TERMINATION REPORT

PROJECT CODE: 00-5 **SUBCONTRACT/ACCOUNT NO:** 556705/556510

PROJECT TITLE: An industry directed feasibility study of the razor clam (*Ensis directus*) as a candidate for intertidal and shallow subtidal culture in the northeastern U.S.

DATES OF WORK: 31 December 2003

PARTICIPANTS:

1) William Burt, Marine Specialist	SouthEastern Mass. Aquaculture Center (MA)
2) Dale Leavitt, Aquaculture Specialist	SouthEastern Mass. Aquaculture Center (MA)
3) Gregg Rivara, Marine Ext. Agent	Suffolk County. Mar. Env. Learning Ctr (NY)
4) Gef Flimlin, Marine Ext. Agent	Ocean County Extension Center (NJ)
5) Tessa Simlick, Aquaculture Specialist	Connecticut Sea Grant Program (CT)
6) Dave Alves, Aquaculture Coordinator	RI-CRMC (RI)
8) Michael Patricio, Marine Ext. Agent	Suffolk County. Mar. Env. Learning Ctr (NY)
8) John Maxwell, Shellfish Grower	Atlantic City Aquaculture, Inc. (NJ)
9) Les Hemmila, Shellfish Grower	Barnstable Sea Farm (MA)
10) Carl Syriala, Shellfish Grower	Finn Shellfish, (MA)
11) Wentzle Ruml, Shellfish Grower	Wellfleet Sea Farms (MA)
12) James O'Connell, Shellfish Grower	Wellfleet (MA)
13) John Wadsworth, Shellfish Grower	Niantic Sea Farms, L.L.C. (CT)
14) Mark Zivan, Shellfish Grower	Nauset Sea Farms (MA)
15) Richard Karney, Shellfish Grower	Martha's Vineyard Shellfish Group (MA)
16) Jeffrey Gardner, Shellfish Grower	Shellfish 4 U (RI)

REASON FOR TERMINATION: The project was completed and the funds were either expended or returned to NRAC as unexpended.

PROJECT OBJECTIVES: The overall objective of this proposal is to provide an opportunity for the current shellfish culture industry to investigate, develop, and optimize the growout technology for a cultured razor clam (*Ensis directus*). This will be achieved through provision of small (one to two inch) seed razor clams, generated by a commercial hatchery, to participating growers and through distribution of sufficient funds to design, construct and test specific grow-out strategies, conceived and implemented by individuals currently practicing shellfish culture at a commercial scale.

The specific objectives of the proposed work include:

1. arrange with the participating commercial hatchery to spawn and raise500,000 larval/juvenile razor clams (per year) to a one to two inch size for distribution within the project (Years 1 & 2),
2. solicit ideas for technology to achieve razor clam grow-out from an array of commercial shellfish growers in Maine, Massachusetts, New York and New Jersey (Year 1),
3. convene a committee of five individuals to select six shellfish growers (two from ME, two from MA, one from NY and one from NJ) for participation in the project, based on their concepts of razor clam growout technology (as solicited by the project) (Year 1),
4. supply each of the six selected growers with 150,000 razor clam seed and $2,500 in operating funds (per year) to construct and implement their concept of appropriate razor clam growout technology (Years 1 & 2),
5. design a data collection system that will permit comparable data to be collected at each of the growout sites, including biological and economic information, and instruct the industry participants on how to collect and record the required data (Year 1),
6. task the industry participants to collect and relay the required data to the Principal Investigator for compilation and analysis (Years 1 & 2),
7. identify sources and track economic data on razor clam markets within the region through the duration of the project (Years 1 & 2),
8. compile the data for the term of the growout program (Years 1 & 2),
9. analyze the data and project the overall benefits and limitations to the development of the razor clam as an alternate commercial aquaculture species in the northeast region of the US (Year 2),

10. distribute the information throughout the region via the publication of a razor clam culture information bulletin, presentations and/or workshops directed at regional aquaculture associations and other industry venues, distribution of information through the NRAC Regional Extension Project, and presentations at academic symposia (Year 2).

ANTICIPATED BENEFITS: The outcome of this proposal was the development of technologies for culturing an alternate shellfish species and making that technology available to shellfish growers. The industry currently relies on two species of shellfish to keep the industry moving and this places an inordinate amount of risk on the growers. By developing an array of shellfish species available for culture, it will allow individual industry members to diversify their crop and/or to change their crop to adapt to changes in the growing environment or the market.

There are two additional outcomes of this project. The first is we propose to jumpstart development of a commercial-scale hatchery procedure for razor clams. As is always the case, the shellfish growers can't grow a thing without a supply of shellfish seed to start their grow-out. By providing the funding to allow a commercial hatchery to generate juveniles of a new shellfish species while not interfering with their regular shellfish production schedule, this provides a significant benefit to the development of alternate shellfish species.

The second additional outcome of this project is associated with the lines of communication within the shellfish industry. The shellfish aquaculture industry relies to a large extent on "word of mouth" type of communication. The shellfish growers rely less on written materials and more on discussion, observation, and demonstration. Through the connections associated with the NRAC Regional Extension Project and through the efforts of individuals such as Richard Kraus at ARC, the information generated by this project will effectively be distributed throughout the industry. As discussed above, there will be a technical bulletin generated as a result of this study and this bulletin will be available through written and electronic media, but the real value and the real deliverables are contained within the design of the project. By distributing the project across the NRAC region and by locating it within an existing industry member's facility, we are ensuring that the data generated by this project, how different techniques to grow razor clams may be successful or not, will be noted and discussed by the industry. If a grower is successful, you can be sure that the information will be distributed very rapidly across the grower's network via discussions with each other and via discussions between the grower and the regional extension agents. The project design has built into it a means to most effectively communicate these results.

PRINCIPAL ACCOMPLISHMENTS:

Objective 1. arrange with the participating commercial hatchery to spawn and raise 500,000 larval/juvenile razor clams (per year) to a one to two inch size for distribution within the project.

2001 - The Project Coordinator provided broodstock razor clams to the Aquaculture Research Corporation (ARC - a commercial shellfish hatchery in Dennis, MA) in January 2001. The hatchery successfully spawned 4 million razor clam larvae and raised them through metamorphosis to an early juvenile life stage. The seed razor clams were subsequently placed in ARC's upwelling nursery system for further growth under protected conditions. Upon delivery from ARC to the project coordinators, there were approximately 150,000 - 20mm razor clam juveniles surviving. These were distributed to the participating shellfish farmers for growout.

2002 - The Project Coordinator provided broodstock razor clams to ARC and to the Teaching Shellfish Hatchery at Massachusetts Maritime Academy (MMA) in January 2002. ARC successfully spawned and set 4 million razor clam larvae. The MMA Hatchery successfully spawned and set two batches of razor clam larvae, with the first batch consisting of 1 million and second batch being 5-6 million. Unfortunately the success of the first season nursery stage was not reflected in the second. Due to a variety of reasons, including personnel illness in the ARC Hatchery and a *Vibrio* problem in the MMA Hatchery, the first early season spawnings of razor clams were lost in both facilities. Subsequent spawnings occurred too late in the season, where it is suspected that increasing water temperatures lead to realized losses from fouling organisms (such as *Vorticella*-like protozoans and other ciliates). Therefore, the second season supply of seed for the project was not available in 2002, forcing the PI's to extend the second growout trial to next year (Spring 2003).

2003 - The Project Coordinator provided broodstock razor clams to MMA in January 2003. ARC was not able to spawn razors in 2003 because of other commercial commitments. MMA accomplished 3 spawns of razors (8 Jan., 14 Mar., and 29 Apr) of 2, 2-3 and 4-5 millions respectively. The larvae from the second and third spawns were set at MMA and then transferred to nursery facilities at ARC and at the Aquaculture Training Facility in Eastham, MA. As occurred in 2002, the early post-set juveniles that were being held on downwellers in the nurseries were infected with *Vibrio*-like bacteria and marine ciliates to the degree that catastrophic mortalities occurred. A small subset of early post-set razor clams were immediately transferred to small sand trays at the Eastham facility that were held in contained raceways and provided with bag filtered seawater (25μm). This post-set survived, suggesting an alternative technology for nursery rearing razor clams in a contained system. The end result of the third year's attempt to provide razor clam seed to the participating growers was unsuccessful. At this point the project was terminated and excess funds were returned to NRAC for redistribution.

Objective 2. *solicit ideas for technology to achieve razor clam grow-out from an array of commercial shellfish growers in Maine, Massachusetts, Connecticut, New York and New Jersey,*
Introductory presentations were made at the Northeast Aquaculture Conference and Exposition (Portland, ME) and the Milford Aquaculture Seminar (Milford, CT) to inform the shellfish farming industry about the upcoming project and to solicit design concepts for rearing razor clams (Milford abstract and presentation PowerPoint included in Appendix A). A Request for Proposals was distributed to shellfish growers in six northeastern states (ME, MA, RI, CT, NY & NJ) to solicit participants for the project. A copy of the RFP is included under Appendix B.

Objective 3. convene a committee of five individuals to select six shellfish growers (two from ME, two from MA, one from NY and one from NJ) for participation in the project, based on their concepts of razor clam grow-out technology (as solicited by the project).
The razor clam advisory committee, consisting of aquaculture extension agents from each of the six participating states, was convened to select participants from the pool of proposals received in response to the RFP. Eleven shellfish growers initially were selected from five states, with two growers dropping out before the seed was ready. Maine did not participate because there were no applicants from that state. The list of participants selected is included in Appendix C.

Objective 4. supply each of the six selected growers with 150,000 razor clam seed and $2,500 in operating funds (per year) to construct and implement their concept of appropriate razor clam growout technology,
The nine shellfish growers selected each received approximately 15,000 razor clam juveniles in August - September 2001 (actual distribution included in Appendix C). They also contracted to receive a maximum of $3,500 over the two-year project to provide materials and supplies for their participation in the project.

Although razor clam seed were not available for growout during the second year (2002), the funds to the growers were distributed as the participating growers had incurred expenses through constructing culture systems in anticipation of acquiring seed. It was expected that the equipment purchased and constructed in 2002 would be available for the second year attempt in the summer of 2003.

Razor clam seed was not available from the participating hatcheries in 2003 due to catastrophic events, primarily at the early nursery stage of rearing razor clam larvae/juveniles. At this point, the project was terminated due to lack of time to complete the objectives.

Objective 5. design a data collection system that will permit comparable data to be collected at each of the growout sites, including biological and economic information, and instruct the industry participants on how to collect and record the required data,
A data collection system was designed and was distributed to the participants prior to their first data collection event. A copy of the Excel file and instructions are included in Appendix D.

Objective 6. task the industry participants to collect and relay the required data to the Principal Investigator for compilation and analysis,
Data were collected on planting density, growth and survival for the first razor clam cohort distributed to the farmers in 2001. Overall, the data supplied were of good quality in those farms where the proposed technology was capable of holding the juvenile razor clams in an appropriate environment. A summary of the results from each of the farms is included in Appendix D.

Objective 7. identify sources and track economic data on razor clam markets within the region through the duration of the project.
Phone surveys of NY dealers who distributed razor clams were conducted to gauge market interest and price. While our inquiries were met with some resistance by the wholesale institutions, we did manage to compile a small amount of information on the economics of the razor clam market.

Objective 8. compile the data for the term of the growout program,
These data have been compiled and are included in the farm summaries provided in Appendix D.

Objective 9. analyze the data and project the overall benefits and limitations to the development of the razor clam as an alternate commercial aquaculture species in the northeast region of the US.
Overall, our initial attempts to develop the razor clam as a commercially viable species for shellfish culture were of

mixed but positive results. While there were setbacks in the project, primarily at the early post-set stage, it is reasonable to conclude that the development of the razor clam as a viable candidate for culture in the northeast is feasible. Specific details of the project are provided below.

Objective 10. *distribute the information throughout the region via the publication of a razor clam culture information bulletin, presentations and/or workshops directed at regional aquaculture associations and other industry venues, distribution of information through the NRAC Regional Extension Project, and presentations at academic symposia.* Presentations on the NRAC Razor Clam Project were made at:

a. The Northeast Aquaculture Conference and Exposition (Portland, ME 2000)
b. The Milford Aquaculture Seminar (New Haven, CT 2001, 2002)
c. The National Shellfisheries Association (Philadelphia, PA 2005)
d. NRAC Research Workshop (North Dartmouth, MA 2005)

IMPACTS: In concise statements (possibly a bulleted list) indicate how the project has or will benefit the aquaculture industry either directly or indirectly and resulting economic values gained (where appropriate).

At the hatchery level, razor clams can be held and handled in a similar manner to surf clams and other "cold-water bivalves". Spawning, larval culture and setting are straightforward and relatively easy to accomplish. A successful cohort was produced in 2001 but the success could not be repeated in 2002 or 2003; however, the failure was in the early post-set nursery stage rather than at the hatchery stage.

The problem with the nursery culture of razor clams was primarily during the early post-set interval (usually in a downweller) where the juveniles were highly sensitive to microbial infestations (e.g. *Vibrio*-like bacteria and ciliated protozoans.) High diligence to maintain cleanliness within the system will be necessary to rear early post-set razor clams. A very limited trial of rearing early post-set razor clams in a clean sediment tray had some success and suggests a nursery strategy that should be further studied.

If the early post-set mortality could be surmounted (as was the case in 2001), the nursery culture of razor clams was relatively straightforward. The juveniles grow very fast in a nursery situation (overall average daily growth rate of 0.25 mm/day). Upwellers, floating sand trays, and bottom sand trays all proved to be viable technologies for nursery rearing juvenile razor clams. Holding razor clams juveniles in shallow sand trays suspended near the surface supported the best growth and survival of the three technologies, presumably due to the warmer water and higher levels of phytoplankton available in that location. Upwelling of razor clams became less attractive as the clams grew (i.e. growth dropped off), presumably due to the lack of sediment support around the individual clam.

The growth rate of razor clams using aquaculture technology is on a par with (and potentially better than) the growth of wild razors in the North Sea (the only data available on growth of razor clams in their natural or naturalized habitat.) The overall average daily growth rate for clams held in the experimental technologies was 0.097 mm/day. Razor clams will grow through the winter under some conditions.

Discovering suitable growout technology was challenging, due to the razor clam being highly mobile and capable of emigrating from a location *en masse*. Emigration is thought to have occurred at a number of sites where the juvenile razor clams were placed on the bottom and covered with a large-mesh containment net, relative to the size of the juveniles (i.e. conventional quahog growout technology.) Overall, with respect to growout, the more restrictive the containment technology, the higher the probability of holding the juvenile clams in place. However, the finer the mesh, the slower the growth rate; most likely due to the water flow being reduced within a fine-mesh containment net resulting in less oxygen supply and lower food flux within the netted system. The most promising growout technology consisted of a natural sediment raceway confined within a boarded enclosure and covered with a clam net. The success of this system to hold juvenile razor clams suggests that the clams can excavate out from the side of the net to escape and this is prevented through the use of the boarded raceways. In addition, the boarded sides provide extra protection from predators that can enter the containment system through subterranean access (i.e. moon snails, small crabs, etc.)

RECOMMENDED FOLLOW-UP ACTIVITIES: State concisely how future studies may be structured.

Hatchery: Razors can be held and handled in a similar manner to surf clams and other "cold-water bivalves". While research could be completed to optimize the hatchery culture system; overall, hatchery rearing was not a significant problem.

Nursery: The primary deterrent to razor clam culture is seed supply, limited due to problems with early post-set culture. Research is necessary to identify the best nursery practices, including both technology and husbandry, which increases survival during the post-set nursery. Possible studies may include the testing of a sand raceway nursery system and methods to optimize culture in downwelling systems.

Later stage nursery systems tested included upwelling, floating and bottom sand trays, cages, and direct planting. While all technologies that included a discrete containment system were effective, further studies should refine the optimal nursery strategy.

Grow-out: Numerous grow-out strategies were evaluated with results similar to those for the nursery systems. That is, the more secure the containment system the higher the probability of holding the razor clams to market size. However, there appeared to be a trade-off between the ability of the system to allow for water movement and food flux through the system and the degree of containment. Further research could look at the relative role that containment versus food flux plays in the optimal grow-out of razor clams.

SUPPORT: Use the format in the table below to indicate NRAC-USDA funding and additional other support, both federal and non-federal, for the project. Indicate the name of the source(s) of other support as a footnote to the table.

YEAR	NRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
2001	$38,450		$ 6,000[2]		$5,000[3]	$11,000	$49,450
2002	$38,450	$ 2,000[1]	$12,000[2]		$5,000[3]	$19,000	$57,450
2003	$0		$ 5,000[2]			$ 5,000	$ 5,000
TOTAL	$76,900	$ 2,000[1]	$23,000[2]		$10,000[3]	$35,000	$111,900

PUBLICATIONS, MANUSCRIPTS, OR: List under an appendix with the following subheadings: *Publications in Print*; *Manuscripts*; and *Papers Presented*. For the first two subheadings, include journal articles, popular articles, extension materials, videos, technical reports, theses and dissertations, etc. using the format of the Transactions of the American Fisheries Society (example below). Under *Papers Presented* subheading include the authors, title, conference/workshop, location, and date(s).

PUBLICATIONS & MANUSCRIPTS:

Leavitt, D.F., W. Burt and D.C. Murphy. (2000). The feasibility of commercially culturing the razor clam. Abstracts of the Northeast Aquaculture Conference and Exposition, Portland, ME.

Leavitt, D.F. and W. Burt. (2001). The razor clam (*Ensis directus)* as a candidate for culture in the northeast: an introduction. J. Shellf. Res. 20:522.

Leavitt, D.F., W. Burt, D.C. Murphy and R. Hanson. 2002. Progress with culturing the razor clam (*Ensis directus*). J. Shellf. Res. 21:345.

Wadsworth, J., T.S. Getchis and N. Balcom. (2003). Razor clam, *Ensis directus*, growth rates in Niantic River, Connecticut. J. Shellf. Res. 22(1):302.

Leavitt, D. J. Gardner, T. Getchis, D. Grunden, D. Murphy, J. O'Connell, M. Patricio, A. Surier, J. Wadsworth, and W. Burt. 2005. A preliminary investigation of the razor clam (*Ensis directus*) as a candidate for commercial farming. J. Shellfish Res. 24:663.

One or two manuscripts are currently being considered for publication, either in the Journal of Shellfish Research or as Technical Bulletins for publication through the NRAC Regional Extension Program.

PAPERS PRESENTED:

Leavitt, D.F., W. Burt and D.C. Murphy. The feasibility of commercially culturing the razor clam. 2000 Northeast Aquaculture Conference and Exposition, Portland, ME.

Leavitt, D.F. and W. Burt. The razor clam (*Ensis directus)* as a candidate for culture in the northeast: an introduction. 2000 Milford Aquaculture Seminar, Milford, CT.

Leavitt, D.F., W. Burt, D.C. Murphy and R. Hanson. Progress with culturing the razor clam (*Ensis directus*). 2001 Milford Aquaculture Seminar, Milford, CT.

Wadsworth, J., T.S. Getchis and N. Balcom. Razor clam, *Ensis directus*, growth rates in Niantic River, Connecticut. 2002 Milford Aquaculture Seminar, Milford, CT.

Leavitt, D. and W. Burt. Razor clams: they're not just for shaving anymore! Final research summary presented at the 2005 NRAC Annual Meeting, North Dartmouth, MA.

Leavitt, D. J. Gardner, T. Getchis, D. Grunden, D. Murphy, J. O'Connell, M. Patricio, A. Surier, J. Wadsworth, and W. Burt. A preliminary investigation of the razor clam (*Ensis directus*) as a candidate for commercial farming. 2004 Annual Meeting of the National Shellfisheries Association, Philadelphia, PA.

PART II

TECHNICAL ANALYSIS AND SUMMARY: Describe the work undertaken and results obtained for each objective. Major results should be presented in detail, including graphs, charts, figures, photomicrographs or other presentations. Methodology should be briefly described and statistical analyses and significance should be included where appropriate. This section of the report should be written with style similar to scientific publication. Reports previously or currently prepared for publication may be submitted as part of this section.

Objective 1. arrange with the participating commercial hatchery to spawn and raise 500,000 larval/juvenile razor clams (per year) to a one to two inch size for distribution within the project.
2001 - The Project Coordinator provided broodstock razor clams to the Aquaculture Research Corporation (ARC - a commercial shellfish hatchery in Dennis, MA) in January 2001. The hatchery successfully spawned 4 million razor clam larvae and raised them through metamorphosis to an early juvenile life stage. The seed razor clams were subsequently placed in ARC's upwelling nursery system for further growth under protected conditions. Upon delivery from ARC to the project coordinators, there were approximately 150,000 - 20mm razor clam juveniles surviving. These were distributed to the participating shellfish farmers for grow-out.

Further attempts to rear razor clam seed in Years 2 & 3 proved to be futile as mortalities occurred during the early post-set stage. The early post-set juveniles that were being held on downwellers in the nurseries were infected with *Vibrio*-like bacteria and marine ciliates to the degree that catastrophic mortalities occurred. A small subset of early post-set razor clams were immediately transferred to small sand trays (at the Aquaculture Training Facility in Eastham, MA) that were held in contained raceways and provided with bag filtered seawater (25μm). These post-set survived, suggesting an alternative technology for nursery rearing razor clams in a contained system.

Objective 2. solicit ideas for technology to achieve razor clam grow-out from an array of commercial shellfish growers in Maine, Massachusetts, Connecticut, New York and New Jersey,
Introductory presentations were made at the Northeast Aquaculture Conference and Exposition (Portland, ME) and the Milford Aquaculture Seminar (Milford, CT) to inform the shellfish farming industry about the upcoming project and to solicit design concepts for rearing razor clams (Milford abstract and presentation PowerPoint included in Appendix A). A Request for Proposals was distributed to shellfish growers in six northeastern states (ME, MA, RI, CT, NY & NJ) to solicit participants for the project (Appendix B.)

Objective 3. convene a committee of five individuals to select six shellfish growers (two from ME, two from MA, one from NY and one from NJ) for participation in the project, based on their concepts of razor clam grow-out technology (as solicited by the project).
The razor clam advisory committee was convened to select participants from the pool of proposals received in response to the RFP. Eleven shellfish growers initially were selected from five states, with two growers dropping out before the seed was ready. The list of participants selected is included in Appendix C.

Objective 4. supply each of the six selected growers with 150,000 razor clam seed and $2,500 in operating funds (per year) to construct and implement their concept of appropriate razor clam grow-out technology,
The nine shellfish growers selected each received approximately 15,000 - 20 mm razor clam juveniles in August - September 2001 (actual distribution included in Appendix C).

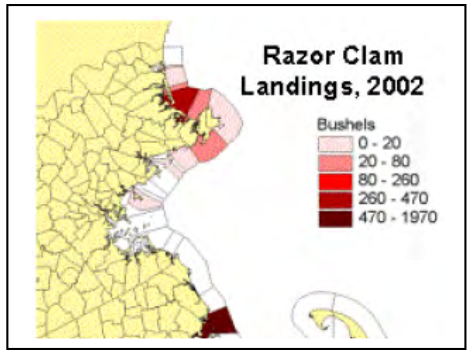
Objective 5. design a data collection system that will permit comparable data to be collected at each of the grow-out sites, including biological and economic information, and instruct the industry participants on how to collect and record the required data,
A data collection system was designed and was distributed to the participants prior to their first data collection event. A copy of the Excel file and instructions are included in Appendix D.

Objective 6. task the industry participants to collect and relay the required data to the Principal Investigator for compilation and analysis,

Data were collected on planting density, growth and survival for the first razor clam cohort distributed to the farmers in 2001. Overall, the data supplied were of good quality in those farms where the proposed technology was capable of holding the juvenile razor clams in an appropriate environment. A summary of the results from each of the farms is included in Appendix E.

Objective 7. identify sources and track economic data on razor clam markets within the region through the duration of the project.

Razor clam landings are not routinely reported for most states in the northeast. When compiled, the levels are relatively small, as is demonstrated in the graphic generated by MA Coastal Zone Management for analysis of their ocean management plan (Figure 1.) The highest landing in any one region of the MA coast was only 1,970 bushels per year. Therefore, it can be estimated that landings are very small when compared to the two primary farmed species, hard clams and oysters.



Phone surveys of NY dealers who distributed razor clams were conducted to gauge market interest and price. While our inquiries were met with some resistance by the wholesale institutions, we did manage to compile a small amount of information on the economics of the razor clam market.

The original markets for razor clams (through the 1970s) were two-fold, initially for canning shucked razor clam meats followed by demand for razor clams when soft shell clams for frying were not available (personal communication – J. Michael Hickey, MA DMF.) During that time, there was a small market for live razors, primarily to the Italian ethnic communities in New Jersey (personal communication from a Montauk fish buyer.) The live market has expanded in recent years due to an expanding market in the Asian ethnic communities (personal communication from a Montauk fish buyer.) During the winter of 2003-2004, razor clam landed value reached $2.00 per pound in the Fulton Fish Market (personal communication from a Fulton Fish Market shellfish dealer.) Since that time, the landed value for live razor clams is estimated to be approximately $1.50 per pound, although this value is very difficult to document.

Market potential for razor clams is estimated to be strong. In discussions with dealers at the Fulton Fish market, dealers indicated they could move 1,000 pounds per day but would not attempt to expand the market because the availability of razor clams was so variable. The size requested by these dealers was approximately a 4" (100 mm) individual clam for the live market. The shucked market required a larger clam (6" or 150 mm).

Objective 8. compile the data for the term of the grow-out program.

These data have been compiled and are included in the individual farm summaries provided in Appendix E. A summary of the collected data follows:

The culture of the razor clam has been separated into two phases for the sake of the data analysis, i.e. the nursery (Year 0) and grow-out (Years 1-2) phases.

Nursery: The capacity of a variety of different nursery technologies is summarized in the graph that follows (Figure 2). The best performance (top 4 growth curves) was observed in Sengecontacket Pond in Martha's Vineyard using sediment filled bottom trays.

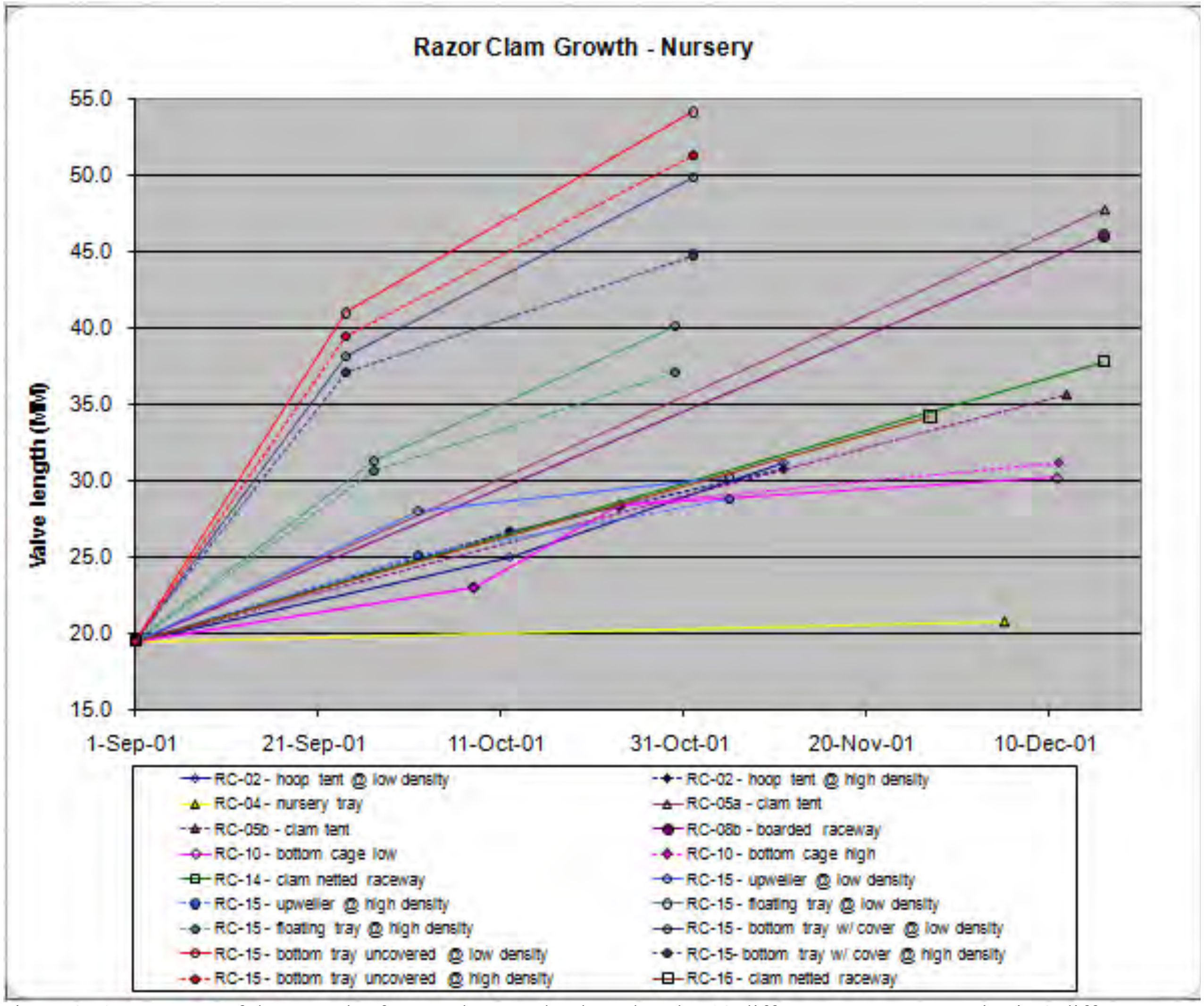


Figure 2: A summary of the growth of razor clam seed cultured under 18 different nursery strategies in 8 different geographical areas.

Overall, the starting length of the razor clam seed was 19.5 (±2.2 – standard deviation) mm and the average final length was 37.8 (±9.3) mm, with a range 20.7 to 54.1 mm (n=18). This represents an average daily gain of 0.252 (±0.158) mm/d.

Grow-out: In most cases, the razor clam juveniles were moved from the nursery phase to the grow-out phase during the fall of Year 0. Therefore, the grow-out phase growth was monitored starting in the spring of Year 1 and onward. Regardless of the starting size, by the end of Year 1, most grow out strategies resulted in animals at approximately the same size (Figure 3), with the exception of those clams held in the bottom sediment filled trays on Martha's Vineyard. The average length at the end of Year 1 was 67.1 (±8.9) mm (range 59.9 to 86.1 mm) representing an average daily gain during Year 1 of 0.097 (±0.023) mm/d.

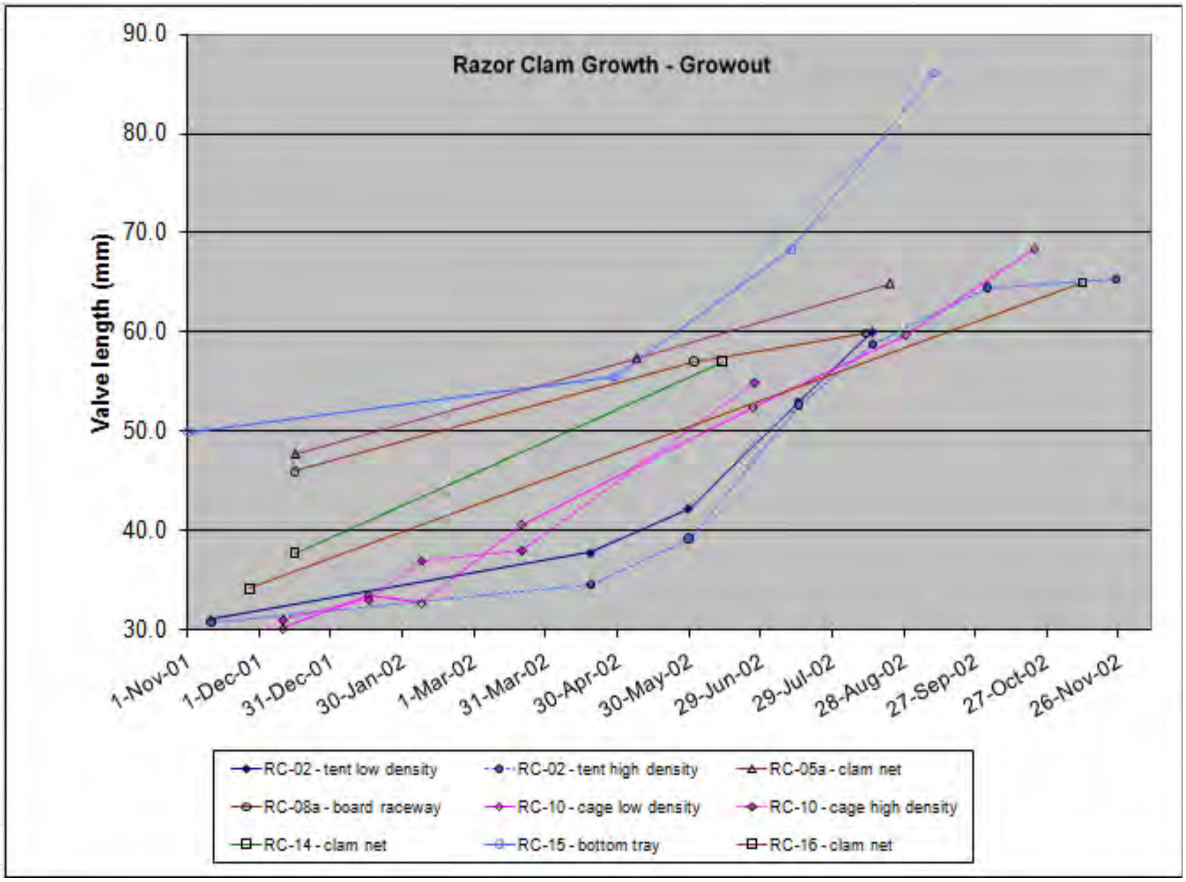


Figure 3: A summary of the growth of razor clam seed cultured under 18 different grow-out strategies in 8 different geographical areas.

Planting Technology: A few important observations on razor clam nursery and grow-out technology can be deduced from this study. The first is that razor clams are highly mobile and will evacuate an area if conditions are not appropriate for the species. In numerous cases during this study, entire plantings of razor clams were lost in very short periods of time (weeks) due to emigration away from the culture site. Therefore, any technology used for growing razor clams must provide a means to contain the seed in the planted area. Otherwise, the seed will use its various forms of mobility, including swimming and digging, to escape from the growing area.

The second observation suggests that razor clams perform better when held in sediment during the nursery and grow-out phases. That is assuming the sediment is of a type that is acceptable for the razor clam. For example, in one case, razor clam seed were not performing well in an upweller so the seed were relayed to a sediment filled raceway. However, the sediment was"sharp" sand provided for building construction purposes rather than a "washed" sand normally found in aquatic situations. For one month following introducing the razor clam seed into the raceway, the juveniles sat at the surface of the sediment and would not burrow into the substrate, although they routinely probed the sediment with their foot as a precursor to digging in. We concluded that the sharp sand was not acceptable to the juveniles and they would not burrow in because of that condition.

Planting Density: Because the growing strategy was left up to the individual growers, we observed a wide range of planting densities (range of 222/m^2 to 2,500/m^2). When planted under net tents in New York at densities of 1,000 & 2,500/m^2, no differences were noted in the rate of growth in the juvenile razor clams. However, in Martha's Vineyard, low density plantings (587/m^2) consistently performed a little better than comparable high density (1,760/m^2) plantings. While more work is needed, there may be a growth advantage if seed are planted at densities of less than 1,000/m^2.

Planting location: in all cases where the razor clam seed were placed in the intertidal area, in locations deemed suitable for quahogs, we observed extensive mortalities during the second and third years of grow-out. It was assumed that the mortality was attributable to high sediment temperatures, as all mortality events occurred during the months of August and into early September. The summer of 2002 was an exceptionally hot summer and one of our growers lost a whole cohort of soft shell clams in the same region at the same time, again thought to be because of temperature.

Objective 9. analyze the data and project the overall benefits and limitations to the development of the razor clam as an alternate commercial aquaculture species in the northeast region of the US.
Overall, our initial attempts to develop the razor clam as a commercially viable species for shellfish culture were of mixed but positive results. While there were setbacks in the project, primarily at the early post-set stage, it is reasonable to conclude that the development of the razor clam as a viable candidate for culture in the northeast is feasible.

Objective 10. distribute the information throughout the region via the publication of a razor clam culture information bulletin, presentations and/or workshops directed at regional aquaculture associations and other industry venues, distribution of information through the NRAC Regional Extension Project, and presentations at academic symposia.
Presentations on the NRAC Razor Clam Project were made at:

a. The Northeast Aquaculture Conference and Exposition (Portland, ME 2000)
b. The Milford Aquaculture Seminar (New Haven, CT 2001, 2002)
c. The National Shellfisheries Association (Philadelphia, PA 2005)
d. NRAC Research Workshop (North Dartmouth, MA 2005)

It is planned that this research will provide 2 NRAC Technical Bulletins, one covering razor clam biology and the second reporting the results of this study. A draft of the first bulletin is attached in Appendix G. The second is forthcoming in the winter of 2010-2011.

TERMINATION REPORT

SIGNATURE PAGE

PROJECT CODE: 00-5 **SUBCONTRACT/ACCOUNT NO:** 556705/556510

PROJECT TITLE: An industry directed feasibility study of the razor clam (*Ensis directus*) as a candidate for intertidal and shallow subtidal culture in the northeastern U.S.

PREPARED BY: Dale F. Leavitt for William Burt

______________________________________ 19 September 2010 ______

Project Coordinator or PI Date

Appendix A: Milford Aquaculture Seminar abstract and PowerPoint used to solicit shellfish farmers for participation in the razor clam project (2001).

The razor clam (*Ensis directus*) as a candidate for culture in the northeast: an introduction.

Dale Leavitt & William Burt
SouthEastern Massachusetts Aquaculture Center
Hurley Library – Mass. Maritime Academy
Buzzards Bay, MA 02532

There is an urgent need for the shellfish culture industry in the northeastern United States to expand their list of candidate species for culture and to diversify their crop. Reliance on two species of bivalve mollusk, given the historic and current prevalence of debilitating diseases, may result in lost opportunities to use sites for farming shellfish. By expanding the selection of candidate species, a grower will have better success in conducting their business by providing alternate crops that may be appropriate for their specific grow-out situation.

The razor clam represents one candidate species that has a high potential for commercialization. Market demand for the razor clam seems to be constant and can be expanded given the relative lack of awareness on the part of consumers regarding the acceptability of the product. Landed value is currently at a level that makes farming the razor clam economically attractive. The constraints at this point are focused on developing the appropriate technology for growing the razor clam to a market size.

The razor clam exhibits biological properties that suggest it is a reasonable candidate for culture. It undergoes a routine bivalve larval cycle that should adapt to hatchery conditions readily. It grows relatively quickly and has been successfully cultured as a by-product under quahog anti-predator netting, due to wild recruitment onto the site. It naturally inhabits intertidal and subtidal areas that are currently being used for quahog culture.

Yet the razor clam will present some challenges to develop it as a commercially viable farmed bivalve. These include

1. Mobility
2. Over-winter survival
3. Predators & disease
4. Shelf-life
5. Overall lack of knowledge about the species.

To aid in diversifying the industry, the Northeast Regional Aquaculture Center (NRAC) has funded us to begin work on developing technology for razor clam grow-out. The overall objective of this project is to provide an opportunity for the current shellfish culture industry to investigate, develop, and optimize the growout technology for a cultured razor clam. An overview of the projected work and a solicitation for industry involvement is included in this presentation.

~ Razor Clams ~
they're not just for shaving anymore!

Dale Leavitt & William Burt
(SouthEastern MA Aquaculture Ctr.)
with
Gef Flimlin
(New Jersey Cooperative Ext)
Dana Morse
(ME Sea Grant Program)
Gregg Rivara
(Cornell Cooperative Ext.)

Why are we interested in diversifying local shellfish culture opportunities?

- Oyster and quahog are the big TWO in northeast!
- What happens to your business if you should lose a crop due to disease or some other uncontrollable environmental change?
- What other options do we have?
  - Soft shell clam
  - Bay scallop
  - Surf clam
  - European oyster

But....

The more options we develop – the more opportunities we create to maintain a viable business and to make a living!

Razor clam fishery

- Small scale fishery on-going in MA.
- Harvesting methods
  - Spearing
  - Dry digging
  - Pumping
  - Method of choice for harvesting is "salting"
- Landed value has approached $2.00/lb live wt.
- At its best, that translates to about $0.40 per piece.

What about farming them?

Need to consider - biology:

- Preferred habitat
- Population characteristics
- Food
- Growth
- Predation & Disease
- Behavior

Razor Clam habitat

- fine to medium sand – can be muddy sand if without silt

Razor Clam habitat

- fine to medium sand – can be muddy sand if without silt
- low intertidal to subtidal

Razor Clam habitat

- fine to medium sand – can be muddy sand if without silt
- low intertidal to subtidal
- can live in unstable sand and tolerate dynamic areas

Razor Clam habitat

- fine to medium sand – can be muddy sand if without silt
- low intertidal to subtidal
- can live in unstable sand and tolerate dynamic areas
- Prefers areas with moderate water flow

Population characteristics

Stocking densities:

- Luczak *et al* (1993) observed recruitment of 30,000ind/m² that dropped to 10,000 within two weeks
- densities of juveniles recorded at 2,000/m² in Chesapeake Bay
- low over-winter survival
- Final density of 4-6/m²

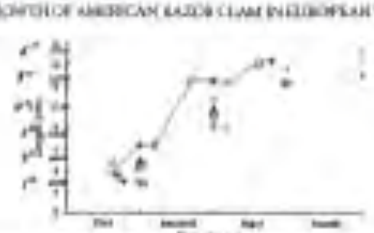
Food & Growth

- Suspension feeder and doesn't seem to feed on detritus

Food & Growth

- Suspension feeder and doesn't seem to feed on detritus
- Growth – data derived from studies in the North Sea

GROWTH OF AMERICAN RAZOR CLAM IN EUROPEAN WATERS



Food & Growth

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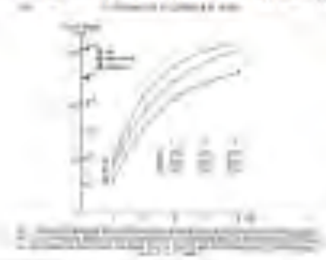

Predation

- There are a number of common bivalve predators that will eat razor clams if given the opportunity, including:

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Predation

- There are a number of common bivalve predators that will eat razor clams if given the opportunity, including:

Disease

No observed diseases in western Atlantic, but…

- West coast razor clam (*Siliqua spp.*) populations devastated by NIX
- In Holland in 1994, researchers observed a large crash of the *Ensis* population without an explanation, no pathology done!

Behavior

Razor clams are very unique bivalves with respect to their mobility.

Behavior

Razor clams are very unique bivalves with respect to their mobility.

- They dig!

Behavior

Razor clams are very unique bivalves with respect to their mobility.

- They dig
- They move on the surface!

Behavior

Razor clams are very unique bivalves with respect to their mobility.

- They dig
- They move on the surface
- They swim!

What about farming them?

First consideration – the market:

- Demand for wild product has been steady but low
- One New York buyer said he can move 1,200 lbs daily
- But, he needs consistent supply to develop market
- I identified six buyers between Cape Cod and New York in a phone survey
- Two markets identified
  - Live market
  - Processor market

What about farming them?

Live market (Fulton Fish Market):

- Formerly (Hoboken) Italian
- Now primarily (New York) Asian
- Product must be high quality – i.e. not sluggish (winter)
- Size acceptability
  - Buyer 1 - minimum 3 inches; not the largest
  - Buyer 2 – minimum 6 inches; only the largest

What about farming them?

Processor market:

- Grind clam for processed product
- Processors prefer largest sizes
- Couldn't find anyone to discuss this market – does it exist now?

Idiosyncrasies & culture considerations

Need to consider:

- **Lack of knowledge about species** – from basic biology to culture technology
- **Mobility** – have to contain clam from escaping via digging, crawling, and swimming
- **Predators/disease** – protection & prevention
- **Over-wintering mortality** – may be a function of tidal exposure
- **Poor shelf-life** – can they survive up to a week out of sediment?

Northeast Regional Aquaculture Center
Industry development of culture practices for the razor clam

The objectives of the project are:

- Contract with a commercial hatchery to produce 500,000 juvenile (5mm) razor clams
- Solicit proposals from the shellfish culture industry to develop techniques for razor clam culture (ME, MA, RI, NY & NJ)
- Provide selected growers with seed razor clams to experimentally culture
- Provide selected growers with funds to construct/develop their proposed culture technology
- Track the razor clam market and provide economic evaluation of culture techniques tested

Northeast Regional Aquaculture Center
Industry development of culture practices for the razor clam

Proposed timeline for the project is:

- 1 March – a request for proposals will be released
- 23 March – Proposals must be postmarked by 5:00PM
- 2 April – Participating growers selected
- 16 April – Contracts completed and funds released
- mid-May – razor clam seed arrives from hatchery

Appendix B: A copy of the Solicitation for Participants that was distributed throughout six northeastern states (ME, MA, RI, CT, NY & NJ).

Request for shellfish farming industry partners in Maine, Massachusetts, Rhode Island, Connecticut, New York, and New Jersey

Feasibility study for growing the razor clam (*Ensis directus*) as a commercial crop

Funded by the Northeast Regional Aquaculture Center
University of Massachusetts - Dartmouth

Objective:

To provide an opportunity for the current shellfish culture industry to investigate, develop and optimize the growout technology for a farmed razor clam. Five to eight growers will be selected to apply their idea of a best technology for growing the razor clam in a contained field culture system. The growers will be provided razor clam seed (app. 10mm in length) and materials/construction funds for two years to implement their plans for rearing the clam.

Why the razor clam?

The current shellfish farming industry in the northeastern United States is limited to two primary shellfish species for culture, the American oyster and the quahog or hard clam. In an effort to expand the mollusk candidates available to the industry, we propose to work with the shellfish farming industry to develop the razor clam into a commercially viable enterprise.

The razor clam is a little understood mollusk. Massachusetts' growers have caught wild set under their clam predator nets and they have remained in place. Early research suggests that it grows rapidly while its range covers the northeastern U.S. area targeted in this project. A market exists for razor clams in the New York area and it has a large potential for expansion as the consumer's awareness is developed.

In addition to the common shellfish culture practices of containment and protection from predators, the razor clam offers some unique challenges with respect to growing it in the field. Some of the limitations that may come into play in this project are the fact that the razor clam is a highly mobile species. It can dig and bury in sediment at a rapid rate and has been observed digging through a complete arch to emerge from the sediment in reverse to avoid predators. In addition it is highly mobile at the sediment surface where its movements range from pushing itself along with its foot to jumping into the water column and culminates in its ability to swim in a manner similar to the scallop. Any field culture system will have to accommodate for these behaviors.

Further information on the razor clam can be solicited from Dale Leavitt – Aquaculture Specialist for SEMAC at (508) 830-6478.

Who is eligible to participate?

This project is open to any currently permitted/licensed shellfish farmer in the states of Maine, Massachusetts, Rhode Island, Connecticut, New York and New Jersey.

Where can I do it?

The project will be undertaken at each participating grower's culture site and managed as a component of their usual farming practice. Permitting for transport of the razor clams into the participating state will be arranged by the project advisors.

How to become a participant:

To apply for inclusion in this program, any licensed shellfish grower in the states listed above may submit a short letter (maximum - two pages) requesting to participate. This letter should focus on an explanation of the technology they propose to use to grow the razor clam from 10mm seed to a targeted market size of 4-5 inches. Diagrams of the proposed technology should be included if necessary to adequately describe the growout system. Because this species has not been grown commercially in the past, the technology proposed can range from a conventional shellfish field containment system to a custom designed system directly developed for the razor clam. It is anticipated that each participant will receive between 50,000 and 100,000 razor clam seed as a participant in this program.

Each applicant must include a short description of their background in commercially growing shellfish and a copy of their current aquaculture permit. The applicant should also include a simple budget outlining the funds requested to construct and deploy the system they are proposing. Funding of up to $3,000 per grower per year will be available, depending on the final number of growers participating in the program.

Following a review of all proposals, participants will be selected from the applicant pool by a team of project advisors. Projects will be selected based on the technology proposed and the experience of the industry partner. The project advisors will also provide continued oversight of the research program within their region.

Timeline:

1 March 2001	Request for participants released
23 March 2001	Proposals must be received or postmarked by 5:00PM
2 April 2001	Participants selected
16 April 2001	Contracts signed and funds released to participants
mid-May 2001	Razor clam seed available from hatchery

Submit Proposals to:

SouthEastern Massachusetts Aquaculture Center
Hurley Library - Mass. Maritime Academy
101 Academy Drive
Buzzards Bay, MA 02532

Questions?

Contact: Dale Leavitt
office: (508) 830-6478
pager: (508) 899-5910

Appendix C: Listing of the participants selected to grow experimental razor clam seed and the technology that they proposed to use.

NRAC Razor Clam Project								
Participants								
								2,001
Proposal	**PI Name**		**Company Name**	**Street**	**Town**	**State**	**Technique summary**	**app. number seed**
Number	**Last**	**First**						
declined	Rose	James	Rose's Oyster Bar	70 Rose Lane	Wellfleet	MA	clam netted raceway	15,000
RC-02	Patricio	Michael	Cornell Cooperative Extension - Suffolk Cnty	3690 Cedar Beach Road	Southold	NY	hoop tent	15,000
RC-04	Maxwell	John	Atlantic City Aquaculture, Inc.	358 Cologne-Port Road	Germania	NJ	nursery box & netted raceway	15,000
RC-05a	Hemmila	Les	Barnstable Sea Farm	PO Box 321	Cummaquid	MA	clam tent	7,500
RC-05b	Syriala	Carl	Finn Farms	951 Oak Street	West Barnstable	MA	boarded raceway	7,500
declined	Ruml	Wentzle	Wellfleet Sea Farms	PO Box 445	South Wellfleet	MA	nursery box & netted raceway	7,500
RC-08b	O'Connell	James		25 Bellamy Lane	Wellfleet	MA	boarded raceway	7,500
RC-10	Wadsworth	John	Niantic Shellfish, L.L.C.	15 First Street	Waterford	CT	wire cage	15,000
RC-14	Zivan	Mark	Nauset Sea Farms	6 Viking Road	South Orleans	MA	clam netted raceway	15,000
RC-15	Karney	Richard	Martha's Vineyard Shellfish Group	Box 1552	Oak Bluffs	MA	upweller, floating and bottom trays	15,000
RC-16	Gardner	Jeffrey	Shellfish 4 U	227 Shore Road	Westerly	RI	clam netted raceway	15,000
							TOTALS	135,000

Appendix D: The data collection sheet and instructions to growers that were supplied to each participant for collecting data on razor clam productivity.

RAZOR CLAM SAMPLING- November/December 2001

1. Please provide more details on the technology you are using to grow razor clams. If you are using more than one technique, please describe all techniques you are employing.

2. We need the following data from you: size, density and survival. If you are employing more than one technique to grow the clams, please gather data from each of the different methods and manipulations you are using.

3. Randomly sample in each grow area. Using a 6 or 8 inch core tube (please specify size), extract all animals to a depth of six inches. Remove the core tube by digging around it. Sieve samples using a 2mm sieve to remove sediment. Repeat cores until about 50 animals have been extracted. Record the number of cores taken and exact number of animals present. Animals should be separated into ALIVE (valve are stuck shut) and DEAD (number of single valves divided by two).

4. Select 25 live individuals for size measurements. To ensure that this is a random process, take the pile of 50 and split it in half. The remaining animals (not used for measurements) can be returned to core hole.

5. Using calipers, measure the length of each animal (along the longest axis). If possible, also measure the width (we don't think we'll need this measurement, but it could be useful in the future). Measurements should be done in millimeters.

6. Save measured animals in a Ziploc freezer bag. Store in your freezer until we figure out some way to get them to SEMAC. Label the bags outside and inside (on a scrap of paper) with the location, technology name (if you are using more than one) your name, and the date.

7. If you have any questions please contact the SEMAC office- (508) 830-6478 or Rebecca Hanson at (508) 432-4015 or rebeccakhanson@yahoo.com. Data can be emailed or mailed to:

    SEMAC
    c/o Hurley Library
    MA Maritime Academy
    101 Academy Drive
    Buzzards Bay, MA 02532

8. The included data sheet can be used as a template, or printed out and used in the field.

9. Thank you and good luck!!! I will be contacting you in the next few weeks.

November/December Razor Clam Sampling Data Sheet
Name:
Date:
Location/Site ID:
Technology Used:
Description of Technology (please attach additional information as needed):
Original Planting Density:
Size of Core (please include units):
Number of Cores Taken:
Number of Alive Animals in Cores:
Number of Dead Animals in Cores (Number of Valves/2):

Invididual	Length (mm)	Width (mm)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
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25		

Appendix E: Summary of results from the participating growers.

Razor Clam Project

Results Summary

RC-02- Southold, NY

Location: Southold, NY

Investigator: Mike Patricio
Suffolk County Marine Environmental Learning Center
3690 Cedar Beach Road
Southold, NY 11971

Technology: Framed clam tents using PVC pipe frame and fly screen mesh over substrate. Shallow subtidal.

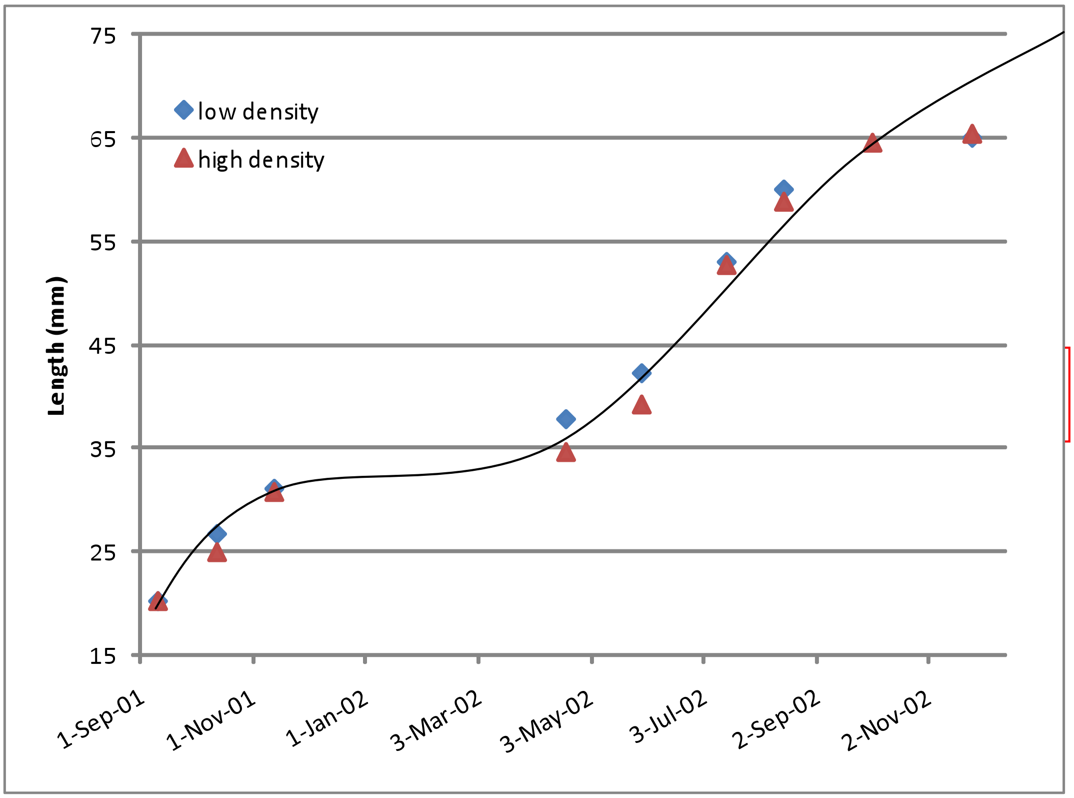
Timeline:

10 Sept 2001: received 15,000 razor clam seed (avg. length 20.2mm $\underline{+}$1.6) and planted then under the clam tents at two densities (1,000 & 2,500/m^2).
12 Oct 2001: measured size (ET 32 days)
12 Nov 2001: measured size (ET 63 days)
19 Apr 2002: measure size (ET 221 days)

30 May 2002: measured size (ET 262 days)
15 July 2002: measured size (ET 308 days)
15 Aug 2002: measured size (ET 339 days)
2 Oct 2002: measured size (ET 387 days)
25 Nov 2002: measured size (ET 441 days)

Results:
2 Oct 2002: All razors in 1,000/m^2 died and few are left in 2,250/m^2

Growth: rate of growth was strong through until July/Aug of 2002 when there was a severe mortality event, probably associated with elevated temperatures in the shallow subtidal area where the clams were placed. If the population had survived, the projected growth, based on the observed growth between April and October, after the second summer would be in the vicinity of 75mm (3") in length.



Survival: was poor for the low density tent during the early summer (May) of the second year. The higher density tent had significant mortality later in the season (around August) average size at death during the later summer of 2002 was 51.5 mm, corresponding to the avg. clam size on 13 July. The mortality was most likely dependent on the high summer water temperatures that occurred during the summer of 2002.

Planting Density: Initial planting densities were 1,000 and 2,500 individuals/m^2. There did not seem to be any effect on planting density within these limits on growth. However, real field densities were not measured during these experiments.

Razor Clam Project
Results Summary

RC-04 - Egg Harbor City, NJ

Investigator: John Maxwell
Atlantic City Aquaculture, Inc.
358 Cologne-Port Road
Germania, NJ

Technology: Nursery Box followed by
14' X 10' area covered by 1/4" mesh net. Intertidal?

Timeline:

12 Sept 2001: received 7,500 razor clam seed (avg. length 20.7mm $\pm$2.5) and planted them in nursery box. Seed razors arrived to him in poor shape, they were inactive. He put them into a nursery system. Initial density was 562/m^2 (7,500 under 14'x10' net.)

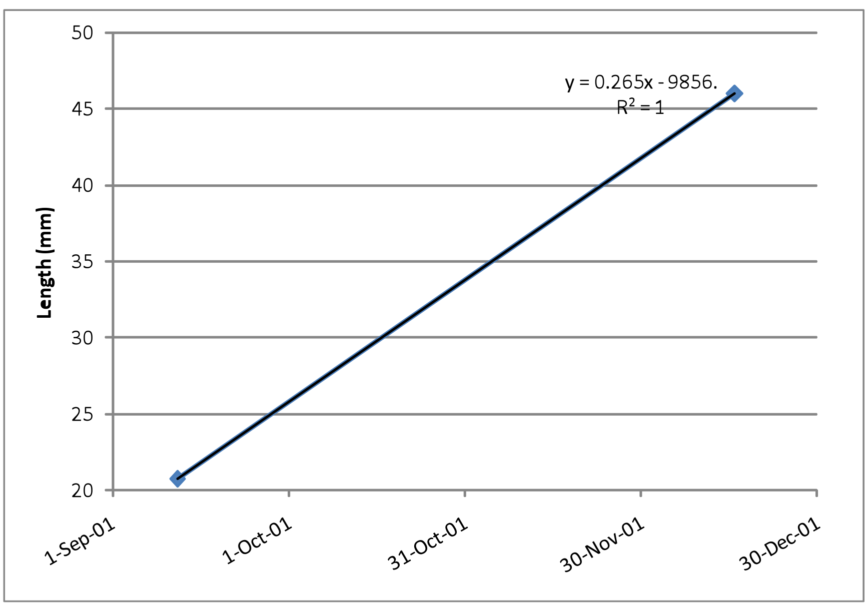
late Nov 2001: It took him a long time to find any alive. Nothing was found during the first sampling time. It took at couple of trips to complete the sample. Sample density was 38.5/m^2 (93.1% loss). He put the live ones into a growout plot.

16 Dec 2001: Clam sampling. Average size = 46.0mm (this length from 16 Dec 01 sampling)

9 Sept 2002: contacted grower, they were all dead. They had not grown much.

Results:

9 Sept 2002: clams arrived - very inactive and in poor shape. Put them in nursery. Nov 2001 took him a long time to find any live clams - grew a little. Put them in flat. (Rebecca has data) All died, arrival time too late in season



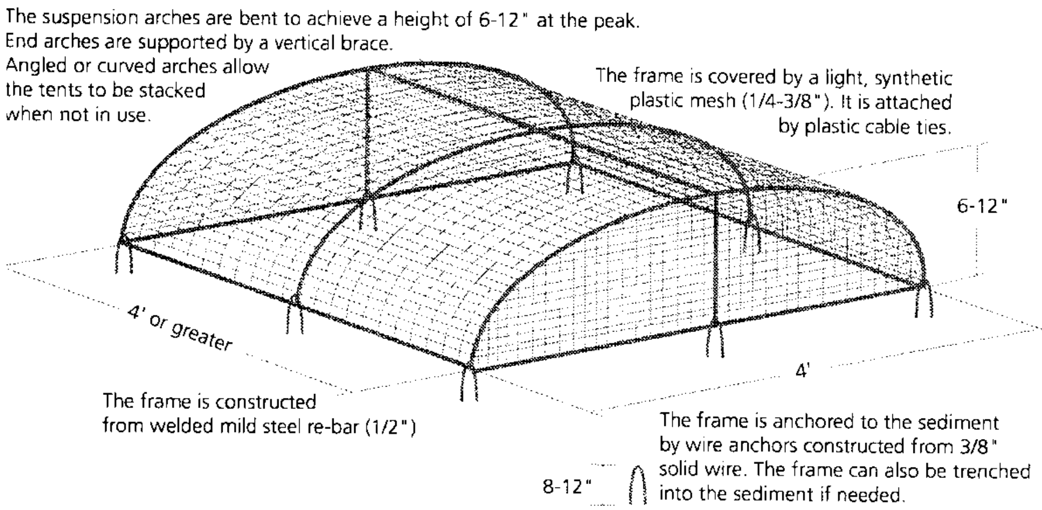
Razor Clam Project

Results Summary

RC-05 – Barnstable Harbor, MA

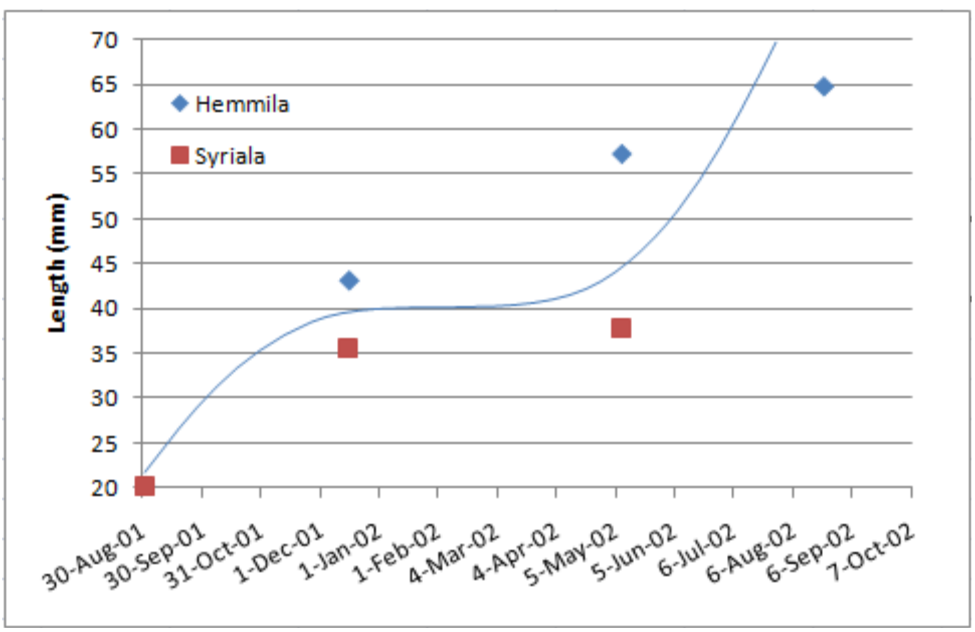
Investigators: see following pages

Technology: Clam tents, as used for capturing wild soft shell clam set. Approximately like picture.
Intertidal.



Results: (Summarized for both sites)

Growth: Actual growth in graph below. ADG for growing periods = 0.145 mm/day



Survival: Both sites had significant mortality during the summer of the second year. Syriala site had no razors by 22 Aug 2002 (although some could have been via emigration). Syriala also had catastrophic mortality of intertidal soft shell clams during same time interval. Hemmila had mortality in mid-summer (before Aug 2002) based on size of mort shells (57.6 mm).

Density: Syriala – $222/m^2$
Hemmila – $414/m^2$

No issues with planting density.

Site specifics follow:

Razor Clam Project

Results Summary

RC-05a – Barnstable Harbor, MA

Investigator: Les Hemmila
Barnstable Sea Farms
PO Box 321
Cummaquid, MA

Technology: Clam Tent - 13'x15' tented net held down by sandbags. Intertidal.

Timeline:

31 Aug 2001: Received 7,500 clams and planted under net.
16 Dec 2001: Measured clams
8 May 2002: Measured clams
22 Aug 2002: Measured clams

Results:

31 Aug 2001: 13'x15' net. Net is tented above sediment. Sandbags hold down the net. Planted at initial density of 414/m^2.

16 Dec 2001: Tide was too high when we were out due to windy conditions. Water was about knee high during sampling period. Samples were obtained by taking an estimated volume of sediment with a spade. There are naturally occurring razor clams in area. Smallest clam could in fact be seed. Sediment was sandy. Density is only a rough estimate (1.08-2.70/m^2).

8 May 2002: Clams seem to be concentrated on edges. They appear to dig holes to use later for escape. Therefore they can escape the cove. They move too quickly for capture. Clams were gathered using a rake. Thus, no density measurements were collected.

22 Aug 2002: at least 2/3 of his 12x 7 ft flat dug up to get this amount (Sample size 19 alive, 6 dead).

Razor Clam Project

Results Summary

RC-05b – Barnstable Harbor, MA

Investigator: Carl Syriala
951 Oak Street
West Barnstable, MA

Technology: Tented net, held by rebar staples. Intertidal.

Timeline:

31 Aug 2001: Received 7,500 clams and planted under net.
12 Dec 2001: Measured clams
24 Apr 2002: Measured clams
22 Aug 2002: Dug 2'x6'x8" and no live no dead razors. His flat is exposed at least 1.5 hr on regular tide and over 2 hrs on high tides. Razors ran away!

Results:

31 Aug 2001: 14'x26' net. Net is tented above sediment. Rebar staples hold down the net. Planted at initial density of $222/m^2$.

12 Dec 2001: Sediment - thick gooey sticky silt covering sand. No evidence of dead shell from planting. Sediment too thick for core, dug a set area with a pitchfork. Density measurements a rough estimate.

24 Apr 2002: Sediment- Mud on dry sand. Dug clams with rake. No density measurements taken.

22 Aug 2002: area sampled was 6' long 2' wide and 8"deep, **No razors!** the flat is high & regularly exposed - 1.5 on an average tide. All of Carl's soft shell clams are dead from heat wave. Quahogs and oysters are doing OK.

Razor Clam Project

Results Summary

RC-08a – Wellfleet Harbor, MA

Investigator: Wentzle Ruml
Wellfleet Sea Farms
PO Box 445
South Wellfleet, MA

Technology: Clams secure in tight surface netting and rebar that was a few inches deep held by pins (regular quahog net). Intertidal.

Timeline:
5 Sep 2001: Received 7,500 clams and planted under net.

Results: No data reported for this site.

Razor Clam Project

Results Summary

RC-08b – Wellfleet Harbor, MA

Investigator: James O'Connell
25 Bellamy Lane
Wellfleet, MA

Technology: 14'x14' net is tented above sediment. Rebar staples hold down the net. 2"x8" spruce planks buried to sediment surface around perimeter of plot so that top of board is flush with sediment. Intertidal.

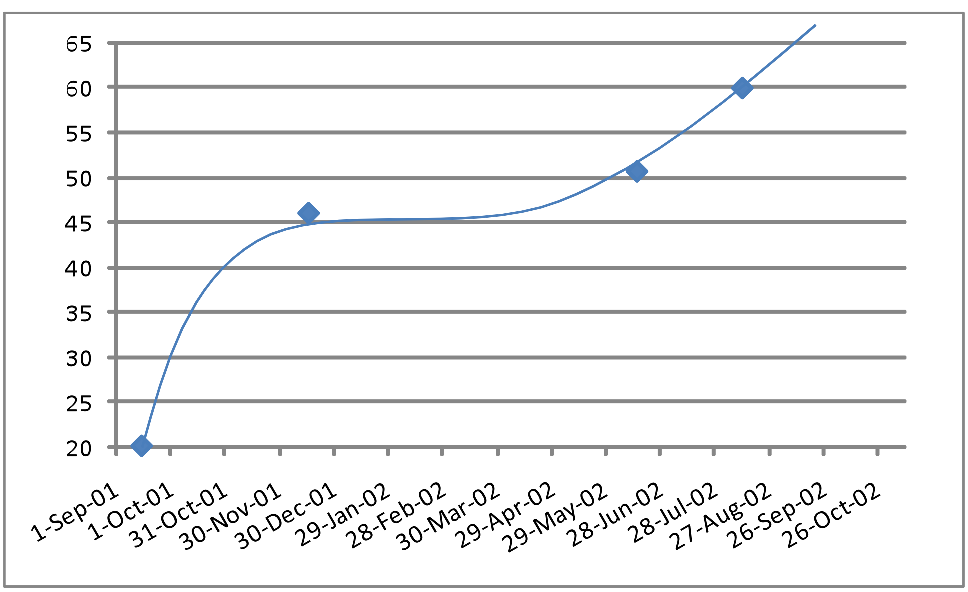
Timeline:

5 Sep 2001:	Received 15,000 clams and planted under net. Initial density of 803/m^2.
16 Dec 2001:	Sampled clams.
xx June 2002:	Sampled clams.
12 Aug 2002:	Sampled clams.
Sept 2002:	Sampled clams.

Results:

16 Dec 2001:	Sediment - sandy, larger chunks of gravel. Some piece of gravel remained in sieve. Density of 1,508/m^2 (2 – 6" cores sampled)
xx June 2002:	Four cores taken. Total of 56 animal found (including the remnants which accounted for 14 unmeasured live clams- the corer killed them). Density of 767/m^2. Could the size range (there appears to be 2 size classes) indicate a recruitment event?
12 Aug 2002:	Observed mortality during this sample time (30.1%).
xx Sept 2002:	Clams died in Sept. and no further measurements were taken.

Growth:



Survival: Survival was reasonable until Aug 2002, where all individuals were lost by Sept. The average size of the dead shells measured in Aug. was 59.3mm, similar to the size measured during sampling date, suggesting the mortality event was in progress at the time of sampling.

Razor Clam Project
Results Summary

RC-010 – Waterford, CT

Investigator: John Wadsworth
Niantic Shellfish, LLC
15 First Street
Waterford, CT

Technology: Initial holding in upweller (7 Sep to 24 Oct).
Transferred to sediment-filled cages made from 1" vinyl-clad wire and lined with "felt" to hold sediment (0.6mL x 0.6mW x 0.3mH; filled to 15cm with sediment). Placed on the bottom (subtidal) in 0.6-0.9m depth (at MLW).

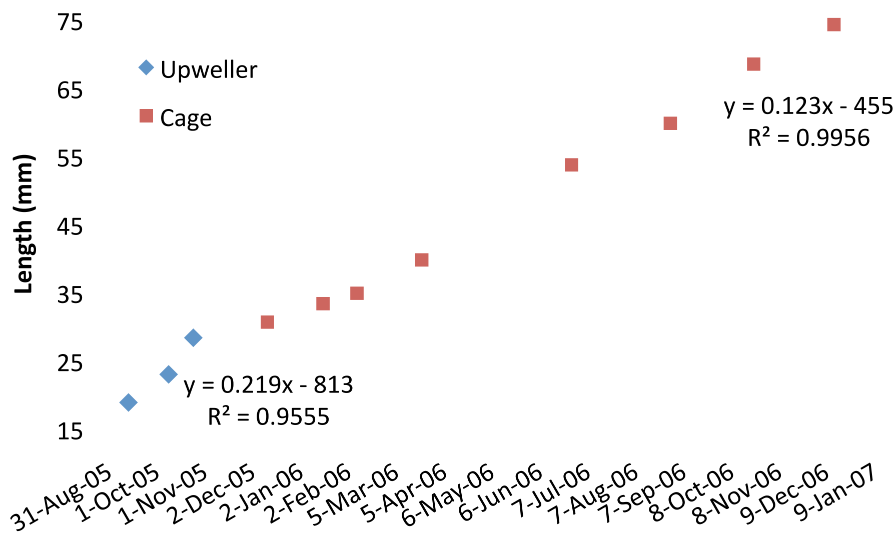
Timeline:

7 Sep 2001:	15,000 razors delivered to facility in CT. Initially placed in upweller.
24 Oct 2001:	razors transferred to cages and placed in Niantic River.
11 Dec 2001:	Measured clams
16 Jan 2002:	Measured clams
7 Feb 2002:	Measured clams
11-12 Dec 2001:	Measured clams
21 Mar 2002:	Measured clams
26 Jun 2002:	Measured clams
29 Aug 2002:	Measured clams

22 Oct 2002: Measured clams
13 Dec 2002: Measured clams

Results:

Growth: Good data on growth rates, including both upweller nursery (0.219 mm/d) and cage grow-out (0.123 mm/d). Achieved growth to 74.2 mm (±6.5) by 13 December 2002. Did not see much decrease in growth rate with cold winter temperatures. Wadsworth *et al.* (2003) suggest growth rate too slow for successful culture (not sure I agree). See graph below:



Survival: Presentation at Milford, suggests green crab predation is a problem in cages. No data collected on mortality and/or changes in density after placing in cages.

Wadsworth, J., T.S. Getchis and N. Balcom 2003. Razor clam, *Ensis directus*, growth rates in Niantic River, Connecticut. Journal of Shellfish Research 22(1):302.

Razor Clam Project

Results Summary

RC-014 – Pleasant Bay, MA

Investigator: Mark Zivan
Nauset Sea Farms
6 Viking Road
South Orleans, MA

Technology: 14'x14' net held in place rebar "hairpins" placed up to 2 feet apart. Subtidal.

Timeline:

10 Sep 2001: Received 15,000 seed

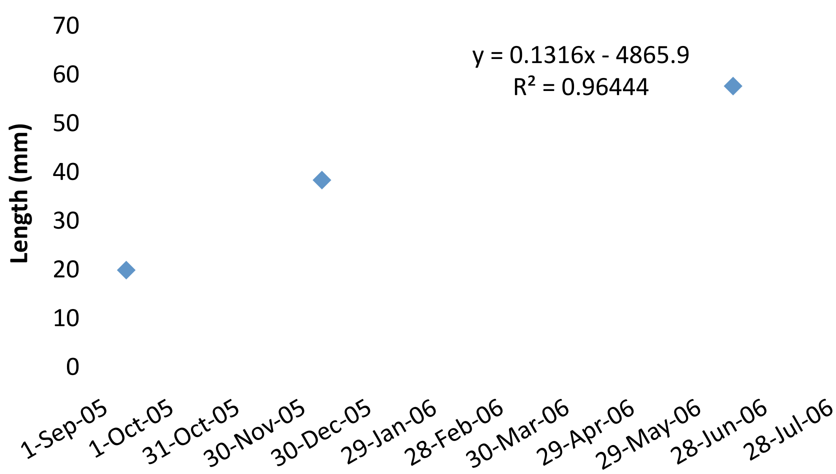
8 Dec 2001: Measured clams - We had a difficult time finding live animals. Cores were dug to at least 1 foot. Is it possible for the clams to "sense" our sampling? Rebecca found that the more we sampled the less clams we found.

13 June 2002: Found 4 razors 60mm long and a few little dead ones 20mm-25mm. Dug 15 to 20 test holes. Grower believes clams emigrating.

24 Aug 2002: The clams ran away! None found

Results:

Growth: Growth seems reasonable for short duration of the experiment (0.131 mm/d). Grower believes emigration occurred.



Survival: No data as clams left site before could assess.

Density: dropped from 795 to 40/m^2 between Sept. and Dec. with no empty shells observed.

Razor Clam Project

Results Summary

RC-015 – Sengekontacket Pond, Martha's Vineyard, MA

Investigator: Richard Karney
Martha's Vineyard Shellfish Group
Box 1552
Oak Bluffs, MA

Technology:
Nursery Technologies:

Tidal upweller with Low and High densities
Bottom sand box (very low intertidal) with low & high densities
Floating sand box with low & high densities and covered versus uncovered.

Grow-out Technologies:

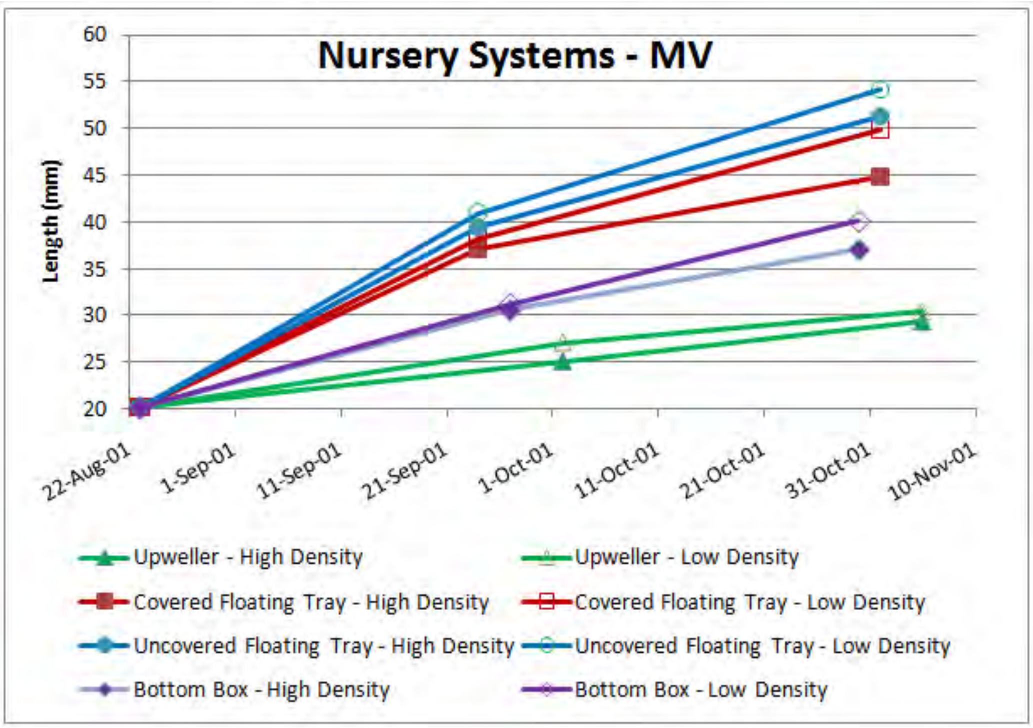
Bottom sand box (very low intertidal) with low & high densities

Timeline:

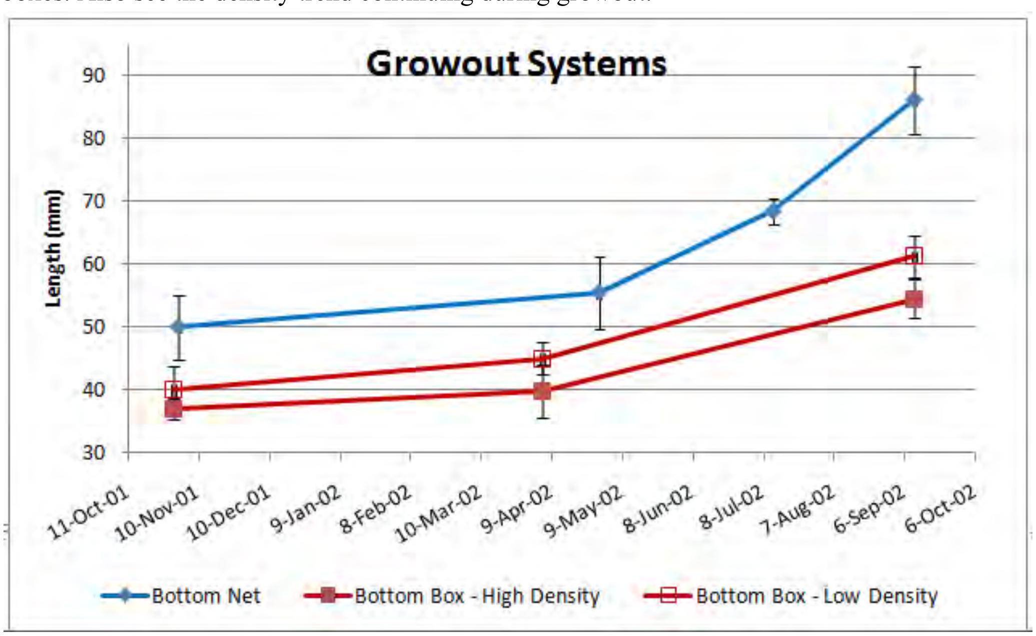
23 Aug 2001:	Received seed and set up experiments
27 Aug 2001:	removed covers from half of floating sand boxes after seeding 4 days ago.
14 Sep 2001:	replaced netting on boxes and collected sample for measure
24 or 27 Sept 2001:	Sampled bottom boxes
2 Oct 2001:	sampled upweller clams
30 Oct 2001:	Sampled bottom boxes
1 Nov 2001:	dismantled rafts and measured clams; planted clams in under bottom net in pond
5 Nov 2001:	shut down upweller and sampled clams
5 Apr 2002:	Sampled bottom boxes
29 Apr 2001:	Sampled bottom nets
10 Sept 2002:	Sampled bottom boxes & nets
1 Nov 2002:	Sampled bottom nets?

Results:

Growth - Nursery Systems: There are trends within the data that suggest that the floating tray is the better culture system with the Tidal FLUPSY being the least effective. It also seems that keeping the containment system uncovered is an advantage, probably due to better access to flow and food flux. There also is a trend for lower density plantings (587/m^2) to grow slightly faster than higher density (1,760/m^2). No statistics have been applied yet.



Growth - Grow-out Systems: Bottom nets support faster growth during the summer season than contained boxes. Also see the density trend continuing during growout.



Survival: Have high loss in floating trays (45-60%) with no difference between covered tray and uncovered tray. May be an emigration problem. Other systems had low mortality rates (~1-2%).

Density: Seems to be a consistent trend that lower density deployments (587/m^2) to perform better than higher density (1,760/m^2) plantings. May not be statistically significant but is consistent among all treatments.

Razor Clam Project

Results Summary

RC-016 – Weekapaug Pond, Westerly, RI

Investigator: Jeff Gardner
Shellfish 4 U
227 Shore Road
Westerly, RI

Technology: ("KISS" - keep it simple stupid). Jeff uses two nets (20'x14' each) for a total area of 580 square feet. Edges of the nets are held down by rebar.

At the lowest tide this site is still covered by almost a foot of water, i.e. subtidal.

Timeline:

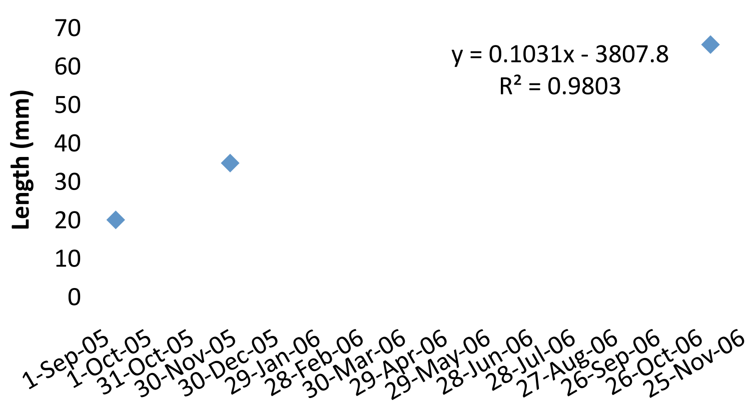
7 Sept 2001: Seed delivered (15,000 juveniles) and placed under two 20' x 14' nets, oriented side by side (initial density = 288/m^2).

27 Nov 2001: Clams measured. Core sampling was largely unsuccessful. Perhaps the clams have dug down too deep (or they dig deeper as they sense movement above according to Jeff). It is also possible that the "KISS" methodology is indeed a little too simple and clams are no longer in planting area. A quadrat and shovel are suggested for a different sampling time. Jeff had a few questions that I couldn't answer. 1. When do razor clams stop siphoning? 2. How does freezing temperatures affect razor clams?

3 Sept 2002: Mr. Gardner believes clams were not contained by clam net. He found very few live clams or dead clams when Rebecca was there in June.

2 Nov 2002: Called with a few measurements of a few razors he found. He dug a 3 X 3 square one foot deep and found 6 razors alive they measured from 58mm- 69mm, average growth 65mm.

Results: We have limited growth data from this location due to the emigration of seed from the growout site. Overall, the growth noted is similar to what we have seen in other locations.



Appendix F: Completed project summary presentation delivered to The National Shellfisheries Association annual meeting in Philadelphia, PA in 2005.

ABSTRACT

A preliminary investigation of the razor clam (*Ensis directus*) as a candidate for commercial farming.

Dale Leavitt*, Jeff Gardner, Tessa Getchis, David Grunden, Diane Murphy, Jim O'Connell, Michael Patricio, Amandine Surier, John Wadsworth, and William Burt. SouthEastern Massachusetts Aquaculture Center, P.O. Box 367, Barnstable, MA 02630.

The razor clam (*Ensis directus*) supports a small but constant commercial fishery in the northeast with the harvested product sold as a live animal in ethnic markets. We initiated studies to develop appropriate commercial grow-out techniques with the assumption that a market existed for a farmed razor clam. Commercial clam farmers in Massachusetts, Rhode Island, Connecticut and New York were contracted to test their best nursery/grow-out strategy when supplied with 0.5cm seed from a hatchery. The test plots of razor clams were monitored for growth and survival during the following two years to evaluate the experimental technologies. Initial hatchery production of 0.5cm juveniles was relatively successful (Yr 1) but subsequent attempts to produce seed failed during the early post-set interval (Yrs. 2 & 3). Given the unique attributes of the razor clam, primarily its high mobility, intensive containment technologies are required to ensure maintenance of the growing crop. The effectiveness of various grow-out strategies will be discussed.

Slides from PowerPoint presentation follow:

A preliminary investigation of the razor clam (*Ensis directus*) as a candidate for commercial farming.

NRAC

Dale Leavitt, Jeff Gardner, Tessa Getchis, Dave Grunden, Diane Murphy, Jim O'Connell, Mike Patricio, Amandine Surier, John Wadsworth & Bill Burt

Roger Williams University

Why are we interested in diversifying local shellfish culture opportunities?

NRAC

- Oyster and quahog are the big TWO in northeast!
- What happens to your business if you should lose a crop due to disease or some other uncontrollable environmental change?
- A variety of other options might be available
  - Soft shell clam – Bay Scallop
  - Surf clam – European oyster
- But, the more options we develop – the more opportunities we create
  - to sustain a viable business,
  - to allow the grower to make a living, and
  - to expand the aquaculture industry in the northeast!

Razor clam fishery

NRAC

- Small scale fishery on-going in northeast
- Harvesting methods
  - Dry digging
  - Pumping
  - Method of choice for harvesting is "salting"
- Landed value has approached $2.00/lb live wt.
  - At its best, that translates to between $0.25 to $0.40 per piece.

What about farming them?

NRAC

Need to consider unique aspects of their biology:

- Preferred habitat: know a little
- Predation: know a little
- Disease: ????
- Behavior: know a little
- Growth: ????

Razor Clam habitat

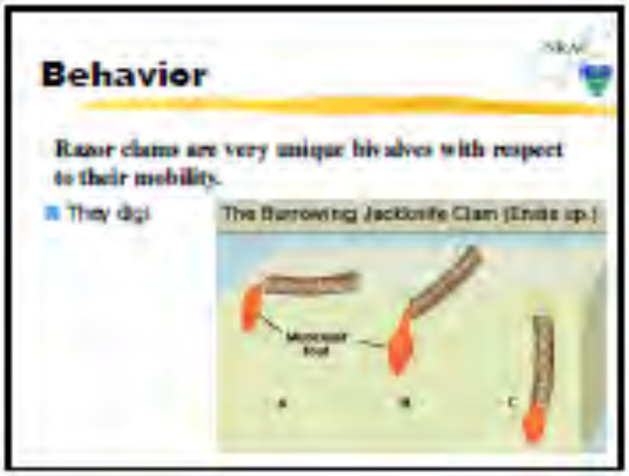
NRAC

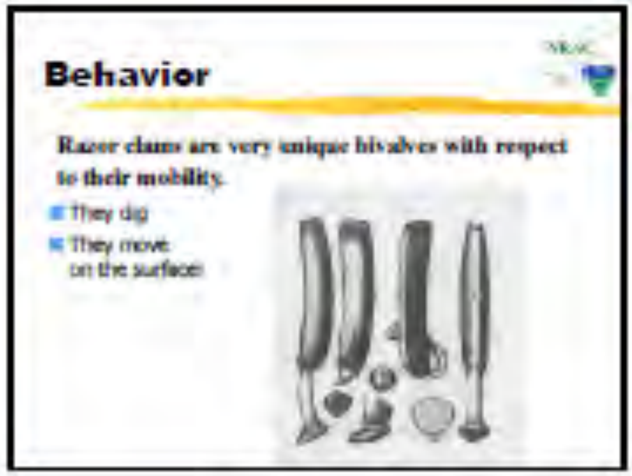
- Fine to medium sand – can be muddy sand if without silt
- Low intertidal to subtidal
- Can live in unstable sand and tolerate dynamic areas
- Prefers areas with moderate water flow

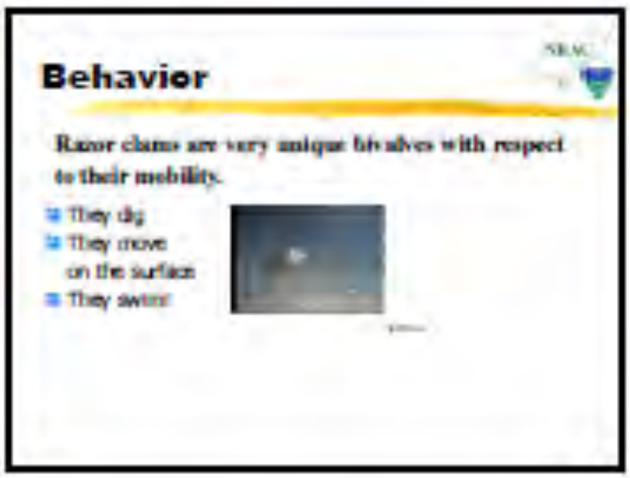
Behavior

NRAC

Razor clams are very unique bivalves with respect to their mobility.


Behavior
Razor clams are very unique bivalves with respect to their mobility.
They dig
The Burrowing Jackknife Clam (Ends up.)


Behavior
Razor clams are very unique bivalves with respect to their mobility.
They dig
They move on the surface


Behavior
Razor clams are very unique bivalves with respect to their mobility.
They dig
They move on the surface
They swim


Idiosyncrasies & culture considerations
Need to consider:
Lack of knowledge about species – from basic biology to culture technology
Mobility – have to contain clam from escaping via digging, crawling, and swimming
Predators/diseases – protection & prevention
Over-wintering mortality – may be a function of tidal exposure
Poor shelf-life – can they survive up to a week out of sediment?


Industry development of culture practices for the razor clam
The objectives of the project are:
Contract with a commercial hatchery to produce 500,000 juvenile (5mm) razor clams
Solicit proposals from the shellfish culture industry to develop techniques for razor clam culture
Provide selected growers with funds to construct/develop their proposed culture technology
Provide selected growers with seed razor clams to experimentally culture
Monitor success of growing razor clams on each farm


Industry development of culture practices for the razor clam
Progress:
Contract with a commercial hatchery to produce 500,000 juvenile (5mm) razor clams
Aquaculture Research Corporation, Dennis, MA
Broodstock from Duxbury Harbor & Nauset Marsh.
Survival poor through setting and nursery
Received app. 150,000 on 24 July 2001 to hold in our upwellers at MMA


Industry development of culture practices for the razor clam
Progress:
Solicit proposals from growers to develop techniques for razor clam culture
16 proposals received on 31 March 2001
11 growers selected
MA, RI, CT, NY, & NJ
2 subsequently dropped out


Industry development of culture practices for the razor clam
Participants selected to grow seed razor clams


Industry development of culture practices for the razor clam
Progress (Year 1):
Provide selected growers with seed razor clams to culture
10–15,000 seed
distributed to gro
between 1 and 1
September, 200
Mean length:
19.46mm (±2.24)


Industry development of culture practices for the razor clam
Progress (Year 1):
Provide selected growers with funds to construct/develop their proposed culture technology
A variety of techniques were tested
Bottom netted raceways


Industry development of culture practices for the razor clam
Progress (Year 1):
Provide selected growers with funds to construct/develop their proposed culture technology
A variety of techniques were tested
Bottom netted raceways
Boarded raceways


Industry development of culture practices for the razor clam
Progress (Year 1):
Provide selected growers with funds to construct/develop their proposed culture technology
A variety of techniques were tested
Bottom netted raceways
Boarded raceways
Bottom tents


Industry development of culture practices for the razor clam
NRAC
Progress (Year 1):
Provide selected growers with funds to construct/develop their proposed culture technology
A variety of techniques were tested


Industry development of culture practices for the razor clam
NRAC
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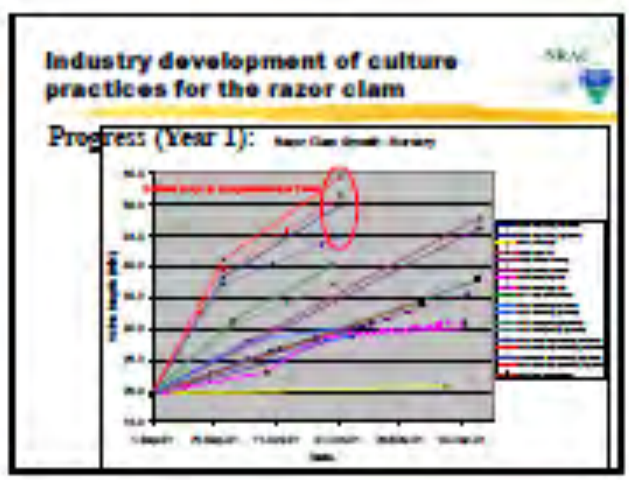
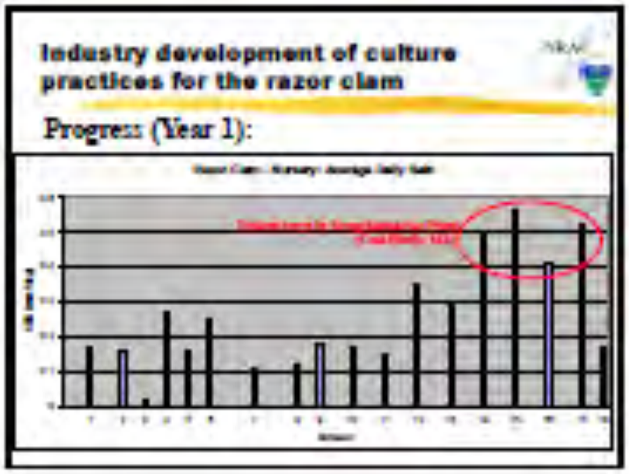
Industry development of culture practices for the razor clam
NRAC
Progress (Year 1):
Provide selected growers with funds to construct/develop their proposed culture technology
A variety of techniques were tested


Industry development of culture practices for the razor clam
NRAC
Progress (Year 1):
Evaluate survival and growth in the various nursery systems
Survival
Growth

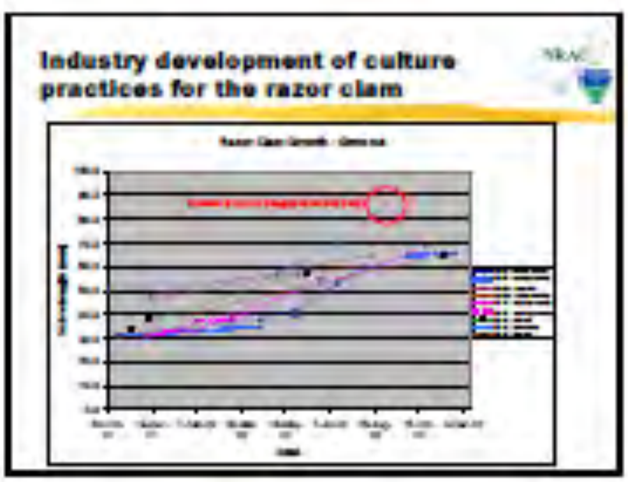

Industry development of culture practices for the razor clam
NRAC
Progress (Year 1):

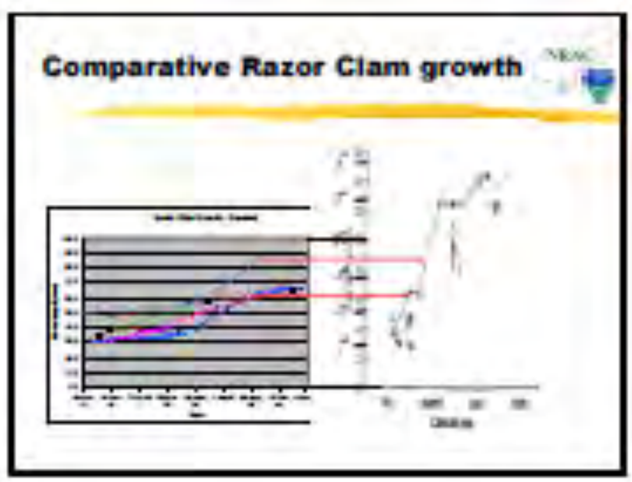

Industry development of culture practices for the razor clam
Progress (Year 1):

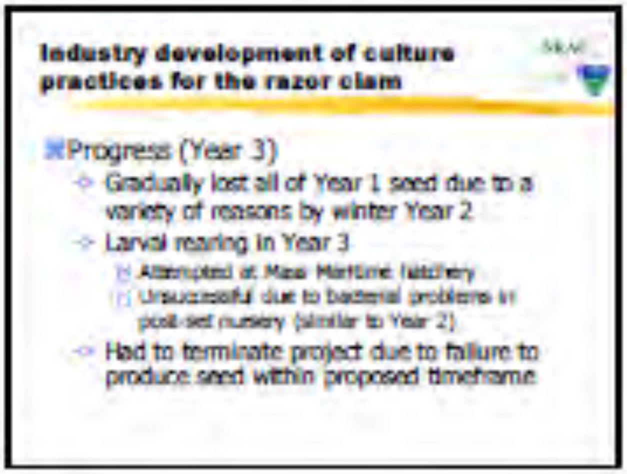

Industry development of culture practices for the razor clam
Progress (Year 2):
Collected broodstock
Distributed to
ARC (commercial hatchery)
Rutgers University
(research hatchery)
Mass. Maritime Academy
(research hatchery)


Industry development of culture practices for the razor clam
Progress(Year 2):
Hatchery attempts in 2002
Spawn in Dec 2001 @ MMA
Spawn in Jan 2002 @ MMA
Spawn in Jan 2002 @ ARC
Spawn in Feb 2002 @ Rutgers
Spawn in Mar 2002 @ MMA with ½ to ARC and a few to EATTC
Bottom Line
No razor clam seed for Year 2 - due to hatchery failure


Industry development of culture practices for the razor clam
Status of Year 1 seed in Year 2
New Jersey
Connecticut
Rhode Island
Massachusetts

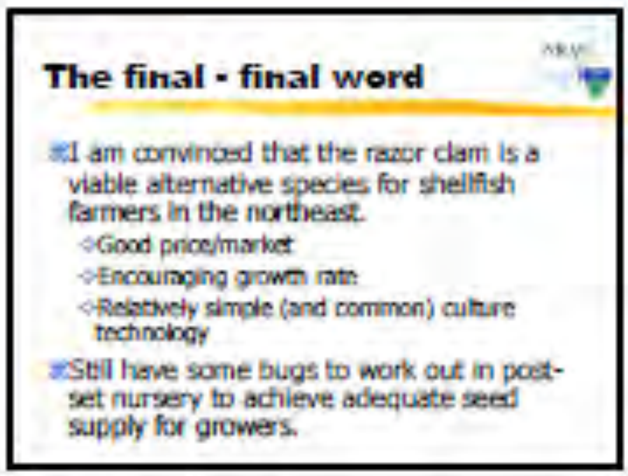

Industry development of culture practices for the razor clam


Comparative Razor Clam growth


Industry development of culture practices for the razor clam
Progress (Year 3)
Gradually lost all of Year 1 seed due to a variety of reasons by winter Year 2
Larval rearing in Year 3
Attempted at Mass Maritime hatchery
Unsuccessful due to bacterial problems in post-set nursery (similar to Year 2)
Had to terminate project due to failure to produce seed within proposed timeframe


Industry development of culture practices for the razor clam
The final word!
Hatchery stage
Razors can be held and handled in a similar manner to surf clams and other "cold-water bivalves"
Spawning, larval culture and setting are straightforward and easy to accomplish
Nursery stage
They grow like weeds (ADG >0.5mm/day)!!
Early post-set juveniles are highly susceptible to bacterial problems when held in conventional downwellers
Require high maintenance with excessively clean rearing conditions
A quick and dirty experiment (@ MFTC) indicated that immediate planting in sediment may be a viable alternative to post-set downwelling (cannot be "sharp" sand).


Industry development of culture practices for the razor clam
The final word!
Growout stage
The growth rate is on a par with (and potentially better than) the growth of wild razors in the North Sea (the only growth data I could find)
Razors will grow through the winter under some conditions
Market size individuals (app. 4-inches) can be harvested in two growing seasons following "field-planting"
Emigration and overheating of sediment (in intertidal) are two problems that need to be considered in selection of site and technology used


The final - final word
I am convinced that the razor clam is a viable alternative species for shellfish farmers in the northeast.
Good price/market
Encouraging growth rate
Relatively simple (and common) culture technology
Still have some bugs to work out in post-set nursery to achieve adequate seed supply for growers.

Appendix G: Draft NRAC Technical Bulletin on the biology of the razor clam.

Biology of the Razor Clam (*Ensis directus*)

Dale F. Leavitt
Roger Williams University, Bristol, RI

There are many clams that are identified by the common name "razor clam". They gain that moniker due to their overall shape of being long and thin, in the nature of an old-time straight razor. Many species of razor clams are noted for their superior taste and texture and have been commercially harvested throughout the world. More recently, interest has been increasing with developing methods to farm razor clams. However, it is important to understand key aspects of the clam's basic biology and natural history before one can start to grow them under controlled conditions.

One species that has been identified as having high potential for aquaculture is the American jack knife or American razor clam, *Ensis directus* (Figure 1, also identified as *Ensis americanus* in Europe). A native of the Atlantic seaboard of North America, the American razor clam ranges from Labrador to South Carolina.

Our knowledge of this razor clam is somewhat enigmatic given that the bulk of the information on *Ensis directus* in North America was published during the turn of the 20th century. The majority of recent information about the razor clam has been generated in studies of *Ensis americanus*, following its introduction into waters of the German Bight in 1978. Since that introduction, the clam has spread through the North Sea coastline from the English Channel to Sweden and has become a dominant bivalve species in the intertidal areas within that range.

Anatomy

The American razor clam is a filter-feeding bivalve mollusk that is easily recognized due to its unique shape, where it is 5-8 times longer (anterio-posteriorly) than it is wide and with a shape that describes a slight arc and does not taper appreciably along its length (Figure 1). The shells are covered with an elastic cuticle (periostracum) that readily sheds sediment and overlaps the valve margins to protect the mantle (Figure 2a). The short siphons are mostly round and separate with many sensory tentacles surrounding the area (Figure 2b).

The most distinctive anatomical feature to the razor clam is the large muscular foot that extends from the anterior end of the clam and is surrounded by a thick collar of mantle tissue (Figure 3). The foot is capable of extending to approximately one-half of the total body length and the combination of foot and mantle collar is responsible for the unique capabilities of the razor clam to dig, to jump and to swim.

a) b)

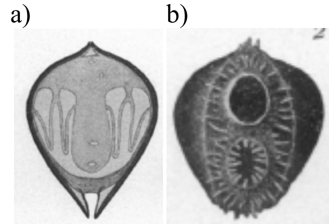


Figure 2: Razor clam views: a) cross-section through mid-point, b) posterior end view (drawings from Drew 1907.)

Mobility

Using the muscular foot and thickened mantle structure, razor clams are unique in terms of their capacity to move through their environment. Under normal conditions, razor clams routinely can be found immediately at the sediment surface and, in some cases, with their posterior end projecting 25 to 50 mm above the sediment surface. However, when disturbed (they are extremely sensitive to surface vibrations), they can dig into the sediment with surprising speed and, within a very short interval, can relocate to depths of up to 1 meter below the surface. To do this, the clam slowly extends its foot with a tapered tip into the sediment. Once extended, the clam can flare the tip (Figure 3) to serve as an anchor as the foot is rapidly retracted; thereby, pulling the clam's streamlined body through the sediment. As the foot is retracting, it is forcing a pressurized stream of water between the base of the foot and the thickened ring of mantle surrounding the foot. As the water is discharged, it fluidizes the sand at the leading edge of the moving shell facilitating its progress through the sediment.

Figure 3: View of razor clam with foot extended and thick mantle collar (drawing from Drew 1907.)

Swimming in razor clams is accomplished in a manner similar to their digging. The difference is that as the foot is rapidly retracted, while the clam is at the sediment surface or in the water column, the pressurized water escaping around the base of the foot acts to propel the clam through the water column, in a manner similar to the jet propulsion of a squid or scallop.

It is not uncommon to find razor clams lying on the surface of the intertidal zone, as they are moving from spot to spot. Often the clams are discovered as they attempt to jump across the flats. The third method that razor clams can use to move is jumping, which is accomplished by curling the foot under the body of the clam and rapidly retracting it (Figure 4.) The result of this action is that the body of the clam jumps into the air and moves a short distance across the flats. Razor clams have been observed repeatedly jumping as they move across the exposed sand flats.

Figure 4: Razor clam foot position during jump behavior (drawing from Drew

Growth

Although the maximum size for the razor clams approaches 20 cm over a life span estimated at 7-8 years, the market size for a razor clam has been determined to be between 10 cm and 15 cm. Based on growth measurements made on wild razor clams collected along the coast of the North Sea, that target size of 100-150 mm could be achieved over a grow-out period of 2-3 years (Figure 5.) However, reports from the coast of England have suggested that the growth rate is significantly slower in that area, with time to achieve market size estimated to be 4-5 years.

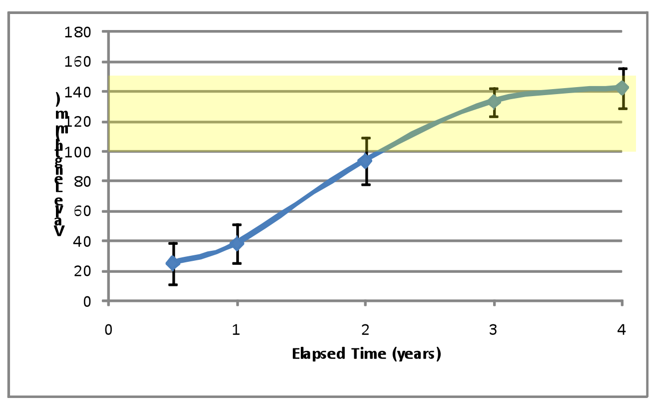


Figure 5: Plot of average growth of razor clams from eleven sites along the North Sea (modified from Armonies & Riese 1999.) Shaded area represents estimated size for market.

Reproduction

Razor clams are dioecious (separate sexes) with their gonadal tissue integrated into their visceral mass. As a cold water species, *E. directus* has been observed to spawn in March-April in the North Sea, early June in Canada and somewhere in between these times in other locations. Following a large synchronized spring spawning, a continuous low level of larvae can be detected in the water column through much of the summer. As a bivalve mollusk, razor clam spawning and larval development follows normal molluscan stages with setting occurring between 10 days and 3 weeks, depending on ambient temperatures.

A unique behavior in post-set razor clams is their capacity to migrate following setting. Juvenile razor clams, up to 10mm in length, have been observed swimming at the surface in subtidal areas, suggesting that the small stage is highly mobile following setting. In addition, small post-set razor clams have been observed undertaking larger-scale migrations through "byssal-drifting." By deploying an attached byssal thread, small razor clams can move with the coastal water currents due to the drag on the byssal "sail". This behavior is thought to have led to the rapid expansion of the introduced American razor clam across northern Europe.

Habitat

In the wild, the razor clam is primarily found in the low subtidal areas (below mean low water) and in subtidal areas to about 20 m water depth, although it has been reported living in depths to 100 m. With the ability of the post-set juvenile to redistribute itself, the razor clam is generally most abundant in shallow subtidal waters with densities decreasing as one moves into the intertidal area. It is reported that spatfall occurs mainly in the intertidal and shallow subtidal but the post-set will move to deeper waters through a combination of swimming and byssal-drifting.

A primary factor governing the redistribution of the post-set razor clam is associated with selection of sediment type. Razor clams prefer clean sand to muddy sand substrate (if devoid of silt) and actively seek those substrate types during the post-set migration. They also seem to orient to sites with moderate water flow. Once an appropriate site has been located, the small razor clam can establish itself into the sediment in a matter of minutes.

Post-set density of razor clams can be exceptionally high, with reported initial densities of post-set juveniles approaching 2,000 individuals per square meter. Following the first winter, through redistribution and overwintering mortality, densities usually stabilize up to a maximum of $200/m^2$. The highest sustained densities have been observed in the shallow subtidal areas. Individuals remaining in the intertidal zone are subject to environmental stresses that reduce survival in areas with aerial exposure.

The predominant factor governing survival in the intertidal has been suggested to be ambient temperature. North Sea razor clams experience high levels of mortality when exposed to air during the winter months, possibly due to the behavior of the clam to approach the sediment surface to feed. However, the biggest problem with rearing razor clams in the northeastern U.S. has been high temperatures on the exposed flats in the summer, resulting in excessive mortality. Regardless of whether the temperature is too high or too low, intertidal exposure of the razor clam is a stressor that can lead to significant mortality in a population.

Risks

In the North Sea, exceptionally dense sets of razor clams have been observed to undergo catastrophic reductions in density over a short period of time. While no research has been undertaken to identify the cause of the mortality, there is a high probability that some sort of disease situation contributed to the large-scale die-off. The Pacific razor clam (*Siliqua patula*) has been impacted by infection from an unknown protistan pathogen, termed Nuclear Inclusion Unknown (NSX) that has resulted in large-scale die-offs at sites in Washington and Oregon. Although no specific diseases have been described for the American razor clam, it is highly probable that razor clam pathogens exist and need to be identified and studied.

Predation, on the other hand, is a significant factor in survival of the razor clam. Numerous predators have been described for the razor clam, including epifaunal and infaunal denizens of the marine environment. Given the razor clams penchant for sitting at the sediment surface, they are highly susceptible to predation by shorebirds, including the American oystercatcher and most gulls, when exposed at low tide. In addition, the numerous crabs and demersal fishes that are foraging at the sediment surface during times of submergence can also prey on razor clams. Siphon nipping has been described as a common source of damage to razor clams in the wild. Infaunal predators are also a factor in razor clam survival. Whether being attacked from above by predatory gastropods, such as the moon snail (*Euspira heros*), or from below by carnivorous worms, such as the ribbon worm (*Cerebratulus lacteus*), they are highly susceptible to these predatory acts because of their inability to completely close their valves to protect the soft tissue and because of the fragility of their shell.

The primary mechanism that razor clams employ to avoid predation is their mobility. If attacked from above, they can rapidly dig to depths that make them inaccessible. One report describes a razor clam digging to such an extreme that its movement described a complete arc in the sediment resulting in the animal exiting the sediment in reverse at a location several meters away from the attack site. If attacked from below, the razor clam can exit the sediment and either swims away if submerged or jump across the flats if exposed to avoid the infaunal predator.

Markets

The traditional market for razor clams in the northeast was as a supplement for soft shell clams that were shucked for frying. When soft shell clam resources were low, harvesters would target razor clams as a replacement. Hence, the preferred size was large (15 cm).

More recently, demand has been increasing for live razor clams, with a market size of between 10 - 15 cm. The challenge with the live razor clam market is their lack of hardiness for transport and holding. Shelf life can be very short (1-2 days) without some type of intervention by the harvester/handler. The most common method for extending the holding time for live razor clams is to bundle them, holding the bundle together with rubber bands, similar to the market strategy for asparagus. This approach compresses the valves of individual clams together and relieves the adductor muscles from having to hold the valves together. Shelf life can be extended to up to a week with bundled razor clams.

Conclusion

The American razor clam is a prime candidate for culture. Although the clam has a few unique attributes, many of the biological characteristics of the species appear to be similar to that of other infaunal bivalves and, therefore, farming should prove to be routine for culturists knowledgeable in infaunal clam culture. However, more biological information on the species is needed to fill in knowledge gaps for improving culture.

The primary consideration in farming the razor clam is siting, as razor clams will evacuate an area rather quickly if the site is not suitable for their needs. One important factor in siting is the sediment type. Observation of farmed razor clams indicate that they will avoid digging in if the sediment type is not appropriate. Unless contained, the razor clam seed will move off the culture site in search of new and more suitable substrate.

The U.S. razor clam market is small but developed. If supply is available, wholesalers have indicated that they can increase the market size but are hesitant to do so without adequate resources.