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OYSTER STUDIES AT THE P. E. I. BIOLOGICAL STATION  
JUNE to SEPTEMBER

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#160

1937

J. C. Medcof.

### Acknowledgments

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J. C. Medcof.

## Table of Contents

Title Page

Acknowledgments

### On Spat

History of the Season's Spatfall.....	1
Age Groups of Larvae and the Prediction of Spatfall.....	4
Spat Survey.....	12
The Intensity of Spatfall with Relation to Depth..	16
On the Effect of Crowding Collectors on the..... Intensity of Spatfall	23
On the Collecting Efficiency of Surfaces and the.. Effects of Fouling	26
On the Efficiency of Tar-Coated Collectors.....	30
The Special Case of Sample 9a of the Spat Survey..	32
Proposed Changes in the Present Arrangement of.... Cultch.	34

### On Larvae

Agencies Destructive of Oyster Larvae.....	26
Dinoflagellate Parasites of Mussel Larvae.....	39
Parasitism of Larvae by Small Flagellates.....	45
Nannoplanktonic Studies.....	47
Feeding Experiments.....	49
On the Feeding and Food of Larvae.....	51
History of the Season's larvae.....	54
Report on Plankton Tows.....	54
Rearing of Oyster larvae from Artificially ..... Fertilized eggs.	57

Table of Contents Continued

Miscellaneous Studies

Observations on Shipworms..... 58  
Observations on the Spat of Quahogs and Soft-Shell  
Clams.....60  
Literature Referred to..... 61

Graphs and Charts

To follow Page

Graph I. Temperature, Salinity and Spatfall for  
1937..... 1  
Chart I. Map showing extent of Spatfall in the  
Bideford river region. 12  
Graph II. Relation of Intensity of Spatfall to..... 17  
Angle of Inclination of Cultch  
Graph III, Relation of Intensity of Spatfall to  
Depth..... 17

## HISTORY OF THE SEASON'S SPATFALL

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In order to study the spatfall, daily counts were made on ten shells exposed to the river water while attached to a fixed support at the station landing stage. These were perforated centrally and arranged at intervals of 18 inches on two separate vertical chains such that the concave surfaces of the shells on one chain faced up while those of the other were inverted. The water at the stage is 7 - 8 feet deep at normal half tide so the support for the shells was arranged in such a way that at that stage of the tide the top shells were immersed to a depth of 4 - 6 inches. In this position the bottom or fifth shell of each chain was within 6 inches of the bottom.

Hopkins ('37), has pointed out that the spatfall of oyster larvae on the rough outer convex surface of shells is usually greater than on the smooth inner concave surface. To simplify counting, which was done with the aid of a 20x lens system in a binocular microscope, the property of Dr. A. B. Needler, only the spat on the smooth surface were counted. The results of the counts appear in tabular form below (Table I.). After each count the shells were thoroughly washed so as to leave the surfaces free of any silt and spat that might have settled on them since the last washing.

Counts on such limited areas as that of 10 shells might permit considerable error but when these are repeated over and over throughout the summer the dependability of the results increase so as to have at least relative significance even if quantitatively, they may be in error.

During most of the summer the daily counts were made at 9 A. M. The spat counted on any particular day are therefore those which settled during the previous 24 hours. In this study the exact time of spatfall is of some importance so that in the record (Table I.), the set is always listed as one day earlier than the actual date of observation.

A clearer idea of the seasonal variation in spatfall may be had by averaging the 10 counts for each day and plotting the results graphically. This latter has been done below the temperature curve on Graph I. The curve represents the average daily potential set on clean shell surface at five different depths at the station landing stage. For the whole season this totals 182 spat per 10 square inches of shell surface, or in terms of commercial collectors, 145 per square (counting both sides).

Similar counts were made on a chain of inverted shells suspended from a float in Paugh's creek but with these daily observations were impossible. In a general way the sets at this station correspond in time with those at the stage but the season's total set, if we compare inverted shells, was only 22% of that at the landing stage. The results of the Paugh's creek counts appear in Table II.

The slighter set may be due partly to the fact that the shells there were cleaned less often than those at the stage. Hopkins ('37) shows that due to fouling collectors exposed in Oyster bay for 10 days before settlement began had only 63% of the collecting efficiency of fresh collectors.

TABLE II.

Date	July																August					
	14	15	16	17	18	(19	20)	(21	22)	23	24	25)	(26	27)	28	(29	30	31	1	2)		
Depth at 8"	4	1	0			20		0		4		4						20				
Normal	26	0	5			4		0		5		10						19				
Half-Tide	44	3	5			4		4		24		4						18				
Inverted	62	5	8			4		3		9		8						17				
<u>Shells</u>	80	0	7			9		11		8		9						16				
Total Set for Date	12	8	25			24		18		52		35						90				
Average set per shell	2.4	1.6	5			3.2	3.2	1.8	1.8	3.3	3.3	3.3	3.5	3.5				1.8	1.8	1.8	1.8	1.8

August Cont'd		Total Catch for Season	% of Total Set
3	4		
	1		13
	2		16
	0		22
	8		26
	2		23
13		284	
1.3 1.3		56.88	

Showing the Spatfall on 5 shells  
Suspended from a Float in Paugh's Creek

Observations on organisms other than oysters that settled on the shells are summarized below (Table III.). Here, contrary to the practise in recording oyster spatfall, the observations are listed opposite the dates on which they were actually made. It will thus be understood that all the spat recorded fell during the 24 hours previous to 9 A. M. of the date listed.

TABLE III.

Date	Number and kind of spat.			Remarks
	Mussel Spat	Slipper Limpet	Barnacles	
June 27		1		
28		1		
29		2		
July 2	1	1	4	All the barnacles were on the inverted shell <u>6'</u> below the half-tide surface.
" 3	1			
" 4		2		
" 7	116			By far the heavier set was on the inverted shells and all but 12 set in the upper 4½' of water.
" 8				
				Examination of the Faugh's creek shells showed that there was a heavy settlement of mussels largely limited to the upper shell.
" 10	240	52	13	The peak settlement of mussels occurred at the 4½' level. All but three of the barnacles settled below the 4½' level.
" 14	53	7	13	The heavier set of barnacles was on the inverted shells and all but 4 were below the 4½' level.
" 16				Examined the Faugh's creek collectors. A heavy set of mussels now grown to 1 mm. in length. Some slipper limpets.
Aug. 9				A light set of mussels during the last few days.

Where not otherwise stated, the data presented here apply to the experimental collector shells, ten in number, suspended at the landing stage of the biological station.

Settlement of Spat (Other than Oysters) on the 10 Shells Held at  
The Station Landing Stage.

AGE GROUPS OF LARVAE AND THE PREDICTION OF SPATFALL

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"Thousands of dollars would be saved annually by the cyster men if they would determine with any approximate accuracy the date when attachment of the young oysters would occur." Winslow ('84).

The lowest curve of Graph I, representing the spatfall, shows distinct peaks. An explanation for the maxima might be sought in the periodical coincidence of suitable conditions for settlement. Hopkins ('31) reports for Galveston bay that only when the salinity rises to 20 parts per mille, does settlement occur. Frytherch ('28) discusses the effects of physical factors on settlement in considerable detail.

As compared with those in Galveston bay where Hopkins did his work the salinity conditions in the Bideford river, whose fluctuations might condition the periods of spatfall, are almost stable. Temperature is the only observed factor that varied to any extent during the settlement period this year and during the latter two-thirds of spatfall, even this remained almost constant. The stability of conditions in the Bideford river make it well adapted to a study of the length of the free-swimming period as influenced by temperatures. There is only a very slight change in water levels during a tidal cycle and the salinity conditions vary scarcely at all throughout the summer, (See the curves for the salinity at station 2003. This location is marked on the chart in the section on the spat survey).

Because of the constancy of these conditions it thus seems plausible to seek an explanation for the occurrence of maxima in

Their correlation with the various spasms of spawning that occurred during the summer, with the consequent establishment of age groups in the larval population. These groups maturing at different dates, might well produce the observed maxima. This attempted correlation study falls into two parts. The easier is the recognition of isolated temperature maxima which might have been responsible for distinct spawning bursts. The dates of the various spasms of spawning should fall in a sequence similar to that of the settlement maxima.

The other part of the study and much the more time-consuming of the two is the recognition of age groups from a size-frequency distributional analysis of samples of the larval population taken at regular intervals throughout the summer. Only the first of these two parts will be attempted here.

From the data of 1934 and 1936, reported in last year's accounts (Medcof '36), it appears that the length of the free-swimming period of the larva is approximately 24-25 days. Frytherch ('28), observed that in Milford Harbour when spawning occurs in an area it involves a great number of adults. The mass spawning requires a comparatively short period of time and thus the larvae are all of approximately the same age and will mature together and all settle at the same time within a day or two. Perkins and Nelson ('31) were able to separate broods that differed in age by only one day. A sharp isolation of age groups may then be expected to obtain whether they are separated by long or short periods in time of establishment, as was the case at Ellerslie in 1936 and 1937 respectively. Each

period of spatfall will be dealt with in the sequence in which it occurred during the season.

The First Set - July 15.

This maximum in spatfall seems to be correlated with a spawning induced by a rise in temperature on June 21 - 22. Although at the observation station itself the temperature did not rise to the spawning threshold of 20°C. (Churchill '20, Nelson '28), it is highly probable that the shallower upper reaches of the river were sufficiently warmed for spawning to have occurred there. To support this belief the maximum and minimum air temperatures for the period are taken from the station records and presented here.

Date	Maximum	Minimum
June 18	71 °F.	53° F.
" 19	79	54
" 20	87	48
" 22	86	54

The heating on June 20 and 22, (There were no records kept for June 21.) would no doubt raise the temperature of shallow waters well above the 20° C. level. The rapid falling off of the temperature on June 23 (See Graph I) would terminate spawning and thus isolate this first age group of the season very sharply.

According to Nelson ('28) there is a considerable latent period in the New Jersey waters after the temperature has risen

to the spawning threshold, before the actual release of eggs and sperms. This he concluded from examinations of plankton samples. Prytherch ('28) on the other hand during experimental observation found that if the ripe oysters are subjected to a sudden rise in temperature of a few degrees spawning will occur within half an hour. An examination of the season's records will show that all the temperature maxima inducing spawning were rather abrupt in their establishment. In calculating it seems logical therefore to include the day on which the temperature rise took place as the first of the free-swimming period. In this case, that of the first brood of the season, the period is 24 days.

It is remarkable that on June 8 and 15, other temperature peaks were reached which, although higher than that of June 22 seem to have induced no spawning at all. Larvae may have been born on these dates but none were recognized in the tows nor did any settlement occur which suggests that the oysters were not "ripe" for spawning at those dates. Another such case is suggested in the 1936 data for Ellerslie. Besides this Prytherch ('28), Hopkins ('31) and others have shown that oysters will not spawn unless they have had time to "prepare" for the process, regardless of how the temperature may fluctuate. It may even reach 25° C. without producing the reaction. Hopkins has summarized the situation ('37), "after the threshold temperature is passed spawning is dependent on other factors".

The Second Set - July 21.

This spatfall, no doubt, is the result of a spawning induced by the temperature rise of June 26 or 27. The free-swimming period

here then is 25 - 26 days. Like the first, this spawning probably occurred only at the head waters of the river for at the landing stage the bottom temperature, which alone is effective, seven feet down, stood at only 17 - 18 °C. The spawning during the few days succeeding June 27 must have been meager for the settlement fell off sharply on July 22. This condition may be accounted for by the relatively calm weather during the interval June 26 - 30 as is described below. The result was a warming of the surface waters so that the spawning wave did not involve the deeper and more extensive oyster population.

The Third Set - July 23 - 24.

The incidence of this set can best be understood from an examination of the weather records for the period June 26 - 30 and a study of the behaviour of the bottom and surface temperatures as represented in Graph II. The following data are taken from the station records.

Date	Time	Observations	Temperatures	
			Maximum	Minimum
June 26	7 A.M.	Mod. W. winds, cloudy	59°F.	51°C.
	6 P.M.	<u>Fresh S. W.</u> , part cloudy	81	58
June 27	7 A.M.	Mod. E. winds, part cloudy	72	50
	6 P.M.	Mod. SE, part cloudy	76	61
June 28	7 A.M.	Mod. SW, showers	65	51
	6 P.M.	Mod. SW, bright	86	65
June 29	7 A.M.	Mod. SE, part cloudy	65	58
	6 P.M.	Mod. SE, part cloudy	77	65
June 30	7 A.M.	<u>Fresh SE</u> , part cloudy, shrs.	69	63
	6 P.M.	Mod. SW, part cloudy	70	60

The table shows that there were two days when fresh winds were blowing. At those times there was, no doubt a churning of the waters to some extent so that spawning took place. That a warming of the bottom waters took place on June 26 is not shown by the water temperature records - it probably was limited to the upper waters of the river as was suggested above but settlement data support the belief that some mixing occurred. There then followed a period of relatively calm weather when the surface temperatures were three degrees higher than those on the bottom. The second "blow" came on the night of June 29 and the morning of June 30 with the fresh south east winds. The water temperature records plainly show that there was a general mixing of the waters from top to bottom until the temperature was almost uniform throughout, standing between 21 and 22° C. This sudden change seems to have brought on the first general spawning of the season, involving even the oysters in the deepest part of the channel of the river. The subsequent drop in water temperatures on July 1 and 2 would limit spawning activity. The isolation of this age group like the last, is not too complete however since the next temperature rise followed very closely.

The advantage of having records of both surface and bottom temperature data to assist in the interpretation of results is here well illustrated.

The Fourth and Peak Set of the Season - July 26 - 28.

This set was probably due to a spawning at a time of surprising heat for that season of the year, on July 4, 5, and 6. The spawning temperature was passed on the first day - July 4.

The only record, 20.0° C. of the bottom temperature which the station has, was made on that day, a Sunday, at 10.00 A.M. The heat of the day must have warmed the water several degrees above this level and brought on spawning the same day. The larval period is in this instance 23 - 25 days.

Settlement peaks after July 29 were too indistinct to justify the sort of treatment we have applied to the earlier maxima. A summary of the attempted correlations of likely spawning dates with those of settlement maxima appear below.

Probable Spawning Date	Date of Settlement Maxima	Length of the Free-Swimming Period
June 22	July 15	24 - 24 days
June 26 - 27	July 21	25 - 26 "
June 30	July 23 -24	24 - 25 "
July 4	July 26 -28	23 - 25 2

These free-swimming periods conform very closely to those for 1934 and 1936 in the Bideford river reported in the writer's report for last year. The apparent fixity in the length of this period within the temperature ranges encountered during these three years, would seem to justify the prediction of the dates of spatfall which the writer has attempted during 1927. It has been pointed out above that every rise of temperature is not followed by a spawning even though it be above 20° C. This<sup>is</sup> more likely to be the case during the early part of the season, if it is possible to generalize from the limited amount of data at our disposal. Conversely abrupt temperature rises which do not reach

the 20° C. level at the temperature observation station, may bring on spawning in the shallower parts of the river where the waters are more quickly warmed and often more thoroughly mixed by winds. In making any predictions then, it would be necessary, not only to examine the temperature records but to determine from plankton studies whether or not spawning takes place at the critical periods suggested by the records. When it can thus be shown that spawning has taken place, probably on the date of temperature rise, a more or less accurate prediction of spatfall can be made for a date 23 - 25 days after.

THE SPAT SURVEY

"The knowledge of the exact location of the settling zone is as important to the oyster culturist as is the knowledge of the time of settling."

Galtsoff, Prytherch and McMillin (1930)

On July 27th a general survey of the intensity of set throughout the various parts of Bideford river was made. After examining several collectors on each float studied, a sample of commercial cultch was made from one that seemed representative. In each case at least two cement-coated cardboard squares were removed and labelled. The sample was always taken from the second tier of squares from the bottom of one of the lower two collectors in the bundle of four. Except in special cases a marginally placed collector was chosen from the float for these counts.

The spat on both sides of each square were later counted under a binocular microscope with a 20x lens combination. A square measures  $2\frac{1}{4}$  x  $1\frac{3}{4}$ " and has a total area of 7.9 square inches or 51 square centimeters. There are 84 such squares in each collector and since there are usually four collectors in each bundle there is little difficulty in determining the catch in terms of number of spat per bundle once the counts have been made.

The results of the counts appear below in Table IV and the average set per square for each location is shown in the accompanying chart. For convenience in recording, these data are reported with other counts made on different dates on samples taken from various places about the district.

When the observations listed in the above table were compiled, there were still many umbone larvae present in the water of Bideford river as plankton catches clearly showed. It was therefore decided

The Spatfall in the Bideford River District 1937.

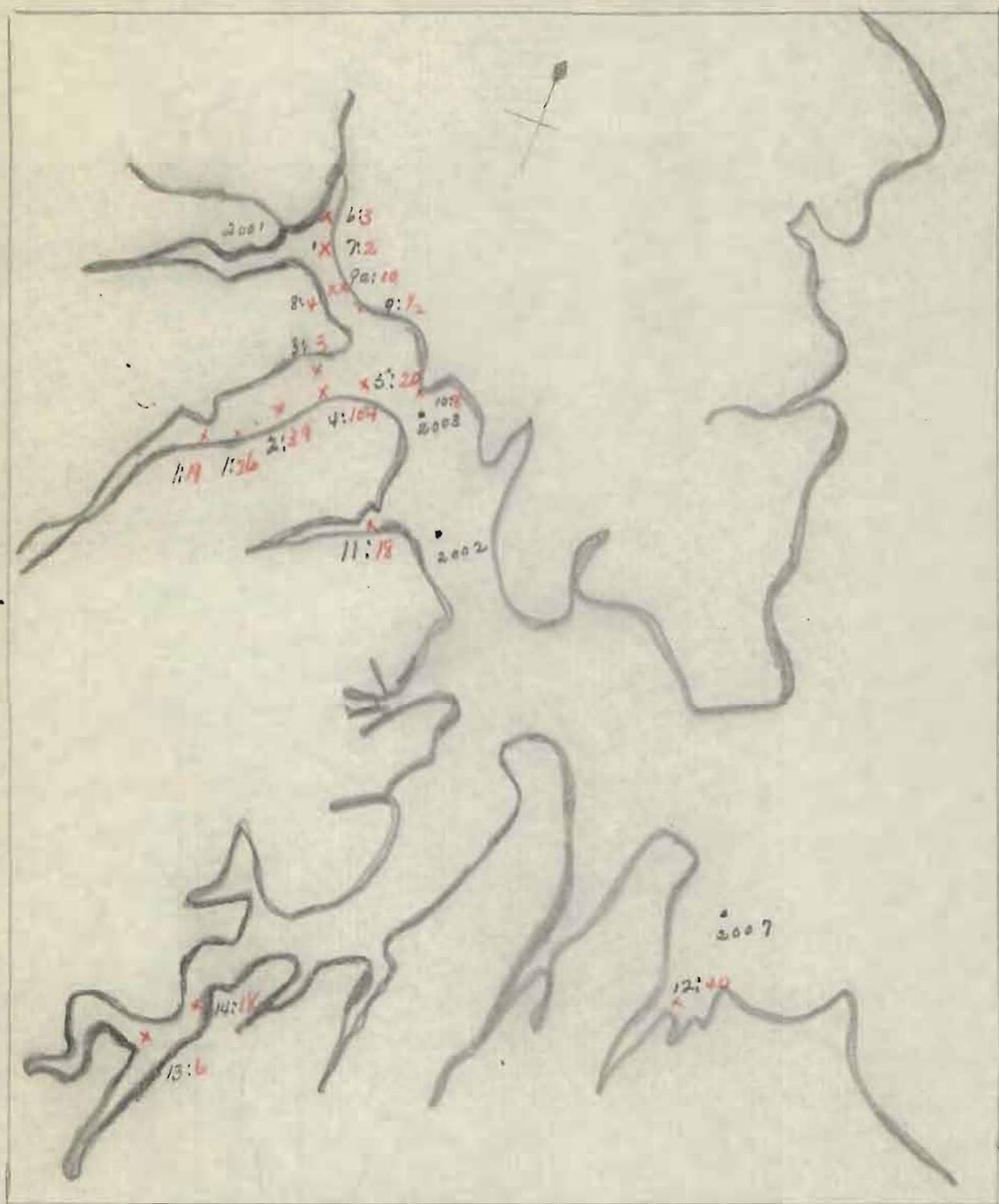


CHART I.

Black figures indicate the number of the location (See Table IV); red figures indicate the number of oyster spat per single square of commercial collector.

(To follow page 12)

to move several of the floats from Paugh's creek and anchor them in the river at points where good sets had been obtained earlier in the season. This was done on July 27-28 in the hope that here they would receive a better catch and that those left in the creek, being then less crowded together, would also benefit by a better catch than they would likely have received if the crowded conditions had not been alleviated. It appears, ironically enough, that the potential set, as judged from the counts on clean shell collectors, between the dates July 28 and August 4 was heavier in Paugh's creek than at the stage, and further, that the sets after July 28 were so slight in both places as to have scarcely warranted the labour of shifting of the cultch. These facts can be deduced from Tables I and II.

Some observations were made on collectors before and after the changes referred to above were made, and are reported below.

July 31

A. Samples were taken from the same positions on the collectors as during the spat survey proper. The first made on this date was from a float held at Shipyard point after removal from Paugh's creek.

3 Spat on 3 squares Average per Square 1

B. Samples were made of Mr. McLean's float held at a point halfway between Shipyard point and the station landing stage after removal from the creek.

7 Spat on 3 squares Average per square  $2 \frac{1}{3}$

C. Samples were taken from Russel Ellis's float held 100 yards east of the station landing stage after removal from the creek.

8 Spat on 3 Squares Average per square  $2 \frac{2}{3}$

AUG. 9.

Further samples were made from the float referred to in "C" of July 31.

21 Spat on 8 Squares Average per square  $2 \frac{1}{2}$   
(Approximately)

AUG. 26.

Samples were made from a float held in the cove just east of Mr. Forbes house since the July change.

5 Spat on 1 Square Average per square 5

Unfortunately for the sake of comparison, no counts were made on collectors that remained in Paugh's creek permanently. From the Table IV it will be seen that the set in the creek up to July 27 was approximately  $2 \frac{1}{2}$  per square. It thus appears that no great advantage was gained by the shifting of the cultch. This conclusion is in keeping with the observations made on the experimental shell collectors.

The possible value of a survey of settlement intensity in different areas is suggested in this account, although this year it was conducted too late in the spatting season to be of practical benefit to the industry. If collectors can be moved to areas where settlement is going on most actively the advantage is obvious. If observations such as this were conducted over a period of years it might well lead to a knowledge of the factors controlling "set" in these waters and to a more intelligent choice of areas

reserved for spat collection than those presently employed. It has already been shown in several localities, that although the extent of spatfall from year to year may vary considerably the areas of maximum settlement are relatively fixed in position.

APPENDIX TO THE SPAT SURVEY

Besides the general survey which is reported above the writer has log records of measurements of samples of spat taken at various times during the summer from the localities listed below.

Boyles river

The Narrows

Bras d'Or lakes

Bedeque

Bideford river (Pulpit bed)

Grand river

INTENSITY OF SPATFALL WITH RELATION TO DEPTH

Data presented in Tables I and II in the discussion of the history of the season's spatfall suggest that the spatfall is not uniform from the surface to the bottom. The results obtained from the inverted and upturned shells as they stand however disagree as to the depth at which the maximum set occurs. If there is a depth at which a maximum occurs one would expect it to show up in both sets of data. The disagreement was noticed while the twenty-nine daily observations reported here were still in progress. It was found then that the shells in the collecting chains which were pierced eccentrically hung at different angles to the horizontal. The limits of these angles were estimated with a protractor for each of the shells held at the stage.

Hopkins ('37) working with Ostrea lurida has shown that there is a close relationship between the angle of inclination of a surface and the relative amount of spatfall on it. The set is greatest on a lower horizontal surface, ( $0^{\circ}$ ), less on a vertical, ( $90^{\circ}$ ), and least on an upper horizontal surface, ( $180^{\circ}$ ). He presents data applying both to commercial collectors of the same general type as those used at Ellerslie, and to plane glass surfaces held at fixed angles in wire brackets.

It is interesting to note here that suspension of egg-case filler cultch vertically from floats as practised at Ellerslie, presents a great deal of horizontal surface available to the settling larvae. Hopkins ('37) has recently introduced this system on the Pacific coast and compares its greater success with that formerly practised in which the collectors were thrown flat on

tidal flats leaving all the collecting surfaces vertical in position.

Hopkins' data have been plotted graphically, Graph II, along with those obtained at Ellerslie in the study of the effect of crowding on the set on commercial collectors, reported in Table V.

Summary of Table V.  
Total Sets on Various Surfaces.

Surface	Total Set	% of entire Catch
Upper Horizontal	138	22
Vertical	187	31
Lower Horizontal	283	47

Hopkins ('37) has pointed out that the irregularities of the concrete film covering the cardboard collectors tend to decrease the horizontal component of a horizontal surface and to introduce a vertical component. Likewise the vertical component of a vertical surface is decreased and a horizontal component is introduced. The larvae will react to such surfaces differently in proportion to their departure from true plane surfaces. The final effect, if we represent it graphically, will be a flattening of our curve referring to plane surfaces, Graph II.

The fact that the percentage of spatfall on the upper horizontal surfaces is much higher in Bideford river than in Oyster bay (Hopkins '37) may be due to a difference in the irregularity of the concrete surface films used in the two areas, or to some genetic difference between the two species of oysters which might

result in differences in larval behaviour. There seems to be little difference in their reaction to vertical surface (See Graph II).

The smooth inner surface of the oyster shell on which counts were made at Ellerslie during the present study were concave and therefore cannot be treated as plane surfaces. This arching of a smooth surface might be expected to effect the extent of settlement in the same direction as would coating a plane surface with concrete. The distortion of the curve from that typical of plane surfaces introduced by a curvature such as that of a normal oyster shell however would scarcely seem to be as great as that produced by coating a plane surface with a concrete film of the type used in the Bideford river. A correction factor which might be applied to the shell catches to compensate for an inclination of any particular angle might therefore be intermediate between a similar correction which would be applied to a plane surface and one coated with a concrete film. For this purpose a dotted curve, representing the mean between Hopkins' curve for plane glass surfaces and those of commercial collectors at Ellerslie, has been drawn in Graph II. This is used tentatively as a basis for correcting settlement data referring to inclined shells.

In the table below are listed the angles of inclination of the ten shells held at the landing stage and the percentage correction factor which is tentatively applied, as read from Graph II, to reduce the counts to a comparative basis, that is, to equivalent sets on a horizontal surface of clean shell. With these is listed the total sets for the season on each of the shells

TABLE

Depth of Shell at Half-Tide in Inches	Angle of Inclination from horizontal	Correction Read From Graph II.	Season's Catch per 10 sq. in shell	Equivalent Set per 10 sq. ins. of plane hor. shell surface	Up-turned and inverted shells combined	% of total catch .. .. depth
		Inverted Shells				
18"	0°	20%	223	268	319	14
36	30	41	214	302	390	18
54	10	30	368	478	516	26
72	60	48	269	398	461	21
90	30	45	262	374	462	21
		Up-Turned Shells				
18"	45°	-12%	58	51		
36	60	+14	102	88		
54	45	-12	94	83		
72	60	-14	74	63		
90	60	-14	160	138		

A summary of Table I, reducing the data to a comparative basis.

held at the landing stage per 10 square inches of shell and the corrected set.

In this altered condition it will be seen that the two sets of data, for inverted and upturned shells, are more nearly in agreement and show that on a stationary set of collectors there is a definite relation between depth and intensity of set. The combined results for inverted and upturned shells are plotted in Graph III. Hopkins ('37) has expressed the same set of conditions as obtaining in Oyster bay as shown by counts on chains of collectors attached to floats. The numerical data of his two most extensive series of counts summarized in his table number 34, are here reproduced graphically and have been drawn in the same diagram as the above, Graph III. There are no extensive data available for the Bideford region that are exactly comparative. The Paugh's creek shell collectors, however, were likewise suspended from floats. The correction angles were never measured for these shells since they were lost in the gale of August 1. The data are nevertheless plotted as they stand in Table II, on Graph III, as are also the averages of settlements at different levels on commercial collectors held on floats and reported in the section on the effect of crowding collectors on the intensity of settlement, for the date August 17. The latter are taken from Table V and are summarised below.

Depth of Sample Below Surface	Average Set Per Square	Average Set Expressed as % of the total catch
3 - 7"	11	13%
16 - 18	18	22
26 - 28	53	65

There are some additional data available which unfortunately apply to a different date and therefore cannot be included in the above table. On July 26 the following counts were made by Dr. Needler on samples from a collector hung deep from the stage.

Depth of Sample Below Surface At Half-Tide	Horizontal Surface		Vertical	Average per Square
	Upper	Lower		
38" (From top of Bundle).	9	21	22	26
60" (From bottom of Bundle).	17	45	28	45

It will be seen from a comparison of this table with that immediately above that when collectors are held near the surface the top layers receive only 20% of the catch settling on the bottom layers of a bundle. When the collectors are hung deeper the catch near the top is 56% that of the bottom. The practical importance of this observation is obvious and is referred to again in the section on recommendations for modifying the present arrangement of collectors on floats.

All the data presented in this section agree in suggesting that a level of maximum settlement does occur at some depth below the surface and the two longer series of data for the Ellerslie, Table I and II, indicate that this depth is 4 to 5 feet below the surface at normal half-tide. No direct explanation is offered here for this peculiarity of settlement and there are in the literature familiar to the writer only two records of observations that can be considered comparatively with the Ellerslie data. One is that of Hopkins ('37), already dealt with above, relating to

Ostrea lurida. In this case the maximum spatfall occurred, as Graph III shows, at a depth of approximately  $1\frac{1}{2}$  feet.

The other report is that of Frytherch (Galtsoff, Frytherch and McMillin '30). Here the heaviest spatfall on a perpendicular pillar in the wharf piling showed just above the level of the low tide surface. This record would have been much more convincing if the pillar had been freshly placed in the water for it could be easily argued that the localization of settlement was due to differential fouling.

Frytherch believes that such zonation is due to concentrations of copper ion at the same level. Hopkins ('37) suggests the same but postulates a salinity effect as well.

Galtsoff (Galtsoff, Frytherch and McMillin, '30) points out that the level of maximum set on exposed tidal beach varies from year to year. There is no reason to suppose that the same variation might not occur in the settlement of larvae on floated cultch, although there are no data to suggest that such is the case. The counts on shells held at the stage, Table I, suggest that from day to day there is a slight variation in the depth at which larvae are likely to settle in numbers. At times they seem to be evenly distributed from top to bottom, e. g., July 21st and 26th. At other times there is a maximum sharply defined at a definite level, e. g., July 23rd and 24th.

An examination such as that conducted this summer continued over a period of years would be valuable in determining the stability of this depth of maximum settlement. It would likewise be of

interest to study the spat distribution on exposed beaches where there are only slight changes in salinity and probably in copper content of the water during tidal cycles as at Ellerslie. This could be compared with the levels of settlement on floated cultch and thus check Frytherch's conclusions as to the factors influencing the catch. Perkins and Nelson ('31) believe that currents are of more significance than any other factor in determining the distribution of settlement, a view which the writer is inclined to favour as probably explaining the conditions in Bideford river.

It is possible that the larvae maintain a definite vertical position in the water relative to the bottom and settle on whatever surface is encountered at that level. When collectors are hung from stationary supports the larvae would then accumulate on the surface constantly at that level. Such a condition would explain the sharpness of the peak in the curve representing the settlement at the stage. When the cultch moves up and down with floats from which they are suspended, due to tidal cycles, several surfaces might pass through the stratum in which the larvae are concentrated. Such a condition would result in a wide vertical distribution of settlement and a flattening of the curve which would represent this distribution. Such a flattening is to be observed in the graph for Paugh's creek settlement, (Graph III). The fact that no corrections were applied to these data however to compensate either for differences in the areas of the shells used or their angles of inclinations to the horizontal renders any conclusion of doubtful significance.

ON THE EFFECT OF CROWDING COLLECTORS ON THE INTENSITY OF SPATFALL

A great many floats bearing collectors were placed in the early part of the season in Faugh's creek because it provides shelter from winds and because successful catches had been made there in former years. The 1937 catch in this area however was very scant. By way of explanation it was suggested that there were too many collectors in the creek in proportion to the actual number of larvae that settled there, for any of them to get a good set.

Prytherch's ('28) observations suggest that larvae in Milford harbour do not move any great distance from the bed on which they are spawned. If this is also true in Malpeque bay then the only larvae that settled in the creek were those that were spawned there. The potential catch was therefore limited and dependent on the number of adult oysters in the immediate area.

The only accessible source of information at all pertinent to the question of crowding in the Bideford river at the time the question presented itself was an examination of the relative intensities of set on collectors placed in the middle and at the edges of large and small floats. In making the study, the most complete counts were made on August 1st, on samples taken from Mr. Roy Ings' four-barrel float which was stationed in Smelt creek 200 yards west of the station warehouse and a little south of the main channel of the creek. Samples which seemed representative were taken only after careful examination of the float as a whole.

The results of these counts along with others for comparison

are summarised below in Table V. The figures show, except in one case, that centrally located collectors all have a lower average catch than those marginally placed and that the larger the float the greater is the difference between the two sets. The one exception referred to is sample 10b made on July 27 and reported also in Table IV, in the section on the spat survey. In this case however the number of spat involved is relatively small and the collectors themselves were not very closely placed on the float. These two conditions would discount the value of this observation in such a study.

An examination of the table would lead to the belief that the outer collectors on a float exercise a "screening" effect on those in the centre of the group. Further, the extent of the screening is directly related to the number of collectors crowded together. The effect is most clearly shown when the sets on the top samples made on August 17 are compared. The explanation here would seem to be that in the upper central part of the float there is a screening in two directions. The bottoms of centrally placed collectors are screened from the sides only by other collectors. The tops, on the other hand, are sheltered both from the sides and from below. Such screening is much less apparent in marginal collectors, or in those hung solitarily as was the case of those hung from the stage. Thus, the upper parts of central collectors receive 37% of the set on the upper parts of marginal collectors. The bottoms of central collectors on the other hand catch 60% as many spat as those of marginal collectors. The bottom of an isolated collector obviously cannot be brought into this comparison but as is shown

in the small table on page 20 the bottom caught the equivalent of 58% of the set on the top of the collector.

The conclusions from this study support Prytherch's (Galtsoff, Prytherch and McMillin '30) counts on shells held in crates where the same effects were noted. Prytherch ('28) had already observed that mature larvae swam about with a byssus thread trailing and would settle on the first suitable surface encountered without regard for the number of spat that had already settled there. This last view is in opposition to that expressed by Nelson ('24) who considered that the "exploratory" stage of settlement insured an even distribution of spat over the surface of cultch.

Summarising, there seems to be a decrease in the efficiency per unit of area of collecting surface produced by overcrowding a float. Whether or not this disadvantage is counter-balanced by the reduction in cost obtained from the necessity for a smaller number of supporting floats, is a question that should be more closely examined if the present method of suspending collectors is to be continued.

Further, since crowding of collectors on floats reduces their collecting efficiency, it is conceivable that the crowding of floats into groups might similarly decrease the efficiency of the float as a whole. The writer is inclined to the opinion that the decrease is the result of interference with currents that would normally strike the floats if they were more widely dispersed. This opinion is based partly on the results of the study of the special case of sample 9a of the spat survey.

ON THE COLLECTING EFFICIENCY OF SURFACES AND THE EFFECT OF FOULING

Sample number 4 reported in the spat survey (Table IV) was taken from a standard collector held at the landing stage. The bottom of this collector was at a depth intermediate between that of the third and fourth shells on the chains of experimental collectors, or slightly more than five feet below the surface at half-tide. The mean settlement on shells at this level from July 17, when the commercial collectors were first put out, to July 29 the time the sample was made, can be computed by averaging the settlement on the shells at the 54" and 72" depths.

We shall compare only the set on the lower horizontal surfaces of the squares counted in the sample (Table IV) with the average set on an equivalent area of inverted shell surface (Table I). The average of the actual spatfall on the two shells was 100 per 3.9 square inches, the area of one side of a square of collector. When this figure is corrected for the angles of inclination of the shells as described in the section on the intensity of spatfall relative to depth, the equivalent set on a horizontal surface is 139 per 3.9 square inches. In the same interval of time the average catch on the lower horizontal surfaces of the commercial cultch was 91 per square as recorded in Table IV. The efficiency of this surface considered over the ten-day period then is 66% that of clean shells.

A similar computation for the lower sample held at the stage and reported under the section on intensity of spatfall relative to depth gives a collecting efficiency of 53%. The average of the

calculations is 60%. The collector from which these samples were taken was kept cleaner than most commercial collectors since several times during the ten-day period it was hauled up for examination and thus "washed" of all the silt that might have collected on it. This may have tended to increase the total catch and to render 50% an exaggeration of the true efficiency. In the calculations however only the set on lower surfaces is being considered in order to counteract this possible error since fouling is much greater on upper surfaces where silt is likely to collect than on lower sides.

On July 29th counts were made on samples of collectors set out at the stage on June 28 to collect clam spat. These showed on their lower surfaces a slight growth of encrusting bryozoans, several *Crepidula* measuring 5 mm. in diameter and 41 and 47 oyster spat on the two squares respectively. In the same interval on shells at that depth the equivalent set was 167. The efficiency here was 25% that of clean shell surface. There is then a reduction of 34% in the "absolute" efficiency of commercial collectors due to fouling developed during the extra 19 days in the water.

The efficiency decrease may appear more significant when expressed wholly in terms of sets on commercial collectors instead of referring it to the more nearly absolute standard the set on clean shells. Calculating from the data in Table IV the collectors placed out on July 17 missed the first 25% of the season's spatfall previous to July 29, the date of removal. To correct for this we should add 25% to the 91, which would give an equivalent catch of

114 on the lower side of each square. The average set on the collectors suspended the extra 19 days was 44. There was thus a decrease of 61% in the relative efficiency due to fouling. Again this figure may be too high because of the washing the first collector received and normal fouling may be less rapid. Hopkins (37) found a smaller decrease, 37% in 10 days.

The above study shows the advantage of having clean collectors at the time of settlement and suggests that it would be considerable value to know more exactly when to set out the commercial cultch. In other words, it would be of great assistance to the oyster industry if the date of spatfall could be predicted with "approximate accuracy", to use Winslow's words.

Types of fouling other than by encrusting bryozoans and silt as mentioned above, were noted during the season. Growths of a red alga tentatively identified as *Polysiphonia* and of a green alga *Enteromorpha linza* occurred on collectors in the river during the latter part of the season. Mr. Roy Ings, on August 24, noticed that a growth of *E. linza* had taken hold on a float of collectors held in Smelt creek at location #1 on the chart in the section on spat survey. He boarded over the top of this float in the hope that by this exclusion of light, the growth of the alga would be halted. Such fouling is considered to interfere with water circulation over the surfaces of the collectors and thus retard the growth of the spat.

A more spectacular type of fouling was found on August 18 in the case of collectors owned by Mr. John Brooks in Boyles river. Shell-bag collectors were completely plastered over with growths of a sea squirt, apparently *Ascidia callosa* which must have cut

down water circulation seriously. In spite of this there had been a good set and the spat had made a good growth for that season of the year. The collectors had been put out on July 12 and the first ascidians were observed by Mr. Brooks on July 19. In an adjacent area, where there was less tidal current no such growths had occurred suggesting that a study might prove that such fouling could be avoided by properly locating cultch. According to fishermen's reports a similar growth of sea squirts appeared in parts of Grand river.

Nelson ('21) states that tunicates in Barnegat bay are predaceous on oyster larvae and are frequently very abundant in that area. Gutsell ('21) finds that at times in Chesapeake bay they become a nuisance by occupying cultch that might otherwise be available to oyster spat. Gates ('10) claims that by covering the oysters they hinder growth in Louisiana waters.

ON THE EFFICIENCY OF TAR-COATED COLLECTORS

On August 26 a sample was taken from a tar-coated collector that had been held at the landing stage since July 17. On the several sections examined closely there were only one or two living spat oysters. Furthermore there were several empty spat shells covered with a white crust. Concrete collectors hanging beside the tar-coated one received satisfactory sets and none of these latter showed dead spat. The tarred surfaces were quite free of encrusting or slimy growths of any kind so that fouling could not be suggested as the reason for the poor set.

Another tar-coated collector was examined during the spat survey on July 27. On the several squares examined there were no spat at all. Concrete collectors from the same float averaged two spat per square. Other collectors of this type were examined during the summer but no written records were made at the time. The results however were much the same as those reported above.

No explanation is offered for the low efficiency of this type of collector but it is apparent that there was at least only a light set on tar surfaces and there is a suggestion that they provide a less wholesome support for the young oyster after settlement has taken place than the concrete surface.

For comparison with the above observations are those of J. Nelson ('17) who carried out several experiments in Malpeque bay to test the efficiency of various types of cultch. He noted

a limited set on tar-coated shells equivalent to 2/5 that on natural shells. His shells had been exposed to the water for only 6 days when the larvae settled on them. The cleanness of the surfaces which he also observed, he attributed to a possible anti-septic quality of the tar.

It might be suggested as a possible explanation of the poor results of this year's experiments that there was some water-soluble substance in the tar that discouraged not only the growth of algae but also the approach of larvae themselves. After the season's exposure in the river water it is possible that this substance may have dissolved out. It would therefore be interesting to set out these same collectors in 1938 and see if any better catches are obtained. It seems likely that there was either a difference in the composition of the two batches of tar used or in the character of the surfaces in the two cases which would account for the wide differences between these results and those of Nelson.

ON THE SPECIAL CASE OF SAMPLE 9a OF THE  
SPAT SURVEY

Of special interest is the observation, Table IV, that while the average set on the floated collectors in Paugh's creek was 2 spat per square, the set on Mr. Clifford Ellis's was 10 per square. There are several peculiarities about the hanging of these that may explain the better catch. Instead of being suspended from floats they were dropped from a platform of poles, the tops of which were just exposed at low neap tide. The tops of the collectors would then be submerged to a depth of a foot and a half or two feet at half tide. Further, the poles were arranged so that the ebb and flood tidal currents could flow through the square openings between the partitions of the collectors swung from them.

In contrast with this is the common floated type of collector arrangement where the tops of the collectors are immersed constantly at a depth of 6" at both low and high tide. They are hung from poles that are strung at right angles to the long axes of the floats. The floats themselves are anchored at one end and swing in the tidal currents. At all times therefore, the currents strike the broad-sides of the collector partitions and never is there a great flow possible through the holes between the partitions themselves.

Nelson ('32) and Hopkins ('37) and others have shown that the best sets, that is evenest and heaviest, are obtained when the water is allowed to circulate freely over the cultch. If this

circulation is interfered with as say when shells are too crowded in bags, the set is reduced (Galtsoff, Prytherch and McMillin '30).

It seems that at least two important factors contributed to the heaviness of the catch on Mr. Ellis's collectors. The first is that they were submerged to the depth of heaviest spatfall. (See section on Intensity of settlement with relation to depth). The second is that there was freer circulation of water over the surfaces.

It would be interesting to test the benefits of these two arrangements that differ from the regular methods, by deliberate experiment as is suggested in the section on proposed changes in the present arrangements of cultch.

PROPOSED CHANGES IN THE PRESENT ARRANGEMENTS OF CULTCH

The several studies reported above would suggest several modifications in the present arrangement of collectors on floats which might be tested during 1938.

1. As was clearly shown in the section on intensity of spatfall relative to depth and on spat survey the collectors should be hung from floats by longer lead wires in order that they should lie in the stratum of most intense spatfall. By this means the catch per square should be improved and the settlement should be more even from top to bottom of the collector.

The heaviest set encountered during the spat survey was that on a collector held at the stage. The top of the bundle was 35-40" below the surface at half-tide level. As was pointed out above this collector was "washed" during the season by being pulled up out of the water for examination. This fact may account partly for the much heavier set and therefore discount the apparent advantage of dropping the collectors to greater depths. Washing, however, should not alter the ratio of the set at the bottom to that at the top of the bundles. Referring back to the section on intensity of spatfall with relation to depth it will be seen that the tops of deep-slung collectors caught 58% of the number of spat settling on the lower part. In the case of a collector hung in the ordinary way the catch at the top is only 20% that at the bottom of the same bundle of collectors (See page 20).

Dropping collectors would prove to be of some advantage even

if the total catch were not improved because uniform and less crowded distribution of spat over a surface improves the chances for the development of separate and better shaped spat oysters.

2. The collectors on a float should be suspended at different depths and thus decrease the crowding or screening effect which has been demonstrated. By staggering the collectors at different depths the same results should be obtained as by the use of more floats with fewer collectors on each. That is, more water is strained per collector by the float.

3. The poles from which the collectors are hung should be arranged parallel to the long axis of the float thus permitting free circulation of water over the collecting surfaces during flood and ebb tides; (See section on the special case of sample 9a of the spat survey, page 32). This improved circulation of water might be expected to reduce the screening effect of marginal collectors on the central ones. Nelson and Perkins ('31) and Hopkins ('37) have shown that the best sets were taken where the currents were greatest, presumably because then the cultch "strains" more water. The same effect is apparent here. This same arrangement might simultaneously increase the growth rate of the settled spat for Nelson ('17a) reports better growth of spat where circulation of water is improved.

AGENCIES DESTRUCTIVE OF OYSTER LARVAE

It seems significant that although there were large numbers of oyster larvae in the water during the last week of July little or no settlement occurred after the twenty-ninth of that month. Judging from the sizes of the larvae there should have been a considerable spatfall during the first ten days of August.

Truitt ('26) states that long severe storms in the Chesapeake bay area will destroy almost all the larvae in the water at the time. The first reaction of the larvae in such weather is to sink from the surface as was reported by Stafford ('09) and Nelson ('17). At Ellerslie on August 1, of 1937 a heavy gale came up that blew several boats and a good deal of the oyster gear ashore. This storm may have had the same effect as those in Chesapeake and have contributed to the lightness of the set after that date.

The death of larvae resulting from parasitization by minute flagellates may partly account for this failure as studies reported elsewhere in this paper suggest.

It seems almost certain that factors other than mere crowding of cultch might well be involved in the local poorness of the set in Paugh's creek where larvae seemed to abound throughout the season even after the period of heavy spatfall was passed. During the summer the several scattered observations reported below may shed some light on and partially explain the peculiarity of the settlement.

July 22.

The intestine of a 2" Menidia was examined. This contained the remains of 10 copepods, 10 larval trematodes and two small mussel larvae.

July 30.

During the latter part of this month the along-shore water swarmed with the fry of Menidia. Two of these small fish,  $\frac{3}{4}$ " long were examined.

The first had a fully distended stomach whose contents consisted of between 70 and 90 molluscan larvae. The rest of the stomach contents, consisting of approximately half the total bulk was of mixed character, nauplii, dinoflagellates etc.

Over  $\frac{3}{4}$  of the larvae were gastropods measuring 160u in length. These abounded in the water at the time. Besides these there were several mussel larvae measuring 150u, a number of large Teredo larvae measuring 130 u and many smaller straight-hinge pelecypod larvae.

In the second fish one third, or slightly less of the bulk of the stomach contents consisted of molluscan larvae. Thirty-five were counted, mostly small straight-hinge bivalve larvae. There were also present several young nauplii of copepods.

August 10.

Two 2" Menidia from Mill river were examined. One contained 20 mussel larvae and the other 12. These ranged in size about 140u. With these were many gastropod larvae.

T. C. Nelson ('37) reports that in Barnegat bay the oyster larvae have usually settled before the season's Menidia fry appear in the water and that they are therefore free of the menace of destruction. The myriads of the fry present in late mid-summer must seriously cut down the population of molluscan larvae in the Bideford river and thus reduce the spatfall subsequent to their appearance. Nelson ('21) found that the surface minnow Fundulus may feed on the newly spawned ova of the oyster but makes no

statement as to its possible ecological significance in this practise.

June 30.

Several bits of tentacles and scrapings from the palpi of a jellyfish (Cyania) taken at the landing stage were examined. In the mucous mass were found numerous gastropod larvae and many copepods.

The jellyfish largely disappeared from the water during the week of July 17th.

Fruitt ('31) believes that the jellyfish Dactylometra do not have any marked effect in reducing the larval oyster populations in Chesapeake bay and regards them as beneficial to the oyster industry since there they prey on the ctenophores. These latter have proved to be a real menace when water conditions favour their abundance. The stomodaeum of one animal may contain as many as 130 oyster larvae.

In the Bideford river apparently the larger Menidia as well as the fry feed on bivalve larvae but the former take also adult copepods and large nauplii that seem to be inaccessible to the fry. Although few oyster larvae were found evidence points to the conclusion that the fish may be considered as important enemies of oyster larvae.

The jellyfish at the peak of their abundance might conceivably play a similar regulating role. In the Bideford river however they seem scarcely numerous enough to be of great importance in this respect.

A short note on the effects of tunicates on oyster larvae is to be found in the section on collecting efficiency of various surfaces and the effects of fouling.

DINOFLAGELLATE PARASITES OF MUSSEL LARVAE

While examining a plankton tow made in Bentinck cove on July 6, a small percentage of the larger mussel larvae was observed to have peculiar stomach contents. Although the greater part of the turning mass of food material in the stomachs was constituted of small cells measuring 1-3u as is normally the case, there were mixed in this small number of especially large brown cells measuring 20 - 24u. These appeared to be unarmoured dinoflagellates# for sulci and annuli were distinctly visible. The protozoans moved back and forth in the stomach cavity with the typical whirling motion of dinoflagellates. Several of these parasitised larvae were isolated and kept in separate Syracuse watch glasses with suitable covers to prevent evaporation. The water on these larvae was changed daily, the old being replaced by fresh river water that had been filtered through # 18 bolting cloth silk. The histories of these were followed and recorded in the log book. Typical cases are reported below.

Isolation #1.

July 6, 2.00 P.M.

This mussel larva measured 280 by 272 u and contained 2 large cells in the stomach measuring 20 to 24 u in diameter.

11.00 P.M.

The two cells were still apparent but the larva was lost during the changing of the water.

Isolation #2.

July 6, 2.00 P.M.

This mussel larva of approximately the same dimensions as the first contained 6 larve cells in the stomach.

July 7, 9.00 a.m.

The flagellates were still present and active in the stomach cavity.

#Tentatively identified as Gymnodinium

From the above observations it was decided that the protozoans were behaving not as food organisms but as parasites or commensals because stomach contents of oyster larvae are normally passed through the intestine and discharged as faeces within 6 minutes after ingestion (Frytherch '34). Accordingly, another tow was made in Bentinck cove as a source for experimental material. Isolations were again made and cared for as described above. Besides the infected larvae several apparently normal animals were also isolated to be used as controls.

Tow was made July 7

July 9.

Two larvae were dead and beginning to disintegrate. Within the dead shells of one of them was a 22u dinoflagellate still active. No large cells could be found swimming free in the watch-glass.

Some of the living animals showed in addition to the large distinctly brown cells additional smaller (12u) transparent cells with a pale yellowish-brown central chloroplast. They were however of the same body form and behaviour as the larger dinoflagellates. Some of the larvae had set to the bottom of the glass.

The histories of some larvae were followed more closely than others from this date on and kept isolated in separate glasses.

Larva #1, measuring 280 by 240u.

July 10, 10.00 A.M.

The larva contained 3 dinoflagellates measuring 24 u and 3 measuring 20 u. Besides these there were several colourless cells 14 - 16 u which appeared to be young stages of the brown cell.

11.00 P.M.

The stomach seems to be filled with protozoa and the younger colourless cells more distinct and larger than in the morning.

July 12, 12.00 noon.

The stomach was now comparatively free of the larger-sized cells. Still present however were several measuring 15u, one 18u, one 24u and one 28u. These clustered mostly towards the anterior end of the stomach.

July 13, 9.00 A.M.

The larva seemed to have further freed itself of the flagellates and an arc of the brown cells seemed to have been sprayed over the bottom of the watch glass opposite the anus. These cast-out cells did not look normal for the flagellar furrows were not apparent.

There were 6 cells measuring 18 - 20u still in the stomach all swimming back and forth with their peculiar twirling motion. One of these was so constricted as to suggest that it was in the incipient stages of binary fission.

In this connection one of the flagellate cells observed on July 10 seemed to be undergoing multiple fission but the thirty odd units resulting from the division did not show active swimming after the rupture of the parent cell.

July 14.

There were only three cells in the stomach now, two measured 20 u and one 22 u. Except for these the stomach cavity was practically empty for no "food" particles were observed. The larva had set to the glass again and was detached during water changes

July 15, 11.00 A.M.

Though otherwise empty the stomach now contained five flagellates all measuring approximately 19 u. For the first time a cell was observed in the intestine which seemed to have become lodged just anterior to the posterior adductor muscle. The cell was still intact however and showed the flagellar grooves distinctly. The larva looked rather lank and transparent and had not set this time.

11.20 A.M.

The intestine seemed to be still congested with the flagellate cell.

July 19

There were only two cells both measuring 26u, one in the stomach and one in the intestine. The latter apparently stuck as was observed on July 15. Some excreted cells were found on the bottom of the watchglass as on July 13 and from these a smear preparation was made.

July 23.

The stomach contained 1 brown cell measuring 20u, and three smaller more nearly colourless ones about 12u besides 4 measuring only 8u.

July 30.

The mussel larva was dead perhaps because of neglect in changing the water during the previous two days. There was however one dinoflagellate moving within the empty shells as was seen on July 9.

Similar histories were kept on two other mussel larvae at the same time. The records in the log are essentially like the above in most respects except in the case of larva #3. This history was kept from July 10 to 30. At one time an intestinal obstruction by a flagellate cell was observed to last for over two hours. Such stoppage must seriously interfere with the elimination of faeces for normally the food residues are retained for a very short time in the intestine (Prytherch '34).

On July 17 the larva seemed to have completely freed itself of the flagellates and the stomach had a "normal" contents. On July 19 the infection re-occurred for two cells measuring 16u were observed. The larva again freed itself however and from July 23 till 30 seemed quite uninfected even though it was placed during this time in the same watchglass with larva #1 which latter remained infected throughout the whole period.

Uninfected larvae isolated from the same tow were kept in the same way as controls but on July 14 several were found dead no doubt due to lack of proper care on the few days preceding. One of the living animals was found to be harbouring the flagellate. On July 15 it was observed to contain a cell measuring 21u. The only other uninfected larva left alive on July 14 was observed to have set to the watchglass on July 19. Instead of replacing the water this time with fresh filtered river water, that

drained from infected larvae was used instead. Unfortunately the larva was lost and no further observations were made on this infection experiment with "contaminated" water.

#### Infection Experiments

An apparently uninfected mussel larva taken from the Bideford river was marked by staining it with a highly diluted solution of neutral red. This animal was added to the same watchglass as larva #1 on July 14. With it was added a large clam larva, *Mya*, and several quarter-grown oyster larvae.

The mussel larva was observed to contract the infection for on July 19 there were two large brown cells measuring 21u found in the stomach. The clam larva was free of any infection.

One of the smaller oyster larvae measuring 85u observed on July 18 seemed to have developed the infection showing one large colourless cell in the stomach. No positive evidence as to the lethal effects of the parasite could be had however since almost all the oyster larvae died without showing the infection.

Teredo larvae were added to the same dish as the infected mussel larva #2, but lived until July 23 without contracting the flagellate.

Two or three infected larvae isolated on July 7 but not so closely studied died possibly from the weakening occasioned by the protozoan. The small 2 - 8u flagellates joined in attacking these in the late stages and abounded in the disintegrating tissue mass that had been the body of the larva.

From the above study it would seem that the following statements could be made.

1. The dinoflagellate behaves as a parasite or a commensal.
2. It possibly hampers the larva by crowding the stomach cavity which would normally be occupied by food materials and by temporarily congesting the intestine.
3. Infections of the flagellate may be contracted when small developmental stages of the parasite are ingested during feeding, and can be brought about experimentally by placing uninfected larvae in the same containers as those suffering from the flagellate. (See in this connection the discussion of the size of the food particle taken by various sized larvae).

4. The digestive processes in the stomach do not seem to greatly effect the parasite but after passage through the intestine and elimination the cells become immobile and possibly dead.
5. Simple exposure to sea water does not result in the immediate death of the adult cells and it is possible that they may live for some time after the death and disintegration of the host larva in the water as a free-swimming organism.
6. The larvae seem capable of freeing themselves of the parasites in some cases at least and of continuing a normal life.
7. An apparently uninfected larva can develop within five days an infection and contain parasites measuring 16u in diameter.
8. The facts that the parasite "took" best with mussel larvae; that no naturally infected oyster larvae were ever found; and that no such infections were observed in the Bideford river would suggest that the dinoflagellate was of minor importance during the summer of 1937 in controlling the population of oyster larvae.
9. There was no suggestion of a symbiotic relationship between the host and "parasite" so far as the writer's observations were concerned.

PARASITISM OF LARVAE BY SMALL FLAGELLATES

July 14.

Several quarter-grown rose-coloured oyster larvae found in a tow from Trout river were isolated in a Syracuse watchglass. These showed little stomach contents and within their shells were a number of small bright spheres of a pale green colour, measuring approximately 3u in diameter. These seemed to be attached to the inner wall of the mantle as though they had entered the cavity with food organisms but had never been eaten. Although they remained stationary most of the time or vibrated only slightly with the beating of the larval cilia, these flagellates made short sallies from place to place within the cavity immediately coming to a state of comparative rest after each sortie.

July 19.

One third of the infected larvae were dead although the water had been changed regularly in the watchglasses throughout the period.

August 15, 12.00 Noon.

A larval Mya measuring 140u in height was isolated from a tow made opposite the landing stage in the river. This larva like those picked out on July 14 had very little stomach contents. Around the margin of the mantle towards the free edge of the shell and crowded towards the anterior end were between 30 and 50 flagellates of a colourless or pale green colour ranging in size from 3 to 3u. One cell was larger than all the rest measuring 14u and by its movements suggested a dinoflagellate. Another cell of the same dimensions could be seen in the stomach. Both these large cells showed greenish-brown chromatophores but no sulcus could be distinguished. A figure of the larva was drawn and kept in the log.

August 17, 2.00 P.M.

The condition of the larva had become much more serious. There was little or no ciliary motion the tissues were becoming transparent and the number of flagellates had greatly increased with more of the smaller varieties present. The water was renewed on the larva.

9.00 P.M.

The tissues of the larva were no longer sharply outlined and the whole shell contents was swarming with flagellates of various sizes, mostly 2 - 6u.

August 16, 2.00 P.M.

A half-grown oyster larva was isolated that showed flagellates in the mantle cavity. There were also quite a few just outside the shell clustered along the opening between the slightly gaping valves.

9.00 P.M.

The larva was dead, the body largely disintegrated and the cavity of the shell swarming with flagellates.

Minute flagellates seem to be quite common as enemies of larvae. This year as in 1936, the larvae grown from artificially fertilized eggs were attacked by flagellates which seemed often to kill the young animals. Winslow ('84) reported the same difficulties in his experiments. Similar small protozoans were found to attack mussel larvae when they were in their last weakened stages from infection with dinoflagellates.

On August 17 approximately a quarter of the small straight-hinge bivalve larvae in Bideford river quite numerous at the time, were either heavily parasitized and showed shrunken bodies or had already been killed and the bodies largely or completely destroyed. This was at the time of the very high density of free-living planktonic flagellates. No such high mortality was observed in the earlier part of the season. Nelson and Perkins ('31) and Nelson ('34) reported a similar dying off of the larval population but did not attribute it to flagellate parasitism.

When parasitized larvae left in uncovered watchglasses are killed from the increased salinity in the vessel resulting from evaporation of the sea water the flagellates still remain active showing their hardiness.

NANNOPLANKTONIC STUDIES

Throughout the summer observations were made on the population density of the planktonic organisms whose dimensions were such as to make them available for food to larvae. The water in Bideford river during the summer is heavily populated as well be seen from the counts. This abundance is no doubt responsible for the brownish-green colour of the water.

In the counting studies carried out in 1937 a modification of the Hensen drop method described by Johnston ('08) was applied. In this system a fine pipette is used to measure out even-sized drops. Counts of the numbers of cells per drop are then made on three to five drops and the volume of 200 drops measured. From such data the population density may be easily estimated.

Flagellated cells constituted almost the entire nanoplanktonic growth during the summer and of these only a very small percentage exceeded a size of 5u. The counts were made with lens combinations giving a magnification of 215x.

The population at different dates per cubic millimeter of water at the landing stage is listed below. Where not otherwise stated the figures refer to surface samples. To express the population as cells per litre the figures should be multiplied by one million.

Date	Population per Cubic Millimeter
July 7	16#
" 14	39 at surfaces; 41 at 3½' depth; 34 at 7' depth.
" 24	40
Aug. 3	48
" 12	58
" 20	73
" 30	65

# This low figure may be partly due to lack of familiarity with the technique on the part of the writer.

This density of population is higher than that reported by Cole ('36) in his control tanks that supported an average growth of larvae of O. edulis. In the more successful spat production in the tanks which he fertilized with ground crab meats however, the flagellate counts often ranged considerably higher than those recorded here.

Attempted identifications of the flagellates were not very successful because of their small size and because several varieties were usually present together. Cryptomonads of a very pale green tint seemed to constitute an important part of the population.

It is apparent, therefore, that in the Biddeford river there was all summer a sufficiently abundant supply of flagellate food organisms alone to support a heavy population of bivalve larvae. Since small flagellates constitute almost the entire nannoplankton of smaller dimensions they might well be the chief source of larval food.

FEEDING EXPERIMENTS

Feeding  
Mussel  
Larvae  
July 2.

10 mussel larvae averaging 200u in length were isolated from a tow made in Paugh's creek. These were kept in a petri dish and the water changed daily, using sterile seawater to replace the old. To keep the water sterile it was boiled and placed in a flask stoppered with gauze. It was found that the water had to be reboiled frequently because flagellates developed often within two days probably due to infection during the opening and closing of the flask.

"Food" was added each day to the petri dish in the form of 3 cm. off a culture of small flagellates, diameter  $1\frac{1}{2}$  - 3u growing in water containing decomposing crab meat.

July 6.

Several of the larvae were observed to be crawling about with the foot. All were quite vigorous although by this time 4 had been lost in changing the water. The others showed what appeared to be, judging from their size, small flagellate cells in the gut. These cells had the typical "wrinkled" or "spiny" appearance to be observed in the stomachs of larvae taken freshly from the river.

July 12.

Several of the larvae had set with the byssus and had developed some dissoconch shell. One larva showed a large colourless cell in the stomach. This measured 16u but no pulcus could be made out. Another larva showed a stomach filled with very dark contents. The rest showed "normal" stomach contents that consisted of cells measuring 1 - 2u.

Feeding  
Oyster  
Larvae  
July 2.

At the same time that the mussel larvae were isolated two groups of 20 oyster larvae, all ranging from 80 - 90u, in height, were picked out from the tow and placed in separate petri dishes. These were given the same treatment and identical records were kept as in the case of the mussel larvae whose history is detailed above.

July 12.

Fifteen of the larvae had been lost during water changes, and one third of the rest had died. The rest were swimming normally but unlike the mussel larvae showed no marked increase in size during the interval.

It is seen from these tests that both mussel and oyster larvae can be kept alive for ten days in comparative health while feeding only on flagellates of the same dimensions as those occurring naturally in the river water. These observations combined with the results of the nanoplanktonic investigations and stomach analyses carried out at Ellerslie, viewed in the light of Cole's researches ('36), offer substantial evidence for the belief that the oyster larvae in natural water depend on the flagellate population for their food supply.

ON THE FEEDING HABITS AND FOOD OF LARVAE

The use of marine glue described by Prytherch ('37) for fixing larvae to slides in order to study their habits was found to be unsatisfactory in this investigation. This was because very young transparent animals that get "bogged" in the glue are need for feeding studies. Most of the work reported here therefore was done with free-swimming larvae. A summary of the study is presented below.

Small flagellates were cultured in several media, the most successful of which was seawater to which had been added a small scrap of animal tissue such as crab meat. Attempts were made to stain these flagellates vitally with Nile blue and neutral red and to feed them to the larvae. It was hoped that the process of digestion of the individual cells could then be followed. The intensity of the blue in the tinted cells however did not serve to distinguish the stained flagellates from many that were naturally coloured slightly green. Both the red and blue dye furthermore tended to collect in the digestive gland of the larvae and obscure the vision during the study of the stomach contents. This same reaction of the gland was noted by Prytherch ('34) which he attributed to the presence of enzymes in that organ.

Finally a culture of a small non-motile unicellular alga resembling *Chlorella* was used. This plant cell, measuring 3 - 7 $\mu$  was successfully grown in mass culture with Miquel solution to which a small amount of urine was added - 4 cc. of urine to 150 cc. of culture medium.

When cells from a culture of a green Chlorophycean flagellate measuring 7 - 9 $\mu$  were "fed" to small larvae measuring 80 $\mu$  in length it was found that the shells, being only partly open during the swimming-feeding process, acted as a sorting screen. None of these larger cells even got between the shells. They were too coarse to be taken as food. These same cells, however, were readily swallowed by large mussel larvae. There seems then to be a relation between the size of the animal and that of food particles it is able to take.

During observations of larvae from the river, occasionally irregular pieces of what appeared to be detritus was found in the stomach contents. The chitinous tests of a small protozoan also appeared at rare intervals. The bulk of the contents at all times however conforms to the description given in the 1936 report, (Medcof '36) and appears to be the remains of flagellate cells.

Essentially the same may be said of all the mulluscan larvae studied during the summer. This observation would seem to be in disagreement with Grave's statement ('28) that he raised *Teredo* larvae on diatoms. At no time during the writer's studies has he encountered a larva with diatoms showing in the stomach. Judging from the size of food particles observed in the stomachs there are no diatoms of common occurrence in the waters familiar to the writer that are sufficiently small to make them available as food to the larvae. Amemiya ('26) found that even the very small *Nitzschia minutissima* was not taken by larvae.

The habits of mussel larvae were studied on several occasions since their behaviour seems essentially the same as that of oyster larvae and because their greater transparency makes much more careful observation possible. The largest particle observed to be taken by a mature mussel larva was an approximately spherical piece of detritus measuring 16u in diameter. It seems highly improbable that dinoflagellates measuring 24 - 28u could ever be taken in by such animals or ones less mature and that the infectious stages of the dinoflagellate parasite is therefore a swarmer of smaller dimensions as suggested in another section of this paper.

Judging from the behaviour of larvae on the slide, which might be considered a very abnormal situation, they spend a good deal of time resting with the shells partly closed and only a few of the beating cilia protruding. Periods of activity alternate with those of rest and the larva swims upwards at random, striking many possible food organisms as it travels. Very few of these however are actually swallowed as food. From counts on *Chlorella* less than one in twenty of those that pass between the shells over the mouth opening are swept into the stomach.

A brief summary of the work on small flagellates and their relation to the food supply of bivalve larvae appears below.

1. There are large numbers of small flagellates in the waters of the Bidford river throughout the summer. In addition, there are relatively few other small nannoplanktonic forms present - notably few non-motile unicellular algae.

2. Larvae have been observed to feed on both green and colourless flagellates and have been cultured for as long as ten days in otherwise sterile water where colourless flagellates were their only available food. These flagellates were grown in mass culture in seawater enriched with organic materials.

3. The bulk of the stomach contents of larvae taken from the river water was constituted of small cellular elements measuring 1 - 3u in diameter and having an appearance identical with that of ingested flagellate cells fed experimentally to larvae. The stomach of a single mussel larva measuring 240u may contain as many as 150 such cells if examination is made immediately after the larva is removed from the river.

4. It thus seems a reasonably certain deduction that the larvae living naturally in the Biddeford river must depend almost entirely on minute flagellates for their nourishment. If this conclusion is valid then it is in agreement with Cole's observation ('36), referring to the European oyster larvae, O. edulis.

### HISTORY OF THE SEASON'S LARVAE

The writer made rather disconnected observations on the plankton of the Bideford river during the summer and a summary of these appears in Table VI. Since the time when these observations were made was very crowded the results of the examinations should be regarded as indicative of only the most outstanding and obvious trends. Samples of the tows were preserved on each of the dates listed and have been kept for study.

The "Diffugia" reported for 1936 (Medcof '36) was really a testate ciliate (Tintinnopsis).

#### Reports on tows made in waters other than Bideford river.

During the summer tows were made at different places, sometimes at the request of resident oyster culturists, for purely qualitative studies - to see if oyster larvae were in the water. In all cases a # 18 net was used and towed for 10 minutes from a boat travelling at approximately one mile per hour.

#### Trout river tows

##### July 10.

A surface tow was made on a bright day with a fresh wind and a high falling tide. There were very few oyster larvae. The tow was not as good as that from the Cooper bed in the Bideford river on the same date.

##### July 14.

A surface tow at high tide with a light breeze. Small oyster larvae fairly abundant, some parasitised with the small flagellate. Dinoflagellates quite common.

#### Bentinck cove tows

##### July 6.

A surface tow from a dory. In several fields examined there were many large mussel larvae, some parasitised with the dinoflagellate, one large Teredo larva, many small straight-hine forms and a few rose coloured oyster larvae of small size.

TABLE VI (To follow page 54).

(Report on plankton tows from the Bideford river and Paugh's creek, '37).

Date	Oyster larvae	Mussel larvae	Teredo larvae	Gastropod larvae	Copepods	Miscellaneous	Remarks
June 19		o	oo	ooo	o	TTTT	Tow at 2001
June 24		ooo	oo	ooo	ooo	JJ	" " "
June 29	oo	oo	oo	ooo	oooo	JJ	Oysters rose coloured. Teredo small
June 30		oo		ooo	oooo	JJ	
July 2	oo			oooo		JJJC	
" 5	oo			oooo		JJCC	O. larvae both large and small
" 8	oooo			oooo	o	JJCCCC	
" 13	ooo				oo	JJ	
" 16	oo				ooo	J	
" 19	o		ooo				
" 23	ooo						
" 28	o			ooo	o	DDD	
Aug. 2	ooo			ooo	o	CCCDD	
" 9	o		oooo		o	(CCCC (FFF CCCC)	Teredo small of the second brood.
" 16	o		oo		o	FFDDDD)	
" 20	o	o	ooo		o	CCFFFF	A few large mussel larvae.
" 25	o		ooo			FFFF	
" 29					oooo	DEFFCCC	

Explanation of table

- o Indicates the presence of a few (some)
- oo common
- ooo abundant (many)
- oooo " a great abundance a heavy catch.

In the column headed Miscellaneous.

- C represents testate ciliates. (Tintinnopsis)
- D " Dinoflagellates (Goniaulax, Exuviaelia & Peridinium)

July 7.

A surface tow made from a dory in Fraser's cove with a half-tide falling. A few early umbone larvae of oysters, a few *Teredo*, many mussel larvae and a heavy catch of copepods and testate ciliates.

Below the Inman bed

Fewer oyster larvae than in the first sample, fewer *Teredo*, some *Mya* and many mussel larvae.

Below Mr. Carr's house

Many mussel larvae and some *Mya*, no apparent oysters.

July 12.

A surface tow from a dory in Fraser's cove with a high tide. No oyster larvae found in the tow after a 10-minute examination.

Below Inman bed

No oyster larvae found.

Below Mr. Carr's house.

Found only three oyster larvae after 10 minutes' examination.

July 22. At Inman bed.

A surface tow from a motor boat. A fairly good tow of oyster larvae of such a size that they might be expected to mature between July 26 and August 6.

July 29. At Inman bed

A poor tow for oyster larvae. The population of larvae seen on July 22 does not seem to be represented in this tow at all.

Grand river tows

July 6.

Grant bed at low tide. Only one oyster larva found in the examination, a few gastropods, many *Tintinnopsis* and copepods.

Above bridge. A few straight-hinge larvae of oysters, many gastropods, some large mussel larvae.

July 7.

At the Grand bed. Two straight-hinge oyster larvae. Many large mussel larvae.

400 yards above the bridge. A very few early umbone oyster larvae. Some large *Teredo*, *Mytilus* and *Mya*. A heavy catch of testate ciliate.

July 13. Tow at Enmore

Tow made below Belam bridge at half-tide. Only one oyster larva and it an early umbone form.

Bideford river special tows

On July 8 tows were made in Paugh's creek at station 2001 and in the Bideford river at stations 2003 and 2007 (See chart for locations). In order of the number of oyster larvae found in they may be arranged as 2001, 2003 and 2007

July 20

Tows were made again at stations 2001 and 2007. The first was by far the better as regards oyster larvae.

The peculiarities of this year's spatfall would cast doubt on the value of making such tows since in Faugh's creek the set was a failure while at 2007 there was a good set. The work of Prytherch ('28), Truitt ('28) and Nelson and Perkins ('31) would further suggest that since the larval behaviour is conditioned by currents, salinities and light intensities, that much must be already known about any particular district before any single tow could possibly mean very much to an examiner.

Furthermore the promise of a spatfall brought by a good tow in the early part of the season seems more likely to be fulfilled than that from a tow made later in the summer, if we may generalize from the 1937 experience in the Bideford river. Hopkins ('31) found that in Galveston bay in Texas, little reliance could be placed on tows alone as a basis for estimating the probable success of the spatfall to come. Prytherch ('28) has noted and Mr. G. F. M. Smith has concluded from his observations in the Bras d'Or lakes that since good sets may often occur in areas where there were very few larvae taken in tows the dependability of that method of sampling is questionable. It would thus appear that each area must be studied individually before random samples can be of any great use. In Canadian waters this would necessitate a whole programme of research on larval reactions to the various factors of their environment.

REARING OF OYSTER LARVAE FROM ARTIFICIALLY FERTILIZED EGGS

In order to study some of the earlier stages in the development of the oyster eggs were artificially fertilized on July 8 in the same way as was described in the last report (Medcof '36). The young larvae however were transferred to a plunger jar in which the water was completely changed every day for fresh river water strained through #18 bolting cloth. Under this treatment the larvae matured up to the stage where they were turning rose-coloured. This point in the life history is reached in nature between the 7th and 8th day (Nelson '21). In the culture jars this was attained only by July 24 when the average length of the larvae was 88u.

The animals' stomach contents as soon as the shells were complete consisted of small cells, apparently flagellates of the same type as those found in the larvae taken in tows in the river. This experiment represents the writer's most successful attempt thus far in the rearing of larvae from eggs. A large number of the larvae were lost during the last week due to a leak that developed in the siphon screen that drained the plunger jar and the experiment was discontinued.

OBSERVATIONS ON SHIPWORMS

Small wooden bars were used to keep the individual shells of the chains of experimental collectors used in studying the season's spatfall from slipping out of their places in the series. These collectors were set out in the river at the stage on June 26. By July 30 the wood was so badly tunneled with shipworms that two of the bars broke when the chains were hauled up. A single animal was dissected out from the wood and examined under the microscope. It was approximately one centimeter long and two millimeters thick and filled with ripe ova.

On August 10, the last of the original series of bars broke during the hauling-up process. Mr. G. F. M. Smith who was visiting the laboratory at the time dissected out several of the adult animals. Single individuals were found to contain at the same time eggs that were ripe, early cleavage stages of fertilized eggs, shellless swimming embryos, embryos with rudimentary and complete shells and finally mature straight-hinge larvae, apparently ready to be extruded. These last in some instances seemed already to have some stomach contents turning about under the action of the gastric cilia. A like condition was found by Sigerfoos ('07) at Beaufort, North Carolina. The animals apparently spawn even when they already contain marsupial young. This is different from the conditions found in the viviparous oyster which contains marsupial young all of approximately the same age and presumably developed from a single spawning (Hopkins '37).

Formalin preservation of bits of the bars were made on the dates of these examinations and left at the station.

Vast numbers of young *Teredo* larvae appeared in the river water during the second and third weeks of August. It thus appears that the shipworms in the Bideford river at least during the summer of 1937, produced two broods of young. The time required to reach sexual maturity and produce young ready for release is not far from six weeks after the initial settlement. The interval corresponds very closely to that reported for the animal in the Woods Hole region by Grave ('28) in New Jersey water by Nelson ('22) and ('24a) and in North Carolina regions by Sigerfoos ('07). The last author observed on the surface of the wood into which the larvae burrow that the tunnels were more frequent where there were crevices. It is interesting to note that the same habit of "seeking" out a sheltered niche before settlement is common among the *Teredo* larvae in Bideford river.

In the pores of commercial collectors formed by bubbles in the surface film of concrete, adult shelled larvae of shipworms are almost invariably found during examinations for oyster spat.

OBSERVATIONS ON THE SPAT OF QUAHOGS AND SOFT-SHELLED CLAMS

While screening the beach sand on August 28 for samples of young *Nassa*, a surprisingly large number of young clams and quahogs was found in the first centimeter below the surface. The quahogs were of particular interest since they were of several different sizes suggesting that they belonged to different "sets". Several length measurements were made - 1.2, 2.5, 2.8, 3.0, and 3.6 mm.

A formalin sample of these was made and kept with the *Nassa*. Both these were left at the station. A similar sample was made in late fall by Mr. Hayes which should be of use in comparison with the first in establishing growth rates during late summer.

This method of collecting seed quahogs seems simple enough to be practicable on a larger scale should "seed" ever be required for cultural purposes. Essentially it is the method worked out by Nightengale ('15) for collecting seed of *Mya* at Essex, Massachusetts.

It is questionable whether or not the quahog can survive the severity of the winter in the shallow on-shore water. A close examination should therefore be made in the spring to determine whether or not they will have suffered winter killing.

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