting just at the time of observation, but usually the lobsters would molt at some time during the interval between two successive observations; in that case the date of the first observation after molting was recorded as the date of the molt.

II.

EXPERIMENTS AND RESULTS.

1.

Explanation of Terms.

The following terms will be used with the meanings indicated below:

Mutilation: An injury to a limb made in such a way that the lobster will throw the limb off by autotomy.

Regeneration: The reproduction or growth of another limb to replace the one lost by mutilation.

The process of regeneration: The series of cell-activities involved in the origin, development, and differentiation of the tissues and organs of the regenerating structure.

The molting process: The series of cell-activities in the old tissue and skin which take place more or less continuously throughout the molting period; and which result in a growth of new tissue and the secretion of a new shell underneath the old one.

The molt, or act of molting: The periodic culmination of the molting process, in which the animal casts off the old shell.

The rate of molting: The length of time required by the process of molting to culminate in the act of molting.

The molting period: The interval between two successive molts.

2.

The Effect of Regeneration upon the Length of the Period Between Molts.

a. Experiments.

The first question in regard to the relation between the processes of regeneration and molting is whether, in the lobster, the process of regenerating an appendage really has any influence upon the length of the molting period. This may be answered by comparing the length of the molting process in a group of normal lobsters with the length of the corresponding process in a group of regenerating lobsters.

For this purpose, on July 8, 1905, 80 fourth stage lobsters were taken from one of the hatching pools. The specimens were selected out of several hundreds which had molted into the fourth stage during the night of July 7. They were all approximately of the same size and in normal condition.

These 80 selected specimens were then separated into three groups which may be designated as series A, A_1, and A_4.* The number of individuals in each group was as follows: Series A, 30; series A_1, 25; series A_4, 25. The lobsters in series A were kept in a normal condition; the 50 specimens in series A_1 and A_4 were all mutilated by the removal of both chelipeds. The difference between series A_1 and A_4 consists in the time of mutilation. As the result of previous observations there were reasons to suspect that an injury occurring immediately after a molt might not perceptibly affect the length of the molting process. Accordingly, in order fairly to test the influence of regeneration, 25 of the lobsters were mutilated July 9, one day after molting to the fourth stage (series A_1); and the other 25 specimens were mutilated July 12, four days after molting to the fourth stage (series A_4).

*The sub-numerals indicates the number of days intervening between the time of mutilation and the preceding molt, as will be described.

b. Tabulation of Results.

The records for series A, A_1, and A_4 are arranged in Tables I, II, and III, respectively. The tables include the date of molting to the fourth and fifth stages; the time of mutilation; and the condition of the specimen after each molt. The lobsters which died before molting to the fifth stage are not included in the tables. In every case where the specimen did not show regenerated chelipeds at the time of molting, the data for the molting period is placed in separate columns in Tables II and III. It may be noticed, also, that the data in all tables have been arranged in the order in which the individuals molted to the fifth stage.

Chart VIII shows the frequency curves plotted for the data in Tables I and III. For the purpose of graphically comparing the frequency of molts in successive days for series A_1 and series A_4, the lobsters have been grouped according to the number of individuals molting on the same day in each series. In Fig. I the ordinates show the number of individuals which molted on the dates indicated on the abscissæ.

Table I.

MOLTING PERIOD FOR NORMAL FOURTH STAGE LOBSTERS, SERIES A.

Number.	Molted to Fourth Stage.	Condition Normal.	Molted to Fifth Stage.	Molting Period in Days.	Normal.
	1905.		1905.		
1	July 8; 8 A. M.	+	July 18; 6 P. M.	10.4	+
2	July 8; 8 A. M.	+	July 18; 6 P. M.	10.4	+
3	July 8; 8 A. M.	+	July 18; 6 P. M.	10.4	+
4	July 8; 8 A. M.	+	July 18; 6 P. M.	10.4	+
5	July 8; 8 A. M.	+	July 19; 8 A .M.	11.0	+
6	July 8; 8 A. M.	+	July 19; 8 A. M.	11.0	+
7	July 8; 8 A. M.	+	July 19; 6 P. M.	11.4	+
8	July 8; 8 A. M.	+	July 19; 6 P. M.	11.4	+
9	July 8; 8 A. M.	+	July 19; 6 P. M.	11.4	+
10	July 8; 8 A. M.	+	July 19; 6 P. M.	11.4	+
11	July 8; 8 A. M.	+	July 20; 8 A. M.	12.0	+
12	July 8; 8 A. M.	+	July 20; 8 A. M.	12.0	+
13	July 8; 8 A. M.	+	July 20; 12 M.	12.2	+
14	July 8; 8 A. M.	+	July 20; 12 M.	12.2	+
15	July 8; 8 A. M.	+	July 20; 12 M.	12.2	+
16	July 8; 8 A. M.	+	July 20; 6 P. M.	12.4	+
17	July 8; 8 A. M.	+	July 20; 6 P. M.	12.4	+
18	July 8; 8 A. M.	+	July 20; 6 P. M.	12.4	+
19	July 8; 8 A. M.	+	July 20; 6 P. M.	12.4	+
20	July 8; 8 A. M.	+	July 20; 6 P. M.	12.4	+
21	July 8; 8 A. M.	+	July 21; 8 A. M.	13.0	+
22	July 8; 8 A. M.	+	July 21; 8 A. M.	13.0	+
23	July 8; 8 A. M.	+	July 21; 8 A. M.	13.0	+
24	July 8; 8 A. M.	+	July 21; 8 A. M.	13.0	+
25	July 8; 8 A. M.	+	July 21; 2 P. M.	13.2	+
26	July 8; 8 A. M.	+	July 22; 6 P. M.	14.4	+
27	July 8; 8 A. M.	+	July 23; 8 A. M.	15.0	+
..	....	....	....	Av. 12 days.	....

Table II.

MOLTING PERIOD FOR REGENERATING FOURTH STAGE LOBSTERS, MUTILATED ONE DAY AFTER MOLT.

SERIES A_1.

Number.	Molted to Fourth Stage	Date of Mutilation.	Molted to Fifth Stage.	Regenerated Chelipeds.	Period for Regenerating Lobsters in days.	Period for Non-regenerating Lobsters in days.
1	July 8; 9 A. M....	July 9; 9 A. M....	July 19; 8 A. M...	+	11.0	....
2	July 8; 9 A. M....	July 9; 9 A. M....	July 19; 1 P. M...	+	11.2	....
3	July 8; 9 A. M....	July 9; 9 A. M....	July 20; 8 A. M...	+	12.0	....
4	July 8; 9 A. M....	July 9; 9 A. M....	July 20; 8 A. M...	+	12.0	....
5	July 8; 9 A. M....	July 9; 9 A. M....	July 20; 1 P. M...	+	12.2	....
6	July 8; 9 .A M....	July 9; 9 A. M....	July 20; 1 P. M...	+	12.2	....
7	July 8; 9 A. M....	July 9; 9 A. M....	July 20; 1 P. M...	+	12.2	....
8	July 8; 9 A. M....	July 9; 9 A. M....	July 20; 1 P. M...	+	12.2	....
9	July 8; 9 A. M....	July 9; 9 A. M....	July 20; 1 P. M...	+	12.2	....
10	July 8; 9 A. M....	July 9; 9 A. M....	July 20; 1 P. M...	+	12.2	....
11	July 8; 9 H. M....	July 9; 9 A. M....	July 20; 1 P. M...	—	....	12.2
12	July 8; 9 A. M....	July 9; 9 A. M....	July 21; 8 A. M...	—	....	13.0
13	July 8; 9 A. M....	July 9; 9 A. M....	July 21; 8 A. M...	—	....	13.0
14	July 8; 9 A. M....	July 9; 9 A. M....	July 21; 1 P. M...	—	....	13.2
15	July 8; 9 A. M....	July 9; 9 A. M....	July 21; 1 P. M...	—	....	13.2
16	July 8; 9 A. M....	July 9; 9 A. M....	July 21; 1 P. M...	+	13.2	....
17	July 8; 9 A. M....	July 9; 9 A. M....	July 21; 1 P. M...	+	13.2	....
18	July 8; 9 A. M....	July 9; 9 A. M....	July 21; 1 P. M...	+	13.2	....
19	July 8; 9 A. M....	July 9; 9 A. M....	July 21; 1 P. M...	+	13.2	....
20	July 8; 9 A. M....	July 9; 9 A. M....	July 22; 1 P. M...	+	14.2	....
21	July 8; 9 A. M....	July 9; 9 A. M....	July 22; 1 P. M...	+	14.2	....
..	....	....	....	....	Av. 12.5 days.	Av. 12.9 days.

All mutilations consisted in the removal of both chelipeds.

+ or —, respectively, indicate that the lobster did or did not regenerate the chelipeds before molting to the fifth stage.

Table III.

MOLTING PERIOD FOR REGENERATING FOURTH STAGE LOBSTERS, MUTILATED FOUR DAYS AFTER MOLT.

SERIES A_4.

Number.	Molted to Fourth Stage.	Date of Mutilation.	Molted to Fifth Stage.	Regenerated Chelipeds.	Period for Regenerating Lobsters in days.	Period for Non-regenerating Lobsters in days.
1	July 8; 8 A. M....	July 12; 9 A. M...	July 20; 12 M.....	+	12.2	....
2	July 8; 8 A. M....	July 12; 9 A. M...	July 21; 8 A. M...	+	13.0	....
3	July 8; 8 A. M....	July 12; 9 A. M...	July 21; 8 A. M...	—	....	13.0..
4	July 8; 8 A. M....	July 12; 9 A. M...	July 21; 1 P. M...	+	13.2	....
5	July 8; 8 A. M....	July 12; 9 A. M...	July 21; 1 P. M...	+	13.2	....
6	July 8; 8 A. M....	July 12; 9 A. M...	July 21; 1 P. M...	+	13.2	....
7	July 8; 8 A. M....	July 12; 9 A. M...	July 21; 1 P M....	+	13.2	....
8	July 8; 8 A. M....	July 12; 9 A. M...	July 21; 1 P. M...	—	....	13.2
9	July 8; 8 A. M....	July 12; 9 A. M...	July 21; 1 P. M...	—	....	13.2
10	July 8; 8 A. M....	July 12; 9 A. M...	July 21; 1 P. M...	+	13.2	....
11	July 8; 8 A. M....	July 12; 9 A. M...	July 21; 1 P. M...	+	13.2	....
12	July 8; 8 A. M....	July 12; 9 A. M...	July 21; 1 P. M...	+	13.2	....
13	July 8; 8 A. M....	July 12; 9 A. M...	July 21; 1 P. M...	+	13.2	....
14	July 8; 8 A. M....	July 12; 9 A. M...	July 21; 1 P. M...	+	13.2	....
15	July 8; 8 A. M....	July 12; 9 A. M...	July 22; 12 M.....	—	....	14.2
16	July 8; 8 A. M....	July 12; 9 A. M...	July 22; 12 M.....	+	14.2	....
17	July 8; 8 A. M....	July 12; 9 A. M...	July 23; 8 A. M...	+	15.0	....
18	July 8; 8 A. M....	July 12; 9 A. M...	July 23; 8 A. M...	+	15.0	....
19	July 8; 8 A. M....	July 12; 9 A. M...	July 23; 1 P. M...	+	15.2	....
20	July 8; 8 A. M....	July 12; 9 A. M...	July 23; 1 P. M...	+	15.2	....
21	July 8; 8 A. M....	July 12; 9 A. M...	July 24; 8 A. M...	+	16.0	....
22	July 8; 8 A. M....	July 12; 9 A. M...	July 24; 1 P. M...	+	16.2	....
23	July 8; 8 A. M....	July 12; 9 A. M...	July 27; 8 A. M...	+	19.0	....
..	....	....	....	....	Av. 14.2 days.	Av. 13.4 days.

All mutilations consisted in the removal of both chelipeds.

+ or —, respectively, indicate that the lobster did or did not regenerate the chelipeds before molting to the fifth stage.

c. Discussion of Results.

A comparison of the data for series A, A_1, and A_4 demonstrates a relation between the length of the molting period and the process of regeneration.

Twenty-seven of the 30 lobsters in series A were in a normal condition before and after molting to the fifth stage. Out of the 21 lobsters which molted to the fifth stage in series A_1, 16 specimens had regenerated the chelipeds. In series A_4, 23 of the 25 specimens lived and molted; 19 of them had regenerated the appendages removed by mutilation.

The average number of days in molting from the fourth to the fifth stage was as follows: Series A, 12 days; series A_1, 12.5 days; and series A_4, 14.2 days. In series A_4 the molting period was $2\frac{1}{6}$ days longer than the corresponding period for series A. In other words, the normal molting period was lengthened over 18 per cent. in the regenerating lobsters.

The effect of regeneration in these experiments is also graphically illustrated by the frequency curves in Chart VIII. If the process of regeneration really has lengthened the molting period, then both the climax and the general position of the curve for the regenerating series A_4 should be to the right of the climax and position of the curve for the normal control series A. A comparative examination of the two curves plainly proves this to be the case; for the climax for curve A occurred July 20, while the corresponding climax for curve A_4 occurred a day later, July 21. Again, curve A_4 both begins and ends several days later than does curve A. Consequently the general outline or position of curve A_4 has been shifted to the right of the normal curve A. It is clearly shown, therefore, that the molting period for the regenerating series is longer than the corresponding period for the normal series.

It may be noted that the form of these two curves is not quite the same. This is largely due, probably, to the smaller number of individuals in series A_4 than in series A. No doubt a larger number of individuals would eliminate the irregularities in contour of the curves and make them very similar in outline.

In regard to the value and conclusive character of these results it seems desirable to emphasize the fact that both series of lobsters (*i. e.* series A and A_4) at the beginning of the experiment molted to the same stage on the same day; were practically equal in size, and all in a normal condition. The only difference between these two series was that in four days after the beginning of the experiment the process of regeneration was introduced into one, with the result that the process of molting was delayed in the regenerating series to such a degree that the average length of the molting period was 18 per cent. longer than the corresponding period for the normal series.

The fact that the effect of regeneration seems to vary according to the time of mutilation, as shown in series A_1 as compared with series A_4, will be considered under the next section.

The results, however, of this experiment, together with the results of previous observations, and the experiments to be described later, indicate very conclusively that the *molting activities of the lobster can be retarded by the process of regeneration.*

3.

The Influence of the Time at Which the Process of Regeneration is Introduced into the Period Between Molts, upon the Length of that Period.

In the description of the experiments of the last section it was observed that there were reasons for expecting that a regeneration which began immediately after a molt might not greatly influence the length of the molting period. That this expectation was justified may be seen by comparing the length of the molting period of series A_1 with the corresponding periods for series A and A_4. The data shows that while in the one case, where the mutilations were made four days after the molt, the resulting regeneration lengthened the normal molting period by 18 per cent.; on the other hand, in the mutilations made *one day* after the molt, the resulting regeneration only increased the rate of molting by the small amount of $1\frac{2}{3}$ per cent.

This marked difference in the results suggests the importance of a more careful study of the effect of introducing the process of regeneration at different times throughout the molting period.

a. Experiments.

The general plan of the following experiments was to select a large number of lobsters which are equal in age, are in the same stage, are approximately equal in size, and in a normal condition; to separate these specimens into two groups; the one for mutilation, and the other to be retained in a normal condition to serve as a control; then to subdivide the former group into a number of smaller groups and to mutilate the lobsters in these sub-groups at several different times.

A more detailed description of the experiments is as follows: On July 21, 1905, at 9 A. M., 160 lobsters were selected which had molted to the fourth stage during the preceding night. Only those individuals were selected which were nearly equal in size and in a normal condition. Sixty of these specimens were reserved as controls; the remaining 100 specimens were subdivided into ten groups of 10 lobsters each. Four days after the molt, on July 25 at 9 A. M., the lobsters in one of these ten sub-groups were mutilated. The mutilation consisted in causing the removal of both chelipeds. On each succeeding day, at as nearly the same time (9 A. M.) as was possible, a similar operation was performed on another of the remaining sub-groups. Thus these ten mutilated groups of lobsters were arranged in a series characterized by a difference of *one day in the time of mutilation in each case.*

For convenience in discussion the normal group will be designated as series B; and the mutilated groups as series C_4, C_5, C_6, C_7, C_8, C_9, C_{10}, C_{11}, C_{12} and C_{13}. The series numerals in each case indicate the number of days after the molt before the mutilations were made.

b. Tabulations of Results.

Table IV contains the record of the date of molt, and the length of the molting period for each of the normal lobsters in series B. The specimens which died or were injured during the course of the experiment were discarded and are not included in the table.

The data for the ten series of mutilated lobsters are arranged in Table V. The records for each series contain the data of molt, the time of mutilation, the length of the molting period, and the condition of every specimen before and after each molt. The data for the individuals which had *not* regenerated the chelipeds by the time of molting are placed in a separate column, as may be seen in the table.

A fact in connection with lobsters Nos. 43, 44, 45, and 46 in Table IV is worthy of note at this place. It may be seen by examining the table that by August 8 all the normal lobsters had molted to the fifth stage, but there were still four specimens left which did not molt till several days later. This tardiness in molting aroused suspicion, and a closer examination was made to ascertain whether these four lobsters were really in a normal condition. It was most interesting to discover that, *without exception, each of these specimens had received injuries* on the ventral side of the abdomen: three of the specimens were each regenerating a swimmeret, and on the fourth lobster as many as five of the swimmerets were missing. This case seems especially interesting because, unintentionally, it is again shown that the tendency of regeneration is to retard the rate of molting.

Table IV.

MOLTING PERIOD FOR NORMAL FOURTH STAGE LOBSTERS.

SERIES B.

Number.	Molted to Fourth Stage.	Condition.	Molted to Fifth Stage.	Molting Period in days.	Condition.
	1905.		1905.		
1	July 21; 9 A. M.*.	Normal.....	Aug. 2; 8 A. M....	12.0	....
2	July 2; 9 A. M...	Normal.....	Aug. 2; 5 P. M....	12.3	Normal.
3	July 21; 9 A. M...	Normal.....	Aug. 2; 5 P. M....	12.3	Normal.
4	July 21; 9 A. M...	Normal.....	Aug. 3; 1 P. M....	13.2	Normal.
5	July 21; 9 A. M...	Normal.....	Aug. 3; 1 P. M....	13.2	Normal.
6	July 21; 9 A. M...	Normal.....	Aug. 3; 1 P. M....	13.2	Normal.
7	July 21; 9 A. M...	Normal.....	Aug. 3; 7 P. M....	13.4	Normal.
8	July 21; 9 A. M...	Normal.....	Aug. 4; 1 P. M....	14.2	Normal.
9	July 21; 9 A. M...	Normal.....	Aug. 4; 1 P. M....	14.2	Normal.
10	July 21; 9 A. M...	Normal.....	Aug. 4; 1 P. M....	14.2	Normal.
11	July 21; 9 A. M...	Normal.....	Aug. 4; 1 P. M....	14.2	Normal.
12	July 21; 9 A. M...	Normal.....	Aug. 4; 1 P. M....	14.2	Normal.
13	July 21; 9 A. M...	Normal.....	Aug. 4; 1 P. M....	14.2	Normal.
14	July 21; 9 A. M...	Normal.....	Aug. 4; 7 P. M....	14.4	Normal.
15	July 21; 9 A. M...	Normal.....	Aug. 4; 7 P. M....	14.4	Normal.
16	July 21; 9 A. M...	Normal.....	Aug. 4; 7 P. M....	14.4	Normal.
17	July 21; 9 A. M...	Normal.....	Aug. 5; 1 P. M....	15.2	Normal.
18	July 21; 9 A. M...	Normal.....	Aug. 5; 1 P. M....	15.2	Normal.
19	July 21; 9 A. M...	Normal.....	Aug. 5; 1 P. M....	15.2	Normal.
20	July 21; 9 A. M...	Normal.....	Aug. 5; 6 P. M....	15.4	Normal.
21	July 21; 9 A. M...	Normal.....	Aug. 5; 6 P. M....	15.4	Normal.
22	July 21; 9 A. M...	Normal.....	Aug. 6; 8 A. M....	16.0	Normal.
23	July 21; 9 A. M...	Normal.....	Aug. 6; 8 A. M....	16.0	Normal.
24	July 21; 9 A. M...	Normal.....	Aug. 6; 8 A. M....	16.0	Normal.
25	July 21; 9 A. M...	Normal.....	Aug. 6; 8 A. M....	16.0	Normal.
26	July 21; 9 A. M...	Normal.....	Aug. 6; 8 A. M....	16.0	Normal.
27	July 21; 9 A. M...	Normal.....	Aug. 6; 8 A. M....	16.0	Normal.
28	July 21; 9 A. M...	Normal.....	Aug. 6; 1 P. M....	16.2	Normal.
29	July 21; 9 A. M...	Normal.....	Aug. 6; 1 P. M....	16.2	Normal.
30	July 21; 9 A. M...	Normal.....	Aug. 6; 1 P. M....	16.2	Normal.
31	July 21; 9 A. M...	Normal.....	Aug. 6; 6 P. M....	16.4	Normal.

TABLE IV.

MOLTING PERIOD FOR FOURTH STAGE LOBSTERS.

SERIES B.—Concluded.

Number.	Molted to Fourth Stage.	Condition.	Molted to Fifth Stage.	Molting Period in days.	Condition.
	1905.		1905.		
32	July 21; 9 A. M...	Normal.....	Aug. 6; 6 P. M....	16.4	Normal.
33	July 21; 9 A. M...	Normal.....	Aug. 6; 6 P. M....	16.4	Normal.
34	July 21; 9 A. M...	Normal.....	Aug. 7; 8 A. M....	17.0	Normal.
35	July 21; 9 A. M...	Normal.....	Aug. 7; 8 A. M....	17.0	Normal.
36	July 21; 9 A. M...	Normal.....	Aug. 7; 8 A. M....	17.0	Normal.
37	July 21; 9 A. M...	Normal.....	Aug. 7; 2 P. M....	17.2	Normal.
38	July 21; 9 A. M...	Normal.....	Aug. 8; 10 A. M...	18.0	Normal.
39	July 21; 9 A. M...	Normal.....	Aug. 8; 10 A. M...	18.0	Normal.
40	July 21; 9 A. M...	Normal.....	Aug. 8; 1 P. M....	18.2	Normal.
41	July 21; 9 A. M...	Normal.....	Aug. 8; 1 P. M....	18.2	Normal.
42	July 21; 9 A. M...	Normal.....	Aug. 8; 6 P. M....	18.4	Normal.
43	July 21; 9 A. M...	Not normal.	Aug. 10; 8 A. M...	20.0	5 swimmerets gone.
44	July 21; 9 A. M...	Not normal.	Aug. 10; 8 A. M...	20.0	Reg. 1st right swimmeret. *
45	July 21; 9 A. M...	Not normal.	Aug. 10; 8 A. M...	20.0	Reg. 1st left swimmeret. *
46	July 21; 9 A. M...	Not normal.	Aug. 13; A. M...	23.0	Reg. 2nd left swimmeret. *
....	....	....	....	Av. 15.4 days.	....

*These four specimens had received injuries on the ventral side of the abdomen, and are not included in the general average.

TABLE V.

LENGTH OF THE MOLTING PERIODS FOR REGENERATING FOURTH STAGE LOBSTERS IN WHICH THE MUTILATIONS WERE MADE AT DIFFERENT TIMES IN THAT PERIOD.

SERIES C_4.

No.	Molted to Fourth Stage.	Date of Mutilation.	Molted to Fifth Stage.	Regenerated chelipeds.	Period for Regenerating Lobsters, in Days.	Period for Non-regenerating Lobsters, in Days.
	1905.	1905.	1905.			
1	July 21; 9 A. M...	July 25; 9 A. M...	Aug. 4; 7 P. M....	+	14.4	....
2	July 21; 9 A. M...	July 25; 9 A. M...	Aug. 6; 1 P. M....	+	16.2	....
3	July 21; 9 A. M...	July 25; 9 A. M...	Aug. 6; 1 P. M....	+	16.2	....
4	July 21; 9 A. M...	July 25; 9 A. M...	Aug. 6; 1 P. M....	+	16.2	....
5	July 21; 9 A. M...	July 25; 9 A. M...	Aug. 6; 1 P. M....	+	16.2	....
6	July 21; 9 A. M...	July 25; 9 A. M...	Aug. 6; 6 P. M....	+	16.4	....
7	July 21; 9 A. M...	July 25; 9 A. M...	Aug. 7; 5 P. M....	+	17.3	....
8	July 21; 9 A. M...	July 25; 9 A. M...	Aug. 8; 10 A. M...	+	18.0	....
9	July 21; 9 A. M...	July 25; 9 A. M...	Aug. 8; 1 P. M....	+	18.2	....
10	July 21; 9 A. M...	July 25; 9 A. M...	Aug. 9; 2 P. M....	+	19.2	....
Av. 10 cases.	....	....	....	....	Av. 16.8 days.	....

SERIES C_5.

1	July 21; 9 A. M...	July 26; 9 A. M...	Aug. 5; 6 P. M....	—	....	15.4
2	July 21; 9 A. M...	July 26; 9 A. M...	Aug. 6; 8 P. M....	+	16.0	....
3	July 21; 9 A. M...	July 26; 9 A. M...	Aug. 6; 8 A. M....	+	16.0	....
4	July 21; 9 A. M...	July 26; 9 A. M...	Aug. 6; 8 A. M....	—	16.0	....
5	July 21; 9 A. M...	July 26; 9 A. M...	Aug. 7; 2 P. M....	+	17.2	....
6	July 21; 9 A. M...	July 26; 9 A. M...	Aug. 7; 5 P. M....	—	....	17.3
7	July 21; 9 A. M...	July 26; 9 A. M...	Aug. 8; 10 A. M...	+	18.0	....
8	July 21; 9 A. M...	July 26; 9 A. M...	Aug. 8; 1 P. M....	+	18.2	....
9	July 21; 9 A. M...	July 26; 9 A. M...	................*	....	....	....
10	July 21; 9 A. M...	July 26; 9 A. M...	................*	....	....	....
Av. 8 cases.	....	....	....	....	Av. 16.9 days.	Av. 16.3 days.

*Did not live to molt to fifth stage.

+ or —, respectively, indicate that the lobster did or did not regenerate the chelipeds before molting to fifth stage.

TABLE V.

LENGTH OF THE MOLTING PERIODS FOR REGENERATING FOURTH STAGE LOBSTERS, IN WHICH THE MUTILATIONS WERE MADE AT DIFFERENT TIMES IN THAT PERIOD.—Continued.

SERIES C_6.

No.	Molted to Fourth Stage.	Date of Mutilations.	Molted to Fifth Stage.	Regenerated Chelipeds.	Period for Regenerating Lobsters in Days.	Period for Non-Regenerating Lobsters in Days.
	1905.	1905.	1905.			
1	July 21; 9 A. M...	July 27; 9 A. M...	Aug. 6; 8 A. M...	+	16.0	....
2	July 21; 9 A. M...	July 27; 9 A. M...	Aug. 6; 1 P. M...	+	16.2	....
3	July 21; 9 A. M...	July 27; 9 A. M...	Aug. 6; 1 P. M...	+	16.2	....
4	July 21; 9 A. M...	July 27; 9 A. M...	Aug. 7; 8 A. M...	+	17.0	....
5	July 21; 9 A. M...	July 27; 9 A. M...	Aug. 7; 2 P. M...	+	17.2	....
6	July 21; 9 A. M...	July 27; 9 A. M...	Aug. 7; 5 P. M...	+	17.3	....
7	July 21; 9 A. M...	July 27; 9 A. M...	Aug. 9; 2 P. M...	+	19.2	....
8	July 21; 9 A. M...	July 27; 9 A. M...	Aug. 10; 6 P. M...	+	20.4	....
9	July 21; 9 A. M...	July 27; 9 A. M...	Aug. 11; 6 P. M...	+	21.4	....
10	July 21; 9 A. M...	July 27; 9 A. M...	...............*	....	....	....
Av. 9 cases.	....	....	....	....	Av. 17 days.	....

SERIES C_7.

No.	Molted to Fourth Stage.	Date of Mutilations.	Molted to Fifth Stage.	Regenerated Chelipeds.	Period for Regenerating Lobsters in Days.	Period for Non-Regenerating Lobsters in Days.
1	July 21; 9 A. M...	July 28; 9 A. M...	Aug. 2; 1 P. M....	—	....	12.2
2	July 21; 9 A. M...	July 28; 9 A. M...	Aug. 2; 5 P. M....	—	....	12.3
3	July 21; 9 A. M...	July 28; 9 A. M...	Aug. 4; 1 P. M....	—	....	14.2
4	July 21; 9 A. M...	July 28; 9 A. M...	Aug. 7; 2 P. M....	+	17.2	....
5	July 21; 9 A. M...	July 28; 9 A. M...	Aug. 7; 2 P. M....	+	17.2	....
6	July 21; 9 A. M...	July 28; 9 A. M...	Aug. 7; 5 P. M....	+	17.3	....
7	July 21; 9 A. M...	July 28; 9 A. M...	Aug. 8; 6 P. M....	—	....	18.4
8	July 21; 9 A. M...	July 28; 9 A. M...	Aug. 9; 2 P. M....	+	19.2	....
9	July 21; 9 A. M...	July 28; 9 A. M...	Aug. 9; 6 P. M....	+	19.4	....
10	July 21; 9 A. M...	July 28; 9 A. M...	...............*	....	....	....
Av. 9 cases.	....	....	....	....	Av. 18.1 days.	Av. 14.3 days.

*Did not live to molt to fifth stage.
+ or —, respectively, indicate that the lobster did or did not regenerate the chelipeds before molting to fifth stage.

Table V.

LENGTH OF THE MOLTING PERIODS FOR REGENERATING FOURTH STAGE LOBSTERS, IN WHICH THE MUTILATIONS WERE MADE AT DIFFERENT TIMES IN THAT PERIOD.—Continued.

SERIES C_8.

No.	Molted to Fourth Stage.	Date of Mutilations.	Molted to Fifth Stage.	Regenerated. Chelipeds.	Period for Regenerating Lobsters, in Days.	Period for Non-Regenerating Lobsters in Days.
	1905.	1905.	1905.			
1	July 21; 9 A. M...	July 29; 9 A. M...	Aug. 2; 5 P. M...	—	....	12.3
2	July 21; 9 A. M...	July 29; 9 A. M...	Aug. 3; 7 P. M...	—	....	13.4
3	July 21; 9 A. M...	July 29; 9 A. M...	Aug. 4; 7 P. M...	—	....	14.4
4	July 21; 9 A. M...	July 29; 9 A. M...	Aug. 6; 1 P. M...	—	....	16.2
5	July 21; 9 A. M...	July 29; 9 A. M...	Aug. 7; 5 P. M...	+	17.3	....
6	July 21; 9 A. M...	July 29; 9 A. M...	Aug. 8; 10 A. M.	+	18.0	....
7	July 21; 9 A. M...	July 29; 9 A. M...	Aug. 8; 10 A. M .	+	18.0	....
8	July 21; 9 A. M...	July 29; 9 A. M...	Aug. 9; 2 P. M...	+	19.2	....
9	July 21; 9 A. M...	July 29; 9 A. M...	Aug. 9; 6 P. M...	+	19.4	....
10	July 21; 9 A. M...	July 29; 9 A. M...	Aug. 10; 2 P. M...	+	20.2	....
Av. 10 cases.	....	....	....	....	Av. 18.7 days.	Av. 14.1 days.

SERIES C_9.

No.	Molted to Fourth Stage.	Date of Mutilations.	Molted to Fifth Stage.	Regenerated. Chelipeds.	Period for Regenerating Lobsters, in Days.	Period for Non-Regenerating Lobsters in Days.
1	July 21; 9 A. M...	July 30; 9 A. M...	Aug. 3; 1 P. M...	—	....	13.2
2	July 21; 9 A. M...	July 30; 9 A. M...	Aug. 5; 6 P. M...	—	....	15.4
3	July 21; 9 A. M...	July 30; 9 A. M...	Aug. 6; 1 P. M...	—	....	16.2
4	July 21; 9 A. M...	July 30; 9 A. M...	Aug. 7; 8 A. M...	+	17.0	....
5	July 21; 9 A. M...	July 30; 9 A. M...	Aug. 9; 2 P. M...	+	19.2	....
6	July 21; 9 A. M...	July 30; 9 A. M...	Aug. 9; 2 P. M...	+	19.2	....
7	July 21; 9 A. M...	July 30; 9 A. M...	Aug. 10; 2 P. M...	+	20.2	....
8	July 21; 9 A. M...	July 30; 9 A. M...	Aug. 23; 6 P. M...	—	....	§23.4
9	July 21; 9 A. M...	July 30; 9 A. M...	...............*	....	....	....
10	July 21; 9 A. M...	July 30; 9 A. M...	...............*	....	....	....
Av. 8 cases.	....	....	....	....	Av. 18.9 days.	Av. 14.9 days.

*Did not live to molt to fifth stage.

+ or —, respectively, indicate that the lobster did or did not regenerate the chelipeds before molting to fifth stage.

§Lobster No. 8, Series C_9, seemed such an exceptional case that it was not included in the average.

Table V.

LENGTH OF THE MOLTING PERIODS FOR REGENERATING FOURTH STAGE LOBSTERS, IN WHICH THE MUTILATIONS WERE MADE AT DIFFERENT TIMES IN THAT PERIOD.—Continued.

SERIES C_{10}.

No.	Molted to Fourth Stage.	Date of Mutilations.	Molted to Fifth Stage.	Regenerated. Chelipeds.	Period for Regenerating Lobsters, in Days.	Period for Non-Regenerating Lobsters, in Days.
	1905.	1905.	1905.			
1	July 21; 9 A. M...	July 31; 9 A. M...	Aug. 1; 6 P. M...	—	....	11.4
2	July 21; 9 A. M...	July 31; 9 A. M...	Aug. 4; 7 P. M...	—	....	14.4
3	July 21; 9 A. M...	July 31; 9 A. M...	Aug. 5; 1 P. M...	—	....	15.2
4	July 21; 9 A. M...	July 31; 9 A. M...	Aug. 5; 1 P. M...	—	....	15.2
5	July 21; 9 A. M...	July 31; 9 A. M...	Aug. 9; 6 P. M...	+	19.4	....
6	July 21; 9 A. M...	July 31; 9 A. M...	Aug. 10; 8 A. M...	+	20.0	....
7	July 21; 9 A. M...	July 31; 9 A. M...	Aug. 11; 2 P. M...	+	21.2	....
8	July 21; 9 A. M...	July 31; 9 A. M...	Aug. 11; 6 P. M...	+	21.4	....
9	July 21; 9 A. M...	July 31; 9 A. M...	Aug. 12; 5 A. M...	+	21.8	....
10	July 21; 9 A. M...	July 31; 9 A. M...	...............*	....	....	....
Av. 9 cases.	....	....	....	....	Av. 20.8 days	Av. 14.0 days.

SERIES C_{11}.

No.	Molted to Fourth Stage.	Date of Mutilations.	Molted to Fifth Stage.	Regenerated. Chelipeds.	Period for Regenerating Lobsters, in Days.	Period for Non-Regenerating Lobsters, in Days.
1	July 21; 9 A. M...	Aug. 1; 9 A. M....	Aug. 2; 5 P. M...	—	....	11.3
2	July 21; 9 A. M...	Aug. 1; 9 A. M....	Aug. 2; 5 P. M...	—	....	11.3
3	July 21; 9 A. M...	Aug. 1; 9 A. M....	Aug. 4; 1 P. M...	—	....	14.2
4	July 21; 9 A. M...	Aug. 1; 9 A. M....	Aug. 5; 1 P. M...	—	....	15.2
5	July 21; 9 A. M...	Aug. 1; 9 A. M....	Aug. 6; 8 A. M...	—	....	16.0
6	July 21; 9 A. M...	Aug. 1; 9 A. M....	Aug. 6; 1 P. M...	—	....	16.2
7	July 21; 9 A. M...	Aug. 1; 9 A. M....	Aug. 8; 10 A. M..	—	....	18.0
8	July 21; 9 A. M...	Aug. 1; 9 A. M....	Aug. 10; 2 P. M...	+	20.2	....
9	July 21; 9 A. M...	Aug. 1; 9 A. M....	Aug. 13; 5 P. M...	+	23.3	....
10	July 21; 9 A. M...	Aug. 1; 9 A. M....	...............*	....	....	....
Av 9 cases.	....	....	....	....	Av. 21.7 days.	Av. 14.6 days.

*Did not live to molt to fifth stage.
+ or —, respectively, indicate that the lobster did or did not regenerate the chelipeds before molting to fifth stage.

Table V.—Concluded.

SERIES C_{12}.

No.	Molted to Fourth Stage.	Date of Mutilations.	Molted to Fifth Stage.	Regenerated Chelipeds.	Period for Regenerating Lobsters, in Days.	Period for Non-Regenerating Lobsters, in Days.
	1905.	1905.	1905.			
1	July 21; 9 A. M...	Aug. 2; 9 A. M....	Aug. 3; 6 A. M...	—	....	12.8
2	July 21; 9 A. M...	Aug. 2; 9 A. M....	Aug. 3; 1 P. M...	—	....	13.2
3	July 21; 9 A. M...	Aug. 2; 9 A. M....	Aug. 4; 1 P. M...	—	....	14.2
4	July 21; 9 A. M...	Aug. 2; 9 A. M....	Aug. 5; 1 P. M...	—	....	15.2
5	July 21; 9 A. M...	Aug. 2; 9 A. M....	Aug. 5; 1 P. M...	—	....	15.2
6	July 21; 9 A. M...	Aug. 2; 9 A. M....	Aug. 7; 8 A. M...	—	....	17.0
7	July 21; 9 A. M...	Aug. 2; 9 A. M....	Aug. 7; 8 A. M...	—	....	17.0
8	July 21; 9 A. M...	Aug. 2; 9 A. M....	Aug. 12; 5 A. M...	—	....	21.8
9	July 21; 9 A. M...	Aug. 2; 9 A. M....	Aug. 12; 6 P. M...	—	....	22.4
10	July 21; 9 A. M...	Aug. 2; 9 A. M....	Aug. 13; 7 A. M...	+	22.9	....
Av. 10 cases.	....	....	....	....	Av. 22.9 days.	Av. 16.5 days.

SERIES C_{13}.

No.	Molted to Fourth Stage.	Date of Mutilations.	Molted to Fifth Stage.	Regenerated Chelipeds.	Period for Regenerating Lobsters, in Days.	Period for Non-Regenerating Lobsters, in Days.
1	July 21; 9 A. M...	Aug. 3; 9 A. M....	Aug. 3; 1 P. M...	—	....	13.2
2	July 21; 9 A. M...	Aug. 3; 9 A. M....	Aug. 3; 1 P. M...	—	....	13.2
3	July 21; 9 A. M...	Aug. 3; 9 A. M....	Aug. 4; 1 P. M...	—	....	14.2
4	July 21; 9 A. M...	Aug. 3; 9 A. M....	Aug. 5; 6 P. M...	—	....	15.4
5	July 21; 9 A. M...	Aug. 3; 9 A. M....	Aug 8; 10 A. M..	—	....	18.0
6	July 21; 9 A. M...	Aug. 3; 9 A. M....	Aug. 8; 6 P. M...	—	....	18.4
7	July 21; 9 A. M...	Aug. 3; 9 A. M....	Aug. 10; 8 A. M...	—	....	20.0
8	July 21; 9 A. M...	Aug. 3; 9 A. M....	Aug. 10; 6 A. M...	+	20.4	....
9	July 21; 9 A. M...	Aug. 3; 9 A. M....	Aug. 13; 7 A. M...	+	22.9	....
10	July 21; 9 A. M...	Aug. 3; 9 A. M....	...............*	....	....	....
Av. 9 cases.	....	....	....	....	Av. 21.6 days.	Av. 16.0 days.

All mutilations consisted in the removal of both chelipeds.

The sub-numerals in each series indicate the number of days after the molt before the mutilations were made; thus "Series C_4" indicates that the chelipeds were removed four days after molting.

*Did not live to molt to fifth stage.

+ or —, respectively, indicate that the lobster did or did not regenerate the chelipeds before molting to fifth stage.

c. *Discussion of Results.*

In series B, 42 lobsters molted to the fifth stage and were in a normal condition throughout the experiment. The average length of the normal molting period was 15.4 days.

In the mutilated series, 91 of the 100 specimens molted to the fifth stage. In regard to the regeneration of the chelipeds, it may be noticed from the data in Table V that from series C_4 to series C_{13}, inclusive, there was a rapid decrease in the number of individuals which had regenerated the chelipeds by the time the molt occurred. The significance of this will be discussed later: for our present purpose we are only concerned with those specimens in which the process of regeneration was actually introduced and the chelipeds regenerated by the time the next molt took place.

The average length of the molting periods of the regenerating lobsters is as follows:

Series.		Days.	Series.		Days.
C_4	=	16.8	C_9	=	18.9
C_5	=	16.9	C_{10}	=	20.8
C_6	=	17.9	C_{11}	=	21.7
C_7	=	18.1	C_{12}	=	22.9
C_8	=	18.7	C_{13}	=	21.6

Keeping in mind that the series numeral in each case indicates the number of days after the molt, before the chelipeds were removed, it is quickly seen that there is a gradual lengthening of the molting period, corresponding very closely with the time at which the regenerative process was introduced.

This relation between the molting period and regeneration is even more clearly brought out by a comparsion of the percentage by which the normal molting period has been lengthened for each regenerating series. This is shown by the following figures, in which one column represents the *percentage* by which the molting period for the regenerating lobsters in the corresponding series has been lengthened as compared with the normal period:

Series.	Percentage of increase in length of Molting Period.	Series.	Percentage of increase in length of Molting Period.
C_4	9.0	C_9	22.7
C_5	9.7	C_{10}	35.0
C_6	16.2	C_{11}	40.9
C_7	17.6	C_{12}	48.7
C_8	21.4	C_{13}	40.2

From this comparison it is evident that in this series, in which the process of regeneration had been introduced at intervals ranging from four to thirteen days after the molt, there was an increase in the length of the molting period, as compared with the normal period, ranging from 9 per cent. to the remarkable amount of 48.7 per cent.

The graphical presentation of the data, as shown in Chart IX, demonstrates in another way the nature of the results of the experiment. This chart represents the molting periods for the regenerating and normal lobsters in each series, and furnishes a ready comparison both for the differences in the average time of molting and for the variation of the individuals of each series about these averages.

The heavy black line slightly below the central part of the figure represents the average time in which the normal lobsters in series B molted to the fifth stage. The variations of these 42 specimens around this average are indicated by the dotted line crossing it near the centre.

The upper part of the figure is broken up into ten segments representing the series C_4 to C_{13}, inclusive. The width of each segment is governed by the number of lobsters which regenerated the chelipeds in each series. The heavy discontinuous lines in each segment represent the average time of molting for the regenerating specimens of each series. It may also be noticed that the order of the segments is determined by the time of mutilation, so that the averages are, accordingly, arranged in a series corresponding to the time at which the regenerative process was introduced into the molting period. The light dotted lines indicate the variation about these averages. Finally, the differences in the levels of the lines representing the regenerating specimens indicate the extent to which the rate of molting has been delayed in the regenerating series, both as compared with each other and as compared with the rate for the normal specimens.

The effect of introducing the process of regeneration at different times in the molting period may be readily perceived. Keeping in mind the significance of the elevation of different lines, it is immediately seen that the average date of molting for the regenerating specimens rises in an ascending series, corresponding in a remarkable way with the time of mutilation. Again, a comparison of the elevation of the regenerating averages above the normal level shows a gradual increase in the length of the molting periods for each sucessive regenerating series.

From a more detailed examination it is also apparent that the variation in the date of molting for both the regenerating and normal specimens, around their respective averages, is fairly constant; and that in the regenerating series, beginning with series C_4, there is a gradual elevation of the point at which the variation begins.

Thus from these comparisons of the averages for the date of molting, and the individual variations about these averages, it seems very evident that there is an increasing *delay in the time of molting* for each series of regenerating lobsters; and also that this delay is *closely correlated with the time at which the process of regeneration began.*

There is a slight irregularity in the averages for series C_{11}, C_{12}, and C_{13}; but it should be observed that, in series C_{11} and C_{13}, there were but two specimens, and in series C_{12} there was only one specimen, which actually regenerated the chelipeds: so that the comparative irregularity in the averages derived from such a small number of individuals does not detract from the essential character of the results.

This experiment, then, clearly demonstrates that, if the regeneration of a cheliped begins immediately after a molt, the length of the molting period may be affected very slightly, if at all; that, on the other hand, if the regeneration begins extremely late in the period, the molting period may be increased in length by even as much as 48 per cent., or, in other words, by nearly one-half the normal period. Accordingly, since the effect of the regenerative process in this experiment is fairly proportionate to the time at which it was introduced, the relation may be stated as follows: *the later the time at which regeneration begins after the molt, the greater the length of the entire molting period of the lobster.*

In estimating for comparative purposes the value of the conditions involved in the experiments so far described, the following observation seems important.

In the introduction to the present subject reference was made to the fact that the season of the year, or, rather, the temperature of the water, which is the essential condition in this instance, has a marked influence upon the length of the molting period. This effect is well illustrated by a comparison of the normal molting period for series A with the normal period for series B, in the preceding experiments.

The lobsters in these two series, it may be recalled, were all in the same stage and in a normal condition. Accordingly it might naturally be expected that, in both series, the molting periods would be practically equal in length. But this was not the case, for while the average period for series A was only 12 days, the corresponding period for series B was 15.4 days; so that, instead of an approximate equality in length, there is a difference of 3.4 days, or an increase of over 28 per cent., in the average length of the normal molting period in favor of series B.

During the course of the experiment with series B it was noticed that the general condition of the weather was cooler than it had been during the previous experiment; indeed, this was so evident that it suggested that this fall in temperature might account for the longer molting period for series B, and accordingly a note of this observation was made in the daily records. Now, since apparently the only difference in the conditions involved in these two series of lobsters consisted in the time at which the experiments were made, it is interesting to see to what extent the difference in the results may be correlated with a difference in temperatures.

It may be seen from the data for these experiments that the molting period for series A extended over the interval between July 8 and July 22; while series B molted between the dates July 21 and August 8. In order to ascertain to what extent there was a difference in the temperature for these two periods corresponding with the differences in molting, a comparison of the water temperature during these periods is necessary. The following average temperature readings of the water are taken from the Station records.*

Average Water Temperatures During the Periods for Series A and Series B.

Series A.		Series B.	
July 8	74°	July 21	74°
July 10	74.5°	July 22	74°
July 10	74.6°	July 23	72°
July 11	77°	July 24	73°
July 12	75°	July 25	68.5°
July 13	75.5°	July 26	69.5°
July 14	74°	July 27	68.5°
July 15	74°	July 29	69.5°
July 16	76°	July 30	72°
July 17	77.5°	July 31	71°
July 18	76.5°	August 1	68°
July 19	76.5°	August 2	68.5°
July 20	74°	†August 8	72°
July 21	74°		
July 22	74°	Average	70°
Average	75°		

*See chart V, page 29, Report of Rhode Island Commission of Inland Fisheries for 1905.

†After the closing of the lobster hatching season, the temperature readings at the station were not taken every day, so it was not possible to get *daily* readings for the month of August.

A comparison of these temperatures shows that during the first part of July the water was much warmer than for the last part of July and the first part of August, so that there was a difference of as much as 5° in the average temperature for these two periods in favor of series A.

This comparatively large difference in temperature undoubtedly accounts, to a very large degree, for the corresponding difference in the normal molting periods for the two series of lobsters. This fact very clearly demonstrates the importance of securing similar conditions in season and temperature for experiments of this nature in order to obtain the most reliable data for comparative purposes.

Again, it may also be observed in the above temperature readings that, during the latter part of July, there was a gradual decline in the temperature of the water. Now, since in the experiments with series C_4 to C_{13} the last molts occurred at late as August 13, it might be suggested that, possibly, the delay in molting in these specimens may have been partly due to a decline in temperature as well as to the process of regeneration. That this could not have been the case, however, may be readily seen from the following temperature readings of the water up to August 13:

August 1	68°
August 2	68.5°
August 8	72°
August 9	74°
August 12	78°

From these readings it will be seen that for some climatic reason, instead of a decline, there was a marked *rise* in the temperature of the water from August 1 to August 13.

This marked increase in temperature during the latter part of the molting period for series C_4 to C_{13} would evidently tend to hasten rather than retard the rate of molting. Accordingly, the temperature conditions in the latter part of this experiment, instead of detracting, serve to emphasize the influence of regeneration in lengthening the molting period of these lobsters.

4.

The Influence of Variation in the Amount of Regeneration, as Determined by Different Degrees of Injury, upon the Length of the Period Between Molts.

In the preceding study of the effect of regeneration upon the rate of molting it will be noticed that in all the experiments the mutilations consisted in the removal of the two chelipeds, and that, consequently, the amount of regeneration consisted only in the development of these two limbs; *i. e.* the degree of injury and the resultant amount of regeneration was *constant.*

The results of these experiments show that the effect of regeneration was to lengthen the molting period. In view of this fact the question arises whether, with an increase in the degree of injury, or, in other words, an increase in the amount of regeneration, there is also a corresponding increase in the length of the molting period.

a. Experiments.

At the time when the following experiment was made it was so late in the season that it was not possible to obtain lobsters which were in the same stage as the specimens in the preceding experiments. The only available source for material at this time was a group of sixth stage lobsters which were being kept for a study of the effect of regeneration upon the rate of growth. These lobsters had all been mutilated in the fifth stage, but they had regenerated the injured limbs and molted to the sixth stage in practically a normal condition. From this group of lobsters 12 specimens were selected which had all molted to the sixth stage at nearly the same time, August 24 and 25. Since the observations on the group of lobsters from which these specimens were selected were made but once a day, and that generally during the forenoon, the date of molting to the sixth stage for each specimen is recorded as having occurred at 12 M.

In order to secure better conditions for comparative purposes, these specimens were also selected in pairs, the members of which were equal in size. Accordingly these 12 lobsters were arranged into six groups, with two specimens of equal length in each group.

Three days after the molt to the sixth stage each specimen was mutilated so as to cause the autotomy of some of the limbs. The degree of mutilation was such that one lobster in each group had only the right cheliped removed, while the other member of each group had both chelipeds and the third and fourth pairs of walking legs removed. Accordingly, in regard to the number of limbs removed, the degree of mutilation for half of these lobsters was six times more than for the remaining specimens. The group of specimens with only one cheliped gone will be designated as series D, and the other group, with the larger degree of mutilation, as series E.

It is evident from the previous results that, if the mutilations in the present experiment had been made later in the molting period, the effect upon the length of the period would have been much greater. But, on the other hand, it is equally evident that in a later mutilation it is not so certain that the injury will be followed by the regeneration of the limb. Accordingly, in order to increase the chances that all the mutilations would be succeeded by the regeneration of the limbs before the next molt, the operations were made early in the molting period. If, however, the amount of regeneration, as determined by the degree of injury, has any influence upon length of the molting period, it seemed reasonable to expect that, even under these rather unfavorable conditions in regard to the time of mutilation, there ought to be some difference in the molting periods of these two series of lobsters corresponding to a difference in the degree of injury.

b. Tabulation of Results.

Table VI contains the records of the experiment. The data includes the time of mutilation, the date of molting, and the condition and length of each specimen after molting. The length of the lobster is the measurement from the tip of the rostrum to the end of the telson in millimeters.

TABLE VI.

THE INFLUENCE OF THE AMOUNT OF REGENERATION AS DETERMINED BY THE DEGREE OF INJURY, UPON THE LENGTH OF THE MOLTING PERIOD.

SERIES D.—(*Right Cheliped Removed*).

No.	Molted to Sixth Stage.	Length in mm.	Date of Mutilation.	Molted to Seventh Stage.	Length in mm.	Molting Period in Days.
14	Aug. 25; 12 M.	15.0	Aug. 28; 4 P. M.	Sept. 8; 8 A. M.	17.5	13.9
16	Aug. 24; 12 M.	15.5	Aug. 27; 4 P. M.	Sept. 10; 6 A. M.	18.0	16.8
17	Aug. 25; 12 M.	16.0	Aug. 28; 4 P. M.	Sept. 12; 2 P. M.	19.0	18.1
9	Aug. 24; 12 M.	16.0	Aug. 27; 4 P. M.	...............*	....	....
11	Aug. 24; 12 M.	17.0	Aug. 27; 4 P. M.	Sept. 12; 7 A. M.	19.0	18.8
7	Aug. 25; 12 M.	17.5	Aug. 28; 4 P. M.	Sept. 12; 7 A. M.	19.5	17.8
.....	....	Average 16.2 mm	....	....	Average 18.6 mm.	Average 17.1 dys.

*Died September 11, before molting.

SERIES E.—(*Both Chelipeds, and Third and Fourth Pair of Legs Removed*).

13	Aug. 24; 12 M.	15.0	Aug. 27; 4 P. M.	Sept. 10; 8 A. M.	17.5	16.9
15	Aug. 24; 12 M.	15.5	Aug. 27; 4 P. M.	Sept. 12; 2 P. M.	18.3	19.1
18	Aug. 25; 12 M.	16.0	Aug. 28; 4 P. M.	Sept. 12; 1 P. M.	19.0	18.0
10	Aug. 24; 12 M.	16.0	Aug. 27; 4 P. M.†	Sept. 12; 4 P. M.§	17.7	19.2
8	Aug. 24; 12 M.	17.5	Aug. 27; 4 P. M.*	Sept. 11; 2 P. M.‡	20.0	18.1
12	Aug. 24; 12 M.	17.0	Aug. 27; 4 P. M.	Sept. 11; 8 A. M.	19.0	17.8
.....	....	Average 16.2 mm.	....	....	Average 18.6 mm.	Average 18.2 dys.

*First right leg gone at time of mutilation.
†Fourth right leg gone at time of mutilation.
‡Had not regenerated fourth left leg.
§Had not regenerated third and fourth right legs.

c. *Discussion of Results.*

The results obtained show that the average length of the molting period for series D was 17.1 days; while for series E it was 18.2 days; or in other words, with the larger amount of regeneration in series E as compared with series D, there was correlated an increase in the length of the molting period for Series E of nearly 7 per cent.

The results of this experiment, therefore, seem to indicate that the relation between the length of the molting period and the amount of regeneration as determined by the degree of injury is that the greater the amount of regeneration the greater the length of the molting period.

Whether this effect of amount of regeneration as determined by the degree of injury is in a *direct ratio* to the degree of injury, or whether it varies according to the time of mutilation, must be answered by fourther experimentation.

5.

The Influence of the Injury of Mutilation upon the Length of the Period Between Molts.

It is evident that thus far one element involved in the conditions of the experiments has been disregarded; namely, the *injury* caused by the process of mutilation.

The facts considered so far have shown that, when the process of regeneration was introduced into the molting period, the act of molting was delayed, and the cause for this increased length of the molting period was ascribed to regeneration. But it might be objected to this conclusion that, instead of the delay in molting being caused by the process of regeneration, possibly it may rather be due to the injuries attending the act of mutilation. It becomes important, therefore, to consider the effect upon the molting period of those mutilations which have not been followed by the regeneration of the removed limbs.

a. Experiments.

In the course of the preceding experiments quite a large percentage of the mutilated specimens had not regenerated the chelipeds by the time the molt following the mutilation occurred. Now the degree of mutilation in all these lobsters was exactly the same. Therefore the molting periods of those specimens which did not regenerate the chelipeds ought to furnish valuable data in regard to the effect of the injury itself of mutilation.

b. Tabulation of Data.

In the preceding description of Tables II, III, and V it was stated that, in series A_1, A_4, and C_4 to C_{13}, a distinction had been made between those specimens which had, and those which had not, regenerated the chelipeds. Accordingly, the right-hand columns of these respective tables which show the results for the molting periods of these latter specimens contain the data necessary for the present purpose.

c. Discussion of Results.

An examination of the data for series A_1 in Table II shows that, out of the 21 lobsters which had been mutilated one day after the molt, five individuals had not regenerated the chelipeds before molting to the fifth stage. The average length of the molting period for these five specimens was 12.9 days. On the other hand, it may be recalled that the length of the corresponding period for the regenerating specimens in the same series was 12.5 days, while the normal molting period of the controls in this experiment was 12 days. From this it may be seen that there is practically little difference in the length of the molting periods for the regenerating and the mutilated non-regenerating lobsters. Accordingly it seems evident that, just as in the case of the process of regeneration, so in the case of the injury of mutilation, it is equally true that, if the mutilation is made immediately after the molt, neither the injury involved in the operation nor the resulting regeneration materially affect the length of the molting period. Naturally, therefore, the results for series A_1 can not furnish an adequate comparison of the effect of the injury of mutilation with the effect of regeneration, because the mutilations were made too early in the molting period.

Proceeding next to an examination of the data in Table III, it may be seen that only four of the 23 lobsters in series A_4 had not regenerated the chelipeds by the time of molting. The results, however, for this comparatively small number of mutilated, non-regenerating specimens, are very suggestive. For in this experiment the average length of the molting period for the regenerating lobsters begins to be longer than the corresponding period for the non-regenerating specimens, so that, while the average for the former was 14.3 days, for the latter the average molting period was only 13.4 days. It may also be noticed that the mutilations in this series of lobsters, instead of being made one day after the molting to the fourth stage, as in series A_1, were made four days after the molt; and this suggests that, if there really is a difference between the effects of the injury of mutilation and the effect of mutilation plus regeneration, it ought to become more apparent in mutilations made still latter in the molting period.

Accordingly, therefore, in passing to the next series of experiments, in which the mutilations were made at various times throughout the entire molting period, it might be expected that a difference between the molting periods for regenerating and the corresponding periods for the mutilated, non-regenerating lobsters would begin to appear; and it is surprising to what extent this is demonstrated in the results for series C_4 to C_{13}.

It will be recalled that Table V contains the data for both the regenerating and the mutilated non-regenerating lobsters in series C_4 to C_{13}. From these data the average length of the molting periods for the regenerating and non-regenerating specimens have been taken and arranged as follows:

Series.	Regenerating lobsters.	Non-regenerating lobsters.
C_4	16.8 days	....
C_5	16.9 days	16.3 days
C_6	17.9 days	....
C_7	18.1 days	14.3 days
C_8	18.7 days	14.1 days
C_9	18.9 days	14.9 days
C_{10}	20.8 days	14.0 days
C_{11}	21.7 days	14.6 days
C_{12}	22.9 days	16.5 days
C_{13}	21.6 days	16.0 days
Average	19.4 days.	Average .... 15.1 days

A comparison of these two columns shows a remarkable difference in the molting periods. In every series the molting periods for the non-regenerating lobsters are shorter, and excepting C_6 are much shorter than the periods for the regenerating specimens, so that the averages for the columns representing these two classes, respectively, are 15.1 days and 19.4 days. In other words the average length of the molting periods for all the non-regenerating lobsters in series C_4 to C_{13} were shorter than the corresponding average period for the regenerating individuals by as much as 4.3 days, or over 22 per cent.

In order to obtain a better conception of the relation of these results to each other and to the normal molting period, the averages for series B and series C_4 to C_{13} have been graphically represented in Chart IX. The heavy black line crossing the figure slightly below the center represents the average normal molting period obtained from the 42 control lobsters in series B.

The figure as a whole has been vertically divided into 10 equal sections, and beginning at the left each successive section corresponds to one of the 10 groups in series C_4 to C_{13}. The heavy discontinuous line represents the regenerating individuals, while the dotted line indicates the non-regenerating individuals in each series; also the length of each line corresponds to the *number of individuals.* It will also be observed that the *elevation* of the lines in each section, with reference to the normal level for series B, indicates the extent to which the average molting period has been lengthened or shortened in each case.

Now if the injury due to mutilation is as great a factor as the process of regeneration in lengthening the molting period, it would be expected that the general elevation of the dotted lines above the normal standard would be approximately equal and be practically coincident with the general level of the heavy broken lines. But it is readily seen that such is not the case; for the general levels of the dotted lines remain comparatively close to the normal standard. Consequently, instead of beginning at the left and taking a course coincident with the level of the broken lines in each section, the dotted lines or non-regenerating levels begin at the left and steadily *diverge* from the broken lines or regenerating levels, and the majority of the dotted lines even lie below the normal. In other words, the average length of the molting periods for the mutilated non-regenerating individuals is not only shorter than the periods for the regenerating specimens, but in the majority of cases the non-regenerating period is even shorter than the normal molting period.

Thus this graphical representation most clearly emphasizes the general character of the data; and the results of these experiments prove that the injury of mutilation alone does not, in general, materially lengthen the molting period. Therefore it seems evident that *the injury due to the act of mutilation can not, to any great extent, account for the increase in the length of the molting period produced by the process of regeneration.*

6.

THE INFLUENCE OF THE MOLTING PROCESS UPON THE REGENERATIVE PROCESS IN REGARD TO ITS RESPONSE TO MUTILATION.

So far in the present study of the relation of regeneration to the molting process only one phase of the problem has been considered, *i. e.* the effect of regeneration upon the length of the molting period. But there remains an equally important aspect of the problem, namely, the relation in the opposite direction, consisting in the influence of molting upon the process of regeneration.

Some data on the amount and rate of regeneration were taken in the course of the preceding experiments, but they are not sufficient to justify positive conclusions. It is intended to conduct another series of experiments on this subject, and by measuring the lengths of the regenerated limbs and the time in which they regenerated, under conditions varying in regard to the time of mutilation, degree of injury, the amount of food, etc., secure data for a more complete investigation of the factors influencing the process of regeneration in the lobster.

As a preliminary, however, to such a further study, some of the present data furnish suggestive results bearing on one aspect of the subject; namely, the *response* of the regenerative process to mutilation, as influenced by the molting process.

On first thought it would be most natural to expect that, whenever a limb is removed from the lobster, the process of regenerating it would immediately begin; and it might also be supposed that the regenerative process would respond with equal readiness to mutilations made either early or late in the molting period. But that this is not the case is shown by some of the results obtained in the course of the preceding experiments.

In the experiments with C_4 to C_{13}, for example, it was attempted to introduce the regenerative process at different times in the molting period, but it was found very difficult to do so in the latter part of the period, because the removed limbs would not always regenerate. The extent of this difficulty may be readily seen by an examination of the graphical representation of the results for series C_4 to C_{13}, as shown in Chart IX. It will be recalled that the heavy discontinuous lines and the dotted lines represent the regenerating and the non-regenerating specimens, respectively; and that the lengths of these lines are proportionate to the number of lobsters in each series which did or did not regenerate the chelipeds before the next molt occurred. A comparison of the relative lengths of these lines in each successive section shows that, beginning at the left with series C_4, in which all the mutilations were followed by regeneration, there was a gradual decrease in the number of regenerating individuals and a corresponding increase in the number of non-regenerating individuals, to such an extent that, in series C_{13}, only two of the nine specimens had regenerated the chelipeds. In other words, the difficulty encountered in introducing the process of regeneration at later stages of the molting period increased to such a degree that over 77 per cent. of the mutilations made in the later part of the period were not followed by the regeneration of the chelipeds.

Accordingly, therefore, it seems evident that the process of regeneration does not respond with equal readiness to mutilations made at any time in the molting period; but that it varies according to the time of mutilation; so that while in the earlier part of the molting period the process of regeneration practically always succeeds a mutilation, in the latter part of the period, on the contrary, the chances that a mutilation will be followed by the regeneration of the limbs may be reduced by as much as 77 per cent.

7.

The Effect of Regeneration upon the Rate of Growth of the Lobster.

It is a well-known fact that the lobster, as well as most crustaceans, increases in size and to all appearances grows only at certain periods; *i. e.* the time of molting. But of course this increase in size is not due to growth merely at the time of molting. The facts are that the animal has been growing more or less continually throughout the whole interval between two successive molts; but the hard chitinous shell or exoskeleton will not expand sufficiently to accommodate the growing organism; therefore the developing tissues and organs must increase in mass and compactness till the time of molting, and mean-while a new shell is formed underneath the old one, and when the organizm is ready to molt a split occurs in the shell on the dorsal side of the body, between the carapace and abdomen; a series of laborious movements begin, and gradually the lobster emerges from his old shell. The compact tissues and organs, thus liberated from their unyielding covering, expand and consequently rapidly increase the size of the animal.

Now, since this increase in the size of the lobster is so clearly correlated with molting, it is evident that whatever condition hastens or retards the frequency of molting must be regarded as an important factor in the growth of the organism. It has been shown in the preceding experiments that the process of regeneration, by retarding the process of molting, tends to diminish the frequency of molting. In view of these facts, therefore, it becomes important to study the effect of regeneration upon the rate of growth of the lobster.

a. Experiments.

For the purpose of studying the effect of regeneration upon the growth of the lobster, comparison was made between the growth of a series of normal and regenerating lobsters, through successive molting periods. It is evident that, in order to compare adequately two series of this nature, it is important that the specimens should all be in the same stage and under similar conditions at the beginning of the experiment. At the time when these observations on growth were begun, however, it was so late in the hatching season that the specimens necessary for the present purpose could not be obtained from the hatchery. Accordingly, the only adequate material at hand were the specimens in series B and series C_4 to C_{13}, remaining from the preceding experiments. These, it may be recalled, all molted to the fourth stage on the same night, July 21. Nineteen normal lobsters were available from series B and 36 were obtained from series C_4 to C_{13}.

Since, in the preceding experiments, the individuals in series B and series C_4 to C_{13} were, respectively, in a normal and regenerating condition, naturally the method in the present experiment consisted in continuing to keep the lobsters from series B in a normal condition, and continuing to mutilate the individuals from Series C_4 to C_{13}, after every molt. These normal and regenerating lobsters will be designated as Group I and Group II, respectively.

The mutilations in Group II consisted in the removal of both chelipeds, as before. If in any case the mutilation included also some of the legs, it was noted in the records. The mutilations were all made on about the third or fourth day after each molt, with the exception of those made after the molt into the fourth stage, which were a part of the previous experiment. The limbs were removed at this time to insure a regeneration of the appendages before the succeeding molt. Although it is evident from the results of preceding experiments that later mutilations would have produced a greater effect upon the length of the molting periods, still the results from even the present mutilations were sufficient to show a distinct effect upon the growth of the lobster.

Each specimen was placed in one of the wire screen cylinders previously described, and the two groups of lobsters were kept in as nearly the same conditions as possible. Observations were made once a day during the month of August and the first part of September. Records for each specimen consisted of the date of molts, the time of mutilation, and the length and condition of the lobster after each molt. By the middle of September the lobsters had all molted to the seventh stage. After the middle of September it became necessary to discontinue the daily records, and only occasional observations and measurements were taken. On December 2nd a final measurement was recorded for each specimen.

b. Tabulation of Results.

Thirteen of the normal lobsters in Group I and 26 of the regenerating specimens molted to the seventh stage and, with the exception of 4 specimens, lived up to December 2, the date of the last observation. The data for these normal and regenerating lobsters are given in Tables VII and VIII, respectively. In order to secure a better basis for comparison, the data for the other specimens in the experiment, which did not continue through to the seventh stage, are not included in these tables. Both tables show the date of molts, and the length and condition of each lobster after every molt; the time of mutilation for the regenerating specimens, and the length of the interval between molts, or, in other words, the length of the stage period for each individual. The length of each lobster is in millimeters, and represents the length from the rostrum to the tip of the telson.

TABLE VII.

Group I.—Data on Molting Period of Normal Lobsters,

Number.	Fourth Stage.				Fifth Stage.				Sixth Stage.				Seventh Stage.				Eighth Stage.	
	Molted to Fourth Stage.	Condition Normal.	Molted to Fifth Stage.	Stage-Period in Days.	Condition Normal.	Molted to Sixth Stage.	Length in mm.	Stage-Period in Days.	Condition Normal.	Molted to Seventh Stage.	Length in mm.	Stage-Period in Days.	Condition Normal.	Molted to Eighth Stage.	Length in mm.	Stage-Period in Days.	Length in mm.	Length on Dec. 2, 1905.
53	July 21	+	Aug. 2	12	+	Aug. 18	16.5	16	+	Sept. 8	20.5	19	+(5)	....	23.0	......	26.7	32.5
54	July 21	+	Aug. 3	13	+	Aug. 16	16.0	13	+	Aug. 28	20.0	12	+	Sept. 17	23.5	20.0	28.0	32.5
50	July 21	+	Aug. 3	13	+	Aug. 13	16.0	10	+	(?)	19.0	......	+	....	23.0	......	28.0	31.0
44	July 21	+	Aug. 3	13	+(1)	Aug. 18	16.0	15	+	Aug. 31	17.5	13	+	....	21.0	......	25.0	.....
43	July 21	+	Aug. 3	13	+(2)	Aug. 18	16.0	15	+	Sept. 4	17.0	17	+	Sept. 19	20.0	15.0	25.0	34.5
52	July 21	+	Aug. 4	14	+	Aug. 17	16.0	13	+	Sept. 1	18.0	14	+(2)	Sept. 19	21.5	18.0	24.0	28.0
51	July 21	+	Aug. 4	14	+	Aug. 18	15.5	14	+	Sept. 4	17.0	17	+	(6)	20.0	......	....	.....
42	July 21	+	Aug. 6	16	+(2)	Aug. 18	15.5	12	+	(?)	16.5	16	+	....	19.5	......	24.0	28.0
49	July 21	+	Aug. 7	17	+	Aug. 18	16.0	11	+	Sept 5	20.0	18	+	....	23.0	......	26.0	26.(7)
46	July 21	+	Aug. 7	17	+	Aug. 22	16.0	15	+	Sept. 7	20.	16	+	....	22.5	......	26.0	.....
40	July 21	+	Aug. 7	17	+	Aug. 20	15.0	13	+(3)	Sept. 6	17.5	17	+	Sept. 23	20.0	17.0	22.7	27.0
39	July 21	+	Aug. 7	17	+	Aug. 25	15.0	18	+(4)	Sept. 7	16.0	13	+	....	18.5	......	23.0	.....
48	July 21	+	Aug. 7	17	+	Aug. 16	......	9	+	Sept. 2	20.0	17	+	....	23.5	......	28.5	33.0
No. of Specimens 13				Av. 14.8 days.			Av. 15.8 mm.	Av. 13.4 days.			Av. 18.4 mm.	Av. 15.7 days.			Av. 21.5 mm.	Av. 17.5 days.	Av. 25.5 mm.	Av. 30.3 mm.

(1) Lost 1st right leg in molting. (2) Lost 4th left leg in molting. (3) Lost left cheliped in molting. (4) Lost 3rd left leg in moulting. (5) Lost 3rd left leg and cheliped. (6) Died September 5th. (7) Had not increased in size and evidently still in the eighth stage.

TABLE VIII.

Group II.—Data on Molting Period of Regenerating Lobsters.

Number.	Fourth Stage.					Fifth Stage.				
	Molt to Fourth Stage.	Date of Mutilation.	Molt to Fifth Stage.	Regenerated.	Stage-Period in Days.	Date of Mutilation.	Molt to Sixth Stage.	Regenerated.	Length in mm.	Stage-Period in Days.
	1905.									
23	July 21; 9 A. M..	July 26..	Aug. 5..	—	15	Aug. 10 (1)	Aug. 20..	+	14.5	15
29	July 21; 9 A. M..	July 26..	Aug. 5..	—	15	Aug. 10 (1)	Aug. 20..	+	14.5	15
31	July 21; 9 A. M..	July 26..	Aug. 6..	+	16	Aug. 10....	Aug. 21..	+	15.0	15
36	July 21; 9 A. M..	July 26..	Aug. 7..	+	17	Aug. 10....	Aug. 22..	+	15.0	15
25	July 21; 9 A. M..	July 28..	Aug. 7..	+	17	Aug. 10....	Aug. 22..	+	14.5	15
15	July 21; 9 A. M..	July 28..	Aug. 7..	+	17	Aug. 10....	Aug. 24..	+	14.5	17
12	July 21; 9 A. M..	July 29..	Aug. 7..	+	17	Aug. 10....	Aug. 24..	+	15.0	17
35	July 21; 9 A. M..	July 25..	Aug. 8..	+ (2)	18	Aug. 12 (3)	Aug. 22..	+	15.5	14
20	July 21; 9 A. M..	July 25..	Aug. 8..	+ (2)	18	Aug. 12 (3)	Aug. 22..	+	15.5	15
11	July 21; 9 A. M..	July 29..	Aug. 8..	+	18	Aug. 13....	Aug. 24..	+	15.0	16
34	July 21; 9 A. M..	July 26..	Aug. 8..	+	18	Aug. 13....	Aug. 29..	+	14.5	21
14	July 21; 9 A. M..	July 26..	Aug. 8..	+	18	Aug. 13 (1)	Aug. 25..	+	14.0	17
16	July 21; 9 A. M..	July 25..	Aug. 9..	+	19	Aug. 13....	Aug. 24..	+	14.0	15
13	July 21; 9 A. M..	July 30..	Aug. 9..	+	19	Aug. 13....	Aug. 24..	+	14.0	15
24	July 21; 9 A. M..	July 29..	Aug. 9..	+	19	Aug. 13....	Aug. 27..	+	14.0	18
32	July 21; 9 A. M..	July 29..	Aug. 9..	+	19	Aug. 13....	Aug. 31..	+	14.5	22
17	July 21; 9 A. M .	Aug. 1..	Aug. 10..	+	20	Aug. 15....	Aug. 25..	+	14.5	15
33	July 21; 9 A. M..	July 27..	Aug. 10..	+ (2)	20	Aug. 15. ..	Aug. 26..	+	15.0	16
18	July 21; 9 A. M..	July 29..	Aug. 10..	+ (2)	20	Aug. 15 (4)	Aug. 25..	+	14.0	15
7	July 21; 9 A. M..	July 30..	Aug. 10..	+ (2)	20	Aug. 15 (4)	Aug. 25..	+	15.0	15
10	July 21; 9 A. M..	July 27..	Aug. 11..	+ (2)	21	Aug. 15 (4)	Aug. 24..	+	14.0	13
22	July 21; 9 A. M..	July 31..	Aug. 10..	+	20	Aug. 15....	Sept. 2..	+	14.5	23
26	July 21; 9 A. M..	Aug. 3.	Aug. 13..	+ (2)	23	Aug. 17 (4)	Aug. 26..	+	14.5	13
27	July 21; 9 A. M..	Aug. 2..	Aug. 13..	+	23	Aug. 17....	Aug. 28..	+	14.5	15
28	July 21; 9 A. M..	July 31..	Aug. 13..	+	23	Aug. 17....	Aug. 29..	+	15.0	13
30	July 21; 9 A. M..	July 30..	Aug. 13..		23	Aug. 17 (1)	Aug. 27..	+	14.0	14
No. of Specimens 26	....	....	....	.....	Av. 18.9 dys.				Av. 14.6 mm.	Av. 16 dys.

(1) Removed 2nd pair of legs.
(2) Regenerated only one cheliped.
(3) Removed left cheliped.
(4) Removed cheliped and 2nd pair of legs.

TABLE VIII.

Group II.—Data on Molting Period of Regenerating Lobsters.—Concluded.

Sixth Stage.					Seventh Stage.					Eighth Stage.	
Date of Mutilation.	Molt to Seventh Stage.	Regenerated.	Length in mm.	Stage-Period in Days.	Date of Mutilation.	Molt to Eighth Stage.	Regenerated.	Length in mm.	Stage-Period in Days.	Length in mm.	Length on Dec. 2, 1905
1905.											
Aug. 25......	Sept. 10.	+	16.0	21	Sept. 14.....	....	+	17.5	....	....	25.0
Aug. 25......	Sept. 7..	+	16.0	18	Sept. 11.....	....	+	18.0	....	23.0	26.
Aug. 25......	Sept. 7.	+ (2)	18.5	17	Sept. 11 (9)	....	+	21.5	....	25.0	30.0
Aug. 26......	Sept. 7.	+	17.5	16	Sept. 11.....	....	+	20.3	....	24.5	28.0
Aug. 26......	Sept. 8..	+	16.0	17	Sept. 12.....	....	+	19.0	....	22.5	28.5
Aug. 27 (5)..	Sept. 12.	+	15.5	19	Sept. 16 (5)	....	....	18.3	....	....	26.0
Aug. 27 (5)..	Sept. 11.	+	17.0	18	Sept. 15 (5)	....	....	19.0	....	....	30.0
Aug. 26......	Sept. 18.	+	16.0	17	Sept. 12 (10)	....	+	18.5	....	21.7	26.0
Aug. 27 (6)..	Sept. 10.	+	17.0	18	Sept. 14.....	....	+	18.5	....	21.0	26.0
Aug. 27 (7)..	Sept. 12.	+	16.5	19	Sept. 16 (7).	....	....	19.0	....	....	30.5
Sept. 2 (8)...	Sept. 17.	+	18.0	19	Sept. 18.....	....	....	20.0	....	....	28.0
Aug. 28 (7)..	Sept. 8..	+	15.0	14	Sept. 12 (7)..	....	....	17.5	....	....	30.5
Aug. 27 (7)..	Sept. 10.	+	15.5	17	Sept. 14 (7)..	....	....	18.0	....	....	26.0
Aug. 27 (5)..	Sept. 10.	+	15.0	17	Sept. 14 (5)..	....	....	17.5	....	....	29.0
Aug. 31......	Sept. 14.	+	15.5	18	Sept. 18.....	....	....	17.5	....	....	26.0
Sept. 6.....	Sept. 18.	+	15.0	18	Sept. 18.....	....	....	18.0	....	....	24.0
Aug. 28 (7)..	Sept. 12.	+	16.0	18	Sept. 16 (7)..	....	....	19.0	....	....	29.0
Aug. 30......	Sept. 14.	+	17.0	19	Sept. 18.....	....	....	20.0	....	....	26.5
Aug. 28 (5)..	Sept. 12.	+	16.0	18	Sept. 16 (5)..	....	....	19.0	....	....	27.0
Aug. 28 (7)..	Sept. 12.	+	17.0	18	Sept. 16 (7)..	....	....	19.5	....	....	29.0
Aug. 27 (5)..	Sept. 12.	+ (8)	16.0	19	Sept. 16 (5)..	.. .	....	17.7	....	....	25.0
Sept. 8......	Sept. ?..	+	20.0	.....	....	....	....	23.0	....	....	29.0
Aug. 30......	Sept. 14.	+	16.0	19	Sept. 18.....	....	....	19.0	....	....	27.5
Sept. 1......	Sept. 15.	+	16.0	18	Sept. 19.....	....	....	19.5	....	....	28.0
Sept. 2......	Sept. 17.	+	17.5	20	Sept. 20.....	....	....	21.0	....	....	28.0
Aug. 31......	Sept. 14.	+	15.3	18	Sept. 18.....	....	....	18.0	....	....	26.0
....	....	......	Av. 16.4 mm.	Av. 18 days.	....	....	....	Av. 19 mm.	....	Av. 22.9 mm.	Av. 27.4 mm.

(5) Removed both chelipeds and 3rd and 4th pair of legs.
(6) Removed cheliped and 3rd right leg.
(7) Removed right cheliped.
(8) Fourth left leg gone.
(9) Removed cheliped and 2nd right leg.
(10) Second right leg lost in molting.

+ or —, respectively, indicates that the lobster did or did not regenerate the mutilated limbs before molting.

c. *Discussion of Results.*

The results of this experiment furnish three points of comparison: (1) the frequency of molting; (2) the increase in size; and (3) the the combination of (1) and (2), or the rate of growth.

(1) *The Frequency of Molting.*

An examination of the data in Tables VII and VIII shows a marked difference in the length of the molting periods for each stage of normal lobsters in Group I, as compared with the corresponding stages of the regenerating specimens in Group II. The average length of the molting periods for the fourth, fifth, and sixth stages are as follows:

	Fourth stage	Fifth stage.	Sixth stage.
Group I, normal period........	14.8 days	13.4 days	15.7 days
Group II, regenerating period..	18.9 days	16.0 days	18.0 days

It is evident from a comparison of these periods that, at each stage, the average length of the molting period for the regenerating lobsters is much longer than the normal period. Accordingly, while the normal lobsters molted from the fourth to the sixth stage in 43.9 days, on the other hand, the regenerating specimens required 52.9 days to molt to the same stage. In other words, *the process of regeneration delayed the frequency of molting to such an extent that the length of the normal interval from the beginning of the fourth to the beginning of the seventh stage was increased by over* 20 *per cent.*

(2) *The Increase in Size.*

It may be seen from the tables that the final measurements on December 2nd gave the following results for the average length of the lobsters in Group I, normal specimens, 30.3 mm.; Group II, regenerating specimens, 27.4 mm. In other words, at the end of the experiment on December 2 the normal lobsters were 10.5 per cent. larger than the regenerating lobsters.

The significance of these results is readily perceived from a comparison of the conditions involved. It will be recalled that, at the beginning of the experiment, the lobsters in Group I and Group II had molted to the fourth stage on the same day, July 21, and were practically equal in size.*

The specimens in Group I were kept in a normal condition, while the specimens in Group II were mutilated after each molt. Accordingly, the only essential difference in the conditions between these two groups of lobsters consisted in the fact that in one group the lobsters were regenerating mutilated appendages, while in the other group the lobsters were in a normal condition. Therefore it seems evident that the introduction of the process of regeneration into Group II has, in the course of 134 days, resulted in a difference of 10.5 per cent. between the size of the regenerating and normal lobsters in favor of the latter.

It is evident that a closer comparison of the effect of regeneration on the increase in size may be made by comparing corresponding stages in the two groups of lobsters; for it may be observed that the measurements for December 2 do not all represent the same stages. For example, on December 2 lobster No. 49 was still in the eighth stage, while most of the other specimens were probably in either the ninth or tenth stages. Accordingly, a more exact comparison can be obtained from the data for the fifth, sixth, and seventh stages, in which every specimen was measured after each molt. For these stages the Tables VII and VIII show the following averages:

---

*(It may be noted that the length for the fourth stage are not given in the tables. When these specimens were selected in the preceding experiments, they were all so nearly equal in size that it was not thought necessary to measure each individual, and so unfortunately the exact fourth stage length for each specimen was not obtained. Some of the preserved fourth stage specimens from Series B and Series C_4 to C_{13} were however, measured later, and the average length was 13.9 mm.)

	Fifth stage.	Sixth stage.	Seventh stage.
Group I,			
Average length of normal lobsters	15.8 mm.	18.4 mm.	21.5 mm.
Group II,			
Average length of regenerating lobsters..................	14.6 mm.	16.4 mm.	19.0 mm.

It may be seen from these results that the normal and regenerating specimens, in going from the fifth to the seventh stage, gained in length 5.7 mm. and 4.4 mm., or 36.1 per cent. and 30.1 per cent., respectively; from the records in the tables it may also be seen that the former specimens molted from the fifth to the seventh stage in 29.1 days, and the latter specimens in 34.0 days. Accordingly, within about a month, the normal lobsters had not only molted sooner, but had also increased in size 6 per cent. more than the regenerating lobsters.

(3) *The Rate of Growth.*

By combining the data for the length of the lobster, the increase in size, and the length of the molting period for both normal and regenerating lobsters an exact comparison of the effect of regeneration upon the rate of growth can be made. For this purpose the data for the rate of growth has been taken from Tables VII and VIII and grouped together in Table IX.

Table IX.

Rate of Growth for Normal and Regenerating Lobsters.

Group I.—Normal Lobsters.							Group II.—Regenerating Lobsters.						
Number.	Length of Fifth and Sixth Stage in Days.	Length of Fifth Stage Lobsters in mm.	Length of Lobsters at Seventh Stage in mm.	Increase in Length in mm.	Increase in Length Per cent.	Specific Rate of Growth*.	Number.	Length of Fifth and Sixth Stage in Days.	Length of Fifth Stage Lobsters in mm.	Length of Lobsters at Seventh Stage in mm.	Increase in Length in mm.	Increase in Length Per Cent.	Specific Rate of Growth.*
53	35	16.5	23.0	6.5	39.3	1.12	23	36	14.5	17.5	3.5	24.1	0.67
54	25	16.0	23.5	7.5	46.9	1.87	29	33	14.5	18.0	3.5	24.1	0.73
50	....	16.0	23.0	7.0	43.7	......	31	32	15.0	20.3	5.5	36.6	1.14
44	28	16.0	21.0	5.0	31.2	1.11	36	31	15.0	20.5	5.5	36.6	1.18
43	32	16.0	20.0	4.0	25.0	0.78	25	32	14.5	19.0	4.5	31.0	0.97
52	27	16.0	21.5	5.5	34.3	1.27	15	36	14.5	18.3	3.8	26.2	0.73
51	31	15.5	20.0	4.5	29.0	0.93	12	35	15.0	19.0	4.0	26.6	0.76
42	28	15.5	19.5	4.0	25.8	0.92	35	31	15.5	18.5	3.0	19.3	0.62
49	29	16.0	23.0	7.0	43.7	1.51	20	33	15.5	18.5	3.0	19.3	0.59
46	31	16.0	22.5	6.5	40.6	1.31	11	35	15.0	19.0	4.0	26.6	0.76
40	30	15.0	20.0	5.0	33.3	1.11	34	40	14.5	20.0	5.5	37.9	0.95
39	31	15.0	18.5	3.5	23.3	0.75	14	31	14.0	17.5	3.5	25.0	0.81
48	26	......	23.5	.....	......	......	16	32	14.0	18.0	4.0	28.5	0.89
.....	....	......	......	.....	......	......	13	32	14.0	17.5	3.5	25.0	0.78
.....	....	......	......	.....	......	......	24	36	14.0	17.5	3.5	25.0	0.69
.....	....	......	......	.....	......	......	32	40	14.5	18.0	3.5	24.1	0.60
.....	....	......	......	.....	......	......	17	33	14.5	19.0	4.5	31.0	0.94
.....	....	......	......	.....	......	......	33	35	15.0	20.0	5.0	33.3	0.95
.....	....	......	......	.....	......	......	18	33	14.0	19.0	5.0	35.7	1.08
.....	....	......	......	.....	......	......	7	33	15.0	19.5	4.5	30.0	0.91
.....	....	......	......	.....	......	......	10	32	14.0	17.7	3.7	26.3	0.82
.....	....	......	......	.....	......	......	22	....	14.5	23.0	8.5	58.6	.....
.....	....	......	......	.....	......	......	26	32	14.5	19.0	4.5	31.0	0.97
.....	....	......	......	.....	......	......	28	33	15.0	21.0	6.0	40.0	1.21
.....	....	......	......	.....	......	......	27	33	14.5	19.5	5.0	34.4	1.04
.....	....	......	......	.....	......	......	30	32	14.0	18.0	4.0	28.5	0.89
Av. 13 cases.	Av. 29.4 dys.	Av. 15.8 mm.	Av. 21.5 mm.	Av. 5.5 mm.	Av. 34.7	Av. 1.15	Av. 26 cases.	Av. 33.6 dys.	Av. 14.6 mm.	Av. 19.0 mm.	Av. 4.4 mm.	Av. 30.2	Av. 0.87 .....

*The specific rate of growth equals the increase in length per cent. divided by the number of days, that is the per cent. of increase per day.

Table IX contains the data for the rate of growth from the fifth to the seventh stage. The column "days" gives the interval between the fifth to the seventh molt. The data for the lengths of the lobsters for the fifth and seventh stages in Group I and Group II were taken directly from Tables VII and VIII, respectively. The column "increase in length" states the difference between the lengths at the fifth and seventh stages. Dividing the increase in length by the length of the seventh stage specimen gives the amount of increase per unit length of the normal; *i. e.*, the "increase in length, per cent." The quotient obtained by dividing the increase in length per cent. by the number of days in which that increase took place equals the amount of growth for a unit of size in a unit of time; this may be termed the "*Specific Rate of Growth.*"

A comparison of the results for Group I and Group II in Table IX shows a marked difference between the rate of growth for the normal and for the regenerating lobsters; while the average rate of growth for the normal specimens was 1.15, it was only 0.87 for the regenerating specimens; a difference of over 24 per cent.

Therefore, since the only difference in the conditions for these two groups of lobsters consisted in the fact that the process of regeneration was introduced into one group of specimens and not into the other, the results of these experiments seem to show conclusively that *the process of regeneration retards the growth ot the lobster, so that the introduction of the process even early in the molting period may reduce the rate of growth more than 24 per cent.*

III.

General Discussion of Results.

It would be premature to attempt to formulate a general theory for the interaction or regulation existing between the processes of regeneration and molting, for the present evidence deals only with one aspect of the relations. It is evident that a more adequate amount of evidence should include such data as the amount and rate of regeneration under conditions differing in regard to the degree of injury, molting, etc. But at this stage of the investigation it may be of value briefly to discuss the general nature and significance of the results derived from the present experiments, as a preliminary to further study.

1. The object of the present series of experiments was to ascertain whether there was any regulation or interaction existing between the processes of regeneration and molting. The results have demonstrated that there is an interaction of such a nature between these two processes that the introduction of the one, regeneration, into the organism will disturb the normal activity of the other, the molting process. Further, it may be seen, also, that the fundamental fact underlying the present results is, *that the rate of the cellular activities involved in the molting process is retarded by the cellular activities concerned in the process of regeneration.*

2. The character of the relations between regeneration and the molting process, as studied so far, suggests an explanation of the interaction on the basis of a variation in the distribution of available energy.

If we analyze the cellular activities involved in the two processes of regeneration and molting it is evident that, although the process of regeneration differs in one respect from that of molting, inasmuch as regeneration involves the origin, development, and differentiation of new tissues, while the molting process consists only in a development and increase in the amount of tissue and the secretion of a new shell, yet both regenerative and molting process alike involve the multiplication and development of new cells from old cells already present in the organism. Now it is a fundamental fact in physiology that one of the essential conditions determining the rate of cell multiplication and development is the amount of energy of the food material assimilated by these cells. Therefore, since the process of regeneration has reduced the rate of molting, it would seem most natural to explain this result by the assumption that *the regenerating* *cells have utilized a part of the energy of food material normally available for the cells concerned in the process of molting.*

This assumption seems to be strongly supported by the comparison of the effects of those mutilations in the preceding experiments, which were followed by the regeneration of the chelipeds, with the effect of mutilations which were not succeeded by this regeneration. In both cases the initial disturbance of the organism, due to mutilation, was exactly the same. Now if the assumption that the regenerating limbs utilize a portion of the energy normally available for the process of molting is correct, then there would be more energy diverted from the molting process in the regenerating specimens than in the mutilated, non-regenerating ones, and the rate of molting for the non-regenerating specimens would be greater than the rate for the regenerating specimens. The results of the experiments demonstrated that this was actually the case.

Again, it is evident that this assumption that the regenerative cells divert and utilize some of the energy normally available for molting is in accord with those results in the experiments which show that the greater the amount of regeneration, as determined by the degree of injury, the slower the rate of molting; and that the later the process of regeneration is introduced after the molt, the greater the length of the whole molting period.

3. An important phase of the problem of regeneration is to determine in what respects this phenomenon is similar to the process of growth. The fact that in these experiments the process of regeneration retarded the process of molting and decreased the rate of growth seems to support the theory that "*the phenomenon of regeneration belongs to the general category of growth phenomena.*"* For if the assumption is correct that the regenerating cells have, either directly or indirectly, utilized the energy which otherwise would have been distributed to the cells involved in the molting process, then it is evident that we have here energy available either for the

*(Morgan T. H. Regeneration, 1901 page 292.)

process of regeneration or for the process of growth involved in the molting activities.

4. The fact that the regenerative process does not respond with equal readiness to mutilations made at different times in the molting periods appears especially significant, for two reasons:

(a) It suggests the existence of an important internal factor influencing the process of regeneration. For, whether a regeneration of the limbs shall succeed a mutilation or not is apparently largely determined by the condition of the molting activities; so that, when the molting process is approaching the climax of the molting period, an inhibiting influence is exerted upon the regenerative process.

While the present data may not throw much light upon the nature of this inhibiting influence, it is interesting to note the modification which they seem to necessitate in the theory of the distribution of energy to the regenerating cells. Since the energy for regeneration does not seem to be equally available at later stages of the molting period, it appears that *there is a tendency toward an increasing stability or permanence in the channels of energy distribution, so that as the molting process approaches its culmination it becomes more and more difficult to divert energy into the cellular process of regeneration.*

It is evident, however, that a different conclusion is also possible. For the regenerating cells may fail to respond readily to mutilations made late in the molting period, not because the energy of food material is unavailable for assimilation, but rather, *because the power of assimilation in the cells themselves has been modified.* This latter conclusion brings us to the recognition of an alternative hypothesis for the relation between regeneration and the process of molting, namely, that the interaction between the two processes may consist n a direct variation in the power of assimilation in the cells concerned, as well as a variation in the material available for assimilation.

(b) The fact that the process of regeneration does not respond with equal readiness to mutilations made at later stages in the molting period raises the question as to whether there is a tendency in the regenerative process to regenerate a *functional* limb before a molt occurs. Perhaps it may be of interest to digress for a moment to a discussion of this question.

It would seem most natural to suppose that the process of regeneration would begin the reconstruction of a limb at any time in the molting period, even though it may not be possible for the reconstruction process to go far enough to develop a functional appendage before the next molt takes place. Now, if this supposition is true, it ought to be a common occurrence to find that injured or mutilated lobsters show, after molting, regenerating limbs in all stages of development, ranging from minute papillæ to large-sized but non-functional buds. But this does not seem to be the case. Indeed it is remarkable how uncommon it is to find a recently molted lobster with its regenerating appendages in any other condition than normally functional or entirely undeveloped.

During the experiments of the present season every opportunity was taken to observe the condition of regenerating limbs of molting lobsters. The result was that, out of a comparatively large number of mutilated and molting lobsters, only a few cases were found which showed any partially developed regenerating limbs after a molt.

One of the instances of such a case is illustrated in Plate XLI, Figs. I and II. These two figures show the stumps or basipodite of the third left leg of an 8-inch lobster before molting (Fig. I) and after the molt (Fig. II). Just before molting this stump showed a small regenerating papilla (Fig. I, Reg.); after the molt the regenerated structure could be seen as a small elevation on the molted stump (Fig. II, Reg.).

The data for the specimen on which this regenerating papilla was found, is as follows: Length of lobster before molting, eight inches; sex, male; July 18th both chelipeds and the second and third pair of walking legs were removed by autotomy. The following records were made on the condition and amount of regeneration which occurred after the mutilations were made:

	Chelipeds.		*Second Pair of Legs.*		*Third Pair of Legs.*	
1905.	*Right.*	*Left.*	*Right.*	*Left.*	*Right*	*Left.*
Aug. 18	6 mm.	6 mm.	papilla	papilla	papilla	papilla
Aug. 29	13 mm.	13 mm.	7 mm.	2 mm.	papilla	papilla
Sept. 9	19 mm.	19 mm.	13 mm.	8 mm.	5½ mm.	papilla
Condition after molt Oct. 5,	Both functional		Both functional		Functional	Non-functional

It may be seen from these data that the six limbs were all removed 49 days before the next molt, and that five of these appendages regenerated and molted as functional limbs, while on the other hand the slight regenerative activities in the third left leg merely produced a structure which molted as the very small non-functional papilla shown in Fig. II.

This case, therefore, shows that it may be possible for the regenerative process to start up without resulting in the reproduction of a functional limb by the time of molting, even when the mutilation is made early in the molting period. But since it is extremely rare to find such a partially developed non-functional limb after a molt, it is evident that a partial regeneration of this character must be regarded as exceptional rather than typical. This, together with the fact that the process of regenerating does not respond readily to mutilation in the latter part of the molting period, seems to support the conclusion that *there is a tendency in the regenerative process to begin only when the conditions are such as to favor the development of a functional structure before the act of molting takes place.*

5. While the present experiments were being made, Zeleny,* published the results of some experiments on regeneration in adult crayfishes. The experiments consisted in the comparison of the rate of regeneration and the rate of molting in two series of regenerating crayfishes, in which the degree of injury in one series was greater than in the other.

The results in the crayfish, with reference to the rate of molting,

*(Journal of Experimental Zoölogy, II, 1905.)

were that the individuals with the greater amount of regeneration, as determined by the degree of injury, molted sooner than the individuals with the lesser amount of regeneration. In other words, an increase in the rate of molting seemed to be correlated with an increase in the amount of regeneration due to an increase in the degree of injury. In view of this fact it becomes evident that the results from the present experiments on young lobsters acquire an additional interest because they seem to contradict this. For the results in series D and series E show that there was not only *no increase, but rather a decrease, in the rate of molting as correlated with the greater or lesser degree of injury and regeneration.*

This interesting difference in the results for these two crustaceans shows the importance of further study of the factors involved in the interactions existing between the process of regeneration, the degree of injury, and the process of molting.

IV.

Summary of Results.

The results from the present series of experiments seem to demonstrate clearly the following points:

1. That the effect of the process of regeneration is to retard the process of molting, and increase the length of the period between two successive molts.

2. That this effect varies in degree, however, directly as the time at which the process of regeneration is introduced into the molting period; so that the later the regenerative process is introduced into the molting period, the greater is the length of that period.

3. And again, that this effect also seems to vary more or less directly with the amount of regeneration as determined by the degree of injury, so that the greater the amount of regeneration the greater the length of the molting period.

4. That these results are due to the process of regeneration and not the effect of the *injury* caused by mutilation, is shown by the

fact that the average length of the molting period for those lobsters in which the mutilations were not succeeded by the regeneration of the limbs, was not only less than the length of the molting period for the regenerating specimens, but also in a large proportion of cases was even shorter than the molting period for the normal lobsters.

5. The response of the regenerative process to mutilation varies according to the time of injury; so that while a mutilation made early in the molting period is almost invariably immediately succeeded by a regeneration, a mutilation made late in the period is rarely followed by the regeneration of the limb before the next molt takes place.

6. And finally, the results show that the process of regeneration, by retarding both the frequency of molting and the increase in size, retards the rate of growth in the lobster.

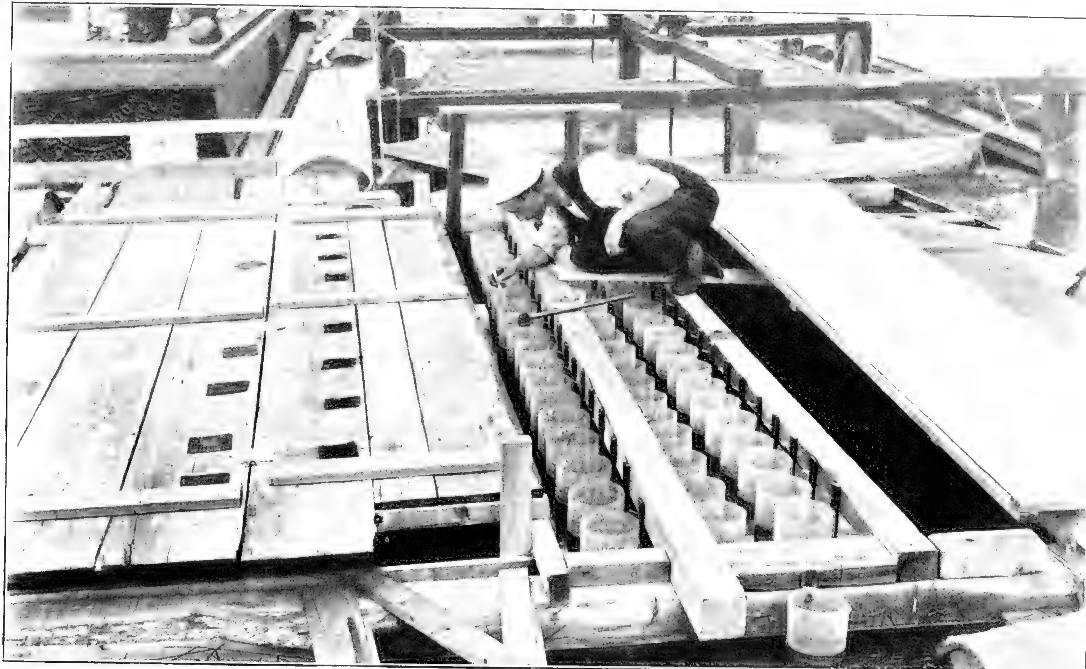


PLATE XL.—Showing the cylinders in which individual lobsters are confined for observation and experiment.

CHART VIII.—Frequency curves for comparing the rate of molting for the normal and regenerating fourth stage lobsters in Series A, and Series A_4.

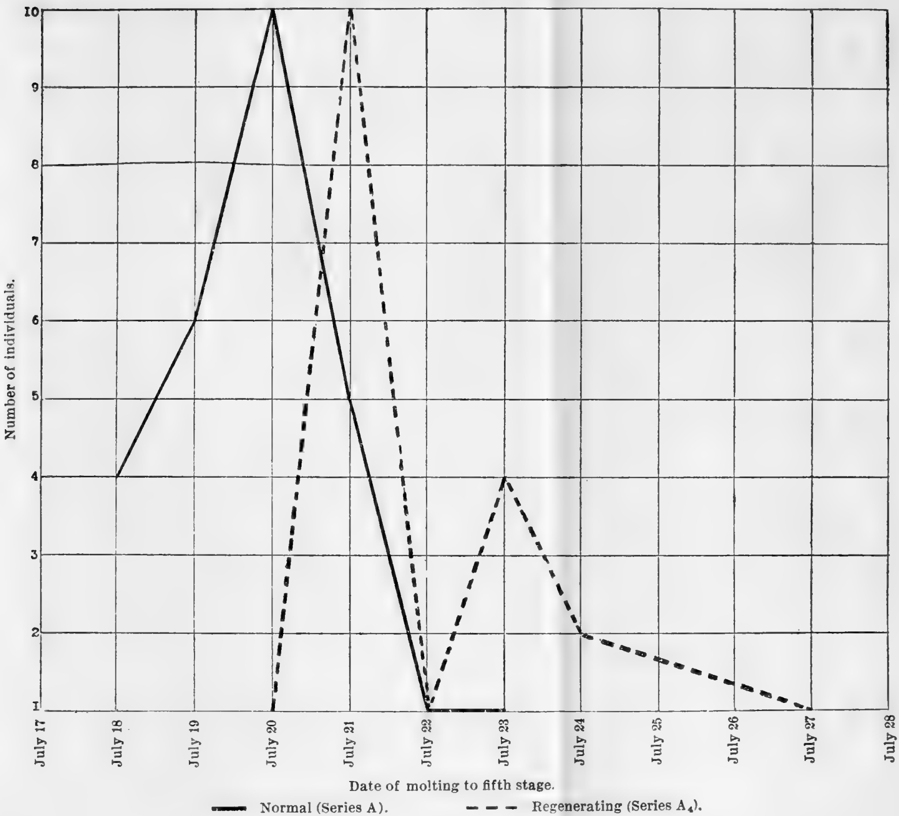


CHART IX.—Showing the effect upon the rate of molting of introducing the process of regeneration at different times in the molting period, in fourth stage lobsters.

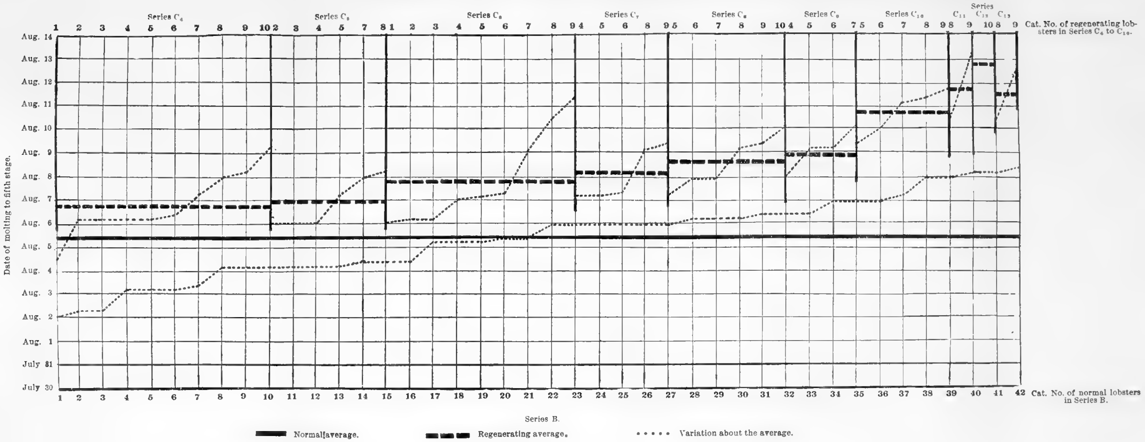
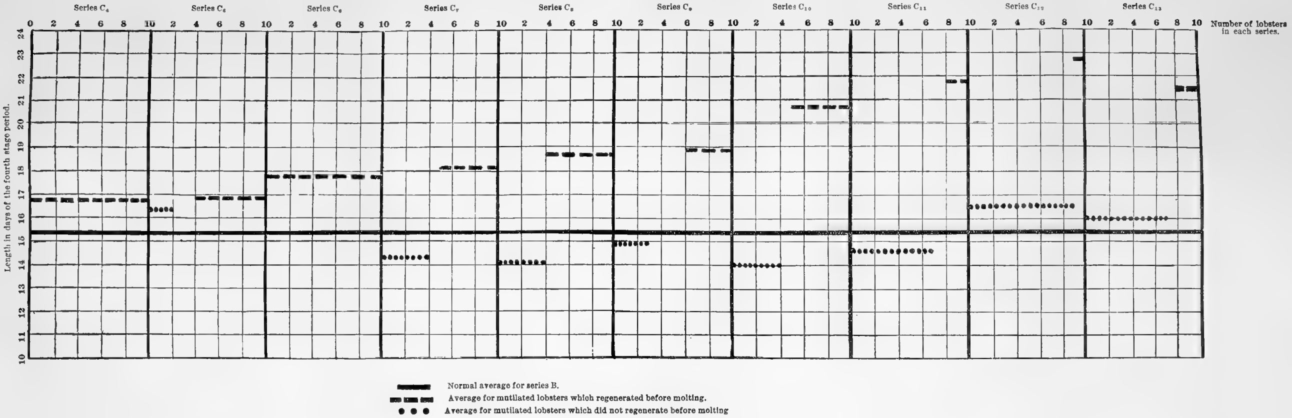


CHART X.—Comparison of the effect of mutilation and the effect of mutilation plus regeneration, upon the length of the molting period in fourth stage lobsters.



[illegible]

APPENDIX A.

UNITED STATES BUREAU OF FISHERIES,

WASHINGTON, D. C.

Commissioner.

GEORGE M. BOWERS.

Deputy Commissioner.

HUGH M. SMITH.

Chief Clerk.

I. H. DUNLAP.

Assistant in Charge of Division of Inquiry Respecting Food Fishes.

B. W. EVERMANN.

Assistant in Charge of Division of Fish Culture.

JOHN W. TITCOMB.

Assistant in Charge of Division of Statistics and Methods of the Fisheries.

A. B. ALEXANDER.

Disbursing Agent.

W. P. TITCOMB.

Architect and Engineer.

HECTOR VON BAYER.

STATE FISHERIES AUTHORITIES.

[Compiled by U. S. Bureau of Fisheries.]

Arizona.

Fish and Game Commission.

T. S. Bunch..Safford.
Eugene Allison..Jerome.
L. W. Penny, Secretary..Phœnix.

California.

California Fish Commission.

W. W. Van Arsdale, President..San Francisco.
W. E. Gerber..Sacramento.
Charles A. Vogelsang, Chief Deputy..San Francisco.

Colorado.

Department of Game and Fish.

J. M. Woodard, Commissioner....Room 35, Capitol Building, Denver.

Connecticut.

Commissioners of Fisheries and Game.

George T. Mathewson, President..Thompsonville.
Robert G. Pike..Middletown.
E. Hart Geer, Secretary..Hadlyme.

Connecticut Shellfish Commission.

George C. Waldo..Bridgeport.
Christian Schwartz..South Norwalk.
William J. Atwater..New Haven.

Florida.

Florida Fish Commission.

John Y. Detwiler, Chairman.................................New Smyrna.
John G. Ruge, Secretary.....................................Appalachicola.
C. R. Walker..Sanford.

Georgia.

Superintendent of Fisheries.

A. T. Dallis...La Grange.

Illinois.

Board of State Fish Commissioners.

Nat. H. Cohen, President....................................Urbana.
August Lenke, Treasurer.....................................Chicago.
S. P. Bartlett, Secretary.....................................Quincy.

Indiana.

Commissioner of Fisheries and Game.

Z. T. Sweeney...Columbus.

Iowa.

State Fish and Game Warden.

George A. Lincoln..Cedar Rapids.

Kansas.

State Fish Warden.

D. W. Travis...Pratt.

Louisiana.

Oyster Commission of Louisiana.

J. M. Breaux, President......................................Houma.
Clement Story...Melonie.
Horace H. Harvey...Harvey.
Ben Michel..Pilottown.
F. P. Parra..Cutoff.

Maine.

Commissioners of Inland Fisheries.

Leroy T. Carleton, Chairman.............................Augusta.
J. W. Brackett..Phillips.
Edgar E. Ring, Secretary................................Orono.

Commissioner of Sea and Shore Fisheries.

A. R. Nickerson...Boothbay Harbor.

Maryland.

State Fish Commission.

Charles F. Brooke, Commissioner for Western Shore.........Sandy Spring.
James D. Anderson, Commissioner for Eastern Shore.........Deals Island.

Massachusetts.

Commission of Fisheries and Game.

Dr. George W. Field, Chairman...............State House, Boston.
J. W. Delano, Superintendent of Hatcheries.....State House, Boston.
E. A. Brackett..Winchester.

Michigan.

State Board of Fish Commissioners.

C. D. Joslin, President.................................Detroit.
F. B. Dickerson, Vice-president.........................Detroit.
George M. Brown...Saginaw.
Seymour Bower, Superintendent...........................Detroit.

Minnesota.

Board of Fish and Game Commissioners.

Uri L. Lamprey, President...............................St. Paul.
H. G. Smith, First Vice-president.......................Winona.
William Bird, Second Vice-president.....................Fairmount.
D. W. Meeker, Secretary.................................Moorhead.
S. F. Fullerton, Executive Agent........................Duluth.

Missouri.

Missouri State Fish Commission.

F. P. Yenawine, President.............................St. Joseph.
J. H. Zollinger, Vice-president.............................Boonville.
Richard Porter, Secretary.............................Paris.
John Gable, Jr.............................Browning.
Col. George J. Chapman.............................St. Louis.

Montana.

State Game and Fish Warden.

W. F. Scott.............................Helena.

New Hampshire.

Fish and Game Commission.

Nathaniel Wentworth, Chairman.............................Hudson Center.
Charles B. Clarke, Financial Agent.............................Concord.
Merrill Shurtleff, Secretary.............................Lancaster.

New Jersey.

Fish and Game Commission.

B. P. Morris.............................Long Branch.
R. T. Miller.............................Camden.
D. P. McClellan.............................Morristown.
P. H. Johnson.............................Bloomfield.

State Oyster Commission.

E. L. Riley.............................Newport.
Jere. N. Ogden.............................Bridgeton.
E. L. Stites, Jr.............................Port Norris.
A. T. Bacon.............................Maurice River.

New York.

Forest, Fish and Game Commission.

DeWitt C. Middleton, Commissioner.............................Albany.
J. Duncan Lawrence, Deputy Commissioner.............................Albany.
B. Frank Wood, Superintendent of Shell Fisheries...........
.............................1 Madison Avenue, New York.
John D. Whish, Secretary.............................Albany.

NEVADA.

Fish and Game Warden.

J. P. Morrill..Verdi.

NORTH DAKOTA.

State Fish Commissioner.

(Office vacant.)

OHIO.

Fish and Game Commission.

Paul North, President..............................Cleveland.
T. B. Paxton..Cincinnati.
D. W. Greene..Dayton.
L. J. Weber...McConnellsville.

OREGON.

Board of Fish Commissioners.

Governor..Salem.
Secretary of State..................................Salem.
State Treasurer.....................................Salem.

Master Fish Warden.

H. G. Van Dusen.....................................Astoria.

PENNSYLVANIA.

Department of Fisheries.

W. E. Meehan, Commissioner..........................Harrisburg.
John Hamberger......................................Erie.
Henry C. Cox..Wellsboro.
Andrew R. Whitaker..................................Phœnixville.
Charles L. Miller...................................Altoona.

RHODE ISLAND.

Commissioners of Inland Fisheries.

Henry T. Root, President, Treasurer, and Auditor...........Providence.
J. M. K. Southwick, Vice-president..................Newport.
Charles W. Willard..................................Westerly.

A. D. Mead............................Brown University, Providence.
William P. Morton, Secretary..............P. O. Box 966, Providence.
Adelbert D. Roberts......................P. O. Box 264, Woonsocket.
William H. Boardman................................Central Falls.

Commissioners of Shell Fisheries.

Philip H. Wilbour...................................Little Compton.
James E. Wright.....................................Clayville.
John H. Northup.....................................Apponaug.
Samuel B. Hoxsie, Jr................................Quonocontaug.
William T. Lewis, Jr................................Drownville.

TEXAS.

State Fish and Oyster Commissioner.

I. P. Kibbe...Port Lavaca.

UTAH.

State Fish and Game Commissioner.

John Sharp..Salt Lake City.

VERMONT.

Commissioner of Fisheries and Game.

Henry G. Thomas.....................................Stowe.

VIRGINIA.

State Board of Fisheries.

J. W. Bowdoin, Chairman.............................Bloxam.
S. F. Miller, Secretary.............................Foster.
George B. Keezell...................................Keezletown.
H. M. Tyler...Richmond.
R. J. Camp..Franklin.

WASHINGTON.

Department of Fisheries and Game.

Board of Fish Commissioners.

Governor..Olympia.
State Treasurer.....................................Olympia.

Fish Commissioner and Game Warden.

T. R. Kershaw.......................................Bellingham.

Wisconsin.

Commissioners of Fisheries.

The Governor.......................................Madison.
Calvert Spensley, President.......................................Mineral Point.
James J. Hogan, Vice-president.......................................LaCrosse.
E. A. Birge, Secretary.......................................Madison.
William J. Starr.......................................Eau Claire.
Currie G. Bell.......................................Bayfield.
Henry D. Smith.......................................Appleton.
Jabe Alford.......................................Madison.

APPENDIX B.

FISHERIES LAWS OF RHODE ISLAND, 1905.

[Compiled by the Commissioners of Inland Fisheries.]

GENERAL LAWS.

CHAPTER 1.

The jurisdiction of the Commissioners of Inland Fisheries covers the territorial limits of the State as given in the following two sections of chapter one, and covers all the fisheries of the State except the oyster and scallop fisheries, which are under the jurisdiction of the shell fish commissioners.

SECTION 1. The territorial limits of this state extend one marine league from its seashore at high water mark. When an inlet or arm of the sea does not exceed two marine leagues in width between its headlands, a straight line from one headland to the other is equivalent to the shore-line. The boundaries of counties bordering on the sea extend to the line of the state as above defined.

SEC. 2. The jurisdiction of the state shall extend to, and embrace, all places within the boundaries thereof, except as to those places that have been ceded to the United States, or have been purchased by the United States with the consent of the state.

CHAPTER 171.

Of Certain Fisheries.

SECTION 1. Every person who shall set or draw any seine in any part of the river running from Warren river through the town of Barrington, except that part lying north of the Congregational church building in the said town of Barrington, shall forfeit twenty dollars.

SEC. 2. Every person who shall set or draw any seine or net in Easton's pond in Newport and Middletown for the purpose of catching fish, or shall set any such net or seine in the creeks or inlets of said pond above the bridge at Easton's beach, shall be fined twenty dollars or be imprisoned ten days.

SEC. 3. Every person who shall set or draw any seine or net in Kickamuit river within half a mile from the place called the narrows shall forfeit fifteen dollars.

SEC. 4. Every person who shall erect or make any weir, pot, or other contrivance to obstruct the course of fish across Puncatest, alias Nomquit, pond, or any part thereof, or in any river or stream leading into or out of said pond at any time, shall forfeit ten dollars.

SEC. 5. Every person who shall set any hanging or mesh net in Puncatest alias Nomquit, pond, or in any river leading into or out of said pond, between the first day of January and the first day of August, shall forfeit ten dollars.

SEC. 6. Every person who shall erect or continue in Palmer's river, above Kelly's bridge, any weir, dam, or other obstruction to prevent the free passage of fish up said river, shall forfeit fifteen dollars for the first offence and ten dollars for every twenty-four hours any such weir or dam or other obstruction shall be continued after the first twenty-four hours.

SEC. 7. Every person not at the time an inhabitant of this state who shall set or draw any seine or net in Palmer's river, above Kelly's bridge, on Thursday, Friday, or Saturday, and every person who shall set or draw any seine or net in said river above said bridge on Sunday, or between the setting and rising of the sun, shall forfeit for each offence fifteen dollars.

SEC. 8. Repealed.

SEC. 9. Repealed.

SEC. 10. Repealed.

SEC. 11. No person shall take any fish with any kind of gill or mesh net, or set any gill or mesh net for the purpose of taking any fish therewith, within one mile from the shore of Block Island, between the first day of June and the first day of November in each year, without first obtaining permission of the town council of New Shoreham; and every person violating any provision of this section shall be fined twenty dollars for each offence; one-half to the use of the complainant and the other half to the use of the town of New Shoreham.

SEC. 12. Any person who shall take any fish with any kind of seine, net, or trap, or set or draw any seine, net, or trap, for the purpose of taking any fish therewith, in any of the fresh water ponds in the town of New Shoreham, except in private ponds owned by one person, shall be fined not exceeding twenty dollars or be imprisoned not exceeding ten days, or be both fined and imprisoned in the discretion of the court.

SEC. 13. The electors of the town of New Shoreham may, in town meeting called for that purpose, enact such ordinances as they may think proper to protect and to regulate the taking of shell-fish and other fish in Great Salt pond, and may impose penalties therefor not exceeding twenty dollars fine and three months' imprisonment for any one offence.

SEC. 14. The electors of the town of Tiverton may, in town meeting called for that purpose, make such regulations for the preservation of the fish, and may exercise such control over the fisheries of Nomquit pond, within the limits of said town, as they may think proper.

SEC. 15. No person shall, between the first Monday in October and the first Monday in January, erect any weir or draw any seine or net for the purpose of catching or obstructing the passage of fish at or within one hundred and sixty rods of the mouth of Pataquamscut river in South Kingstown, nor shall any person erect or put down any weir, standing seine, or trap-seine, or hoop-net of any kind, either within or across said river at any other season of the year.

SEC. 16. Nothing in the preceding section shall be so construed as to prohibit any person from using nets or fishing crafts for the catching of smelts, such as are commonly used in the smelt fishery, between the first day of February and the first day of April, or to prohibit the setting of gill nets for bass in said river or pond: *Provided*, that such nets shall not exceed twenty fathoms in length, nor be set within twenty fathoms of each other, nor south of the dividing line between lands now or formerly of William G. Watson and George W. Crandall, nor within twenty rods of the narrows that connect the upper and lower ponds; nor shall any person maintain any such standing seine or net in the same place for more than twenty-four hours if any other person demands the same place for the purpose of setting a like net or drawing a seine therein.

SEC. 17. Every person who shall violate any of the provisions of the preceding two sections shall be fined not less than twenty dollars nor more than fifty dollars for each offence, and shall forfeit the seine, net, boat, and other apparatus by him used in such violation.

SEC. 18. Every person who shall set any trap or net or draw any seine at any time west of a line drawn from Calf-pasture Point on the north side of Allen's harbor to Rocky Point on the south side thereof, or west of a line drawn from Pojack Point on the south side of Potowomut river to Marsh Point on the north side thereof, shall be fined not less than five dollars nor more than twenty dollars; one-half thereof to the use of the complainant and one-half thereof to the use of the state.

SEC. 19. No person shall between the fifteenth day of April and the fifteenth day of June, inclusive of both days, or between the fifteenth day of August and the fifteenth day of December, inclusive of both days, commencing at the rising of the sun on both days, erect any weir or set or draw any seine or net for obstructing, catching, or hauling of fish within half a mile east from Point Judith ponds breach, meaning the breach for the time being into the sea, or within a point on the west side of said breach four rods distant from Joseph Champlin's fish-house, so called, or within said breach, or within any channel leading to said ponds, or any branch thereof from the sea, or within a quarter of a mile of the entrance of such channel into said ponds or branches of said ponds; and whenever the fifteenth day of December happens on Sunday this prohibition shall continue to the rising of the sun on the next succeeding day.

SEC. 20. No weir shall be erected, nor any standing seine or net set, in any part of Charlestown pond, Quonochontaug pond, or Babcock's pond, otherwise know as Brightman's pond, nor across the channel, or in Point Judith's ponds within a quarter of a mile from the following places, namely: Alder Point near where Saukatucket river flows into said ponds; Princes narrows, which connects the upper with the lower ponds; Strawberry hill on Great Island; High Point, so-called, on lands of the heirs of Joseph Sherman, and Gooseberry Hole.

SEC. 21. No person shall, between sunset on the first Monday in April and sunrise on the second Monday in June, erect any weir or net or draw any seine or net for the purpose of catching or obstructing the passage of fish in any part of Point Judith pond south of a line drawn from the most northerly point of Strawberry hill on Great Island to the most northerly point of High Point in said pond.

SEC. 22. No person shall erect any weir or set or draw any seine or net for the obstructing, catching, or hauling of fish within any part of said ponds or any branch thereof, at any time between sunset on the fifteenth day of August and sunrise on the fifteenth day of December.

SEC. 23. No seine or net of any sort shall be used at any time within said ponds or any branch thereof, of over one hundred fathoms in length, nor any standing seine or net of over twenty-five fathoms in length.

SEC. 24. No person shall set any standing seine or net, at any time, within forty rods of any place within said ponds or any branch thereof where another person may have already set his standing seine or net, nor shall any person maintain any such standing seine or net in the same place for more than forty-eight hours if any other person desires to occupy the place.

SEC. 25. Every person violating any provision of the preceding six sections shall be fined not less than twenty dollars nor more than fifty dollars, and shall also forfeit the boat, seine, net, and other apparatus by him used in such violation, one-half of said fine and forfeiture to the use of the person complaining and one-half thereof to the use of the state.

SEC. 26. Every person living without the state who shall take any lobsters, tautog, bass, or other fish within the harbors, rivers, or waters of this state, for the purpose of carrying them thence in vessels or smacks, shall be fined ten dollars for every offence, and shall forfeit all the fish or lobsters so taken.

Sec. 27. Every person who shall take any fish in any stream or fresh pond, except upon his own land, otherwise than by a single hook and line, or who shall take or carry away any fish from any private pond, brook, stream, preserve, or any other place made, constructed, or used for the purpose of breeding or growing fish therein, without the consent of the proprietor or lessee of such pond, brook, stream, or preserve, shall be fined not exceeding twenty dollars or be imprisoned not exceeding thirty days, or be both fined and imprisoned; but nothing herein contained shall be so construed as to authorize the taking of any fish from any pond or stream stocked with fish at the expense of the state.

Sec. 28. Every person who shall take any trout between the fifteenth day of July and the first day of April shall be fined twenty dollars for each offence, and every person who shall take or have in his or her possession any trout less than six inches in length at any time of the year shall be fined twenty dollars for each trout found in his or her possession, but nothing herein contained shall be so construed as to prohibit the taking and sale of trout artificially cultivated in private ponds at any season of the year: *Provided*, that all persons raising brook-trout artificially in private ponds shall use the initials of their names as a brand, which brand shall be put on every box of trout shipped or put on the market by them between the fifteenth of July and the first day of April in each year. All persons raising and disposing of trout as aforesaid shall cause their brand required herein to be registered by the secretary of state.

Sec. 29. All actions for violations of the provisions of the preceding two sections shall be commenced within thirty days after the commission of the offence.

Sec. 30. Every person who shall, by any seine or stop-net, or otherwise, obstruct the channel leading from the sea into Ward's pond, and up through said pond on each side of Watermelon, Gooseberry, or Larkin's islands, shall be fined not less than five dollars nor more than twenty dollars.

Sec. 31. Every person who shall erect any dam, weir, or other obstruction across Mill cove in Warwick, or from the mouth of said cove to the pond of fresh water that runs into said cove, or such streams as run into said pond, or who shall keep up any dam, or weir, or other obstruction therein made, and every owner or occupant of lands adjoining said Mill cove or the stream leading from said pond into said cove who shall permit any such obstruction to be erected on continued in or upon said cove or stream adjacent to his land, at any time between the first day of March and the first day of November, shall forfeit one hundred dollars for each offence.

Sec. 32. Every person who on Saturday or Sunday shall fish in said cove except with a hook and line, or who shall catch or hinder any alewives coming down said Mill cove or said stream, or shall therein at any time set any weir or device to prevent the passage of the fish, shall forfeit ten dollars for each offence: *Provided*, that nothing herein contained shall be so construed as to authorize fishing on Sunday.

SEC. 33. Every person who shall set or draw any seine or net in said Mill cove, or off from the mouth thereof to Long Meadow rocks, or from the mouth thereof to the pond of fresh water which empties into said cove, between the first day of March and the fifteenth day of June, or who shall take any alewives from said pond, or streams flowing into said pond, between the first day of March and the first day of November in any year, shall for each offence forfeit one hundred dollars and the boats, seines, and other apparatus used in the commission thereof: *Provided, however*, that nothing in this chapter shall be so construed as to prohibit any person from fishing for alewives in said cove, or stream running from said pond into said cove, with a bowed net not larger than twelve feet around the mouth of said net, on days other than those excepted in section thirty-two of this chapter.

SEC. 34. There shall be, between the first day of May and the first day of August, a weekly close-time extending from Saturday morning at sunrise to Monday morning at sunrise, during which time no fish of any description shall be taken by weirs, traps, or similar contrivances, from any of the waters of the coast-line of the state and Narragansett bay. If there be any weir, trap, or other stationary contrivances used for the purpose of catching or obstructing the passage of fish in that part thereof where the fish are usually taken, the netting at the mouth of the same shall be floated to the surface of the water so as to effectually close the mouth thereof during the weekly close-time, so that during said time the fish may have a free, unobstructed passage, and no device shall be placed in any part of said limits which shall tend to hinder such fish from running up the waters of such rivers. In case the inclosure where the fish are taken is furnished with a board floor, an opening three feet wide shall be made extending from the floor to the top of the weir, trap, or other contrivances: *Provided, however*, that nothing herein shall be so construed as to apply to the shad and herring fisheries in the tributaries of Narragansett bay.

SEC. 35. The Commissioners of Inland Fisheries shall have a general supervision of all matters relating to the subjects contained in sections eight, ten, twenty-six, twenty-seven, and thirty-four of this chapter, and may make all needful regulations to carry out the provisions of said sections, and shall from time to time examine all the weirs, traps, or other contrivances, with a view of carrying out such regulations as are most beneficial to the people of the state, and shall prosecute for the violation of such regulations or for the infringement of the provisions of any of said sections. They may co-operate with the fish commissioners of other states, and shall make an annual report to the general assembly of their doings, with such facts and suggestions in relation to the object for which they are appointed as they may deem proper. Said commissioners shall be allowed their actual disbursements made in the execution of this chapter.

SEC. 36. Every person who shall violate any of the regulations made by said commissioners under the authority of the provisions of the preceding section of this chapter, or who, during the close-time mentioned in section thirty-four, shall set any weir, trap, or contrivances contrary to such provisions, shall be fined not exceeding one hundred dollars or be imprisoned not exceeding three months, or both, in the discretion of the court before which the offender shall be tried.

SEC. 37. All forfeitures under this chapter shall, where there is no other provision made to the contrary, enure one-half thereof to the use of the town where the offence shall be committed and one-half thereof to the use of the person suing for the same.

CHAPTER 172.

Of the Fishery of Pawcatuck River.

SECTION 1. No weir or pound or other obstructions shall be erected or continued in the channel of Pawcatuck river, dividing the states of Rhode Island and Connecticut, so as to interfere with the main channel of said river, upon penalty of twenty dollars for the first offence, and seven dollars for every twenty hours or any less space of time any such weir or other obstruction shall be continued in the main channel of said river after the first offence.

SEC. 2. No weir or pound shall be erected or continued upon any flat or other part of the bottom of said river, eastward or westward of the aforesaid channel of said river, between the first day of June and the twentieth of March, annually, upon penalty of fourteen dollars for the first offence and seven dollars for every succeeding day such weir or pound shall be continued in said river, from the first day of June to the twentieth day of March, annually.

SEC. 3. No person shall fish with mesh or scoop nets in Pawcatuck river, or any of its branches, after sunset on Friday until sunrise on Monday in each week, from the twentieth day of March to the first day of June, annually, and no person shall use more than one net at a time upon penalty of five dollars for every offence.

SEC. 4. All penalties incurred for violation of any of the provisions of this chapter shall enure one-half thereof to the use of the complainant and one-half thereof to the use of the town where the offence is committed.

Sec. 5. The foregoing provisions of this chapter shall be considered as forming a compact with the state of Connecticut, from which the general assembly will not depart until the legislature of the state of Connecticut shall agree with the general assembly of this state to a repeal thereof, alterations therein, or additions thereto.

Sec. 6. If any owner of land adjoining Pawcatuck river in this state shall permit any weir, pound, or other obstruction to be erected or continued upon any flat or bottom of said river, whether done, erected, or continued by himself, servant, lessee, or any other person, by his privity or consent, such owner shall be liable for any such breach or violation of section two of this chapter in the same manner as though the same had been committed by such owner in person.

CHAPTER 174.

Of the Inland Fisheries.

Section 1. The governor shall appoint seven commissioners of inland fisheries, who shall hold their offices for three years and until their successors are appointed.

Sec. 2. The Commissioners of Inland Fisheries shall introduce, protect, and cultivate fish in the inland waters of the state, and may make all needful regulations for the protection of such fish, and shall prosecute for the violation of such regulations and of the laws of the state concerning inland fisheries. (They may, in their discretion, from time to time make experiments in planting cultivating, propagating, and developing any and all kinds of shell fish; and for the purpose of so doing may from time to time take, hold, and occupy, to the exclusion of all others, in one or more parcels, any portions of the shores of the public waters of the state, or land within the state covered by tide-water at either high or low tide not within any harbor line, and which is not at the time of such taking under lease as a private and several oyster fishery: *Provided*, that the land so held and occupied at any one time shall not exceed three acres. Said commissioners upon taking such land shall forthwith give public notice thereof by advertisement in some newspaper in the county in which said land is situated, which advertisement shall contain a description of said land; they shall also forthwith notify the commissioners of shell fisheries of such taking and shall transmit to them a description of said land, and shall also take out or otherwise mark the bounds of said land. Said commissioners may make all needful regulations for the protection of the land so taken, and of all animal life and other property within the lines thereof, and shall prosecute the violations thereof.) They may co-operate with the fish commissioners of other states, and they shall make an annual report to the general assembly of their doings, with such facts and suggestions in relation to the object for which they were appointed as they may deem proper. Said commissioners, whenever complaint is made by them, or either of them, for a violation of any regulation made by them as aforesaid, or for violation of any of the provisions of this chapter or of chapters 171, 172, and 173, shall be not required to enter into recognizance on such complaint or become liable for costs thereon.

Sec. 3. The said commissioners shall cause a copy of any regulation made under the authority of the preceding section to be filed in the office of the town clerk of any town in which any waters stocked with fish, or land occupied for experiments under the authority of the preceding section and to which such regulations may apply, may be, and shall also cause a copy of such regulations to be advertised in some newspaper published in the same county.

Sec. 4. Every person who shall violate any of the regulations made by the commissioners of inland fisheries under the authority of the provisions of the preceding three sections, or who shall take any fish, fish-spawn, or any apparatus used in hatching or protecting fish, from any pond, lake, river, or stream stocked with or set apart by said commissioners, or by private parties, for the protection and cultivation of fish with the consent of the town council of the town where such cultivation is carried on, without the consent of such commissioners, or, if the cultivation of fish be carried on by a private party, without the consent of the person cultivating the same, or who shall trespass within the boundaries of any land which may be taken and occupied by said commissioners for their experiments in relation to shell-fish, authorized by section two of this chapter, shall be fined not exceeding three hundred dollars or be imprisoned not exceeding six months, or be both fined and imprisoned in the discretion of the court before which the offender shall be tried.

Sec. 5. Every person who shall catch any fish or shall use any seine for catching fish within half a mile from the mouth or outlet of any fishery set apart as is herein provided, and within any waters into which the waters of such fishery are let out, and every person who shall violate any of the provisions of sections seven, eight, and ten of this chapter, shall forfeit for the first offence the sum of fifty dollars, and for every subsequent offence shall forfeit one hundred dollars; and in addition to the penalties herein provided shall forfeit all the apparatus by him used in violation of the provisions of this section.

Sec. 6. Each of the commissioners of inland fisheries may, personally or by deputy, seize and remove, summarily if need be, all obstructions erected to hinder the passage of migrating fish, or which are illegally erected to obstruct or in any way to impede the growth and culture of fish.

Sec. 7. No person shall take or catch fish of any kind from any of the inland waters of the state, set apart by the commissioners of inland fisheries for the cultivation of fish, except at such times and in such manner as is hereinafter provided.

Sec. 8. The prohibition of the catching of fish by hook and line, from fisheries stocked as hereinbefore provided, shall extend and be continued for and during the term of three years from and after the time when such fishery was first established: *Provided, however*, that fish may be caught through the ice only, and with hook and hand-line only, in those ponds set apart for the cultivation of black bass, during the months of December, January, and February, until the expiration of the aforesaid term of three years.

Sec. 9. After the expiration of said three years no black bass shall be taken in any waters of this state, except Sneach pond in the town of Cumberland, and Moswansicut pond in the town of Scituate, between the first day of March and the first day of July in each year, nor at any time except by hook and line as aforesaid. Every person taking any black bass during the time aforesaid, or in any other manner except by hook and line, shall be fined fifteen dollars for each black bass so taken, and every person who shall take or have in his or her possession any black bass less than eight inches in length at any time of the year shall be fined fifteen dollars for each black bass found in his or her possession; and possession by any person of any black bass less than eight inches in length, or during the time aforenamed, shall be evidence that such black bass were taken in violation of this chapter; but nothing herein contained shall be so construed as to prohibit the taking and sale of black bass artificially cultivated in private ponds at any season of the year.

Sec. 10. After the expiration of said three years no fish shall be taken by any person from any waters legally set apart by said commissioners for the cultivation of shad or salmon, or within one mile of the outlet of the streams so set apart, except from and after the fifteenth day of April until the fifteenth day of July, or at any time except by hook and hand-line, or by not less than three-inch mess nets or seines.

Sec. 11. One-half of the fines and forfeitures recovered for violation of the provisions of this chapter shall accrue to the complainant and one-half thereof to the use of the state.

Sec. 12. The commissioners of inland fisheries may take fish from the fisheries hereinbefore referred to, for any purpose connected with fish culture or for scientific observation.

Sec. 13. Each of said commissioners may, in the discharge of his duties, enter upon and pass over private property without rendering himself liable in an action of trespass.

SEC. 14. The commissioners of inland fisheries shall be allowed their actual disbursements made in carrying into effect the provisions of this chapter.

CHAPTER 175.

General Provisions for the Protection of Fisheries.

SECTION 1. Every person who shall throw into or deposit in, or cause to be thrown into or to be deposited in, any of the public tide-waters of the state or upon the shores of any such tide-waters any fish-offal or any water impregnated with fish, unless the same be filtered in such manner as may be determined by the town council of the town wherein such deposit shall be made, and every person who shall cause any deleterious substance resulting from the smelting or manufacture of copper or from other manufactures, or from other sources, which is destructive to fish or which repels them from coming into the said public waters, or which shall do anything which tends to drive them therefrom, to be emptied, deposited, or run into the said public waters, shall forfeit one hundred dollars.

SEC. 2. Every vessel, craft, boat, or floating apparatus employed in the procuring of fish-oil, or in the dressing of bait for the mackerel fisheries, or the dressing of fish for other purposes, in violation of this chapter, shall be liable for any forfeiture and costs resulting from prosecution hereunder; and the same may be attached on the original writ and held, as other personal property attached may be held, to secure any judgment which may be recovered in any action brought to enforce any such forfeiture; and any person, upon view of any offence in violation of this chapter, may seize and detain any vessel, craft, boat, or floating apparatus, the same to be detained for a period not exceeding six hours.

SEC. 3. Every person who shall boil any menhaden fish, or press any fish for the purpose of extracting oil therefrom, on board of any vessel on any of the public tide-waters, shall be fined not exceeding fifty dollars.

SEC. 4. Any person who shall wilfully place any brush, trees, or limbs of trees in any of the waters of Charlestown pond shall be fined not more than twenty dollars nor less than five dollars for each offence; and all fines under this section shall enure one-half thereof to the use of the complainant and one-half thereof to the use of the town of Charlestown.

PUBLIC LAWS.

CHAPTER 969.

AN ACT IN SUBSTITUTION OF CHAPTER 857 OF THE PUBLIC LAWS, PASSED AT THE JANUARY SESSION, A. D. 1901, ENTITLED "AN ACT FOR THE BETTER PROTECTION OF THE LOBSTER FISHERIES."

SECTION 1. Every person who catches, takes, or has in his or her possession any lobster less than nine inches in length, measuring from the end of the bone projecting from the head to the end of the bone of the middle flipper of the tail, the lobster extended on its back its natural length, and every person who has in his or her possession any cooked lobster less than eight and three-quarters inches in length, and every person who has in his or her possession any female lobster bearing eggs or from which the eggs have been brushed or removed, shall be fined five dollars for every such lobster; but a person catching or taking any such live lobster and immediately returning the same alive to the water from which taken shall not be subject to such fine. The possession of any such lobster, cooked or uncooked, not of the prescribed length, shall be *prima facie* evidence to convict.

SEC. 2. All lobster pots, cars, and other contrivances used for the catching or keeping of lobsters shall be plainly marked with the name or names of the owner or owners. And every person who shall not have his lobster pots, cars, or other contrivances so marked shall be fined twenty dollars and be imprisoned not more than thirty days for each such offence. And all pots, cars, and other contrivances used contrary to the provisions of this section shall be seized by the officer engaged in the enforcement of this law, and said property shall be forfeited.

SEC. 3. There shall be, between the fifteenth day of November and the fifteenth day of April next succeeding, a close-time, during which time it shall be unlawful for any person to set or keep, or cause to be set or kept, within any of the waters of this state, any pots or nets for the catching of lobsters, or to take any lobsters during such close-time. Every person violating any of the provisions of this section shall be fined twenty dollars and be imprisoned not more than thirty days for each such offence.

Sec. 4. No person shall be allowed to set or keep, or cause to be set or kept, within any of the waters of the state, any pots or nets for the catching of lobsters who has not had his home and residence in this state for the period of one year next preceding the time of his catching such lobsters. Every person violating any of the provisions of this section shall be fined twenty dollars and be imprisoned not more than thirty days for each such offence.

Sec. 5. Every person, except the commissioners of inland fisheries and their deputies, who shall lift or raise any pot or net set for the catching of lobsters, without the permission of the owner or owners thereof, shall be fined ten dollars for each such offence.

Sec. 6. Every person who mutilates a lobster by severing its tail from its body, or has in his or her possession any such tail or tails of lobsters before such lobsters are cooked, shall be fined five dollars for each such offence; and in all prosecutions under this act the possession of any such tail or tails of uncooked lobsters shall be *prima facie* evidence to convict.

Sec. 7. The Commissioners of Inland Fisheries shall appoint at least two deputies, whose duties shall be the enforcing of the provisions of this act. Each of said deputies appointed as aforesaid shall be, by virtue of his office, a special constable, and as such deputy may, without warrants, arrest any person found violating any of the provisions of this act and detain such person for prosecution not exceeding twenty-four hours. Said deputies shall not be required to enter into recognizance or become liable for costs.

Sec. 8. For the purpose of enforcing the provisions relative to the protection of lobsters, the Commissioners of Inland Fisheries and their appointed deputies may search in suspected places, or upon any boat or vessel that they may believe is used in the catching or transporting of lobsters, and may seize and remove lobsters taken, held, or offered for sale in violation of the provisions of this act.

Sec. 9. Fines incurred under any of the provisions of this act shall enure one-half thereof to the use of the complainant and one-half thereof to the use of the state.

Sec. 10. The several district courts shall have concurrent jurisdiction with the common pleas division of the supreme court over all offences under this act, and to the full extent of the penalties therein specified; parties defendant, however, having the same right to appeal from the sentences of said district courts as is now provided by law in other criminal cases.

Sec. 11. Sections eight, nine, and ten of Chapter 171 of the General Laws, entitled "Of certain fisheries," and also Chapters 316 and 857 of the Public Laws, and all acts and parts of acts inconsistent herewith, are hereby repealed.

Sec. 12. This act shall take effect upon and after its passage.

CHAPTER 1006.

AN ACT IN RELATION TO TRESPASS ON LAND.

SECTION 1. Whoever shall enter upon the land of another for the purpose of either shooting, trapping, or fishing when the same shall be conspicuously posted by the owner or occupant with notices that shooting, trapping, or fishing is prohibited thereon, or whoever shall without right mutilate, destroy, or remove any such notice, shall be fined not exceeding twenty dollars.

SEC. 2. All acts or parts of acts inconsistent herewith are hereby repealed, and this act shall take effect July 1st, 1902.

CHAPTER 1132.

AN ACT PROHIBITING THE TAKING OF FISH OF ANY SPECIES FROM THE WATERS OF GORTON'S LAKE, SO-CALLED, IN THE TOWN OF WARWICK, R. I., BEFORE APRIL 1, 1906.

SECTION 1. Every person who shall take fish of any species from the waters of Gorton's Lake, so-called, in the town of Warwick, before the first day of April, A. D. 1906, shall be fined not exceeding one dollar for the first offence, and not to exceed ten dollars for each subsequent offence.

SEC. 2. This act shall take effect immediately.

CHAPTER 1225.

AN ACT FOR THE PROTECTION OF PICKEREL AND IN ADDITION TO CHAPTER 171 OF THE GENERAL LAWS, ENTITLED "OF CERTAIN FISHERIES."

SECTION 1. Every person who catches or takes from any of the waters of this state or has in his or her possession any pickerel less than ten inches in length shall be fined five dollars for each such offence; but any person catching or taking any pickerel less than ten inches from any of the waters of this state and immediately returning the same alive to the water from which taken shall not be subject to such fine. The possession of any such pickerel not of the prescribed length shall be *prima facie* evidence to convict.

SEC. 2. This act shall take effect upon and after its passage.