Experimental transplant of the American oyster, *Crassostrea virginica* (Gmelin), to western Newfoundland

by M. C. Mercer

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TECHNICAL REPORT NO. 188

EXPERIMENTAL TRANSPLANT OF THE AMERICAN OYSTER, *CRASSOSTREA VIRGINICA* (GMELIN), TO WESTERN NEWFOUNDLAND

by

M. C. Mercer

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INTRODUCTION

The American oyster, *Crassostrea virginica* (Gmelin), ranges from the Gulf of St. Lawrence to the Gulf of Mexico. Except for a few small populations on the outer coast of Nova Scotia and Maine the distribution is discontinuous between the Gulf of St. Lawrence and Cape Cod.

In May 1964, ministerial approval was obtained to plant Prince Edward Island oysters at Newfoundland and in May 1965 the transplant was made. The purpose was to assess the possibility of oyster culture in selected Newfoundland areas, the first step being to monitor growth, condition and mortality of a small scale planting. While the project was initiated by the Fisheries Research Board, the original plans were expanded and transplantations were made to three sites with monitoring of two of these being done by the Resource Development Branch, Canada Department of Fisheries and Forestry and the Department of Biology, Memorial University of Newfoundland. This paper constitutes a report on the population of transplanted oysters at Two-Guts Pond, a saltwater pond in Port au Port Bay (Fig. 1).

MATERIALS AND METHODS

The transplant

One hundred bushels of oysters were brought from Prince Edward Island on board the C.G.S. *Cape Freels* at a holding temperature of 5 C for the 1½-day trip. They were planted on May 24, 1965 by personnel of the Resource Development Branch, Canada Department of Fisheries and Forestry and the Fisheries Research Board. Water temperatures were 5 to 8 C. The oysters were set at four pre-determined locations in Two-Guts Pond (Fig. 1).

In order to facilitate the monitoring of growth, totals of 529 "seed" (average length 6 cm) and 400 "adult" (average length 11 cm) oysters were measured and placed in four trays; one tray of each group was suspended at the surface and the others were anchored on the bottom in depths of about four feet. The surface tray containing seed oysters was missing one month after it was set while bottom and surface trays containing adult oysters were maintained through the summer of 1966.

The remaining oysters were initially dumped from the side of a small boat but on June 27 all the adult and most of the seed oysters were spread out by a SCUBA diver.

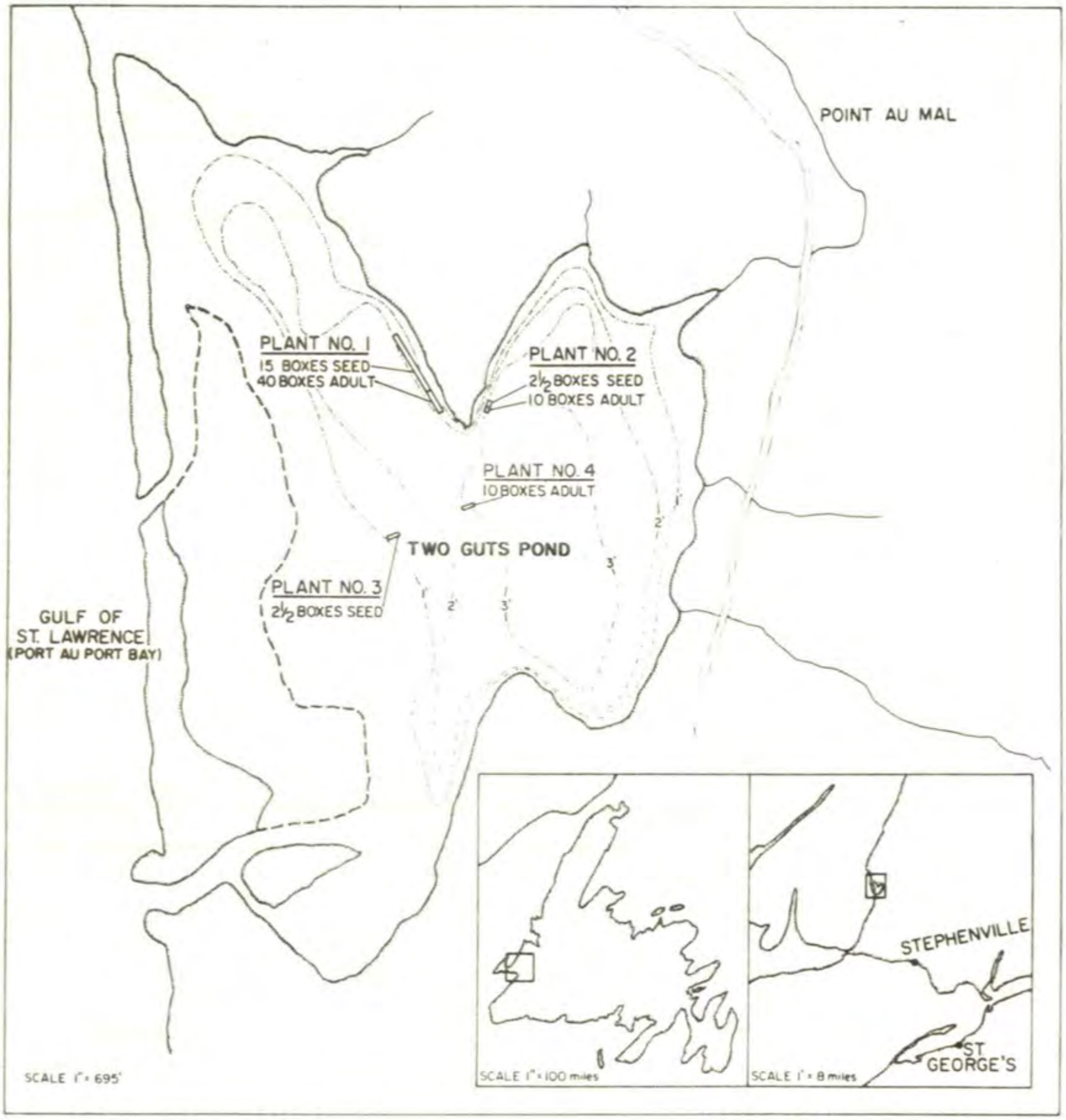

Fig. 1. Bathymetric chart of Two-Guts Pond showing location and quantities of transplanted oysters (modified from Canada Department of Fisheries and Forestry drawing N-D-203).

Sampling

Random samples, comprising about 50 specimens each, were tonged from plant No. 1 for analysis of meat volume and condition. Lengths and widths were measured of all specimens held in trays; however, no tray samples were examined for meat volume or condition. Samples were obtained monthly from May to November in 1965 and 1968; one sample only was examined in each of 1966 and 1967.

Measurements

Length and width of oysters (common usage for height and length, respectively) were measured to the nearest millimetre using vernier calipers in 1965-66 and a millimetre board in 1967-68. Length was measured from the umbo to the ventral margin of the larger left valve; width was measured parallel to the hinge axis as the maximum distance between the anterior and posterior margins. Care was taken not to damage the bill.

Volumes of meats were estimated to the nearest 0.1 ml by water displacement in a 50 ml graduated cylinder. Straight line regressions were fitted to logarithmically transformed data of meat volume versus sum of shell length and width for seed and adult oysters in each 1965 and 1968 sample; covariance analyses were performed between samples from all adjacent months and between years for samples from the same month.

All areas were read by planimeter from Canada Department of Fisheries and Forestry drawing N-D-203.

Condition

"Condition", or meat quality, was assessed subjectively by the simple technique of visual inspection. Oysters were rated on an arbitrary scale of indices[1] defined as follows:

1. More than 75 percent translucent.
2. Less than 75 percent translucent, but more than 25 percent translucent.
3. Digestive gland visible, less than 25 percent translucent.
4. Transition between 3 and 5.
5. Digestive gland not visible, less than 25 percent translucent.

[1]The origin of this scale is obscure. While I have heard it attributed to Dr P. A. Butler, Dr Butler informs me (in litt.) that the scale was already an established procedure when he began work on oyster quality in 1946.

6. Transition between 5 and 7.

7. Digestive gland not visible, tissues opaque.

8. Transition between 7 and 9.

9. Digestive gland not visible, tissues more opaque.

10. Entire animal cream-coloured and opaque.

The visual index was used exclusively until late in 1968 when comparisons with objective measurements were made. Two hundred oysters, half from Malpeque Bay, Prince Edward Island, and half from Two-Guts Pond, were rated on the visual scale and the Henderson Index (Drinnan and Henderson, in preparation) was then determined as defined below:

$$\text{Henderson Index} = \frac{\text{dry weight of meat}}{\text{total weight of oyster minus weight of shell in air}}$$

Glycogen determinations were made following the procedure of Westenhouse (1968) subsequent to storage of the meats in liquid nitrogen. Analyses were run on samples of fifteen adult and fifteen seed oysters collected on November 12, 1968.

Mortalities

Mortalities in trays were determined from total counts. Estimates of mortality in free plants were made from diving observations using a randomly placed .5 m^2 grid. The number of counts on which an estimate was based depended upon numbers of oysters present within the random squares; at least 250 specimens were counted for each estimate.

Spat collectors

Spat collectors were set over plant No. 1 on July 22, 1968. These consisted of four wires, each with about 25 scallop shells spread at 15 cm intervals and suspended at a depth of 15-50 cm below the surface. On August 8 two more strings were set. All were found to be resting on the bottom on September 9. One was examined for spat at this time and the remainder were picked up on October 15. Spatfall was not looked for during 1965-67.

Water temperature and salinity

Bottom temperatures were recorded continuously from mid-May to mid-November in 1965, to mid-October in 1967 and to mid-December in 1968; there were a few short breaks in the record each year. The instruments were stationed in about one metre of water at the south end of plant No. 1.

Mean daily temperature was calculated by averaging high and low daily temperatures and these were averaged over 5-day intervals for graphing. No temperature recordings were made during the months January-April although the barachois was visited for hydrographic observations on three occasions.

Surface salinity samples were collected each time oysters were sampled; these were analysed by silver nitrate titration. On July 22, 1968 samples were obtained hourly over a 13-hour period.

RESULTS

Growth

Shell growth. Data for all years 1965-68 are available only for seed oysters held in a bottom tray (Appendix Table 1). Shell growth begins in May. On May 8, 1968 there was no new growth at the edge but by June 11 a thin wide bill was present. Maximum length and width increased to a peak in August of each year after which they decreased slightly. Most rapid growth occurred in 1965 when increments of length and width from May to August were 7.7 and 13.4 mm (12.5 and 35.7 percent). In 1968 increments were much smaller, 4.3 and 3.4 mm (6.1 and 7.0 percent) although they were apparently larger than those for 1966 and 1967, years for which data are incomplete.

Lack of May measurements and irregularities in numbers measured, due partly to mortalities, make it difficult to assess growth in 1966. However, growth appeared to be greater in the bottom tray (Appendix Table 2). Shell length and width were found to increase each year until August and thereafter to decrease slightly during the autumn.

Meat volumes. There appeared to be little variation in mean meat volumes of seed oysters from June to September in 1965; the drop in November can be largely accounted for by the smaller size of the oysters sampled (Fig. 2). Volumes for August samples during the subsequent three years were approximately equal. Monthly samples taken during 1968 showed an increase over the season of about 1 ml; the only anomalies were of samples of smaller or larger mean length.

In adult oysters little variation was again evident in 1965; the anomaly in August was related partly to the smaller size of sampled oysters. Monthly samples taken during 1968 showed an increase over the season.

In the covariance analysis significant differences (5% level) between years were indicated in June and September intercepts for adults but no differences were demonstrated in August or October (July data were not compared). For seed the June intercepts and August slopes differed. In general adult volumes were higher at the same shell size in 1968 than in 1965 while seed volumes were lower in the early season and higher in September and October (Table 1).

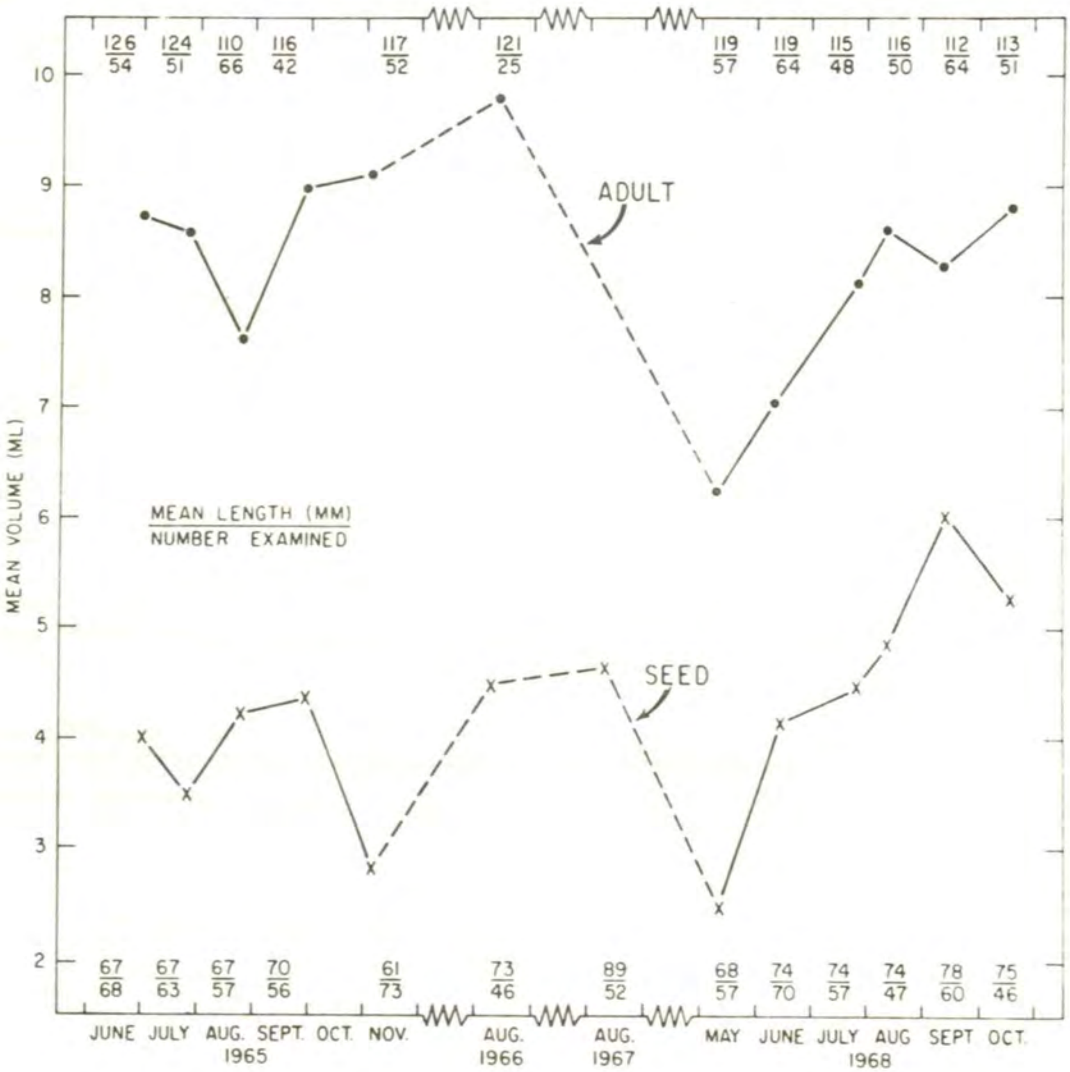

Fig. 2. Meat volumes of adult and seed oysters sampled at Two-Guts Pond, 1965-68.

Table 1. Regressions of log volume versus log sum of length and width for oysters sampled at Two-Guts Pond in 1965 and 1968.

Date	Adult	Seed
	1965	
June 28	$y = 1.59x - 1.03$	$y = 1.93x - 1.42$
July 21	$y = 1.41x - 0.85$	$y = 2.60x - 2.22$
Aug. 25	$y = 1.20x - 0.56$	$y = 2.81x - 2.36$
Sept. 28	$y = 1.84x - 1.27$	$y = 1.74x - 1.26$
Nov. 2	$y = 1.89x - 1.34$	$y = 2.38x - 1.99$
	1968	
May 8	$y = 1.98x - 1.64$	$y = 2.48x - 2.26$
June 11	$y = 1.84x - 1.44$	$y = 2.34x - 1.96$
July 22	$y = 1.76x - 1.25$	$y = 2.32x - 1.92$
Aug. 5	$y = 1.55x - 0.98$	$y = 1.77x - 1.28$
Sept. 9	$y = 2.12x - 1.66$	$y = 2.35x - 1.90$
Oct. 15	$y = 1.84x - 1.30$	$y = 2.85x - 2.46$

Significant differences in regressions were found for adjacent months in each comparison of seed volumes for 1965; differences in slope were found in only the June-July and August-September comparisons. Equations for adults showed no demonstrable difference. In 1968 the May-June and July-August comparisons of seed showed significant differences in intercepts as did the June-July comparison of adults. A distinct trend was observable in the pattern of the regressions. Volumes at a given size decreased from May to August, thereafter increasing from September to November (excepting that the October 1968 intercept was lower than that for September in adults). This pattern obtained in all but the 1965 seed samples where volume at a given size increased from June to August, then fell in September, and increased again in November.

Mortality

Free plants. Initial mortality was quite low, particularly in seed (samples taken two months after planting). Total mortalities for the three-year period were 57.6 and 4.8 percent in adult and seed, respectively (Table 2). The 1968 estimate of seed mortality is inconsistent with previous estimates. Likewise the 1967 estimate of adult mortality is anomalous in showing only a 1.6 percent increase over that of the previous year when the average was about 20 percent per year. Adult mortality was about ten times as high as that in seed.

Table 2. Estimates of total mortality for oysters at Two-Guts Pond, planted May 24, 1965.

Date	Adult		Seed	
	Total mortality %	Number in sample	Total mortality %	Number in sample
Aug. 24, 1965	10.0	369	0.4	513
Aug. 10, 1966	31.0	255	3.7	514
Aug. 6, 1967	32.6	264	6.7	387
July 22, 1968	57.6	533	4.8	374

Tray-held oysters. Mortalities of seed oysters held in the bottom tray were very low. Only 2.7 percent died in 1965, all in the month immediately after planting. From November 1965 to July 1966 an additional 1.0 percent of the remaining oysters died. Overwinter mortality from October 1966 to May 1967 was 1.5 percent and subsequent mortality during the year a further 2.0 percent. Overwinter mortality from October 1967 to May 1968 was 1.8 percent and a further 1.2 percent died by mid-October. Total mortality in the tray for the three and half year duration of the experiment was 9.8 percent. Counts from which these figures were derived are given in Appendix Tables 1 and 2.

Adults held in the surface tray showed an initial mortality of 4.9 percent. Deaths to the end of September accounted for a further 8.8 percent and additional mortality to August of 1966 took 9.7 percent. Total mortality over the first 15 months of the experiment was 21.7 percent. Adults held in the bottom tray had an initial mortality of 5.0 percent and further deaths to the end of September accounted for 10.5 percent of the remainder. However, mortalities from September 1965 to August 1966 were 22.8 percent, considerably higher than those which occurred in the surface tray. Total mortality for the 15 months was 34.3 percent.

Condition

Visual ratings. In 1965 indices of condition were maintained fairly constant through June and July but declined over the autumn months. Seed condition indices declined continuously except for an anomaly in the August sample (Fig. 3).

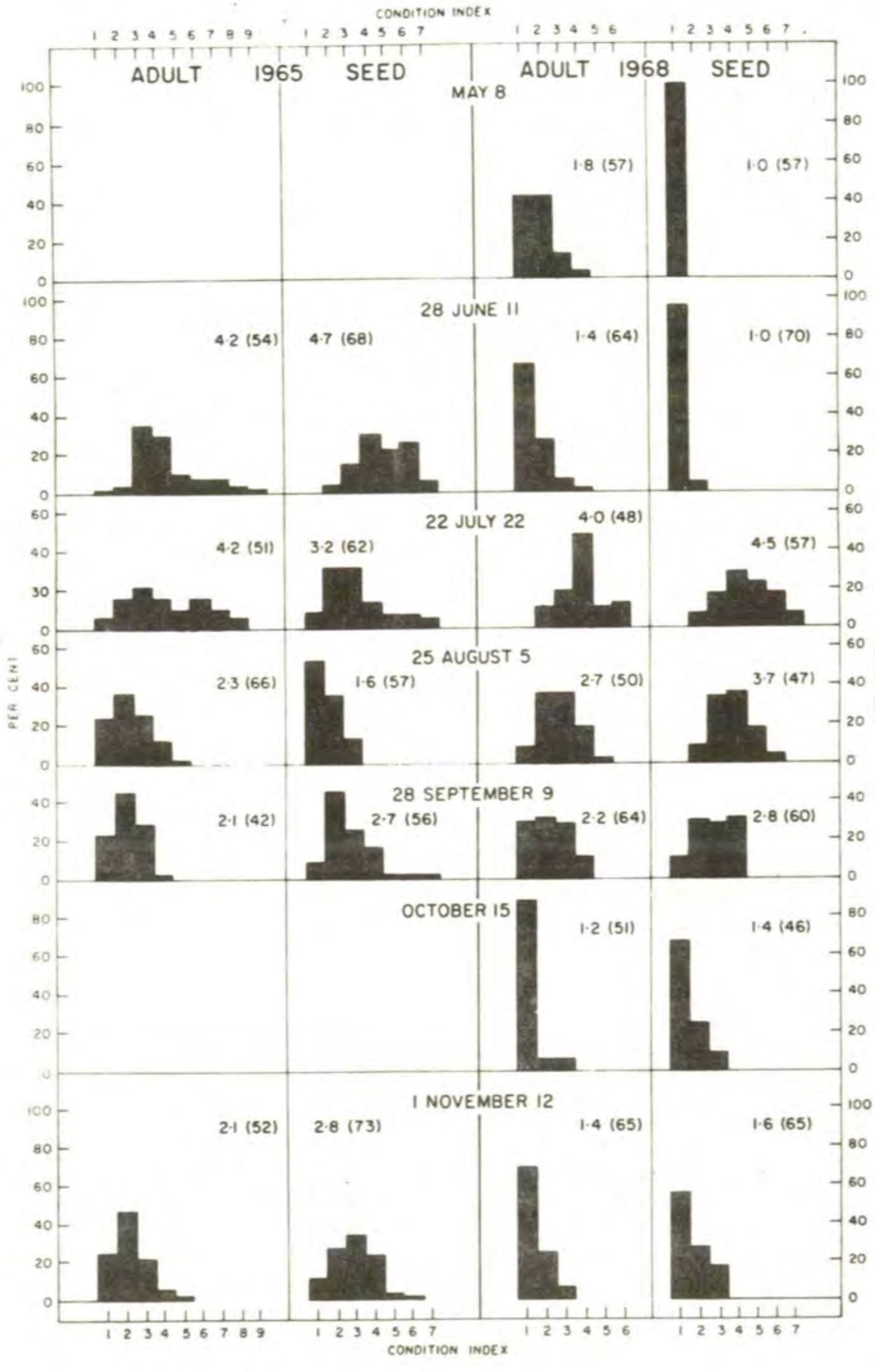

Fig. 3. Visual condition indices of adult and seed oysters sampled at Two-Guts Pond in 1965 and 1968. Numbers indicate means and sample sizes (in brackets).

Single samples were examined in each of 1966 and 1967, taken on August 10 and 8, respectively. Indices were 1-2.7-6[2] and 1-2.8-5 for adults and 1-3.3-6 and 2-3.2-5 for seed in these two years, respectively.

Monthly samples were analysed in 1968. Seed condition indices were extremely low in May and June when nearly all specimens examined were assigned an index of 1. A peak was reached in late July after which indices declined regularly over the autumn months with no recovery. Adults were rated higher during May and June. A peak again occurred in July but was lower than for seed; it fell consistently during subsequent months.

Henderson Index. Oysters given the same visual index showed great variation and overlap in Henderson indices although the mean Henderson index increased with higher visual indices (Table 3). Seed oysters rated visually at the same level as adults had higher mean Henderson indices. Drinnan and Henderson (in preparation) found that there is a consistent difference of 3 percent between indices obtained by their technique and that of Medcof and Needler (1941); the difference is due to the different methods of measuring shell cavity volume.

Table 3. Comparison of the Henderson indices and visual condition indices of oysters sampled from Two-Guts Pond, November 13, 1968, and Malpeque Bay, Prince Edward Island, October 9, 1968.

Visual Index	Henderson Index range and mean	No. examined
	Two-Guts Pond adults	
1	14.9 - 31.2 - 56.1	39
2	27.0 - 40.8 - 56.0	10
3	48.9	1
	Two-Guts Pond seed	
1	13.1 - 46.3 - 66.7	33
2	44.7 - 56.8 - 73.9	17
	Malpeque Bay	
3	26.8 - 77.8 - 137.4	24
4	54.4 - 90.2 - 154.4	73
5	66.6 - 82.2 - 95.0	3

[2]Indicating the range and mean of the ratings.

Glycogen content. Concentrations, expressed as a percentage of wet weight, varied from 0.40 to 3.72 and, based upon the small amount of comparative data, the visual indices were found to bear no relation to glycogen content over the narrow range of ratings examined (Table 4). Seed oysters had approximately 2 percent glycogen while adults had approximately 1 percent.

Table 4. Comparison of glycogen levels at various visual condition indices for oysters sampled at Two-Guts Pond on November 12, 1968.

Visual Index	% glycogen range and mean	No. examined
	Adult	
1	.46 - 1.11 - 2.05	6
2	.40 - 1.10 - 1.50	6
3	.54 - 1.08 - 1.63	3
	Seed	
1	1.44 - 2.05 - 2.89	3
2	1.67	1
3	0.93 - 2.16 - 3.72	11

Reproduction

Single spat 17.4 and 12.0 mm long were found on the surface of adult oysters collected from plant No. 1 on May 8 and November 12, 1968. No spat were found attached to the spat collectors.

Environmental factors

Geography, morphometry and flushing. Two-Guts Pond (Fig. 1) is a shallow saltwater pond, or barachois, located near the settlement of Point au Mal (43°38'N, 58°40'W), about 14 miles from Stephenville on the Newfoundland west coast. It is separated from the eastern side of Port au Port Bay (Gulf of St. Lawrence) by a narrow barrier beach and is bounded to the north and east by a peat bog. Inside the beach and between the two small entrances is a large sand bar which is exposed at low tide. The bottom is generally a mixture of sand and mud.

The pond has an area of about 500 acres of which 85 acres are exposed at low tide. Areas within the 1-, 2-, and 3-foot contours are 220, 154, and 58 acres, respectively. Volume of water in the pond at low tide is calculated at 26.6 X 10^6 feet^3. If we assume a tide height of two feet, high tide volume would be 81.2 X 10^6 feet^3, giving an exchange ratio of about 24 percent; exchange ratio would of course vary with tidal amplitude.

Temperature and ice conditions. The data are shown in Fig. 4 and additional comparative data are given in Table 5.

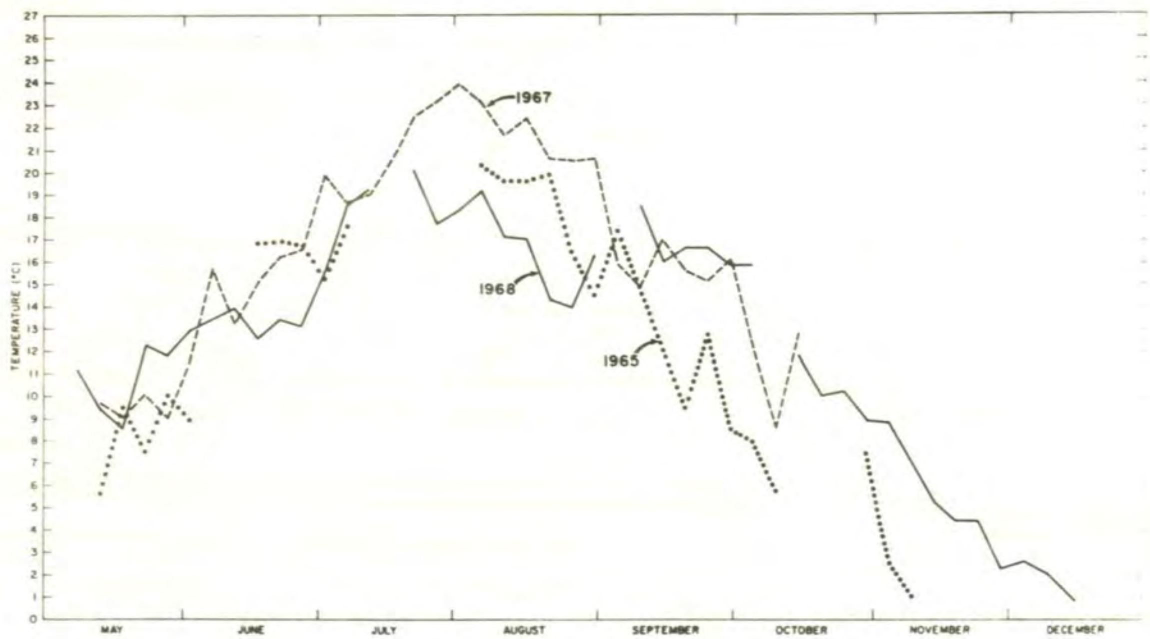

Fig. 4. Bottom temperatures at Two-Guts Pond, 1965, 1967 and 1968.

Table 5. Three-year comparison of bottom temperatures in Two-Guts Pond.

	Number of days temperature reached or exceeded		
Year	6 C	10 C	20 C
1965	166	135	22+ (≤ 50)
1967	145+	145+[a]	62
1968	176+	167+[a]	23

[a]In 1967 and 1968 temperatures had already reached 10 C prior to stationing of the thermographs. No data are available after October 13 for 1967 when the temperature was still above 10 C.

It is evident that the temperature regime varies greatly from year to year. Summer temperatures were highest in 1967 when daily highs exceeded 20 C for two months and lowest in 1968 when temperature reached this level for only three weeks. Summer temperatures in 1965 were intermediate between those of the other two years but autumn cooling was most rapid in that year.

On January 28, 1968 ice 7.5 cm thick was present inside the barrier beach; bottom temperatures were -0.6 to -1.9 C (depths 0.7-1.7 m) and surface temperature was -1.0 C. By March 5 the ice thickness had increased to 54 cm and surface temperatures were 0.4-0.6 C. On March 22, 1966 ice over the oyster beds was 35 cm thick. Local residents reported that the thickest ice present during this winter was 45 cm. Bottom temperatures were 1.0-1.5 C and surface temperatures were 0.2-0.6 C.

<u>Salinity</u>. The variation is less than 2‰ from falling tide to high tide, as indicated by hourly observations over a 13-hour period on July 22-23, 1968 (Fig. 5). The range observed was 28.48-30.21‰. No lower salinities were recorded in several other observations made during 1968; the highest was 30.84‰.

<u>Associated organisms</u>. A record was kept of all organisms observed on oysters sampled in 1968 (Appendix Table 3). In addition to the species listed, small amounts of hydroid and bryozoan growth were observed; fouling was light throughout the season.

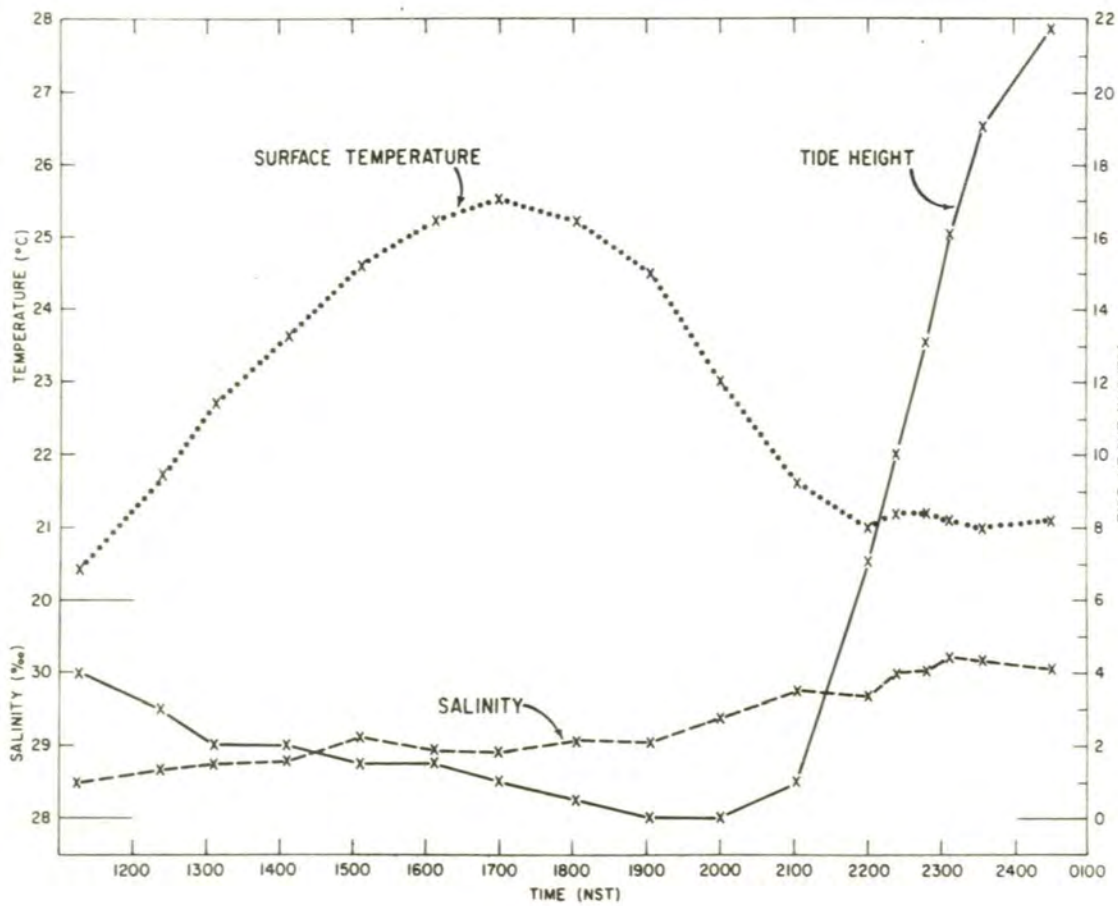

Fig. 5. Variation of surface temperature and salinity with tidal height at a station inside plant No. 1, Two-Guts, July 22-23, 1968.

The tray-held seed had the lowest incidence of epibionts; no *Crepidula* were present in any season. However, few associated organisms were found on the free plants; most *Mytilus*, *Littorina* and *Anomia* were young of the year.

DISCUSSION

Growth

Loosanoff and Nomejko (1949), working on New England oysters, found that the chief increase in length and width occurred during the first half of the growing period while the increase in depth and volume was greatest in the second half. (The maximum growing period was April-November.)

Butler (1953) has discussed the relative merits of length versus volume for determining growth in oysters; he found that under a variety of environmental conditions (in Florida) essentially no changes in length and width might occur although substantial gains were made in weight and volume. He found significant increases in weight and volume in each month throughout the year whereas increases in length and width after the first year occurred primarily in winter.

It is thus concluded that length measurements alone do not give an adequate representation of oyster growth.

Shell growth of tray seed in Two-Guts Pond occurred, as would be expected, in May-August; slight decreases in mean shell length and width occurred in the fall months of each year. This consistency eliminates the explanation of errors of measurement. Also, since cases were observed where no mortality occurred between times of measurement, bias due to mortalities is not the cause.

The apparent length and width decrease observed in this study are probably due to shell breakage exceeding shell growth. The growth pattern at Two-Guts Pond was consistent with the findings of Loosanoff (1949) in showing an early season increase in shell length and width followed by a late season increase in meat volume (and probably depth). The anomalous volume pattern in seed oysters in 1965 may be related to spawning activity.

Mortality

The general decline in average size of adult oysters in the samples from 1965 to 1968 may be related to mortality of the larger specimens. During the same period there was an increase in the average size of sampled seed oysters as would be expected because of growth.

The great difference in seed and adult mortalities cannot be accounted for by local environmental differences since plants were adjacent and adult mortalities were everywhere higher. The greater viability of seed observed here evinces the normal survival pattern which obtains under poor growing conditions.

Condition

The visual "condition" rating used in this study is a qualitative estimate of tissue opacity, this being taken as an indication of the concentration of stored glycogen; unfortunately there is no published calibration of the scale related to percentage glycogen or other objective measurement. Such a method obviates the possibility of proper statistical evaluation of any inter-sample variation found and no significance can be attached to minor differences. However, trends are observable in the data and variations in the ratings were considerable.

While adult condition indices declined throughout the sampling period in 1965, seed oysters, initially "fatter" than adults, showed a marked mid-summer decline after which they recovered in the autumn. This may be explained by spawning and subsequent recovery of the seed oysters in the general pattern observed in the Canadian Maritime area (Medcof, 1961a).

In 1968 the decline in condition indices in autumn occurred when the hydrographic climate was favourable for feeding while "fattening" occurred in summer at the time when spawn is normally discharged. Of course, "condition" is affected by factors other than the reproductive cycle.

Since mortalities were low it is more likely that the poor growth and low indices of condition are related to the influence of biological productivity than to microbial infestation. Insufficient abundance of plankters suitable for oyster digestion may have caused the abnormal condition cycle. Presence of silt has been shown by Loosanoff and Tommers (1948) and Hsiao (1950) to cause a decrease in rate of pumping, and the light silting found may have been a contributing factor, although less important than food availability.

The November samples analysed for percentage glycogen and the Henderson modification of the Medcof-Needler condition index give quantitative data directly comparable with that from other areas and with visual condition indices of the same specimens. It is obvious that visual inspection provides only a crude indication of meat quality.

Glycogen content of oysters has been demonstrated to exhibit cyclic change (see Galtsoff, 1964). In the New England area the glycogen level declines during proliferation of the sex cells and subsequent summer spawning. Minimum glycogen levels usually occur immediately after spawning following which reserves are again restored (Galtsoff, 1964). A similar cycle of the index of condition is described by Medcof (1961a) for oysters in the Canadian Maritime provinces.

Ingle (1949) obtained a correlation coefficient of only .38 when he plotted the Medcof-Needler index against percentage glycogen for 31 samples (each an aliquot from 10 specimens) of low quality oysters from Louisiana and Florida. Addition of three samples of high quality oysters raised the correlation coefficient to .69. He concluded that the poor correlation was due to dependence of the condition index upon water content, absolute size of meats, and other factors. The poorer quality oysters examined by Ingle had .5-2 percent glycogen (mostly 1-1.5 percent) and had condition indices of about 40 to 85.

Galtsoff (1964) graphed glycogen content as a percentage of dry weight for three years data on Long Island oysters. Figures ranged from 5 to about 75 percent; nearly all were above 20 percent. Taking 80 percent as an average water content, percentages of glycogen in terms of wet meat weights were nearly all above 4 percent and ranged upwards to about 8 percent.

Medcof (1961a) stated that the index of condition for high quality meats usually ranges from 100 to 150; for medium quality meats, 80 to 100, and for poor meats, below 80.

Thus the November glycogen levels and visual indices of Two-Guts Pond oysters show a very poor meat quality compared with that in other areas. It is noteworthy that seed oysters had a higher Henderson index and glycogen content than did adults even at the same visual condition index and that condition indices were higher for seed. This, along with lower mortalities, indicates the better acclimation of the seed than the adults to the new environment.

Reproduction

The 17.4 mm spat found in May 1968 is presumably from the 1967 set while the 12.0 mm specimen found in November was probably spawned in 1968.

It must be noted that there is negligible natural cultch in the barachois pond (and the exchange ratio is fairly high) so even with heavy spawning a large set could not be expected. Because of the poor condition of the oysters, it is doubtful whether maturation and discharge of gametes were as successful as in better oyster growing areas; unfortunately no data were collected on gonad thickness or stage of development.

Since the disproof of Nelson's (1928a, b) assertion that oyster spawning is triggered by a specific "critical" temperature which is constant throughout its range (Hopkins, 1931; Loosanoff, 1932) a considerable amount of research has been conducted on oyster spawning in relation to temperature. Interpopulation differences in temperature requirements for spawning have been demonstrated, northern populations being adapted to spawning at lower temperatures (see Loosanoff and Engle, 1942; Stauber, 1950; Loosanoff and Nomejko, 1951; Loosanoff, 1965). Loosanoff and Davis (1952) found that the time required for maturation varies inversely with temperature although there is wide individual variation.

Because of the important genetic component (besides individual thermal history) in temperature requirements for maturation and spawning, and doubtless other physiological processes, careful consideration should be given to the selection of appropriate populations for any transplantation;

for the Newfoundland area a cold-adapted population is required. Since the Prince Edward Island estuaries where the oysters used in this experiment originated have warmer conditions than do several other oyster producing areas in New England and northern New Brunswick the latter areas would be more appropriate as sources of spat for transplantation to Newfoundland. If New England were used as a source area, hatchery rearing and quarantine would be necessary. There is also the possibility of artificial laboratory selection under controlled temperature conditions to produce cold-adapted populations.

Environmental factors

Loosanoff (1958) found that, although there was some individual variation, Long Island oysters did not feed at temperatures below about 5 C. His results supported Galtsoff's (1928) findings in a study of the mechanical activity of gills in relation to temperature. Galtsoff (1964) gave 6-7 C as the temperature at which oysters cease to feed. It is evident then that temperatures at Two-Guts Pond are high enough to permit feeding for about 5-6 months per year.

Taking 20 C as the approximate temperature required for spawning (but see discussion of reproduction), the spawning season at Two-Guts Pond would last from about three weeks to two months per year.

Because of the low overwinter mortalities, ice conditions cannot be considered an adverse factor affecting the population. Overall temperature conditions in the barachois appear suitable for oyster culture.

While available salinity data are not extensive, it is unlikely that conditions adverse to oysters ever occur in the barachois. Since tidal amplitude is more than half the greatest depth occurring in the barachois, flushing is extremely rapid and even spring runoff would not be expected to depress salinities appreciably, although this, combined with heavy precipitation might eradicate stenohaline species such as the predatory starfish (*Asterias vulgaris*).

The incidence of epibionts was extremely low throughout the experiment and fouling or smothering with slipper limpets and blue mussels was not encountered. The absence of mussels from the oyster beds was probably due to the soft substrate since mussel beds occur on the inner part of the barrier beach nearby.

The heavy cover of eelgrass (*Zostera marina*) over the beds interfered with the tonging of oysters. Herbicidal control of this pest is now possible however (see Thomas, 1968).

While silting resulted in only a light cover over the oysters on most of plant No. 1, this would be sufficient to interfere with spatfall.

CONCLUSIONS AND RECOMMENDATIONS

Two-Guts Pond may be a suitable area for raising spat to bedding size by raft or shell-string culture, but poor meat conditions would indicate it to be unsuitable for "fattening".

In general, Newfoundland can be considered a marginal area for culture of the American oyster. The Canadian Atlantic oyster population is isolated from the main distribution of the species in a single large warmwater area, the discontinuity probably being a result of post-hypsithermal extinction (see Clarke et al., 1967; Medcof et al., 1965). Water temperatures around Newfoundland are generally lower than those occurring at Nova Scotia and Maine (which, except for a small region of the latter, do not support oyster industries) and it is only in some shallow warm barachois ponds that the hydrographic climate would be favourable for oyster culture. If a larger scale transplant of the species were to be attempted for an economic evaluation of the potential industry, care should be taken to select a cold-adapted stock.

A more suitable species for introduction to Newfoundland would probably be the European oyster, *Ostrea edulis* L.

Welch (1966) has summarized data on this species in Maine, where it was first introduced from Holland in 1949. There survival, spawning and setting have occurred each year although the rate of recruitment appears to be low.

Conway (Wales) oysters introduced to St. Andrews, N.B. and Ellerslie, P.E.I. showed heavy mortalities associated with low winter water temperatures (Medcof, 1961b). Gaarder and Bjerkan (1934) stated that *O. edulis* can tolerate temperatures slightly below 0 C. Korringa (1957) suggested that there are races which show differences in cold hardiness.

Spawning can occur at 15 to 16 C with more successful spatfall resulting from more prolonged higher temperatures (Korringa, 1941); minimum salinity for normal growth and setting of larvae was found to be about 22.5‰ (Davis and Ansell, 1962). Davis and Calabrese (1964, 1969) showed that satisfactory larval growth occurred at lower temperatures in this species than in *C. virginica*. The species is larviparous and is therefore better suited to open or high-exchange conditions.

Since this report was prepared Dutch oysters (imported via the United States) have survived a winter at Ellerslie, P.E.I., with several weeks below 0 C; these have been successfully bred for trial introduction in eastern Canada (Drinnan, in litt.).

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APPENDICES - - TABLES 1 TO 3

Appendix Table 1. Measurements of seed oysters held in a bottom tray at Two-Guts Pond.

Date		Mean length (mm)	Mean width (mm)	No. examined live	dead[a]
1965	May 24	61.7	38.4	511[b]	0
	June 28	63.0	40.7	288	8
	July 21	65.3	44.2	289	0
	Aug. 25	69.4	51.8	289	0
	Sept. 28	69.6	49.8	289	0
	Nov. 2	68.9	48.0	288	0
	Nov. 25	68.3	48.3	289	0
1966	July 12	70.5	50.1	283	3
	Oct. 31	70.4	49.6	281	0
1967	May 11	69.0	47.4	259	4
	Aug. 6	71.1	50.9	124[c]	1
	Oct. 17	70.0	47.2	164	2
1968	May 8	70.0	48.3	160	3
	June 11	73.0	50.3	159	1
	July 22	73.8	51.0	160	0
	Aug. 5	74.3	51.7	159	0
	Sept. 9	73.9	50.5	157	1
	Oct. 15	73.6	49.9	97[d]	0

[a]Dead specimens not measured.

[b]Measurements include specimens placed in surface tray.

[c]Specimens added to tray (after measurements taken) to replace those lost through damaged tray bottom.

[d]Specimens lost through disintegration of tray bottom.

Appendix Table 2. Measurements of adult oysters held in trays at Two-Guts Pond.

Date		Mean length (mm)	Mean width (mm)	No. examined live	dead[a]
		Surface tray			
1965	June 28	112.4	38.2	156	8
	July 21	106.5	36.9	169	2
	Aug. 25	114.6	39.7	145	6
	Sept. 28	104.2	37.8	159	6
1966	Aug. 9	113.4	41.3	121	13
		Bottom tray			
1965	June 28	105.8	31.6	228	12
	July 21	111.5	39.5	237	15
	Aug. 25	115.4	43.9	217	8
	Sept. 28	113.4	43.2	225	2
1966	Aug. 9	114.1	42.6	169	50

[a]Dead specimens not measured.

Appendix Table 3. Percentages of oysters examined at Two-Guts Pond in 1968 which had the given epibionts.

	May	June	July	Aug.	Sept.	Oct.	Nov.
				Bottom Tray Seed			
Mytilus edulis	0.0	1.3	0.6	0.6	0.6	0.0	...
Littorina sp.	8.1	8.2	13.1	0.0	7.0	3.1	...
Anomia aculeata	1.3	0.0	0.0	0.0	0.0	1.0	...
Crepidula fornicata	0.0	0.0	0.0	0.0	0.0	0.0	...
Scale worms	0.0	0.6	1.9	0.0	0.6	0.0	...
No. examined	160	159	160	159	157	97	...
				Free Plant Seed			
Mytilus edulis	0.0	0.0	0.0	0.0	1.7	0.0	0.0
Littorina sp.	3.4	0.0	0.0	0.0	1.7	6.5	0.0
Anomia aculeata	0.0	0.0	1.8	0.0	5.0	4.3	4.0
Crepidula fornicata	0.0	1.4	1.8	6.4	1.7	10.9	10.0
Scale worms	0.0	0.0	0.0	0.0	0.0	6.5	2.0
No. examined	58	70	57	47	60	46	50
				Free Plant Adult			
Mytilus edulis	0.0	0.0	2.1	0.0	0.0	0.0	0.0
Littorina sp.	3.4	0.0	2.1	0.0	0.0	0.0	2.0
Anomia aculeata	0.0	4.7	0.0	0.0	0.0	5.9	2.0
Crepidula fornicata	10.3	9.4	8.3	4.0	3.1	5.9	8.0
Scale worms	5.2	0.0	0.0	0.0	0.0	3.9	4.0
No. examined	58	64	48	50	64	51	50