

# Moving Out the Learning Curve: An Analysis of Hard Clam, *Mercenaria mercenaria*, Nursery Operations in South Carolina

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## Introduction

Trident Seafarms Company's<sup>1</sup> cooperative venture with the South Carolina Wildlife and Marine Resources Department started in late September 1980 with the goal of demonstrating the commercial feasibility of hard clam mariculture in South Carolina. The cooperative agreement requires Trident Seafarms to provide the total capital funding for the culture operations, while the Marine Resource Research Institute of the South Carolina Wildlife and Marine Resources Department provides technical direction and scientific expertise to the project. The South Carolina Sea Grant Consortium provides funding for scientific research associated with the project, and has provided staff

<sup>1</sup>Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

*ABSTRACT—Economic and performance analyses of the nursery phase of a commercial-scale hard clam farming operation are presented. The cooperative venture between the State of South Carolina and the private, for profit, company has passed 18 months of nursery operations. During the first full year 2,354,000 seed clams in the size range of 8-13 mm were planted at a direct cost of 2.58 cents each. It is projected that in the third year of operations this will increase to 12,000,000 clams at a direct cost of 1.07 cents each. Survival in the nursery has averaged 93.3 percent per month, which indicates a 63.4 percent overall nursery survival rate.*

time for some of the analytical work presented in this paper.

The project purchases its seed stock from commercial shellfish hatcheries, which provide postlarvae, or set, averaging 1 mm in size (longest dimension). Upon arrival, the 1 mm animals are placed in the project's nursery, which is a shore-based facility for intermediate growout before field planting.

The very small animals are placed either in trays or in upflow silos in the nursery, where estuarine water is continuously pumped over them (Manzi et al., 1981). The seed clams extract all of their nutritional requirements from natural flora in the water, and no supplemental feeding is used.

As the clams attain a size of 8-10 mm, they are taken from the nursery and placed in vinyl-coated wire trays for field growout (Manzi et al., 1981). These trays are placed in the intertidal zone of a salt marsh creek. The clams

are allowed to grow to a size of approximately 25 mm, undisturbed except for the routine maintenance of the trays, and the washing off of excess silt with a high-pressure hose.

When the clams reach 25 mm, the trays are opened, the clams are sorted and replanted at about one-quarter of the original density in less well protected trays. These trays are again placed in the intertidal zone, and the clams are allowed to grow to a marketable size of about 50 mm. The technical aspects of the project have been described in earlier publications (Manzi et al., 1981; and Manzi et al., In press). Growth rates and density relationships were described by Hadley and Manzi (In press).

This report is an analysis of the economics of the nursery operations and the learning experiences that occurred during the first 18 months of operation.

## Production Overview

The farm was started with 5,142,000 clams, purchased from late September to mid-November 1980. These clams ranged in size from 1 to 13 mm. No additional seed clams were purchased until May 1981, when slightly over one-half million clams entered the nursery. The next major series of purchases occurred between July and November 1981 when 14,060,000 clams of approximately 1 mm were obtained. The total number of seed clams entering the nursery during the

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Table 1.—Nursery production summary.

Item	Introduction 9/29/80	First quarter 12/1/80	Second quarter 4/1/81	Third quarter 6/24/81	Fourth quarter 9/1/81	Fifth quarter 12/1/81	Total to date (3/22/82)
Starting Stock							
Trays	0	4,012,440	4,031,733	2,687,661	2,053,725	2,215,915	0
Silos	0	0	0	352,771	3,492,180	10,792,238	0
Box & 50 cm	0	0	0	0	0	0	0
Purchases	<sup>1</sup> 5,142,000	0	<sup>2</sup> 581,000	3,710,000	10,300,000	0	19,733,000
Field Returns	0	0	0	0	14,700	0	14,700
Subtotal to account for:	5,142,000	4,912,440	4,612,733	6,750,432	15,860,605	13,008,153	19,747,700
Planted	512,000	409,600	770,800	457,200	717,000	128,000	2,994,600
Finishing Stock							
Trays	<sup>2</sup> 4,912,440	4,031,733	2,687,661	2,053,725	2,215,915	964,411	964,411
Silos	0	0	352,771	3,492,180	10,792,238	7,515,833	7,515,833
Box & 50 cm	0	0	0	0	0	677,756	677,756
Subtotal accounted for:	5,428,040	4,441,333	3,811,232	6,003,105	13,725,153	9,286,000	12,156,200
Difference (net mortality)	286,040	(- 471,107)	(- 801,501)	(- 747,327)	(- 2,135,452)	(- 3,722,153)	(- 7,591,500)

<sup>1</sup>Does not include 500,000 written off as bad shipment.

<sup>2</sup>Does not include 237,000 lost.

<sup>3</sup>Does not include 500,000 written off as bad shipment.

period of analysis was 19,733,000 (Table 1).

The differences between the two major purchases of seed stock emphasize two of the major learning experiences that we want to relate in this report. The first concerns the size of the clams purchased. The initial purchase of seed was defined by a much larger range of sizes (from 1 to 13 mm) than was the second major purchase (from 1 to 2 mm). This occurred because the cost and scarcity of larger sizes of seed made the purchase of 1 mm seed stock a more economically feasible purchase. The price of seed in the first purchase averaged \$6.38 per 1,000, while the second purchase averaged \$3.72 per 1,000.

The second difference between the two purchases was in the quantities purchased. The second major purchase involved almost three times the quantity of clams as the first. This was because the nursery was fully operational, and the original nursery operation was not taking full advantage of cost reductions from the economies of scale available to it, an element which will be discussed later in the paper.

A total of 2,994,600 clams were transferred to the field operations. The timing and quantities of the

plantings are given in Table 1. The plantings can be broken into roughly three time periods. The clams planted during the first period consisted of clams greater than 6 mm from the original purchase. This period lasted from the beginning until about the end of April 1981 and included the first 1,216,000 clams planted. The second period of plantings was composed of the smaller sized clams in the original purchase. It started in about May 1981 and continued through December 1981 and consisted of 1,778,000 clams. The third period just began in May 1982 and consisted of clams imported into the nursery in the last half of 1981.

The number of clams remaining in the nursery after plantings and mortalities as of the latest inventory (mid-March 1982) was 9,158,000. Thus an estimate of the overall mortality in the nursery can be made by starting with the 19,733,000 clams purchased and subtracting the 2,994,600 clams planted along with the 9,158,000 clams remaining which yields a mortality of 7,580,400 clams (Table 1). This is a loss of 38.4 percent of the total number of clams purchased.

However, this calculation of an overall mortality figure could be highly misleading because it does not take

Table 2.—Input and output flows of seed clams for an April to December seed purchasing season at constant and seasonally decreasing seed prices.

Month	Constant prices @\$6.00/1,000		Seasonally decreasing prices		
	Input (000)	Output (000)	Input (000)	Price (\$/1,000)	Output (000)
Jan.	0	730	0	0	724
Feb.	0	292	0	0	289
Mar.	0	219	0	0	217
Apr.	411	480	1,049	\$6.50	217
May	1,804	146	0	6.00	0
June	1,367	352	1,735	6.00	351
July	228	206	1,275	5.50	281
Aug.	0	727	348	5.00	651
Sept.	0	241	0	4.50	232
Oct.	2,181	897	0	4.00	892
Nov.	435	412	2,162	3.50	411
Dec.	777	122	0	3.00	132
Total	7,203	4,817	6,569		4,397

into account the variations in the number of clams in the nursery over time, nor does it consider the timing of the purchases and planting of the seed clams. In order to overcome the weakness in the calculation of the total nursery mortality rate, we calculated an estimated monthly survival rate for each inventory period beginning with the first quarter of 1981 to the end of the analysis (Table 2). This assumes a fixed survival percentage within each quarter, accomplished by calculating an estimated average number of clams in the nursery for each

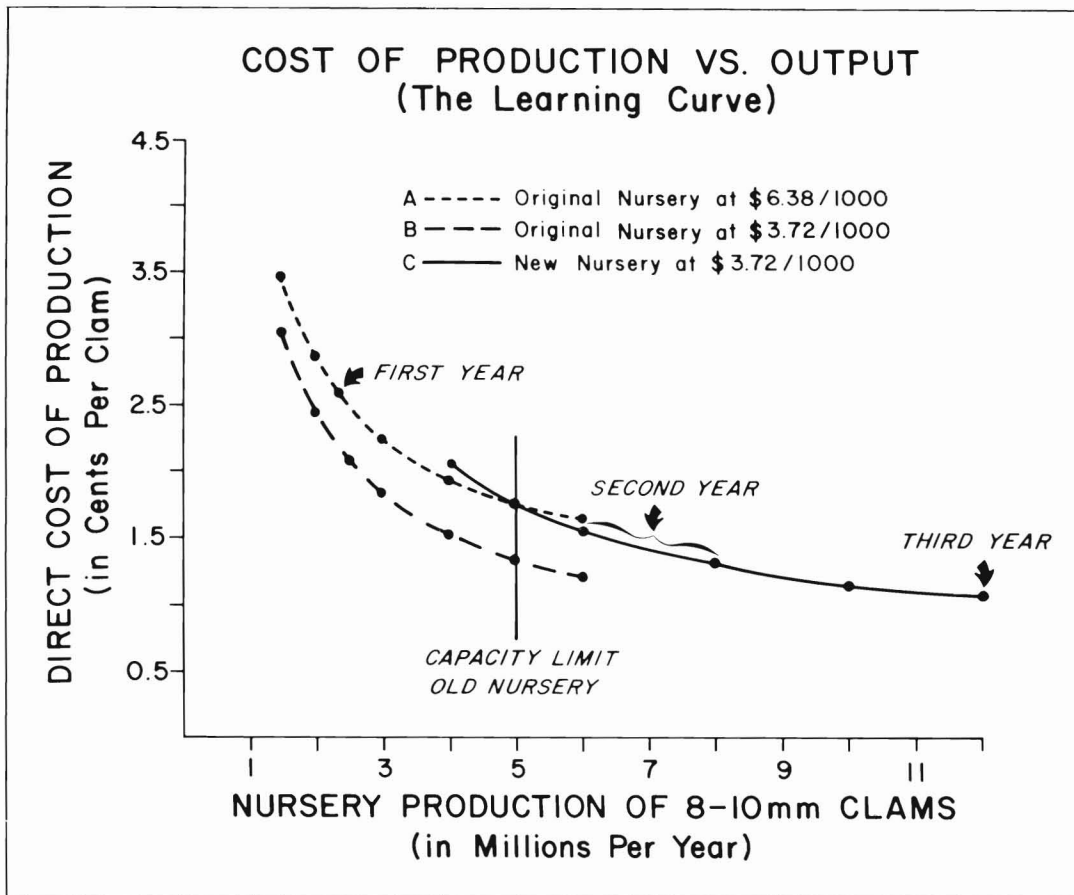


Figure 1.—Unit production costs per 8-10 mm clam. Direct production costs are shown for the original nursery system at two 1 mm seed purchase prices, \$6.38/1,000 (line A) and \$3.72/1,000 (line B), and the new nursery system at a 1 mm seed purchase price of \$3.72/1,000 (line C).

month during the quarter; taking the actual starting count, adding to it the number of clams purchased and subtracting the number of clams planted. This number was then multiplied by the calculated survival rate to give the starting count for each of the following months in the quarter. The calculated finishing balance for the last month of the quarter was subtracted from the actual inventory at the end of the quarter. The estimated survival rate was adjusted in an iterative procedure until the calculated balance matched the actual inventory at the end of each quarter. We also used the same procedure to calculate the overall monthly survival rate (93.3 percent

per month). If one wanted to estimate the number of clams surviving through to the end of the 7 months in the nursery, then one would take the monthly survival rate to the seventh power, i.e.,  $(0.937)^7 = 63.4$  percent.

#### Direct Costs

The estimated monthly survival rates were used to calculate the total purchased seed costs for the field-planted stock leaving the nursery. These costs along with the other nursery costs for the first full year of normal nursery operations are given in Table 2. During this period, 2,354,600 seed clams were transferred

to the field. The calculated overall nursery survival rate used was 63.4 percent. The average cost for the seed clams purchased earlier and planted during this period was \$6.38 per 1,000. Thus, the actual seed cost component for the clams leaving the nursery was  $(1/0.633)$  times \$6.38 which is \$10.08 per 1,000 or 1.01 cent apiece.

However, seed cost was not the largest cost component for the nursery. The largest cost was labor, mainly because of the extra work required to overcome the high silt loading found in trays. The equivalent of three full-time persons was used to operate the nursery: One technician and two hourly employees. The labor

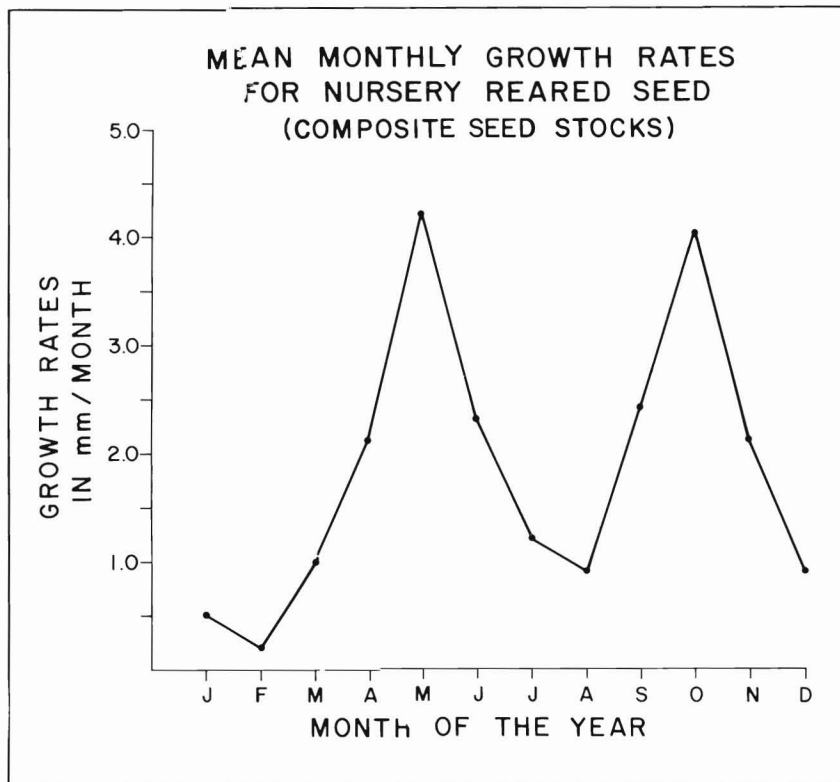


Figure 2.—Monthly growth rates for a composite of all seed sizes in the nursery. (Data from Manzi et al., 1981).

cost was \$25,900 or 1.10 cents per clam leaving the nursery.

The capital investment in the nursery as of 1 October 1981 was \$18,000. Using a 5-year straight line depreciation rate, the yearly depreciation charges are \$3,600. This amounts to only 0.15 cent per clam. Straight line depreciation is used to give a more accurate image of the costs of production without the complications of taxes. The monthly electric bill averaged about \$250 or \$3,000 per year, which amounts to 0.13 cent per clam. These and the remaining costs are summarized in Table 3. The total direct cost to operate the nursery during this 12-month period was \$60,659.43. This resulted in a direct cost of 2.58 cents per 8-10 mm clam produced during the period.

It should be remembered that these are direct costs of operating the nurs-

ery and do not include such things as a share of the administrative overhead, interest costs, or selling costs (Horngren, 1972). Also very importantly, these costs are not adjusted for the value added to the work-in-progress (i.e., the additional growth put on the clams remaining in the nursery). An example of work-in-progress is that during the latter months of 1981 an additional 14,010,000 seed clams were imported into the nursery. The additional seed clams necessitated an expansion of the nursery. This was done with the installation of forced upflow silos, which are comparatively more labor efficient in the culture of seed clams in the 1-4 mm size range. Their support was in addition to the effort needed to produce the 2.354 million clams planted during the budget year of this analysis; and the direct costs of the

production of the 2,354,000 clams sent to the field should be adjusted to reflect this fact. Once the nursery enters a steady-state production schedule, the adjustments for work-in-progress should be relatively unimportant to the costing analysis.

The direct cost figures are for the nursery system that was in place for most of the period of analysis. Unit costs of production for various levels of output of this system are given in Figure 1. Throughout the range of production available from the old nursery, costs strongly decline with increases in production. This was a result of the spreading relatively fixed costs over a larger production base. The curves are continued beyond the theoretical capacity of the nursery only to show that a majority, but not all, of the decreases in direct unit costs have been captured at a production level of 5 million clams per year transferred to the field.

Unit production costs are also illustrated in Figure 1 for the original nursery system at a seed purchase price of \$3.72/1,000 and for the new nursery system under construction using a seed purchase price of \$3.72/1,000. The new nursery system is designed to eventually produce 12

Table 3.—Estimated first year costs and projected third year costs of the nursery operation.<sup>1</sup>

Item	First year		Third year cost per clam in cents
	Actual costs in dollars	Cost per clam in cents	
<b>Variable costs</b>			
Seed	\$23,731.99	1.01	0.59
Labor	25,884.89	1.10	0.22
Utilities	3,000.00	0.13	0.05
Supplies	1,200.00	0.05	0.01
Automobile	1,138.44	0.05	0.01
Phone	600.00	0.03	0.01
<b>Fixed Costs</b>			
Rent	1,500.00	0.06	0.13
Insurance	0.00	0.00	0.00
Depreciation	3,604.00	0.15	0.07
<b>Grand total</b>	<b>\$60,659.43</b>	<b>2.58</b>	<b>1.07</b>

<sup>1</sup>The analysis is based on: First year a total of 2,354,600 8-10 mm clams planted during the period 1 Dec. 1980 to 1 Dec. 1981 and an average purchase price of \$6.38. Third year: A total plant of 12,000,000, and an average purchase price of \$3.72. Both years: A survival rate of 63.3 percent.

million 8-10 mm seed clams per year for the field growout phase. It will do this while using less labor than the old nursery system. The gains in labor efficiency are being made by switching from a tray (raceway) culture system to a silo culture system (Manzi et al., In press). The original nursery design used only trays which proved to be very labor intensive because of a rapid buildup of silt. The silt is also more difficult to remove from the trays. The first improvement in efficiency was the installation into the old nursery of the small forced upflow silos in mid-1981. The new nursery will convert the tray culture used in the 4-10 mm growth period over to a passive upflow silo system, so that no trays will be used in the nursery.

The theoretical limit of the mid-1981 nursery system's productive capacity was determined with the use of linear programming (LP) techniques (Hillier and Lieberman, 1974). The variation in monthly growth rates that were encountered are shown in Figure 2. These growth rates were then used to map the production of field growout sized seed for each month. The maps were then combined with estimates of the carrying capacity of the trays and silos for each size range of clam found in the nursery to form a LP model of the system. This LP model was used to investigate the effects of the length of the seed purchasing season upon both the maximum output of the nursery (Fig. 3) and the percentage of the maximal utilization of available tray space by months (Fig. 4). This was done by setting up the LP to maximize the output of the nursery by varying the timing and quantity of the seed purchases within the bounds set by the seed purchasing season.

This produced a highly pulsed stream of inputs and production from the nursery. The scheduling requirements were such that the maximum production might never be reached because of an inability to or the lack of desire to obtain 1 mm clams in predetermined quantities at the specified dates. The input and output schedules for an April-December purchasing

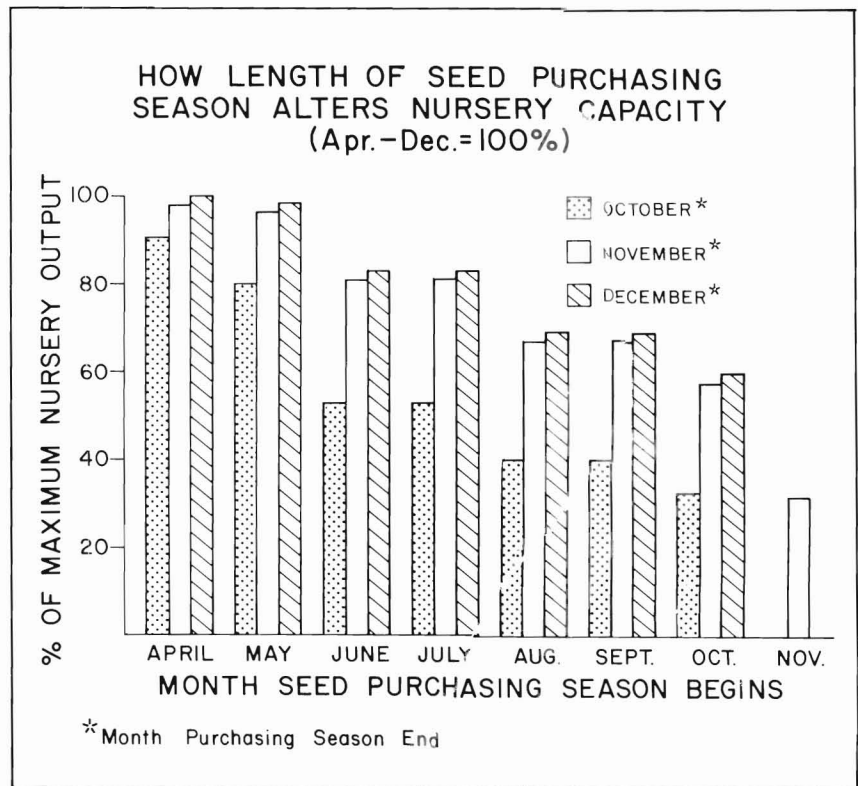


Figure 3.—The percentage of maximal output as a function of the 1 mm seed purchasing season. To determine the percentage of maximal output, first locate the first month of the purchasing season along the bottom of the figure, then move directly above and locate the bar for the last month of the purchasing season. The percentage of maximal output will be found on the left axis.

season are given in Table 4. This table also shows the changes in the timing of the input and output when a seasonal decrease in price of 1 mm clams is included into the model.

### Discussion

The most important piece of knowledge that has been gained in the past 18 months is that the nursery system as it was designed works. The nursery is able to raise 1 mm postlarvae up to a size where they are able to be planted in the field growout stages of the farming operation.

First among the operational lessons learned in the nursery is that the horizontal tray or raceway is not economically practical for South Caro-

Table 4.—Estimated monthly survival rates.

Quarter	Beginning date	Survival rate in percent per month
Introduction	September 1980	N.A.
First	1 December 1980	97.4
Second	1 April 1981	92.6
Third	24 June 1981	92.6
Fourth	1 September 1981	94.2
Fifth	1 December 1981	89.0
Overall	1 December 1980 to 22 March 1982	93.7

lina waters. This is because of two factors. First, the siltation rate is far too high, and this makes frequent cleaning a tedious necessity. The amount of labor involved is overwhelming. Second, the trays do not

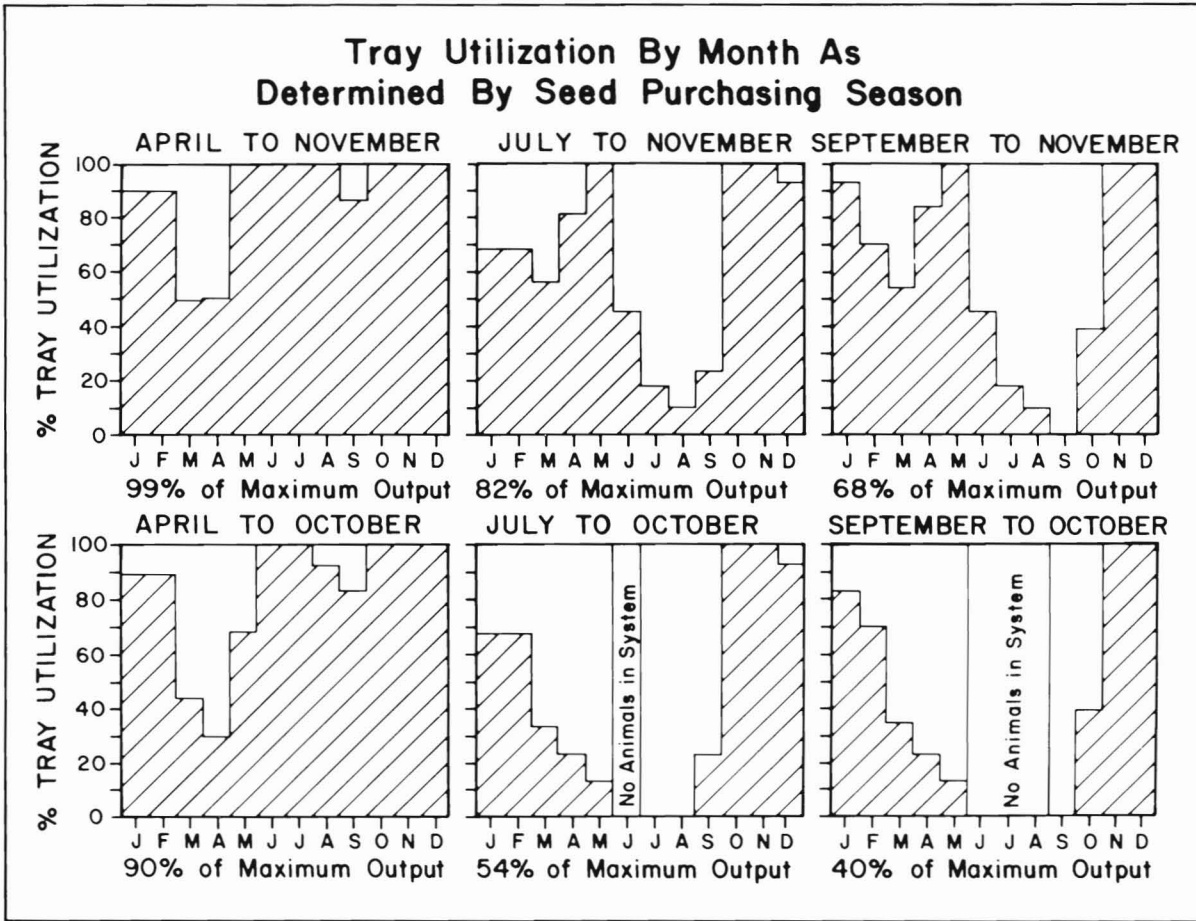


Figure 4.—Percentage of tray utilization in the mid-1981 nursery for six selected seed purchasing seasons.

make the most efficient use of nursery floor space, and when they are stacked the awkwardness of cleaning them is increased dramatically.

Next, the importance of quality control of the seed purchases has been realized. In South Carolina, we can obtain growth in the nursery well into the fall, and this factor has led to purchases late in the season at discounted prices. However, these seed clams may have been the slow growers (culls) that did not make it out of the more northern nurseries in a reasonable length of time, and thus, were available during the latter part of the season at smaller sizes and low prices.

Economies of scale are important; Trident Seafarms is now moving to a

larger, more capital intensive nursery system. The new system is designed for much greater production using essentially the same amount of labor as the old tray-based nursery system. This will drastically decrease the labor component of the unit production costs.

The importance of inventory control and good record keeping in order to evaluate performance should be emphasized.

Finally, the importance of building sufficient extra capacity into the nursery so that seasonal increases in the availability of nursery size seed clams can be accommodated without disruption of the production schedules must be stressed.

#### Literature Cited

- Hadley, N. H., and J. J. Manzi. In Press. Growth of seed clams, *Mercenaria mercenaria*, at various densities in a commercial scale nursery system. Aquaculture.
- Hillier, F. S., and G. J. Lieberman. 1974. Operations research. Holden-Day, Inc., San Francisco, 800 p.
- Horngren, C. T. 1972. Cost accounting: A managerial emphasis. Prentice-Hall, Englewood Cliffs, N.J., 963 p.
- Manzi, J. J., V. C. Burrell Jr., and H. Q. M. Clawson. 1981. Commercialization of hard clam, *Mercenaria mercenaria*, mariculture in South Carolina: Preliminary report. World Mariculture Soc. 12(1):181-195.
- Stevens, F. S., and M. B. Maddox. In press. Commercialization of hard clam, *Mercenaria mercenaria*, mariculture in South Carolina: One year later. J. Shellfish. Res.