MANUSCRIPT REPORTS OF THE BIOLOGICAL STATIONS

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by

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BIOLOGICAL BOARD OF CANADA

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Report on work conducted at the
Atlantic Biological Station,
St. Andrews, N. B.
June - September, 1933.

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Introduction

On the lobster fishing grounds of the Maritime provinces many variations in physical conditions are known to exist. The most unprotected part of the life history of the lobster is during the early free-swimming or larval period. Since in nature there is known to be a tremendous mortality among the larval lobsters most of our experiments were directed toward finding how variation in certain environmental factors led to a large percentage survival of larvae in certain regions and a small percentage survival in others.

In the following discussion the larva immediately after hatching is said to be in the first stage which ends with the first moult. The larva is now in the second stage which ends with the second moult which produces the third stage lobster. The third stage ends with the third moult which produces the fourth stage lobster or lobsterling. In the fourth stage the larva possesses a better sense of balance and direction and has assumed the characteristic lobster shape.

The average age when a lobster ceases to be pelagic and seeks the bottom has received too little attention both in the

following experiments and in the general study of lobster larvae by other workers. The lobster larvae are usually supposed to seek the bottom toward the end of the fourth stage or during the fifth stage. After having reached the fourth stage, however, the rearing of the individual larva offers little difficulty and in most of the following experiments the larvae were not reared beyond the fourth stage since it was judged wiser to concentrate more on the early larval forms. Thus, it will be necessary to do further work on stages beyond the fourth.

The sea-water used in the experiments was obtained from the end of the station wharf. Except where otherwise stated all larvae used in any particular experiment have been hatched from the same lobster on the same day. Recently hatched first stage larvae were always used.

Food such as clam and lobster larva was fed to the larvae on the point of a toothpick, feeding being successfully accomplished when the larva grasped the food and swam away with it.

In the experiments with a relatively constant temperature varying not more than one degree during the day the temperature was taken daily at irregular hours. Experiments with more variable temperatures were checked moring and afternoon, usually at 9 a.m. and 5 p.m. The temperatures given are all in degrees centigrade. All thermometers used were checked and the necessary corrections have been made in the temperatures given in this report.

A. Preliminary experiments

Before much real experimenting could be done many problems of feeding, light and purity of water had to be cleared away. The only feasible method of controlling temperature or food lay in the use of still water in glass containers. In general, Best Bottles 6 inches high, 3½ inches diameter were used with about 2½ inches of sea-water, and one larva in each bottle. It was found that at temperatures below 18°C changing the water once every three days was satisfactory while at progressively higher temperatures the water needed to be changed oftener.

Clam muscle, calf liver and fish-meal were found to be unsatisfactory as food in still water while clam muscle and gonad fed alternately, the first stage larvae themselves and live copepod plankton were found highly satisfactory. The best results were obtained with live copepod plankton, using which on one occasion from 18 first stage larvae 15 fourth stage larvae were obtained and in two other experiments 9 and 8 fourth stage larvae were obtained from 12 and 13 first stage larvae respectively.

Using plankton as food, the dim light of the basement of the main lab where ordinarily an object could barely be seen ten or fifteen feet away and poorly lighted by electric lamps for several hours a day, was found to be completely satisfactory, the above highly successful results being obtained in this light.

The condition of the first stage larvae is also a factor of great significance and renders difficult the comparison of experiments conducted with larvae hatched at different periods or

or from different lobsters. With certain batches of larvae hardly any survived to the fourth stage even under the most favourable conditions.

Various preliminary experiments on phototropism indicated that first stage lobster larvae were attracted to light of a weak intensity and repelled by light of a strong intensity. Tows taken by Dr.A.W.H.Needler at Hog island reef in Malpeque bay to test this hypothesis yielded one first stage larva taken at or near the bottom in 4 or 5 fathoms in bright sunlight at 11:30 a.m., July 28.

B. Survival of larvae at low temperatures

Experiment 1. One larva in each of 14 Best Bottles. Larvae fed on live copepods and water changed every three days. The bottles were placed in a constant temperature box in basement of the main lab and the larvae were kept in absolute darkness except when the water was being changed. Larvae hatched between 11:00 a.m. July 23 and 2:30 p.m. July 24. Experiment began at 5:00 p.m. July 25.

Dates of moulting or death of larvae

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Died without moulting	Aug.2	Aug.2	Au.4	Au.3		Au.17	Au.17				Au.4		July 29	
1st moult					Au.9			Au.10	Au.2	Au.2		Au.2		July 3
2nd moult										Au.16		Au.14		Au.12
3rd moult										Au.26-29		Au.26-29		Au.25
Died without further moulting					Sep.5			Sep.9	Au.19					

N.B. Larvae in 1,2,3 and 4 were replaced by newly-hatched larvae on Aug.4. Both 1 and 2 died before Aug.12 and 3 and 4 before Aug.14. Temperature range 1 and 2 = 1.7 - 2.5°C and 3 and 4 4.4 - 5.8°C.

Temperature during periods between two moults or previous to death

	1 & 2	3 & 4	5	6	7 & 8	9 & 10	11 & 12	13 & 14
Previous to dying before moulting	2.3-3.0	5.0-6.0		8.0-9.5				
Before 1st moult			8.4-9.9		10.8-12.0	13.6-14.4	15.4-16.3	17.0-17.6
Before 2nd moult						12.9-14.0	15.0-16.0	17.0-17.7
Before 3rd moult						13.3-14.2	14.6-16.5	16.8-18.0
Final moult to death			8.3-9.9		10.8-12.0			

Experiment 2. One larva hatched on July 11 was placed in each of two 4-oz. bottles with necks cut off, on July 11. Bottles one-half full of sea-water. Water in bottles changed every three days. Lobsters fed once every three days on live copepods. Relatively constant temperature was obtained by keeping the bottles containing the larvae in an insulated box equipped with a thermoregulator.

	Larva A	Larva B	Temperature preceding moulting Larva A	Larva B
1st moult	July 21	July 23	11.4 - 11.8	11.4 - 11.9
2nd moult	July 30	Aug. 2	11.6 - 12.0	11.6 - 12.1
3rd moult	Aug. 16		11.9 - 12.1	11.9 - 12.1

Larva B died on Aug.30 without moulting 3rd time.

Experiment 3. Carried out with bottles on floor of refrigerator room of Fish Handling building where the temperature was lowered and kept fairly constant by using ice. Light supplied by a 25-watt bulb about twelve hours daily. One larva in each of 12 Best Bottles. Water changed and larvae fed on live copepods every three days. Larvae hatched between 8:00 p.m. Aug. 8 and 10:00 a.m. Aug.9. Experiment began at 4:30 p.m. Aug.9.

Dates of moulting or death of larvae

	1	2	3	4	5	6	7	8	9	10	11	12
Died without moulting		Aug.17					Au.20			Au.26		Au.24
1st moult	Au.23		Au.23	Au. 23	Au. 23	Au. 24		Au.27	Au. 27		Au.23	
2nd moult	Sep.6		Sep.18	Sep. 5	Sep. 6			Sep.22				
3rd moult				Sep. 26								
Died without further moulting						Sep.17		Sep. 23	Sep. 1		Sep.1	

Experiment closed September 28

Temperature range of water in which larvae were reared.

		Av.daily temp.
Aug. 9-20	9.5 - 11.0°C	10.2
" 21-31	10.5 - 11.3	10.9
Sep. 1-10	9.4 - 10.7	10.2
" 11-20	9.6 - 10.6	10.1
" 21-28	9.4 - 10.5	10.0
Aug.9-Sep.28	9.4 - 11.3	10.3

Summary. Very low temperatures were investigated using a constant temperature box, unlighted, the larvae being fed copepod plankton (Expt.1). Four first stage larvae at 1.7-3.0°C and four at 4.4-6.0°C all died in from 8 to 11 days without moulting. One first stage larva at 8.0-9.5°C died after 24 days without moulting. One larva at 8.4-9.9°C moulted once after 16 days and died 25 days later without moulting a second time, while at temperatures of 13.5, 15.5 and 17.5 one of the two larvae at each temperature moulted three times and reached the fourth stage in 30 to 33 days.

Two larvae fed on copepods were reared to the third stage in an incubator kept at 11.4-12.1°C and one of these was healthy and in the fourth stage when the experiment closed (Expt.2).

Out of twelve larvae kept at 9.4-11.3°C (average daily temperature 10.3) and fed copepods, eight reached the second stage and five the third stage. One had reached the fourth stage and three others were still in the third stage and healthy when the experiment closed (Expt.3).

C. Survival of larvae at high temperatures

High temperature experiments were carried on in incubators maintained at a constant temperature.

Experiment 4. July 16-18. One recently hatched larvae in each of four 4-oz. bottles with necks cut off. Bottles one-half full of water. Larvae fed daily on dead lobster larvae. Water changed every three days. Temperature 25.5 - 26.8°. All larvae died without moulting.

Experiment 5. July 16-18. One recently hatched larva in each of three Best Bottles. Treatment as in experiment 4. Temperature 26.1 - 26.8°. All larvae died without moulting.

Experiment 6. July 18-22. One recently hatched larva in each of five Best Bottles. Treatment as in experiment 4. Temperature 25.6 - 27.3°. All larvae died without moulting.

Experiment 7. July 23-25. One recently hatched larva in each of four Best Bottles. Larvae fed twice daily on lobster larvae. Water changed every three days. Temperature 25.6 - 26.0°. All larvae died without moulting.

Experiment 8. July 28-Aug.2. One recently hatched larva in each of four Best Bottles. Fed twice daily on clam muscle and gonad alternately. Water changed every three days. Temperature 24.0 - 24.8°. All larvae died without moulting.

Experiment 9. Aug.3-14. One larva in each of four Best Bottles. Larvae hatched between 4:00 p.m. Aug. 1 and 9:30 p.m. Aug.2. Fed twice daily on clam muscle and gonad alternately. Water changed daily. Experiment started at 2:50 p.m. Aug. 3.

	Dates of moulting or death of larvae			
	1	2	3	4
Died without moulting	Aug. 7	Aug. 6		
1st moult			Aug. 6	Aug. 7
2ndd moult			Aug. 9	Aug.10
3rd moult				Aug.14
Died without further moulting			Aug.14	

Temperature of water in bottles
Aug.3-14 = 23.6 - 24.5°C

Experiment 10. Aug.18-20. One recently hatched larva in each of four Best Bottles. Fed twice a day on clam muscle and gonad alternately. Water changed daily. Temperature 25.6 - 26.3°C. All larvae died without moulting.

Experiment 11. Aug.20-25. One recently hatched larva in each of four Best Bottles. Treated as in Expt.10. Temperature 25.0 - 26.2°C. Three larvae died without moulting. One moulted for the first time on Aug.23 and died without further moulting on Aug.25.

Experiment 12. Aug.20-22. One recently hatched larva in each of four Perfect Seal pint bottles, ½ full of water. Treated as in experiment 10. Temperature 25.0 - 27.0. All larvae died without moulting.

Summary. Many unsuccessful attempts were made to rear lobsters at 25 - 27°C. The highest temperatures at which lobsters were actually reared to the fourth stage in the incubators were 23.6 - 24.5°C. Other investigators have reared lobster larvae at 25°. It seems probable that owing to the quick pollution and low oxygen capacity of water at high temperatures, the glass

containers with still water are entirely unsuitable for determining the upper temperature limit at which lobster larvae can safely be reared. A limit of 24°C, however, is well above any that the larva is likely to encounter anywhere in its Canadian range so that establishing the fact that larvae could be reared at still higher temperatures would havelittle application.

D. Relation between quantity of food and survival.

Experiment 13. Quantitative food experiment in bottles half immersed in water in tank in basement of main lab. One larva in each of four sets of three Best Bottles. All larvae kept at the same temperature. Larvae hatched August 19. Experiment started Aug. 19. Larvae fed every three days on varying amounts of live copepod plankton. Water changed every three days.

	Fed usual amt. of copepods			Fed ½ usual amt. copepods			Fed ¼ usual amt. copepods			Fed 1/8 usual amt. copepods		
	A_1	A_2	A_3	B_1	B_2	B_3	C_1	C_2	C_3	D_1	D_2	D_3
Died without moulting				Au.21			Au.21		Au.27			
1st moult	Au.27	Au.27	Au.27		Au.27	Au.27		Au.27		Au.27	Au.27	Au. 27
2nd "	Sep.5	Sep.3	Sep.5									
3rd "		Sep.16	" 18									
Died without further moulting	Sep.22				Sep.6	Sep.20		Au.31		?	Au.30	Au.3

Experiment closed on Septemberr27th

Temperature range Aug.19-Sep.22 = 12.8 - 14.6°C

Experiment 14. Quantitative food experiment in refrigerator room of fish handling building. One larva in each of four sets of three Best Bottles. All larvae kept at same temperature. Larvae hatched Aug. 19. Experiment started Aug.19. Larvae fed every three days on varying amounts of live copepod plankton. Water changed every three days. Room lighted by 25 watt bulb about 12 hours daily.

Dates of moulting or dealth of larvae

	Fed usual amt. live copepods			Fed ½ usual amount			Fed ¼ usual amount			Fed 1/8 usual amount		
	A_1	A_2	A_3	B_1	B_2	B_3	C_1	C_2	C_3	D_1	D_2	D_3
Died without moulting						Au.21		Sep.5	Sep. 11		Au.25	Sep. 8
1st moult	Au.27	Au.30	Au.30	Au.27	Au.30			Au.28			Au.28	
2nd moult	Sep.11	Sep. 19	Sep.14	Sep. 13								
3rd moult												
Died without further moulting										Sep. 18		

Experiment closed September 28th

Temperature range Aug.19-28 = 11.1 - 13.3°C
Aug.29-Sep.28 = 9.4 - 11.2°C

Number of copepods in 1/8 usual amount in Experiment 14. Copepods counted in the three 1/8 jars immediately after changing water and feeding.

		Number of copepods in 1/8 usual amount of food.
Aug.28	10-15	small copepods, mostly Acartia
31	10-20	"
Sep. 3	20-40	"
6	10-15	"
9	15-30	"
12	10-15	large copepods
15	20-35	small "

Summary. Two experiments were carried out on the relation of quantity of food to survival of larvae. In both experiments some of the larvae were fed the usual amount of live copepods that has proven to be suitable in the other experiments, some approximately ½, some ¼ and the remainder 1/8 of the usual number. In the 1/8 jars there were usually about 20 small copepods, mainly Acartia.

At 12.8 - 14.6°C of the three larvae fed the usual number of copepods all reached the third stage and two the fourth stage, while three larvae fed ½, three fed ¼ and three fed 1/8 the usual number all died before reaching the third stage. (Expt. 13).

In a second experiment at 9.4 - 13.3°C (Expt.14) three larvae fed the usual amount of copepods had all reached the third stage when the experiment was brought to a close. At the end of the experiment, of the three larvae fed ½ the usual amount one had died without moulting, one had moulted once and the other had moulted twice. Of three larvae fed ¼ the usual amount two had died without moulting and one was still alive and in the second stage. Of three larvae fed 1/8 the usual number of copepods two died without moulting, one moulted once and died without moulting the second time.

E. Survival at different salinities

Experiment 15. One recently hatched larva in each Best Bottle. Larvae kept at salinities of about 30, 28, 26, 24, 22, 20, 17, 14 and 11 per mille. Fed copepod plankton and water changed every three days. All kept under identical favourable temperature, food, water and light conditions in basement of main lab. Temperature range during experiment = 14.7 - 18.4°C.

	Approximate salinity per mille								
Number of 1st stage larvae used	30	28	26	24	22	20	17	14	11
	4	4	5	7	4	5	5	6	7
Moulted once	2	3	4	3	4	3	1	2	0
Moulted twice	1	1	4	1	1	0	0	0	0
Moulted three times	0	1	1	1	1				

Summary. Larvae moulted successfully into the second stage at all salinities from about 30 per mille to about 14 per mille. Seven larvae, however, placed in sea-water with a salinity of about 11 per mille all died after one or two days without moulting. Larvae were successfully reared to the fourth stage at salinities ranging from 28 - 22 per mille and in other experiments, of course, at the ordinary salinity of about 30 per mille.

E. Survival under different light conditions

Experiments 16, 17, 18. Each recently hatched larva placed in a separate Best Bottle. Larvae fed copepod plankton and water changed every three days. Part of larvae kept in absolute darkness except during process of changing water and

feeding, and part open to the dim light of basement under light conditions described in introduction. Larvae in each experiment kept under the same favourable temperature, water and food conditions.

	Expt.16		Expt.17		Expt.18		Total	
	Light	Dark	Light	Dark	Light	Dark	Light	Dark
Number of 1st stage larvae used	12	6	13	12	12	16	37	34
Moulted once	11	4	9	7	11	8	31	19
Moulted twice	11	4	9	6	10	7	30	17
Moulted three times	11	4	8	6	9	7	28	17
Percentage reaching 4th stage							76%	50%

Temperature range: Expt.16 = 16.0 - 18.0°C
Expt.17 = 15.8 - 18.0
Expt.18 - 16.0 - 18.2

Experiment 19. A set of three Best Bottles (one in full sunlight, one with the sides protected from direct sunlight by tar paper and one completely covered by tar paper) were placed near a window in a lobster jar. The temperature was kept approximately the same in all bottles by running water from the tap through the lobster jar. One recently hatched lobster larva was placed in each Best Bottle. Larvae fed on dead lobster larvae two or three times a day. Larvae hatched between 8:30 p.m. July 18 and 8:00 p.m. July 19. Experiment started at 5:00 p.m. July 20.

	Completely shaded jar	Side-shaded jar	Full sunlight jar	Temperature range preceding moult
1st moult	3 larvae	July 23	July 24	18.2 - 25.0 mostly 18.2-20.8
2nd "	were used	" 27	" 28	17.7 - 21.8
3rd "	in succession	Aug. 2	Aug. 2	16.4 - 22.2
4th "	All died without	" 20	" 19	16.6 - 21.2
5th "	moulting	Sep. 5	Sep. 6	15.7 - 23.0

Notes on Experiment 19. Larvae fed one lobster larva twice daily July 20-24, three times daily July 25-Aug.19. Larvae fed on clam muscle and gonadalternately twice daily after Aug19.

Occasionally during the days with most sunlight the temperature was 0.1 or 0.2°C higher in the full sunlight jar than in the jar with the sides protected from complete sunlight.

The jars were shifted to different windows so that they were exposed to all sunlight after 10:00 a.m.

Summary. Of 37 larvae reared in the dim light of the basement and fed plankton 76% reached the fourth stage. Of 34 similar first stage larvae reared under identical conditions, except that they were kept in complete darkness, only 50% moulted three times to reach the fourth stage. It will be noted that the great difference between the survival of larvae reared in the dark and in the dim light is due to deaths occurring before the first moult. After the first moult had taken place there was no noticeable difference in survival in light and dark. Thus, the difference in survival in the dim light and in the dark jars may be a question of the relative ability of the larva in its different stages to obtain food under conditions of darkness rather than the direct effect of the light.

Two recently-hatched first stage larvae under the same favourable conditions of food and temperature were placed in full sunlight in the window of the lab and the other shaded from the direct rays of the sun, diffuse light coming from the top and bottom only. The bottles were shifted so as to have the advantage

of all sunlight after 10:00 a.m. The experiment lasted from July 23 to September 28 during which time each lobster moulted five times. The periods required for the five moults in the case of the two larvae showed no significant difference.

G. Hatching

Twenty egg-bearing lobsters were obtained from Caraquet and placed in the basement tank on June 15.

Hatching record of Caraquet lobsters	
June 30	The first lobster started hatching immediately after a violent aeration of the water in cleaning tank on June 30.
July 16	Four lobsters with eggs completely hatched off, 8 hatching, 7 almost ready for hatching, 1 not ready for hatching.
Aug. 6	Nineteen lobsters with eggs completely hatched off, 1 not hatched (eggs spoilt)

Notes:

The last record of larvae being collected from the Caraquet lobsters was on August 2.

Hatching record of Grand Manan lobsters. Nine egg-bearing lobsters were obtained from Grand Manan and were placed in the basement tank on June 10. One of these died before hatching her eggs.

Aug. 6	One lobster with eggs almost completely hatched off, 1 hatching, 5 almost ready for hatching, 1 not ready for hatching.
Aug. 14	Five lobsters with eggs completely hatched off, 2 hatching, 1 almost ready for hatching.

Note: Second last Grand Manan lobster finished hatching on August 15, and last hatching from Grand Manan lobsters was on August 23.

Temperature range in basement tank

June 12-30	10,4 - 12.2°C
July 1 -15	11.9 - 12.5
16-31	12.1 - 14.1
Aug. 1-15	13.0 - 14.0
16-31	13.6 - 15.3
Sep. 1-15	13.0 - 14.1
16-27	12.7 - 13.6

(A) Caraquet egg-bearing lobster, 27 cms.long, started hatching at 11:15 a.m. June 30 after violent aeration of the water.

		No.larvae collected
June 30	4:00 p.m.	7
July 1	9:30 a.m.	4
22	10:15 a.m.	48
2	7:40 p.m.	46
3	9:30 p.m.	35
4	8:10 p.m.	67
5	10:10 p.m.	325
6	9:45 p.m.	152
8	9:00 a.m.	66
9	5:00 p.m.	43
10	2:30 p.m.	21
12	7:00 p.m.	4
13	9:00 p.m.	1

Only about half the eggs hatched. Remainder spoilt.

Temperature range in tank, June 30-July 13 = 11.9 - 12.5°C

(B) Caraquet egg-bearin lobster, 25 cms.long. Placed in compartment for collecting larvae at 4:00 p.m. Aug.16. Lobster fully berried and ready to hatch at this time. If any eggs have hatched these have been few.

		No.of larvae collected
July 17	2:30 p.m.	103
18	3:30 "	76
19	3:00 "	174
20	8:45 "	493
21	5:40 "	278
23	11:00 a.m.	157
24	2:30 p.m.	146
26	3:05 p.m.	60
27	7:45 p.m.	50
29	--	10
31	--	4
Aug. 1	--	0

Only about half the eggs hatched. Remainder spoilt.

Temperature range in tank, July 17-31 = 12.2 - 14.1°C

Summary. Eight berried lobsters obtained from Grand Manan were placed in the basement tank on June 10, and 20 from Caraquet were placed in the tank on June 15. The first Caraquet female started hatching on June 30. By July 16, of the Caraquet females 4 had completely hatched, 8 were hatching, 7 were ready for hatching and 1 was not yet ready. By August 6 all the Caraquet females had hatched their eggs.

On August 6 of the 8 Grand Manan females 1 had almost completely hatched, 1 was hatching and 6 had not yet begun hatching. By August 14, 5 Grand Manan females had hatched, 2 were hatching and 1 had not yet begun hatching. The last record of larvae being collected from the Caraquet females was on August 2 and from the Grand Manan lobsters on August 23.

Thus, in the laboratory tanks the Caraquet lobsters essentially hatched their eggs in July and the Grand Manan lobsters in August about a month later. The temperatures in the tanks from June 12 to August 15 ranged from 10.4 to 14.1°C. These temperatures are several degrees lower than those which the Caraquet lobsters would experience during the same period on their natural grounds and several degrees higher than the Grand Manan lobsters would encounter near Grand Manan. Thus, the Caraquet lobsters would have hatched still earlier and the Grand Manan lobsters still later if they had been allowed to remain at Caraquet and at Grand Manan respectively.

In two Caraquet females observed the hatching period lasted for 14 and for 15 days respectively at temperatures ranging from 11.9 to 14.1°C.

H. Length of periods between moults, at different temperatures.

Expt.	Food	change of water	Days in 1st stage: Days after hatching	Days after expt. started	Temp. range	No. of larvae	Days in 2nd stage	Temp. range	No. of larvae	Days in 3rd stage	Temp. range	No. of larvae	Days in 4th stage	Temp. range	No. of larvae	Days in first 3 stages	Temp. range	No. of larvae
9	Clam muscle & gonad	Daily	4½	3½	23.6-24.0	2	5	23.6-24.5	2	8½	23.8-24.3	1				12	23.6-24.5	1
16	Plankton	Every 3 days	5	5	16.5-17.0	6	4	17.0-18.0	6	6½	16.0-17.5	6				15½	16.0-18.0	6
18	"	"	5	5	16.0-17.0	11	6½	16.0-17.7	9	7½	16.1-18.2	8				19½	16.0-18.2	8
20	Lobster larvae	"	8	8	14.1-14.3	1	8	14.2-14.3	1	11	14.0-14.4	1				27	14.0-14.4	1
21	Plankton	"	8½	8½	13.0-13.6	10	8½	13.2-15.3	8	12	13.6-14.0	7	25	12.7-14.1	6	28	13.0-15.3	7
22	Lobster larvae	"	8	8	12.8-13.3	1	8	12.7-12.9	1	14	12.7-13.2	1				30	12.7-13.3	1
2	Plankton	"	10	10	11.4-11.8	1	9	11.6-12.0	1	17	11.9-12.1	1				36	11.4-12.1	1
3	"	"	14	14	9.5-11.3	1	13	9.4-11.3	1	21	9.4-10.6	1				48	9.4-11.3	1
3	"	"	15	15	9.5-11.3	8	17	"	4		"							

Summary. At the highest temperatures investigated (24.0°) the three moults necessary to reach the fourth stage were completed in less than 12 days. At temperatures 16-18° the fourth stage was reached in 15-19 days. Larvae at 12-14° attained the fourth stage in from 27-30 days after hatching. At 11.4-12.1° the fourth stage was reached in 36 days while at the lowest temperature investigated (9.4-11.3°C, average daily temperature of 10.3°) the first larva to reach the fourth stage required 48 days after hatching and three larvae were still in the third stage when the experiment ended after 50 days.

Discussion and Conclusions

(a) Qualitative natural survival. Possibly the lowest summer temperatures on the coast of the Maritime provinces are found at the mouth of the bay of Fundy where during special lobster fishing at Grand Manan, Aug. 5-15, 1932, the inshore bottom temperature ranged between 10.5 and 11.4°C while the surface temperature ranged between 10.8-12.2°C. In our experiments during the past summer lobster larvae were successfully reared to the fourth or lobsterling stage at a temperature ranging from 9.4-11.3°C with an average daily temperature of 10.3°C.

At lower temperatures no success was obtained in rearing although this was possibly due to technical rather than absolute causes since no attempt was made to rear larvae at temperatures lower than 9.4-11.3°C under the same favourable conditions. Further experiments will doubtless lower slightly, possibly by 1 degree, the minimum temperature at which lobsters will survive.

Thus, there seems to be no reason to assume that there are many areas near the coast of the Maritime provinces with so low a temperature that the lobster larvae hatched in July or early August cannot in theory survive to the lobsterling stage.

Similarly, lobsters were reared at 24°C so that no temperatures would be encountered in the Maritime area which are too high for larval survival.

Since, as shown by experiment 19, the larvae period can be successfully passed through when the only protection from the sunlight is a layer of about ¼ inch of transparent glass and 1 or 2 inches of water there is no reason to suppose that in Nature the larva cannot always so modify its position as to encounter less intense sunlight than in this experiment. Thus, we can rule out the lethal effect of sunlight under natural conditions.

Lobsters were raised to the lobsterling stage at all salinities from about 22 per mille to about 30-31 per mille. Thus, it is only in very limited areas such as river mouths that salinities would be low enough to be lethal.

(b) Quantitative natural survival. Although it has been shown practicable to rear lobsters to the lobsterling stage at temperatures between 24° and 9.4-11.3°, yet the time spent in the three stages previous to the lobsterling stage increases from less than 12 days at 24° to 15-19 days at 16-18° and to more than 50 days at 9.4-11.3°. Since undoubtedly it is the free-swimming planktonic stage that is in greatest danger of destruction this great increase in the length of the larval period at low temperatures should result

in a much lower percentage survival to the lobsterling stage than does the short larval period at higher temperatures.

Another factor which will make the percentage larval survival less in cold waters such as at Grand Manan is the late hatching in such waters. As shown by observations on Grand Manan and Caraquet lobsters held in the lab tanks and by field work in other years, the hatching period in the warm southern gulf of St. Lawrence area is largely over before the end of July while the bulk of the hatching in the cold Grand Manan area would take place about a month later in August. The larvae hatching in a cold water area in late August and early September might toward the latter part of their larval life encounter a temperature which is below the minimum for survival.

The fact that larval lobsters were unable to survive on a reduced copepod food supply indicates that the years when larval lobsters in the plankton encounter an especially good copepod or other food supply should be good survival years.

The great range of salinities in which larvae can survive calls for more experiments directed toward finding what are the most favourable salinities. This information, if significant, could ppssibly be correlated with presumably good and bad years for larval survival as calculated from the fluctuations in the lobster catch.

Acknowledgment

I wish to acknowledge the help of Miss Elizabeth Huntsman who performed some of the preliminary experiments as well as experiment 18.