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COST ANALYSIS OF FLOATING RAFT OYSTER PRODUCTION IN CHESAPEAKE BAY

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ABSTRACT Previous research has shown that oysters grow very rapidly in floating rafts in Chesapeake Bay. In order to assess the economic feasibility of floating raft culture in Chesapeake Bay, 400,000 clutchless spat (10 mm) were purchased from a local hatchery and grown to market size (>76 mm). Capital equipment, supplies, hours and type of labor, and support equipment and activities were carefully recorded. This information provided a basis for the estimation of the cost of oyster production using floating raft culture.

The production site was located on the Wye River, MD. Previous research had shown that the site supported good growth rates and had a history of low disease (MSX and dermo) prevalence. The animals were introduced in weekly batches of 100,000 during September, 1989. Spat were initially maintained in closed 3 mm mesh cages to protect them from predators, primarily mud crabs, and moved into sequentially larger mesh cages and rafts as they grew. Twelve months later, when the animals reached 50–60 mm in height, they were moved from the Wye River to Mobjack Bay, VA, where they were "finished". Finishing was comprised of a two to four month tray culture period in which the animals grew an additional 25 to 30 mm and acquired a saltier taste for marketing. The animals were sent directly to market from Mobjack Bay.

Depending on the manner of capital expenditure treatment, the cost of raising oysters in floating raft culture was estimated at $0.13–0.19/oyster. This estimate was calculated as the sum of labor, capital, supply and ancillary expenditures necessary to grow to market size an estimated 150,000 oysters. The relative costs of oyster production and alternative culture methods will be discussed.

KEY WORDS: oysters, cost analysis, aquaculture, Chesapeake Bay, growth

INTRODUCTION

The catastrophic decline in natural oyster populations in Chesapeake Bay has left the Maryland and Virginia oyster industries in near collapse. While the main cause of the historical decline (since the late 19th century) is most likely overharvesting, more recent dermo and MSX occurrences, caused respectively by the parasitic protozoans *Perkinsus marinus* and *Haplosporidium nelsoni*, have essentially wiped out remaining natural stocks and made traditional culture methods in the region unproductive. With natural stocks not available and traditional methods compromised, renewed interest in alternate oyster culture methods has occurred in the region. Most of these alternate methods involve suspended or off-bottom culture.

Off bottom culture has long been known to enhance bivalve growth rates. Truitt (1931) showed that lifting oysters off the bottom, even by only a few inches, increased their growth rate by 50 to 100%. More recently, Paynter and DiMichele (1990) showed that oysters raised in floating rafts exhibited very high growth rates (15 mm/month) and that oysters selectively inbred for faster growth grew more rapidly than their native counterparts. These observations led to the suggestion that large-scale intensive oyster aquaculture in floating rafts might be economically feasible in the Chesapeake Bay region.

In order to assess this possibility, 400,000 oyster spat of a selectively inbred line (see Brown and Paynter 1991) were purchased from a local hatchery in 1989 and raised in floating rafts to market size from 1989 through 1991. Records were kept which quantified the number of rafts and cages needed, supplies and associated equipment, as well as the labor performed in maintaining the animals. A cost model was constructed based on estimated labor costs and observed mortality and handling loss.

MATERIALS AND METHODS

The production site was located on the Wye River, MD, where an experimental oyster growing site had been maintained for the previous two years. This site was characterized by low salinity (8–10 ppt) and high chlorophyll *a* levels. It has supported good growth and had shown little, if any, prevalence of *P. marinus* during the study period. This was critical because *P. marinus* infection severely reduces growth in oysters (Andrews 1961, Paynter and Burreson 1991) and would significantly influence our estimation of production times. Furthermore, the site offered the water surface area and security required for the relatively large-scale operation.

The oysters were raised in floating rafts made of polyethylene mesh designed by F. Wilde (Chesapeake Bay Oyster Culture Co., Shady Side, MD). The rafts consisted of wooden frames with polyethylene mesh (12.5 or 21 mm) folded into a rectangular box which hung below the wooden frame and was stapled to the wooden frame along the edges. The resulting mesh box was 91 cm long × 61 cm wide × 20 cm deep. A 91 cm × 61 cm panel of extruded styrofoam wedged underneath the wooden frame was used to keep the tray afloat. The rafts were attached to long lines (6.35 mm diameter; approx. 183 m long) at 1.2 m intervals by a 1.2 m length of 3 mm diameter line with a brass snap at the raft end.

At the time of purchase (from Chesapeake Bay Oyster Culture

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TABLE 1.

Description of tasks and labor required for raising oysters in floating rafts. Tasks and time estimates are broken down by 4 groups of 100,000 oysters introduced over a 5 week period.

Group	Date	Description of Work	Men × Hours	Total Hours
1989-G1	25AUG89	100,000 Animals introduced	2 × 4	8
	30AUG89	Rafts cleaned	2 × 5	10
	14SEP89	Move up to ⅛″ cages	2 × 2.5	5
	22SEP89	Storm (Hugo) pre-check	1 × 1	1
	27SEP89	Animals bucket rinsed	2 × 1	2
	05OCT89	¼″ line work	1 × 1	1
	26OCT89	New ¼″ line set-up	2 × 0.5	1
	07NOV89	Animals hose-rinsed, some rafts replaced, snap work	2 × 4.5	9
	14MAR90	Rafts and animals hosed thoroughly	2 × 1.5	3
	03MAY90	Move up to ¾″ rafts, pressure-washing rafts and cages	2 × 7	14
	18MAY90	¼″ line and ⅛″ snap work	3 × 1	3
	22MAY90	¼″ line and ⅛″ snap work	2 × 1.25	2.5
	05JUL90	Animals and rafts bucket rinsed	1 × 7	7
	21AUG90	Move ⅜″ cages to ½″ rafts	1 × 4	4
	23AUG90	Pressure-washing cages and rafts	1 × 4	4
	02OCT90	Transferring animals into new rafts	2 × 7	14
	09OCT90	Transferring animals into new rafts	1 × 3	3
	12OCT90	Pressure-washing rafts	1 × 7	7
Total				98.5
1989-G2	05SEP89	120,000 Animals introduced	2 × 6	12
	14SEP89	Animals rinsed	2 × 1	2
	22SEP89	Storm (Hugo) pre-check	1 × 1	1
	25SEP89	Move up to ⅜″ cages	2 × 3.5	7
	05OCT89	¼″ line work	1 × 1	1
	26OCT89	New ¼″ line set-up	2 × 0.5	1
	07NOV89	Animal and tray check	2 × 0.5	1
	14MAR90	Rafts and animals hosed thoroughly	2 × 1.5	3
	18MAY90	¼″ line and ⅛″ snap work	3 × 1	3
	21MAY90	Move up to ½″ and ¾″ rafts	2 × 7	14
	22MAY90	¼″ line and ⅛″ snap work	2 × 1.25	2.5
	31MAY90	Pressure-washing cages and rafts	2 × 1.5	3
	24JUL90	Animals and rafts bucket rinsed	1 × 7	7
	22AUG90	Move ½″ rafts up to ¾″ rafts	1 × 7.5	7.5
	23AUG90	Pressure-washing cages and rafts	1 × 5	5
	19,20,21 SEP90	Move to Mobjack Bay (includes bringing animals in, rinsing them, putting them in clean rafts, trailering them to Mobjack, putting them overboard at Mobjack, and returning Pintail's trailer) (travel time included)	1 × 26 1 × 19	26 19
	13OCT90	Pressure-washing rafts	1 × 7	7
Total				122
1989-G3	14SEP89	100,000 Animals introduced, new ¼″ line set-up	2 × 2.5	5
	23SEP89	Storm (Hugo) post-check	1 × 1	1
	25SEP89	Animals rinsed, rafts replaced	2 × 1.5	3
	05OCT89	¼″ line work	1 × 1	1
	26OCT89	Move up to ⅜″ cages	2 × 4	8
	07NOV89	Animal and tray check	2 × 0.5	1
	14MAR90	Rafts and animals hosed thoroughly	2 × 1.5	3
	18MAY90	¼″ line and ⅛″ snap work	3 × 1	3
	22MAY90	¼″ line and ⅛″ snap work	2 × 1.25	2.5
	24MAY90	Move up to ½″ and ¾″ rafts	2 × 8	16
	31MAY90	Pressure-washing cages and rafts	2 × 1.5	3
	31JUL90	Animals and rafts bucket rinsed	1 × 7	7
	09OCT90	Transferring animals into new rafts	1 × 3	3
	10OCT90	Transferring animals into new rafts	2 × 7	14
	12OCT90	Move ½″ rafts to ¾″ rafts	1 × 7	7
	14OCT90	Pressure-washing rafts	1 × 7	7
	15OCT90	Pressure-washing rafts	1 × 2	2

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TABLE 1.

continued

Group	Date	Description of Work	Men × Hours	Total Hours
Total				86.5
1989-G4	27SEP89	100,000 Animals introduced	2 × 4	8
	05OCT89	¼" line work	1 × 1	1
	26OCT89	Animals hose-rinsed	2 × 1	2
	07NOV89	Animal and tray check	2 × 0.5	1
	14MAR90	Rafts and animals hosed thoroughly	2 × 1.5	3
	18MAY90	¼" line and ⅛" snap work	3 × 1	3
	22MAY90	¼" line and ⅛" snap work	2 × 1.25	2.5
	30MAY90	Move up to ⅜" cages ½" rafts	2 × 5	10
	31MAY90	Pressure-washing cages and rafts	2 × 1.5	3
	21AUG90	Move ⅜" cages to ½" rafts	1 × 3	3
	24AUG90	Pressure-washing cages and rafts	1 × 3	3
	15OCT90	Move ½" rafts to ¾" rafts	2 × 5	10
	15OCT90	¼" line work	1 × 2	2
	16OCT90	Transferring animals into new rafts	2 × 7	14
	18OCT90	Pressure-washing rafts	1 × 10	10
Total				75.5
Extras	14SEP89	Working raft (section 1) built	2 × 2	4
	11,15,16,18DEC89	Ice checks	1 × 5.5	5.5
	21DEC89	Aeration system installed	1 × 6	6
	23,26,29DEC89	Ice checks	1 × 2.5	2.5
	04,08,10,22JAN90	Ice checks	1 × 3.5	3.5
	25JAN90	Expanding aeration system	1 × 2	2
	18MAY90	Working raft (section 2) built and connected	3 × 1	3
Total				26.5

Co., Shady Side, MD), the spat were approximately 10 mm long and were provided in groups of 100,000 at 1 week intervals. These oysters were first put into a rectangular polyethylene mesh (3 mm) cage (10,000/cage) which protected them from mud crab (*Rhithropanopeus harrisii*) predation. The cage was then inserted into a floating raft. After two to three weeks the oysters, which had more than doubled in size, were removed from the 3 mm mesh cages and placed in 9.5 mm mesh cages at lower densities (2,500/cage). The oysters remained in the 9.5 mm mesh cages for 4 to 6 weeks. After that time the animals were culled using 13 mm mesh. The oysters caught on 13 mm mesh were placed in rafts made from the same mesh (1,500/raft). At each step, the oysters which fell through the larger mesh were placed back onto the smaller mesh cages or rafts at similar densities. This treatment was used for each group of 100,000 oysters introduced in 1989. The oysters were maintained on the 13 mm mesh for the remainder of the growing season (until November) and the smaller animals which were not originally moved up were transferred into the 13 mm mesh rafts as they grew larger. The oysters were kept in the floating rafts throughout the winter months.

During the following March and April (1990) the animals were culled again using a 21 mm mesh. Oysters which were caught on this mesh were maintained in rafts made of 21 mm mesh (approx. 1,000/raft). Oysters which fell through the mesh were returned to the 13 mm mesh rafts. The culling procedure was performed every other month throughout the 1990 growing season. Fouling of the oysters and the mesh rafts required that both be rinsed and changed regularly. The raft changes generally coincided with culling efforts described above, but the rinsings occurred more often to discourage the sometimes rampant fouling problem. In mid-September a group of approximately 30,000 oysters which were 50 to 65 mm (2 to 2.5 inches) long were transferred to Mobjack Bay, VA, where they were deployed in a system similar to the one on the Wye River. The animals were transferred for two reasons: 1) to enhance the growth rates of the oysters and bring them to market size before the end of the growing season, 2) previous research had shown that oysters transferred to areas of high *P. marinus* prevalence (like Mobjack Bay) during September would acquire little disease but grow very well for several months. The animals were maintained at Mobjack Bay until they were sent to market.

Growth, condition index, mortality, disease status, and total number of the oysters were monitored closely. Activities associated with raising the oysters according to the description above were recorded along with the amount of time dedicated to a specific activity (Table 1). These activities included culling oysters, washing oysters, rafts and cages, changing rafts, making lines and checking the status of the rafts during inclement weather. Supplies and equipment needs were also documented so that a final list of labor, supply and equipment needs could be produced.

A cost model was constructed by incorporating labor cost (set at $10.00/hr), fringe benefit costs (25% of total wages), supply costs, equipment costs, and spat costs. The total of these costs was related to the estimated production of oysters for the time frame described.

RESULTS

Growth

The oyster spat grew relatively well for the low salinity (Fig. 1). By the end of the initial growing season (Nov. 1989), the average height of the spat had reached 25 mm. The next spring growth returned and the animals continued to grow well (9 mm/

month) throughout the growing season. When a subgroup of animals was transferred to Mobjack Bay on Sept. 15, 1990, growth rates increased nearly doubled (17 mm/month; Fig. 1). The average size of the animals at Mobjack Bay by December, 1990, was 98 mm (3.86 in) while the average size of the animals retained in the Wye River was 78 mm (3 in).

Mortality and Loss

Observed mortality was low throughout the growing effort; less than 1%/month on the average. However, mortality and/or handling loss resulted in the loss of 55% of the spat originally purchased from the hatchery. What happened to these spat is unknown. Observations indicate that the animals simply disappeared within 3 weeks of introduction in the 3 mm mesh cages. Neither empty shells nor decomposing tissue were evident in the cages. No mud crabs or flatworms (*Stylochus ellipticus*) were found inside any of the cages. We believe that the animals may have simply fallen through the mesh. Low rates of mortality and loss of the larger oysters continued throughout the second growing season. Although only 30,000 animals were moved to Mobjack Bay in September as an experiment, 150,000 oysters would have been moved had the success of the transfer been anticipated.

Labor

The labor involved with the culture effort was recorded as date, task description, number of individuals involved and hours spent (Table 1). As can be seen from the task descriptions, most of the labor involved the cleaning and changing of rafts with the concomitant culling or thinning of oysters within the rafts. Cleaning fouled rafts was another labor-intensive process. The labor involved in processing and cleaning the animals for market was not included in the cost analysis nor were management and marketing costs.

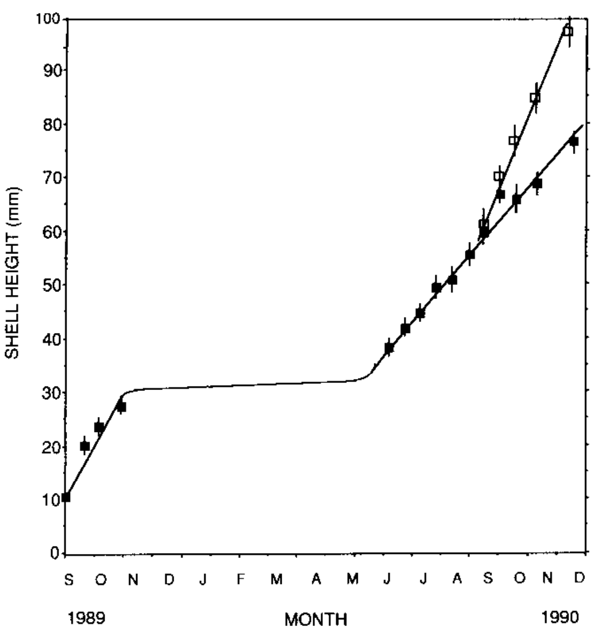

Figure 1. Increase in shell height (mm) of oysters grown at the Wye River (solid points) and Mobjack Bay (open points) between September 1989 and December 1990. Bars represent the standard error of the mean (SEM) of each point.

TABLE 2.

Costs associated with oyster culture in floating rafts.

	Actual	Annualized
Salaries		
500 man hours @ $10.00/hr	$5,000	$5,000
Sub-total	$5,000	$5,000
Fringe benefits (25%)	$1,250	$1,250
Total personnel	$6,250	$6,250
Supplies/Materials	$1,506	$1,506
Major equipment		
Rafts (600 @ $17 ea)	$10,200	$2,040
Cages (150 @ $3.85 ea)	$578	$115
Services		
Spat	$10,000	$10,000
Total direct costs	$28,534	$19,911

Annualized column represents costs in which equipment expenditures were spread over 5 years.

Supplies and Equipment

Rafts, rope, and cages comprised the bulk of the equipment necessary for the growout. Miscellaneous supplies including cable ties, brass snaps, gloves, boots, and tools were also needed. A large working raft (2.4 m × 7.3 m) was constructed from pressure-treated lumber and two 2.4 m styrofoam flotation logs (Read Plastics, Inc., Rockville, MD).

Costs and Estimated Returns

In estimating the cost of production we will assume that between 100,000 and 150,000 oysters would have been produced by the end of 1990. The budget used in estimating the cost of oyster production is presented in Table 2. For cost estimating purposes, labor was estimated at $10.00/hr. and fringe benefit costs were added to that figure. Labor hours were figured from Table 1 (409 hr) with 91 hr added to estimate the time needed for the transportation of all groups to Mobjack Bay. The most expensive equipment involved in the project was the purchase of the rafts ($10,200). Supplies and materials, including lines, snaps, cable ties, gloves, etc., cost $1,506. Seed oysters (spat) cost $10,000. Processing and shipping costs were not estimated. The total cost of the project was $28,534.

To estimate returns relative to the above costs, we assumed that the percentage of animals which grew to market size in group 1 (the only group moved to Mobjack Bay) was representative of the production if all oysters had been moved to VA. This assumption resulted in the prediction that 150,000 market size oysters would have been produced from the 400,000 originally planted 16 months before. Cost per oyster was then figured as:

$$\frac{\text{Total costs (\$28,534)}}{\text{Total oysters (150,000)}} = \text{\$0.19/oyster}$$

When major equipment costs were annualized over 5 yr (the estimated life of a raft without interest added), the cost was reduced to $0.133/oyster. If a higher mortality was factored in which resulted in only 100,000 oysters reaching to market size, then the estimated costs rise to $0.285 or $0.199/oyster, respectively.

DISCUSSION

The costs of oyster production as estimated in this study show that raft oyster culture in the Chesapeake Bay region is expensive.

Wholesale prices for premium half-shell quality oysters during the 1991/92 were $0.25–0.30 (S. Taylor, Capitol Seafood, Jessup, MD). While those prices may appear to provide enough profit over the $0.133/oyster cost estimated by this study to make raft culture in the Chesapeake Bay region feasible, it should be noted that this study estimated the costs of oyster production alone. A more thorough analysis of larger-scale capital, management, marketing costs and current market prices needs to be conducted in order to assess the economic feasibility of raft oyster culture. The production of oysters in floating rafts is a labor-intensive method and its economic feasibility depends on high turnover of oyster stocks and low mortality. This requires identification of good growing areas free from disease (specifically *Perkinsus marinus*), and intensive cultivation and care of the oysters.

Unfortunately, oysters grow best in areas where MSX and dermo are most prevalent (higher salinity). The strategy developed for this project was based on previous research (Paynter and Mallonee 1991, Paynter and Burreson 1991) and employed two distinct sites: a nursery site in a low salinity area with low disease prevalence and a high salinity area which had a high disease prevalence but supported extremely rapid growth (until the animals became infected). The research had shown that oysters introduced into Mobjack Bay in late August or early September would acquire little or no *P. marinus* infection and would grow very well until mid-December (Paynter and Burreson 1991). Furthermore, market research by World's End Aquaculture, Inc., concluded that the low salinity Wye River oysters were not as palatable as the oysters grown in Mobjack Bay, and that a premium half-shell oyster would require a higher salt content than that acquired at the Wye River site.

The growth rate observed in the oysters at low salinity was moderate. Experimental groups of oysters raised at the same site in previous years had grown about 30% faster. However, genetic and seasonal differences in growth rates are not unexpected. A higher growth rate would have resulted in more oysters getting to market size during the study period and lowered the cost per oyster. The mortality suffered in the early part of the study was unexplainable and recurred in 1990. We believe that many of the small spat fell through the mesh and were lost. In 1991, spat were maintained in upwellers for several weeks before deployment in cages and this lowered early losses considerably.

Most oysters grown in floating rafts in areas of high *P. marinus* prevalence failed to reach market size before dying (Paynter and Burreson 1991). This observation suggests that efforts to grow large seed oysters (30 to 50 mm) in areas of low disease prevalence might be more productive than attempting to "force" oysters to grow in areas of higher salinity where growth is much better but soon retarded by disease. The large seed oysters could then be "finished" in areas of higher salinity. This strategy has several advantages. First, low salinity nursery sites might not have to be in approved shellfish harvesting areas since they will not be marketed from that site. This removes a limitation on many of the available areas of low salinity in Chesapeake Bay. Second, it "diversifies" any individual farm so that oysters are in at least two areas at any given time. This might help in times of bad weather, pollution, and with disease problems. As shown in Table 1, the transportation costs are relatively small.

Unfortunately, there are many problems associated with raft culture as well. It is obviously a labor intensive operation which requires a great deal of time and management. It requires a relatively large capital investment and the floating rafts are vulnerable to weather (wind and ice) and theft. It is also likely that *P. marinus* infection, and maybe *H. nelsoni* as well, spreads more readily in highly concentrated groups of oysters. Hence, intensive oyster cultivation may be much more sensitive to disease and its effects. Recently, an oyster growing company in southern Maryland which utilized raft culture closed due to a great extent to the problems associated with *P. marinus* and intensive oyster cultivation (pers. commun., D. Bowers, St. George Oyster Co., Piney Pt., MD). However, if *P. marinus* continues to plague the Chesapeake Bay, many oysters grown on leased bottom will not grow to market size before succumbing to the disease (see Paynter and Burreson 1991). Finally, floating or suspended culture may be severely restricted, even prohibited, by legal restraints and permit regulations. These vary from state to state but represent a significant stumbling block to the development of large-scale alternative oyster culture in many states where alternative culture methods may be required for the survival of the oyster industry. In consideration of the impediments to oyster cultivation, the successful production of large numbers of oysters in an economically feasible way in the Chesapeake Bay region will be quite challenging.

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LITERATURE CITED

Andrews, J. D. 1961. Measurement of shell growth in oysters by weighing in water. *Proc. Nat. Shellfish. Assoc.* 52:1–11.

Brown, B. B. & K. T. Paynter. 1991. Mitochondrial DNA analysis of native and selectively inbred Chesapeake Bay oysters (*Crassostrea virginica*). *Mar. Biol.* 110:343–352.

Burreson, E. M. 1991. Effects of *Perkinsus marinus* Infection in the eastern oyster, *Crassostrea virginica:* I. Susceptibility of native and MSX-resistant stocks. *J. Shellfish Res.* 10(2):417–423.

Paynter, K. T. & L. DiMichele. 1990. Growth of tray cultured oysters (*Crassostrea virginica* Gmelin) in the Chesapeake Bay. *Aquaculture* 87:289–298.

Paynter, K. T. & M. E. Mallonee. 1991. Site-specific growth rates and associated water qualities. Proceedings of the Chesapeake Research Consortium 1990. CRC Publication No. 137:391–399.

Paynter, K. T. & E. M. Burreson. 1991. Effects of *Perkinsus marinus* infection in Eastern oysters: II. Effects of infection on the growth rate of oysters raised at different salinities. *J. Shellfish Res.* 10(2):425–431.

Truitt, R. V. 1931. Recent oyster researches on Chesapeake Bay in Maryland. Official Publication, Chesapeake Biological Laboratory, Solomons, MD. 28 p.