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Factors Limiting the Survival of Lobsters

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D. W. McLeese

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by D. W. McLeese.

INTRODUCTION

In nature, lobsters are found where the environmental factors, temperature and salinity, vary widely. In winter, water temperatures may drop below 0°C. and in certain areas may exceed 21°C. in summer. Lobsters normally are found in water whose salinity is close to 30 parts per thousand, but they are found in the Bras d'Or Lakes where salinities as low as 21 parts per thousand have been recorded in 5 to 15 fathoms.

In commercial handling, more severe conditions are often encountered. Frequently lobsters are held in warm inshore waters and after heavy rains, may be exposed for several days to greatly reduced surface salinities. Sudden extreme changes in temperature are experienced when lobsters are taken from air temperatures of 30°C. or more and placed in refrigerated trucks and cars for transport.

Some general information about the effects of temperature and salinity on the survivial of lobsters was already known. More precise information, of the exact conditons of temperature and salinity, at the various levels of temperature acclimation, that can be tolerated by the lobster, was desired to provide a sound basis for advice to the industry, and to eventually provide a possible means for better understanding of such factors as activity and catchability.

The tests reported here concern themselves primarily with temperature. The rate of thermal acclimation, thermal death points, size and differences in life history in relation to heat tolerance, and effect of moulting on heat tolerance have all been investigated. To a lesser degree, work was done with lethal salinities in relation to environment of temperature.

Methods and Materials

The experiments were done during the summer periods May 15 to September 15, 1949 and 1950. At present, the results have not been fully analyzed. During 1949, lobsters were purchased directly from Conley's Lobsters Limited, St. Andrews, N.B. In addition to some purchased from Conley's in 1950, lobsters were also obtained from the fishing areas at Grand Manan, N.B., and Escuminac, N.B. In 1949, lobsters were stored in concrete tanks in the basement of the Administration building. In 1950, a floating car at the end of the Station wharf held lobsters before use.

In 1949, a record was kept of the salinity and temperature variations in the holding tanks. The temperature gradually rose from 10.0°C. in June to 15.0°C. at the end of August. The salinity fluctuated between 29.7 and 31.3‰. During 1950, twice daily wharf-end temperatures routinely taken by the station were used since the lobsters were held near the spot where temperatures were read. Salinity determinations were not made since the fluctuation as seen in 1949 was small.

Lethal temperature determinations were run in a series of constant temperature baths, maintained at 1.0°C. intervals apart.

At the start of an experiment, observation times were close, at hourly intervals. As exposure times increased, observations were taken less frequently until the animals were checked at a maximum time of 24 hours after the first day.

Tests were arranged so that 0% mortality was found at the low test temperature, and 100% mortality occurred at a temperature about 3.0°C. higher. These temperatures were obtained by heating a 3' x 3' x 18" salt water tank with a copper coil. The coil was painted with Tygon paint, to cut down the reactivity of copper with the salt water. Water from a thermostatically controlled oil heater flowed through the coil providing heat at the desired constant temperature in the tank. Two test tanks, 3' x 3' x 6" could be used at one time. By adjusting rate of flow of hot water into the test tanks, the temperatures were kept within ±0.3°C. or less for the most part. Only very rarely, fluctuations of ±0.5°C. were noted and corrected as soon as noticed. In no case was the accuracy of the experiment upset since these fluctuations usually happened after the 48 hour period, and no further deaths were reported in the tests unless stated in the results.

An attempt was made to use 10 animals for each test. Sometimes it was impossible to have 10 animals available, and less were used. In no case were less than 6 lobsters used. In the tabled results, the number is always indicated.

To prevent lobsters injuring each other, the large claws were either plugged with wooden wedges, or banded with stout elastic bands. In addition the test tanks were divided in 10 compartments by galvanized screening so that individual animals could be isolated. The volume of the test tanks was such that each lobster was provided with 2½ gallons of water. Porous air stones placed in the test tanks kept the oxygen concentration over 75% for the most part, although occasionally it dropped to 60%.

For comparing the effects of different levels of acclimation, on the resistance of lobsters to heat, the lethal temperature was defined as the temperature that would kill 50% of the population in 48 hours. If the exact temperature was not found experimentally, the value was read from a survival curve drawn for the 48 hour period. It was thought that 48 hours was a sufficientally long time for the mortality caused by the lethal temperature to reach a constant value. In any case, where lobsters were living past the 48 hour period, the test was continued till 72 hours. The 72 hour survival curves coincide almost exactly with the 48 hour curves.

Test salinities were obtained by mixing flowing salt water and fresh water in the proper ratios. Buffer tanks smoothed out any variations in salinity that might occur due to minor fluctuations in water pressure. Water then flowed into two test tanks, each divided into 10 compartments by galvanized screening.

Salinity determinations were done by titrations, based on the Knudsen method, and by hydrometer readings. Test salinities varied less than ±.4‰.

A sufficient flow of water was maintained in the salinity tests so that a high oxygen level was ensured. For the 25.0°C. salinity test it was necessary to use a smaller flow of water, so four air stones were placed in the tanks to ensure a high oxygen concentration.

The lethal salinity was defined as that salinity that killed 50% of the population when exposed to it for 48 hours. When necessary, this value was found by interpolation as in the case of temperature tests. At the lowest temperature, 5°C., significant mortality took place after the 48 hour period. However, at higher temperatures, the per cent mortality had leveled off at this time. In any test where lobsters were still living after 48 hours, exposure was extended to 96 hours for most tests but if any lobsters appeared to be weakening, the period was again extended to 120 hours.

Loosanoff in a publication entitled "The effects of sea water on the starfish of Long Island Sound" states that exposures to reduced salinities must, in cases that are only slightly lower than the threshold value below which the starfish can no longer live normally, be increased to periods as long as 2 months before harmful effects are observed.

It was not convenient to extend exposure periods past the 120 hour time in this series of tests. Under natural and near natural conditions, lobsters would not be exposed to greatly reduced salinities for periods exceeding this time.

RESULTS

Temperature

Rate of gain of heat tolerance to increased temperature.

In order to illustrate thermal acclimation of lobsters, lobsters conditioned to 14.5°C. water for at least one month were exposed to 24°C. for periods up to 31 days. Their average survival time when exposed to 30° was taken as a measure of acclimation. 30° was chosen since for animals acclimated to 14.5°, 80% mortality in 12 hours and 100% mortality in 15 hours resulted from exposure to 30°C. Acclimation would show as an increased survival time in this temperature. Acclimation times of 0, 1, 3, 7, 10, 14, 19, 24, 26, and 31 days were tested. The results of this test are presented in table I. The average survival time is plotted against acclimation time in figure 1. When animals lived longer than 72 hours, this 72 hours was taken as the length of survival for calculating average survival time. Acclimation over the first 10 days is very slow, only a slight increase in time of survival being shown. A rapid increase in heat tolerance came after the tenth day, and the rapid rise continued until about the twenty-second day. Further increased tolerance to heat did not occur even after an adaptation time of 31 days in 24.0°C. A ten degree rise in acclimation temperature from 14 to 24 requires a time of approximately 20-22 days for complete adaption to take place, or a time of 2 days for each degree upward in acclimation temperature.

Rate of loss of heat tolerance when acclimating to a low temperature.

To demonstrate the rate of loss of heat tolerance of lobsters, animals taken from 14°C. water were placed in 5° water for periods of 0, 1, 3, 6, 13, 20, and 25 days. The average survival time when exposed to 26° was taken as a measure of loss of heat tolerance. From 1949 results, lobsters acclimated to 14.5° showed 100% survival up to 72 hours when exposed to 26°C. water. Loss of heat tolerance should be illustrated by an appearance of mortality when exposed to the test temperature. The average survival time, table II, drops to 19 hours when acclimated for 13 days, but after that time an increase is seen in the survival time. When table III is consulted, it can be seen that for 5.0° acclimated lobsters, 70% mortality is experienced in 26.0°C. in 72 hours. This gives an average survival time of 40 hours. A higher temperature as 30°C. should have been chosen as the test temperature. Since the 9 day group was an average survival time of 40.3 hours, acclimation down seems to be complete.

TABLE I. Rate of Gain of Heat Tolerance of Lobsters when taken from 14.5°C. and put in 24±1°C. for periods from 1 to 31 days. Survival tested in 30°C.

Accl. Time Days	Size Range Cm.	No. Used	Average Survival Time hrs.	% Mortality at Stated Times (Hours)											
				1	2	3	5	6	9	12	14	24	48	72*	96
0	23-24	10	8.1	0	10	20		60		80		100			
1	23-24	8	10.2	0	0	0	12.5	25		100					
3	23-25	7	13.7	0	0	0	0	0	0	43		100			
7	23-25	8	12.2	0	0	0	12.5	12.5	75	75		100			
10	23-25	6	16.0	0	0	0	0	0	0	0		100			
19	23-27	8	54.2	0	0	0	0	0	0	0	25	25	37.5	50	75
26	23-26	6	72.0	0		0		0	0	0	0	0	0	0	0
31	17-22	8	66.2	0		0		0	0	0	0	12.5	12.5	25	25

* Survival time for lobsters living past 72 hours, taken as 72 hours in calculation of survival time.

Fig. 1. Rate of acclimation of lobsters when taken from water of 14.5°C. and placed in 24±1°C. from 1 to 31 days. Tested in water of 30°C.

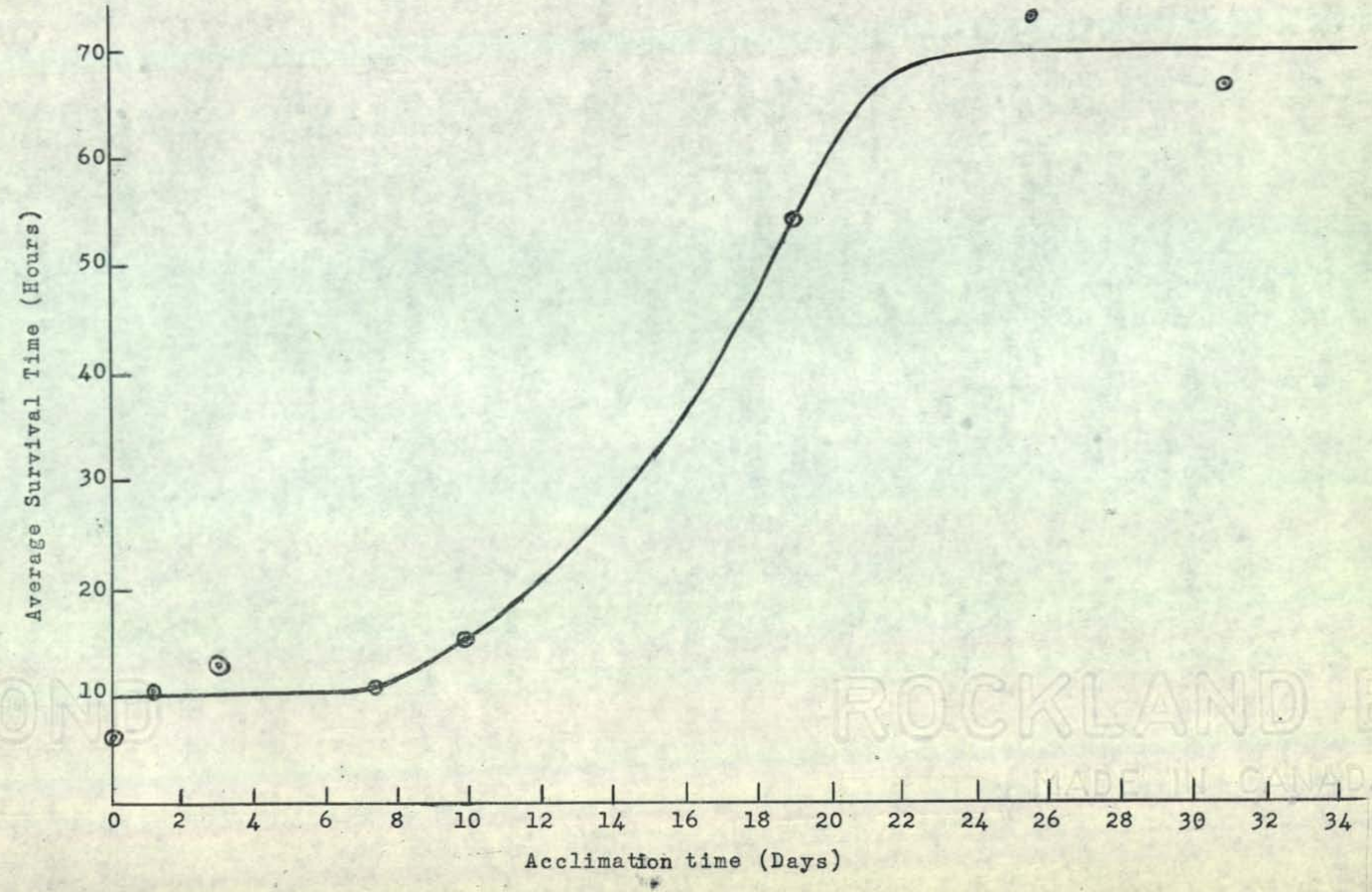


TABLE II. Rate of loss of Heat Tolerance of Lobsters when taken from 14.5°C. and put in 5°C. for periods of from 1 to 25 days. Survival tested at 26°C.

	Accl. Time Days	Size Range Cm.	No. Used	Average Survival Time hrs.	% Mortality at Stated Times (Hours)											
					1	2	3	6	9	12	18	24	36	48	72	96
	0	23-26	10	72	0	0	0	0		0	0	0	0	0	0	
	1	17-22	10	70	0	0	0	10		10	10	10	10	10	10	10
*	3	17-18	10	48	0	0	0	0		0	0	0	10	100		
*	6	16-18	10	42	0	0	0	10		10	10	10	40	100		
	9	19-20	10	40.3	0	0	0	20		30	30	40		70	70	70
	13	17-20	10	19.0	0	0	40	60		60		80		90	90	
*	20	17-20	10	25	0	0	0	0	10	30		30		30	30	
	25	20-22	10	36	0	10	20	20	30			40		70	70	

* Survival time possibly too low from copper poisoning.

A 1000 watt copper heating element was used to heat water to 26.0°C. for the 3, 6, and 20 day periods. The survival times for these periods is too short, probably caused by toxic effects of copper. The 13 day group shows an unexplained low survival time.

Upper Lethal Temperatures

It was shown that lobsters will acclimate to increased temperatures. The survival time in 30° was increased from 8.1 hours for lobsters directly from 14.5° to over 72 hours when acclimated for 26 days to 24°C.

Because of this acclimation, any statement of lethal temperatures would be useless without also knowing the acclimation level. Lethal temperature determinations were made at acclimation levels of 5, 9, 14, 19, and 24°C. The results which were obtained from this series of tests appear summarized in table III. These results are plotted in figure 2, with per cent mortality against temperature. Sigmoid S-shaped curves result from plotting the data in this manner. The end point for mortality was taken as the 48 hour period as explained in the section on materials and methods. The 50% lethal point for each level of acclimation can be read by interpolation. The lethal level is 25.7° for 5° adaption and rises to 30.4 for 24° acclimation. Figure 3, line A, shows the relation of acclimation temperature to lethal temperature. A 20° rise in acclimation temperature causes an increase of 4.7 or approximately 5° in upper lethal temperature, that is. a 4° rise causes a rise of 1° in the lethal temperature. Line B shows the temperatures below which no mortality occurred at the various acclimation levels.

Where extreme changes in temperature were encountered, as in the case of 5° conditioned lobsters put into water of 25°C., an upward change of 20 degrees, a period of inactivity that remained for 3 to 5 minutes was noted. Lobsters appeared to recover from the tetanic state and showed no apparent ill effects. When less extreme changes were encountered, lobsters showed no indication of tetanus, but did show an increased activity. Temperatures that were rapidly lethal as 29°C. for 9°C. acclimation showed no effect on the lobster after the 3 to 5 minute period on first being immersed in the test temperature, except a gradual weakening. Temperatures that were slowly lethal as 27° for 9°C. acclimation showed an effect on the central nervous system. When picked up, the walking legs were seen to quiver rapidly.

It can be seen from table III, that for all levels of acclimation the difference between the temperature that causes 0% mortality and 100% mortality is 4°C. This is an indication that this method gives a rather precise end point. Possibly 0.5° intervals instead of 1.0°C. intervals would give a more accurate

TABLE III. Per cent mortality of lobsters at high temperatures in relation to acclimation temperature. Ten animals for each point.

Accl. Temp.	Size Range cm.	Test Temp.	% Mortality at Stated Times (Hours)										
			½	1	3	6	9	12	18	24	48	72	96
5°C	20-22	25°C.	0	0	10	10	10	10	10	10	10	10	
		26°C.	0	0	20	20	30	30	30	40	70	70	
		27°C.	0	0	0	20	30	60		90	100	100	
9°C	20-23	25°C.	0	0	0	0	0	0	0	0	0	0	
		26°C.	0	0	0	0	0	0	0	10	20	20	
		27°C.	0	0	10	10	30	50		90	90	90	
		29°C.	0	0	50	90	100						
14°C	23-26	27°C.	0	0	0	0	0	0	0	0	0	0	
		28°C.	0	0	10	10	10	10		20	40	50	
		29°C.	0	0	0	10	10	10		60	70	80	
		30°C.	0	0	20	60		80		100			
		31°C.	0	50	100								
19°C	22-25	27°C.	0	0	0	0	0	0	0	0	0	0	
		28°C.	0	0	0	0	0	0	0	10	10	10	
		29°C.	0	0	0	0	0	20	50	50	50		
		30°C.	0	0	0	10	50	70		100			
24±1°	20-22	29°C.	0	0	0	0	0	0	0	10	10	10	
		30°C.	0	0	0	0	0	0	0	10	20	20	
		31°C.	0	0	0	0	0	0	0	20	75	75	

Fig. 2. Lethal Temperature Curves for lobsters acclimated at 5°, 9°, 14°, 19°, and 24°.

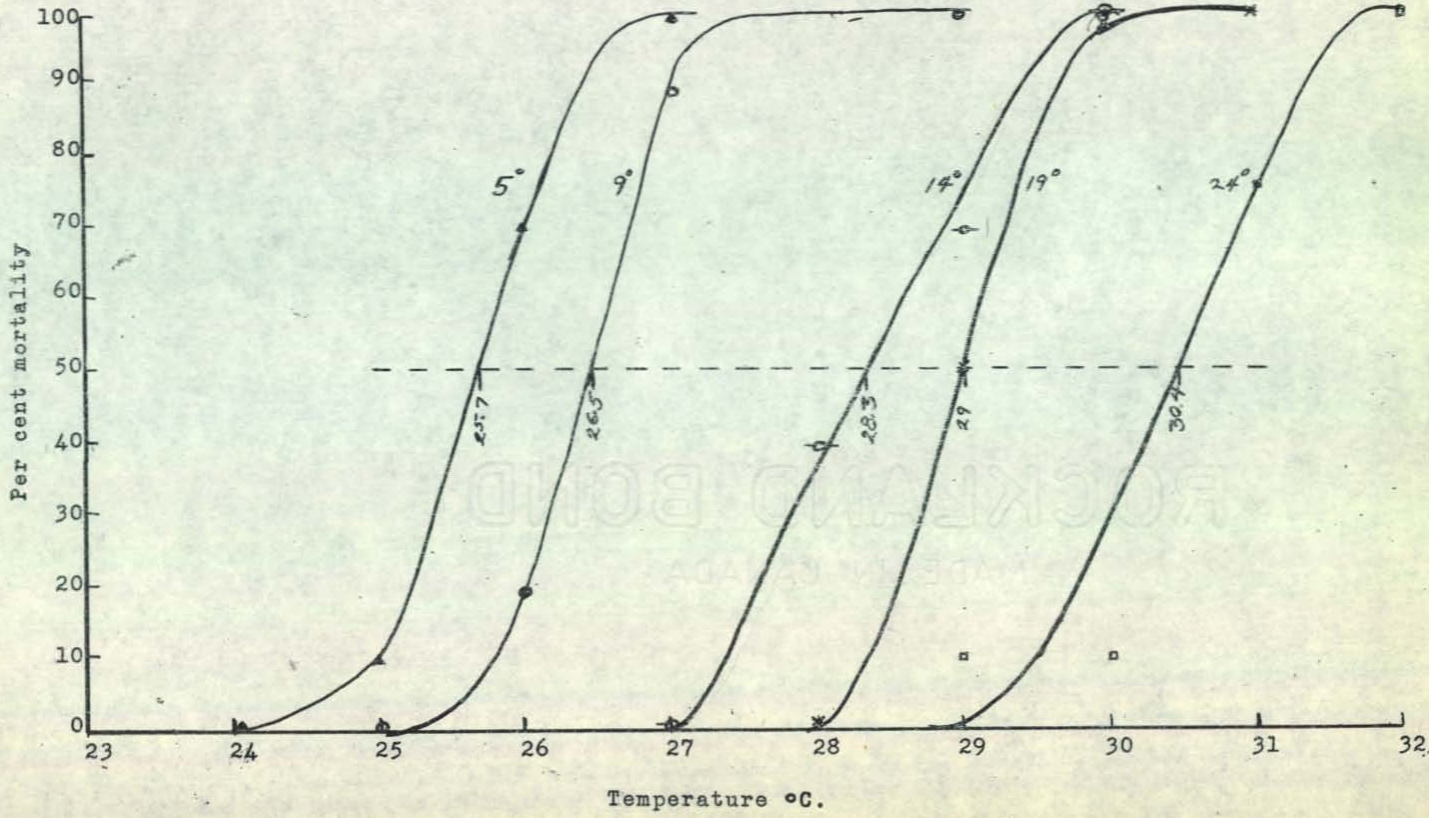
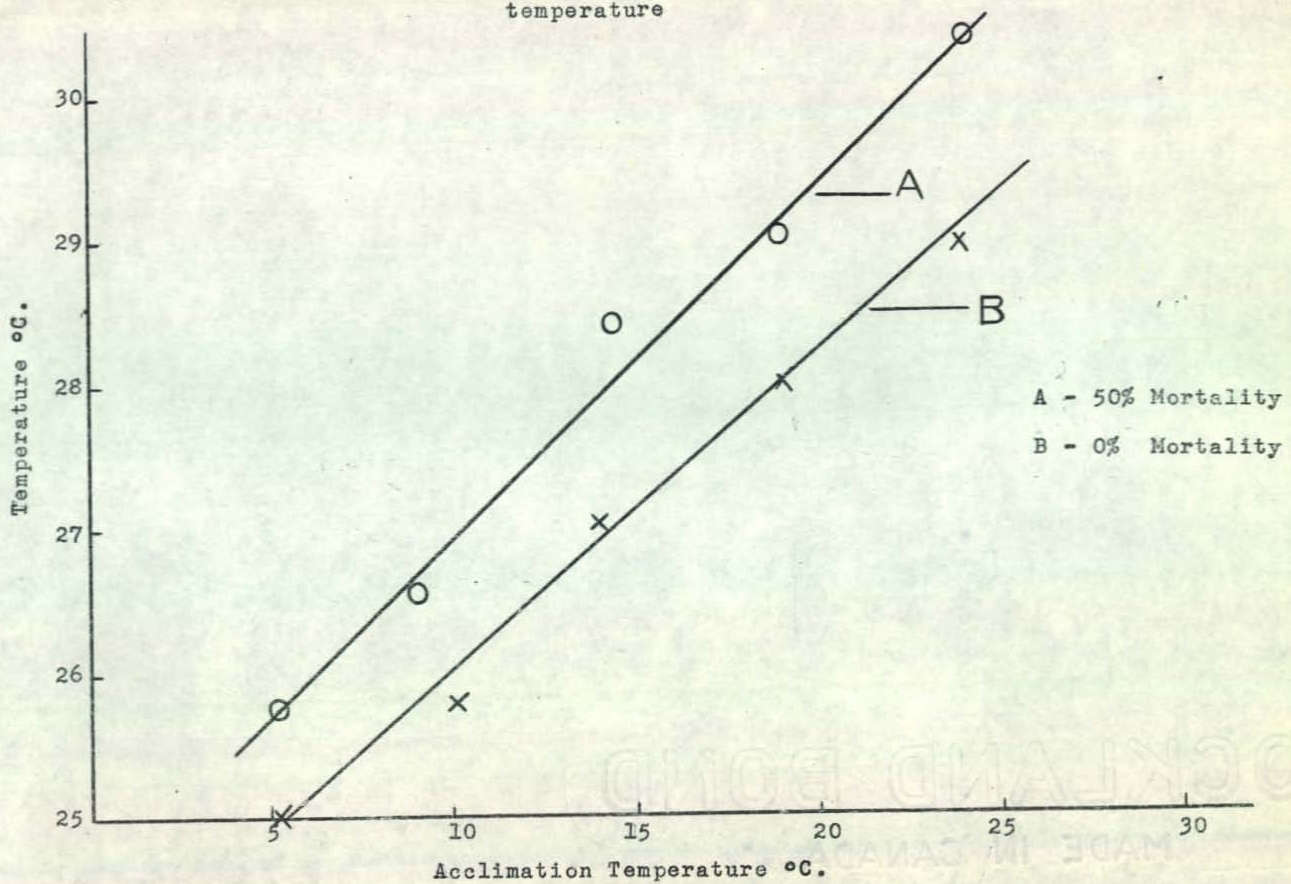


Fig. 3. Relations of Lethal Temperature and sub-lethal temperature to acclimation temperature



value, but the difficulty of maintaining temperatures at a greater accuracy than ±0.3° in the test tanks ruled this out.

The lobster industry is interested in finding out the temperatures below which no deaths are caused by exposure to heat. All values below line B on figure 3 are safe under ideal conditions for the survival of lobsters, providing they are acclimated fully to the values on the abscissa of the graph.

Lower Lethal Temperatures

As animals show a gain of heat tolerance on acclimation to increased environmental temperature, their resistance to cold is lost. In order to test the decrease in cold tolerance, 10 lobsters acclimated to 28° were placed in 4.5-5.0°C. A mortality of 60% was noted in 48 hours. Seven animals acclimated to 27°C. were placed in 5.5-6.5°C. None of these died in a 120 hour exposure. Both groups of lobsters were very sluggish in the low temperatures.

Lobsters acclimated to 17° were tested at 0.3°C. Since all died in 18 hours, the lower lethal temperature for 17° acclimated lobsters is above 0.3°C. From results at upper lethals, the 50% mortality point is about 1.5°C. above the temperature that causes all to die. This point was not determined experimentally for the lower lethal, but the estimated value 2.0°C. is used in figure 4. The results for the cold test are given in table IV.

Thermal Tolerance of Lobsters

A graph of thermal tolerance can be prepared by plotting lethal temperature against acclimation temperature if upper and lower lethals have been determined for different acclimations. This has been done for the lobster in figure 4. The diagonal line is drawn through the points where acclimation and lethal temperatures are equal. It was estimated that the upper lethal would become constant at 28°C. Acclimation above about 28° is impossible since it is the point where the upper lethal, after leveling off, cuts the diagonal. A vertical line dropped from this point limits the thermal tolerance in this direction. The lower line represented the temperature level below which lobsters can not survive for an indefinite time. The area inside these boundary lines is a measure of the complete thermal range under which lobsters can survive.

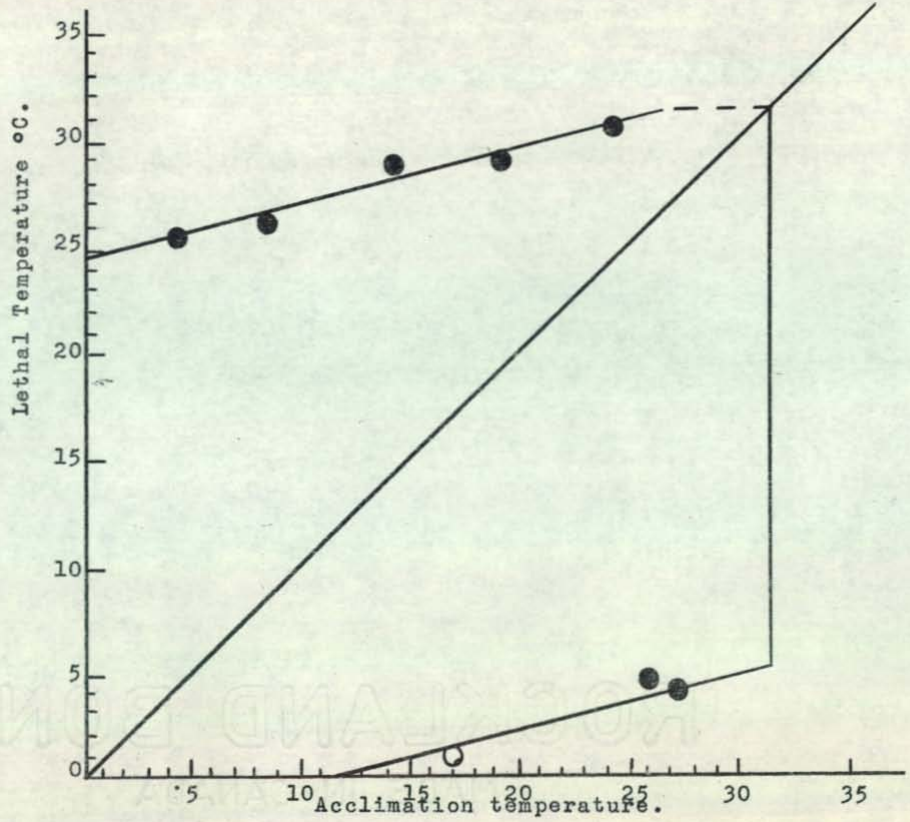
Temperature and Size Effect

Most lobsters used in the tests were of one size range, mostly between 23 and 26 cm. total length. Any effect of size in relation to order of death would not be apparent with such individuals. To test size, a supply of lobsters was procured from Grand Manan. Lobsters from 20 to 30 cm. comprised the shipment. These

TABLE IV. Per cent Mortality of Lobsters at low temperatures in relation to acclimation temperature.

Accl. Temp.	Size Range Cm.	Test Temp.	No. Used	% Mortality at Stated Times (Hours)									
				1	3	6	12	18	24	48	72	96	120
28° C.	17-20	4.5-5.0° C.	10	0	10	20		40	50	60	60	70	80
27° C.	18-22	5.5-6.5° C.	7	0	0	0		0	0	0	0	0	0
17-18°C.	22-24	0.2-0.5° C.	7	0	0	0		85	100				

Fig. 4. Thermal Tolerance of Lobsters.



were divided into two groups, 21-22 cm. and 26-28 cm. Ten animals of each size group were tested for survival in 25, 26, 27, and 29°C. at acclimation of 9°C. The lethal temperature for both groups at 48 hours is 26.5°C. The results are in table V.

Only slight variation was noted in all the time of deaths of large and small lobsters. In the 26° test, one small lobster died between 36 and 48 hours. This causes the survival curves of large and small to diverge a bit, but the death of one animal does not carry enough significance to indicate any real difference. In the 27° and 29° tests, a slight lag is noted in time to death for the two groups, but it is a matter of only 2-3 hours before the time-mortality curves again coincide. The 48 hour survival curve for both groups is identical except for the death of one lobster as previously mentioned.

Local Differences

Lobsters from different parts of the coast of the Maritime Provinces show a marked difference in life history. Lobsters from warmer regions have a faster rate of growth and reach sexual maturity at an earlier age than those from colder water regions. Equal size groups from the two areas, Escuminac, N. B., and Grand Manan will differ in age and state of maturity. To determine if any difference in tolerance to heat existed between the two groups, equal size groups from the two areas, acclimated at 10°, were tested in 27° and 29°. Another group acclimated to 14.5° was tested at 30°. Table VI presents the results.

No difference in tolerance to temperature could be detected from this test.

Moulting and its Effect on Heat Tolerance

A few lobsters moulted in the car, but hard-shelled lobsters in the tanks killed them. When found, lobsters preparing to moult were isolated. Six shedders were saved by doing this. The first to moult had a relatively hard shell by the time the six were collected, so the group tested consisted of 2 soft-shelled lobsters that had moulted about one week previously and 2 lobsters that had been held 3 to 4 weeks since moulting. Six animals that had not moulted during the season, and showed no indication of shedding, were taken for controls. These, as well as the shedders, were held at 19.0°C. for at least 10 days before testing. The survival of the lobsters was tested at 29°C. This temperature was chosen because animals acclimated to the same conditions as these test animals suffered 50% mortality in 48 hours at 29°C. Any difference in tolerance to heat should show as a change in survival time. As seen in table VII, both the soft-shelled died within one hour. The 2 medium-shelled died within 3 hours, and the hardened recently moulted lobsters died between 24 and 72 hours. Lobsters

TABLE V. Lethal Temperature determinations of large (26-28 cm.) and small lobsters (21-22 cm.) to note any possible size influence on survival. Ten large and ten small lobsters tested at each temperature.

Size	Test Temp.	% Mortality at Stated Times									
		½	1	2	3	6	9	12	24	36	48
Large	25°	0	0	0	0	0	0	0	0	0	0
Small		0	0	0	0	0	0	0	0	0	0
Large	26°	0	0	0	0	0	0	10	10	10	10
Small		0	0	0	0	0	0	0	10	10	20
Large	27°	0	0	0	10	30	30	60	90	90	90
Small		0	0	0	10	10	30	50	90	90	90
Large	29°	0	0	30	80	80	100				
Small		0	0	10	50	90	100				

TABLE VI. Comparative survival times of Grand Manan and Escuminac lobsters of nearly equal size, exposed to 27, 29, and 30° C. Ten lobsters from each place tested at each temperature

Area	Size Range Cm.	Accl. Temp.	Test Temp.	% Mortality at Stated Times											
				1	1½	2	2½	3	3½	6	9	12	24	48	
G. Manan	21-23	10°	27°	0	0	0	0	0	0	0	0	0	0	0	
Escuminac	21-23	10°	27°	0	0	0	0	0	0	0	0	0	0	0	
G. Manan	21-23	10°	29°	0	10	30	30	40	40	70	90	100			
Escuminac	21-23	10°	29°	0	20	30	30	40	40	70	90	100			
G. Manan	22-23	14.5°	30°	0	0	0	0	0	10	50	60	80	100		
Escuminac	17-20	14.5°	30°	0	0	0	0	0	10	50	60	70	100		

TABLE VII. Comparative survival times of 6 moulted and 6 non-moulted lobsters when placed in 29° C. water

Shell Condition	Size Range	Accl. Temp.	Test Temp.	No. of lobsters dead at stated times										
				½	1	2	3	6	9	12	18	24	48	72*
Soft	25+27	18-19°	29°	0	2									
Medium	23+24			0	0	1	2							
Hardened	23									0	0	0	1	2
Hard	22-24	18-19°	29°							1	3	3	3	6

* Temperature rose to 30° C. between 48 and 72 hours.

that had not moulted indicated a much greater resistance to this temperature.

This test, although limited by the number of test animals available, shows quite conclusively that freshly moulted lobsters are much more susceptable to high levels of temperature than normal hard-shelled lobsters.

Lower Lethal Salinities

Although most of the work reported here deals with lethal effect of temperature, some work was done on salinity. A series of lethal salinities were determined at various levels of temperature acclimation. It was assumed that lobsters were conditioned to approximately 30‰ salinity, since they were taken directly from a float in the sea or from Conley's tanks, where the salinity approximates 30‰. Lethal salinity determinations were done by maintaining tanks at salinities between fresh water and 75% sea water, that is, 3.7‰, 7.7‰, 11.6‰, 15.5‰, 19.4‰, and 23.3‰. If still surviving, lobsters were left in these tanks for 120 hours. In order to give a more complete picture of lethal salinities, tests were run at 5, 10, 13, 17, and 25°C.

The death of marine invertebrates in reduced salinity has been attributed mainly to the loss of essential salts. Intersegmental membranes swelled considerably in lower salinities, indicating an inflow of fresh water into the animal. If this is a process of osmosis, temperature would effect the rate of water flow into the body.

Advantage was taken of natural temperature rises that occurred over the summer season, to determine lethal salinity at 10, 13 and 17°C. Water for the 5° test was cooled by flowing it through a 40 foot coil of 3/8 inch rubber tubing immersed in crushed ice and salt. A metal coil was purposefully avoided to eliminate any possible chance of metal poisoning. Water for the 25° test was heated by mixing hot salt water with fresh water.

The results are summarized in table VIII, and figure 5. The end point for mortality was taken as 48 hours as explained in the methods and materials.

At 5°C., the lethal salinity is 5.8‰ and at 25°, it has risen to 19.4‰. Figure 6 shows the relation of exposure temperature to lethal salinity. It is a straight line relationship, a 1° rise in temperature causing a rise of 0.8‰ in lethal salinity.

Upper Lethal Salinities

No work was done to establish upper lethal levels of salinity. Templeman (1936) states that 6 lobster larvae died in from 4 to 8 days without moulting, in salinity of 42.5‰. In a

TABLE VIII. Per Cent mortality of lobsters in various reduced salinities in relation to acclimation temperature and exposure times.

Accl. Temp.	Size Range Cm.	Test Salinity Parts per Thousand	% Mortality at Stated Times											
			½	1	3	5	9	12	18	24	48	72	96	120
5°C	23-25	0 ‰	0	0	0	30		100						
		3.7‰	0	0	0	0		30		100				
		7.7‰	0	0	0	0				0	10	30	50	
		11.6‰	0	0	0	0		0		0	0	10		
		15.5‰	0	0	0	0		0		0	0	0	0	
10°C	24-25	0.‰	0	0	60	100								
		3.7‰	0	0	10	60		100						
		7.7‰	0	0	0	0		50		70	100			
		11.6‰	0	0	0	0		20		30	30	30	40	40
		15.5‰	0	0	0	0		0		0	0	0	10	10
		19.4‰	0	0	0	0		0		0	0	0	0	0
		23.3‰	0	0	0	0		0		0	0	0	0	0
13°C	22-23	7.7‰	0	0	0	0	30	70	100	100				
		11.6‰	0	0	0	0	0	10	30	50	80	80	80	90
		15.4‰	0	0	0	0	0	0	10	10	10	10	10	10
		19.4‰	0	0	0	0	0	0	0	0	0	10	10	10
17°C	23-25	7.7‰	0	0	0	80		100						
		11.6‰	0	0	0	10		80		100				
		15.4‰	0	0	0	0		10		10	20	20	20	20
		19.4‰	0	0	0	0		0		10	10	10	10	10
		23.3‰	0	0	0	0		0		0	0	10	10	10
25°C	22-23	15.4‰	0	0	30	70	80	80		90	100			
		19.4‰	0	0	10	20		30		30	50	50	50	50
		23.3‰	0	0	0	0	0	0		0	0	0	0	0

Fig. 5. Lethal Salinity Curves for lobsters acclimated to 5°, 10°, 13°, 17° and 25°C.

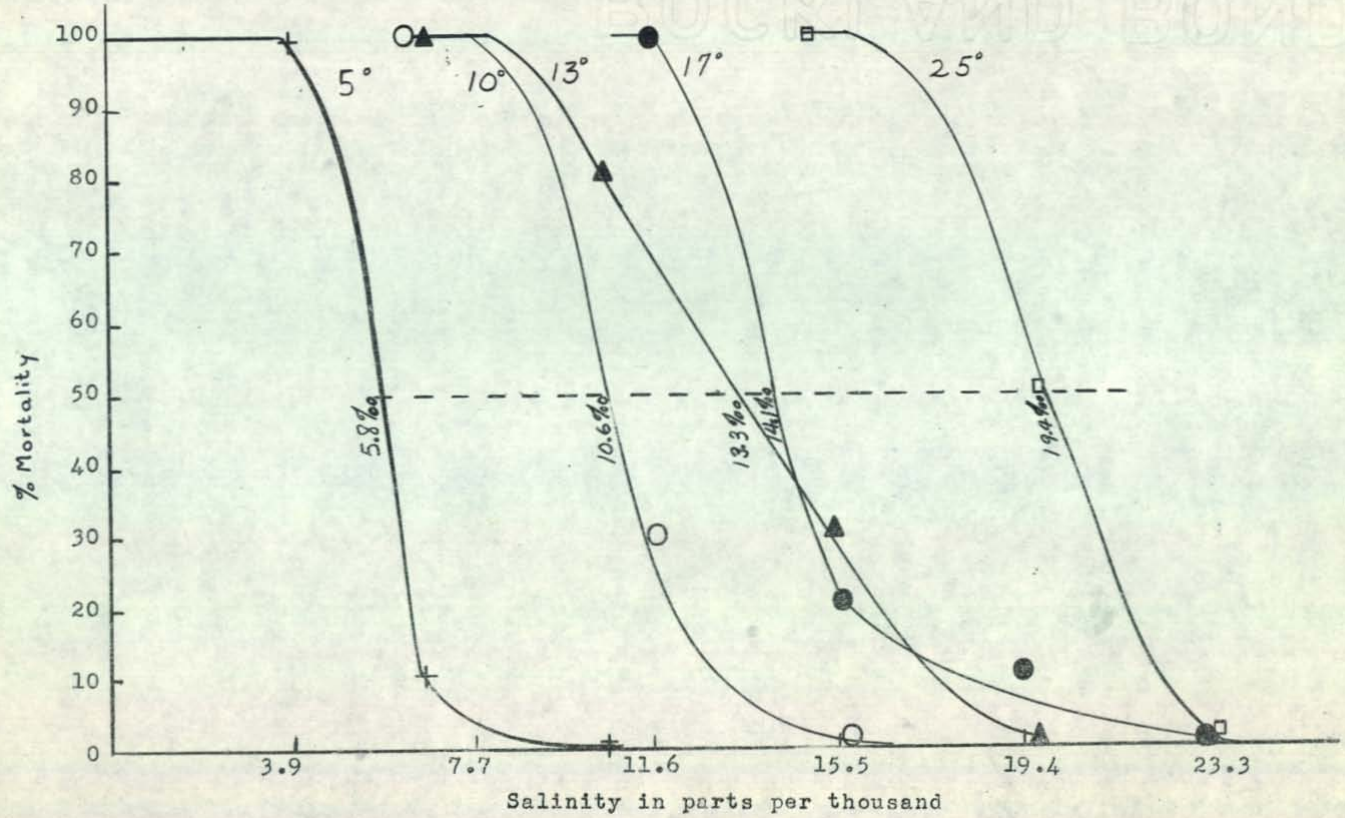
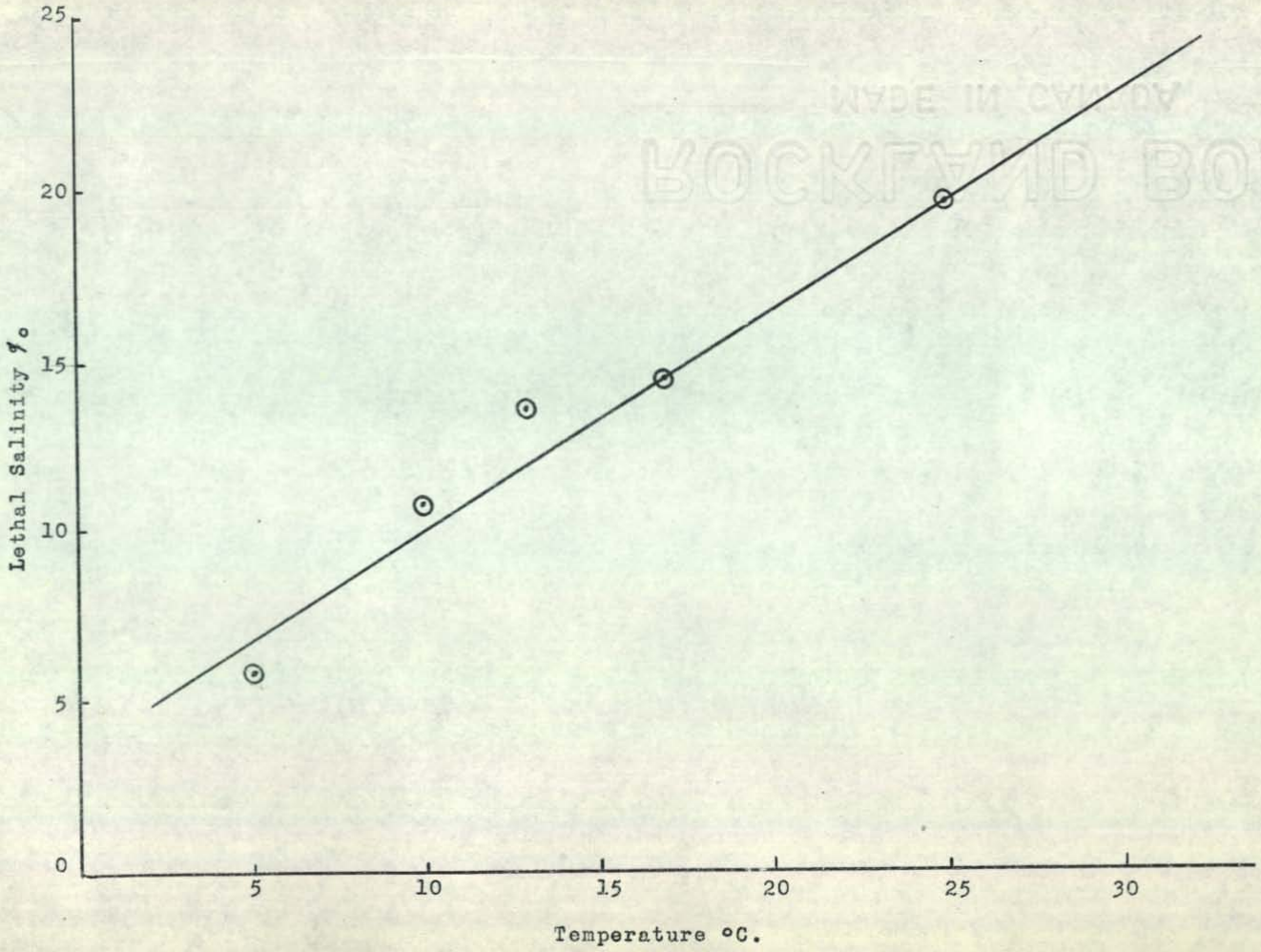


Fig. 6. Relation of lethal salinity to Environmental Temperature.



test done at St. Andrews during 1950, by Dr. D. G. Wilder, lobsters were held for long periods in stagnant water. The salinity gradually increased by evaporation. At one time the salinity was up to 38.8‰. No harmful effects resulted from exposure to this salinity.

Salinity and Size

Lobsters employed in the salinity tests were between 22 and 25 cm. in length. To demonstrate size effect, groups of 16-17cm., 21-23 cm. and 28-34 cm. were selected.

The results in table IX indicate that smaller lobsters are more resistant to exposure to reduced salinity than large sized lobsters. This was a consistant observation for the four levels done at 13°C. In table X, the test done at 25°C., small lobsters tested in 50% salt water appeared more resistant. However, in the 62.5% trial, large lobsters showed a better survival.

SUMMARY

It was shown that lobsters will acclimate to increased temperatures. Lobsters stored in 14.5°C. water were placed in 24.0±1°C. for periods ranging between 1 and 31 days. Acclimation was demonstrated by exposing the lobsters, held in 24.0±1°C. to a test temperature of 30°C., and finding the average survival time. The average survival time increased from 8.1 hours for lobsters directly from 14.5°C. water to over 72 hours for lobsters acclimated to 24.0±1°C. for 26-31 days.

Upper lethal temperatures were determined for lobsters acclimated to various temperatures between 5.0°C. and 25.0°C. The temperatures that killed 50% of the lobsters in 48 hours was taken as a measure of the lethal temperature. The lethal temperatures for the various levels of acclimation are as follows:

°C. acclimation	lethal temperature
5.0°C.	25.7°C.
9.0	26.5
14.0	28.3
19.0	29.0
24.0	30.4

Lower lethal temperatures were determined for lobsters acclimated to 17.0°C. and 28.0°C. The lower lethal temperature for 17.0°C. acclimation was found to be approximately 2.0°C., and for 28.0°C. acclimation was found to be approximately 4.5°C.

No size difference in relation to heat tolerance was demonstrated. No difference in heat tolerance was demonstrated with lobsters from the Grand Manan area and the Escuminac area.

TABLE IX. Size Effect in Reduced Salinity at 13° C.

Size Range Cm.	Test Salinity	% Mortality at Stated Times													
		½	1	2	3	6	9	12	18	24	48	72	96	144	
16-17	25%	0	0	0	0	0	0	10	40	60	70	70	70		
21-25		0	0	0	0	0	30	70	100	100					
17-18	37.5%	0	0	0	0	0	0	0	10	40	70	70	70	80	
21-28		0	0	0	0	0	0	10	30	50	80	80	80	90	
16-18	50%	0	0	0	0	0	0	0	10	10	10	10	10	10	
24-28		0	0	0	0	0	0	0	10	30	30	40	40	40	
17-18	62.5%	0	0	0	0	0	0	0	0	0	0	0	10	10	
22-25		0	0	0	0	0	0	0	0	0	0	10	10	10	

TABLE X. Size Effect in Reduced Salinity at 25° C.

Size Range Cm.	Test Salinity	% Mortality at Stated Times												
		½	1	2	3	4	5	6	9	12	24	36	48	72
16-18	50%	0	0	0	20	20	30	30	30	30	30	30	40	40
22-24		0	0	0	0	0	30	50	60	70	80		90	100
29-34		0	0	0	30	40	70		80	80	90	100		
22-23	62.5%	0	0	0	0	0	0	10	20	30	60		90	
32-34		0	0	0	0	10	20	20	20	30	30		50	50
22-23	75%	0	0	0	0	0	0	0	0	0	0	0	0	0
30-34		0	0	0	0	0	0	0	0	0	0	0	0	0

Recently moulted lobsters showed a loss in heat tolerance when exposed to high temperatures, being killed within 3 hours in a temperature that failed to kill hard-shelled lobsters until after 12 hours exposure.

Lower lethal salinities were determined for groups of lobsters acclimated to various temperatures between 5°C. and 25°C.

The salinity that killed 50% of the lobsters in 48 hours was taken as a measure of the lethal salinity. The lethal salinities for the various levels of acclimation temperature are as follows:

°C. acclimation	lethal salinity
5.0°C	5.8‰
10.0	10.6‰
13.0	13.3‰
17.0	14.1‰
25.0	19.4‰

Salinity and size - From experiments done to test size effect, there is an indication that large lobsters are less tolerant to reduced salinities than small lobsters.