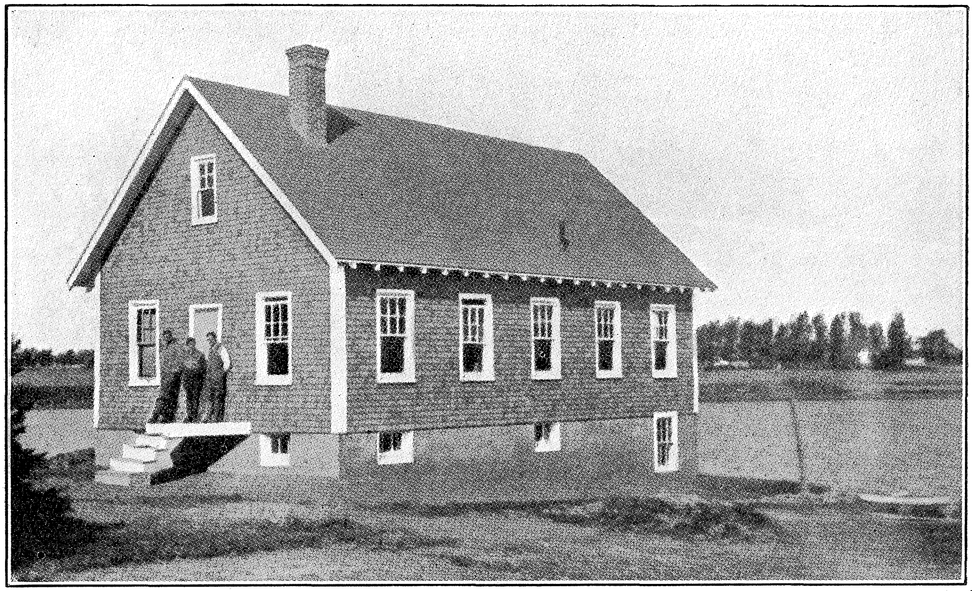
THE BIOLOGICAL BOARD OF CANADA
UNDER THE CONTROL OF
THE HON. E. N. RHODES
Minister of Fisheries

BULLETIN No. XXII

THE OYSTERS OF MALPEQUE BAY

BY
A. W. H. NEEDLER
Prince Edward Island Marine Station

OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1931



The Prince Edward Island Marine Station, Ellerslie, P.E.I., established by the Biological Board of Canada, principally for the investigation of problems connected with the oyster industry.

(Photograph by H. P. Sherwood).

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INTRODUCTION

In the present paper a summary is given of the conditions in the Malpeque bay area which have a bearing on the prospects for oyster cultivation. It makes no pretence of being more than a preliminary survey of the situation, made to enable us to take as intelligent action as is possible now and to pave the way for further investigations which are already under way. No attempt has been made to present in detail recent scientific results, but rather to give them briefly and only in so far as they have immediate application. Reference has been made to earlier work in this area and to that of investigators elsewhere.

In this area, as in all known cases, the natural reproduction of the oysters has not been able to compensate for the drain of intensive fishing and the oysters became scarcer as time went on. The great yield of the "eighties" and early "nineties" of the past century was reduced to one-sixth by 1905. The necessity of oyster culture to maintain the yield was early realized, but, owing to misunderstanding between the Dominion and Provincial governments regarding jurisdiction over the leasing of oyster grounds, neither was in a position to encourage private culture. Before 1913 only one or two men with leases of long standing engaged in active oyster culture. In 1910 the Fisheries Act was amended to enable the leasing of oyster grounds, and working agreements were entered into by which the provinces had control of leasing. In 1913 the Prince Edward Island government leased about 5,000 acres in Malpeque bay to about a dozen companies. The activity was cut short in 1915 and 1916 by a disease which killed almost all the oysters of the area and for many years thereafter no oysters from the bay were marketed.

The working agreements between the Dominion and Provincial governments were not entirely satisfactory in that the latter did not take over the administration of the public as well as the private beds and a dual control of the oyster industry resulted. This was brought to an end as far as Malpeque bay was concerned by an agreement in 1928 by which the Dominion government was given complete control of the oyster industry in Prince Edward Island. The Dominion government, on the other hand, undertook to carry out investigations to ascertain the best methods of developing the industry and to take measures towards that end. The services of an oyster farmer from Rhode Island, Mr. D. R. Dodge, were secured in 1928 and 1929 to conduct trials of oyster cultivation in Malpeque bay. His operations included the introduction of oysters from other areas to build up a spawning stock and the collection and planting of spat in Grand and Bideford rivers. The direction of this work was taken over by the writer in 1930.

Scientific investigations of the oysters in the Malpeque bay area were commenced as early as 1903 when the movable laboratory then maintained by the Biological Board of Canada was stationed at Malpeque. Dr. Jos. Stafford started a special study of the life history of the oyster there in 1904 and continued it in succeeding years. (STAFFORD, Jos. "The Canadian oyster, its development, environment and culture," *Commission of Conservation, Canada,* 1913). When the necessity of cultivation became more obvious as the abundance of the oysters declined, further surveys of the conditions in the bay were made under the auspices of the Biological Board. In 1914 A. D. Robertson (Report on the barren oyster bottoms, Richmond bay, P.E.I. *Contributions to Canadian Biology,* 1914-15, pp. 55-72) and in 1915 Dr. Julius Nelson (An investigation of oyster propagation in Richmond bay, P.E.I., during 1915. *Contributions to Canadian Biology,* 1915-1916, pp. 53-78) carried out investigations of the hydrography, the production of larvae and spat, and other aspects of the subject.

After most of the oysters had been killed by the disease in 1915 and 1916 no intensive investigations were carried out in the area until the writer commenced work there in 1929 for the Biological Board of Canada. This was an integral part of the attempt of the Dominion government to re-establish the oyster industry of the area. The work in 1929 included a general survey of the hydrography and of the oyster population and experiments in the collection of spat in which we had the assistance of Mr. W. J. Duchemin as a volunteer. In 1930 the services of Mr. H. P. Sherwood, who had had considerable experience in oyster research in Great Britain, were obtained for part of the year and Dr. A. B. Needler and Mr. E. T. McEvoy carried on work as volunteers. The Prince Edward Island Marine Station (shown in the frontispiece) was established near the head of Bideford river as a centre for the oyster investigations. The work included study of the hydrographic conditions, the spawning and distribution of the larvae, collection of spat, transplantation at various ages and other aspects of the problems arising in cultivation.

The purpose of the various investigations has been to lay the basis for cultivation, using methods adapted to the special conditions of the bay. Even before the disease of 1915-1916 the annual yield of the area had reached a level only a fraction of that of earlier years. The disease completed the work of intensive fishing without cultivation and reduced the stock to a level so low that for years the number of marketable oysters present was negligible from an economic point of view. Now oysters immune to the disease are increasing somewhat in numbers at the heads of the inlets and to a lesser extent everywhere along the shores. These can serve as the basis for the development of the industry through cultivation, whereas there can be little doubt that fishing without cultivation would prevent the development of any considerable stock and, indeed, reduce even what little there is. The only hope of the industry in this area is, then, cultivation. The recent investigations have had as their goal the accumulation of knowledge of the local conditions and of the life history of the oysters sufficient to adapt known methods of culture to the needs of the area and, if possible, to discover improvements.

GEOGRAPHY OF AREA

Figure 1 is a map of the area showing outlines of the shores and the depths. The principal features can be readily seen. The points of particular interest may be mentioned: (1) The mouth of the bay is almost closed by sandbars and the channels are narrow and not very deep. This hinders the mixing of the water inside with that outside and allows the water of the bay to reach a higher temperature in the summer; (2) The bay is broken by shoals and islands which further hinder exchange with the outside; (3) There are a large number of inlets, locally called "rivers," opening on the bay and these are still better protected.

The greatest depth in the bay is about fifty feet but only a small part of the area is more than eighteen feet deep and about half no deeper than twelve feet. The small depths favour warming of the water in summer and hence the growth of oysters. The shores are, as a rule, quite shelving and considerable flats are exposed at low tide in spite of an average rise and fall of only about three feet. This also is an aid to warming of the water in summer.

The bottom of the bay and inlets consists in different parts of sand, oyster-bed or mud. Mud predominates in the deeper parts, in the channels and at the very heads of the inlets. Sand is common in the shallower stretches of the bay and the mouths of the rivers. Oyster beds or bottoms covered with shells are to be found throughout the area in small or large patches, except near the entrance to the bay and in the deep central portion. The beds vary in size from a small fraction of an acre—mere spots—to many or even hundreds of acres.

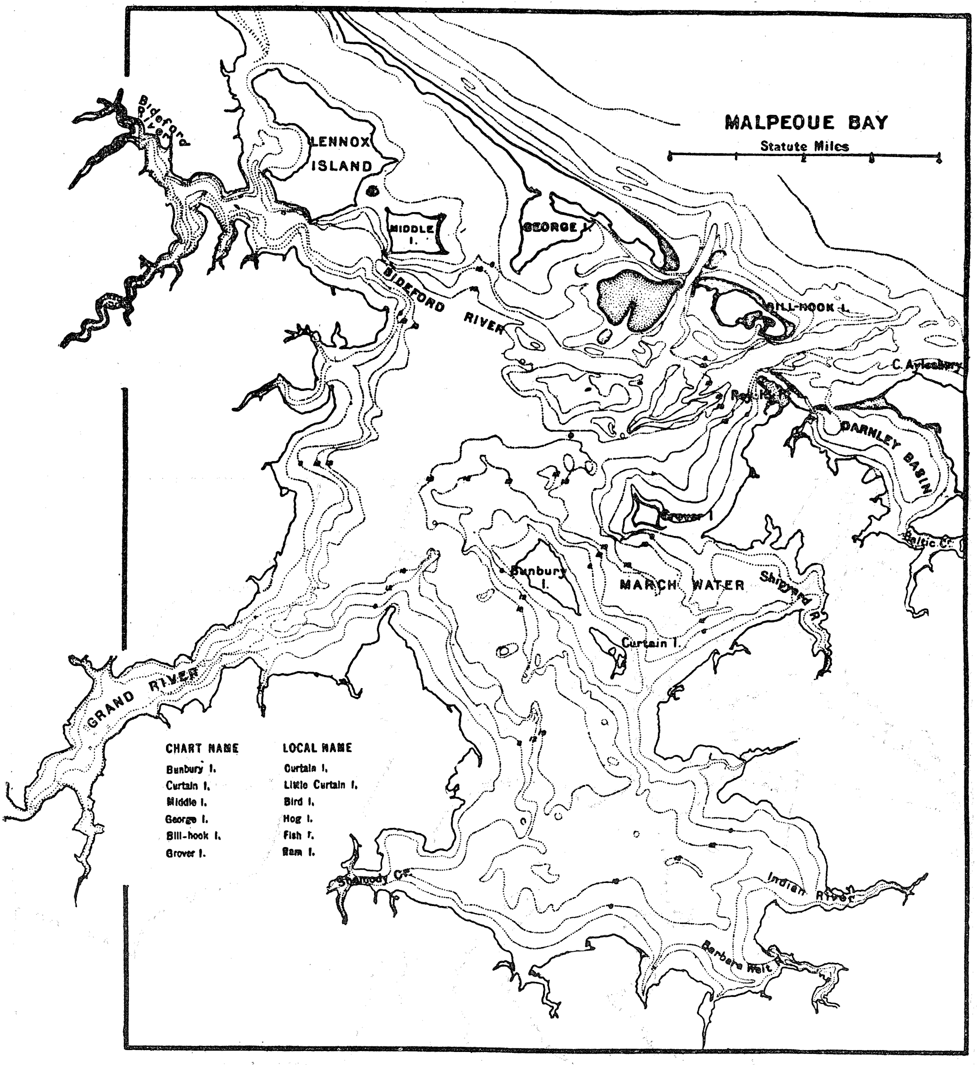

FIGURE 1—Malpeque bay and its tributary inlets. Since this chart was made the channel between George and Bill-hook islands has become much shallower being open only when the tide is high.

The total area of the bay and its inlets is about 40,000 acres. Of this we would estimate that at least a quarter might be used for the production of oysters. The remainder would not be available without great expense, chiefly on account of the nature of the bottom. In parts next to the entrance of the bay hydrographic conditions are unfavourable.

HYDROGRAPHY OF AREA

The chief features of the hydrography may be briefly outlined.

SALINITIES

The salinities prevailing in the bay are higher than might be expected. The protected nature of the bay and the small tides do, it is true, make the amount of mixing with waters outside the bay small. But the area of the surrounding land is small compared with the length of the coast and the streams have only very small drainage areas. As a result fairly high salinities prevail right up to the heads of the "rivers" which are in reality inlets with only small brooks entering them.

Robertson, in 1914, found salinities from 2·3 per cent (towards the heads of the inlets) to 2·9 per cent and even 3·0 per cent in the bay. Those found by Nelson in the summer of 1915 were somewhat lower but very similar. The salinities observed by the writer in 1929 and 1930 were also similar. Even after heavy rain the salinity at the bottom in five feet of water near the head of Bideford "river" (figure 2, A) never fell below 2·3 per cent and it was usually about 2·7 per cent to 2·9 per cent. Salinities of this sort are apparently the rule to within two or three hundred yards of the head of tide and the water may be over three quarters as salt as that of the gulf outside even at the very heads of creeks which one can easily wade. From the prevailing value of 2·7 per cent to 2·9 per cent a few hundred yards from the heads of the inlets the salinity gradually increases as we approach the open gulf, where, at the surface, it is 2·9 per cent to 3·0 per cent.

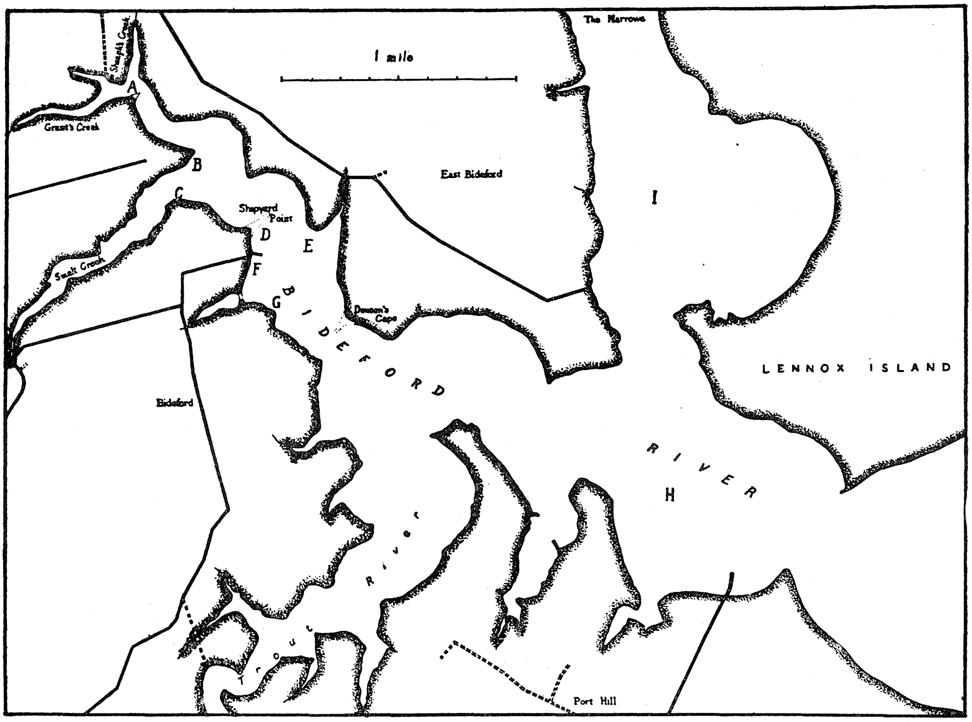

FIGURE 2.—Bideford river. The letters A to I show the approximate position of experiments mentioned in the text. C is the position of the Prince Edward Island Marine Station.

There is very little difference between the salinity of the surface and the bottom water in the bay or in the inlets, except at the heads of the latter for short periods after heavy rains. Then a thin layer of very fresh water lies over the water of usual salinity.

It may be found that these salinities are considerably reduced in very rainy seasons, but the figures serve to give a general conception of the saltness of the water in the area and to show the difference between conditions there and where there is a considerable amount of fresh water entering—as, for example, in many oyster areas of the Nova Scotia and New Brunswick coast of Northumberland strait. The fact that relatively salt water is present almost to the very heads of the inlets of Malpeque bay must be borne in mind in connection with the quality to be expected. Conditions near the heads of these inlets are still comparable to those in the lower stretches of the estuaries on the south side of the strait.

TEMPERATURES

It has long been established that temperatures of about 68° F. or higher are necessary for the spawning of oysters. Higher temperatures are more favourable still. The temperature is also of importance in feeding and growth. Galtsoff found that oysters do not feed when the water is colder than 40° F. (GALTSOFF, P.S.). The effect of temperature on the mechanical activity of the gills of the oyster, *Ostrea virginica Gm. J. Gen. Physiol.* XI (4) 415-431 1928.) Growth tends to become more rapid as the temperature increases. Thus the temperature is of great importance in oyster culture.

The following is a brief outline of the water temperature changes of the bay.

In the winter the temperature of the water beneath the ice is about 30° F. After the ice breaks up in the spring the water is warmed by the sun and air and by flowing over flats warmed when the tide is out. It warms most rapidly towards the heads of the inlets and reaches there the highest maximum. As we proceed down the inlets towards the bay and finally to the open gulf the warming becomes slower and the maximum lower. In the shallow waters of the bay and inlets the temperature is readily influenced by the weather and may fluctuate considerably but it tends to reach its maximum at some time in July or August. As the cold weather comes the water cools and here again the cooling is more rapid towards the heads of the inlets. It catches up to the water of the bay some time in the autumn when both reach the same temperature, usually a rather cool one, and thereafter the inlets are colder and freeze first.

Temperatures taken by Robertson in 1914 indicate that at the southern extremity of the bay and in Bideford river the water was above 68° F. for a considerable time and, at its maximum, was over 70° F. In the lower reaches of Grand river and in the area south of Curtain (Bunbury) island it surpassed 68° F. for some time but was not apparently as warm as in the inner bay or Bideford river, while in the main body of the bay, towards the entrance of the bay, and even in the inner parts of the " March water " (figure 1) it is doubtful whether the water reached 68° F. for any considerable time. It must be understood, of course, that on shelving shores the very shallow water seemed to warm up well in all parts of the bay.

In 1915 Nelson found water of 74° F. at the heads of various inlets and of the inner bay. Lower reaches of the inlets showed temperature of 70° or 72° F. In the open bay and the stretches near the entrance the highest records were 68° F. and it seems that this temperature was reached only for a short time in these parts.

In 1929 the water in Bideford river, towards the head, was over 68° F. for more than a month and reached a maximum of over 75° F. The few observations in the lower part of the bay indicate that the water over the oyster beds just south of Curtain island reached 68° F., for only a short time if at all.

In 1930 the temperature in the upper reaches of Bideford river was at 68° F. or above (reaching a maximum of over 72° F.) from early in June until August 5 with the exception of a few days in July, thus giving two considerable periods when the water was warm enough for spawning. This year was warmer than the average, and the water in the gulf outside the bay was considerably warmer than in the previous year, reaching almost 66° F. in the upper layers by the end of July. As a result the water in the parts of Malpeque bay near the open was not cooled by mixing with that outside to such an extent as usual, and the water of the entire bay seems to have been 68° F. or warmer for some time. It resulted, too, in less rapid cooling of the water of the bay than usual and the latter remained over 68° F. into September.

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Summary of Hydrography

The following conclusions may be reached from the hydrographic data outlined briefly above.

1. Fairly high salinities prevail to within a few hundred yards of the heads of the inlets and except for the extreme uppermost stretches salinities within the bay are very similar. There are no considerable areas of low salinities such as the upper stretches of estuaries on the south side of Northumberland strait where oysters of very low quality are to be found.

2. In all of the four years studied, temperatures above the minimum for spawning were to be found for a considerable time at the heads of the inlets and of the inner bay (southernmost part). There is every reason to believe that this is the case in almost every year, as the shallowness and the distance from the open are in favour of summer warming.

3. As we go towards the entrance of the bay the amount of the warming decreases. Near the entrance of the bay it is probably only in exceptional years that it is sufficient for spawning. In the main part of the bay and at the mouths of the inlets the maximum temperature in the summer is lower than in the upper stretches, and the length of time during which it exceeds the minimum for spawning is shorter. In some years there is probably not sufficient warming here for any considerable spawning, and in every year temperatures are less favourable than they are farther from the open.

4. The greater summer warming at the heads of the inlets as compared with the lower reaches should be borne in mind in connection with growth as well as spawning. The temperatures become more favourable for rapid growth as we go farther from the entrance of the bay and approach the heads of the inlets or the extreme southern corner of the bay.

HISTORY OF OYSTER FISHERY OF AREA

The accompanying graph (figure 3) shows the catches of oysters in the Malpeque bay area from 1878 to 1918. The catches were estimated from the figures given in the annual statistics published by the Department of Fisheries. The catches are given for a number of districts but some of them include other grounds as well as parts of Malpeque bay. As a result it is impossible to get the separate catch of the bay and its inlets with accuracy. A further inaccuracy is introduced by the activities of schooners from other points which came, fished and took cargoes of oysters away which were not included in the local statistics. These vessels operated chiefly in the early days of the fishery and if their catches were included they would probably only emphasize the depletion. Yet another inaccuracy is introduced by a variation in the size of the barrels. The barrels used in the early days were flour barrels. But as time went on smaller barrels came into use. The latter catches should therefore be discounted an unknown small amount. This would make the decreasing yield even more pronounced. The figures plotted in the graph are, then, only estimates, but it is believed that they show fairly reliably the changes in the fishery.

The area was not exploited very intensively until the yields of the New Brunswick areas and of Bédeque bay and other more accessible grounds were seriously declining. By 1878 the oysters had been "completely extirpated" in Bédeque bay by overfishing, according to departmental reports, and the abundance of oysters on many New Brunswick beds had been seriously reduced. At this time the catches in the Malpeque bay area were increasing, and the increase continued until the late eighties or early nineties. Then the yield commenced to decline and continued to do so with fluctuations until 1915-1916 when a disease completed the work of overfishing. The increase in the catch was due to increased intensity of the fishery and was made possible for a long time, in spite of reduced abundance of the oysters, by the discovery of new beds. The intensity of the fishing was maintained later in the face of a reduced supply by increasing prices which kept the return to the fishermen high enough to repay their effort. By 1910 the yield had already been reduced to only one-sixth of the maximum. At this time the fishing was still quite intense in spite of reductions in the length of the open season and prohibition of the use of dredges. From 1890 on, the reports contain many references to overfishing in this area. Although destruction of beds by removal for use as fertilizer must have contributed to the decline, and an increase in the number of starfish present (reported from 1905 on) probably helped, there can be little doubt that the chief reason for the great reduction in the abundance of the oysters was simply the

FIGURE 3.—Landings of oysters from the Malpeque bay area

failure of the natural reproduction to replace the oysters removed by the intensive fishing. This was aggravated by the failure to return small oysters to the beds, and by the almost complete absence of any effort to maintain the stock by any known method of cultivation.

The history of the fishery demonstrates the inability of the natural reproduction of the oysters unaided by cultivation to maintain the yield in this area in the face of public fishing at any but a very low level. In this it has repeated the experience in almost all oyster producing areas which have been subjected to intensive fishing.

Up to 1913 only a few hundred barrels had been produced annually on private beds in the Malpeque bay area. The methods employed in these areas had consisted chiefly of saving the small and poorly shaped oysters, building up a stock on the beds in this manner and increasing the set of spat on the beds by spreading clean shells on them just before the spatting season. In 1913 the provincial government leased about 5,000 acres in the bay to about a dozen companies. Some of the latter adopted the practice of purchasing seed oysters from the United States to plant on their beds. They would then be left for two or three years until they attained marketable size, dredged up again and sold. Other operations for the improvement of their leases were also undertaken to a greater or less extent—mopping to catch starfish which appear to have been increasing in numbers, spreading clean shells, etc. These enterprises were,

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however, cut short by the appearance in 1915 of a disease which caused the death of large numbers of oysters in that year and spread in 1916 to kill almost all of the oysters in the area. As it commenced only two or three years after the first extensive operations the latter had realized few profits.

This disease was first observed on the beds south of Curtain island in the summer of 1915, but it is possible that it was present earlier and took some time to start an epidemic of sufficient proportions to be noticed. Considerable quantities were killed that year and in 1916 the disease had spread to other parts of the bay. Almost all of the oysters were killed in the Malpeque bay area but a few survived. These produced spat and although there was some mortality for a few years the disease became less evident as time went on. In 1922 Inspector Gallant reported that the district appeared to be recovering although the beds were badly silted. Conditions improved and the oysters increased in numbers. Several barrels fished in Bideford river were marketed from 1925 on and in 1930, when 300 barrels were transferred from shallow to deeper water, several men caught an average of more than three barrels a day. These were in good healthy condition.

There is evidence in support of the following conception of the disease. It was apparently caused by a minute parasite or "germ" of some kind introduced with oysters from outside waters. As the disease was new to the oysters of Malpeque bay they could not resist it—just as new diseases may kill a large proportion of the people of a nation when introduced for the first time.

But the Malpeque bay oysters soon developed the ability to resist it, that is, they became immune to it. This was perhaps largely due to the destruction of the most susceptible oysters and the survival and increase of the resistant individuals. A stock has been developed which is immune to the disease.

This epidemic in 1915-1916 was a good example of what is risked in transferring oysters from one area to another. It is impossible to avoid the danger of introducing new diseases or parasites. Immune and healthy oysters may carry "germs" to which other oysters are susceptible—as is well known with human ailments and as appears to have been the case with the oysters introduced into the Malpeque bay area in 1915-1916. It is impossible to examine oysters closely enough to eliminate the possibility of introducing other enemies—the eggs of kinds of drills or other enemies new to the area would be quite inconspicuous. In this way foreign enemies and competitors of the oysters have been taken to European oyster beds and to those of the Pacific coast, causing much damage. The only sane procedure is to develop the local stock and avoid transplantations from one area to another, which are likely to be both dangerous and unprofitable.

PRESENT CONDITION OF AREA

Distribution of Oysters

The disease in 1915 and 1916 killed a very large proportion of the oysters in the area. Just what proportion cannot be told but apparently even as much as 99 per cent or more. It seems that the proportion killed was slightly lower at the heads of the inlets and this might be explained as the result of better conditions for growth there and stronger, healthier oysters. There is no doubt, however, that the oysters have reproduced and increased in numbers much more rapidly at the heads of the inlets and in shallow water than in the lower reaches of the inlets, in the open bay or in deeper water. The temperature conditions for spawning are much less favourable, as we have seen already, in the latter places than in the former, and, when the reduced number of parent oysters made the chances of the production of larvae so small, it was only in the most favourable conditions that any setting of spat occurred. Another factor which probably contributed was the greater amount of clean surfaces in the shore zone as compared with deeper water where no wave wash occurred.

As a result it is now only at the heads of the inlets and in shallow water on shelving shores that any large quantities of oysters are to be found. In such places throughout the area there seem to be some oysters and considerable numbers in a few localities, *e.g.*, in Bideford river above Dawson's cape (figure 2). Here, in the autumn of 1930, several men caught an average of more than three barrels a day when about 300 barrels were transferred from shallow water, where they were in danger from the ice, to a neighbouring bed. This locality probably has more oysters than most, but several approach it. Considerable quantities have been observed by the writer in Grand river, Trout river, the southernmost part of the bay and other places.

In all these places it is in shallow water along the shore that the bulk of the oysters are to be found. On the beds there are usually only a very few scattered here and there—mostly rather old individuals.

As a result what oysters there are can be observed readily and the total quantity is not as large as might be estimated. They would be easily and quickly fished were public fishing allowed and it would probably result in removal of most of the stock in the first year, unless drastically restricted.

Condition of Beds

Particularly towards the heads of the inlets the oyster beds are almost all covered with a few inches of silt. The layer, of course, varies in thickness on different beds, being thinnest where the current is greatest, but there are few beds in the inlets on which the shells are at all clean (excepting, of course, those recently cleaned in the course of experiments in cultivation).

The silt on the beds is doubtless the principal reason for the absence of oysters on the shallower beds near the heads of the inlets. The shells are not sufficiently clean for the oyster spat to settle on them. There is less cleaning by wave action than along the shores, nothing to disturb the silt, and no living oysters which usually have relatively clean shells as compared with dead shells on the beds.

This condition can be readily remedied by removing the thicker layers of silt with drags or by disturbing the shells in any way when the layer is thin.

Certain of the beds are overgrown with mussels which should be removed in the course of cultivation operations. The beds, then, must be thoroughly cleaned of mussels and mud to be made productive.

Source of Seed Oysters

The question must arise in the mind of anyone considering the possibility of cultivation of oysters in this area of whether there is a sufficient supply of seed oysters—spat or yearlings.

The answer to this question is that the spat produced now under natural conditions is not encouraging in quantity but that when clean cultch is provided good quantities can be obtained. The best localities for the production of spat are, of course, at the heads of the inlets where the oysters are now most abundant and where the temperature conditions are most favourable.

The quantities that can be collected are not nearly as great as in various regions where oysters are now abundant but are quite sufficient to be profitable.

The collection of spat in this area will be treated in greater detail later and it will suffice here to note briefly the numbers obtained. On oyster shells in bags made of wire netting each containing about a bushel, from about 500 to 4,300 spat were obtained per bag in the upper reaches of Bideford river (figure 2, A to G). The average was over 2,500 per bushel and in this were included a number which were not put out at the best time but deliberately at poorer times in the course of investigations. This means an average of about five spat per shell of medium to small size. The spat were counted in the autumn after they had most of them grown to a length of a quarter of an inch or more, and after a number had died in the earliest stages and could not be counted. On shells which were broadcast at the proper time on two beds cleaned for the purpose in the upper reaches of Bideford river (figure 2, A and D), an average of fifteen spat per shell was obtained in one case and an average of five in the other. Good sets were also obtained on brush at the heads of Grant's and Sheagh's creeks.

As further evidence of the presence of the potential supply of spat, were cultch provided, it may be mentioned that as many as 140 larvae were obtained in 50 gallon samples of water in Bideford river last summer (1930). This maximum is about half the maximum obtained by Dr. Julius Nelson in 1915 in the Malpeque bay area and the general run of the samples is comparable. It must of course be remembered that such comparisons are robbed of much of their significance by the great differences between individual years. But it is suggested that at the heads of the inlets we have now a large—not a small—fraction of the supply of larvae present before the disease.

These figures indicate that a sufficient quantity of spat can be obtained to serve as a basis for profitable cultivation.

Enemies and Competitors

Among the enemies and competitors of the oyster present in the Malpeque bay area the most important are starfish and mussels.

Starfish are numerous and are a serious menace. They are somewhat more abundant in the lower reaches of the inlets but are sufficiently numerous to cause damage almost to the heads. Every possible measure must be taken to reduce their numbers and to protect the oysters, especially the spat and yearlings, from them.

Starfish can be caught by dragging mops made of cotton waste over the bottom. The proportion captured is uncertain and needs to be tested but the operation is fairly inexpensive and should be incorporated in any oyster cultivation operations where starfish are numerous. The spat can be protected by continually picking starfish from the bags of cultch before planting.

Mussels are numerous and a considerable amount of work will be necessary to remove them in preparing some grounds for the production of oysters.

No other serious enemies or competitors of the fixed stages of the oysters seem to be present. It should be borne in mind that the mussels and starfish are probably not more abundant than they have been in this area at various times, or are now in areas where oysters are produced successfully. They should not be regarded as able to prevent the production of oysters but rather as hindrances. Combating them is yet another way in which man can increase the natural productivity of the area.

Summary

This brief consideration of the present conditions in the Malpeque bay area brings to light several points of importance regarding the cultivation of oysters.

1. Although the disease of 1915-1916 killed a very large proportion of the oysters in the area considerable numbers are present at the heads of the inlets and in the shallow water along the shores generally.

2. On the oyster beds in deeper water, in the lower reaches of the inlets and in the open bay there are very few oysters.

3. Almost all the beds are covered with a layer of silt and have very few if any clean shells exposed on which spat could settle. They will have to be cleaned to make them productive at all.

4. By exposing clean shells or other cultch at the proper time sufficiently large quantities of spat for profitable cultivation can be obtained. On the other hand, the natural set is rather light.

5. Of the enemies or competitors of the oysters after it has settled only starfish and mussels are at all serious in the area. The former are the most

serious menace and must be combated by mopping, etc. The latter will have to be removed in many instances in preparing the ground for production of oysters.

6. The above statements make plain the necessity of cultivation to make the bay productive. The beds must be cleaned, clean cultch must be provided for spat and enemies must be combated. Sufficient spat can be obtained for profitable cultivation.

OYSTER CULTIVATION IN THE AREA

The means by which man can increase the production of oysters are numerous and for convenience may be grouped as follows. First comes increase of the production of larvae by improving the conditions for spawning. Next there is increase in the numbers of spat by providing clean cultch at the time when the larvae are settling. Thirdly, improvement of conditions for growth after the larvae have settled: this includes transplanting to the best possible conditions for rapid growth or high quality with the least possible loss, improvement of the bottom, protection of the oysters from enemies, etc. These measures follow the development of the oysters from the beginning to the end of their lives. We shall attempt to review briefly the information on these subjects applicable to Malpeque bay.

A. Production of Larvae

Three factors seem to be of prime importance in the production of an abundance of larvae—(1) the number of spawning oysters and their proximity to one another, (2) a temperature favourable to spawning, and (3) a warm spring and favourable conditions previous to spawning.

The last factor is beyond control, although it may be of use in predicting the production of larvae and the intensity of the setting of spat. H. F. Prytherch (Investigation of the physical conditions controlling spawning of oysters and the occurrence, distribution, and setting of oyster larvae in Milford Harbour, Conn., *Bull. U.S. Bur. Fish.* XLIV, 429-503, 32 figs., 1929) has shown that the temperature in the month previous to spawning influences the amount of eggs or sperm produced by each individual oyster. A warm spring favours the production of large quantities of these elements and, consequently, of larvae. This should be borne in mind in any attempt to predict the intensity of the " set " of spat.

TEMPERATURE AND SPAWNING

We have already seen that the oyster requires a temperature of 68° F. before it will spawn. This is the minimum and spawning at that temperature tends to be more sporadic and less complete than if the water becomes warmer still. We have, furthermore, seen that the water becomes warmer at the heads of the inlets than in the open bay and that the warming is less pronounced the nearer we approach the entrance to the bay. Whereas water warm enough for spawning seems to be present almost every summer at the heads of the inlets, this is not the case at the mouths of the inlets or in the open bay and the favourable years are less frequent there. In every year the maximum temperature will be higher and the length of time for which the temperature is over 68° F. will be longer further from the open and thus conditions will be more favourable for spawning.

In 1915 Dr. Julius Nelson found considerably larger quantities of spat in the inlets than in the open bay and even in the southern part of the bay (" Inner bay ") found more larvae along the shores and on the flats than in the open central part. This confirms the view that the production of larvae becomes greater as we leave the open water and that this will tend to be the condition of affairs even after large quantities of oysters are present in the lower reaches of the inlets and in the open bay.

The application of these facts lies in the choice between cultivation operations in the inlets and in the open bay. As oysters must not be brought in from outside the area, any removal of adult oysters from the inlets to plant them farther down is reducing the parent stock in the place where it is most likely to be productive and taking it to a place where the success of spawning is doubtful. In the present state of the stock with the numbers greatly reduced the best possible use should be made of all the parent oysters and this means concentration for the present in the inlets. After the stock is increased gradual expansion towards the open bay could be made. A further argument against any attempt at a rapid development in the bay lies in the danger of loss in transplanting, especially when the conditions in the two places concerned vary to any considerable degree.

This principle also applies to the disposition of any spat that may be collected. It would be better to plant it fairly well up the inlets both in order to make the best possible use of it in building up the stock by the production of spat, and in order to avoid losses from great changes in environment. In this connection it should be noted that the oyster becomes mature at an early age. The investigations of Dr. A. B. Needler in the summer of 1930 showed that fifteen to twenty per cent of the one-year-old and almost all of the two-year-old oysters contained sexual elements. Although the amount of eggs and sperms produced seems to increase greatly as the oyster becomes older these young ones are not to be disregarded in the production of larvae and spat.

NUMBER AND CONCENTRATION OF PARENT OYSTERS

It is obvious to all that the number of parent oysters is of importance to the number of larvae produced—the more mature oysters the more eggs and sperms are liberated into the water. It is also an advantage to have the parent oysters concentrated to some extent at least. Galtsoff has shown that the presence of sperms in the water stimulates the female oysters to spawn and that, similarly, the products of spawning of the females stimulate the males. (GALTSOFF, P. S. The role of chemical stimulation in the spawning reactions of *Ostrea virginica* and *O. gigas*. *Proc. Nat. Acad. Sci.*, *16*, (9) 555-559, 1930). Thus when oysters are close together the spawning of one will tend to start all the rest. As the eggs and sperms are simply poured forth into the water and fertilization is a matter of the meetings of sperms with eggs it is an advantage to have as many as possible of both present at the same time and place. This increases the chances which each egg has of being fertilized.

The practical application of this lies in the establishment of spawning beds. Relatively poor results are to be expected from scattering oysters thinly over the bottom. One thousand bushels of spawning oysters per acre is probably a conservative estimate of the concentration desirable—judging from statements by United States investigators.

Although it is advantageous to have concentrations of spawning oysters it must be borne in mind that it will not always pay to gather up the oysters in any place and plant them thickly on a few beds. Loss is likely to result in transplanting, especially if the bottom to which they are taken is at all soft, or if there is much "shoot" or soft new shell. Furthermore, if they are taken from shallower to deeper water the poorer temperature conditions may counteract the advantages of concentration.

PRESENT REDUCTION OF LARVAE IN BAY

We have seen that it is only at the heads of the inlets and in the shallow water along the shores that there is at present any quantity of oysters. As a result it is only in these places that any larvae can be produced. The extent to which the larvae may be carried about by the currents is not definitely known for the area but it is probable that very few settle far from where they were spawned. In a region with much stronger currents (Milford bay, Connecticut) Prytherch see reference p. 17) found that only a very small proportion settled more than a quarter of a mile away from the spawning bed. It is, therefore, to be expected that at present the larvae are limited to the upper reaches of the inlets and to the shallow shores.

In 1930 tows with a fine net, suitable for catching the larvae, were made in the upper parts of Bideford river, in the central part of the bay and just south of Curtain island. These were examined by Mr. Sherwood. No larvae were found in the latter places. In Bideford river, on the other hand, they were taken in considerable numbers. We have already pointed out above that the numbers taken were of the same order as those taken by Dr. Julius Nelson in 1915 before the stock had been greatly reduced in numbers by the disease. 1930 was apparently somewhat warmer than 1915 and, therefore, more favourable for the production of larvae. On the other hand, there was in 1930 such an abundance of other mollusc larvae (clams, mussels, etc.) very difficult to distinguish from the oysters in the early stages and present at the same time, that the youngest oyster larvae which constituted a large proportion of Dr. Nelson's figures were not included in the 1930 counts.

Thus it seems that the present production of larvae in the upper reaches is a considerable proportion of that before the disease. This is borne out by the number of oysters present. As mentioned above, fishermen obtained an average of three barrels a day in Bideford river when some oysters were transplanted. Further evidence lies in the quantities of spat to be given later.

SUMMARY

1. To make best use of the available mature oysters it is best to confine operations to the inlets where the conditions are favourable to spawning. After the stock is increased gradual expansion can be made towards the open. Even were oysters abundant in the bay the production of larvae would be uncertain there owing to temperature conditions, and the greatest production of spat will continue to be in the inlets.

2. Concentration of the parent oysters (1,000 bushels per acre or more) is favourable to the production of larvae as the oysters stimulate one another to spawn and the chances of each egg being fertilized are increased.

3. As an aid to the prediction of the quantities of spat that will be produced attention is called to the discoveries of Galtsoff and others, that warm conditions previous to spawning favour the production of large quantities of eggs and sperms, and, therefore, of spat.

4. There is a sufficient production of larvae at the heads of the inlets to serve as a starting point for the development of the stock if used to the best advantage.

B. Collection of Spat

The larvae of the oyster require clean, firm surfaces, free from slime (chiefly minute plants) and mud, on which to settle. As most surfaces in the places where the oysters grow tend to become covered with a coating of slime or a thin layer of silt the number of larvae which settles can be greatly increased by providing clean material ("cultch") at the proper place and time. To get the best results it is necessary to provide the cultch just before the oysters are ready to settle as a layer of slime or silt soon develops. This involves the prediction of the time at which the larvae will attach themselves and become "spat." It is furthermore important to put the cultch in the right place and to use suitable material which is cheap and convenient to handle.

PREDICTION OF TIME OF "SETTING"

The prediction of the time at which the larvae will attach themselves depends on the observation of three things,—the temperature, the spawning of the oysters and the presence of larvae in the water. Spawning will not take place until the water reaches a certain temperature and setting cannot be expected until about three weeks after this takes place. The spawning can be followed by examining oysters and observing the quantity of eggs or sperms that is left in them. The time of setting can be predicted more accurately still by determinations of the numbers and sizes of the larvae present in the water. The first two methods (temperature and spawning) can be carried out with little equipment or special knowledge and will suffice fairly well for practical purposes. The observation of the larvae can be done only with rather expensive equipment and some training and experience.

The temperature which the oysters of the Atlantic coast of North America require for spawning has been established as about 68° F. by investigators in the United States (Thurlow Nelson, Galtsoff, Prytherch and others). This temperature seems to be applicable in the Malpeque bay area. Julius Nelson in 1915 found no larvae before the water had warmed to this temperature.

Observations by the writer in Bideford river in 1929 may be summarized briefly as follows. The temperature reached the neighbourhood of 68° F. for a short time at the end of June but fell again. It reached and passed 68° F. in the second week of July and remained warm until the end of the month. No spawning could be noticed by examination of the oysters before the middle of July but apparently a small amount of spawning took place when the temperature reached 68° F. at the end of June, as a very light set of spat occurred in the third week of July. When the water reached 68° F. at the middle of July spawning commenced on a larger scale and the oysters were almost entirely spawned out by the end of the month. This outburst of spawning resulted in a heavy "set" starting at the end of the first week of August. Thus spawning commenced as soon as the temperature reached 68° F. and a set occurred about three weeks later in each instance.

In 1930, after a cool May the water temperature rose suddenly from about 55° F. to 68° F. in the second week of June, reached a maximum of about 72° F. or 73° on June 26, and fell below 68° F. again at the end of the first week of July. There was a sudden rise to about 70° F. on July 14-15, the temperature fluctuated about 68° until the 21st, rose to a maximum of 71° or 72° on July 24-25, and remained above 68° into the first week of August. This is, of course, only a brief general summary which cannot take account of small or local differences. Examination by Mr. Sherwood of the larvae in frequent samples taken with a fine net showed that spawning began within a day or two of the temperature exceeding 68° Fahrenheit. But the main spawning took place in July up to the middle of the month and a third spurt on July 25 was indicated. A small amount of spawning continued considerably later. These conditions regarding the spawning were confirmed by examinations of the oysters by Dr. A. B. Needler.

From these observations we see that in Malpeque bay, or elsewhere, spawning does not commence until the temperature reaches 68° F. But we see further that, although this temperature is required for spawning, the bulk of the spawning may not take place until considerably later. In 1930 most of the spawning occurred after the maximum temperature had been reached and passed. It is possible that the cold spring and sudden warming did not give the oysters sufficient time to prepare for spawning in the early warm spell or a number of other factors may have reduced the spawning during what was apparently the most favourable time as regards temperature.

We see, then, that temperatures alone will not suffice for prediction of the time of the heaviest set. We can be confident that the latter will not occur until three weeks after the temperature first reaches 68° F. But from that time observation of the spawning should be made either by examination of the oysters or, better still, by following the number of the larvae. Owing to the facts that all oysters do not spawn at the same time and do not have the same amounts of spawn, and, owing to the difficulty of estimating the amount of spawn in the oysters with accuracy a number of oysters should be examined. As soon as it seems that there has been a sudden decrease in the amount of spawn or that a large proportion of the spawn has been shed cultch should be put out almost immediately if relying on this method to predict the proper time. This advice is given because it is easy to miss a considerable amount of spawning and it is better to be early than late.

It might be noted here that the more rapid warming in shallow water, even within a small area, is another complicating factor and tends to produce spawning spread over a considerable time with the oysters in shallow water spawning first. Oysters both in deep and shallow water should be examined, paying particular attention to the greatest abundance of spawners.

The importance of putting out the cultch just before the greatest number of larvae settle varies according to the situation of the cultch. In some places it may be very important; in others the cultch will remain effective for a fortnight. In this connection it is tentatively suggested, subject to confirmation by further investigation, that the cultch remains effective longer at the very heads of the rivers, in the "creeks," than farther down and longer in sheltered situations than exposed (such as the points) although otherwise the latter may be very favourable for the collection of spat. This suggestion is based on direct observation of the growth of algae (slime) on the cultch and on observation of the spatting. Regarding the latter it may be stated that in Bideford river in 1930 considerable quantities of cultch were placed in the water in a very sheltered situation about the junctions of Sheagh's and Grant's creeks (figure 2, A) and in an exposed situation below Bideford wharf (figure 2, near G). In the former place it was found that the amounts of spat settling on successive days were about the same in spite of fluctuations in numbers of large larvae found in the samples: but in the latter the amounts of spat varied greatly in accordance with the numbers of large larvae found in the samples immediately following the putting out of the cultch. This was probably a contributory cause of the greater numbers of spat obtained in the creeks. In the upper, more sheltered position cultch put out over a period of more than a fortnight obtained good sets similar in abundance, while profitable sets were obtained over a period of a month. It must be borne in mind, however, that the growth of the slime will vary from year to year in both types of situation and that the general importance of the time at which the cultch is put in the water is confirmed by our observations.

The correlation, mentioned above, of the number of spat obtained and the number of larvae found shows the possibilities of accurate prediction of the time of setting by observing the number of larvae present. This has been demonstrated in oyster areas in the United States. Unfortunately it is a troublesome procedure, involving some expense and a considerable amount of training and time, and is, therefore, in general, beyond the reach of members of the industry.

LEVELS AT WHICH SPAT SETTLE

The level at which the greatest number of spat settle is a matter of importance in the collection of spat. The level varies greatly in different areas.

In 1929 cultch was placed at different levels in order to determine the distribution. The cultch used for this purpose was shells (a mixture of mussel, oyster and quahaug, chiefly the two first), in cylindrical bags of chicken wire. The latter were about a foot in diameter, two and a half to three feet long, and held about a bushel. They were placed singly, directly on the bottom, where the latter was hard and supported by branches where it was soft. The range of depths was from the level of an ordinary high tide to a depth of about fifteen feet below low tide.

The tides of the area are small, having a range of from two and a half to four feet. They are very irregular and seemingly much influenced by the wind. It is, therefore, difficult to refer definitely to the tide levels and the following statement of the results is only approximate.

The relative numbers of spat settling at different levels are shown in figure 4. It was found that very few spat settled above half tide. From that level downward, however, the numbers increased reaching a maximum in the first two or three feet below the level of an ordinary low tide. As we go still farther down, the numbers of spat decreased slowly reaching a little more than half of the maximum at a depth of fifteen feet. Towards the heads of the creeks where the maximum depth was about six to eight feet the decrease from just below low tide down was less pronounced. This distribution of the spat received confirmation in 1930 and was correlated with the distribution of the larvae. Mr. Sherwood found that in the creeks (figure 2, A) there were almost as many larvae at the surface as at the bottom, while down the inlet in more open

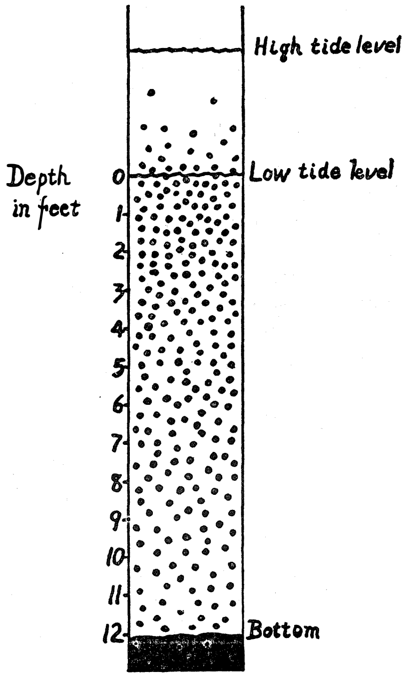

FIGURE 4.—The relative abundance of spat at different levels in Bideford river.

water (figure 2, G) there were twice as many at the surface as at the bottom. Of the oldest stages, ready or almost ready to settle, there were 50 per cent more at the bottom than at the top in the creeks but 50 per cent more at the top than at the bottom farther down the inlet.

The first three feet below tide level is, then, the best depth for the collection of spat. It is also the most convenient zone in which to place cultch which it is intended to transplant.

USE OF LOOSE SHELLS AS CULTCH

In some instances loose shells are very suitable as cultch. This is especially true where a bed exists in such a position that there is a good probability of obtaining a set on the shells and when it is intended to leave the spat to grow for a year or more (over at least one winter) in the place where the cultch is planted. In cases where spat is being collected to be planted elsewhere, other methods are more convenient than the use of loose shells. But even in these cases loose shells may be of value as they form perhaps the best kind of cultch for use on the beds as compared with the shore.

In 1930 loose shells were planted on two beds in Bideford river (figure 2, A and D). Both of these beds were cleaned (mud and mussels removed) and the shells spread on them just before the heaviest set of spat. They were in each case in a rather thin layer—not more than two or three inches thick. The method of spreading was simply to shovel them overboard from motor-boats using stakes to divide off the area as an aid to covering the whole.

On the upper bed (A)—a small patch at the junction of Sheagh's and Grant's creeks—the shells were spread on July 15-17. On August 7 some of the shells were examined and were found to have an average of 15 spat per shell—a higher *average* than any of the bags of shells which will be described below. The numbers on individual shells varied from 0 to 67. About a sixth of the shells had no spat. Only a few of the spat on each shell could survive and it is, on the whole, a disadvantage to have as many as 67.

On the lower bed (D)—just below Shipyard point—shells were planted on July 10. When examined on August 7 they had an average of 4·5 spat per shell, and only about a tenth of the shells had no spat. On these shells there was apparently a greater growth of slime than on the others.

We see, then, that good sets of spat were obtained on shells which were placed on beds in Bideford river in 1930. In 1929 shells were placed in shallow water by Mr. Dodge. Although a reasonably large number of spat settled on the shells, the results as a whole were not encouraging. In the less sheltered places the shells tended to become covered over by the action of waves—especially where the bottom was at all sandy (*e.g.*, on Shipyard point). In the end only a small proportion were of use.

A few general remarks regarding the use of loose shells as cultch may be of interest.

The *expense* of spreading is small and depends on the proximity of the supply of shells, the cost of the shells and the weather. It is impossible to give an estimate of the cost.

The *bottom* should be clean and hard. Wave action is to be avoided. The best conditions are, then, to be found on the oyster beds. In this the method differs from others which are adapted to use along the shores.

The *time* at which the shells should be spread is as important as with all kinds of cultch. The shells will become covered with silt and slime in a short time on most beds.

The *kind of shell* used is not of great importance. Little difference was observed between the numbers of spat settling on oyster, clam, mussel and quahaug shells.

The *number* of spat collected on shells spread loose on beds compares favourably with the number obtained on shells in wire bags—probably more spat are obtained per shell on the loose shells.

USE OF SHELLS IN WIRE BAGS

The method of exposing shells in wire bags, to collect spat, has been developed on a large scale recently in the United States oyster areas. The method as applicable to the Malpeque bay area is outlined below. The statements are based on trials conducted by the writer in Bideford river in 1929 and 1930.

The *wire bags* were made of wire netting. In 1929 ordinary hexagonal one-inch mesh chicken wire was used. But it was found that the wire was too fine and not sufficiently heavily galvanized to withstand the rusting; only about half of the bags could be used another year and they were easily broken. In

1930 netting made of No. 17 wire, in hexagonal meshes 1½ inches in diameter, and heavily galvanized before and after weaving, was used. This had not rusted at all when put away for the winter and the bags show every sign of standing many season's use.

The method of *making the bags* was as follows: Netting three feet wide was used and lengths of this three feet long were cut. Each length was rolled to form a cylinder and the edges laced together with No. 18 galvanized lacing wire. One of the ends was sewn up with lacing wire and the other left open to be sewn when the bag was filled.

The *shape* of the bags made in this way was cylindrical. They were about three feet long and about a foot in diameter.

The *capacity* of each bag was nearly a bushel.

The *cost* of the bags consists of the cost of the wire and of the labour. Fifty-yard rolls of the wire cost about $9 or less making the cost of the wire in each bag about 18 cents. The cost of the labour may be estimated from the fact that a man experienced in work with wire can make about forty in a day.

The *shells* used in the bags should be large and free from mud. The currents in the area tend to be weak owing to the small size of the tides. This tends to make the penetration of the spat to the innermost shells relatively poor. Small shells make the penetration poorer still and small debris or mud prevents it. It was found in 1929 that on bags filled with mussel shells there was an excellent set on the outside but little or none in the centre. The mussel shells fit closely and the set in the centre of bags filled with oyster shells was much better. Oyster shells, even of medium or small size, are preferable.

The shells should be clean and, preferably, should be exposed to the weather for a year. But good results can be obtained with shells dredged for the purpose and exposed only for a month. The advantage of the longer exposure lies largely in the crumbling of the shell which makes it possible for them to break up easily and produce single oysters rather than clusters.

It is suggested that dirty shells be screened with a piece of the netting used for the bags, to get rid of mud and small fragments.

The *time* when the bags are put in the water is important and has been discussed above. The shells become covered with a coating of slime, and are then less effective in collecting spat.

The *place* where the bags are placed should be along shores just below the level of an ordinary low tide.

When *piled* in stacks of six as many spat are apparently obtained per bag as when placed singly. If the bottom is at all soft, slabs or poles may be placed under the bags to prevent sinking. The bags may be piled two on two or stooked like sheaves of grain.

The *numbers of spat* obtained on bags placed in the water at the proper time in Bideford river were as follows: In 1929, in spite of poor penetration into the bags, the number of spat per bag averaged about 3,000. In 1930 the number on those bags which were put out at the proper time (*i.e.*, excluding those put out at other times for experimental purposes) varied roughly from 2,000 to 4,000 per bag. As the average number of shells per bag was about 500 this meant an average of 4 to 8 spat per shell. Thus it may be seen that the number is not quite as high as on the shells spread loose. The reason for this lies in the small number of spat in the interior of the bags.

The distribution of the spat on the bags may be summarized briefly as follows. The spat are most abundant on the surface of the bags and, of the surface, the lower side of the bag is the better. The distribution of the spat on the shells of a typical bag was as follows:—

	Percentage of shells	Percentage of spat
Shells with no spat..	13	0
1 to 5 spat per shell..	38	13·5
6 to 10 spat per shell..	27	27·0
11 to 15 spat per shell..	11	19·6
16 to 20 spat per shell..	5	12·1
21 to 25 spat per shell..	3	7·8
26 to 30 spat per shell..	1·4	5·5
31 to 35 spat per shell..	0·4	1·7
36 to 40 spat per shell..	0·4	2·0
Fragments of shell..	....	10·1

We see, then, that the distribution on the shells is fairly good—better, indeed, than on the loose shells examined—only a small proportion of the shells have no spat and few are badly crowded.

The *advantages* of the bags are two. Convenience in handling is at present the chief one. The bags are easily taken up again and emptied wherever desired. They can also be filled with shells ahead of time and can be put in the water quickly. In both these ways they show an advantage over loose shells. The second advantage is that use can be made, with the bags, of bottom that is unsuitable for loose shells, and that a great many shells can be exposed in a small area by piling the bags. Furthermore, the bags are most easily used at the level at which the spat are most abundant. On the other hand, the bags do not collect more spat per shell than do loose shells and show no advantages over the latter if it is desired to seed a bed on which a good set of spat can be obtained.

USE OF CARDBOARD COLLECTORS

In 1930 a trial was made of cardboard collectors composed of interlocking strips and similar in form to the partitions in an egg crate. The collectors are coated with a mixture of lime, cement and sand. Collectors of this nature have been developed lately in United States oyster areas through the efforts of the investigators of the Bureau of Fisheries. A number were imported and tried.

The trial was not a success but this seems to have been due rather to imperfect knowledge of the conditions and use than to any inherent defects in the method. A further trial will be made in which the experience of the past year will be used.

Here it is only worth while to say that we cannot recommend the method until further adaptation to local conditions can be made by experiment. The subjects which require investigation in the connection are: (1) the proper proportions of the local sand with lime and cement, (2) the amount of exposure and rough usage that the properly coated collectors will stand, (3) the number of spat obtained under local conditions, and (4) their growth and separation to produce single oysters, etc.

It is hoped that the method will prove a successful one when given a more thorough trial.

USE OF BRUSH AS CULTCH

It may be briefly noted here that good sets of spat were obtained in the summer of 1930 on brush which had been placed in the water in 1929 and abandoned because the set on it was negligible. When put out it was freshly cut and it is believed that when seasoned in the air or water it will prove a very useful collector. Further trials will be made in the coming year.

The advantages of brush, if it proves successful, are: (1) there is an almost unlimited supply in the area, (2) it is cheap to obtain and plant, (3) it can be used over very soft muddy bottoms unsuitable for other kinds of cultch, but which are common at the heads of the rivers where good sets of spat are obtainable, and (4) the action of shipworms (Teredo) make it easy to break up the brush and separate the spat to produce single oysters.

COMPARISON OF CLEAN AND "NATURAL" CULTCH

The great advantage of clean cultch of any kind placed in the water at the right time might perhaps be noted here. It will suffice to say that clean shells put out just before the setting of spat may collect hundreds of spat while it is difficult to find even one or two on the "natural" shells lying about the shore, which have been there all year. This is the rule rather than the exception and is due to the coating of slime or silt on the "natural" shells. But it serves to show to what an extent the provision of clean cultch can increase the production of spat.

SUMMARY OF COLLECTION OF SPAT

1. It is important that cultch should be placed in the water just before the setting of large numbers of larvae as a thin coating of slime develops soon, which prevents the setting.

2. The time at which the larvae will settle can be predicted by three means: (*a*) Spawning will not commence until the water has reached 68° F. and no spat will appear until three weeks later. However, the bulk of the spawning may not occur until some time after the water warms to this temperature. (*b*) The time when the bulk of the spawning takes place can be determined approximately by examination of the oysters at frequent intervals. (*c*) More accurate prediction of the time when spatting will occur can be made by determining the number of larvae in samples of the water taken at frequent intervals.

3. In this area very few spat occur above half-tide level. From there down numbers increase to a maximum in the first two or three feet below the level of an ordinary low tide. Below this there is a gradual decrease in numbers to about half the maximum at a depth of fifteen feet.

4. Loose shells spread at the proper time are suitable cultch for use on oyster beds where a good number of spat can be obtained and especially when there is no necessity of transplanting for a year or more. Some account is given of the use of this kind of cultch.

5. An account is given of the use of shells in bags made of wire netting. These do not collect greater numbers of spat for a given quantity of shells than do the loose shells. The advantages of this kind of cultch are the ease of transplanting (making the method suitable for those cases where the spat cannot be obtained where it is to be planted), and the fact that use can be made of kinds of bottom unsuitable for loose shells.

6. The use of cardboard collectors and of brush are now under investigation.

7. Using loose shells and shells in wire bags an abundance of spat can now be obtained in Bideford river, in places where the natural set is small. The numbers obtained are sufficient to serve as the basis of profitable cultivation.

C. Planting and Survival of Spat

It has been shown above that large quantities of spat can be obtained in the upper reaches of Bideford river and there is evidence that the same is true of other inlets in the area. Having obtained the spat the next step is to make the best possible use of it. There is almost always a considerable death-rate among oysters in the first year of their lives. The question is how can this be reduced to a minimum.

Several factors contribute to the death of the young oysters. Among these are enemies, sudden changes in conditions of temperature and salinity, etc., overcrowding, losses in planting due to soft bottom, crushing by ice and others. Of these, enemies and sudden changes in conditions are the most serious. Overcrowding need not as yet worry us. Crushing by ice can be prevented by placing the spat at a sufficient depth. Losses in transplanting due to smothering in the bottom can be reduced to a minimum by cleaning the bottom. Starfish are more serious but our course is plain in avoiding that danger,—reduce the number of starfish as much as possible by mopping for them and picking them up along the shores, and develop first those places where there are fewest starfish. As regards the sudden changes in conditions on planting we must find out how great differences the young oysters will stand.

As a starting point we may say with confidence that in 1929 and 1930 the deaths among the spat, from the time when they become readily visible to the naked eye to the time when they are planted, were small in number with two exceptions,—on shells which were overcrowded and where starfish were found eating the spat. The former loss is unavoidable when using shells as cultch; the latter can be controlled by picking the starfish from the bags of shells. The figures, given above, are based on counts of spat made, for most part, late in the season.

There is, then, no serious death rate previous to planting even if this is done late. (Not late enough to expose the spat to temperatures which would freeze them. For the result of such treatment we have no data.) What is the best time at which to plant the spat?

1930 Spat

To test this the spat obtained in 1930 were planted at three different times. The final results cannot, of course, be given at this early date, but this much can be said.

Spat from the neighbourhood of Bideford wharf were planted on the Cooper bed (figure 2, H) at three different times—near the beginning of August, near the end of August and near the end of September. Samples examined at the end of November indicate that almost all of the first lot, 70 per cent of the second lot and 35 per cent of the last lot were dead. In spite of much mopping, starfish were still present in considerable numbers on the bed and it is impossible to evaluate the proportion of the mortality caused by them. But the results suggest that the larger or older the spat the better they are able to stand the transfer to somewhat different conditions. This is an accepted principle in French oyster culture and may apply here.

Among spat planted on a bed above Shipyard point (figure 2, B) no death rate comparable to the above occurred.

1929 Spat

In 1929 three lots of spat were collected and planted in Bideford river. All were collected in the neighbourhood of Shipyard point. One lot was planted by Mr. Dodge on a bed in the same vicinity (Totten bed, figure 2, E) at the beginning of September. The bed had been well cleaned and levelled and mopped for starfish. On examination in the Spring of 1930 it was estimated that only about a quarter of the spat planted had died.

The second lot, planted by the writer on a bed also in the same vicinity (figure 2, F) did not fare quite so well, but apparently about half remained alive. The bed was not as thoroughly cleaned nor as well mopped for starfish. The planting was done chiefly in October.

Both these plantings may be characterized as fairly successful but the third lot was less encouraging. They were planted by Mr. G. S. Sharp on his "Peter Creek" bed (figure 2, I) in the narrows between Lennox Island and East Bideford. Of these only 5 per cent remained alive in the spring of 1930. The time of this planting was intermediate between that by Mr. Dodge and that by the writer. The distance which the spat were taken was much greater than in the other two cases. Quite a few small starfish were present on the bed in the summer of 1930 and they were probably responsible for some of the deaths.

The 1929 spat in the upper reaches of Bideford river were examined from time to time during the summer of 1930. The death rate is very difficult to estimate but did not seem to be serious. Some deaths are to be expected. The spat grew well and seemed to be, on the whole, quite healthy. It is interesting to note that Dr. A. B. Needler found that the proportion of those which had attained a relatively small growth in the previous year decreased as the summer progressed. This indicates that larger size of the spat is an advantage not only to survival of planting and of the winter but even to survival in the following summer. Spat which attain only a small size before winter tend to exhibit a higher death-rate than their larger brothers.

SUMMARY

Experiments on this aspect of the cultivation of oysters in the area are still in progress and more are planned, as this is one of the most important questions that face us. We can as yet do no more than state the few facts we have and make tentative explanations. The following points arise from a consideration of the results stated briefly above:—

1. Spat planted in the upper reaches of the river, close to where they were collected, in 1929, survived the winter well. The proportion surviving was, in both cases, estimated to be about 50 per cent or more of the number planted.

2. On the other hand, spat planted on the Cooper bed and on Mr. G. S. Sharp's "Peter Creek" bed—both places a considerable distance farther down the inlet—exhibited a high death rate.

3. The data suggest that when spat are to be planted some distance from the place where they are collected they will stand the change better when older and larger.

4. Starfish probably accounted for quite a proportion of the deaths but it is believed that the sudden changes in conditions were responsible in large part for the higher death rate occurring among those moved down the inlet.

5. On the basis of these findings it is recommended that spat be planted as near as possible to the place where they are collected.

6. It is recommended that the cultch be planted late so as to keep the spat in shallow water as long as possible. This favours rapid growth and a greater size is attained before winter. The greater size seems to favour survival of the change of conditions, consequent on planting, of the winter and of the next summer. The retention in shallow water also makes possible better protection from starfish.

7. In consideration of the high death rate that appears to result from moving spat any distance, the question arises of the effects of transplanting at a later age. As yet no definite results are available but experiments are in progress.

8. In this discussion no attention has been given to the fate of spat collected on shells spread loose on beds. As these do not need to be moved at all, the question of the best time for planting does not arise. The spat on cultch put out along the shores has to be moved before winter for protection from the action of the ice and of extreme low temperatures.

COMPARISON OF INLETS AND BAY

It may be of value to bring together our knowledge of the differences between the heads of the "rivers" on the one hand and the lower reaches and the open bay on the other.

The known differences in *hydrography* may be very briefly summarized as follows: The *salinities* are slightly lower at the heads of the inlets than in the open bay but it is not until the uppermost few hundred yards that any great differences can be found. The *temperatures* are higher in summer at the heads of the rivers and almost always become high enough for spawning, while in the open bay the water apparently frequently remains too cold for any considerable amount of spawning.

The present stock of oysters is largely limited to the upper reaches of the inlets and to shallow shores. In the lower reaches of the inlets, in the open bay, and everywhere in deep water very few oysters can be found.

We have seen that it is only in the rivers that we can rely on *spawning and the production of spat* almost every year. The removal of oysters to the open bay would be taking them from a place favourable to reproduction to one unfavourable. To make best use of the available parent stock, which is limited, we should confine operations for the present to the rivers.

Growth is more rapid at the heads of the rivers than nearer the open. Dr. A. B. Needler estimated the ages and made measurements of oysters obtained at the very head of Bideford river and below Bideford wharf (on Dawson's capes) at the end of September, 1930. The former had grown more rapidly than the latter. In the creeks oysters just over two years of age (in their third summer) were about $3\frac{1}{2}$ inches in length, those just over three years old about $4\frac{1}{2}$ inches, and those just over four years old $5\frac{1}{2}$ inches. Oysters of corresponding ages below Bideford wharf were about $2\frac{3}{4}$, $3\frac{1}{4}$ and $3\frac{3}{4}$ inches in length respectively.

The *quality* of the oysters at the heads of the rivers is not quite as good as farther down where the growth is slower, the shells thicker, the shape more "cupped" and the flavour slightly more salty. But oysters of fairly good quality are to be found well towards the heads of the inlets. In this area there is so little fresh water entering that there are no great stretches where the oysters are unsaleable as is the case with estuaries on the south side of Northumberland strait.

The *ground* available in the upper parts of the inlets is not so extensive as in the open bay. If the industry expands use will eventually have to be made of the areas below but, for the present, there are great areas of good oyster beds in the rivers which are not productive.

The *starfish,* which are the most serious enemies of the oysters in the area, are not as abundant towards the heads of the rivers as in the lower reaches. Furthermore, the possibility of reducing their numbers is greater in the more confined area.

The rivers offer more shelter than the open bay and are nearer shipping points and the dwellings of the people. This would tend to reduce the cost of operations in the rivers as compared with the open bay. If ground is leased there is greater possibility of protecting it in the inlets.

SUMMARY

On the basis of these comparisons we see that, to make best possible use of the present local supply of oysters to build up the stock, operations should be concentrated in the rivers. Here are to be found the best conditions for reproduction, for rapid growth, for protection from enemies and for convenience of operation. The disadvantages are two—smaller area of good ground (which is not serious until the cultivation of oysters expands enough to produce a shortage of space), and the rather lower quality of the oysters produced. The quality in the rivers, however, is fairly high and grading with respect to shape would protect the industry sufficiently from degradation of price and demand.

SUMMARY AND RECOMMENDATIONS

1. The Malpeque bay area has, in the past, produced large quantities of oysters, and being a shallow, sheltered bay offers conditions suitable for the growth and reproduction of oysters.

2. A consideration of the history of the oyster fishery of the area shows that the yield rose to a maximum about 1890. Previous to that time increasing attention had been paid to Malpeque bay as more accessible grounds became depleted. The demand continued to increase and increasing prices maintained the intensity of the fishing in spite of reductions in the yield. From 1890, when the yield had been fluctuating about 30,000 barrels annually, oysters became scarcer until by 1910 the average amount of the yield had fallen to only one sixth of that figure.

3. Although removal of oyster beds for use as fertilizer and an apparent increase in the number of starfish present (1905 and later) probably contributed to the depletion, there can be little doubt that the chief reason for the reduction in the abundance was the failure of natural reproduction to replace the drain of the intensive fishing. The history of the fishery demonstrates the inability of the natural reproduction to maintain the yield, in the face of public fishing, at any but a very low level.

4. Commencing about 1915 a disease caused the death of almost all the oysters in the area. It was probably introduced with seed oysters from places where it had been for a considerable time and where the oysters could resist it but were "carriers."

5. A population has been developed which can resist it. The disease, then, ceases to be a danger if the local stock is developed. The danger of transplanting oysters from one area to another is emphasized. *The only sane procedure is to develop the local stock.*

(*a*) It is recommenended, on the basis of the above conclusions, that cultivation of the local stock be encouraged in every possible way, as the only means of re-establishing the oyster industry of the area. The only feasible means of making those who reap the profit do the work of cultivation seems to be the leasing of areas to private individuals for use for oyster culture. This has been the most successful method elsewhere of building up the industry.

(*b*) It is recommended that planting of oysters from other areas in the Malpeque bay area be strictly prohibited as it is not only unprofitable but dangerous—other diseases and parasites may be brought in.

6. The present stock of oysters is limited almost entirely to the heads of the inlets and to shallow shores. Considerable quantities are present in some such places.

7. Evidence is presented showing that the production of larvae is great enough to provide a good supply of spat if clean cultch is made available for it to settle on. The "natural" set of spat is not numerous owing to the lack of clean cultch and this provides a means by which the production of oysters can be greatly increased.

8. Although a sufficient number of oysters are present to produce good quantities of spat in the upper reaches of the inlets, the deeper beds, even in these places, are almost all so covered with a layer of mud as to be very unproductive if not cleaned by man. Cleaning operations are necessary and

this is another argument for the encouragement of oyster cultural activities. Nature alone cannot restore the productivity except in an extremely slow and, indeed, uncertain fashion.

9. The fact that the oysters are largely limited to shallow water gives an exaggerated idea of their abundance, and makes them readily fished. It is believed that, were the area thrown open to public fishing, not only would further increase of the stock be stopped, but the existing stock would be so reduced as to jeopardize the supply of spat. If oyster culture is to proceed this supply must be protected jealously.

(*c*) It is recommended, therefore, that the area be kept closed to public fishing.

10. Means of increasing the production of larvae are discussed. These include (*a*) the exploitation first, of the areas where conditions are most favourable for spawn—*i.e.*, the heads of the inlets, and (*b*) the concentration of parent oysters so that they may readily stimulate one another to spawn. It is pointed out that to plant oysters in the lower reaches of the rivers or in the open bay, is to take stock from the places favourable to reproduction and place it in places unfavourable. To make best use of the present limited amount of parent oysters, the stock should be built up first in the upper parts of the inlets, before taking it to less favourable surroundings.

11. Means of collecting spat are discussed, including the use of cultch of loose shells, shells in wire bags, cardboard collectors and brush. The great increase in the number of spat which can be produced by providing clean cultch for the larvae to settle on, is pointed out.

12. The planting of spat is discussed. It is pointed out that, in recent trials, good survival of spat planted close to where it was collected was obtained, whereas that planted some distance down the inlet showed a high death rate. This is further confirmation of the advisability of first attempting to build up the stock at the heads of the inlets. There is evidently danger of considerable loss when the transfer of spat down the inlet is attempted. Experiments in the transfer at later ages are in progress.

13. The growth is more rapid towards the heads of the inlets, as is to be expected from the warmer conditions.

14. Although the quality of the oysters produced in the inlets is somewhat lower (in saltiness and in the "cupped" shape of shell) than those farther down, fairly high salinities prevail to within a few hundred yards of the extreme heads of the "rivers" and there are no areas of very poor quality oysters comparable to those found in the upper parts of estuaries where there is a larger inflow of fresh water.

15. A comparison of the conditions in the upper parts of the rivers with those in the open bay shows that the former are more favourable for oyster cultivation, showing higher temperatures, much greater certainty of water warm enough for spawning each year, more rapid growth, more parent oysters at the present time, fewer enemies and greater possibility of controlling them and greater convenience. The inlets offer immediate prospects for profitable oyster culture; the lower reaches and the open bay do not.

(*d*) On the basis of the above considerations it is recommended that oyster culture in the upper reaches of the inlets be encouraged and that ground be leased there for the purpose.

(*e*) It is further recommended that the reputation of the area for high quality oysters be protected by strict grading because the production will be, for the present, largely at the heads of the inlets. To make control possible the shipments will have to be clearly marked with the name of the producer and the place of production.

16. It is pointed out above that the conditions for the production of spat are much better at the heads of the inlets than farther down. It is believed that, even after the stock in lower reaches of the inlets or in the open bay is

increased the greatest production of seed oysters will still be in the upper parts. Measures should therefore be taken to prevent monopoly of the best supply of young stock.

17. It has been shown, in connection with the collection of spat, that it is for the first two or three feet below low tide that the greatest abundance of spat occurs. The bags of shells are, also, most easily handled when placed along the shores in this depth. The shores are, therefore, of special value for the collection of spat.

(*f*) It is recommended, therefore, that a strip along the shore out to a depth of three feet at an ordinary low tide be considered separately from the rest in leasing, and that no one be permitted to obtain a lease of more shore than is sufficient for the collection of spat to be used on his area.

(*g*) To prevent the production of oysters on ground subject to pollution (extremely unlikely in this area) to prevent the possible monopoly of spatting grounds, and to prevent the use of grounds where the quality of the oysters produced might be too low, it is recommended that no leases be granted until a careful examination of the proposed area is made by a qualified employee of the Department and a favourable report is received.

(*h*) As a great number of questions remain to be solved which are of importance to oyster culture in this area, it is recommended that Bideford river above the point locally known as Dawson's cape be set aside for experiments in the production of oysters, it being understood that operations such as the collection of spat which do not interfere with the experiments will be allowed, that the area will be utilized intensively for the cultivation of oysters and that stock from this experimental farm will be available for use in other parts of the Malpeque bay area.