REPORT

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Costs of Quahog Seeding on Cape Cod

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Executive Summary

Cape Cod municipal shellfish programs were surveyed over the summer of 2000 to assess the different methods used to purchase seed, grow-out, and deliver viable quahogs to their managed shellfish beds. A survey of town shellfish officers was conducted along with site visits and interviews.

Though this study is limited in it's scope, relying on estimates from shellfish officers, and covering only a single growth cycle, it points to several conclusions and recommendations.

It appears that larger programs can grow viable quahog seed at a lower cost than the current purchase cost for similar size seed from commercial vendors. Average costs for those programs which purchased large seed (10-22.5mm) commercially were $47 per thousand seed broadcast to the flats. Average costs for all small seed programs was $35 per thousand. Small seed programs are those who purchased seed of size1-2.5 mm for grow-out prior to broadcast.

Furthermore, economies of scale appear to exist in quahog seed grow-out. For three "large-scale" programs, those who began with 2 million seed or more, the average cost per broadcast quahog was only $13.33 per thousand.

Wide variation exists in the operations and cost of individual towns propagation efforts. Several towns reported high mortality of their seed at one or more stages in the grow-out process. Unusual mortality or loss from theft drove up unit costs significantly. Particularly troubling was the impact of mortality at the over-wintering stage. Losses at this stage affect larger sized quahog seed which have had substantial value added since the time of purchase. Continued research and discussion of best management practices to minimize losses during the over-winter stage are recommended.

Several towns choose not to over-winter seed and a wide variation was shown in the reported seed size at time of broadcast to flats (10 – 37.5mm avg. size). Predation by crabs is thought to increase with decreasing seed size. In order to determine the least cost method of growing seed to harvestable size, the optimum broadcast size should be determined. A long term study should be performed to assess the predation rates as a function of seed broadcast size. Knowing predation rates, and accumulating more extensive and accurate grow-out cost data can then lead to discovery of an optimal grow-out strategy.

1. Background and Project Description

During 1999 Barnstable County and the Massachusetts Division of Marine Fisheries funded a study to assess the feasibility of developing a municipal shellfish hatchery for Cape Cod, Massachusetts. Through the course of this work it became evident that many of the communities on Cape Cod employed different methods to purchase seed, grow-out, and deliver viable quahogs to their managed shellfish beds. This observation led to the following questions;

- What are the costs of each method?
- Is there a preferred "low cost" method that can be employed by other communities on Cape Cod?
- What can the town's learn from each other in their quahog propagation efforts that will promote "best management practices" and enhance each towns propagation success?

To help answer these questions the following work was proposed and conducted over the period August – September, 2000:

- Interview (by site visit and/or phone) all Cape Cod shellfish wardens with active quahog seeding operations to determine methods, equipment, timelines and costs involved.
- Estimate a "delivered" cost per viable quahog that is seeded for each community

A survey instrument was developed and reviewed by Barnstable County Cooperative Extension and Mass. DMF staff which included, material cost, operating costs, labor costs, and estimated lifespan of the various quahog propagation equipment and methods employed in each of the towns.

Site visits were made to all active Cape Cod municipal upwelling facilities including:

- Brewster
- Chatham
- Eastham
- Falmouth
- Harwich
- Mashpee
- W. Yarmouth

In addition, to these site visits the following towns completed and returned the quahog seed cost survey:

- Barnstable
- Bourne
- Brewster
- Chatham
- Eastham
- Falmouth
- Harwich
- Mashpee
- Provincetown
- W. Yarmouth

Finally, three towns were paid an additional site visit and in-depth interviews were conducted with the town's shellfish officer(s). These towns were: Barnstable, Chatham and W. Yarmouth.

The quahog seed cost survey, included as Appendix 1, attempted to capture each town's cost experience for the most recently completed quahog field plant cycle. The "cycle" typically incorporated some or all of the following 4 phases:

1) Seed purchase
2) Grow-out – Initial in up-wellers
3) Grow-out - Seabed grow-out (often including over-wintering)
4) Seed harvest for broadcast planting to flats

The shellfish officers were asked to give cost, labor, and seed data and mortality estimates for each of these phases.

The site visits and in-depth interviews provided additional information on the processes and techniques used in each town's quahog propagation effort.

I would like to thank Mike Hickey, of Mass. DMF, and Bill Burt and Dale Leavitt of Barnstable County Cooperative Extension for funding this project and arranging trips to many of the Cape Cod Up-wellers.

2. Quahog Seeding Operations

2.1 Town quahog seeding methods

Purchase Size Differences

Two basic methods of quahog propagation exist among municipal shellfish propagation efforts on Cape Cod. One believes, that given a sufficient volume of seed to be handled, the most cost effective way to conduct the propagation effort is to purchase large quantities of juvenile quahog seed (approx. 1mm in size) and grow these out to a sufficient size to minimize predation in the field (by crabs) prior to field planting. The second basic philosophy is to purchase larger size seed commercially, and either field plant directly or over-winter them under netting, and then field plant. This second method requires that the seed supplier grow the seed to the larger size, and consequently they charge a higher price per animal.

A recent price list from a commercial seed supplier, Figure 2, shows the 2000 price increasing from $3.00 per thousand seed for 1-2mm animals, to $25.00 per thousand for 12 – 17mm animals.

Which method is more cost effective? Intuitively one can imagine that below a certain scale, the cost of capital equipment, operating costs, labor, and additional mortality from the early grow-out process will exceed the higher cost of purchasing larger seed directly. This notion is often referred to as economies of scale. Above a certain quantity, the unit costs of growing-out small seed fall below the unit costs of purchasing the larger size seed. This occurs from the ability to spread the fixed costs of the grow-out equipment (and set-up times in the labor components) over a larger quantity of seed handled.

In addition to these purchase size differences, several towns reported participation in relay programs where quahogs have been removed from polluted waters, either locally, or from Mount Hope Bay in New Bedford, and re-planted in clean waters for depuration. Quahogs are tested regularly and are opened for harvest when they have been deemed clean and healthy. The relay programs were not covered as a focus of this research project.

Broadcast size differences

The towns showed a wide range of "target" size for field planting/broadcast to flats.

No. of Towns	Size for Seeding on Flats
10-14mm	3
15-19mm	3
20-24mm	0
25-29mm	2
30-34mm	2
35-39mm	1

The results given above represent usable survey responses from 9 towns. Two of those towns (Barnstable, and Falmouth) provided two sets of information representing two different cultural practices, namely their experience in purchasing big seed and little seed.

The issue of size at time of seeding to the flats is a critical one which merits further study. Anecdotal experience indicates that smaller size clams are subject to predation, from crabs principally. Opinion on what a "safe" minimum size for field planting varies. Some feel that planting clams under 15mm is an exercise in "feeding the crabs". This issue was not part of the scope of this study, but determining the

relationship between planting size and field survival to harvest is a key recommendation for future research.

Over-wintering

Related to the size at field planting is the willingness to undertake over-wintering of the quahog seed. For seed spawned in the spring of the year, most towns report single season growth in the range of 12-15mm+. As noted above 3 of the towns reported that the average size of their quahog seed at the time of broadcasting to the flats was under 15 mm.

The towns were split evenly on the question of over-wintering. Five reported that they do and four that they do not.

2.2 Seed purchasing

Small seed is typically purchased in the springtime, anywhere from March to June. Many of the towns participated in the County sponsored seed purchase program over the past two years. For the purposes of this study the towns were asked to report the quantities of seed that they purchased in the past that led to this years broadcast seeding of animals to the town's harvesting flats. A typical example would be large seed purchased in the Fall of 1999 (or small seed purchased in the Spring of 1999), over-wintered, then dug up and broadcast to flats in the summer of 2000.

The following towns reported participating in the County seed purchase program: Barnstable, Bourne, Brewster, Chatham, Eastham, Falmouth, Orleans, Provincetown and Yarmouth. Their seed was specified at 1mm. Other "small" sizes reported were R1 and "2mm-3mm". Costs for this seed ranged from the county purchase range of $3.50-$5.10 per thousand, to $11.00/thouand for the 2-3mm animals. Delivery dates for small seed are typically late-spring, in May or June.

Large seed was purchased by three towns (not counting relay programs). Sizes and prices were as follows:

10 mm	@ $40/thousand
12-15 mm	@ $25/thousand
15mm +	@ $30-35/thousand

Large seed is typically purchased in the Fall, September or October.

2.3 Grow-out operations

Grow-out methods ranged from the simply field planting "large" seed purchased from commercial quahog seed growers, a more complex cultural method:

> raft mounted down-wellers ⇒ shore based up-wellers ⇒ raft-mounted tidal wellers ⇒ over-wintering in seabed cages ⇒ final grow-out in tidal up-wellers ⇒ field planting

Most towns employed a methodology somewhere in between.

A total of 7 different cultural methods were identified for the propagation of quahogs. The methods and towns reporting each method are shown on Figure 3.

2.3.1 Up-weller technologies

The up-weller technologies used by Cape Cod towns varied considerably in age, capacity, cost (both capital cost and operating cost), construction type, location, and flow rate. At the time of the writing of this report, pictures of several of these up-wellers were available at the following web address: http://www-unix.oit.umass.edu/~ddamery/capecod1.htm

Time spent in up-wellers

The time seed spent in up-wellers was primarily determined by growth rate. In towns where up-weller capacity was fully utilized, the seeds were rotated out of the up-weller, typically to a seabed based to a cage-netting stage, when they reached a certain size. The desired size for this rotation was reported to be 10-15mm by several towns (Mashpee, Chatham, Eastham). Time spent in up-wellers ranged from 10-25 weeks with a mean of 17 weeks reported.

Operations and maintenance issues with up-wellers

All officers had regular up-weller cleaning schedules, depending on the rate of fouling and the quality of the intake water. Most also reported the need to regularly clean fouling from pumps and intake lines. Several towns tried to minimize fouling by the inclusion of a "mesh-bag-filter" to trap sea squirts prior to the intake water reaching the up-weller boxes. Several towns employed dual intake line systems. This allowed easy cleaning of the intake lines by simply switching lines, allowing the dis-used one to stagnate killing the accumulated algae and then flushing.

Growth of quahog seed in the up-wellers is related to many factors including:

- health of the intake water (available food (algae) levels)
- density of the quahog seed
- and the rate of flow.

Site visits captured anecdotal evidence of flow rates which varied considerably.

2.3.2 Cages/Netting – Summer

When starting with small quahog seed, most towns placed seed in sea-based cages (wire mesh boxes) or under "netting" (14' wide black mesh netting, typically held to the seabed with re-bar) to enable additional growth prior to field plant. The primary goal is to allow the quahog to achieve sufficient size so that it can survive crab predation. Several shellfish officers reported their "ideal" field plant size to be close to 25mm. Mortality from crabs was thought to increase below this size, and to be excessive for quahog seed under a 15mm size. This points to an area for future research. Town's might be better able to choose an optimal grow-out method if data were available that compared predation rates with costs to grow to certain sizes would help towns devise an optimal grow-out strategy.

Two towns reported using seabed based cages/netting systems only during the summer season, Mashpee and Brewster. The resultant field plant size for these two towns were 18mm and 15mm averages respectively.

Mashpee uses a system that employs two cage tops for each cage in the field. This enables a "fouled" cage top to be removed and replaced with a clean one quickly. The "fouled" top is then returned to shore for drying out and to allow accumulated algae to die and fall off. This minimizes time spent cleaning the cages in the field.

2.3.3 Cages/Netting - Over-wintering

More towns kept the quahogs in these seabed cage/netting systems over the winter. These included Barnstable, Brewster, Chatham, Eastham, Orleans and Yarmouth. Issues surrounding the over-wintering phase include:

- Cost of monitoring and maintenance
- Winter storm and ice damage
- Growth rates (reported to be slow to non-existent over the months November – March)

2.4 Distribution to flats

The most frequently reported distribution method was by boat. Seed is taken from the up-wellers or cage/netting system and broadcast over the side of a small boat. Alternatively seed is broadcast from shore/wading.

Those towns who used a seabed grow-out (either summer, or winter, or both) had the additional step of recovering the quahogs from the cages/netting. Staff, and volunteers, when used, raked the quahogs from the un-covered beds transferred to sacks and then to boat for broadcast.

3. Cost Estimates

Based on the survey data costs were estimated for both large seed and small seed programs. Large seed programs costs were dominated by the purchase price of the seed. Over-wintering costs and the costs of seeding to the flats are added to the purchase price.

Small seed programs costs were made up largely of labor costs associated with grow-out. Costs were estimated at the following stages:

- Purchase
- Up-weller stage
- Summer cage/netting
- Winter cage/netting
- Seeding to beds

Details for each of these elements is discussed below.

Finally, a total estimated cost per thousand quahog seed broadcast to the flats was made. Results indicate an average cost for large seed programs of $47 per thousand, and $35 per thousand for small seed programs. Additionally, there appears to be evidence that larger scale programs are more cost effective. An average cost for those programs working with at least 2 million small seed at the time of purchase yield an average cost per broadcast quahog of only $13.33 per thousand.

3.1 Seed costs

County seed purchase program

The 1999 County seed program awarded purchase orders for seed to 3 different vendors as follows:

- Fisher's Island Oyster Farm – 6,000,000 @ 1mm - $3.50/1,000
- Pemaquid Shellfish Co. – 4,020,000 @ 1mm - $5.00/1,000
- Mook Sea Farm, Inc. - 4,020,000 @ 1mm - $5.00/1,000

The seed purchased from Pemaquid arrived with "a great amount" of mortality, and was later replaced by additional seed purchased from Fisher's Island. This points out a benefit of diversifying purchase orders for seed. The variability in seed culture is still sufficiently risky to discourage sole sourcing the seed purchase at this time.

Other reported seed purchase prices:

Size	Cost ($/1,000)
1mm	$4.75, $6.00
1.5 mm	$11.00
1-2.5 mm	$4.93
10 mm	$40.00
15 mm +	$30 - $35.00
22.5 mm	$30.00

See also Figure 2, the Bayfarm Inc. 2000 pricelist which shows a similar range of prices for sizes ranging from 0.5-1 mm through 12-17mm.

3.2 Grow-out costs

Grow-out costs were broken down into chronological stages: upwelling, cages/netting-summer, cages-netting-over-winter, and seeding on flats. Within these stages, each town was asked to estimate their capital cost (and equipment lifespan), operating costs, paid staff costs, and volunteer hours.

3.2.1 Upwelling

Capital costs

Estimates for each town varied widely due to the scope of the operation, capacity, and the decision to build vs. buy. Several towns used "home-made" up-wellers of plywood "box" construction, or of PVC "bucket" construction. At the other end of the spectrum was a newly purchased "axial-up-weller" system which Brewster was in the process of installing in the Summer, 2000. This had a capacity of 1 million quahogs of 15mm size. It employed a 600 gpm propeller pump and cost an estimated $8,000.

Some town's used outdoor areas with no "fixed structure" as an up-weller area, others had dock mounted or float mounted systems, and others had substantial buildings to shelter their shore based systems.

Reported capital costs for up-weller systems ranged from $500 to $25,000.
Figure 4 shows up-weller cost per 1,000 quahog seed purchased for 1999. The low report of $500 up-weller capital cost (Eastham) bears further investigation as it also resulted in the lowest cost per thousand capacity of only $0.23. The next lowest reported cost was Brewster at $1.50 per thousand. Both these towns used "home-made" up-wellers of plywood construction. It is unclear if all costs of construction and installation are included in the estimate. Cost estimates may be low due to uncounted fabrication and installation man-hours expended in their construction. Eastham also incorporated several different up-weller technologies including shore-based, and floating.

The remaining costs ranged from $3.33 to $18.00 per thousand generally showing a decreasing unit cost with size of the facility, pointing to economies of scale in up-weller capital cost.

Labor Costs

Towns were asked to estimate hours of effort expended by the shellfish officer, other paid staff, and volunteers. All labor costs reported herein were estimated on an "opportunity cost" basis. That is, costs were estimated as if you had to pay for all hours expended. This ignores, "down time", and assumes that hours spent on this effort could have been spent in some other productive enterprise. For comparison purposes only, the following hourly labor rates were applied:

- Shellfish officer hours: $20.00/hr.
- Other paid staff: $15.00/hr.
- Volunteer time: $10.00/hr.

Using this methodology total up-weller labor costs ranged from $900 to $17,080 for 1999. Labor costs typically dominated all other costs during the up-weller stage.

Operating Costs

Operating costs for the up-weller stage were estimated by dividing the average number of weeks that seeds remained in the up-weller stage by 4. This figure was then multiplied by the estimated monthly operating costs. Results ranged from $500 to $2,450 for 1999.

Total Up-weller Stage Costs

Total up-weller stage costs combine the labor, operating and capital equipment costs. Equipment costs were determined by dividing the total reported capital costs by the estimated lifespan. A better comparison can be made by adjusting these aggregate costs for up-weller capacity. When dividing total cost by the seed quantity purchased, unit up-weller costs vary from $0.70 to $10.18 per thousand, as shown in Figure 5. Eastham costs appear lowest followed by Mashpee. Omitting these two the trend of up-weller stage cost per unit again shows economies of scale. That is, the larger facilities showed a substantially lower unit cost of operation.

3.2.2 Cages/Netting - Summer

Ranges for estimated capital costs, labor, and operating costs during this summer grow-out stage are as follows:

Capital equipment (annualized)	$50 - $300
Labor cost	$1,280 - $10,560
Operating Costs	$0 - $25

Overall total costs can be converted to unit costs for comparison. This is done by summing the annualized estimate for 1999 and dividing by the seed count adjusted for mortality through the up-weller stage. Calculated unit costs ($ per thousand seed delivered to this stage) for summer cages/netting were: $1.21, $1.90, $3.23 and $16.15 per thousand for the 4 towns reporting. The largest figure came from Barnstable which included the highest estimate for labor hours used for this stage of the grow-out operation.

3.2.3 Cages/Netting - Over-wintering

Similar to the ranges for the summer grow-out period above, estimated capital costs, labor, and operating costs for over-wintering in 1999 are as follows:

Capital equipment (annualized)	$100 - 1,000
Labor cost	$900 – 21,840
Operating Costs	$0 – 2,600

Most operating costs were estimated at $0. Orleans reported an operating cost of <$100 per month that led to the high estimate which should be investigated further.

Unit costs for over-wintering ($ per thousand seed delivered to this stage) can be calculated as described in section 3.2.2. Figure 6 shows these for the 7 cases with usable data. These ranged from $0.59 to $14.18 per thousand. The Eastham estimate again proved lowest, due to the lowest estimated labor costs. The highest unit cost of $14.18 was the Yarmouth estimate and is due to the high mortality rate and a theft incident during the 1999 up-weller phase. The Orleans unit cost during the over-winter phase was calculated at $11.35 per thousand and is a result of the operating cost estimate mentioned above. The remaining 4 towns had unit costs of: $4.89, $4.94, $5.33, and $9.48 per thousand.

3.2.4 Seeding on flats

Costs associated with seeding to the flats were largely labor again. Survey respondents were also given a chance to identify other costs related to this effort. Calculated cost ranges for each category were:

Labor cost	$65 – 8,000

Other costs $0 – 800

Total unit costs for seeding ranged from $0.25 per thousand, to $20.05 per thousand. This extreme range needs further investigation. Partial explanations result from the size of the quahog at time of seeding. The low estimate came from Harwich which also reported one of the smallest quahog sizes (13.5mm average) at time of seeding. The highest unit cost was reported by Orleans which reported the largest clam size at the time of seeding (37.5 mm average).

3.3 Staffing

Estimates of paid staff devoted to shellfish propagation ranged from 1/10 of a person to 1.0. Local funding levels for shellfish propagation vary widely from town to town.

Towns varied widely in their use of part time staff including: summer paid staff, summer student interns and part-time winter net observers/maintainers.

Several towns reported heavy usage of volunteer efforts to assist in various aspects of their shellfish propagation efforts. The following types of volunteers were reported:

- Students
- Prisoners
- Senior Citizens
- Summer residents
- Americorps volunteers
- Commercial shellfishermen

Several towns reported large numbers of volunteer man-hours, particularly those towns with a large commercial shellfishery. Several shellfish officers pointed to the volunteer hours as contributing heavily to the success of their shellfish propagation efforts.

3.4 Cost per "broadcast" quahog calculation

Finally a total cost per "broadcast" quahog was estimated. Each of the total annualized costs for the various stages were summed and divided by the final quahog count (after mortality) for 1999. These results are reported in the following figures:

- Large seed programs – Unit cost per broadcast quahog- Figure 7
- Small seed programs – Unit cost per broadcast quahog- Figure 8
- Unit cost vs. Size at broadcast – All programs – Figure 9

<u>Large seed programs</u>
The beauty of purchasing large seed is that you avoid all of the labor, equipment, and expense of performing the grow-out on your own. The trade-off is, of course, cost. The three programs which reported data on large seed programs showed broadcast seed costs of $38, $40 and $63 per thousand. The highest of the three costs arises from the use of an over-wintering program to increase seed size, which the other two programs do not employ. They have simply chosen to field plant all purchased seed in the Fall.

Figure 10 shows the cost breakdown by "stage" for the large seed programs. The bulk of the cost, as expected, is the up-front purchase cost of the large seed. Barnstable reported some over-wintering expense and Orleans reported significant over-winter and seeding costs.

Small seed programs

Costs ranged from $11 to $88 per thousand quahogs broadcast for the small seed programs, as shown in Figure 11. Cost variances are evident at all stages in the grow-out process. Significant differences in reported up-weller, summer and winter cages/netting, and in seeding costs are noted.

The two "high-cost" cases arise primarily from the large mortality percentages that were reported. Barnstable reported a combined mortality rate of 69% and Yarmouth a combined mortality rate of 85%. Yarmouth also noted that this was not typical. Figure 12 presents a scatter plot of cost vs. overall mortality rate.

Eliminating the high mortality cases the range of the remaining programs is $11-$33 per thousand clams a the time of broadcast. The entire range falls below the ranges reported for the large seed programs, but this comes with a cost of reduced seed size at time of broadcast.

4. Mortality Estimates

As noted above in Section 3.1 the county seed purchase program experienced significant mortality at the time of delivery and shortly thereafter from one vendor in 1999. Presumably, the cost of mortality at the time of purchase should be borne by the seed vendor, and the town's cost might be limited to a delay in receipt of seed, if it can be replenished. Mortality should, of course, be minimized at any stage. However, mortality at later stages is more costly in the sense that quahog seed has been increasing in value through each growth stage.

The cost of quahog seed mortality rises as the seed grows in size. This is a result of the value added to the quahog seed at each state of the grow-out process. Reducing mortality at the later grow-out stages (winter cage/netting) will have the greatest cost savings to the towns as the seed value is highest at this point.

4.1 At seed purchase

The town's were asked to estimate seed mortality at the time of purchase. Large seed programs reported a range of mortality of 0-1.5%. Small seed programs had a wider range from 0-20%, with an average of 5.4%.

4.2 Grow-out

Estimated mortality through the up-weller stage ranged from 0-75% and averaged 19%. The high mortality estimate from Yarmouth, resulted form a pump failure and theft. Eliminating this one estimate reduces the reported average mortality to 11% for the remaining 7 small seed programs.

4.3 Cages/netting – Summer and Winter

Reported mortality estimates through summer and winter cage/netting phases were as follows

	Range	Average
Summer	0-25%	11%
Winter	10-60%	39%

The losses which occur during the winter cage/netting phase are particularly disturbing. Average seed size at this stage is close to 15 mm and the "market price" for seed of this size is on the order of $25-$30 per thousand. This is 6 to 7 times the original purchase price of 1mm seed. Winter is, of course, the time period subject to the most severe conditions, icing, storms etc. It might benefit the towns to research and discuss the most successful over-wintering practices, including:

- Locations – bottom type, coastal protection, tidal, inter-tidal, sub-tidal etc.
- Net/cage types – sizes, fastening practices
- Operations – Maintenance, inspection frequency

5. Timelines

5.1 Seed purchase

For the 1999-2000 growing cycle, the large seed programs reported purchase dates of August, September and October. The small seed programs reported May and June purchase dates.

5.2 Grow-out

Time spent in up-wellers varied depending on the program. The reported average time in the up-weller stage ranged from 10 weeks to 25 weeks with a mean of 16 weeks. Seed which will be over-wintered, or grown-out in summer cages/netting is typically removed from the up-wellers once reaching a size

5.3 Seeding on flats

Seeding of the "grown-out" animals is generally done in the summer and fall months. Several towns reported significant shellfish officer time and volunteer time in these seeding efforts. The process generally requires raking of animals from their grow-out beds, placement in mesh bags. Transport to boat and broadcasting to the flats over the side.

Ranges for total hours spent on the seeding effort were as follows:

- Shellfish officer – 1 – 160 hours
- Other Paid Staff - 3 – 320 hours
- Volunteers - 0 – 160 hours

6. Study Limitations

6.1 Nature of Estimates

The data presented in this report is based on written surveys and interviews with shellfish officers in each of the Cape Cod towns. Officers were asked to "estimate" values for each of the questions and the data has not been independently verified. The accuracy and precision of the data collected is subject to the vagaries of human memory. Varying levels of effort went into each effort to fill out the survey and differences between actual costs incurred and reported are certain to exist. However, despite this inherent variance in the data, general conclusions and recommendations can be drawn from the sum of information collected and are put forward in Section 7.

The intent of the study was to identify potential best management practices, operational success and failures. The data should not be relied upon to accurately model the true costs of quahog seeding programs. The data is only meant to show the range of variance in costs which Cape Cod programs experience today.

6.2 Single season information

The shellfish officer's surveyed were asked to estimate cost, labor, timeline, and mortality data for "the most recent completed seeding" of quahog seeds. For small seed programs that included those seed first purchased in spring of 1999. For large seed programs that included those seed purchased in the fall, 1999. This represents only one year of experience. Results should not be extended or interpreted as being typical. Weather, storms, sea temperature, and a host of other variables contribute to the growth rates, costs, success and failure of the various quahog propagation programs. These all, of course, can vary significantly from year to year. Additional work is necessary to gauge the year to year range of variation in all of the data analyzed.

7. Conclusions and Recommendations

Costs and methods of quahog seed grow-out vary widely among Cape Cod communities with shellfish propagation programs. This "snap-shot" of quahog propagation, though limited by the accuracy of estimates and the single season of data, provides a number of insights for Cape Cod aquaculture programs to consider.

Economies of scale

The grow-out process shows evidence of economies of scale. McConnell, describes scale economies as an industry which shows declining average costs as output increases. Towns with large quahog seed programs seem to show lower costs per broadcast quahog than towns with smaller programs. 5 towns had programs that started with fewer than 2 million seed. These program's average cost was $48.00 per thousand broadcast. This can be compared with 3 programs that started with more than 2 million seed which averaged $13.33 per thousand. For the 5 "small scale" programs, even removing the 2 high mortality cases the average only falls to $25 per thousand which is still twice the average cost of the "large scale" programs.

Further research

The results clearly show the large negative impacts of unusual mortality rates prior to field planting. Furthermore, the issue of mortality rates once in the field warrants additional research. In particular I propose analyzing the incidence of predation on quahogs vs. field plant size. Once scientific data on predation rates are developed and greater accuracy in the costs of grow-out are determined an optimal target size for field planting can be determined. This will take account of the economic trade-off of cost to grow to larger sizes vs. the expected reduced predation rates for the larger field plant size.

The county and towns should continue to discuss best management practices in grow-out operations. This represents an additional area for research. Several questions came to light during the interview process for this report including:

- What is the effect of pump flow rate on seed growth rate?
- What is the optimal filter configuration for trapping sea squirts (or other un-wanted species) at the head of the up-weller?
- How can crab predation be minimized during the cage/netting stages in summer and winter?
    - Is cleaning the netting preferred, or "swapping" out a spare cover for nets/cages?
    - Should crab traps be used close to the cage/netting area?
- What can be done to minimize ice damage during over-winter stage?

Future studies might attempt to find answers to these questions.

Diversification

As shown with the experience of the year 2000 county purchase program the benefits of diversification at the seed purchase stage can minimize disruption of the town's propagation efforts. Several of the towns with larger propagation efforts mentioned the benefits of diversification in program beneficiaries (commercial and recreational) and in staffing (paid staff, summer staff, and volunteers.)

One of the final survey questions asked the respondents to estimate who benefits from their propagation program, commercial or recreational shell-fishers. All respondents indicated that it was a mix, though some were heavily oriented toward commercial beneficiaries (90:10 in favor of commercial) and others favoring recreational fishers (80:20 in favor of recreational). The median response was (50:50).

Interviews and survey responses indicated that larger programs benefited significantly from having a diversified staffing mix. These included paid year-round, and summer employees, and volunteers.

Community support

Several of the town's indicated that much of their propagation efforts couldn't be accomplished without volunteers. Volunteers came from a variety of sources including:

- Schools
- Seniors
- Americorps
- Prisons
- Commercial shell-fishers

An additional benefit of broad community involvement with the propagation programs is political awareness. Those towns with broad community involvement believed that this helped with fiscal support from their town boards.

References

Damery, David T., " The Feasibility of Developing a Municipal Shellfish Hatchery on Cape Cod", Research Report, Cape Cod Cooperative Extension, Barnstable, MA, December, 1999

McConnell, Campbell R. and Stanley L. Brue, Economics, Eleventh edition, McGraw Hill Publishing, New York, 1990, p. 481

Figure 3

Grow-out Methods Used

Method	1	2	3	4	5	6	7
Seed Size (1)	Large	Large	Small	Small	Small	Small	Small
Up-weller (2)	No	No	Yes	Yes	Yes	Yes	Yes
Floating Cages/Netting	No	No	No	No	No	No	Yes
Seabed Cages/Netting	No	No	No	Yes	No	Yes	Yes
Over-winter Cages/Netting	No	Yes	No	No	Yes	Yes	Yes
2nd Season in Floating Cages/Netting	No	No	No	No	No	No	Yes
Field Plant	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Towns	Barnstable, Falmouth	Barnstable, Brewster, Orleans	Harwich	Falmouth, Mashpee	Brewster	Barnstable, Chatham, Bourne, Provincetown	Eastham

Notes:

(1) Large seed refers to size at time of seed purchase and ranged from 10-25mm. Small seed was purchased through the County-DMF purchase program of 1mm animals or of similar size purchased by the individual towns.

(2) Several different up-weller technologies were used including, shore based, float based, down-wellers, and tidal-wellers. For details of the various technologies refer to report section 2.3.1

Appendices

Appendix 1 - Quahog Seed Cost Survey
Appendix 2 - Survey Results Spreadsheet
Appendix 3 - Trip Reports