Assessment of Two Ecologically Contrasting Sites on the Jamaican Coast as Potential Sites for Oyster Culture

SANDRA M. WRIGHT
Zoology Department
University of the West Indies
Mona, Kingston 7, Jamaica

ABSTRACT

If suitability of sites for oyster culture can be determined by measuring basic environmental parameters, a cost-effective method will be available for choosing such sites. This will provide a more scientific approach than the trial and error method presently used in many countries.

In Jamaica, there is a small oyster farm in operation at Bowden, St. Thomas. This, at present, is the only site which has been found suitable for collection of *Crassotrea rhizophorae* spat upon which the industry depends. However, several sites are used for grow-out and, as the industry expands, oyster culture is likely to spread to a range of other sites. The Great Salt Pond was the first of several sites chosen to investigate its suitability for oyster culture.

Twelve oyster growth experiments, each lasting approximately six weeks, were conducted from April 1988 to April 1989. One experiment was started each month, simultaneously at both sites. Along with growth measurements, salinity, temperature, dissolved oxygen, and dissolved nutrients were measured.

Although the sites were ecologically different, it was found that there was no significant difference between their physicochemical regimes. This is perhaps one of several factors which resulted in similar growth rates on both sites.

Multiple regression analysis was performed on the environmental parameters expected to affect the growth rates of oysters. It was found that none of these variables significantly affected the growth rate. Data on variations in salinity, temperature, dissolved oxygen, dissolved nutrients, and growth rates can be used to assess the suitability of a site for oyster culture. However, since no significant difference was found between the two sites, it was not possible to say which factors were growth limiting and which were not.

INTRODUCTION

In Jamaica oysters are not a major source of protein. In fact, relative to other meats like chicken or bee, oysters are expensive, and are considered a "luxury" food usually served only at hotels and restaurants. Because of the steady depletion of natural oyster beds by overharvesting, and by destruction of their natural substrate, the red mangrove, *Rhizophora mangle*, through coastal development, an oyster culture project was launched in 1977 by the Ministry of Agriculture, at Bowden (Fig. 1 and 2), to assess the feasibility of cultivating the mangrove oyster *Crassostrea rhizophorae*. The method used is a raft, string-type hanging method (Wade *et al.*, 1981).

C. rhizophorae is common to many areas in the Caribbean including Jamaica, but the overall fishery is not well developed at this time. This is partly because of a lack of technology and partly because of the problems involved in

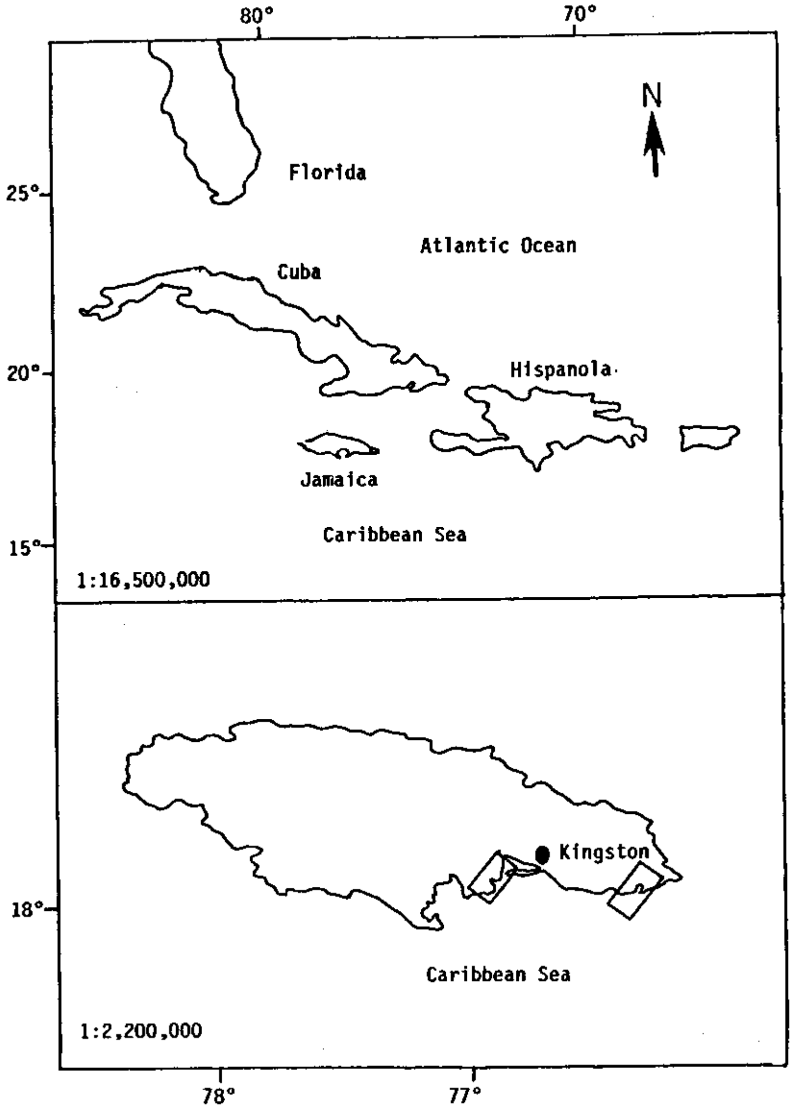

Figure 1. Map of the Caribbean and Jamaica showing relative positions of experimental sites.

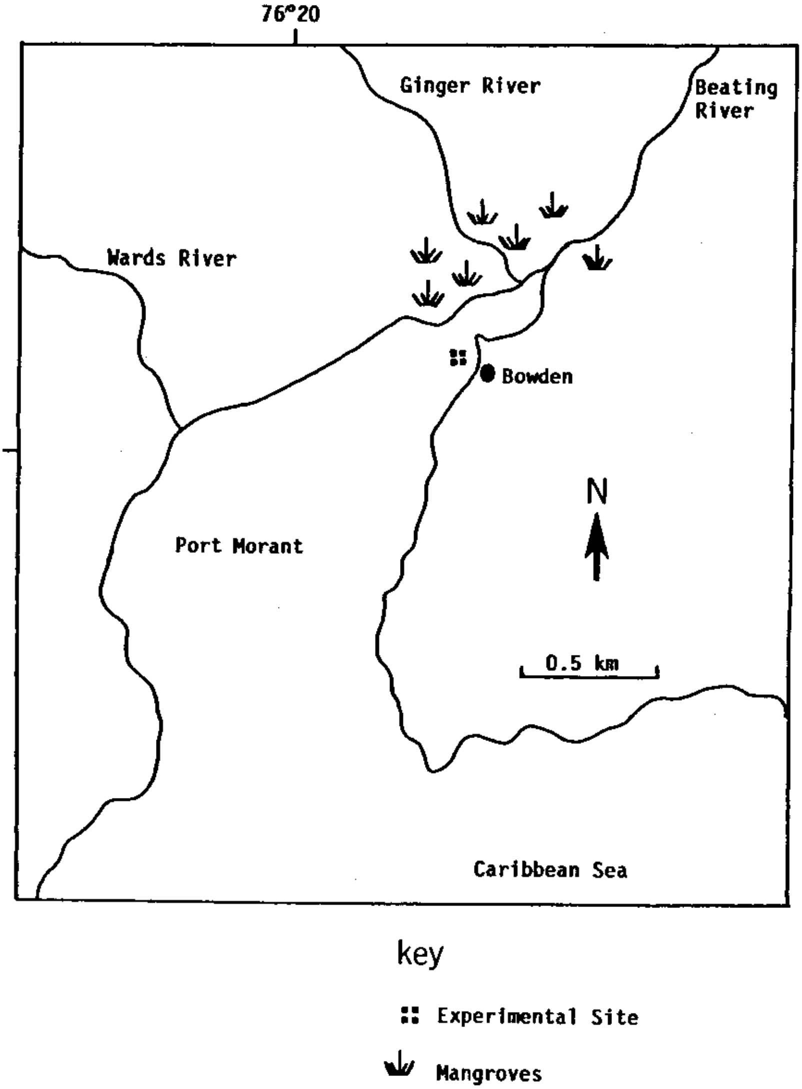

Figure 2. Map of Port Morant showing position of experimental site.

culturing tropical oysters.

Jamaican oyster farmers are confronted with the difficulty of predicting spatfall from populations of oysters that may be spawning continuously. Fouling is also a serious problem, and culture systems must be designed which can deal with it economically.

Bowden, at present, is the only site which has been found suitable for collection of *Crassostrea rhizophorae* spat upon which the industry depends. However, several sites are used for grow-out, and, as the industry expands, oyster culture is likely to spread to a range of other sites.

If suitability of site for oyster culture can be determined by measuring basic environmental parameters, a cost-effective method will be available for choosing such sites. This will provide a more scientific approach than the trial and error method presently used in many countries.

The Great Salt Pond was the first of several sites chosen to investigate its suitability for oyster culture. The Great Salt Pond, was chosen as an experimental grow-out site because it is a shallow coastal lagoon with mangroves on the margins. It being a mangrove environment, the waters are nutrient rich, and not subject to strong wave or current action. There are no marked seasonal changes in hydrographic conditions.

These features suggest that it should be a suitable site for grow-out of cultured oysters. In this way, this coastal resource could be properly managed and used efficiently.

Bowden was chosen as the second experimental site because even though oyster culture is well established, there has never been a formal investigation into the suitability of the area as a culture site. The industry was initially set up at Bowden mainly because of the existence of a natural source of spat.

Bowden, Port Morant (Lat 17°53′ N; 76°19′ W)

The bay is divided into an inner bay and an outer bay (Fig. 2). The inner bay has a shallow, muddy bottom and is surrounded by *Rhizophora mangle* on which a natural oyster population is found. Two rivers, Ginger River and Beating River, flow into this part of the bay. The outer part of the bay is more exposed and considerably deeper.

The Great Salt Pond (17°55′ N; 77°54′ W)

The Great Salt Pond (Fig. 3) is shallow with an area of 17.2 hectares (Reeson, 1971). It receives freshwater from the Bernard Lodge Sugar Estates via a drainage canal and brackish water from the mangrove swamps (The Flashes) to the west.

The whole area is very dry with rainfall less than 37.5 mm/yr (Chin, in prep.)

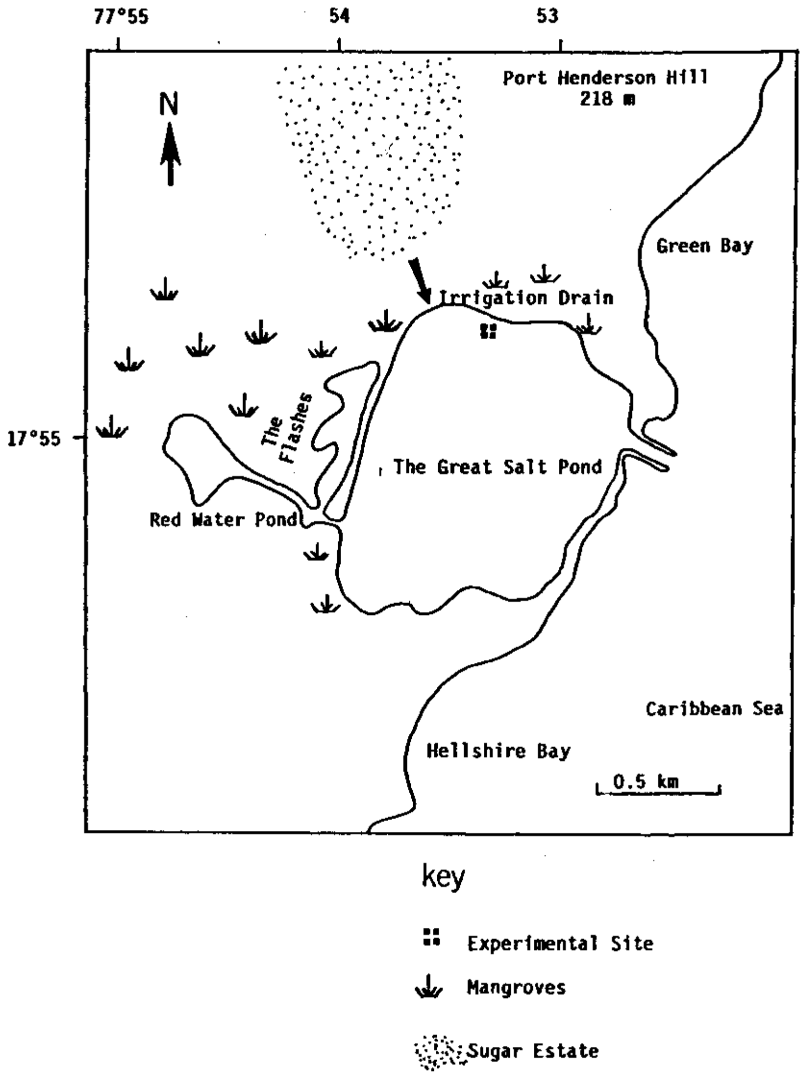

Figure 3. Map of the Great Salt Pond showing position of experimental site.

MATERIALS AND METHODS

Physical Parameters

Salinity, water temperature, and dissolved oxygen were measured. Salinity was measured with an American Optical, temperature-compensated refractometer. Dissolved oxygen was measured with a Galvanic Cell Oxygen Analyzer (YSI model 51B). Water temperature was measured with a mercury thermometer.

Water Chemistry: Nitrates and Phosphates in the Great Salt Pond and Bowden

The standard cadmium reduction method for nitrate determination was used in this analysis. For further details see APHA'S *Standard methods for the examination of water and wastewater*, 14th edition, p. 423, method 419C (1976).

For this study the method was modified as follows: the standard length of the cadmium column is usually at least 18 inches long. However, this length column was not available, and a shorter column of about 9 inches long was used instead. Therefore, a much slower flow rate of sample through the column was used in order to compensate for this.

Growth of Oysters at the Great Salt Pond and Bowden

For this preliminary growth trial, spat collected from Bowden were grown subtidally at both sites, using a suspended hanging culture method. Figure 4 illustrates the design of the strings and rack structure.

For each experiment seven strings were hung out to grow. The spat, when taken from the spat collecting area at Bowden, were crowded all over each cultch. In order to prevent each spat from growing into another the crowded spat were removed, leaving only a few on the cultch. Fortnightly, the height of each oyster was measured.

Fouling organisms such as barnacles and algae were manually removed from the strings.

RESULTS

Environmental Data:

Water Temperature (Figure 5)

At the Great Salt Pond, there was a dramatic increase in temperature between November 1987 and March 1988. During this period, the temperature rose steadily from 21°C to 29°C. The lower temperatures observed between November and February were typical for those months of the year. Between March and September the temperature remained fairly constant at around 30°C after which there was a gradual decrease to 26.5°C in March 1989. The mean temperature for the experimental period at the Salt Pond was 27.4°C.

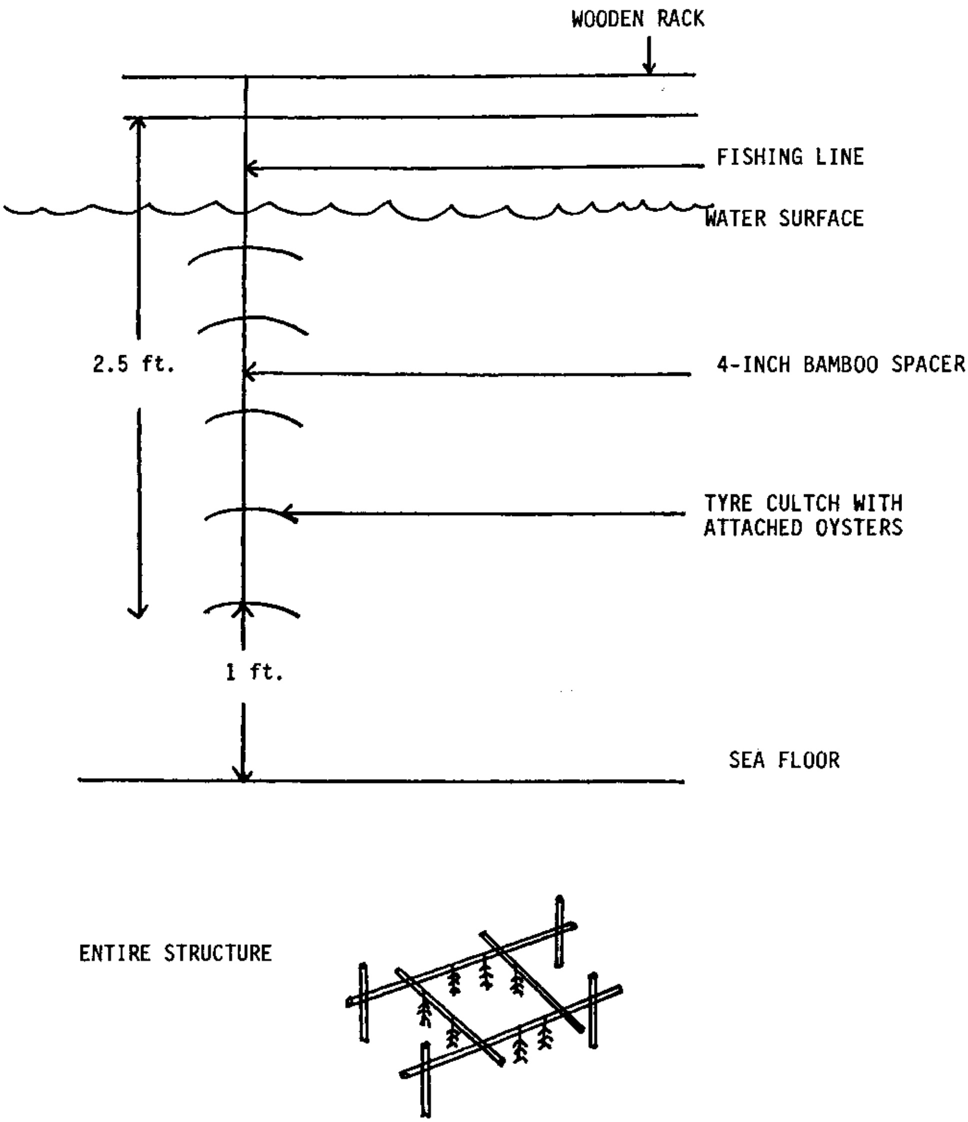

Figure 4. Diagram showing hanging method used in oyster culture. (Depth of water column refers to the Great Salt Pond).

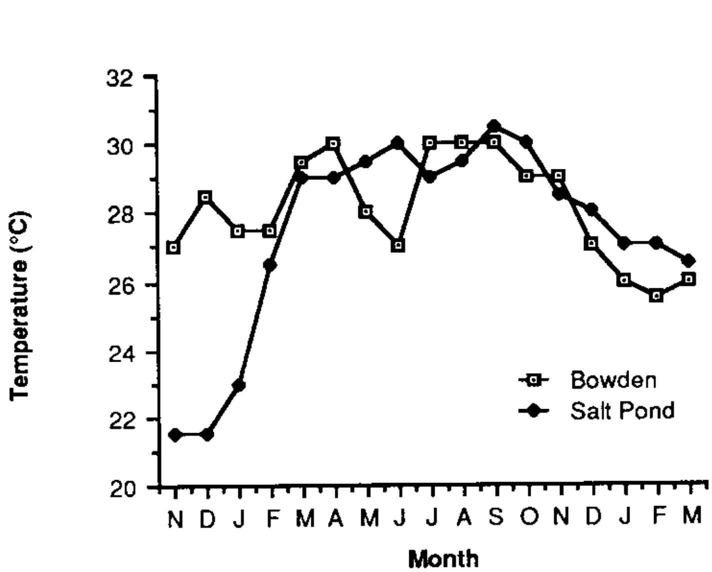

Figure 5. Mean monthly water temperature at Bowden and the Great Salt Pond from November 1987 to March 1989.

At Bowden there were no major temperature fluctuations for the year, which is normal for the Caribbean. The highest temperature observed was 30°C and occurred in April, July, August, and September. The lowest temperature observed was 25.5°C, and this occurred in February 1989. The mean temperature for the experimental period at Bowden was 28.1°C.

Analysis of variance shows that there was no significant difference between temperatures observed at both sites.

Salinity (Figure 6)

Salinity at both sites did not fluctuate much throughout the experimental period. At Bowden the highest salinity recorded was 36.5‰ which occurred in September 1988, and the lowest was 30‰ which occurred in November 1987, and which coincided with and the low temperature also observed at this time (Figure 5). The mean salinity observed for Bowden during the experimental period was 34.9‰.

Analysis of variance showed that there was no significant difference between the salinities observed at both sites.

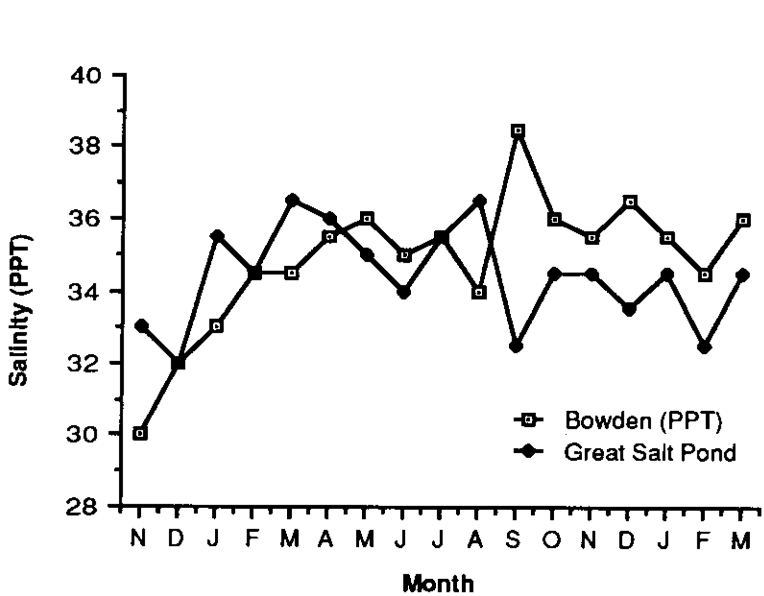

Figure 6. Mean monthly salinity at Bowden and the Great Salt Pond from November 1987 to March 1989.

Dissolved Oxygen (Figure 7)

There were large fluctuations in dissolved oxygen (DO) at both sites during the experimental period. At Bowden the highest recorded DO level (10 ppm) was observed in November 1987, which coincided with the lowest salinity observed at the same time (Fig. 6). The lowest DO recorded was 1.2 mg L^{-1} which occurred in December 1988. The mean DO recorded for the experimental period was 4.6 mg L^{-1}.

At the Salt Pond, the lowest DO recorded was 0.9 mg L^{-1} in December 1988, and the highest was 6.0 mg L^{-1} in March 1988. The mean DO for the experimental period at the Salt Pond was mg L^{-1}.

Chin (in prep) observed a mean dissolved oxygen level of 7.1 mg L^{-1} during the period November 1983 to March 1985. This shows that there has been a decrease in the DO levels in the pond over the last few years. The lower mean DO level observed during the experimental period could have been caused by Hurricane Gilbert which occurred on September 12, 1988 and which transported extra loads of detritus and organic debris into the pond, which then decayed over the next few months, causing high biological oxygen demands, and thus, low levels of dissolved oxygen.

Analysis of variance showed that there was no significant difference

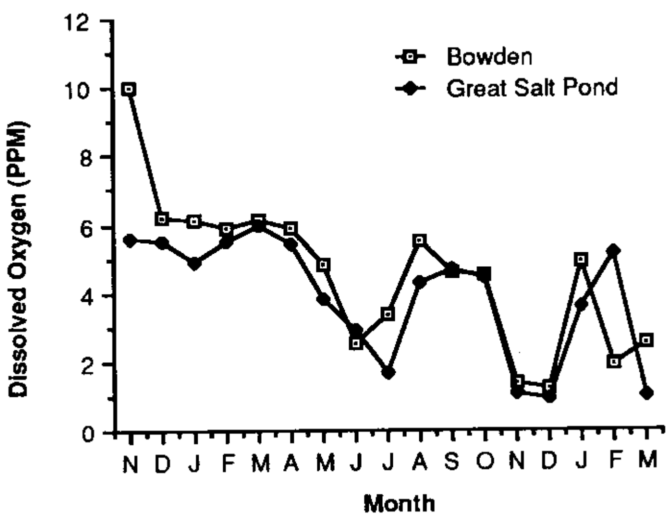

Figure 7. Mean monthly dissolved oxygen readings at Bowden and the Great Salt Pond from November 1987 to March 1989.

between dissolved oxygen levels observed at both sites.

Total Dissolved Phosphorus

The reason for doing phosphate and nitrate studies is that the level of plant growth in a body of water is controlled by the availability of these nutrients. It is generally accepted that phytoplankton is the food of oysters, therefore oyster feeding and growth are indirectly affected by the concentration of phosphates and nitrates.

The data analysis for total dissolved phosphorus (TDP) was divided into two six month periods:

- from November 1987 to April 1988
- from October 1988 to March 1989

During the period November 1987 to April 1988, there was very little fluctuation in TDP at both sites. The mean TDP recorded at Bowden for the experimental period was 1.261 mg L^{-1} The mean TDP recorded at the Salt Pond was 0.679 mg L^{-1}.

For the period October 1988 to March 1989, at the Salt Pond, there was a large increase in TDP between November and December. During this time it rose from 1.3 mg L^{-1} to 7.9 mg L^{-1}. Between December 1988 and January 1989 it fell just as sharply as it rose. In January it fell to a low of 0.2 mg L^{-1}. The mean TDP recorded at the Salt Pond for the experimental period was 18.8 mg L^{-1}.

At Bowden, during the period October 1988 to March 1989 the level of TDP remained relatively low and fluctuated very little. The lowest reading of 0.145 mgL^{-1} was observed in December 1988. The mean TDP at Bowden for the experimental period was 0.688 mgL^{-1}. The hurricane in September undoubtedly increased the load of detritus and organic debris entering the Bay. This extra organic matter may have fertilized the pond to such an extent that algal growth increased, thereby utilizing the dissolved phosphorus and keeping the level low.

Analysis of variance shows that there was no significant difference between levels of total dissolved phosphorus at both sites.

Total Dissolved Nitrogen

During the period October 1988 to March 1989, at Bowden the TDN gradually fell from a high of 34.7 mg L^{-1} in October to a low of 2.6 mg L^{-1} in December, after which there was very little fluctuation in TDN concentration. The mean TDN recorded for the experimental period at Bowden was 11.8 mg L^{-1}.

At the Salt Pond there was an increase from 17.6 mg L^{-1} to a high of 31.9 mg L^{-1} between October and November. Between November and December there was a sharp drop to 4.5 mg L^{-1}. After this, there was very little fluctuation in TDN concentration. The mean TDN recorded for the experimental period was 11.4 mg L^{-1}.

The low TDN levels could be due to greater utilization of nutrients by the increased algal abundance, which may have been caused by fertilization of the water by organic debris brought to the area by Hurricane Gilbert.

Analysis of variance showed that there was no significant difference between levels of total dissolved nitrogen at both sites.

Growth of Oysters

Figure 8 shows that growth rates fluctuated throughout the experimental period. At the Salt Pond the fastest growth rate (0.61 mm/day) was observed in April and December. At Bowden the fastest growth rate (0.53 mm/day) was observed in December.

The lowest growth rate observed at the Salt Pond during the experimental period occurred in September 1988. This may be the result of hurricane Gilbert. The increased turbulence and turbidity in the pond during the hurricane may

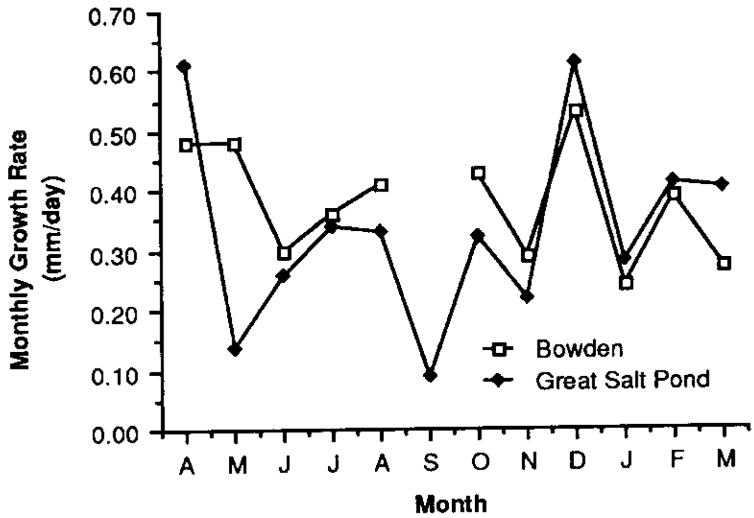

Figure 8. Mean monthly growth rate at Bowden and the Great Salt Pond from April 1988 to March 1989. Mean growth rate at Salt Pond = 0.33 ± 0.26 mm/day. Mean growth rate at Bowden = 0.38 ± 0.10 mm/day.

have traumatized the oysters, which responded by reducing their growth rates.

Figure 8 shows that there is no September reading at Bowden. This is because September's experiment was destroyed by the hurricane.

The mean growth rate for the year at the Great Salt Pond and at Bowden were 0.33 mm/day and 0.38 mm/day, respectively. Analysis of variance showed that there was no significant difference in growth rates at both sites.

Mortality of Oysters (Figure 9)

At Bowden in September 1988, total mortality was experienced, because hurricane Gilbert, which occurred during that month, destroyed the experimental rack, killing all the oysters.

This is in contrast to the 33.9% mortality observed in the Salt Pond in the same period. This suggests that the Salt Pond is much more sheltered than Bowden, and in this respect is a much better site for growing oysters.

DISCUSSION

Salinity and Temperature Effects

Low salinity and heavy siltation following heavy tropical rains may cause

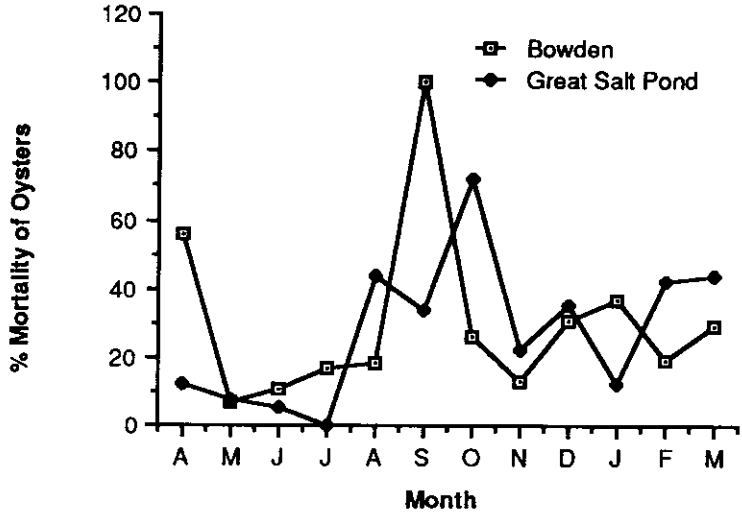

Figure 9. Percent mortality of oysters at Bowden and the Great Salt Pond from April 1988 to March 1989.

mass mortalities of oysters (Angell, 1986). The prolonged heavy rains following hurricane Gilbert in September 1988 seemed to have increased mortality of oysters at the Salt Pond. This increase was observed in October.

Regression analysis showed that salinity and temperature had no significant effect on growth rate of oysters.

However, changes in salinity may be reflected by changes in the nutritional quality or abundance of food organisms of oysters (Angell, 1986). In the Caribbean, *Crassostrea rhizophorae* shows similar growth rate reduction as a result of freshwater intrusion (Forbes, 1973). The growth rate of *C. rhizophorae* is also highest during the period of increasing salinity, which is concurrent with a fall in temperature from 30 to 25°C (Farfante, 1954).

Studies such as the above suggest that adequate nutrition for growth and maturation of tropical oysters require food sources which are much more abundant in higher salinity water. High runoff would dilute intruding seawater, alter temperature, salinity, and light penetration, thereby affecting the growth of phytoplankton as well as the species composition of the phytoplankton community. In the case of lagoons, detritus which may be an important constituent of the oysters' diet (Odum and Healy, 1975) could also be flushed out to sea.

Dissolved Oxygen Effects

Up until now, there has been no documented data for dissolved oxygen (DO) levels required for successful oyster cultivation in Jamaica.

Even though the DO levels at Bowden and the Salt Pond fluctuated by large amounts, this did not appear to have an adverse effect on the growth rate of the oysters.

The results show that the DO levels in the Salt Pond have decreased since 1983. This could be due to increased eutrophication caused by sewage outfall into the pond from the Braeton sewage plant and agricultural irrigation runoff from the Bernard Lodge Sugar Estate.

Nutrients

It appears that there is no documented data on the levels of nitrates and phosphates which can adequately support the growth and maturation of *Crassostrea rhizophorae*. However, since the experimental oysters used in this study grew satisfactorily, it would seem as though the range of nutrient levels experienced by the oysters were sufficient to support their growth and maturation.

Growth of Oysters

The elevated water temperature of the tropics can produce high oyster growth rates if adequate food is available (Angell, 1986). Given the mean growth rates observed at the Salt Pond and Bowden (0.33 and 0.38 mm/day respectively), oysters grown at these sites can attain market size in five to six months. This suggests that the prevailing conditions at both sites are suitable for the grow-out of oysters for the market.

At Bowden and the Great Salt Pond, the temperature range observed for the experimental period was narrow. Similar to Littlewood's (1987) findings, the growth of oysters was not significantly different throughout the experimental period. It therefore appears that the growth pattern of the oyster was unaffected by the slight temperature differences observed.

SUMMARY

The selection of a site for oyster culture is extremely important because an oyster farmer's success is determined to a great extent by the physical conditions under which he works. The commercial culture of oysters depends on selecting a site where both the necessary water properties and bottom type occur together. The choice of oyster ground that will satisfy the needs of the prospective grower is therefore an important and complex problem.

Under the prevailing environmental conditions, oysters grew well at both the Great Salt Pond and Bowden. Therefore, the range of conditions which exist at both these sites are suitable for the growth and maturation of *Crassostrea*

rhizophorae.

Therefore, temperature, salinity, dissolved oxygen, and dissolved nutrients are basic parameters which can be used to determine the suitability of a site for oyster culture.

The results show that there is no significant difference between the existing conditions at both sites. However, the Salt Pond appears to be the more suitable site for growing oysters because it affords greater physical protection from high winds and rough seas which are common in the Caribbean during the annual hurricane season.

LITERATURE CITED

American Public Health Association (APHA). 1976. *Standard Methods for the examination of water and wastewater*, 14th ed. Washington Press.

Angell, C.L. 1986. The biology and culture of tropical oysters ICLARM #315 42 pp.

Chin, A.N. Studies on populations of shallow water penaeid shrimp and callinectid crabs from the south coast of Jamaica. In preparation.

Farfante, I.P. 1954. El ostion comercial en Cuba. Centro de Investigactiones Pesqueras Contribucion No. 3. Cuba.

Forbes, M. 1973. Setting and growth of *Crassostrea rhizophorae*. College of the Virgin Islands, St. Croix Campus, U.S. Virgin Is. Unpubl. MS.

Littlewood, D.T.J. 1987. Biological consequences of aerial exposure of the mangrove oyster *Crassostrea rhizophorae* (Guilding, 1828) (Mollusca: Bivalvia). Ph.D. Dissertation. University of the West Indies, Mona. 464 pp.

Odum, W.E. and E.J. Healy. 1975. The detritus-based food web of an estuarine mangrove community. Pages 265-286 *in* L.E. Cronin, ed. *Estuarine Research*. Academic Press, New York.

Reeson, P. 1971. Biological studies in a Jamaican coastal lagoon. M. Phil. Thesis. Univ. West Indies, Mona.

Wade, B.A., R.A. Brown, C. Hanson, R. Hubbard, L. Alexander, and B. Lopez. 1981. The development of a low-technology oyster culture industry in Jamaica. *Proc. Gulf Carib. Fish. Inst.* 33:6-18.