INVESTIGATIONS ON OYSTERS

[*Crassostrea virginica* (Gmelin)]

PLANTED AT BROAD LAKE, BELLEVUE
TRINITY BAY

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DECEMBER, 1965

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Trinity Bay

by

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INTRODUCTION

The American oyster Crassostrea virginica Gmelin is a shellfish of considerable economic importance. Throughout its range along the eastern seaboard of the North American continent it is harvested from both natural strike and in areas where it is commercially farmed. Not only does it figure as a major item in total shellfish species consumed but the income of many Maritime people is greatly augmented by the profits derived from this delicacy. Total oyster landings in Virginia for one year alone (1954) amounted to 21,225,000 pounds at a value of $9,840,000, or an amount equivalent to over one-third of the total income of the people of Virginia engaged in the harvesting of seafood (McHugh and Bailey, 1957).

Medcof (1961) presents a brief history of oyster farming in eastern Canadian waters, indicating that it dates from the early 20th century and the work of Dr. Joseph Stafford. No statement of the features of oyster farming in Canada is even approximating completeness without reference to the pioneering work of Dr. William A. Found and Dr. A.W.H. Needler whose contributions, and those of his colleagues did so much to elucidate the disasterous effects of the so-called Malpeque oyster disease.

It is the purpose of this paper to discuss the possibility of introducing stocks of Prince Edward Island oysters to Newfoundland. It is reported that an abortive effort was made to introduce oysters earlier to the West Coast of Newfoundland. Be this as it may, the investigation here reported represents the first large scale effort to establish populations of C. virginica within the coastal waters of this Province.

The author wishes to express his appreciation and that of the Department of Fisheries for being afforded the opportunity to participate in this operation and to be charged with the responsibility for following the progress of oysters planted on the bottom and maintained in trays at Broad Lake, Bellevue Beach, Trinity Bay.

I especially wish to acknowledge the cooperation of Messrs. H.R. Found, V. Taylor and R. Mercer of the Department of Fisheries for their numerous contributions to this study - not the least of which is the actual installation of the oysters. Personnel of the Department of Biology who were instrumental in the project in numerous ways, include Messrs. M.J. Mercer, R.P. Scaplen and G.D. Barbour. Misses Linda E. Roberts and Patricia F. Andrews were helpful in analysing the individual oysters at various stages of the project.

Special thanks go to Mr. David H. Barnes for assistance in the statistical evaluation of the data gained in this project, and to Miss Elizabeth L. Brown and Mrs. M.M. Aldrich for assistance in the preparation of this report. Again, the outstanding secretarial and stenographic services of Miss Lillian Sullivan proved to be invaluable and indespensible.

MATERIALS AND METHODS

THE PLANTINGS

Oysters for the experimental planting were transported from P.E.I. aboard the Canadian Department of Fisheries patrol vessel CAPE FREELS. Plantings were made at Bellevue Beach in Broad Lake on May 26, 1965. The sites of planting are presented in drawing number N-D-205, presented as Figure 1 at the end of this report.

Details of plantings are as follows:

Plant No. 1 (main planting)

50 boxes of adult oysters in an area 175 ft. x 75 ft.

10 boxes of seed oysters in an area 200 ft. x 50 ft.

Plant No. 2

5 boxes of adult oysters in an area 100 ft. x 25 ft.

1 box of seed oysters in an area of 100 ft. x 5 ft.

Plant No. 3

4.5 boxes of seed oysters in an area of 150 ft. x 20 ft.

Plant No. 4

13 boxes of adult oysters in an area 100 ft. x 30 ft.

The exact location of these planting areas is presented in Figure 1. In addition, trays of seed and adult oysters were suspended in Area A (Fig. 1). Also, trays were anchored to the bottom, therefore we will subsequently refer to top and bottom trays.

PROCEDURES

At the time of planting, a sample of 100 seed oysters and 100 adults were analysed for the characteristics indicated in the sample data sheet presented in Fig. 2. Subsequently, monthly samples were examined at the site of oysters tonged from the bottom plantings. Analysis was also made of the contents of each tray. Top-riding trays were designated "01", bottom trays were designated "02". Seed was designated "00", while adults were designated "01",therefore, data bearing the designation "01 01" signifies adults, top tray, while "00 02" signifies seed, bottom tray.

Oysters tonged from the bottom were first counted and then measured. Care was taken to record the incidence of all fouling or epizooitic plant or animal forms associated with the oysters.

In the case of the trays, everything within the trays was analysed, with primary emphasis being given to the number of living and dead oysters. Live oysters were initially classified as to whether their lengths exceeded three inches or not. Subsequently all live oysters were measured for both greatest length and greatest width. With respect to dead oysters, counts were made in the following categories:

Boxes - both valves attached but void of oyster meat.

Blanks - single valves (an oyster shell is composed of two, right and left valves).

Gapers - two intact valves with intact oyster (meat) present.

In addition, a statistically derived but randomly selected sample of oysters from bottom plantings was sacrificed for analysis with respect to numerous internal characteristics, among which were:

Figure 2.

SAMPLE OF OYSTER DATA SHEET.

DATE: OYSTERS:

AREA: POSITION:

Oysters 1-2	Position 3-4	Oyster No. 5-6	Length (mm.) 7-9	Breadth (mm.) 10-11	Condition 12-13	Recent shell growth 14	Watery: present or absent 15	Watery: little or much 16	Polydora blisters 17	Gonad layer 18	Style 19	Pinnotheres 20	Mud pustules 21	Stylochus 22	Volume 23 24	Mud in shell 25	Cliona: present or absent 26	Cliona: living or dead 27	Drilled 28
		01																	
		02																	
		03																	
		04																	
		05																	
		06																	
		07																	
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		09																	
		10																	
		11																	
		12																	
		13																	
		14																	
		15																	
		16																	
		17																	

Crystalline style - presence or absence of same
Gonadal development
Watery tissue
Condition rating
Internal parasites - presence or absence of same.

In no instances were oysters from the trays sacrificed and analyzed as were oysters from the bottom plantings. Such analyses as here described were made at monthly intervals; June 28, July 27, and August 26, 1965.

Hourly determinations of tidal height, bottom and top conductivity, temperature and salinity were made over 24-hour periods. These studies were conducted on June 17-18, July 25-26, and August 25-26, 1965.

Back at the University, all data were analyzed and treated statistically for incorporation in this report.

RESULTS

The results of the 24-hour analysis of physical perameters of conductivity, tide height, temperature and salinity for June 17-18, July 25-26, and August 25-26, are presented in Tables 1, 2, and 3, respectively. Mean values for the characteristics are presented in Table 4.

The oysters analysed as a sample from the original planting (May) demonstrated mean condition ratings of 3.439 (seed oysters) and 3.602 (adult oysters). These values were considered to be a base for comparison with data from subsequent analyses.

It is in order here to define "condition rating". This is not to be confused with other indices which involve chemical analyses. Condition index, as used here, is a visual index of the "condition" of each oyster examined internally.

This is a numerical rating based on the glycogen content of the oyster and is an arbitrary scale developed by Dr. P.A. Butler of the U.S. Fish and Wildlife Service at Gulfbreeze, Florida. The ratings are based on the opacity of the oyster meat, which is a function of the amount of glycogen.

It would have been impractical to run actual glycogen determinations on the relatively large number of oysters involved in this study. However, Miss Y.H. Swabey and the author have calibrated the condition scale in terms of actual glycogen content of oysters from the York River, Chesapeake Bay, Virginia, while the latter was on the staff of the Division of Estuarine Science of the Academy of Natural Sciences of Philadelphia.

Butler's scale has the following ratings:

1. Poor. More than 75 percent translucent.
2. Poor. Less than 75 percent translucent, but more than 25 percent translucent.

3. Fair. Digestive gland visible, less than 25 percent translucent.
4. Fair. Transition between 3 and 5.
5. Fair. Digestive gland not visible, less than 25 percent translucent.
6. Fair. Transition between 5 and 7.
7. Good. Digestive gland not visible, tissues opague.
8. Good. Transition between 7 and 9.
9. Good. Digestive gland not visible, tissues more opague.
10. Good. Entire animal cream-colored and opague.

This rating applied only to the market condition of the oyster and does not necessarily imply that the oysters are normal or abnormal.

This system of evaluation has been used by the author in an earlier (1954 - 1961) study of over 40,000 oysters (Aldrich, 1957 et seq.). Personnel of the Department of Biology, particularly Messers. Scaplen and Barbour, were adequately trained in the application of the Butler Scale for the purposes of this study of Broad Lake oysters.

In Table 5 are presented the mean condition index for all plantings, both seed and adult, at all "points" (1, 2, 3 or 4) in Broad Lake. The values are therein compared with the baseline values for seed and adult as determined from the inspection of the May sample at time of planting.

In Table 6 is to be found the percent occurrence of the crystalline style in oysters planted at points 1, 2, and 3 or 4, depending on whether plantings were seed or adult oysters.

Mean lengths of the seed oysters, both plantings and trays, are presented in Table 7. The percent increments over the baseline mean length (5.998 cms.), are presented in Table 8. In each case (/0) after a value represents the percent increment over the baseline mean length; (/1), over the June mean length; and (/2), over the July mean length.

In Tables 9 and 10 are presented the same mean data for length of adult oysters and the percent increment. Likewise, information on width is presented for seed (Tables 11 and 12) and adult (Tables 13 and 14).

One of the major important aspects of this study was to ascertain the mortality of the oysters in the experimental trays. Counts of living and dead seed oysters in the trays, both top and bottom stationed, are presented in Table 15. Similar data on adult tray oysters are to be found in Table 16.

The percent mortality and its increment between examinations are presented in Table 17.

Finally, there is yet to be presented the results of the examination of tray and free planting oysters for external epizootic flora and fauna. A total of 13 different varieties were noted over the examination period, but not all on the same oysters at the same time or place. The percent occurrence of these varieties on top and bottom tray oysters and on seed and adult oysters in the several plantings (P. 1, 2, 3 or 4) examined in June are presented in Table 18. Similar data for July and August are presented in Tables 19 and 20 respectively.

The data sheets with the data from which all of the above summations are based, are being maintained by the author at the Department of Biology of Memorial University.

TABLE 1. Results of 24-hour determinations of selected water characteristics at Broad Lake, Bellevue Beach, T.B., June 17-18, 1965.

		BOTTOM			TOP		
Time	Tide Ht. (in.)	Cond.	Temp. (°C)	Sal. (o/oo)	Cond.	Temp. (°C)	Sal. (o/oo)
15.30	--	33.84	10.68	30.52	33.90	10.52	30.44
16.30	--	33.72	10.64	30.36	33.66	10.44	30.40
17.30	5.5	34.08	11.04	30.32	33.84	10.44	30.20
18.30	7.5	34.02	10.84	30.12	33.72	11.08	29.72
19.30	10.5	33.42	11.20	29.28	33.42	11.08	29.40
20.30	15.5	33.24	11.00	29.24	33.24	11.00	29.20
21.30	22.0	33.18	10.80	29.40	33.18	10.84	29.52
22.30	31.0	33.06	10.40	29.52	33.00	10.44	29.52
23.30	35.5	32.88	10.28	29.36	32.88	10.32	29.04
1.30	34.0	32.88	10.24	29.48	30.94	10.28	29.60
2.30	30.5	32.82	10.08	29.56	32.76	10.04	29.44
3.30	21.0	32.82	9.96	29.60	32.58	9.88	29.36
4.30	13.0	32.46	9.72	29.68	32.40	9.64	29.36
5.30	11.0	32.82	9.68	29.92	32.34	9.64	29.44
6.30	8.25	32.34	9.52	29.44	32.34	9.64	29.36
7.30	9.5	32.58	9.80	29.84	32.58	9.72	29.80
8.30	13.5	33.24	10.44	29.84	33.18	10.28	29.72
9.30	16.5	33.29	10.68	29.64	33.18	10.44	29.88
10.30	22.5	33.84	11.16	29.92	33.66	10.72	30.00
11.30	26.0	34.38	11.72	30.20	34.44	11.52	30.12
12.30	28.0	34.20	11.52	30.00	34.08	11.36	29.92
13.30	24.5	34.74	12.16	30.16	34.86	11.84	30.28
14.30	19.5	34.80	12.56	30.00	35.16	12.20	30.28
15.30	16.0	34.92	12.00	30.36	34.98	12.04	30.32

TABLE 2. Results of 24-hour determinations of selected water characteristics at Broad Lake, Bellevue Beach, T.B., July 25-26, 1965

		BOTTOM			TOP		
Time	Tide Ht. (in.)	Cond.	Temp. (°C)	Sal. (o/oo)	Cond.	Temp. (°C)	Sal. (o/oo)
14.45	25	40.68	16.48	32.00	40.74	16.48	31.92
15.45	25	40.56	16.12	31.68	40.44	16.40	31.92
16.45	22	40.08	16.48	31.52	40.14	16.44	31.60
17.45	19	40.08	16.48	31.36	40.02	16.44	31.40
18.45	16	39.96	16.40	31.40	39.96	16.44	31.44
19.45	13	39.84	16.28	31.32		VERY SHALLOW	
20.45	11	39.66	16.16	31.28			
21.45	9.5	39.42	15.92	31.80			
22.45	10.3	39.78	16.12	31.80			
23.45	12.5	38.94	15.80	30.64			
00.45	15.5	39.48	12.36	31.20	39.48	15.84	31.24
01.45	19.0	39.06	15.88	31.24	39.48	15.84	31.20
02.45	22.5	38.76	15.76	31.20	39.36	15.80	31.16
03.45	23.0	39.18	15.76	31.16	39.18	15.56	30.80
04.45	20.0	39.48	15.80	31.44	39.48	15.80	31.40
05.45	17.0	39.42	15.84	31.36	39.48	15.76	31.44
06.45	14.5	39.18	15.56	31.28		VERY SHALLOW	
07.45	12.3	39.18	15.64	31.20			
08.45	10.0	39.78	15.96	31.40			
09.45	8.8	39.96	16.36	31.32			
10.45	8.8	40.68	16.92	31.76			
11.45	12.5	40.68	16.64	31.92			
12.45	15.0	40.44	16.84	31.44			
13.45	19.0	40.74	16.96	31.76	41.04	17.36	31.72
14.45	23.0	40.74	17.20	31.64	40.92	17.12	31.56

TABLE 3 Results of 24-hour determinations of selected water characteristics at Broad Lake, Bellevue Beach, T.B. August 25-26, 1965.

		BOTTOM			TOP		
Time	Tide Ht. (in.)	Cond.	Temp. (°C)	Salinity (°/oo)	Cond.	Temp. (°C)	Salinity (°/oo)
13.15	8.5				41.40	16.76	32.28
14.15	6.5				41.64	17.28	32.20
15.15	6.0				41.22	16.36	32.52
16.15	9.5				41.28	16.48	32.24
17.15	14.0				40.50	15.84	32.24
18.15	21.5	40.50	16.00	32.16	40.44	16.12	32.00
19.15	29.5	40.14	15.84	31.96	40.20	15.84	31.88
20.15	37.5	39.72	15.36	31.76	39.78	15.76	31.68
21.15	36.0	39.66	15.60	31.48	39.72	15.72	31.64
22.15	31.5	39.60	15.40	31.60	39.54	15.52	31.56
23.15	29.0	39.78	15.36	31.84	39.66	15.44	31.72
00.15	21.0	39.66	15.24	31.88			
01.15	16.0	39.66	15.16	32.08			
02.15	11.5	39.48	15.00	31.80			
03.15	8.0	39.00	14.92	31.60		VERY SHALLOW	
04.15	7.0	39.18	14.92	31.84			
05.15	9.0	39.06	14.60	31.80			
06.15	14.0	39.18	14.96	31.80			
07.15	21.0	39.00	14.48	31.96	39.00	14.48	31.88
08.15	26.0	39.18	14.48	31.96	39.00	14.56	31.96
09.15	31.0	39.66	15.00	32.16	39.42	14.96	31.88
10.15	28.0	39.96	15.36	32.08	39.96	15.36	32.12
11.15	22.0	39.90	15.24	32.00	40.02	15.40	32.12
12.15	18.0	40.38	15.52	32.32	40.32	15.80	32.16
13.15	15.0	40.68	16.00	32.28	-	-	-

TABLE 4. Mean values for selected physical characteristics of water in Area A, Broad Lake, Bellevue Beach, T.B.

		BOTTOM			TOP		
	Tide Ht. (in.)	Cond.	Temp. (°C)	Salinity (°/oo)	Cond.	Temp. (°C)	Salinity (°/oo)
June (17th-18th)	19.15	33.48	10.8	29.82	33.43	10.64	29.75
July (25th-26th)	15.73	39.83	16.07	31.44	39.89	15.8	31.44
August (25th-26th)	19.08	39.98	15.5	31.99	39.96	15.52	31.97

TABLE Mean condition index for all free plantings, Broad Lake, compared with May baseline.

ADULTS	Mean Values			
	0 (Original)	1 (June)	2 (July)	3 (August)
Position 1	3.602	2.98	2.88	2.86
2	3.602	3.86	2.93	5.40
4	3.602	3.40	2.60	2.60
All	3.602	3.73	2.80	3.62

SEEDS	Mean Values			
	0 (Original)	1 (June)	2 (July)	3 (August)
Position 1	3.439	2.55	2.94	3.54
2	3.439	4.88	4.00	1.93
3	3.439	3.55	2.54	3.33
All	3.439	3.66	3.16	2.93

TABLE 6. Percent Occurrence of Crystalline style in sampled oysters from plantings, Broad Lake.

	Seed			Adult		
	Pos.1	Pos.2	Pos.3	Pos.1	Pos.2	Pos.4
June	86.7	66.7	90.0	70.4	86.7	40.0
July	84.0	86.7	86.7	66.7	72.2	5.9
August	94.0	86.7	93.3	90.0	76.5	68.8

TABLE 7. Mean length (in centimeters) of seed oysters from free plantings and in trays, Broad Lake.

	Seeds	0	June	July	August
Tray	Top	5.998	6.167	6.841	7.017
	Bottom	5.998	6.004	6.572	6.605
Free Plant	Pos.1	5.998	6.232	6.874	6.442
	Pos.2	5.998	6.566	7.180	7.020
	Pos.3	5.998	6.225	6.746	6.160

TABLE 8. Percent increment in mean length of seed oysters from free plantings and in trays, Broad Lake.

		June	July	August
Top	Tray	+2.81%/0	+14.05%/0 +10.92%/1	+16.98%/0 + 2.57%/2
Bottom		+0.10%/0	+ 9.56%/0 + 8.55%/1	+10.12%/0 + 0.5%/2
Pos.1	Free Plant	+3.90%/0	+14.60%/0 +10.30%/1	+ 7.40%/0 - 6.28%/2
Pos.2		+9.47%/0	+19.71%/0 + 9.35%/1	+17.04%/0 - 2.23%/2
Pos.3		+3.78%/0	+12.47%/0 + 8.37%/1	+ 2.70%/0 - 8.69%/2

TABLE 9. Mean length (in centimeters) of adult oysters from free plantings and in trays, Broad Lake.

		May	June	July	August
Top	Tray	11.799	12.703	11.620	12.491
Bottom		11.799	11.98	11.856	12.416
Pos.1	Free Plant	11.799	11.587	11.269	11.926
Pos.2		11.799	12.100	11.983	12.324
Pos.4		11.799	12.440	11.600	10.350

TABLE 10. Percent increment in mean length of adult oysters from plantings and in trays, Broad Lake

		June	July	August
Top	Tray	+7.66%/0	-1.51%/0 -8.52%/1	+5.86%/0 +7.49%/2
Bottom	Tray	+1.53%/0	+0.48%/0 -1.10%/1	+5.23%/0 +4.73%/2
Pos.1	Free Plant	-1.80%/0	-4.49%/0 -2.74%/1	+1.08%/0 +5.83%/2
Pos.2	Free Plant	+2.55%/0	+1.56%/0 -0.97%/1	+4.45%/0 +2.84%/2
Pos.4	Free Plant	+5.43%/0	-1.69%/0 -6.75%/1	-12.28%/0 -10.78%/2

TABLE 11. Mean width (in centimeters) of seed oysters from free plantings and in trays from Broad Lake.

		Original	June	July	August
Tray	Top	3.888	4.116	4.883	4.943
	Bottom	3.888	4.129	4.587	4.750
Free Plant	Pos.1	3.888	4.090	4.600	4.334
	Pos.2	3.888	4.222	4.630	4.453
	Pos.3	3.888	4.190	4.573	4.313

TABLE 12. Percent increment in mean width of seed oysters from free plantings and trays from Broad Lake.

		June	July	August
Tray	Top	+5.86%/0	+25.56%/0 +20.35%/1	+27.10%/0 + 1.22%/2
	Bottom	+6.17%/0	+17.95%/0 +11.09%/1	+22.14%/0 + 3.55%/2
FREE PLANT	Pos.1	+5.20%/0	+18.31%/0 +12.47%/1	+11.47%/0 - 5.78%/2
	Pos.2	+8.59%/0	+19.08%/0 + 9.66%/1	+14.53%/0 - 3.82%/2
	Pos.3	+7.77%/0	+17.62%/0 9.14%/1	+10.93%/0 - 5.68%/2

TABLE 13. Mean width (in centimeters) of adult oysters from free plantings and in trays from Broad Lake.

		May (Original)	June	July	August
Tray	Top	4.416	4.430	4.087	4.488
	Bottom	4.416	4.439	4.174	4.560
FREE PLANT	Pos.1	4.416	4.440	3.981	4.436
	Pos.2	4.416	4.410	4.466	4.512
	Pos.4	4.416	3.990	4.123	3.994

TABLE 14. Percent increment in mean width of adult oysters from free plantings and in trays from Broad Lake.

		June	July	August
Top	Tray	+0.30%/0	-7.46%/0	+1.61%/0
			−7.73%/1	+9.81%/2
Bottom		+0.50%/0	-5.51%/0	+3.24%/0
			-5.96%/1	+9.24%/2
Pos.1	Free Plant	+0.54%/0	-9.85%/0	+0.452%/0
			-10.34%/1	+11.43%/2
Pos.2		-0.14%/0	+1.13% 0	+2.17%/0
			+1.27%/1	+1.03%/2
Pos.4		-9.65%/0	-6.63%/0	-9.56%/0
			+3.33%/1	-3.13%/2

TABLE 15. Total numbers of living and dead seed oysters in trays, June through August, Broad Lake.

	June	July	August
TOP TRAYS			
Total seed oysters	479	473	470
Total living	473	472	468
Total dead	6	1	2
BOTTOM TRAYS			
Total seed oysters	502	494	466
Total living	494	493	466
Total dead	8	1	0

TABLE 16. Total numbers of living and dead adult oysters in trays, June through August, Broad Lake.

	June	July	August
TOP TRAYS			
Total adult oysters	255	226	233
Total living	226	214	203
Total dead	29	12	30
BOTTOM TRAYS			
Total adult oysters	497	474	417
Total living	448	463	394
Total dead	49	11	23

TABLE 17. Percent mortality of tray oysters and increment of mortality, June through August, Broad Lake.

(/0 refers to baseline, 0/1 refers to June data, and /2 refers to July data)

	June	July	August
Adults (Top)	11.37/0	16.07/0 5.30/1	27.84/0 12.88/2
Adults (Bottom)	9.85/0	12.07/0 2.32/1	16.70/0 5.52/2
Seed (Top)	1 25/0	1.67/0 0.21/1	2.08/0 0.47/2
Seed (Bottom)	1.59/0	1.79/0 0.20/1	1.79/0 0.00/2

TABLE 18. Percent occurrence of epifauna on trays and planted oysters at Broad Lake, June 1965.

	Seed					Adult				
	Top	Btm	P.1	P.2	P.3	Top	Btm	P.1	P.2	P.4
Littorina spp.	-	-	15.0	-	n.d.*	-	4.0	33.0	-	-
Mytilus edulis	2.0	7.0	17.0	-	n.d.	-	3.0	15.0	-	-
Barnacles	-	-	-	-	n.d.	90.0	9.0	73.0	-	40.0
Bryozoans	-	-	-	33.0	n.d.	-	-	54.0	73.0	50.0
Algae	-	83.0	-	-	n.d.	-	-	-	-	-
Limpets	17.0	3.0	8.0	-	n.d.	-	-	12.0	7.0	15.0
Polychaetes	-	-	-	-	n.d.	-	-	-	-	-
Hydroids	100.0	-	-	-	n.d.	62.0	1.0	-	-	10.0
Drilled	-	-	-	-	n.d.	8.0	-	-	-	-
Gastropods	-	12.0	-	-	n.d.	-	-	-	-	-
Anemones	-	-	2.0	11.0	n.d.	-	-	-	-	-
Chalk deposits	-	-	93.0	-	n.d.	-	-	-	-	-
Lepidonotus sp.	-	-	-	-	n.d.	-	-	6.0	-	-
Polydora spp.	-	-	55.0	-	n.d.	-	-	8.0	46.0	-

* n.d. - no data

TABLE 19. Percent occurrence of epifauna on tray and planted oysters at Broad Lake, July 1965.

	Seed					Adult				
	Top	Btm	P.1	P.2	P.3	Top	Btm	P.1	P.2	P.4
Littorina spp.	-	9.0	2.5	20.0	20.0	3.0	14.0	25.0	17.0	40.0
Mytilus edulis	-	-	4.3	-	20.0	-	5.0	43.0	33.0	-
Barnacles	1.0	1.0	-	-	-	87.0	18.0	-	61.0	100.0
Bryozoans	1.0	-	-	-	-	75.0	11.0	-	44.0	87.0
Algae	56.0	32.0	-	-	6.7	84.0	43.0	-	-	-
Limpets	-	-	0.6	33.0	6.7	-	8.0	6.0	39.0	-
Polychaetes	-	-	0.2	-	-	-	11.0	2.0	-	-
Hydroids	-	-	-	-	-	-	-	-	-	-
Drilled	-	-	-	-	-	1.0	-	-	-	-
Lepidonotus	-	-	0.5	-	13.0	-	-	8.0	17.0	6.7
Polydora	-	-	60.0	80.0	40.0	-	-	59.0	80.0	73.0
Pelecypods	1.0	4.0	-	-	-	1.0	1.0	-	-	-
Isopods	-	-	-	-	-	-	3.0	-	-	-

TABLE 20. Percent occurrence of epifauna on tray and planted oysters at Broad Lake, August 1965.

	Seed					Adult				
	Top	Btm	P.1	P.2	P.3	Top	Btm	P.1	P.2	P.4
Littorina spp.	-	22	24	53	7	-	21	25	29	81
Mytilus edulis	1	9	-	-	87	-	16	23	6	6
Barnacles	-	5	-	-	-	90	33	88	65	56
Bryozoans	13	5	2	-	-	91	31	61	29	50
Algae	7	18	16	7	33	67	38	18	18	50
Limpets	-	10	44	67	20	-	13	14	88	6
Polychaetes	-	2	-	-	-	-	2	-	-	6
Hydroids	-	-	-	-	-	-	-	-	-	-
Drilled	-	-	-	-	-	2	-	12	6	6
Lepidonotus	-	-	6	7	13	1	2	7	12	-
Polydora sp.	-	-	78	87	-	-	-	40	80	56
Pelecypods	14	-	2	7	-	88	20	2	-	6

DISCUSSION

Mortality of Tray Oysters

Reference to Table 17 will indicate that seed oysters demonstrated little if any mortality throughout the period of these observations, while adult oysters suffered mortalities as high as 27.84%. Most mortality (adult) occurred between the months of July and August and was greatest in top-suspended trays.

The consequences of incidence of fouling organisms on this mortality will be discussed later.

The mortality of adult oysters is in line with observations made earlier by this author (Aldrich, 1957 et. seq.), but the mortality of seed oysters is far below what one would expect in a transplant and tray study of this nature. Hewatt and Andrews (1954) pointed out that tray studies need six months or more for a period of acclimatization. Either the three months of this study proved to be of insufficient duration for the true picture to evolve, as Hewatt and Andrews seem to suggest, or the P.E.I. seed acclimated rapidly to the conditions presented to them. The examinations to be made in the early spring of 1966 will give an insight into which is the correct interpretation.

The lack of success of the adult oysters, when compared to the seed, may be due to the state of the oysters as transplanted. However, reference to Table 5 will indicate that the adult oysters were of a slightly higher, but insignificantly different, condition index when they were planted. One is led to assume on the basis of the incomplete information to date, that the seed oysters were better enabled to adjust to the conditions in Broad Lake than were the adults.

Mortality data are presented graphically in Figure 3.

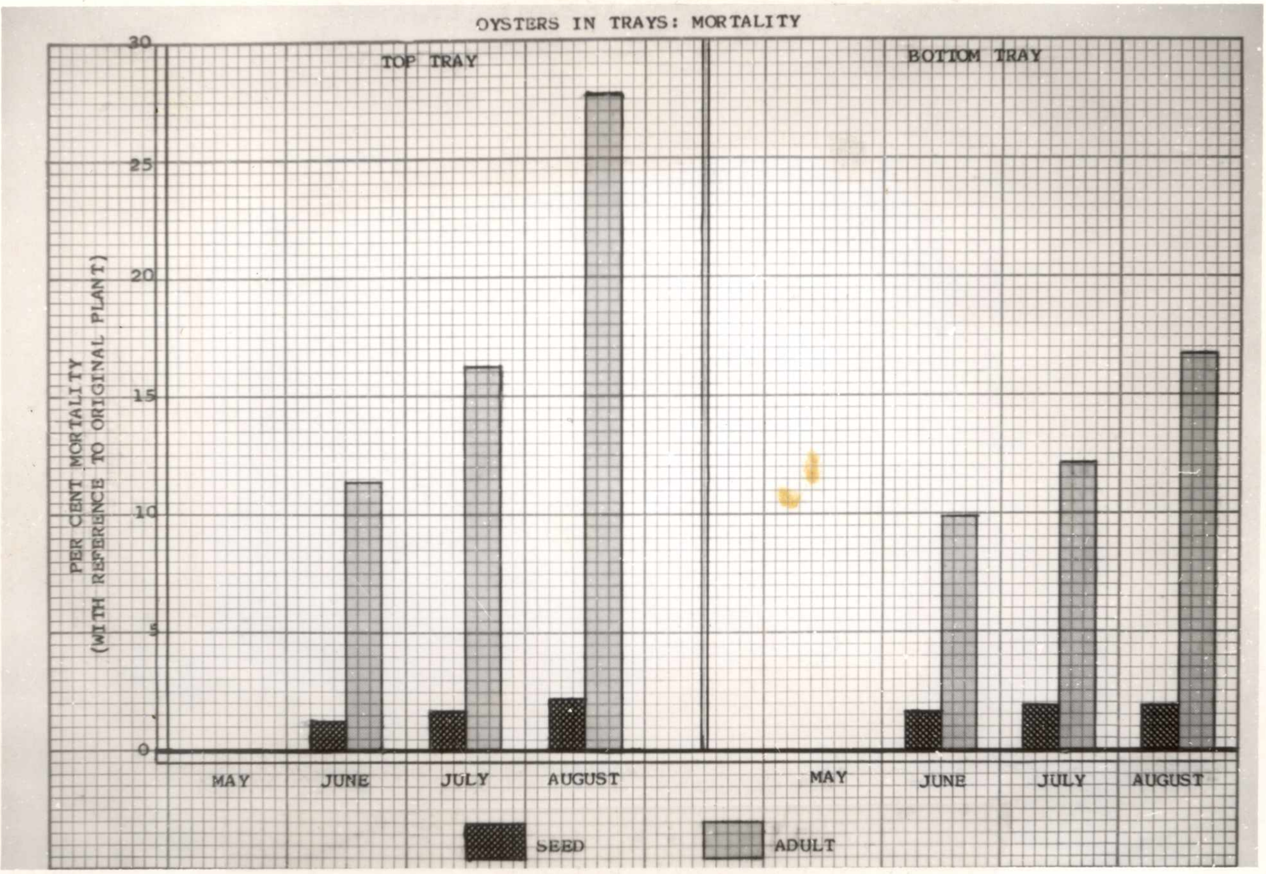

Figure 3. Mortality of oysters held in trays, Broad Lake, May through August, 1965.

Growth of Oysters

The term "length" used in this report refers to the greatest measurement from the hinge of the oyster to the advancing edge of the bill. "Width" is the measurement across one valve, over the adductor muscle. The measurements of length and width of the oysters were made to the nearest millimeter. Greater accuracy was not attempted because of the obvious difficulty of such methods in the field. The method is supported by the logical arguments of G. Robert Lunz (1951). Lunz asserted that measurements to 0.1 mm. should not be attempted because of the nature of oyster growth, because of limitations of the measuring instruments, and because of the "time growth" element. In periods of rapid growth, oysters produce three to five millimeters of thin flexible bill, which is extremely susceptible to injury. If the bill is secured intact its very flexibility subjects it to distortion and endangers accurate measurement. As for instruments, calipers used for measurement have been found to be inaccurate. According to Lunz, if oysters are theoretically growing at the rate of 0.03 mm. per hour, their measurements would differ by more than 0.1 mm. during the course of an examination period lasting several hours. For this study the following device was constructed. It consisted of two boards, fastened together at right angles. In the portion on which the oyster was to be placed, the beak butted against the "head board", a millimeter rule was inlaid. The greatest measurement was then read against the rule.

Tray Oysters

The growth in length is presented graphically in Figure 4 and growth in width in Figure 5, for both seed and adult oysters.

As seen from an examination of the data presented in Tables 7 and 8, and Figure 4, seed oysters held in trays increased in length consistently through-

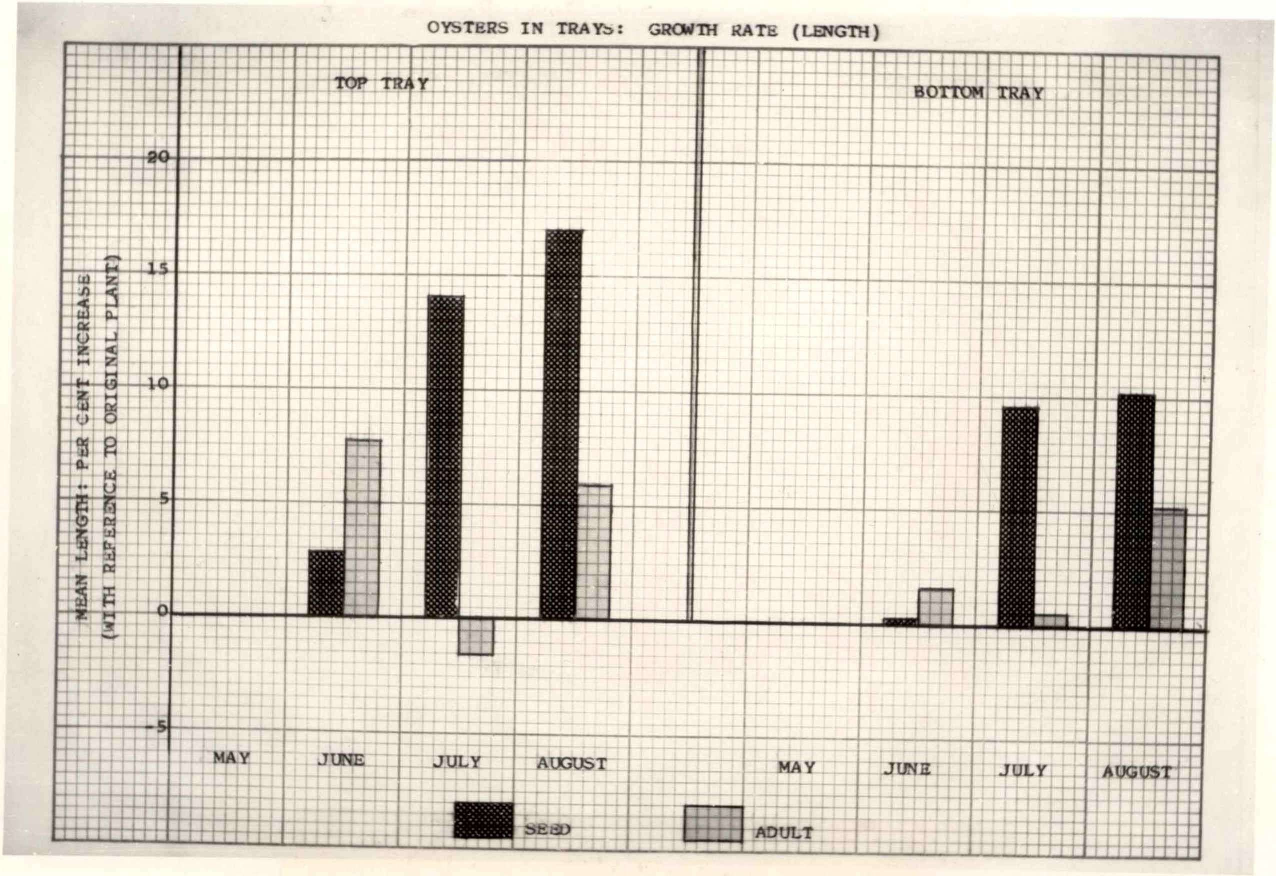

Figure 4. Growth in length of seed and adult oysters held in trays, Broad Lake, May through August, 1965.

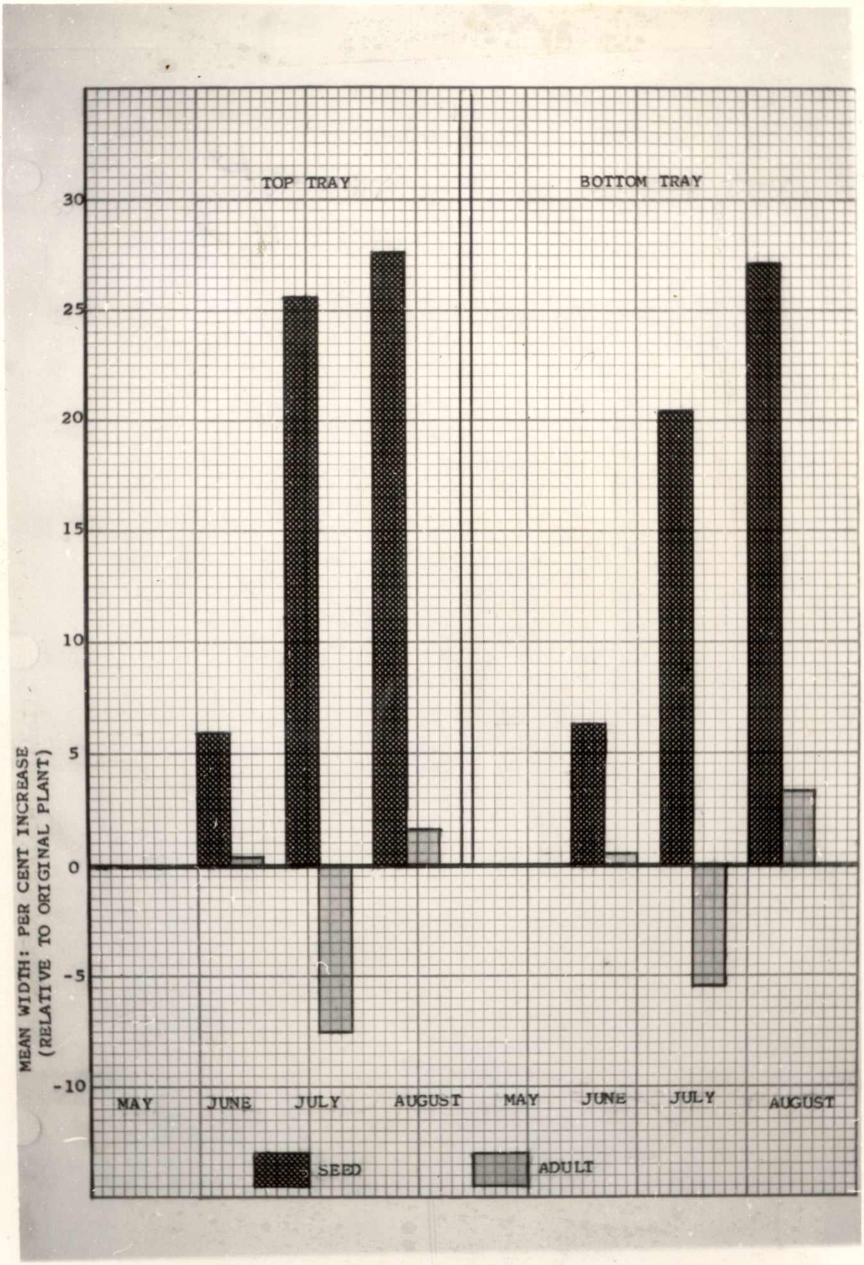

Figure 5. Growth in width of seed and adult oysters held in trays, Broad Lake, May through August, 1965.

out the study period. Greatest increments were noted in the seed at the top station, the growth of seed in the bottom tray lagging somewhat behind. Adults, after an initial period of no growth or even "negative growth", recovered and showed increments of 7.49% and 4.73%, August increment over June, for the case of top and bottom trays, respectively (table 10).

Apparently, the seed oysters acclimated better and more rapidly to the transplant environment than did the adults, even in the trays. The tray environment appears to be a better environment than the natural bottom, however.

McHugh(ms) reported a similar situation for seed oysters from the James River seed area of Virginia. He reported that James River seed oysters transplanted to "natural bottom" elsewhere grew "somewhat slower" than did similar seed cultured in trays.

In our data, it is evident that the seed fared far better than did the adults. The data for width presents a slightly different picture.

The tray oysters again "performed" better than did the free plants, with respect to increase in width.

Throughout the data we see references to minus (-) values for growth. You may ask: "Does this mean that the oysters have "shrunk"?" To a certain extent it may, but probably not. Minus growth figures may result from an actual decline in size, individually, as there are numerous instances to this in various works by Lunz and by Gunter. It must be remembered that the tabulated figures are means of a population or populations, not individuals, and that these populations have experienced varying degrees of mortality. Thus, similar data are asked of smaller populations. The loss in size may, however, be authentic, as I have discussed elsewhere (Aldrich, 1957).

Free Plantings

The period covered by the four months under observation is the period of greatest - if not all-growth of Maritime oysters, namely mid-May through mid-September (Medcof, 1961). Medcof pointed out that this growth, in general, begins when the water temperature reaches 50°F (approximately 10°C.), which in Maritime oyster areas is in mid-May. Growth ceases finally in October, when the temperature again falls below this apparently critical temperature.

References to Tables 1, 2, and 3 will demonstrate that the "critical maritime" temperature of 10°C was not characteristic of the water of Broad Lake during the June sampling period, although at times the temperature did exceed 10°C. Throughout the remainder of the test period herein reported on, the temperature, both at the top and on the bottom, remained well above Medcof's value for the critical temperature, and showed sign of a decline by August.

Coe's (1948) study on bivalves showed that "a considerable degree of correlation is found between the growth rate during each month of the year and the temperature and solar radiation and other environmental conditions". Admittedly using data on Connecticut oysters, it is interesting to point out the results of experimental studies made by Loosanoff and Nomejko (1949). From their work it is evident that 15°C - a common water temperature for Broad Lake, July and August - is the lower limit of temperature conducive for maximal oyster growth in both length and width. (15°C - 20°C).

Observing that a period of 4 to 7 years is necessary for C. virginica to reach a length of 3 inches in the Maritimes, Medcof (1961) pointed out that actual growth in oysters of different sizes differs in different months. Specifically, "yearling" oysters grow throughout the entire growth period, while older oysters demonstrate a period of growth in spring, slow down in early summer, and then accomplish most of their growth for the year in the late summer.

All other factors considered equal, it would appear that the water temperatures in Broad Lake in the summer are acceptable, but the growing period would be of a limited duration at best.

CONDITION RATING

As was pointed out earlier, the Butler system of evaluating oyster condition is at best a qualitative estimate of the degree of opacity of the tissues. Since glycogen is the main substance stored by the oysters (Mitchell, 1918), the opacity is a function of the glycogen content and the condition rating reflects this. "Fat" oysters, therefore, do not appear so due to accumulations of fat and protein, but of glycogen, which is a complex polysaccharide $(C_6 H_{10} O_5)_x$ commonly called "animal starch" (Hawk et. al., 1949). Oysters store glycogen in the Leydig cells of tissues. The highest concentrations occur in the interstitial connective tissue of the gonads (Bargeton, 1941, 1942). Mitchell (1918) stated that glycogen is especially prominent in the region of the liver.

As the glycogen content of the tissue rises, the water content decreases proportionately. York River, Virginia, oysters in 1935-37 were found by Galtsoff et. al. (1947) to be about 82 percent water on the average. Aldrich (1957), on the York River, showed that all one- and two-year oyster plantings exhibited significant negative correlations between mean condition rating and incidence of watery meats (some 40,000 oysters involved).

There were appreciable differences between the mean condition ratings of the oysters examined. Seed oysters from the James River were found by Calderwood and Armstrong (1941) to contain approximately 1.0 percent glycogen (net weight basis), whereas a group of "lean" York River oysters contained 2.5 to 2.7 per cent glycogen. Galtsoff et al. (1947) reported that glycogen content of experimental James River seed was 2.7 percent, but after 11 months in the York River it had risen to 4.31 percent. Apparently the seed oysters are "lean" in the James River, but become "fatter" on beds in the York. One factor which may have a bearing on this phenomenon is the lower salinity prevalent in the seed areas of the James River, since Medcof and Needler (1941) stated that no "fattening" was observed in oysters in salinities less than 20 ppt. even though suitable temperatures prevailed. Salinity would not be a factor in Broad Lake.

Another factor to be considered is the prevalence of epifauna on the seed oysters. Engle and Chapman (1952) found that mussel-covered oysters were poor in glycogen, and had 27.5 percent less meat than those which were mussel-free. However, they reported that when freed of mussels, oysters accumulated sufficient glycogen in about a month to regain their normal condition.

There are several factors which might separately, or probably collectively, cause oysters to exhibit a poorer condition. Fundamental are the seasonal changes in stored glycogen which occur normally. Korringa (1952) stated that the three predominant factors influencing "fattening" were fluctuations in the quantity of available food, variations in feeding intensity, and interference by the use of reserve food in spawning. Nelson (1923), in a three-year study of Delaware Bay oysters, found a fairly close correlation between the abundance of plankton and the "fatness" of oysters. While certain associated organisms like mussels rob oysters of food (Lotsy, 1893), others such as red algae accumulate plankters which are available to the oysters. Nelson (1917) quoted New Jersey oystermen to the effect that oysters "whiskered" with red algae were always "fat". These observations illustrate the effects of food availability on oyster condition.

Seasonal variation in glycogen content has been associated with spawning and temperature, which are themselves interrelated. Mitchell (1917) reported that a depletion of glycogen occurs in warm weather but is followed by a storing-up in late summer and fall. He observed a slight decrease of glycogen in the coldest weather. Mitchell's observations agreed with those of Milroy (1909). Medcof and Needler (1941) attempted to show the "fattening" of oysters as a function of specific temperature ranges. It was noted by Gunter (1942, 1955) that condition of oysters as "market quality", is inversely correlated with temperature since oysters become "fat" only in the fall and winter when the temperature drops. Native York River oysters were found by Galtsoff and his associates (1947) to contain most glycogen in November and December, least in August. For spawning activity, which takes place in the warm months, oysters draw on reserve glycogen thus depleting their stores. The coincident loss in glycogen with spawning has been observed in Crassostrea gigas (Hatanaka, 1940) and C. commercialis (Humphrey, 1941) as well as in the American oyster. Medcof and Needler (1941) reported that spawning caused "thinning" in the latter, while Gunter (1942) stated that he had observed oysters in poor condition in October due to spawning activity as late as the previous month. Spawning activity was probably the cause of minimum carbohydrate values found during September and October by Lee and Pepper (1956). Glycogen-bearing Leydig cells were observed by Bargeton (1943) to rise sharply in numbers when spawning was completed.

Medcof (1961), with specific reference to Maritime oysters, demonstrated that in the spring, with an increase in temperature, there is an initial decrease in fattness, followed by a steady increase with rising temperatures, until spawning, the oysters being in poor condition during the warmest months. Fattening resumes in the autumn months, following spawning.

Tray oysters

No condition rating data is available on the tray oysters, as we were asked not to sacrifice tray oysters. Emphasis was to be placed on survival. This is a definite weakness in the study. All other variables on which we have continual data with respect to the tray oysters could be better evaluated if we knew the progressive changes in condition rating of these same tray oysters.

Free plantings

The data on mean condition rating of the several plantings are presented graphically in Figure 6.

It is evident from the mean values presented in Table 5 that seed oysters had a slightly lower condition rating in the original plant population (3.439) that did the adults (3.602). There seems to be no definite trend at all locations during the period of our observations. The mean seed condition, all locations, was seen to demonstrate a steady decline, June through August, with an August mean of 2.93. With respect to the adults, they showed little average change, with an August mean for all locations almost identical to that of the original plant (3.62).

Position 2, however, is of considerable interest, for it was there in August that adults demonstrated a high rating of 5.4, a seed low of 1.93. The data is inconclusive, but this will depend on future comparisons with additional data.

Glycogen

Efforts have been made (Swabey and Aldrich) to calibrate the Butler condition rating scale as used here with actual glycogen concentration in oyster tissues. Medcof (1961) quotes Pease as giving the figure of 6.14%

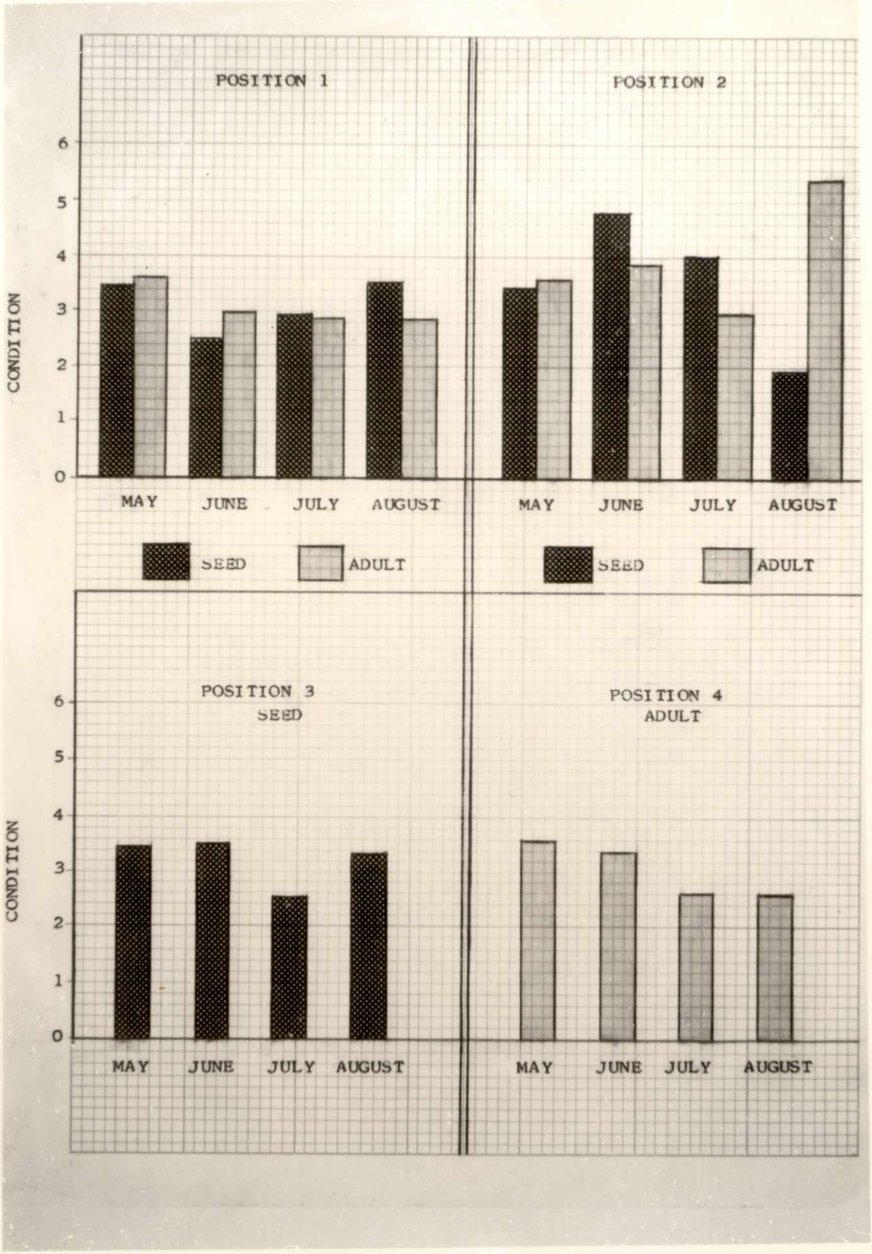

Figure 6. Mean condition rating of seed and adult oysters (free plantings) Broad Lake, May through August, 1965.

(fresh meats) and 25.75% (dry weight) for glycogen composition. We have learned that such a figure, unless it be an average, has little validity. Glycogen varies greatly throughout a year and throughout the life of an oyster, and is dependent on numerous physical, chemical and biological factors in the environment.

Using the method of Calderwood and Armstrong (1941), the glycogen of York River oysters was extracted . The top line of beakers in Figure 7 demonstrate ten oysters of each of the classes 2, 4, 6 and 8 in the Scale. At the bottom of each beaker shown in the bottom row can be seen the slight precipitate of glycogen extracted in the analysis of each of the four key classes. Our studies are not complete, but it is hoped that the classes of the Butler Scale can be calibrated for all seasons in terms of actual glycogen content. So far autumn (November) samples have been completed, using York River oysters from Virginia. The glycogen composition varies from less than 1% (Class 2) to over 4% (up to 7.05%) for class 8. There is good correlation between the composition and the Butler scale, but classes 4 and 6 are often close in glycogen composition. Similar work is reported by Ingle (1949) for Louisiana bayou oysters.

In terms of mean values, the oysters planted at Broad Lake were "poor", with individuals tending to demonstrate a "fair", even "good", condition. The mean values are almost identical to those I have seen in much larger populations of comparable age and size in commercially producing areas.

Crystalline Style

One of the unique structures of molluscans is the crystalline style. It is a crystalline, hyaline rod, residing in an appendix to the digestive tract (the style sac). The eipthelial cells of the sac secrete the style.

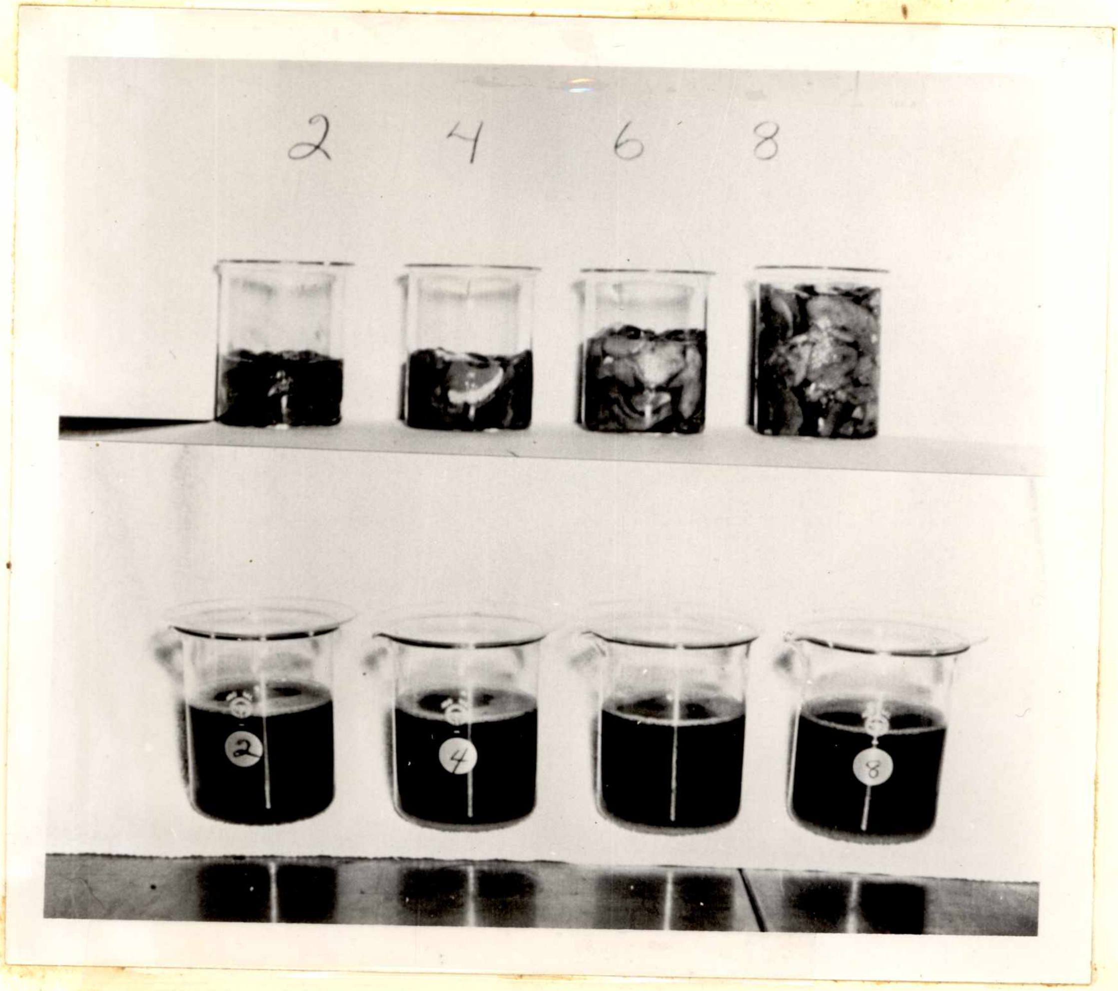

Figure 7. Glycogen and Condition Rating.

Top Row: Beakers with 10 oysters of classes 2, 4, 6 & 8 respectively.

Bottom Row: Glycogen precipitate from the same oysters.
(Photo by F.A. Aldrich)

T.C. Nelson (1918) confirmed late 19th century views of Coupen and Mitra to the effect that the style is a deposition of digestive enzymes and demonstrated its strong amylolytic nature. This was later confirmed by Yonge (1923). Large cilia on the epithelial cells rotate the crystalline style and push it into the lumen of the stomach (Nelson, 1918), where the head of the rod gathers the entering food-laden mucous strings. Enzymes are liberated by the wearing away of the distal end against a hard structure found on the wall of the stomach, named the gastric shield by Nelson. (In 1791 this same structure had been observed by Poli who referred to it as the "fleche tricuspide". Berkeley (1935) determined that chitin was the chief component of the shield). Digestion in oysters is not at all well understood. Yonge, Nelson and others have debated several points regarding the presence of intra- versus extracellular enzymes throughout recent years. But the presence of the style carbohydrate is well established.

In oysters that were observed feeding, Nelson (1923) reported that the crystalline style was large and firm. Oysters engaged in digestive processes contained styles which, when found at all, were "soft amorphous masses of jelly". The regeneration of the style has long been thought to be correlated with either the presence or the nutritive value of food of the oyster (Nelson, 1918, 1925; Allen, 1914, 1921). In all of his experimental work evaluating the different food organisms, Allen (1921) used the presence of the style as the criterion of feeding. Although the style is not to be found in oysters after the cessation, the regeneration is rapid. Edmundson (1920) and Nelson (1925) reported the regeneration of the style in Crassostrea virginica in 15 minutes. The time necessary for regeneration was found to vary considerably in different species of molluscs.

The regeneration of the style in oysters may be stimulated by the presence of nannoplankton (Martin, 1923a). The presence of food is not necessary for regeneration to occur (Martin, 1923b), however, Martin concluded that the triggering of style formation may be a response to simple siphoning by the oyster. Correlated with this is the statement by Berkeley (1923) that he was unable to demonstrate a style in oysters under anaerobic conditions. Martin's theory (1923b) takes on added significance when considered in light of the findings by Edmundson (1920) that the intake of food by an oyster is dependent upon the degree of development of the crystalline style. Certainly the oyster "siphons", thereby "testing" the environment, before it "feeds". Thus, by the style being regenerated in response to siphoning, it would follow that there would be some development of the enzymatic structure before the entry of food. All in all, the siphoning, feeding and formation of the crystalline style are interrelated. Galtsoff (1956) preferred to use the presence or absence of the crystalline style over plankton counts as a criterion of nutritive relations on an oyster ground.

Tray Oysters

As in the case of condition rating, we have no data on the incidence of crystalline styles in the case of tray-held oysters. This is due to the prohibition against the sacrifice of tray oysters.

Free Plantings

As can be seen from a consideration of Table 6, there was a uniformly high incidence of crystalline style except at Position 4 (5.9%) in the month of July. This may perhaps explain the lower condition rating of this same group of oysters. All groups improved throughout the summer with respect to crystalline style incidence, with the seed again indicating better conditions than did the adult oysters.

Oyster Associates

Even the most cursory examination of Tables 18, 19 and 20 will indicate one fact above all others. That fact is that the oysters, relatively "clean" at time of planting in May, became more excessively "fouled" by epifaunal growth as the summer progressed. This can be correlated with the greater exposure to local native fauna, in that the oysters themselves offer and serve as a most suitable and natural substratum for the attachment and growth of numerous species of benthic flora and fauna. Furthermore, as the summer progressed, other species, having reproduced, were present in stages where attachment is necessary.

This work, if continued, will afford a fine and welcome opportunity to study the succession in the structure of this now oyster-dominated (?) community.

In June, the "pioneer" elements populating the tray oyster shells were different with respect tothe age of the oysters. These were barnacles in the case of the adults; the seed oysters being completely free of Cirrepedians, while 90.0% of the adults in the top tray were shown to be the habitat for juvenile barnacles. This will be discussed further at a later point.

Barnacles and bryozoans predominated on free planted adults, while hydroids were numerous (62%) on top adult tray oysters. By comparison, hydroids were present on 100% of the seed oysters in the top tray (June).

Hydroids were gone in the July and August period, with barnacles maintaining their dominance in July on adults' shells. By July, bryozoans and algae had assumed considerable proportions on the adults, and these levels were maintained through August.

The significant thing about the August situation is that <u>more</u> oysters, of both groups (seed and adult) were encrusted or infested with <u>more</u> kinds of organisms. This data has great potential as the basis of what may prove to be an important study of succession.

Let us consider some of these forms in some detail, with some information on their importance to the success of oysters.

(a) Littorina

Littorina is the genus of the common periwinkles. Three species are present, Littorina littorea L., L. obtusata L. and L. saxatilis Olivi. These appear to be normal components of the fauna of Broad Lake, and offer no particular danger to the survival of the oysters.

(b) Mytilus edulis

The blue (or edible) mussel is Mytilus edulis L., with a maximum size of three inches. This is a very common form in the Broad Lake area, ranging from the intertidal zone to a depth of several fathoms, where it is found attached to rocks, shells, pilings and the like by means of byssus threads.

Mussels are the oyster's chief competition for food and space (Medcof, 1961). Medcof concluded that it is impossible to grow good oysters where mussels are in abundance. Not only do they compete for space, but they compete for the same planktonic food supply. Local differences in the distribution of mussels were observed, such as the predominance of the species at Position No. 3 (August, Table 20).

Often mussels deposit thick accumulations of soft, sticky "mussel mud", the product of their feeding activities. Such "mussel mud" smothers recently attached oyster spat, and also renders once hard bottom unsuitable for the attachment of successive oyster spat.

Mussels also crowd oysters, forcing them into elongated, irregular shapes. Such mussel-crowded oysters have less meat (27.5% less), with less glycogen content than normal oysters. Upon removal of the mussels, the oysters recovered "in four weeks to the same condition of percent solids and per cent glycogen as the oysters originally free of mussels". The foregoing observations are those of Engle and Chapman (1952).

The dominance of M. edulis at Broad Lake may prove to be a matter of considerable concern in the future.

(c) Barnacles

Balanus balanoides L. is the most common barnacle found in the Broad Lake area, from the tidal zone to a depth of five fathoms. They clearly demonstrated a preference for the older oysters, very seldom being found attached to the seed oysters. The earlier incidence of hydroids on the seed may explain this in part, for McDougall (1943) pointed out that forms like hydroids and bryozoans tend to smother later attached barnacle larvae.

Walne (1956) indicated that barnacles are "generally less troublesome" to oysters (primarily spat) than are other forms that compete with the commercially important bivales.

In general terms, barnacles offer no particular threat to adult oysters, as was concluded by Galtsoff et al (1947) from their studies on the York River, Virginia.

(d) Bryozoans

Several species of encrusting bryozoans of the Family Membraniporidae were found on the Broad Lake oysters. The incidence increased throughout the summer, but more often encrusted adult shells, rather than seed. These forms may cause a smothering of spat oysters, if and when setting of juvenile oysters occurs.

(e) Algae

Numerous algaL forms were found on the oysters. Their incidence increased throughout the summer. In general, these are considered to be pests, the implication being that they interfere with the normal functioning of oysters.

Such need not be the case, however, as Nelson (1917) found that oysters "whiskered" by algae may be expected to be "fat". Martin (1923) reported that epizoöic algae, primarily red algae, serve as substrata for a variety of epiphytic diatoms. He further stated that the oyster is in part responsible for the formation of such "gardens", as mucus from the oyster forms a gelatinous coating which is the basis of the accumulation of the epiphytes. Presumably the oysters "harvest" this crop of diatoms which serve as a concentrated food supply. To support his contention Martin stated further that he found more algae on the shells of living oysters than dead oysters.

(f) Limpet

The common limpet or plate limpet (Family Acmaeidae) at Broad Lake is *Acmea testudinalis* Muller. The slipper limpets (*Crepidula* spp.) of more southerly waters, assumes considerably more importance on oyster beds. If *A. testudinalis* has any adverse affect on oysters it is probably one of crowding and occupancy of space thus not available to the oyster spat.

(g) Polychaeta

Numerous species of polychaete worms occur in Broad Lake. We may infer that all those found in oyster plantings are local, since they "arose" since the June check, at which time their incidence was "zero", and therefore they were not transplanted with the oysters. Most common were two species of the "coil worms" (Family Serpulidae). *Spirorbis borealis* Daudin (the northern coil worm) and *S. vermicularis* L. (the common coil worm). Both of these worms secrete calcareous tubes which may be tightly coiled (*S. borealis*) or twisted or loosely coiled (S. vermicularis.) They may be found encrusting algal fronds, rocks, pilings, or oyster shells. Loosanoff (1956) indicated that these worms may smother oysters.

The polychaete of most importance to oysters is the genus Polydora, commonly known as the "blister worm" or "mud worm". Polydora is a spionid polychaete worm which is cosmopolitan in occurance. The adult is cylindrical, a half inch long, has 40 segments, is yellow or flesh colored and bears a pair of long periostomal cirri. This organism prefers soft mud bottom for its habitat and invades bivalve molluscs. The worm does not come into direct contact with the meat, does not secrete a toxic substance nor subsist on the oyster meat. It would therefore not be considered a parasite.

It is believed that Polydora occurs throughout the range of distribution of the American oyster (Lunz, 1941). Several species have been reported from the Atlantic and Gulf of Mexico coasts, including P. ligni Webster, P. calca Webster and probably P. anaculata Moore (Galtsoff, et. al. 1947). Korringa (1952) however, stated that probably practically all of the specimens are P. websteri Hartman. Lunz (1941) has described the behaviour of P. websteri associated with oysters. Upon entering an oyster, the young worm settles close to the outer edge of the shell and within a few hours has collected a deposit of mud around itself. The presence of this foreign material causes the oyster to cover the worm with a secretion of conchyolin reinforced with a layer of nacre. Polydora in its turn secretes two canals which open to the outside edge of the shell. The worm perhaps accomplishes the formation of these canals by the secretion of a strong acid (Lankester, 1868). The Polydora is able to enlarge its burrow by etching canals in the nacre of the oyster shell. As time goes on more mud is collected by the worm and such accumulations form "blisters" on the inner valves. Subsequent generations of worms may invade the shell and form burrows on top of the older ones producing increasingly large mud blisters.

The incidence of Polydora in oysters has been reported for several coastal areas. Lunz (1941) found that 40% of South Carolina oysters were infested with the worm, but that the infestation was not increasing. Lunz believed that 40 per cent was a "high" figure, but Owen (1957) reported a 100 per cent incidence in Louisiana oysters. The percentage of oysters infested with Polydora does not change materially with the seasons (Grice, 1951). Mackin and Cauthron (1952) studied the actual numbers of worms present and found that the number of Polydora worms in a single oyster often exceeded 500.

Loosanoff and Engle (1943) examined 1,000 oysters from Long Island Sound and found that only 2 percent were infested with Polydora. When similar oysters were held in trays four feet above the bottom for two and a half years, however, it was found that almost all of them sheltered Polydora. The authors noted that the salinity of the water bathing the trays was about 1 to 5 ppt in August, whereas the salinity of the bottom water was greater than 25 ppt. They suggested, therefore, that Polydora apparently prefers a low salinity, and that fresh water inflow may favor the spread of the organism. This suggestion agrees with Lunz's (1941) observation that Polydora is more prevalent in areas of low salinity, but conflicts with Owen's (1957) statement that populations of Polydora were greater in areas of high salinity remote from fresh water.

The possible effects of Polydora infestation upon oysters have been considered by several workers. Lunz (1941) stated that the primary effects are the restriction of the oyster's living space and the expenditure of energy which might otherwise be used in the building of new shell. Loosanoff and Engle (1943), however, found that growth of very heavily infested oysters held in trays was excellent and exceeded the growth rate of oysters on the bottom. Korringa (1952) reported that oysters heavily infested with Polydora showed poorer growth than non-infested oysters on the same beds. Lunz (1941) asserted that Polydora infestation did not render oysters "unfit for food". The presence of mud blisters affects the market value, however, especially for the "half-shell trade" (Lunz, 1940 , 1941; Medcof, 1946). In ten years of studies, Lunz (1941) found no correlation between the percentage of mud blisters present and the yield of oyster meats per bushel. Loosanoff and Engle (1943) reported that heavily infested oysters in trays were in "excellent condition" and had more meat proportionately than oysters on the bottom. Korringa (1952) pointed out, however, that "oysters living under less favorable nutritional conditions than those kept on the trays in Milford Harbor may suffer from heavy blistering". In studying York River oysters, Galtsoff and his associates (1947) found that Polydora was present in both good and poor oysters and asserted that it was "impossible to correlate the presence or absence of blisters with the condition of the oyster".

Gunter (1955) correctly pointed out that Polydora may "open the way" for other invaders. Medcoff (1961) concluded that the blister worms are "never abundant enough to be seriously harmful to the oyster" in the Canadian Maritime Provinces. Other than unsightlyness that detracts from commercial value, with possible disagreeable taste and flavor, he discounts possible detrimental effects, save the occasional conditions reported from the Bras d'Or Lake area.

Polydora incidence was relatively high in the Broad Lake plantings.

(h) Hydroids

Species of colonial hydroids were found growing attached to the experimental oysters. These are flower-like invertebrates much like the classical example, *Hydra*, but of a colonial habit. They form sessile moss-like or fern-like growths. Characteristically these forms have an alternate mobile (or medusa) stage, which accounts for the widespread distribution of a given species in an area.

The effect of hydroids on oysters is primarily one of crowding and smothering oyster spat (McDougall, 1943). However, Poisson (1946) wondered if certain species of hydroids might be the causative factor for a "characteristic irritating flavor" mentioned also by Korringa (1952) as occuring in *Ostrea vitrefacta* of Madagascar (Malagasy). There is also a possibility that such hydroids cause light attacks of nettlerash in persons eating oysters so encumbered (Korringa, 1952).

(i) Drills

We here refer to boring snails of the Family Muricidae, commonly referred to as "oyster drills" or "screw borers". Adams (1947) stated that the Atlantic oyster drill, *Urosalpinx cinera* Say, is responsible for 30% of oyster mortality in the Atlantic Provinces. This figure is in good agreement with the 32% mortality of Florida oysters attributed to *U. cinerea* by Butler (1953). Such drills also feed on mussels and barnacles (Medcof, 1961). This is accomplished, as with the oyster, by the snail boring a hole, 1/16 of an inch in diameter, through the shell. The drilling is accomplished by alternate use of a rasping organ (the radula) and the ABO (aboral boring organ), which softens the spot to be drilled. The ravages of these pests are of considerable economic importance. We recommend reference to Carriker (1955) for a superbly thorough review of the pertinent literature.

To the best of our knowledge, *U. cinerea* does not occur naturally in Broad Lake. It could easily have been introduced with the plantings in May, 1965, however. Medcof (1961) is correct in his conclusion that "it is almost impossible to avoid including drills and their egg cases in summer shipments of oysters from infested areas".

Few oysters were drilled (Tables 18, 19 and 20) and these were adults. These could be the signs of earlier activities prior to planting in Newfoundland, but not necessarily.

Another muricid is a normal faunal inhabitant of Broad Lake - indeed, of most Newfoundland coastal areas. We refer to the Atlantic dogwinkle, or dog whelk, *Thais lapillus* L. This snail has the ability to develop into a considerably important oyster pest. Another species of *Thais*, *T. haemastoma*, has been found to be responsible for heavy oyster mortality in the Gulf of Mexico (Sieling, 1956).

Only time and future careful checks on the success of the Broad Lake plantings and tray installations will bear this out.

(j) Others

We need not go into the deprivations of oyster beds due to the predation by sea stars. They are well known and of tremendous importance. Medcof (1961) referred to *Asterias vulgaris* Verrill, the purple or Northern sea star, as "the (Atlantic Provinces) oyster's worst enemy and the biggest obstacle to oyster farming". *A. vulgaris* shares this distinction with the similar species, *A. forbesi* Desor, to the south.

No sea stars were found on the Broad Lake oyster areas during the summer period herein reported on. During visits to Broad Lake during September through November, however, the sea stars were abundant and actively engaged in decimating the oyster stocks. Future reports will, undoubtedly, record their influence on the oyster populations.

Incidently, of the six species of sea stars in this area (*A. vulgaris*, *Henricia sanguinolenta*, *Leptasterias polaris*, *L. groenlandica*, *Crossaster papposus*, and *Solaster endeca*), only *A. vulgaris* reportedly feeds on oysters.

The boring sponge or sulphur sponge (*Cliona celata* Grant) is, according to Verrill, the principal agent responsible for the "disintegration of shells that accumulate on the sea bottom" (Miner, 1950). It also bores, by enzymatic action, through the valves of shells of living oysters, forming irregular and eventually anastomosing galleries, resulting in the erosion of the shell. Eventually the sponge overgrows the shell, forming sulphur-yellow irregular masses eight inches or more in diameter, covering over adjacent shells which, in turn, are bored. Therefore, as Higgins (1937) reported, the crowded conditions of oysters on a "bed" are perfect for the spread of the sponge.

Medcof (1961) believed *C. celata** to be a "first-rate menace to any oyster industry that caters to half-shell trade", pointing out that the worst of the sponge effects were local and temporal. Other authorities believed *C. celata* to be something worse than an inconvenience, however. Topsent (1887, 1900), Cary (1907), Old (1940, 1941) Laubenfels (1947), Galtsoff et al (1947), and Gunter (1955) all concluded that the boring sponge was a serious enemy of the oyster, being responsible for a "general weakening". Korringa (1951) stated that the death of the oyster is a consequence of successful complete perforation of the valves by the sponge. According to Loosanoff (1956) this perforation could be accomplished "in a short time".

Numerous oysters examined in May 1965, prior to planting, were observed to bear evidence of sponge excavations. "Time will tell" if the species becomes established at Broad Lake. Conditions there would tend to favor such an event, since *C. celata* thrives in the high salinity water characteristic

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* Two other species, *C. vastifica* and *C. lobata*, are also responsible for oyster infestation (Old, 1941, 1942).

of the area (Hopkins, 1956). Wells and Old (in Higgins, 1937) stated that C. virginica "rarely survive (in Maryland) more than two years because of sponge attack in highly saline areas".

MISCELLANEOUS

We wish to merely comment here on the fact that none of the sacrificed oysters, upon examination, showed signs of maturing gonads. The factors that govern gonad development and spawning are complex and, at best, only partly understood.

The Maritime oysters spawn at a temperature of 68°F (20°C), according to Medcof (1961), and usually when the temperature is rising. The temperature is often much higher when the oysters actually do spawn. The surface water temperature failed to reach 20°C even as late as late August. It will be interesting to see if oysters there do produce ova and sperm and if these are ever liberated.

CONCLUSIONS

The data secured during the months of May, June, July and August, indicate that the oysters suspended in trays in Broad Lake acclimated better than did the oysters broadcast over the bottom. Free plantings in some areas of Broad Lake did better than those in others.

Hydrographically, conditions in Broad Lake are within acceptable limits. If chemical and physical characteristics were the only ones to be considered, oysters should survive and fatten. It will afford the oysters a brief but relatively satisfactory growing period. It is doubted, however that oysters will spawn and reproduce in Broad Lake.

Mortality was accumulative and the peak was demonstrated in August. Seed oysters experienced extremely little mortality, in fact, no mortality of seed oysters in bottom trays occurred between June and August, 1965.

Good growth (maximally, 27%) was characteristic of seed oysters, with the greatest increments being demonstrated in seed maintained in surface trays.

The condition index of the seed oysters deteriorated throughout the summer, falling to an August mean of 2.933. In general, the condition index of the adults was maintained around the 3.6 value. In effect, the August adults are better oysters than are the seed, but there are fewer of them remaining.

All of this data are to be considered as a base line. The full value of this study can only be realized when it is used as a basis of comparison for future data.

The study has considerable potential as the basis for a survey of the ecological succession which will eventually unfold in this new oyster-dominated community.

A number of established oyster pests, predators and competitors "awaited" the introduction of the oysters. Others may have been transplanted with the oysters. It is particularly critical that we follow the progress of individual species of this community, such as the mussels, the muricid *Thais lapillus*, sea stars and the boring sponge.

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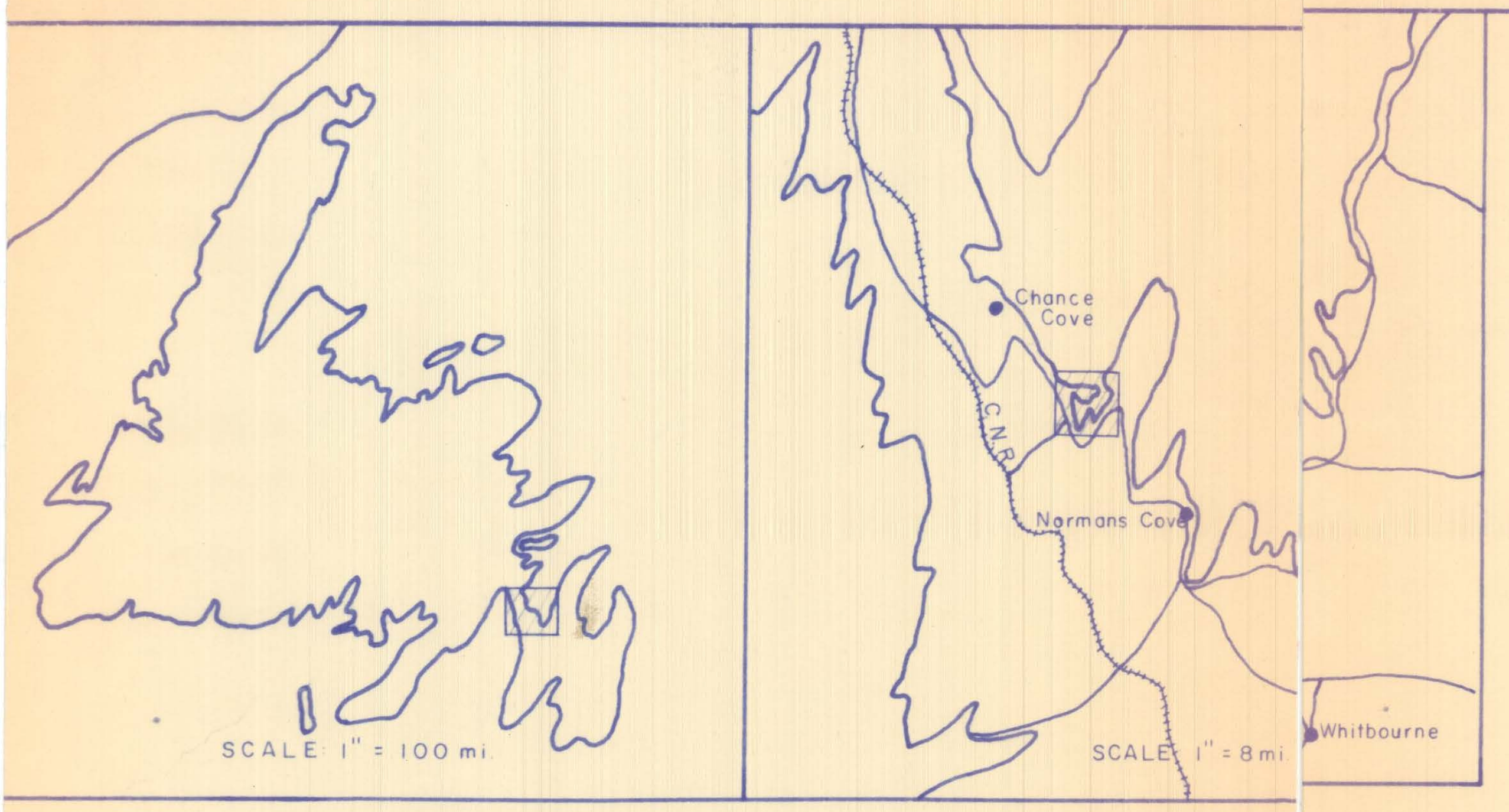

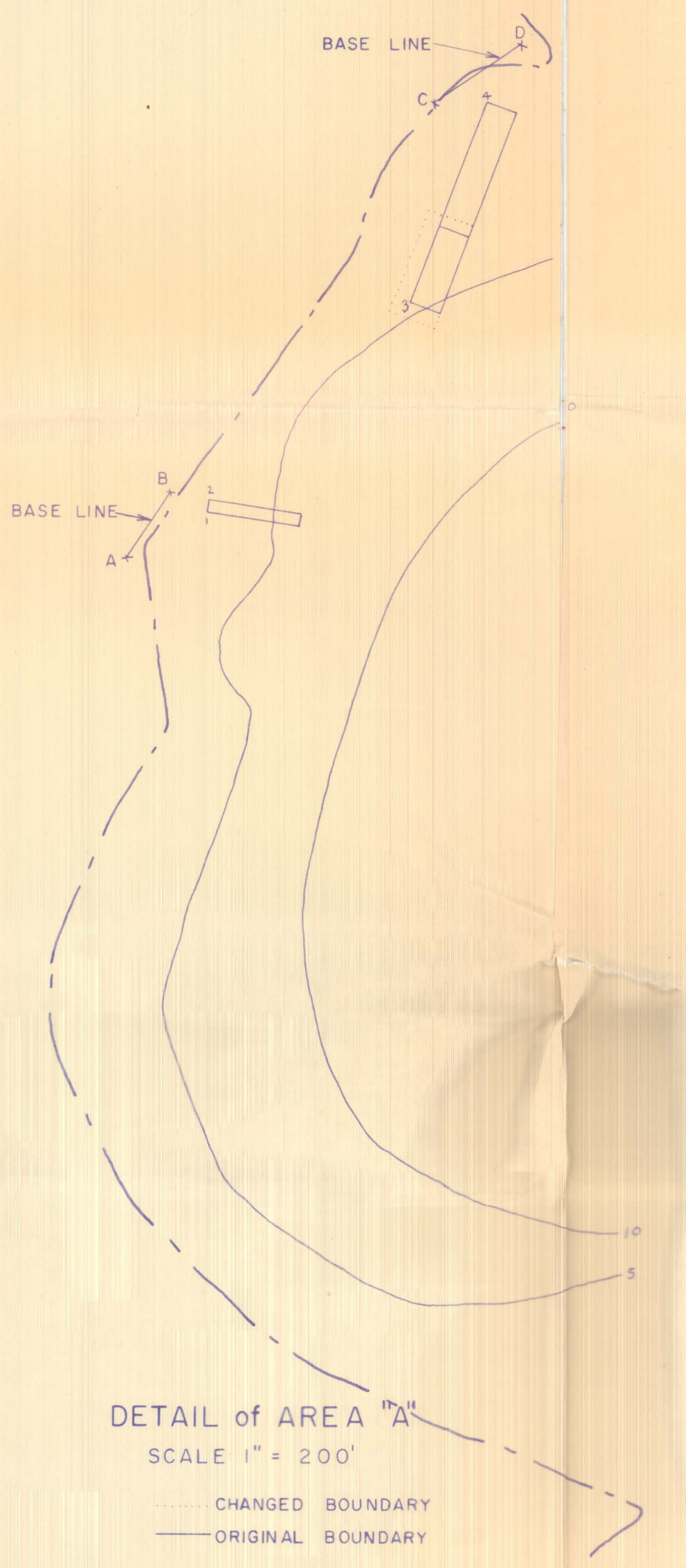

DETAIL of AREA "A"
SCALE 1" = 200'

SCALE 1" = 695'
CONTOUR INTERVAL = 5'

DATE	NO.	REVISION	BY

DEPARTMENT OF FISHERIES, CANADA

BROAD LAKE
BELLEVUE BEACH
TRINITY BAY

DATE: JAN 27, 1965
DRAWN: R. B. C.
SCALE: AS SHOWN
DESIGN:
CHECK:
APPROVED:
SENIOR ENGINEER
CHIEF ENGINEER
DWG. NO. N-D-205

P. Report No 26

REQ.14 9512