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REARING OYSTER SPAT PROTECTED FROM STARFISH

Report on work during 1933.

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Rearing oyster spat protected from starfish.

Report on work during 1933. A.W.H. Needler.

Scope and significance. In this report are described some experiments in rearing oyster spat on trays, in boxes or in protected enclosures which were initiated in 1933 chiefly as an attack on the starfish problem. Losses caused by starfish from the time of planting spat until they reach a length of 1½ or 2 inches are the most serious obstacle to profitable oyster farming. Although profitable yields have been obtained by planting spat on beds from which starfish had been mopped even in the best cases the loss was large. In some cases almost all the spat were killed, in many over 90% were killed and a survival of 20% would be considered good and would assure a profitable yield. The collection of spat has met with good success each year since the work was commenced at the head of Bideford river in 1929 and mortality of the oysters has everywhere been low after a size of 1½ inches has been reached. So that the starfish problem is one of the most important facing us.

In another report already submitted by the writer this year ("Starfish and Oysters") an account is given of experiments and investigations attacking the problem including improvement of methods for catching starfish, study of the distribution and life history of starfish and study of the sizes of starfish which can attack oysters of various sizes. The latter experiments showed that oysters could usually resist successfully the attacks of starfish if two-thirds as long as the "diameter" of the starfish, and it was found that the very great majority of our starfish were too small to attack successfully oysters 1½ to 2 inches long. This confirms our previous observations that the mortality of oysters was low after reaching that size and our explanation of the losses as caused by starfish.

In this report an account is given of another attack on the problem - an attempt to rear the spat out of reach of the starfish to the size at which they are relatively safe. The attempt introduces immediately a number of other problems - factors influencing growth and survival, designing cheap apparatus, crowding and clustering and shape - and offers prospects of a number of beneficial results in addition to protection from starfish - e.g. prevention of smothering, production of single oysters, more rapid growth etc. The experiments during 1933 serve only to introduce the subject and extensions are planned during 1934.

The experiments were carried on at or near the Prince Edward Island Marine Station at the head of Bideford river. Many of the statements made above apply only to the Malpeque bay or similar areas as in other areas, of course, other problems are often much more serious than the starfish problem - e.g. spat collection, losses from drills etc.

Sources of spat. Methods of spat collection are related to the problems of rearing spat. The spat used in the experiments in 1933 were collected on cement-coated cardboard "egg-crate filler" spat collectors in 1932. These collectors allow easy separation of the individual spat which is, of course, an advantage in the rearing of single oysters. In previous reports on spat collection it has been pointed out that when large pieces of these collectors were planted on the oyster grounds crowding and clustering resulted which was practically as bad as with shell cultch and that they offered little advantage over the latter. On the other hand the singled spat when planted on ordinary or even relatively clean bottoms smothered easily and heavy losses occurred. Thus to make the cement-coated cardboard collectors worth while special methods of rearing the spat are necessary, and the rearing of spat on trays etc. in addition to its other advantages would bring into usefulness another kind of "cultch" to supplement the shell cultch which has been hitherto the chief satisfactory material for spat collection.

It is planned to extend the experiments to include some trials with spat on shells as it may be found that the rearing methods would be beneficial for them as well as for the singled spat from the cardboard collectors, although special problems of separating the spat would arise. Shells, when available, are more satisfactory than the cardboard collectors in a number of ways depending chiefly on the more fragile nature of the latter, and may be a better "cultch" material when spat are to be reared on trays etc. as well as when the spat are planted directly on the beds.

Holding spat over the winter. Our waters are frozen over for about four months and oysters do not grow for about six. The holding of the spat during this season when no growth occurs offers a special problem. The requirements for a method of holding them include: cheapness, convenience, sufficient circulation to prevent smothering and a method of placing the containers on hard bottom deeper than the bottom of the ice and of recovering them in the spring. As it has been found by several investigators that oysters remain almost continuously closed during the winter (ca.0°C) it was thought that it would be possible to hold them in bulk piled fairly deeply. This has been found to be the case.

Over the winter of 1932-33 spat were held in trays about 2' x 3' made of ¼" mesh galvanized wire cloth supported by copper painted hardwood strips 2" x 1" in cross-section. Two of these trays, which were originally made for rearing the spat, were tied together face to face leaving a space about 4" deep. In each of two trays about 20,000 spat were placed piled 2" to 3" deep. The spat were mostly 1 cm. to 2.5 cm. in length and many had a small piece of the cardboard collector attached. The trays were placed on a hard bed sufficiently far below the surface to escape the ice. The strips supporting the netting of which the trays were made supported them off the bottom slightly so that circulation was possible from below as well as from above. The spat were kept in the trays until the end of May and at that time between 5% and 10% were found to be dead. A higher proportion of the smaller were dead than of the larger. It is to be noted that a certain small proportion of the spat were doubtless dead when placed in the trays in 1932 and it is safe to estimate the mortality during the winter at about 5%.

To test the effects of holding the spat in bulk at the higher temperatures which were reached after the end of May, a small box of the ¼" wire cloth 6" x 5" x 5" was filled with spat and suspended from a float on June 2nd. By July 11th no mortality had occurred, those on the outside were growing well and those inside not at all. Some silt had settled among the spat which must have reduced the circulation greatly. The absence of mortality in this case shows that in holding spat over the winter piled some inches deep there is no need to spread the spat on trays immediately to avoid mortality, i.e. that there is plenty of time to arrange the trays and put out the spat even allowing for bad weather and large quantities to be handled.

Spat put out in the autumn of 1933 were placed in simpler containers made for the purpose. A rectangular frame of 2 x 4 spruce on edge was made, the wire cloth for the bottom nailed directly to it and protected by wooden strips, and a simple cover made with wire cloth and strips. For use in the winter copper-painting is not necessary and unplaned lumber is satisfactory, as the larvae of Teredo settle only in the summer. Thus one of the chief sources of danger and expense is absent in winter. The containers used in 1933 were filled completely and held about 22,000 spat each of an average length of 2 cm. The cost of the materials in these containers (inside dimensions 20" x 36" x 4") was about 55 cents (7 ft. 2x4 spruce at .02, 6 sq. ft. wire cloth at .06, and nails etc.).

Details of rearing experiments. The experiments were rather crude attempts along what appeared to be promising lines. They do, however, indicate a number of factors influencing the growth and survival and their action, and in a number of instances met with considerable success. They serve as preliminary trials on which to base more intelligently planned experiments. The methods included (1) enclosure on firm shore at low tide, (2) large open floating tray, (3) trays suspended from floats and (4) shelved boxes of wire cloth suspended from floats.

The spat used in the trials were obtained from cardboard collectors in 1932 and held over the winter as reported above. The size varied between extremes of about 0.5 and 3.0 cm. with most between 1.0 and 2.5 and average and mode about 1.75 cm. Samples set aside for measurement were unfortunately left at the Prince Edward Island Marine Station and the size frequencies cannot now be presented in detail, but the above will serve to indicate the original size which was approximately the same in all the trials.

1. Enclosure on firm shore at low tide level. An area 8'x8' was selected on firm gravel-mud shore in the cove just west of the P.E.I.M.S. at the level of an ordinary low tide. It was surrounded on three sides by small stakes placed about 2" apart to which wire cloth was attached making an effective barrier keeping out starfish.

Fig. 1. Enclosure for rearing spat. Bideford river, 1933.

The enclosure was prepared on June 2nd and 3rd and 4,500 spat were planted in it on June 5th there being an area of about 1½ square inches per spat. A storm from the NE piled many of the spat into the inner western corner of the enclosure on June 25th but apparently few escaped from the enclosure, the force of the waves being broken by the spruce trees which had been anchored as break-waters. By July 9th there had been little or no mortality, considerable growth and a growth of algae (largely green) without as yet an accumulation of silt. On Aug. 9th silt was accumulating among the algae, the growth appeared to have slackened and a considerable proportion of the spat were dying. A sample was measured and a second sample on Aug. 31st showed little growth in the interval and an increased mortality. By Aug. 31st about 2" of soft silt had accumulated. On Sept. 30th the spat were removed, 2210 being recovered alive and between 1,000 and 1,500 dead (largely as seperate valves). The shape was very poor as compared with that of the spat reared on floats - being crooked, long and thin relatively. A few measurements indicate this: in inches 2½x1 1-8, 1¼x1½, 1¾x1, 1¼x1, 1⅜x1, 2x1½, 1⅜x1¼, 1¾x1¼, 2⅜x1, 1⅜x7-8, 1¾x7-8. Average length (width =1.65 (11 indiv.). Range 1.2 to 2.5.

Table 1. Spat reared in enclosure on shore.

Length (")	When planted. Number	August 2. Number	August 31. Number	Sept. 30. Number
½		1	4	0
¾		3	3	1
1		24	11	7
1¼		33	25	13
1½		26	27	13
1¾		12	22	27
2		1	10	8
2¼		0	4	4
2½		0	0	2
2¾		0	0	0
3		0	0	1
Av. length.	ca. .75	1.35	1.46	1.63
Number weighed	———	———	54	50
Av. weight (gm.)	———	———	4.8	6.4

These shapes vary a great deal and some are extremely long and narrow.

The general results of this experiment are not as satisfactory as in many cases of rearing on floats. The spat were not crowded more than on floats (not nearly as much as in some cases) as regards the area per spat, but the circulation was probably much poorer. This is indicated by the accumulation of very soft fine silt which was apparently responsible for most of the mortality and poor shape, and possibly in part at least for the poor growth. On neighbouring unsheltered shore no silt accumulated and the spat occurring there naturally were of excellent shape and somewhat greater average size.

I had imagined, as a possible development, the use of a stretch of shore protected from severe wave action by anchored trees. It may be possible to arrange a second experiment in which more circulation is permitted without allowing sufficiently severe wave action to remove or destroy the spat. On the whole, however, the results of this trial are much less encouraging than those on floats, with poorer shape and growth, and a loss of about 50%.

2. Large floating tray. A tray 15' x 4' was made with 4x6 spruce on edge along the sides and 2x6 spruce on edge across the ends. The floor of the tray was made of galvanized wire cloth nailed to the frame and supported underneath by 2"x1" strips from side to side of the tray. All the wood was copper-painted after a priming coat of white lead paint. The tray when placed in the water with small spat at the beginning of the season floated with about 3" of the stringers out of water and gradually sank until they were almost covered at the end of the season. The tray was anchored in a very sheltered situation in McKinnon's creek at the head of Bideford river and a bundle of brush was tied to the line by which it was anchored, to form a breakwater.

The tray was prepared on June 6th and 15,000 spat placed in it. The inside area of the tray was about 7,500 square inches and there was about one half of a square inch per spat. Growth, however, was at first fairly rapid and there was an extremely low mortality. Green filamentous algae grew luxuriantly in the tray and large quantities were removed on July 11th and Aug. 30th. The spat overlapped one another almost from the beginning and by Aug. 30th were piled about 2" deep. Few, however, were grown to one another and the mortality remained low.

13,800 were recovered alive from the tray and about 1,100 (less than 10%) dead, a few being lost. The percentage grown to one another was about 5% the remainder being single. The shape, although much better than that of spat from the enclosure on shore, was on the average poorer than best obtained in the experiments which follow. Measurements in inches (sample taken Nov. 6th):

1.3 x 1.1, 1.6 x 1.1, 1.8 x 1.2, 1.8 x 1.1, 2.1 x 1.3, 1.9 x 1.3, 1.6 x 1.2, 2.1 x 1.2, 1.7 x 1.3, 2.4 x 1.4, 1.4 d 0.8, 1.6 x 0.9, 1.8 x 1.1, 2.0 x 1.4, 2.0 x 1.2, 2.1 x 1.2, 1.3 x 1.1, 1.8 x 1.2, 2.0 x 1.4, 2.4 x 1.3, 1.8 x 1.4, 1.9 x 1.3, 2.2 x 1.3, 1.7 x 1.5, 1.1 x 0.6, 1.6 x 1.3, 1.9 x 1.5, 1.3 x 1.1, 1.2 x 0.6, 2.3 x 1.8, 1.9 x 1.7, 2.0 x 1.2, 1.9 x 1.2, 1.7 x 1.1, 1.7 x 1.2, 1.9 x 1.1, 1.8 x 1.0, 2.4 x 1.4, 1.4 x 1.3, 1.5 x 1.0, 1.8 x 1.0, 1.6 x 1.1, 1.4 x 1.1, 1.5 x 1.1, 1.7 x 1.2, 1.7 x 1.1, 0.8 x 0.5, 1.6 x 1.1, 1.6 x 1.2, 1.8 x 1.1, 1.4 x 1.0, 1.3 x 1.0, 2.0 x 1.3, 1.2 x 1.1, 1.1 x 0.8, 1.2 x 0.8, 2.6 x 1.6, 1.3 x 1.0, 1.0 x 0.7, 2.2 x 1.5, 1.8 x 1.2, 1.5 x 1.2, 1.6 x 1.1, 1.1 x 0.9, 1.3 x 1.0, 1.8 x 1.2, 1.6 x 1.1, 1.2 x 0.9, 2.0 x 1.1, 1.3 x 1.0, 1.4 x 0.7, 1.8 x 1.0, 1.7 x 1.1, 1.3 x 1.2, 1.8 x 1.0, 1.4 x 1.4, 1.2 x 0.8, 1.0 x 0.7, 2.0 x 1.5, 1.9 x 1.4, 1.7 x 1.2. Average Length / width = 1.49. (81 indiv.) Range 1.0 to 2.0.

Table 2. Growth of spat on large floating tray.

Length (")	When planted	August 30	October 17	November 6
½		——	——	1
¾		——	1	3
1		5	1	19
1¼		13	3	48
1½		16	21	83
1¾		21	13	68
2		29	17	37
2¼		16	11	10
2½		8	4	6
2¾		3	——	——
No. measured		111	204	444
Av. length	ca. 0.75	1.84	1.81	1.59
Av. weight (gm)		6.7	10.7	7.5
No. weighed		38	70	80

The above table shows a decrease in the average length of spat in samples taken Aug. 30th to November 6th. The first sample was apparently not representative as my notes show that of 1,000 taken on that date and transferred to floats only 25% were 2" long or longer, as compared with over 50% in the sample in the table. No growth occurred between Oct. 17th and Nov. 6th as the temperature was approaching the lower limit at which feeding occurs. The Nov. 6th sample was taken because it was suspected that the Oct. 17th sample was not representative. The average for the whole probably lies between the two.

The cost of the tray may be estimated as follows: wood of frame - ca. 100 ft. at 2.50, wire cloth - 60 sq. ft. at .06 = 3.60, nails, labour and copper paint ca. 2.00. Total original cost about 8.00. The trays would probably last for three years, with repainting, and the annual cost of the tray would be about 4.00 of which nearly half might be labour. This is a cost of ca. .30 per 1,000 oysters if the number reared is about 13,000. As this is apparently too high a number the cost, for best results, would probably be .40 or .50 per 1,000.

To summarise the results with the large floating tray. It was found to rear 13,800 oysters to an average length of close to 1¾" with a mortality of about 10% and the production of a reasonably good - though not the best - shape. Only 5% were grown to one another The tray was moored in a <u>very sheltered</u> place and very little trouble was involved in looking after it. The oysters were apparently not overcrowded early in the season but became very much so later - as is indicated by the small amount of growth after the end of August. Possibly one of the hindrances to growth was the strong growth of algae in the tray.

It is planned to extend the experiments with trays of this type. By covering the trays the effect of exclusion of light and prevention of algal growth will be studied and at the same time more exposed situations can be used without danger of loss. In addition to this it is planned to try various concentrations, the effects of thinning part way through the season, the variations in growth and shape in different situations etc.

3. Trays suspended from floats. A number of trays ca. 2' x 3' made of wire cloth supported by copper-painted hardwood strips (1"x2") were suspended from a float similar to those designed for spat collection. The floats are described and figured in Note #28, Progress Reports, Atlantic Biological Station. The inside dimensions of the trays were 22" by 34" - an area of about 748 sq. inches. The sides were formed by 2"x1" wooden strips on edge.

The suspension of trays from floats offers some practical difficulty. The method employed was briefly as follows: For each set of trays four heavy (40 lb. ±) concrete weights were suspended by heavy galvanized wire (#9) (the "brace wire" fences) spaced so that they passed the ends of the trays close to the sides. The trays, provided with wires to the corners which could be hooked with a boat-hook, were attached to the large wires with small wire loops and allowed to slide down. The trays were weighted with bricks to make them sink and each tray rested on two pieces of wooden strips nailed on edge on the top of the tray beneath. This method was found to be cumbersome but it is difficult to design a method of suspending a large number of trays one above the other.

Two such series of trays were suspended from one of the two-puncheon floats. In each the lowest tray was about 8 feet below the surface, and six trays were spaced evenly between that depth and a depth of about 3 feet. Trays were not placed nearer the surface as they would then have been in slack water caused by the puncheons and the wire bags of shells which were hung about the float to make it more stable.

Unfortunately a heavy storm on Oct. 29th, after removing many of the bags of shells caused the float to overturn and the loss of much of their material just before the final examination. The data are, therefore, somewhat limited.

In one series the trays were open and in the other they were covered by a second similar tray fastened upside down over each. Let us first consider the open trays.

Six open trays were put out on June 5th to 9th each with 950 spat, leaving just over ¼" sq. in. per spat.

Table 3. Spat reared on uppermost open tray.

Length(")	When planted	Aug. 4th	Aug. 31st	Sept. 29th
¾		1	6	0
1		6	6	16
1¼		17	20	30
1½		16	42	89
1¾		7	27	115
2		8	17	105
2¼		1	3	22
2½		0	1	9
2¾		0	0	0
3		0	0	0
Number measured		56	122	386
Av. Length	ca.0.75	1.47	1.55	1.74
No. weighed			51	
Av. weight (gm.)			7.0	

The growth of the spat in the uppermost open tray is indicated by the data in Table 3. An average length of 1¾ inches was reached - slightly higher than in the large floating tray. The shape was excellent and the weight at the end of September was high. No clustering occurred and mortality was only about 5%.

The uppermost tray was examined much more often than the lower trays as it was necessary to remove the upper trays to get at the lower. There was also some thinning in the uppermost - samples preserved etc. The lower trays were all closely similar and in general it may be stated that the growth was greater, the shape poorer and the clustering worse (about 5% grown to one another). The mortality was about 5%.

After the storm on Oct. 29th, 1960 living and 125 dead spat were recovered which had been dumped out of the lower open trays. Tongs specially prepared to catch small material by weaving wires between the teeth were used. But it must be realized that the spat recovered were probably larger on the average than the spat as a whole on the lower trays. They are of some interest, however.

Table 4. Spat from lower open trays on float, recovered after storm.

Length (")	Number
1	4
1¼	10
1½	30
1¾	56
2	96
2¼	36
2½	120
2¾	77
3	24
3¼	26
3½	0
3¾	0
4	1

Average length 2.21"

The average weight was 16.8 gm. The largest was 4"x1¾"x1". The shape was poor and there was a considerable amount of clustering.

Turning now to the double or covered trays, they were put out at the end of May (27th to 31st) with the same number of spat in each as in the open trays. When examined on July 11th the uppermost tray showed no mortality, not much algae and 2" as the maximum size of the spat. When recovered after the storm of Oct. 29th the order of the trays could not be distinguished as they had broken loose. The three recovered were, however, similar in every way indicating little or no effect of depth on the growth. 6.0% of the 2966 spat in the three trays were dead, and of the living 6.2% were clustered the remainder being single. In shape and proportion clustered these were indistinguishable from those recovered after dumping from the lower open trays. The shapes are indicated by the following measurements: 2.5 x 1.3, 2.3 x 1.0, 3.5 x 2.3, 2.0 x 1.4, 3.0 x 1.6, 3.5 x 2.0, 2.3 x 1.3, 3.0 x 1.3, 1.8 x 1.3, 2.2 x 1.6, 2.0 x 1.0, 2.2 x 1.2, 3.0 x 2.0, 2.5 x 1.5, 3.0 x 1.5, 2.6 x 1.6, 2.7 x 1.9, 2.4 x 1.7, 1.6 x 0.7, 1.5 x 1.0, 2.1 x 1.8, 2.5 x 1.4, 3.4,x 1.6, 2.8 x 1.3, 2.7 x 1.4, 2.7 x 1.6, 2.9 x 1.7, 2.0 x 1.0, 3.4 x 2.0, 1.3 x 1.4, 1

1.9 x 1.4, 3.0 x 1.8, 2.4 x 1.6, 2.7 x 1.3, 2.6 x 1.3, 2.0 x 1.3, 1.7 x 1.3, 1.7 x 1.2, 1.4 x 1.0, 1.6 x 1.0, 1.3 x 1.0. Average length-width 1/70. (41 indiv.).

Table 5. Length of spat from double trays.

Length (")	Number
1	4
1¼	13
1½	22
1¾	19
2	20
2¼	14
2½	23
2¾	18
3	18
3¼	4
3½	7
3¾	1
4	2

The table shows the length frequencies. The average weight of 40 was 15.9 gm.

When allowing for some influence of selection by the tongs the spat from the covered trays and from the lower open trays are very similar indeed. The former being somewhat longer but the latter slightly heavier for their length. We may summarize those trays as producing the largest growth of any of the experiments both in length and weight, but poor shape (L-W=1.7) and some clustering (ca. 6%). The mortality was low. The shape was inferior to any of the others except those in the enclosure on the shore. This is contrasted with the excellent shape in the uppermost open tray. The latter was handled very often whereas the lower open trays and the covered trays were hardly handled at all.

Although the trays suspended from the floats were shown to be capable of producing good growth and shape, the method is not very promising from a practical point of view. The suspension is cumbersome and so few trays can be suspended from a float that it becomes expensive. The cheaper open trays must be ruled out owing to danger of loss. These difficulties must be overcome if this general scheme is to be made as good as the large floating tray or as the shelved wire-cloth boxes which follow?

4. Shelved boxes of wire cloth. A box of ¼" galvanized wire cloth was made 6" x 12" x 24" (the dimensions being determined largely by the size of the pieces of cloth) and suspended on end with five horizontal partitions or shelves making four compartments about 3" high at the bottom and two about 6" deep at the top. Into these were counted (from bottom to top) 150, 250, 350, 450, 550, 650 spat respectively. They were put out on the float June 15, and on July 11th, had grown well but none of the compartments were yet full. The box was hung with the top about 2' below the surface and few algae or mussels settled on it.

On Aug. 2nd about one half of the spat from each compartment were transferred to the corresponding compartment in another box similar in every way except that it was divided into six equal compartments about 6" x 11½" x 4".

Table 6. Thinning of spat in shelved box.

Comp't	Transferred to new	Left in old	Dead	Lost	
Bottom A	75	71	4	—	
B	125	86	15	24	
C	175	178	27		30 extra
D	225	182	45		2 extra
E	275	234	21	20	
F	325	260	55	10	

It can be seen that some were lost or made their way from one compartment to another. These would be small enough to fall through the meshes and must either have died soon after putting out the box or have fallen through then. It is indicated, however, that there was a smaller loss or mortality in the bottom compartment (about 5%) and more in the upper compartments (up to about 10%).

Table 7. Sizes of spat in shelved boxes, Aug. 2nd.

Size (")	Compartments. A (new)	A (old)	D (new)	D (old)	E (new)	E (old)
¾	—	—	1	6	—	1
7-8	1	—	1	2	1	6
1	2	1	3	3	1	5
1 1-8	1	4	2	3	2	5
1¼	—	1	7	6	5	10
1 3-8	1	5	8	10	3	8
1½	4	2	4	10	5	4
1 5-8	7	3	3	3	5	1
1¾	3	5	2	5	8	1
1 7-8	5	5	1	1	2	2
2	—	1	1	—	4	—
Av. Lgt.	1.56	1.54	1.36	1.31	1.55	1.24

Table 7 gives the sizes of samples of spat measured. It shows a tendency to select the larger spat in transferring to the new box, but it also indicates that the spat in the lowest compartment grew best, in the "D" compartment least and better in "E". "E" had more spat but was twice as large. "D" was actually bulging and none of the other compartments had much room left. Rough observation indicated a gradation from "A" to "D" (and smaller spat in "F" than in "E"??).

Table 8. Lengths of spat in shelved box, Aug. 31st.

Size	Compartment. A (new)	D (new)
½	—	1
¾	—	6
1	3	27
1¼	10	40
1½	17	40
1¾	20	36
2	17	25
2¼	5	4
2½	—	1
Av. Lgt.	1.69	1.48

Table 9. Spat reared in shelved box, Nov. 9.

	Compartment.					
	A.	B.	C.	D.	E.	F.
Alive	73	128	162	213	259	304
Dead	1	0	4	11	3	11
Average weight (gm)	14.1	13.2	10.9	9.9	7.7	9.4
Length.						
$\frac{3}{4}$	—	1	—	2	4	2
1	1	1	4	3	9	10
$1\frac{1}{4}$	8	9	8	11	11	12
$1\frac{1}{2}$	19	12	15	13	13	21
$1\frac{3}{4}$	21	19	13	19	15	15
2	15	19	13	16	11	19
$2\frac{1}{4}$	6	6	5	3	3	6
$2\frac{1}{2}$	3	5	7	2	3	4
$2\frac{3}{4}$	—	2	—	1	1	1
Av. Lgt. (")	1.74	1.77	1.75	1.70	1.61	1.66

Tables 8 and 9 show the growth of the spat transferred to the new box. It shows that the lowest three compartments produced spat of similar lengths, that the lengths decreased to D and E and increased again slightly to F. The average weight of the spat showed a steady decrease from A to E and a slight increase again to F. F, although with more spat than E, has the advantage of another uncovered side from which to get circulation. The shape of all the spat was good. In the fuller compartments it was evident that the spat in the centre had grown least.

The above results, though somewhat crude, show that there are practical prospects to such a method. The mortality was low, the shape produced was good and the growth fairly good. The method will be used in further experiments in 1934 which will include comparison of effects of crowding independently of depth, and of depth independently of crowding, the effects of handling and jarring in regard to the formation of clusters and other minor points.

The boxes as constructed in 1933 require about 11 sq. ft. of wire cloth (at .06 66 cents) and a considerable amount of labour.

Supposing 125 spat to the compartment or 750 to the whole this represents a cost of 0.80 per 1,000 for materials alone and not including a means of suspension. This indicates that the cost of this method without modifications is double that of the large floating tray. A number of improvements are, however, possible. It was found that the wearing quality depends to a large extent on avoiding racking the wire cloth. Bending cracks the galvanized surface and permits rusting. It was found that the wire suspending the boxes should encircle them woven into the sides, instead of passing through only the upper corners.

General discussion. After the outline of each experiment given above it may be worth while to make what generalizations are possible, or rather to discuss various problems and results in the light of all the experiments combined. At this early stage this is a matter of sketching the problems and putting forward questions or suggested explanations, not one of summarizing results.

Growth. A great variation in the size attained by the spat at the end of their second summer (15 months old) was found, - both in the average sizes attained in the different experiments and in the sizes of the individuals within each experiment. The latter was always very large - e.g. ¾" to 2¼" in shelved box, 1 " to 4" in covered trays suspended from the float. In fact the minimum size always approached the maximum size of the spat planted and we can say that there were always some which grew very little and some which died without growing at all. This suggests that some were always in very poor situations for growth - often through overcrowding. It seems possible also that some were weakly or injured by the spring and would not have grown or lived in the best conditions. A whole series of problems are raised in this connection. What causes the individual variations and can they be avoided or, rather, reduced by altering the arrangement of the spat or trays, by thinning etc.? From the practical point of view this is very important and the relation between the increased cost (possible smaller number of spat per container) and increased growth is of interest in deciding what alteration of method pays. The observations hitherto suggest that in many instances spat have been crowded to such a degree that some have been unable to grow more than a very little, and that crowding would be profitably reduced until these extreme conditions were eliminated as such spat are just so much extra trouble with no profit. Experiments on crowding and its effects are planned for next season to supplement the preliminary experiments with the shelved boxes (p. 15) in which overcrowding was indicated as a factor in the reduction of growth. Position in the container - such as in sheltered corners - also appears to play a part in the individual variation superimposed on the effect of crowding. It is expected that more detailed observations in this regard will lead to alteration in the design of the trays, boxes etc.

The average sizes attained by spat reared may be summarized as follows:

	Av. Length (")	Av. Weight (gm.)	
Enclosure on shore.	1.63	4.8	v. poor shape.
Large floating tray	ca. 1.6	ca. 8.	good shape.
Uppermost open tray	1.74	?	v. good shape.
Lower open, and covered trays.	ca. 2.2	ca. 16.	poor shape.
Shelved boxes,-			
most crowded	1.6	7.7	fair shape.
least crowded	1.74	14.0	good shape.

"Poor shape" means long, thin or twisted. It is always accompanied by low weight in relation to length.

Crowding is indicated as one of the chief factors influencing the average as well as the individual growth. It is the chief variant in the wire-cloth shelved boxes. The effects of crowding are more evident in the average weights than in the average lengths owing to its influence on shape. With the exception of the enclosure on the shore in which siltiness and smothering played a part, the average size attained is roughly in inverse proportion to the crowding - the least crowded being the trays suspended from the floats and the most crowded being the large floating trays and the more crowded shelves in the wire boxes. Crowding is, of course, related to circulation and probably is effective through reducing the circulation and, consequently, the food supply. In the large floating tray circulation was possible only from below through the wire and growth may be increased by opening the ends to circulation, or by changing the situation of the tray to places with a stronger current. Experiments are planned to study influence of crowding and of strength of current.

The experiments do not give reliable indication of the influence of depth on the growth. Near the surface algae grow luxuriantly and tend to reduce the circulation, while below a depth of about 2 feet the growth is negligible from that point of view (probably owing to reduction of light). In the large floating tray the algal growth was very pronounced and, it is believed, greatly reduced the circulation. It is proposed to try excluding the light. Changes in depth are also probably correlated with changes in the quantity of food and in this respect very different in different situations. The depth also influences the amount of light, of which the direct effects are not yet indicated.

The influence of the foods supply, as may be seen, enters into crowding, circulation, depth and situation in the inlet; and progress in the study of all these factors needs first of all observations on the food supply and its correlation with growth, and, if ~~possible,~~ possible, experiments on the effects of altering the food. One of the chief fundamental questions is what is the degree and nature of the influence of the food supply on growth and fatness.

The influence of temperature and salinity on growth are not evident from our results hitherto in the rearing of spat. Other studies have indicated that areas of high temperature (usually associated with low salinity and low currents) are favourable to rapid growth, and this probably applies to the rearing of spat. Our experiments in 1935 have not been sufficient to dissassociate temperature or salinity from other factors.

Enough has been said to indicate the complexity of the conditions and some lines of attack. As regards the experiments as a whole it is worth mentioning that, except for the enclosure on the shore, the growth appeared to be well above the average occurring in nature when spat are growing on the bottom. If increased by further improvements it will probably be more than double the latter. This is in itself a valuable result, in addition to the reduction in mortality which was the chief object in developing these rearing methods.

Survival. The survival was everywhere good and even in the enclosure on the shore the loss (about 50%) was below the average obtained when spat are spread on beds even after an effort has been made to remove the starfish by mopping. In the other experiments the mortality was about 10% or less, and, as has been suggested above, may be considerably reduced by avoiding overcrowding.

Starfish settle on the trays early in the summer but do not reach a large enough size to attack the spat being reared although they are quite large enough to attack the spat of the current year. The avoidance of destruction by starfish is probably the chief factor in the reduction of the mortality. The high proportion of the spat passing a length of 1½" offers good prospects of avoiding the starfish problem by a single year's rearing.

Shape and clustering. The overcrowding is indicated as the chief factor producing poor shape and clustering. In the enclosure on the shore siltiness was evidently the chief cause of the very poor shape, but in the floating experiments overcrowding is indicated. In instances in which the experimental trays were not disturbed all season about 5% of the spat grew to other spat - often to a degree making it impossible to separate them without killing one. On the other hand when the spat were frequently handled practically none of this occurred even in the extreme crowding in the shelved boxes. It seems that shaking separates the spat again in the early stages of the clustering. Even 5% is a small proportion in clusters and the production of single oysters is one of the advantages of these rearing methods.

Economic value. The cost of the rearing indicates that the methods when properly developed will be of definite value to the industry. Thus in the cheapest method tried - large floating tray - the cost of the rearing itself was about .30 per 1,000 and in this experiment 70% had reached or passed lengths of 1½" and 20% 2" - i.e. were past the greatest danger of loss by destruction by starfish. Thus, by bringing into use another form of cultch (concrete-coated cardboard collectors) and avoiding the great losses in the first year, the rearing of spat by these methods promises to be economically profitable.

Toronto, April, 1934.