Subtidal Culture of the Mangrove Oyster, *Crassostrea rhizophorae*, in Jamaica

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ABSTRACT

Cultivation of the mangrove oyster (*Crassostrea rhizophorae*) was identified as the solution to the drastic overfishing resulting in the near depletion of feral populations in Jamaica. As a result, the Oyster Culture Project Jamaica was instituted in 1977 to conduct Biological and Production-oriented research on the oyster. The Project has since developed a commercial culture technique. This technology however, is dynamic, as the aim of the Project is to obtain maximum yields.

Spat are collected subtidally on tyre cultch 15 cm by 10 cm suspended from adjustable racks at Bowden, St. Thomas, the only existing nursery. Six to eight weeks after set, the spat attain a mean size of 2.5 cm. They are sold to farmers who grow them suspended subtidally from racks (36 m x 1.5 m) at various sites across the island. The oysters are harvested selectively after three months and totally after five. They are then sold to restaurants and/or local vendors. Present production is approximately four hundred (400) dozen per rack unit with the ratio of small to large oyster being 3:1. Market prices for small and large are three dollars (J$3.00) per dozen and eight dollars (J$8.00) per dozen respectively, enabling farmers to secure a relatively good income at the end of a crop.

INTRODUCTION

The mangrove oyster is found intertidally on the roots of the red mangrove tree (*Rhizophora mangle*) in bays and estuaries throughout the Caribbean region.

Exploitation of feral populations by coastal dwellers since the days of the Arawaks, in addition to the destruction of mangrove in coastal development, has resulted in a serious reduction in habitat as well as animals. This has reached such an extent that many countries have resorted to culture to maintain a supply of oysters to meet demand, and in some areas the "Flat oyster" (*Isognomon alatus*) is being used as a substitute.

Culture methods vary throughout the region but all are based on intertidal culture using as cheap a method as possible. In Jamaica a technology was introduced as a result of research done with the cooperation of the International Development Research Centre (IDRC) of Canada, the University of the West Indies (UWI), and the Government of Jamaica (Ministry of Agriculture).

The methodology is two-phased, the first involving the collection of spat from the plankton and the second phase involving the nurturing of the seed to marketable size.

Since introduction of the technology in 1977, it has undergone numerous modifications, and this paper will describe the technological developments over the twelve (12) years of the project.

PROJECT AREA

The Jamaica coastline is broken by a number of bays and estuaries. The number of bays suitable to oyster culture, however, is limited by fresh water inflows and pollution.

At Bowden in Port Morant, St. Thomas, Lat. 17°35′ Long. 76°19′ (Figure 1) ideal conditions were identified. The bay has two distinct areas separated by a mud spit. The inner bay is shallow (1 m depth) and is fringed by mangroves, the roots of which bears a substantial population of oysters in a band 10 m from the mangrove fringe.

The outer bay is up to 10 m deeper with a muddy, sand bottom colonized by turtle grass (*Thalassia testudium*) interspaced with a few coral outcrops.

Two small rivers empty into the inner bay and create the ideal brackish condition for oyster growth. Salinity fluctuates between 10 and 35 ppt with the wet and dry seasons. Temperature variation is minimal, and currents are light and upredictable. Tidal range is about 24 cm and is modified by wind direction and intensity.

The bay is well sheltered from strong winds by low hills on all sides. All these factors in association with very easy access, made the location ideally suited to oyster culture development.

HISTORICAL BACKGROUND

Phase I

In 1977, the first phase of the Oyster Culture Project was initiated. The early work was geared towards biological studies of the life cycle and natural habitat of the animal and technological development of a suitable method of culture under the existing conditions in Jamaica. This phase saw much input from the University of the West Indies and IDRC who provided funding as well as consultancy.

Work was done on cultch suitability, grow out methodology, and surveys to identify other sites suitable for the culture of oysters.

By 1980, a period of three (3) years, a viable technique was developed and introduced. This involved the collection of seed on tyre cultch 8 x 8 cm separated by 1 cm plastic spacers hung from fixed frame racks built of mangrove and bamboo (Figure 2). The cultch were hung intertidally.

For grow out, the cultch were restrung with spacings to 10 cm provided by bamboo rods and were hung from rafts of bamboo of the Japanese cantilever type floated by 44-gallon drums (Figure 3).

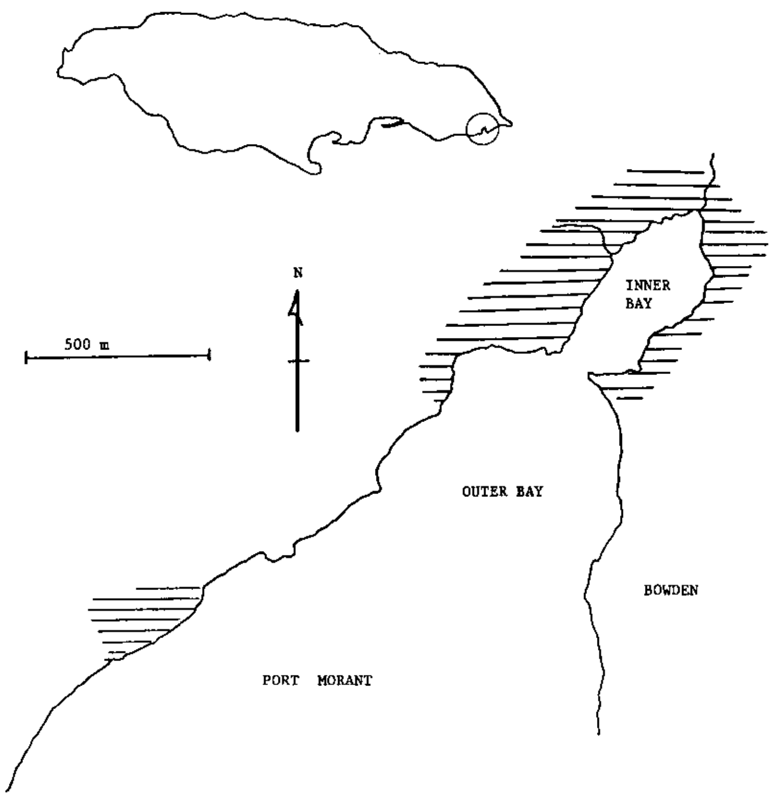


Figure 1. Map of Jamaica and site of oyster cultivation.

Phase II

July 1982 marked the start of the second phase of the Project with the goal of developing a self-sustaining small industry.

During this phase, numerous modifications occurred to the technology:

1. A new grow out structure was introduced in an attempt to overcome the unsuitability of rafts in areas subject to seasonal choppy seas. This was the longline (Figure 4).
2. Research work showed that higher yields would result from moving

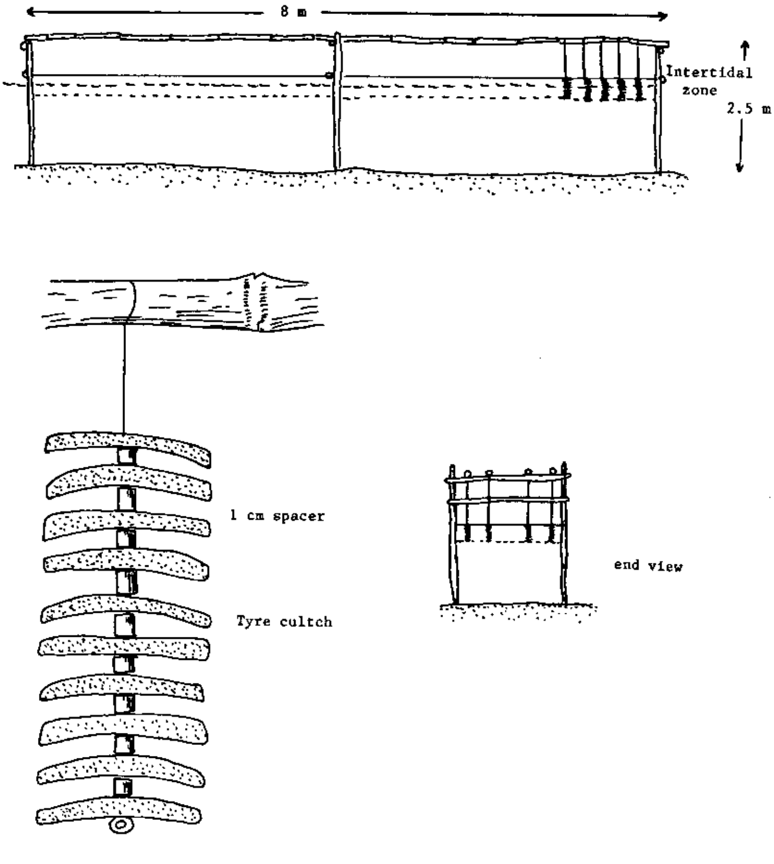


Figure 2. Fixed rack construction.

seeds to grow out at a larger size (2.5 cm) rather than at 1.5 cm as was the practice.

3. There was the introduction of the "Slip down" rack which was aimed at reducing the time needed to adjust the level of cultch in the intertidal zone when the tidal range moved.
4. Introduction of the "splitting" technique involving the division of ten (10) cultch and eight (8) cultch strings after spat collection into strings of five (5) cultch each in the attempt to better fit all cultch in the lower region of the intertidal zone.

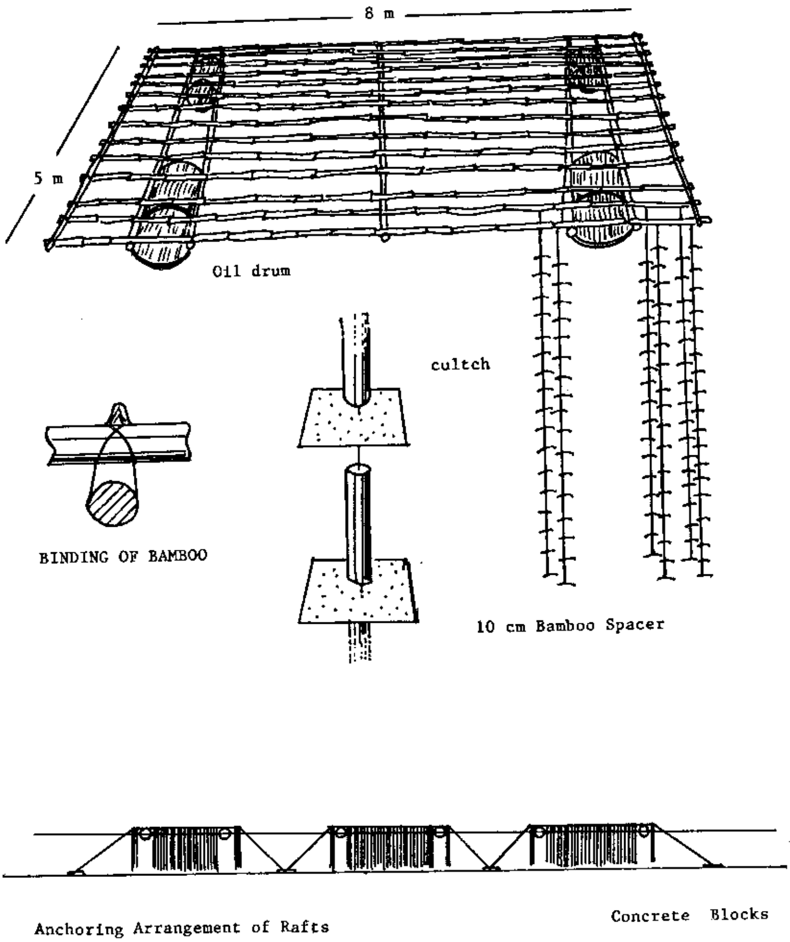
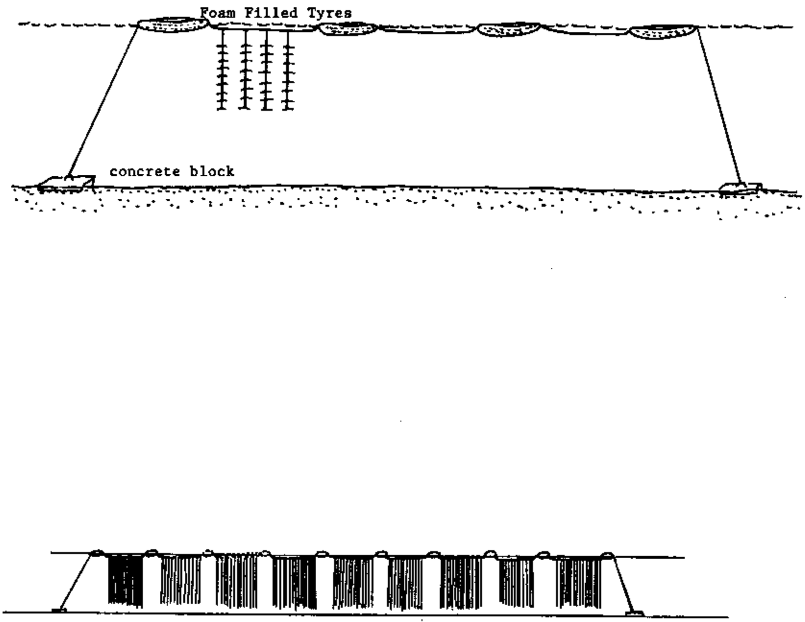


Figure 3. Raft construction and arrangement.

5. The introduction of 2.5 cm spacers of bamboo on the spat collection strings, and the elimination of the 1 cm plastic spacers.
6. There was also the incorporation of other agencies to assist in Industry Development. This included the Bureau of Standards, Scientific Research Council, National Water Commission, and Ministry of Health.



Section of Long Line Showing Anchorage

Figure 4. Longline construction and arrangement.

Phase III

July 1987 marked the start of the third and final phase of the Project to be funded by IDRC, and the goal of this phase was to further enterprise developments with the major elements being:

1. Biotechnical research;
2. A financial support program;
3. Mobilization of Government resources to monitor, support, and regulate the new Industry.

This was to be the take-off phase for the Oyster Culture Industry as a viable entity.

SPAT COLLECTION

The collection of seed oysters from the plankton is the initial stage in the culture process. This aspect has probably undergone the most changes over the years. The process essentially involves the hanging of strings of collectors in the upper layer of the water column. Collectors are separated by spacers to allow for water circulation and filter feeding with as little competition as possible among the animals.

The settlement of oysters is monitored by weekly observation of spat density on frosted panels hung out at various locations in the inner bay and the collection area. These data allow a prediction of spat settlement and identification of a spawning season by analysis of accumulated data. Two animal spawning seasons have been identified in Jamaica. They are not well defined temporally due to seasonal variations, but predictions and thus preparations can be made.

In Phase I various cultch types were tried with varying results (Table 1). The ultimate choice was tyre as this was readily available, and the only disadvantage was not significant.

In the early years strings of cultch which were made up by stringing tyre cultch 8 x 8 cm separated by spacers onto nylon lines were hung intertidally from fixed-frame racks (Figure 2). They were exposed at low tide and submerged at high tide, and thus with proper hanging, fouling organisms could be controlled by the natural exposure.

The hanging of cultch strings which were on average 20 cm long in the narrow intertidal range of approximately 24 cm was a very difficult task, and secondly this range shifted seasonally. When this shift occurred an individual adjustment of each string was therefore necessary, and this was highly labour-intensive with the number of rack units being over three hundred (300) each bearing one hundred and sixty (160) strings. The inability to fit these cultch strings in the intertidal zone meant that fouling would be a problem on the lower cultch and over-exposure on the upper ones.

Secondly, longer immersion of the lower cultch meant faster growth and the net result was a grading in size of spat on a string. Thus, some would reach sorting stage before others, and this meant that on sorting:

- some cultch would not have spat due to overexposure;
- some would bear small spat;
- some would bear spat ready for grow out;
- some would be fouled over.

The percentage of cultch going to grow out at any one sorting was therefore approximately 25%.

The process of "Splitting" was introduced as a partial solution. This process involved the division of a string to produce two (2) strings of five (5) cultch each as soon as spat could be identified on the cultch. This process enabled a

Table 1. Materials tested for their suitability as cultch and their advantages and disadvantages.

CULTCH	ADVANTAGES	DISADVANTAGES
Coconut shells	Cheap. Easily available. Durable.	Often have to be broken to remove oysters, therefore not re-usable. Too brittle.
Plastic bottles (rejects)	Good substrate for spat collection. Very durable & re-usable. Spat good for tray culture.	Unpredictable supply. Spat fall off easily when handled.
Mangrove branches	Cheap. Readily available. Good intertidal settlement.	Spat usually greatly clustered at the nodes, needs shade. Outer bark shed easily with age, larger oysters, and wave action. Not re-usable and difficult to transport.
Bamboo	Has natural curvature which minimizes silt.	Oysters very difficult to remove. Difficult to split and bore, to work with generally. Not re-usable.
Isognomon alatus shells	Numerous. Excellent for collecting spat to be used in tray culture can be easily broken up into spat bearing pieces.	Too brittle to work with in large quantities. Not re-usable. Difficult to bore.
Tires	Cheap and plentiful. Very durable and reusable. Oysters easily removed with out damaging. Easy to work with and transport.	Heavy.

large percentage of cultch to be moved to grow out on sorting but had serious implications in terms of increased labour, rack space, and nylon line utilized.

It was also evident that even five cultch were not easily fitted into the intertidal zone, and with movement of the tidal range, losses due to fouling were still occurring. This process therefore, in total only intensified the problem.

The advent of the "Slip down" rack was a major break through. This rack was constructed with the horizontal frame to which the strings were attached suspended from the main vertical frame by ropes. This greatly reduced adjustment time during tide range changes as half the rack unit could be adjusted simultaneously. This rack was short lived as its operations contributed to the development of the "adjustable rack" with which came subtidal collection of spat (Figure 5).

The adjustable rack is similar to the "Slip down" rack except the former has a higher vertical frame to allow for the exposure of cultch by a shortening of the ropes suspending the horizontal frame.

This introduction of subtidal spat collection eliminated all the problems of the previous method as they existed, and increased productivity per rack unit to over 75% on average with some yielding 100% transfer to grow out of spatted cultch.

The major disadvantage of this method is the need for close monitoring of exposure every fortnight to prevent fouling.

The immediate impact of the new collection method was high-lighted by the reduction in the number of spat collecting racks operated at the farm from over four hundred (400) at the time of introduction to just over one hundred (100) units with the capability of meeting increased demand and still having a surplus.

Due to longer submersion the rate of growth of spat was increased, but the growth rate of fouling organism similarly increased. By two-weekly exposures, these organisms are effectively controlled. During exposure, the strings are air-dried for four to six hours facilitated by the ability of the oyster to survive for long periods in exposed conditions. The increased growth rate of seed also reduces the time lapse from set to sorting for grow out, thus the number of exposures needed is minimized. Also for the first four weeks after submersion, the cultch needs no exposure. On average a total of three exposures are needed from set to sorting. Another development which has reduced cost of seed production is the change in spacers being used.

In the early period, 1 cm plastic spacers were used. In later years spacer size was increased to 2.5 cm to enable better circulation between cultch and faster growth. This resulted in a move to the use of bamboo as spacers because the plastic used at the time was too flexible in 2.5 cm lengths and would collapse.

With subtidal culture the life span of bamboo spacers was only one crop, and as a solution second hand irrigation tubing was introduced. This tubing costs four times as much per foot as bamboo. However, it has unlimited life and thus

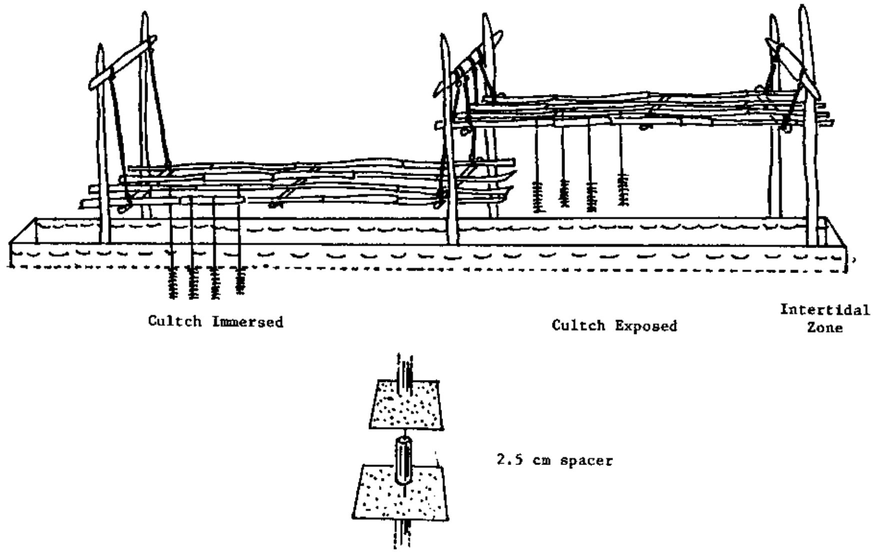


Figure 5. Adjustable rack (spacers of old plastic drip-irrigation tubing).

significant long run implications.

GROW OUT

Since the early years it was known that even though *C. rhizophorae* is characteristically an intertidal dweller it thrives under subtidal conditions (Siung, 1976). The grow out method developed was therefore based on subtidal cultivation. In this method of culture, the strings of oysters are grown totally submerged throughout the growing period of five (5) months. During this period the strings are exposed to remove and control organisms. In the exposure process strings are individually lifted and laid horizontal on top of the raft where they are subject to aerial drying for four to six hours, depending on sunlight intensity. They are then re-submerged to be re-exposed after another two weeks have elapsed. The effect of this method is increased growth rate due to longer feed time compared to intertidal culture.

In the early years, the bamboo raft was the structure used and was ideal for the relative calmness of the Bowden bay. However, when introduced to the Port Antonio and Green Island sites, they were not very resistant to the choppy conditions which occurred periodically. Thus, the foam-filled tyre longline was introduced. This structure was better suited to the conditions. It, however, required a work raft for exposure which was a larger, longer version of a grow out raft floated by six (6) 44-gallon drums.

This work raft was required as the longline has no area on which to lay the strings for exposure. This raft was towed to a sheltered area during rough weather and towed back when needed for exposures. Longlines were however, very expensive and with deterioration could not be replaced due to the inhibiting high cost.

The grow out rack was introduced as a result and tends to incorporate the better qualities of the raft and the longline structures (Figure 6). This rack is also very similar to the spat collection rack and is made of mangrove and bamboo poles. This method of grow out is advantageous in that it can withstand rough seas, and it eliminates the need to purchase nylon ropes and cement for anchorage as the vertical poles are planted in the sea floor.

There are also advantages in exposure as the structure has an upper layer of poles from which the strings are hung for exposure. Secondly, the structure is sturdy enough to bear the weight of the farmer. Therefore, he can expose his strings from atop the rack.

The introduction of the usage of old irrigation tubing as spacers instead of bamboo on grow out lines was also significant as over the years the supply of bamboo spacers was becoming a limiting factor in the production of grow out units as suppliers, realizing the importance of spacers, were using this as a bargaining tool to demand higher prices.

Secondly, they were not able to meet delivery deadlines which seriously affected spat distribution. The tubing is available in large quantities and stock piling ensures that farmers can be stocked on demand. The susceptibility of bamboo to termites etc., prevented stock piling for long periods, unlike the plastic tubing. Also, the life span of the tubing enables recycling and thus, similarly to the spat collection process, reduces costs in the long run. The grow out process therefore became cheaper, and this meant increased returns to the farmers as a result of these innovations.

DISCUSSIONS

Technological

The advent of total subtidal culture of the mangrove oyster has had significant effects on the oyster culture operations and in association with the developments in collection and grow-out structures has changed the outlook for the future of oyster culture.

With subtidal culture spat collection efficiency has increased significantly. The need for "Splitting" has been eliminated, as well as the production of "Back to rack" (BTR) (*i.e.* small seed which after sorting had to be put back in the seed collection area for further development). As a result productivity per rack has increased by more than 100%.

The increased productivity was chiefly derived from the fact that with

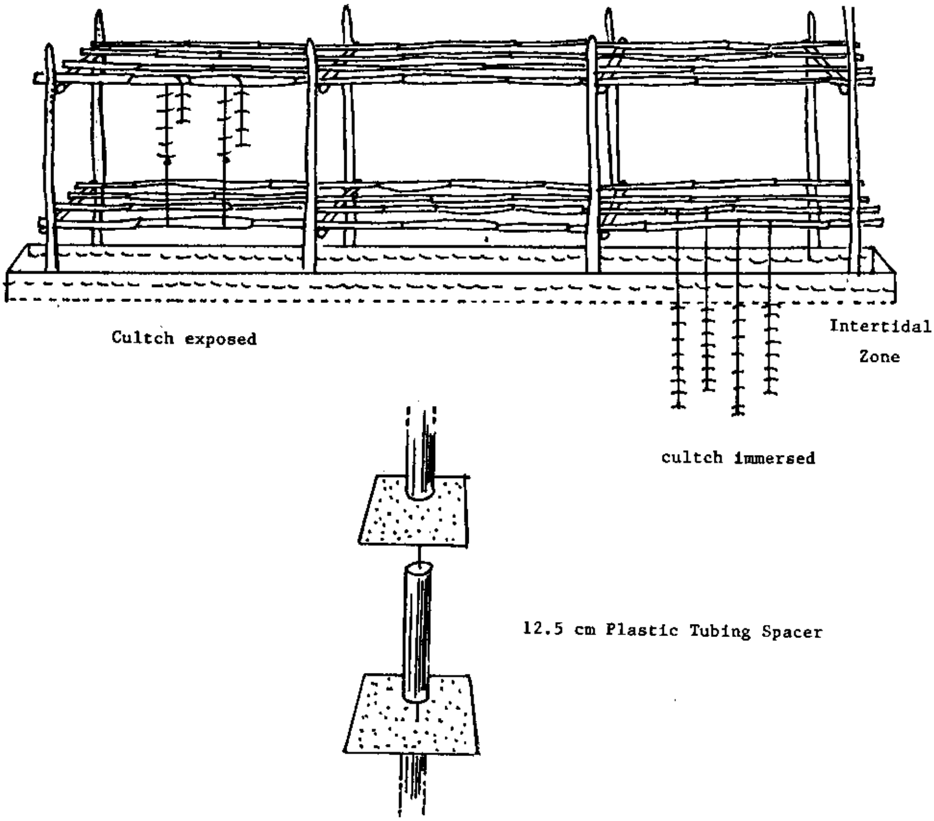


Figure 6. Grow out rack.

subtidal collection, unlike intertidal, a uniform growth of seed was the norm on all cultch, and, in addition, the rate of growth was higher and therefore on sorting no size grading was observed on the cultch along the length of a string. This development meant that seed costs would be reduced; therefore, farmers could better afford to purchase seed stock and increase the number of units operated. As a direct result there was also a reduction in the labour intensiveness of the operation and thus reductions in operating cost of the Project.

The new developments have eliminated the need for relatively expensive materials used in the construction of grow out structures. These include cement, antirust paint, and wire which had to be purchased at local hardware stores at ever increasing costs (Table 2).

The elimination of these materials was a further step in the development of a low cost technology using indigenous materials (Wade *et al.*, 1981).

This was significant in that the farmers are from low income coastal communities like Bowden where their only other source of income is from occasional employment by the Project.

With the grow out raft farmers would occasionally lose their crops due to the deterioration of drums or loss of drums in rough conditions. Theft of ropes and loss of anchors also meant increased expenditure for the farmer. The grow out rack was therefore a significant introduction as its structure enabled easy repairs and minimized losses of stock due to deterioration as the probability of an entire rack collapsing is very low.

The availability of mangrove poles has declined as a result of the hurricane which directly hit the eastern parishes. Transportation of poles from distant areas would mean increased expenditure. Alternatively, another source of poles may be located for the rack construction.

The linear structure of the rack has enabled each structure to carry two units due to a higher stocking density than a raft. This therefore results in a large number of units per unit area and thus greater exploitation of the bays are possible.

It also minimizes the time for exposure as a farmer can expose two units in one exposure unlike with the raft where only one half could be exposed at any one time due to the space limitation atop a raft or work-raft.

The exposure on the racks are also less strenuous as unlike on the raft the farmer does not remain in a constant bent over position during exposure. In an analysis of production data over the years, it was noted that there seems to exist certain time periods which usually have faster growth rates manifested in the larger numbers of marketable oysters produced from units operated in this period. This phenomenon is currently being exploited, and after two months indications are that this observation holds true. To exploit this necessitates stocking units as close to a spatfall and this is allowed by the faster uniform growth resulting from subtidal collection.

Table 2. Main materials used in oyster culture at Morant Bay.

MATERIALS	SOURCE	PURPOSE
Tires: a) Reject	Goodyear tire factory	Cultch
b) Old	Local garages	Cultch
Mangrove wood	Local	Rack struts
Bamboo (large)	Local	Rack crossbars rafts
Old irrigation tubing	Spring Plain Farm	Spacers
Plastic monofilament line	Fisheries cooperatives	Cultch hanging
Nylon rope	Fisheries cooperatives	Raft anchoring
Nails, wire	Local hardware stores	Rack construction

ECONOMIC VIABILITY

Developments in the various phases, but more so in the third phase, resulted in significant reductions in cost of production, and thus with the increased prices for oysters, returns should be increased. This is not readily evident as in the early years the full cost of production was not borne by the farmers. The effects of the break-through in culture technique is therefore masked by the removal of subsidies. Current trends in commercial production are favourable and returns to farmers are increasing as they adopt better farming practices.

Prior to the third phase farmers operated on a very small scale, and thus returns were low as economies of scale were not exploited. During the third phase, financial assistance for the farmers was introduced through the establishment of a revolving loan program which enables each farmer granted a loan to operate a minimum of four (4) units.

To date, the farmers have gone through one production cycle, and indications are that four units are not economical as even with very good returns farmers were not able to cover expenses and restock their units. An evaluation is currently underway, and from early observations it is being realized that for farmers to earn a worthwhile income a minimum of eight (8) units must be operated. This can be supported by the loan program, but it will mean the number of farmers who will benefit in total will be reduced.

With an expansion in the number of units operated by a farmer, economic viability of oyster culture should become more evident. At present, the Project operates a pilot farm of fourteen (14) units, and this should greatly assist in the evaluation of the economics of oyster farming. This farm is being operated by two individuals and to date labour problems are non-existent which indicates that a single farmer can handle eight units easily. One future objective is therefore to encourage farm expansion.

This expansion of farms can be achieved as the bays in which oyster culture is currently being practiced has great potential and are underexploited. With increased production however, comes the need for improved marketing. The scope for oyster in the Jamaican market is currently very good, in that, the demand for the product is large and due to the fact that over-picking has depleted all the wild stock, farmers are in a situation to monopolize the market.

Currently, the demand for oyster in Jamaica is being met by a supply of *Isognomon alatus* which is fairly abundant in mangrove lined bays. There is therefore some competition which can be overcome by a promotion campaign or by incorporation of the persons involved in the sale of *Isognomon*.

The latter choice is currently being studied with the intention of implementing this strategy. This may necessitate price concession initially. However, in the long run it will pay off, as the cost will be lower than to effectively carry out a promotion campaign. The incorporation of the peddlers is also economically good in that more persons will benefit from the operation of the Project.

The bulk of the marketable oysters produced to date is consumed on the half shelf. This trend will continue to dominate as it eliminates the need for any form of processing.

There is however an expanding demand for "Oyster punch" which is a drink produced from the blending of oyster tissue. This process utilizes the small oysters not suited to the half shelf trade, and this means a further return to a farmer.

With the economic developments and technological changes currently occurring, the Oyster Culture Project seems well on its way to becoming a viable industry providing employment and income and thereby enhancing development in coastal communities.

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