Reprinted from

PROCEEDINGS OF THE NATIONAL SHELLFISHERIES ASSOCIATION

Volume 52

1961

MORTALITY IN PACIFIC OYSTER SEED

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With a Statistical Appendix by W. E. Ricker

ABSTRACT

Mortality in Pacific oyster seed is due mainly to silting and to competition for space on the cultching medium. This takes place within a year of planting and silting mortality probably occurs within a few months. Competition for space may vary with the rate of growth and rate of silting mortality. The possibility of reducing these losses is discussed.

Growers of oysters, whether Eastern or Pacific, have no illusions about the fact that mortality occurs in their seed. In British Columbia there has been little appreciation of the extent of mortality, the time, or the cause. This has, in part, been due to the fact that the industry thinks in terms of volume rather than numbers until the point where oysters are shucked. The Pacific oyster grower, in contemplating yields of 7 to 10 bushels for each bushel of seed planted, tends to congratulate himself when he thinks of his eastern counterpart with an approximate one-to-one return.

In terms of numbers, however, the British Columbia grower suffers average mortalities of 75 per cent or more during the period from planting to harvesting. This amount of loss warrants examination. For this purpose three sources of data are available.

1. Mortality of High Count Seed

Five cases of Japanese oyster seed containing 422,000 spat counted when packed in Japan were planted at the 3-foot tide level in Ladysmith Harbour on mud-gravel ground with a thin layer of silt. The firmness and lack of silt provided ground that would be considered somewhat better than average. Estimates of the number surviving were made at yearly intervals for three years. Assuming no mortality in transit the successive total mortalities at survival intervals were 87.5 per cent, 91.5 per cent and 91.7 per cent. Allowing for shipping mortality the loss during the first year is considerable in contrast to that during the remaining two years. This provided an indication of the approximate amount and time of mortality.

2. Raft Culture Mortality

During work on the development of raft culture techniques applicable to British Columbia conditions information was obtained on the survival of spat on hanging strings. With the cultch off the bottom the problem of silting was eliminated along with significant predator activity. Mortality in one study amounted to about 60 percent in a period of 12 months while in another one over a period of 8 months the mortality was only 35 per cent. The main difference was a reduced number of spat per unit of cultch and increased size of spat, in addition to a shorter time period, in the second trial.

3. Designed Experiment

The information derived from the two described studies indicated a designed experiment combining the essentials of each one. Simply, this was a comparison of the mortality of seed grown on the bottom with that grown off the bottom.

The experiment was arranged in a 2 x 2 Latin Square replicated four times. Each treatment (on bottom, off bottom) was repeated twice in each of the four blocks which were laid out at equal intervals on a predator-free intertidal beach in Ladysmith Harbour between the 6-foot and the 1-foot tide levels.(Mean sea level 8.0 ft, range 16 ft.)

Each square consisted of two 3 x 3 ft plots on the bottom and two 3 ft x 3 ft x 4 inch trays of 10 gauge, one-inch mesh galvanized wire trays held about 12 inches off the bottom by posts driven into the beach. The bottom plots were fenced by six inches of one-inch mesh chicken wire to prevent possible movement of the seed out of the plot.

The spat on 16 random groups of 100 shells of 1956 Japanese unbroken seed was counted. Each group of shells was allotted by chance (random numbers) to one of the 16 plots.

The seed was placed on the trays on 28 April 1956, and removed for counting on 17 November 1956. The tabulated results (survival) are shown in Fig. 1. The blocks and plots are arranged in the figure in the same relative position they held on the beach.

6-foot tide level

1238 (994) 80.2%	1406 (844) 55.6%
1518 (1015) 66.7%	2269 (1186) 52.3%

	Mean Survival	Mean Mortality
Tray	66.2	33.8
Bottom	61.1	38.9

2386 (1236) 51.4%	217 (753) 35.6%
1532 (5 48) 35.8%	1953 (1194) 61.1%

	Mean Survival	Mean Mortality
Tray	56.2	43.8
Bottom	35.7	64.3

1489 (1087) 73.8%	1827 (521) 25.8%
1670 (506) 30.3%	1956 (1325) 67.7%

	Mean Survival	Mean Mortality
Tray	70.7	29.3
Bottom	29.4	70.6

1-foot tide level

1330 (952) 71.5%	1385 (221) 15.9%
1470 (420) 28.6%	2133 (1224) 54.4%

	Mean Survival	Mean Mortality
Tray	64.4	35.6
Bottom	22.2	77.8
Total:		
Tray	69.4	35.6
Bottom	37.1	62.9

Fig. 1. Top number: original spat count April 27, 1956; bracket number: survival to November 17, 1956; T : tray.

Since the tray survival was nearly double bottom survival there is little doubt that the difference between the two treatments accorded the seed is significant. This is confirmed by a simple analysis of variance (Table 1).

Table 1.

Source of variation	D.F.	S.S.	M.S.	F.	P.
Blocks	3	995.2	331.7	-	-
Treatment	1	2,889.0	2,889.0	18.98**	< 0.01
Error	11	1,675.2	152.3	-	-
Total	15	5,559.4			

The significant factors contributing to seed mortality in the two treatments may be expressed as follows:

Bottom mortality = natural + competition for space + silting = 62.9%

Tray mortality = natural + competition for space = 35.6%

silting = 27.3%

Substituting the experimental values and cancelling out the common factors of natural mortality and competition, an estimation of 27.3 per cent is obtained for silting mortality. This assumes, though it is not strictly true, that natural mortality and competition for space are equal for the two treatments. There is no evidence to suggest appreciable natural mortality so the tray mortality of 35.6 per cent may be accepted as a measure of mortality due to competition for space. This is illustrated in Table 2 where lowest mortality on the trays is shown to occur where the spatfall per unit of area, and consequently, competition for space, is least.

Table 2.

Spat count (100 shells)	Survival	Per cent survival	Per cent mortality
2,386	1,236	51.4	48.6
2,269	1,186	52.3	47.7
2,133	1,224	57.4	42.6
1,956	1,325	67.7	32.3
1,953	1,194	61.4	38.6
1,489	1,087	73.8	26.2
1,330	952	71.5	28.5
1,238	994	80.2	19.8

Of interest is the relationship between mortality (Fig. 1), particularly on the bottom, and tidal height, for there is a marked silting gradient down the experimental beach as there is on most sloping beaches in British Columbia. Silt tends to be deposited and remain at the lower tidal levels due largely to reduced wave action. Greater wave action keeps the higher levels clear. Statistical analysis indicated there is a near-significant difference in mortality between blocks with reference to the bottom plots (Table 3), correlating well with the known degree of silting.

Table 3. Test of significance of differences between blocks in percentage mortality (data from the Appendix)

Effect	D. of F.	S. S.	M. S.
Blocks	3	995.2	331.7
Error	8	699.4	87.4
Total	11	1,694.6	

$$F = \frac{331.7}{87.4} = 3.79 \quad \text{d. f. 3, and 8} \quad P = \text{ca. } 0.06$$

A similar correlation was obtained from raft culture studies where presumably the main source of mortality is competition for space. In Appendix A, Dr. W. E. Ricker has developed a more sophisticated analysis of the data.

This discussion of spat mortality is reduced to its simplest terms for it is much more complicated. The degree of natural mortality with the two treatments is not known though it is unlikely to be high. The relationship between silting mortality and competition for space is probably quite complex and how they interact probably depends largely on the rate of growth: the greater growth is, the less silting mortality, but the higher is the rate due to competition for space.

ECONOMICS

The economic implications are fairly obvious. The greater the seed mortality the greater the amount of seed required for a given production.

Silting mortality may be reduced by using special seed grounds, for instance, Olympia oyster dikes produce from 2 to 3 times the average industry yield of Pacific oysters. It is possible to create seed ground. In British Columbia there is considerable ground that is submarginal for a full Pacific oyster culture but could grow seed most effectively.

Competition for space on the cultching medium is inevitable but it may be reduced by using smaller units of cultch.

APPENDIX A

STATISTICAL ANALYSIS

The scheme below gives the percentage mortality in each box of the experiment, and the various groupings used. The raised trays ("treated" samples) are marked "T".

Actually, row 1 and row 2 were always side by side, as were column 1 and column 2, so that no detectable differences were expected to result from relative positions in rows or columns. However, partly to test this expectation, and partly to show how a moderately complex analysis can be done, the contributions of rows and columns are separated out below.

	Column 1	Column 2	Totals	Totals	
Row 1	80(T)	56	136	255	Block 1
Row 2	67	52(T)	119		
Row 1	51(T)	36	87	184	Block 2
Row 2	36	61(T)	97		
Row 1	73(T)	28	101	199	Block 3
Row 2	30	68(T)	98		
Row 1	71(T)	16	87	173	Block 4
Row 2	29	57(T)	86		
Totals	437	374	811		

The first step is to compute the correction term and total sum of squares:

Correction term $= 811^2/16 = 657721/16 = 41107.6 = C$

Total sum of squares $= \dfrac{80^2 + 56^2 + 67^2 + \ldots + 57^2}{1} = 46667 - C = 5559.4.$

The sum of squares for the obvious groupings are as follows:

$$\text{S.S. for columns} = \frac{437^2 + 374^2}{8} - C = 247.0; \qquad \text{d.f.} = 1$$

$$\text{S.S. for rows} = \frac{411^2 + 400^2}{8} - C = 7.5; \qquad \text{d.f.} = 1$$

$$\text{S.S. for treatments} = \frac{513^2 + 298^2}{8} - C = 2889.0; \qquad \text{d.f.} = 1$$

$$\text{S.S. for blocks} = \frac{255^2 + 184^2 + 199^2 + 173^2}{4} - C = 995.2; \qquad \text{d.f.} = 3$$

The figures in each block of four can be combined by two's in 3 ways: horizontally, vertically and diagonally. This gives a measure of the interaction of block differences with row effects (I, below), with column effects (II), and with treatment effects (III), respectively.

I. Sum of squares for rows (r) + blocks (b) + r - b interaction

$$= \frac{136^2 + 119^2 + 87^2 + \ldots + 86^2}{2} - C = 1094.9$$

Effects	S.S.	d.f.
r + b + r - b interaction	1094.9	7
r	7.5	1
b	995.2	3
r-b interaction (by difference)	92.2	3

II. Sum of squares for columns (c) + blocks (b) + c-b interaction

$$= \frac{147^2 + 108^2 + 87^2 + \ldots + 73^2}{2} - C = 1594.9$$

Effects	S.S.	d.f.
c + b + c - b interaction	1594.9	7
c	247.0	1
b	995.2	3
c-b interaction (by difference)	352.7	3

III. Sum of squares for treatments (t) + blocks (b) + t-b interaction

$$= \frac{132^2 + 123^2 + 112^2 + \ldots + 45^2}{2} - C = 4859.9$$

Effects	S.S.	d.f.
t + b + t-b interaction	4859.9	7
t	2889.0	1
b	995.2	3
t - b interaction (by difference)	975.7	3

IV. The breakdown above is summarized as follows:

Effects	d.f.	S.S.	M.S.
1. Treatments	1	2889.0	2889.0
2. Columns	1	247.0	247.0
3. Rows	1	7.5	7.5
4. Blocks	3	995.2	331.7
5. t - b interaction	3	975.7	325.2
6. c - b interaction	3	352.7	117.6
7. r - b interaction	3	92.2	30.7
Total	15	5559.3	

As mentioned above, the design of the experiment suggests there should be no real difference between columns or rows, hence, also no interactions between these and the blocks. If so, items 2, 3, 6 and 7 above should be added to obtain the best estimate of random variability in the experiment:

Effects	d.f.	S.S.	M.S.
c + r + c - b + r - b	8	699.4	87.4

This is now used to test the significance of the block effect and the block-treatment interaction (the treatments themselves were tested with sufficient precision in Table 1, but they, too, could be tested in this way):

For blocks, $F = \frac{331.7}{87.4} = 3.79$; d.f. = 3, 8; $P \sim 0.06$

For b-t interaction, $F = \frac{325.2}{87.4} = 3.72$; d.f. = 3, 8; $P \sim 0.06$

Both of the above are only slightly below the conventional 5 per cent level of significance.

It is noteworthy that the mean squares for the columns and (to a less extent) the column-block interaction are much larger than those for rows and row-block interaction. It is perhaps imaginable that the two first-mentioned differences could be real, because of some net "set" of the current along the beach, for example. If so, they should be removed from the random error estimate, which latter then becomes the sum of items 3 and 7, giving a mean square of 24.9 for 4 degrees of freedom. Using this in the F test, the block differences and b-t interaction yield P values about 0.02—0.03. However, the more conservative F values first quoted are sufficient to demonstrate the likelihood of real differences between blocks (namely, decreased survival with increasing depth) and a real interaction between blocks and treatments (the raised trays doing more to reduce mortality in the deeper water than in the shallower). The probable reason for the direct effect is increased silting in deeper water, as explained earlier. The interaction also is quite reasonable, for the greater mortality in controls at the lower levels gives more scope for the "treatment" to be effective.

Designs similar to the above should have wide application in shellfish culture experiments. The one used here could be made to have a wider applicability with little or no extra work, simply by varying the conditions in the rows or the columns. For example, the two columns could be set out on different beaches instead of side by side; or in the two rows the spat might be set out at different densities. In fact, both these could be varied simultaneously, though there would then be some risk of inflating the error estimate because of possible column-block and row-block interactions, hence making it difficult to recognize block or even treatment effects. Another technical improvement, in an experiment where mortalities were really severe, would be to use survival rates instead of mortality rates in the analysis; or better, to use the logarithms of survival rates, which are proportional to the instantaneous mortality rates.

SELECTED BIBLIOGRAPHY

Cochran, W. G., and G. M. Cox. 1957. Experimental Designs. 2nd Ed. John Wiley and Sons, Inc., New York.

Cochran, W. G. 1953. Sampling Techniques. John Wiley and Sons, Inc., New York.

Cox, D. R. 1958. Planning of Experiments. John Wiley and Sons, Inc., New York.

Wishart, J., and H. G. Sanders. 1955. Principles and Practices of Field Experimentation. 2nd Ed. Technical Communication No. 18, Commonwealth Bureau of Plant Breeding and Genetics. W. Heffer and Sons, Ltd., Cambridge.

Yates, F. 1953. Sampling Methods for Censuses and Surveys. 2nd Ed. Charles Griffin and Co., Ltd., London.