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Preliminary Observations and Experiments on Starfish with Reference to the Oyster.

by

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PRELIMINARY OBSERVATIONS AND EXPERIMENTS ON STARFISH WITH REFERENCE TO THE OYSTER

A report of work at Prince Edward Island Biological Station, Summer 1934.

by G. F. M. Smith,
University of Toronto.

The starfish (Asterias vulgaris (Verr)) is the most important enemy of the oyster in Malpeque Bay, P.E.I. Dr. Needler had noticed that the average size of the starfish found in the bay was much smaller than the size of individuals of the same species commonly seen at St. Andrews, at low tide. This suggested investigating rate of growth, and limiting factors of local distribution of the starfish. The time of spawning and the conditions necessary were unknown to the writer. The water in the bay is fresher and warmer than the ocean or gulf water, so it was not expected that spawning conditions and time would resemble those that could be observed at St. Andrews. There is an abundance of literature concerned with the embryology and larval stages of starfish, but the writer, to date, has found little of a physiological or ecological character on adult starfish, and especially on the species with which this report is concerned.

The work consisted of three more or less distinct divisions. Part A was an unsuccessful attempt to determine the time and conditions of spawning. Part B was concerned with rate of growth and occurrence of the starfish, and Part C was experimental in nature, being a study of the effect of various temperatures and salinities on adult starfish.

Part A. Attempt to determine spawning period.

The summer's work was begun about June 20, 1934. In an attempt to determine the spawning period, three methods were tried. Regular plankton tows,

every second day, were made at various points in the river, where starfish were known to be abundant, and also where starfish were not abundant. These tows were continued until the beginning of August, when the frequency was diminished. The second method was to examine the gonads of adult starfish, (also taken from various parts of the river) for ripe ova and sperms. Thirdly, ground glass microscope slides were suspended in the water at the surface, floating with the tide, and another set anchored to the bottom, at two points in the river, in an attempt to catch the settling larvae.

All three attempts were unsuccessful. At no time were starfish larvae obtained in plankton tows. The gonads of adult starfish were distended in only a few of the specimens that were examined, beginning on June 22, and continuing two times a week during July. A few starfish taken from the Gulf of St. Lawrence, just off from a mouth of the bay, showed gonads distended with eggs that were not quite ripe. This condition was not observed in the case of starfish taken from the bay. The few starfish that had distended gonads were laden with mature eggs or sperm, but the great majority of specimens had small undistended gonads. No starfish larvae settled on the ground glass slides, but the time of the major settling of mussel larvae and oyster spat was observed for the 1934 season. From July 20 to July 23, the spat settled on slides at the bottom of the river, (at the station landing stage) to a density of 10 per square centimeter. Very few spat settled on the slides at the surface during this period. The first appearance of spat on the slides was on July 18, on slides at the bottom of the river.

It seems that the starfish had spawned well before June 22, but the evidence is all of a negative character. This early spawning of the starfish would make the period well in advance of the oyster spawning period. The writer hopes to make a further effort to determine the starfish spawning period, beginning work earlier in the season in 1935.

Part B. Rate of Growth and Occurrence.

The starfish, for size frequency observation, and for experimental and observational material, were obtained by the commercial method of mopping. This method consists of towing a series of (8 or 9) mops made of cotton waste attached to a heavy bar iron triangle, along the bottom over the oyster beds, behind a motor boat at reduced speed. Each mop, when in good condition, is about three feet long. Starfish get tangled up in the loose threads and are picked out of the mops by hand. As the frayed ends become worn, the mops become much less efficient. Starfish less than one centimeter in mean diameter, are not usually very well entangled, since they do not possess large enough spines. With worn mops, starfish much over twelve centimeters are not well entangled, but are caught tighter in new mops with long frayed ends. The reason for lower efficiency in the case of large starfish, is apparently the relation of length of frayed cotton waste to the size of the starfish. In observations made in summer 1934, the mops that were at hand were used, being worn mops in the first part of the season, and new mops near the end of July, which became somewhat worn in August. This obvious variation in efficiency could be remedied by using only new mops for obtaining starfish for the size frequency observations. The new mops could then be used in routine mopping until worn out.

Relatively small catches of starfish were taken, since the oyster beds are not large, and there would be a possibility of cutting down the population to such an extent that the next mopping at the same point would not be of starfish that were originally on the bed, but of individuals that had migrated there since the previous mopping. (The mopping of Martin Landry bed shows that migration to a relatively clean ground where food is abundant, is considerable.) On the other hand, a catch of fewer individuals would not show the year classes so distinctly as a larger sample. Possibly the writer has made the latter mistake. A sample of between 400 and 500 specimens would probably be best, and would be considerably in excess of most of the samples taken in summer 1934. The moppings were made over small areas, and as nearly as possible, over the same area each time.

The three beds from which regular samples were taken were Black Buoy Bed, Trout River, (Claude Hayes' Bed) and Cooper Bed. Black Buoy Bed is an on shore bed about a mile below the station. This bed has been mopped before. Trout River Bed is similar in its general character and is about two miles below the Biological Station. This bed in contrast to the Black Buoy Bed and Cooper Bed, had never been mopped until samples were taken for rate of growth investigations of this report. For this reason it was supposed that the density of population would be more nearly static, than on those beds that had been previously mopped. Cooper Bed does not touch the shore at any point, and is more exposed than the two beds mentioned above. There is also a very deep spot in the river, near the west margin of the bed that is south of Indian Island.

The details of the samples and the graphs plotted are as follows. The average diameter, ø, of the starfish is measured to the nearest half centimeter.

Black Buoy Bed

ø	June 26, 1934. Number	%	June 30, 1934. Number	%	Sept. 6, 1934. Number	%
1.5	3	3.5	1	.7	1	.7
2	29	34	2	1.5	6	4.5
2.5	14	16	19	14	9	6.5
3	13	15	25	19	20	15
3.5	8	9	35	26	22	16
4.	9	10	24	18	24	18
4.5	5	6	12	9	14	10
5	1	1	6	4.5	18	13
5.5	2	2.5	3	2.5	13	10
6.			3	2.5	3	2.5
6.5	1	1				
7					1	.7
7.5						
8	1	1			1	.7
8.5						
9			2	1.5		
9.5					1	.7
12					1	.7
	86		132		134	


Size frequencies of Starfish taken from Black Buoy Bed
June 26, 1934.
July 30, 1934.
Sept. 6, 1934
% of Starfish taken in 12 minutes mapping.
34
32
28
24
20
18
12
8
4
2
1
2
3
4
5
6
7
8
9
10
11
12
Ø = Diameter in cm.

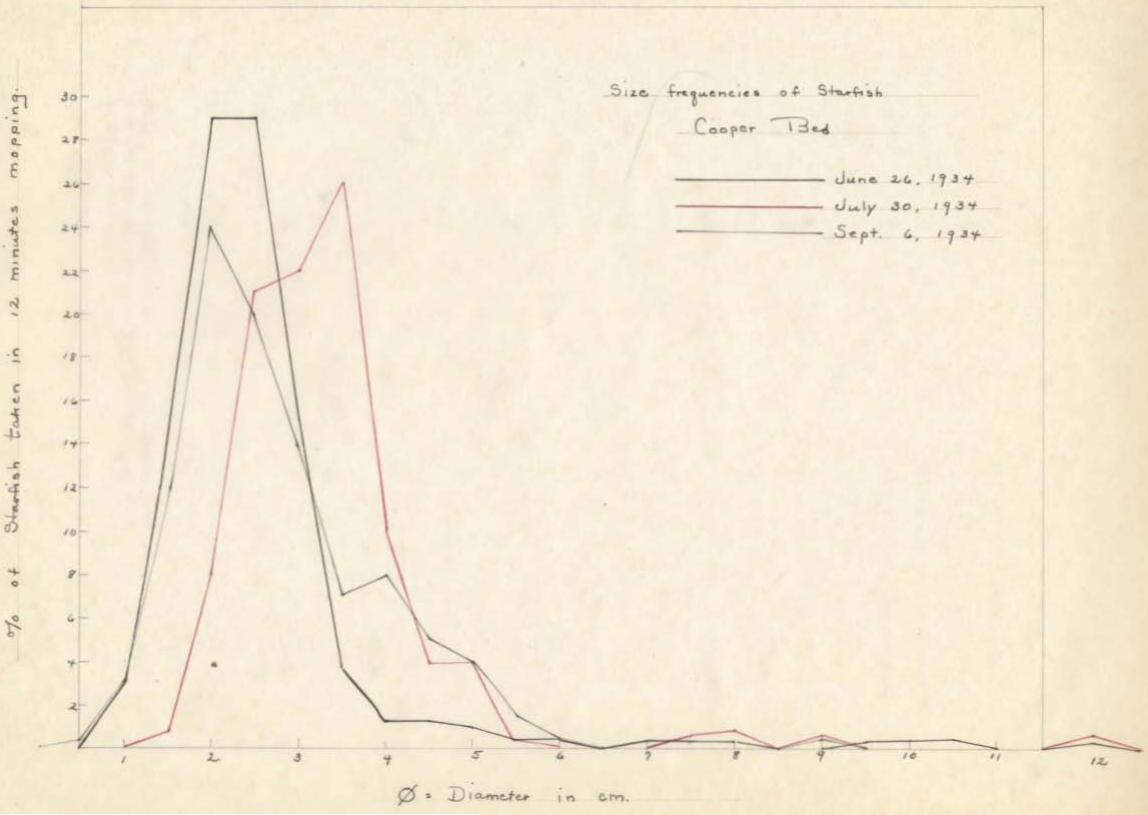
Trout River. (Claude Hayes' Lease)

	June 26, 1934.		July 23, 1934.		Sept. 6, 1934.	
ø cm.	Number	%	Number	%	Number	%
1.			1	.3		
1.5	4	2	6	2	4	3
2	26	11	24	7	4	3
2.5	54	24	23	6.5	11	9
3	56	25	98	27	19	15
3.5	42	19	67	19	28	22
4	16	7	60	17	22	17
4.5	8	3.5	34	9	20	16
5	6	3	20	5	9	7
5.5	2	.9	11	3	3	2.5
6	1	.5	3	.8	5	4
6.5	1	.5				
7	2	.9	1	.3		
7.5	1	.5	2	.5		
8	1	.5	1	.3		
8.5					1	.8
9			6	2		
10			1	.3		
12	1	.5				
16			1	.3		
	221		359		126	


Size frequencies of Starfish
Trout River (Claude Hayes' Bed)
June 26, 1934
July 23, 1937
Sept. 6, 1934
% of Starfish taken in 12 minutes mopping.
Ø = Diameter in cm.

Cooper Bed

	June 26, 1934 Bed 5 3½ ft. water		Mud 12 ft.		Weeds 12 ft.		48 ft.		July 30/34		Sept. 6/34		June 26/34 Total of Col. 1,2,3.	
♀	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
.5											1	0.3	10	3
1	10	4	2		6		2				8	3	18	3
1.5	22	9	6		51		33		2	0.7	34	12	79	14
2	56	23	9		93		43		22	8	67	24	158	29
2.5	79	32	6		74		25		58	21	57	20	159	29
3	41	17	4		37		19		62	22	40	14	82	15
3.5	12	5	2		7		4		73	26	20	7	21	3.8
4	6	2.5			1		4		27	10	24	8	7	1.3
4.5	5	2			2				10	4	14	5	7	1.3
5	4	2			1				12	4	12	4	5	1
5.5	1	.4			1				1	.4	4	1.5	2	.4
6	2	1							5		1	.3	2	.4
6.5														
7	1	.4					1						1	.2
7.5					1				1	.4			1	.2
8	1	.4							2	.7			1	.2
8.5														
9									1	.4	1	.3		
9.5	1	.4											1	.2
10	1	.4											1	.2
10.5	1	.4											1	.2
12									1	.4				
12.5	1	.4	—		—		—		—		—		1	.2
	244		29		274		131		277		283		547	


Size frequencies of Starfish
Cooper Bed
June 26, 1934
July 30, 1934
Sept. 6, 1934
% of Starfish taken in 12 minutes mapping.
Ø = Diameter in cm.

Martin Landry Bed

	July 23, 1934.		Sept. 11, 1934.
ϕ	Number	Per cent.	Fifteen minutes mopping.
2	2	1	75 starfish.
2.5	5	2	Average, 5 to 6 centimeters.
3	8	3	Largest, 10.5 centimeters.
3.5	13	5	
4	31	12	
4.5	29	11	
5	25	10	
5.5	27	10	
6	18	7	
6.5	15	6	
7	18	7	
7.5	13	5	
8	13	5	
9	19	7	
10	12	4	
11	6	2	
12	1	.4	
13	1	.4	
14	1	.4	
15	1	.4	
16	1	.4	
	259		

This bed had spat planted on it on June 2, 1934, and had been mopped continuously for three days previous to June 2.


Comparison of size frequencies
Trout River (Claude Hayes' Bed)
Martin Landry Bed
July 29/34
% of Starfish taken in mapping
Ø = Diameter in cm.

The frequency diagrams show that the rate of growth of starfish varies considerably on different beds. The peak of the diagram for the September mopping on Cooper Bed, is to the left of the peak for the July mopping for the same bed. This suggests that this is the 1934 set of starfish which do not appear on the diagrams for Black Buoy or Trout River. If this is the case, the second year class would appear as a small peak at the 4 cm. mark. More extensive observations will have to be made, before any definite conclusions may be drawn.

The comparison of size frequencies of starfish, mopped on the same day from Martin Landry Bed and Trout River Bed, shows how great may be the divergence in starfish size, between two beds that are only about two miles apart, but which have a different history. A large proportion of the starfish on the Martin Landry Bed must have migrated on from deeper adjacent water, since this bed was mopped for three days previous to June 2, 1934, which would remove most of the starfish. The large size of the starfish, found on this occasion, is probably due to the abundance of food, since 1933 spat were planted on this bed, on June 2, 1934. In July a large proportion of these spat were found to have been eaten by starfish. On the other hand, the Trout River Bed had never been mopped previous to June 26, 1934, nor had small spat been planted on it.

There are two possibilities which have been suggested in considering the great predominance of only one year class in the size frequency diagrams. There may be an extremely high mortality in the second year, or in the warm water of the bay the starfish may grow faster than in cold water, mature much younger, and never reach the same ultimate size. To test out the latter suggestion, a comparison would have to be made between starfish of Malpeque Bay and some place such as St. Andrews.

No starfish were found on a sharp sand bed at the mouth of Trout River, about half a mile from Trout River, (Claude Hayes') Bed, although oysters were plentiful on this bed. On hard beds, other than sharp sand, both up, (Black Buoy Bed, etc.) and down, (Cooper Bed, etc.) there was an abundance of starfish. Mud bottoms surrounding the beds, (Trout River, Black Buoy, and numerous others) were found to be

free, or almost free from starfish. The small artificial beds in Paugh's Creek were apparently free from starfish, but Part C of this report may explain this absence. The deep water, south of Indian Island, west of Cooper Bed, contains many starfish. The water here is about forty-eight feet deep, and is a possible constant source of supply for Cooper Bed, should the population on this bed become reduced by artificial or natural agency of some sort.

Part C. The effect of various temperatures and salinities on Adult Starfish.

Oysters occur farther up the "rivers" than do the starfish, that is in fresher and warmer water. Huntsman and Sparks have shown that the lethal temperature, with a rapidly rising temperature, (1°C per 5 minutes) of Asterias vulgaris is 32°C, and Henderson, that the lethal temperature of Ostrea virginica is 46.5°C. Doubtless the rate of rise of temperature would affect the lethal temperature found in these experiments. The following experiments are intended to show in what range of constant temperatures and salinities the adult starfish can live.

In the first set of experiments, starfish were kept in thermostats at various temperatures, from 12°C to 30°C and salinities from 0‰ to 40‰. Starfish of various sizes were placed in "fox-pans" with about 800 cc. of sea water. The water was changed twice a day, each experiment lasting three days. If the starfish were apparently normal at the end of this period, it was assumed that that particular salinity and temperature would not be injurious.

In all cases of a variation of salinity from the normal, the starfish were acclimatized at an approximately constant rate, the process taking about one and one half hours to change the salinity from 27‰ to 12‰. This rapid change no doubt narrows the limits of temperature and salinity that is not injurious. The effects of various rates of change of salinity will be part of next year's work. The fresh water used to decrease the salinity was well water, there being no observable difference in effect between well water and fresh water obtained from a neighbouring stream. Distilled water, in sufficient quantities, was not obtainable.

Oxygen determinations showed that changing the water twice a day was quite sufficient. To test this, starfish were kept for varying lengths of time, up to a week, in fox-pans, without disturbing the water, at salinity 27‰, temperature 20°C ±, and were apparently uninjured at the end of this time. The diameter of fox-pans in all experiments was 18 cm, and the water from 3.5 to 4 cm. deep.

In these experiments and in the later caging experiments, a starfish was not termed dead, unless, at the end of the three day period, it was limp, did not cling to the dish, showed no reaction with its tube feet to a needle point, and did not revive in twelve hours when the water was gradually brought to 27‰ salinity, and room temperature. In some cases the pigment from the starfish was leached out. These individuals did not revive. In other cases the starfish became swollen, and some of these revived, as shown in caging experiment No. 6. At the beginning of each thermostat experiment, the water was saturated with air, by means of an egg beater, and the changes of water, twice a day, were also saturated at the temperature at which they were to be used.

In the second set of experiments, starfish were caged in wooden boxes with a wire screen end, and the cages placed in parts of the river where starfish were not observed to occur, that is in the upper part of the river. The temperature was recorded by maximum-minimum thermometers, and the salinities determined at high and low tide. These observations were intended, merely, to be a check on the thermostat experiments, since, in the river, neither the temperature variation, (day and night,) nor the salinity variation, (high and low tide,) could be predetermined. The rate of change of the factors, however, it is expected are reflected in the results, as will be noted later. No location was found with a relatively constant low salinity.

The starfish, for all experimental work, were obtained by mopping, and held in a large floating storage tray, about twenty yards from the station landing stage. Small mussels were used as food. The detailed results of the experiments are as follows. A + sign in the table indicates that the starfish was apparently normal at the end of three days experiment.

Temperature 30°± ½°C.

S‰					
	ø 8.5	5.0	5.0	4.0	2.0
40					
	Dead, (colour bleached) in 1 day, swollen in 4 hrs.				
	8.5	6.0	3.5	3.5	2.0
35					
	Dead, (colour bleached) in 1 day, swollen in 4 hrs.				
	7.5	5.0	3.0		2.0
25					
	Dead, (colour bleached) in 1 day.				
	7.0	6.0	3.5		1.5
15					
	Dead, (colour bleached) in 1 day.				

Temperature 27½°C ±½°C.

	7.0	6.0	5.5	3.5	1.5
20					
	Dead after about 30 hours, bleached.				
	7.5	4.0	3.5	3.0	2.0
10					
	Dead in less than 20 hours, bleached.				

Temperature 25°C ± ½°C.

S‰					
	ø 9.5 cm	5.0	4.5	4.0	2.0
40					
	Dead, (bleached in 1½ days).				
	12.0	5.0	4.5	3.5	2.0
35					
	Dead, (bleached in 1½ days).				
	11.5	7.0	4.0	3.5	2.5
27					
	2 days	+	+	+	+
	Lost all but 1 arm				
	13.0	7.5	4.0	3.0	2.5
20					
	2 days	2 days	+	+	+
	13.0	6.0			
20					
	1 day	2 days			
	11.5	6.0	4.5	3.5	2.0
15					
	2 days	3 days minus	2 days	+	+
	10.0	6.0	5.0	3.5	2.0
10					
	All dead in less than 2 days.				
	10.0	9.5	5.0	2.5	1.5
5					
	At no time clinging to the dish.				
	Dead, (bleached) in less than 18 hours.				

Temperature 23°C ± ½°C.

S‰				
	12.0	8.0	5.5	2.5
27				
	Dead, 2½days	+	+	+
	10.5	9.0	6.5	3.0
15				
	Dead, 2 days	Dead, 2 days	+	+
	10.0	7.0	3.0	2.5
12				
	Dead, ½ day much swollen	Dead, ½ day swollen	Dead, 1 day not swollen	Dead, 1 day not swollen

Temperature 20.0 ± ½°C.

∅	12.0 cm	6.0	3.5	2.5
15				
	+	+	+	+
	9.0	7.5	4.0	2.5
14				
	+ swollen	+ slightly swollen.	+	+
	9.0	5.5	5.5	2.5
13				
	Dead, 1 day	Dead, 1 day	+	+
	11.5	7.5	4.0	3.0
12				
	Dead	Dead	Dead	Dead
	All dead in 1 day, but not swollen or bleached.			

Temperature 15°C ± ½°C.

S‰					
	∅ 12.0 cm	5.0	4.0	4.0	2.5
40					
	Lived almost 3 days	+	+	+	+
	Arms became greatly elongated and thinner.				
	10.5	5.0	3.5	3.0	2.0
35					
	Lived 2 days	+	+	+	+
	10.5	7.5	6.0	4.0	2.5
27					
	+	+	+	+	+
	8.5	6.5	6.0	3.0	2.0
20					
	+	+	+	+	+
	14.5	7.5	4.0	3.5	1.5
15					
	+	+	+	+	+
	9.0	5.0	5.0	3.5	2.0
10					
	Dead in about 1 day but did not bleach.				
	12.0	10.0	4.5	2.5	2.0
5					
	Bleached in 2 days, did not cling to dish at any time.				

Temperature 12 to 14°C.

S‰					
	ϕ 11.5 cm	5.0	4.0	3.5	2.0
40					
	+	+	+	+	+
	11.5	7.5	4.5	3.5	2.0
35					
	+	+	+	+	+
	13.0	7.0	4.0	4.0	2.5
30					
	+	+	+	+	+
	9.0	6.0	4.0	4.0	2.0
25					
	+	+	+	+	1 day
	16.0	6.0	3.5	3.0	2.0
20					
	+	+	+	+	+
	6.5	6.0	5.0	3.5	2.0
15					
	+	+	+	+	+
	7.5	5.0	3.5	3.0	1.5
10					
	All dead, time uncertain (less than 3 days) not bleached in 3 days.				
	10.0	5.5	5.0	3.5	2.5
5					
	All dead, time uncertain, bleached in 2 days, did not cling to dish at any time.				
	9.0	5.5	4.5	2.5	2.0
0					
	Dead with colour bleached in 4 hours.				

Caging Experiments

(1) Note on starfish kept on storage tray.

On July 30, most of the starfish, over 6 cm in diameter, that were being held in a large storage tray, 20 yards from the station landing stage, were found dead, but no smaller ones were dead. The salinity at this point is 27‰ +, and may be as low as 25‰, after continued rains. The record of surface temperature at the stage, for a few days previous, is as follows:-

	8 A.M.	5 P.M.
July 23	20.0°C	21.7°C
" 24	20.8	23.4
" 25	21.6	23.7
" 26	21.0	24.0
" 27	21.5	23.0
" 28	21.3	
" 30	22.6	25.0

(2) Caged at Paugh's Creek, below Hydrographic Station 2001. Set out Aug. 2, without food. ø of starfish in cm were 16, 8, 5, 4, 3.

Aug. 3. Temperature, (min) 21°C. All starfish alive.

Aug. 4. Temp. (Max. 22°C, min. 20.5°C, salinity 26.1‰,(low tide). All starfish alive.

Aug. 6. Temp. maximum 23°C, minimum 20°C. Salinity 27.7‰ (high tide). All starfish alive.

Aug. 8. Temp. maximum 24°C minimum 18°C, All starfish alive. Experiment concluded.

(3) Caged at Station 2001. Set out Aug. 2, without food. ø of starfish in cm were 14, 8, 5, 4, 2.

Aug. 3. Temp. minimum 21°C, All starfish alive.

Aug. 4. Temp. maximum 23°C, minimum 20.5°C. Salinity 27.5‰(low tide). All starfish alive.

Aug. 6. Temp. maximum 23°C, minimum 20.5°C. Salinity, 27.7‰(high tide). All starfish alive.

Aug. 8. Temp. max. 24°C, min. 21°C. Starfish alive, but 2 escaped. Experiment concluded.

(4) Caged at Paugh's Creek above Station 2001.

Set out Aug. 2, without food. ø of starfish in cm were 12, 8, 6.5, 4.5, 3.5.

Aug. 3, Temp. minimum 21°C. All starfish alive.

Aug. 4, Temp. maximum 23°C, minimum 20.5°C. Salinity 16.3‰ (low tide). Starfish ø 8 and 6.5, dead.

Aug. 6, Temp. maximum 26½°C, minimum 21°C. Salinity 25.8‰ (high tide). Starfish ø 12 cm, dead.

Aug. 8, Temp. maximum 27°C, minimum 21°C. Starfish ø 3.5 cm dead, survivor ø 4.5. Experiment concluded.

(5) Caged at McKinnon's Creek.

Set out Aug. 2, without food. ø of starfish were 13, 6.0, 5, 4, 3.

Aug. 4, Temp. maximum 23°C, minimum 19.5°C. Salinity 26.3‰ (low tide). Starfish ø 6 cm died.

Aug. 6, Temp. maximum 24.5°C, minimum 21°C. Salinity 27.0‰ (high tide). Starfish alive.

Aug. 8, Temp. maximum 29.C (?), minimum 20°C. Starfish ø 13 cm swollen somewhat. Experiment concluded.

(6) Caged at upper part of Smelt Creek.

Set out Aug. 21, with small mussels as food. ø of starfish in cm, 10, 8, 5, 3, 2.5.

Aug. 21, Temp. 24.5°C. Salinity 17.2‰.

Aug. 24, Temp. maximum 26.5°C, minimum 18°C. Salinity 16.4‰(low tide). All starfish alive but swollen.

Aug. 27, Temp. maximum 26°C, minimum 17.5°C. Salinity 26.5‰ (high tide). Starfish ø 10 cm dead.

Sept. 1, Temp. maximum 23°C, minimum 12°C. Salinity 12.0‰ (tide ⅓, heavy rain on Aug. 21). All starfish dead. Experiment concluded.

(7) Caged at Claude Williams' Creek.

Set out Aug. 21, with small mussels as food. ø of starfish in cm, 10, 7, 4.5, 3, 3.

Aug. 21, Temp. 23°C, salinity 4.5‰.

Aug. 24, Temp. maximum 27°C, minimum 18°C. Salinity 5.7‰ (low tide). All starfish dead.

Aug. 27, Salinity 26.9‰ (high tide). Experiment concluded.

(8) Caged at Claude Williams' Creek, 40 yards from (7).

Set out Aug. 21, with small mussels as food. ♀ of starfish in cm, 8, 7, 5, 3.

Aug. 21, Temp. 21°C, salinity 26.3‰.

Aug. 24, Temp. maximum 25.5°C, minimum 18°C. Salinity 16.0‰ (low tide). All starfish alive.

Aug. 27, Temp. maximum 28°C, minimum 17°C. Salinity 27.2‰ (high tide). All starfish alive.

Sept. 1, Temp. maximum 26°C, minimum 13°C. Salinity 26.8‰ (tide ↓, heavy rains Aug. 31). Starfish ♀ 5 dead, others alive. Experiment concluded.

Oxygen consumption of Starfish.

The following determinations were made merely to see whether or not, the starfish in the thermostat experiments, suffered from lack of oxygen.

Twelve starfish, of 10 cm., approximately, in diameter, were placed each in a fox pan with 600 cc water, salinity 27‰, and saturated with air at 20°C, and held at room temperature.

Calculation of % saturation is based on water 27‰, and 20°C, although the temperature was not absolutely constant. (± 2°C).

Starfish No.	Time	% Saturation	Condition of Starfish
	0	100	
1	2 hours	58	normal
2	4 "	72	"
3	6 "	47	"
4	8 "	44	"
5	12 "	55	"
6	16 "	49	"
7	24	44	"
8	40	55	"
9	49	58	"
10	62	57	"
11	1 week	43	"

At 25°C.

Starfish	Time	% Saturation	Condition of Starfish
	0	100	
12	24 hours	52	normal

The survival in normal conditions up to one week, shows that starfish in thermostat experiments, would suffer neither from lack of oxygen nor accumulation of waste products, to any recognizable degree, during the three day period of the experiments.

Thermostat Experiments.

Above 25°C no starfish lived for the three day period, at any salinity.

At 25°C starfish less than 5 cm survived in salinities of 27‰, 20‰, 15‰, but no other.

At 23°C the results were similar to 25°C, except that a larger size (less than 9 cm) of starfish survived.

At 20°C a salinity of 14‰ was minimum for starfish of larger sizes, and 13‰ was minimum for starfish of less than 5 cm.

At 15°C all starfish died at 10‰ , and all lived at 15‰, and starfish over 10 cm died in 35‰ and 40‰.

At 12°C the results were similar to those at 15°C, except that all starfish at 35‰ and 40‰ lived.

It seems, from these results, that large starfish cannot stand as large a range of temperature and salinity, as can the small starfish which are so abundant in these waters. The large starfish cannot be easily acclimatized to normal sea water (35‰) at temperatures above 12°C. (Water in Bideford R, 27 to 28‰).

The starfish at 25°C survived normal sea water, 35‰, for only 1½ days, although gradually acclimatized to the higher salinity, and the water was thoroughly oxygenated. The rate of change of salinity, in introducing the starfish to a salinity of 35‰, was probably the limiting factor in these experiments.

Caging Experiments.

These experiments checked very well with the thermostat experiments, in showing that the smaller starfish are more adaptable, than the large ones, to changes in temperature and salinity. The temperature may rise above 25°C, for a short time, without injurious effect, as is to be expected, since the lethal temperature is 32°C, as quoted previously. A salinity below 15‰, however, was injurious, probably because it lasted a considerable time, and also was accompanied by a moderately high temperature.

These experiments show that temperature and salinity are both limiting factors in the local distribution of starfish, whereas, in the case of the oysters, the limiting factor is probably salinity alone. The lack of many large starfish, as shown by the frequency diagrams, is probably, in some measure, due to non-survival of the larger starfish. The marked greater survival of small starfish in these experiments, is possibly also partly dependent upon the rate of change of salinity used, the more juvenile starfish being more easily adaptable to rapid changes. The local distribution apparently varies from year to year. In summer 1933, Dr. Needler found many small starfish on spat collections in Paugh's Creek. This year, 1934, however, the writer found none in this locality.

Outline of proposed continuation of work for summer 1935.

(1) Attempt to determine spawning period of starfish in Malpeque Bay, beginning work about the middle of May.

(2) Size and age of starfish that spawn in Malpeque Bay, and possibly a comparison with those at St. Andrews.

(3) Continuation of Rate of Growth problem.

(4) Range of temperature and salinity, found locally, that is suitable for normal growth and development of starfish larvae.

(5) Effect of various rates of change of salinity on adult starfish of various sizes, as shown by laboratory experiments, and observation of rate of change of salinity in upper parts of rivers by tidal action.

Literature cited

A. G. Huntsman and M. J. Sparks.

Limiting factors for Marine Animals.

Relative Resistance to High Temperatures.

Contr. Can. Biol. Vol. 2, No. 6, New Series.

Jean T. Henderson.

Lethal Temperatures of Lamellibranchiata.

Contr. Can. Biol. Vol. IV, No. 25, New Series.

Nov. 14, 1934.