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OBSERVATIONS ON THE OYSTER (*Ostrea edulis*) BREEDING EXPERIMENTS AT CONWAY, 1939 - 1953.

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Introduction.

Experiments on breeding oysters on a semi-commercial scale have been made in many countries - Denmark, Germany, Great Britain, Holland, Japan, Norway and the U.S.A. The longest series of such experiments has been made at this laboratory where frequent successful spatfalls have been obtained. Some of the earlier experiments, those for the years 1936-38, have been described by Cole (1937, 1939). In this paper, some of the conditions observed in the years 1939-53 are described and their importance for successful tank breeding is discussed. The author has been associated with the experiments since 1947.

The general technique followed at Conway in the years 1939-53 was the same as described by Cole (1938), and there has therefore been a long series of comparable experiments; in some a heavy spatfall occured while in the others the spatfall was less heavy or occasionally negligible. An examination of the conditions observed during these experiments throws some light on the conditions which may lead to success.

Each year, two identical concrete tanks, labelled respectively 'A' and 'B', have been filled with 85,000 gallons (386,000 l.) of sea water pumped up from the estuary of the Conway river during a spring tide, sometime between the middle of May and the middle of June. Each tank was stocked with between 500 and 600 adult oysters. A high density of larvae - more than 50 per litre - was invariably present at intervals during July and August. In most years the major part of the spatfall occurred during the month of July. A study, therefore, of the conditions during this month can be expected to give some indication of the conditions necessary for the production of a heavy spatfall.

Salinity was measured as specific gravity by hydrometers and converted, using Knudsen's tables, and pH by comparison with standard buffer tubes of the indicator, Thymol Blue. Flagellates were counted on a haemacytometer after concentration according to the technique described by Cole and Knight-Jones (1949). Spatfall was recorded by counting daily the number of spat which settled on 10 bleached oyster shells placed on a slatted tray hanging 1 foot (30 cm.) below the water surface. After the daily count all spat were removed and the shells carefully cleaned. The total number of spat which settled on these shells in the course of July gave a good indication of the successful growth and metamorphosis of the oyster larvae. Weather conditions are recorded at the laboratory but use has also been made of records from Llandudno, four miles away.

Physical & chemical Factors.

Weather. No connection can be demonstrated between the weather conditions in July (Table 1) and the spatfall during that month. Good spatfalls have been obtained in both sunny years (1946) and very dull years (1944); wet years (1939) and dry years (1946); warm years (1941) and cold years (1940).

Water temperature. The range of the mean daily temperature in July for 9 years in 'B' tank is shown in Table 2. During July, the temperature generally exceeds 20°C. for several days, but a spell of wind will quickly reduce the temperature by several degrees. In general, the water in the tanks always becomes warm enough for a period each summer for the liberation and growth of oyster larvae.

Some investigations have been made of the temperature rise resulting from the establishment of a fresh water layer on the surface of the tank. A 4 in. (10 cm.) layer of fresh water on the surface of 'B' tank (1950) protected the tank from loss of heat during a cold spell. For 8 days after the fresh water layer had been established, the weather was fine and sunny and the temperature of both 'A' tank (without a fresh water layer) and 'B' (with a fresh water layer) tank rose from about 17.5° to 20.1°C. During the following 7 days the weather deteriorated and the temperature in 'A' tank fell steadily to 16.0°C. whereas in 'B' the temperature remained at over 20°C. At the end of the experiment, when the tanks had to be emptied, oyster larvae were present in larger numbers in 'B' tank than in 'A'. Other experiments have been made with similar results, but, as the fresh water layer is quickly dispersed by a strong wind, its practical value is limited. Temperature control is not, at present, an important problem.

Salinity. The initial salinity in the tanks ranges from 31.0 to 33.0‰, according to the amount of fresh water present in the estuary when the tanks are filled. The salinity of the tanks generally rises a little during the summer, as evaporation exceeds rainfall, but it rarely exceeds 34‰.

Salinity does not seem to be a very important factor as successful spatfalls have been obtained in July with the minimum salinity varying from 31.7‰ to 34.0‰ although a higher proportion of years were successful where the minimum salinity was less than 32‰.

pH. None of the pH figures quoted in this paper have been corrected for salt error.

The pH of the water in the tanks immediately after filling varied between 8.0 and 8.4. A high initial pH indicates a recent high level of phytoplankton production in the estuary. At Conway in May and June the most frequent cause is a *Phaeocystis* bloom. If the pH is high at the beginning of the season it usually remains high throughout the summer but if the initial pH is low, a marked rise may or may not occur in July; in either set of circumstances large populations of flagellates may develop in the tanks. A bloom of flagellates, 2 μ or less in size, has much less effect on the pH than a multiplication of diatoms and non-motile Chlorophyceae.

In Figure 1, the minimum pH in the tanks in July is related to the maximum flagellate count and the spatfall. It will be seen that, with one exception, successful spatfalls have only occured when the minimum pH in July has been below 8.3. This may be a direct or an indirect relationship, as these good spatfalls are also associated with high populations of flagellates (Fig.1). It is possible that water of a high initial pH has already been impoverished, e.g. by a *Phaeocystis* bloom, and is therefore unsuitable for supporting the high population of flagellates which would in turn nourish a large population of oyster larvae.

Phosphate. Some observations were made during the 1951 season when about 8 mg.P per m^3. were present at the end of June. During July the level varied between 5.5 and 6.2 mg.P in 'A' and 3.3 and 6.7 mg.P in 'B' per m^3. The addition of balanced quantities of sodium or potassium nitrate and sodium phosphate to various smaller tanks (20,000 - 30,000 gallons) has always stimulated the production of diatoms and not flagellates.

Oxygen. The few determinations which have been made from time to time have given results lying between 95 and 106% saturation. No evidence of stratification was found.

Turbidity. Observations with a photocell in 1949 showed that the absorption of the light at the bottom of the tank varied between 29% and 45% during the summer. The variation was principally due to changes in the concentration of nanoplankton.

Biological Factors.

Zooplankton. Within two or three weeks of filling, most of the original zooplankton has either metamorphosed or died during the remainder of the season copepods, especially *Isias clavipes*, are, with oyster larvae, often the only abundant members of the zooplankton.

Phytoplankton. Phytoplankton is sometimes abundant when the tanks are filled, especially one or more species of Phaeocystis, Rhizosolenia or Chaetoceros. These do not persist in the still waters of the tanks and during the rest of the season pelagic diatoms are generally scarce.

Detailed records have been kept of the abundance of flagellates less than 10 μ in size as it has been amply demonstrated that it is on such forms that oyster larvae feed. The range of densities of flagellates less than 10 μ in size is shown in Tables 2 and 3 and in Figure 1 the maximum density is related to the spatfall and minimum pH. It is apparent that, with high populations of flagellates, the chances of a good spatfall are considerably enhanced.

Finely ground shore crabs (Carcinus maenas) have been used as a source of organic enrichment in an endeavour to promote a favourable flagellate population (Tables 2 and 3). The results show that the denser population of flagellates produced is not necessarily of value in increasing the spatfall; further, substantial populations of flagellates have occurred in tanks which have not been enriched ('A' tank in 1940 and 1943).

Discussion.

These notes have outlined the range of conditions which have been observed at Conway in the oyster breeding experiments during the last 15 years. Taking the cumulative daily spatfall on 10 oyster shells as an index, successful spatfalls (over 1,000 spat) in July seems to be associated with a low minimum pH (below 8.3), and a maximum flagellate count of over 100 flagellates of less than 10 μ in size per mm^3. (see Figure 1). It is also possible, but not so clearly demonstrated, that a minimum salinity of less than 32‰ is also favourable.

The exception is 1939 (tank 'B'), when a very good spatfall occurred in July with a maximum flagellate count of 43. That season, although very good spatfalls occurred in both tanks ('A' tank in August and 'B' in July), the flagellate counts were always rather low.

There were three other seasons in which the major spatfall did not occur in July. In 1945 there was one in both tanks in the first fortnight in August when the high flagellate population continued from July. In 1947 (tank 'A') the spatfall was high in August although the flagellate population was only moderate.

In the period of 15 years (1939-53) under review, 11 very successful spatfalls have been recorded, of which 8 have occurred in conditions of low minimum pH in July, combined with a high flagellate population.

It is apparent from Figure 1 that a high flagellate population is associated with a low minimum pH in July; high flagellate populations have not been recorded in tanks in which the pH of the water has exceeded 8.3 at the beginning of the month. If the pH in the tanks is high at the beginning of the season, it is usually because they have been filled at the time of a phytoplankton outburst and it is reasonable to assume that such water has been impoverished and will not support a large flagellate population. The success which has been associated with a low pH may not, therefore, be due only to a reaction between the oyster larvae and water of a low pH, but in part also to the fact that such water is more often capable of supporting a large population of food organisms for the larvae. Experiments, however, made in this laboratory show that, with equal food supplies, better growth and settlement of oyster larvae are obtained from pure culture feeding experiments with a low pH than those with a high pH.

Allthough there is ample quantitative data on the flagellate population in the tanks, flagellate systematics is not sufficiently advanced for the population to be regularly explored qualitatively. The following paragraph is, therefore, largely speculative.

A high flagellate population is probably needed because the population is mixed and only a proportion of the species present are suitable food organisms. Occasions will, therefore, occur when although the flagellate population is high, good results are not obtained because the useful food organisms comprise too small a proportion of the species present (e.g. 1944, tank 'A' and 1943, tank 'B'). Similarly, very good spatfalls may be obtained when the flagellate population is low (tanks 'A' and 'B', 1939) because most of the species present are satisfactory food organisms.

To make further advances in tank breeding possible, the writer considers that a method must be found by which a high density of a proved suitable food organism may be maintained in breeding tanks. Oyster larvae are thought to be nourished by a comparatively small range of flagellate species and simple enrichment may not be satisfactory as it does not necessarily produce an outburst of food species. Smaller tanks, in which the conditions may be more closely controlled, may be required. Experiments in this laboratory (unpublished) have shown that, with suitable feeding, more than 1,000 larvae will mature and metamorphose per litre of sea water.

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Table 1.

The weather during July 1939-53. The rainfall and sunshine were recorded at Conway and the temperature at Llandudno.

	Rainfall mm.	Sunshine hours	Mean temperature °C	
			Maximum	Minimum
1939	102.87	127	18.3	12.8
1940	83.82	141	17.8	12.8
1941	38.60	170	19.4	12.8
1942	56.13	153	18.3	12.2
1943	38.35	197	18.9	12.2
1944	45.97	90	18.9	13.3
1945	41.91	145	18.9	12.8
1946	25.65	194	18.3	12.2
1947	30.98	127	19.4	12.8
1948	33.78	129	18.6	12.9
1949	20.82	154	20.6	13.3
1950	36.83	146	19.4	12.8
1951	20.86	124	19.4	12.8
1952	40.89	144	19.2	13.6
1953	40.64	157	18.6	12.9

Table 2.

Tank 'A'. The range of conditions during the month of July. In the enrichment column, the total number of crushed crabs added in the two months, June and July, is given.

	Salinity ‰	pH	Flagellates less than 10 $/^{u}$ per mm^3	Enrichment Crushed crabs	Spatfall on 10 shells	
					July	June, July and August
1939	31.6 - 32.7	8.22-8.35	10 - 32	0	541	2355
1940	32.9 - 33.5	8.10-8.57	13 - 161	0	5001	5018
1941	33.3-33.9	8.10-8.37	23 - 79	0	176	176
1942	33.1 - 33.9	9.20-8.25	19 - 44	0	1	149
1943	32.6 - 33.3	8.22-8.50	57 - 139	0	449	467
1944	32.6 - 33.1	8.20-8.30	69 - 136	96	70	70
1945	32.8 - 33.3	8.12-8.32	77 - 145	46	103	2109
1946	31.7-33.2	8.07-8.17	14 - 158	38	1022	1291
1947	32.4-33.9	8.10-8.17	22 - 68	0	219	2135
1948	30.6-33.0	8.02-8.10	18 - 54	0	0	588
1949	33.0-34.0	8.20-8.37	10 - 32	0	0	0
1950	31.7-33.9	8.35-8.65	32 - 60	30	64	68
1951	32.5-33.7	8.42-8.52	11 - 33	5	0	0
1952	33.3-33.9	8.35-8.55	12 - 20	0	12	12
1953	31.4-32.4	8.30-8.40	17 - 53	0	248	338

Table 3.

Tank 'B'. The range of conditions during the month of July. In the enrichment column, the total number of crushed crabs added in the two months, June and July, is given. The tank was enriched in 1939, 1940 and 1941 but no record was kept of the total number added. In 1952 a very large number of *Ascidiella aspersa* settled in the tank and kept the nanoplankton at a very low density.

	Salinity ‰	pH	Water Temperature °C	Flagellates less than 10 μ per mm^3	Enrichment Crushed crabs.	Spatfall on 10 shells July	Spatfall on 10 shells June, July and August
1939	31.8-32.7	8.4 - 8.50	-	8 - 43	Not recorded	4713	5550
1940	32.0-33.6	8.15- 8.70	-	43 - 281	"	1677	1942
1941	34.0-34.8	8.22- 8.47	-	23 - 104	"	8574	8602
1942	33.0-34.1	8.25- 8.35	-	24 - 68	137	1	201
1943	32.6-33.5	8.32- 8.67	-	55 - 176	88	42	99
1944	32.5-32.9	8.27- 8.37	15.8-20.7	62 - 424	48	4275	5897
1945	32.9-33.2	8.12- 8.40	15.7-20.6	72 - 140	46	852	2334
1946	31.8-33.3	8.12- 8.20	16.4-22.1	40 - 123	38	3806	3817
1947	32.6-33.7	8.12- 8.32	-	28 - 56	0	167	182
1948	32.7-33.0		14.0-22.8	21 - 36	0	18	25
1949	33.1-33.9	8.30- 8.45	17.9-22.8	21 - 24	30	0	8
1950	32.4-33.2	8.40- 8.50	18.6-20.4	23 - 68	42	48	118
1951	32.5-33.5	8.47- 8.55	16.8-20.6	13 - 50	0	6	26
1952	33.4-34.1	8.40- 8.60	16.7-21.7	11 - 23	184	84	84
1953	31.0-32.7	8.30- 8.45	17.3-22.9	18 - 51	120	60	66

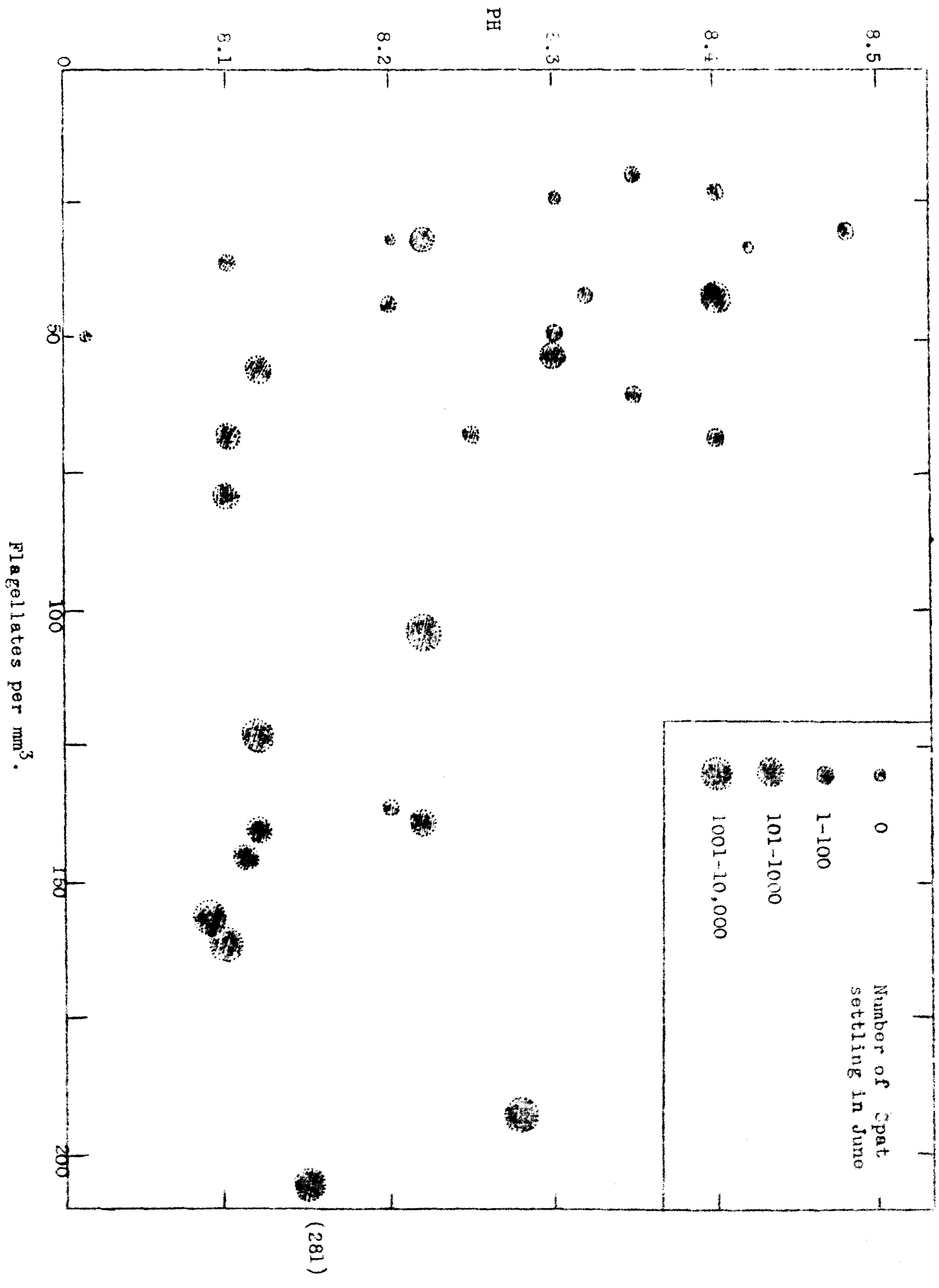

Fig. 1. The relation between the size of the spatfall, the minimum pH and maximum flagellate count during July, 1939-53. Each spot, the size of which varies according to the total spatfall recorded on 10 shells, represents the conditions in one experiment.