FINAL PROGRESS REPORT

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Development of Hatchery and Field Culture Methods for the Atlantic Sea Scallop, Placopecten magellanicus.

Martha's Vineyard Shellfish Group, Inc.

Award Period: From 2/1/95 to 6/30/96 (extended)

EXECUTIVE SUMMARY

Fishermen involved in the traditional fishery for sea scallops face increasingly limited harvests and economic hardship. The application of aquaculture techniques for stock enhancement and/or private aquaculture operations may well provide the only viable option for an industry dependent on ever dwindling natural stocks.

The objective of this project was to adapt and transfer hatchery and field culture methods for bay scallops to the aquaculture of the Atlantic sea scallop. During the project, sea scallops were successfully spawned and cultured in the hatchery, in a land based nursery system, floating inshore nursery cages, and bottom cultured in cages on a deep water site in Cape Cod Bay. We demonstrated and documented a culture methodology which resulted in the production of over 50,000 38mm sea scallops from fertilized eggs over the course of a year and a half.

Starting with just over seven million eggs, we sucessfully took 1,350,000 pediveligers to set systems during a larval culture period which lasted almost forty days. These were cultured in both upweller and downweller land based nursery culture systems. A total of 519,000 2mm seed were successfully transferred to inshore culture systems which included Japanese style spat bags and floating nursery cages. Over 80% of the 2mm seed scallops were, however, lost due to heat stress during the month of July when regulatory agency delays prevented the scheduled transfer of the seed stock to the cold water offshore growout site.

The 90,000 surviving scallops were hastily transferred to pearl nets and plastic mesh bag growout units at the offshore growout site in Cape Cod Bay in late July. Two months later, at the end of September, 60,000 seed scallops remained (66% survival) and averaged 16mm in shell height. The observed mortality was not recent, and is suspected to be the result of the heat stress before and during transfer from the inshore site.

When examined on 11. November, the offshore cultures showed little evidence of recent mortality and had grown to an average of 22.4mm. At the time of the final monitoring in May, the least dense cultures averaged 38.4mm with a survival rate of 96% from the September baseline. Seed scallops cultured at a higher density grew to an average of 35mm with a 90.5% survival from September.

The most significant problem encountered during the project was the difficulty of securing the required permits for the offshore culture sites.

The pioneering culture efforts for sea scallops initiated in this project provide an important

foundation for future sea scallop culture endeavors which are key in reversing the crisis of supply in the Northeast fishing industry.The development of a sea scallop culture technology can help restore natural depleted beds through stock enhancement efforts, or be used in the development of aquaculture ventures that can provide alternative employment and new business opportunities for fishermen displaced by the collapse of natural offshore stocks.

The Atlantic or giant sea scallop, Placopecten magellanicus.

INTRODUCTION

The giant sea scallop, Placopecten magellanicus, is the most important commercial pectinid species in the world. It is responsible for over half of the world's wild scallop landings (Halvorson, 1995).

Natural populations have failed to keep pace with exploitation. Of late, precipitous declines in the natural stocks have forced regulators to further restrict harvests. Fishermen involved in the traditional fishery for sea scallops face increasingly limited harvests and economic hardship.

In contrast, the stunning success of aquaculture operations for scallops in Japan and China and the promising development of culture methods for Placopecten by the Canadians provide a glimmer of hope in the otherwise bleak horizon of the U.S. sea scallop industry. The application of aquaculture techniques for stock enhancement and/or private aquaculture operations may well provide the only viable option for an industry dependent on ever dwindling natural stocks.

PURPOSE
Problem

The sea scallop industry based on Georges Bank reached its peak in the late 1950's and early 1960's, when U.S. and Canadian landings topped 30 million pounds annually. Since then, the

natural abundance of sea scallops has fallen. By 1971, the total U.S. and Canadian landings from Georges Bank fell to about 12.4 million pounds. Further, the larger scallops were depleted, and mostly young sea scallops were harvested (Altobello, et al. 1977). Despite regulations aimed at increasing the average size of sea scallops harvested on Georges Bank, natural stocks continued to decline. Wild stocks fell to such low levels that in 1995, the New England Fisheries Management Council Scallop Committee closed selected areas of Georges Bank to scallop fishing. This drastic action has been devastating for New England's commercial scallopers (Halvorson, 1995). Scallop recruitment is notoriously sporadic. Sea scallop catch statistics suggest "periodic recruitment pulses every nine, eighteen or twenty one years" (Couturier et al., 1995). Certainly, the odds for a quick recovery of the natural stocks are not high. Even if these severe restrictions are successful, it is unlikely that the industry will ever again reach the levels of economic activity seen in the past.

Even while the domestic sea scallop industry based on the exploitation of natural stocks declines, foreign cultured scallops fill the niche in domestic markets. Cultured scallops now exceed the total landings of the world's wild catch. In 1993 Japan and China cultured 300, 000 MT and 200,000 MT of Placopecten yessoensis, respectively (Halvorson, 1995)!

Could a cultured domestic product fill the void in supply caused by dwindling natural stocks? Could methods be developed to economically produce seed scallops to enhance depleted natural beds? The odds are at least as good as those of the natural population making a speedy recovery!

Project Goals and Objectives

The development of aquaculture methods for over exploited species in the Northeast, including the sea scallop, has potential to increase natural stocks through enhancement with hatchery produced seed. Development of field culture methods for the sea scallop promises to further increase supplies of this species and can provide alternative employment for fishermen presently harvesting the dwindling natural supplies.

The objective of this project was to develop and demonstrate hatchery and field culture methods for the giant sea scallop. Specifically, we proposed to adapt our already successful production methods for bay scallops (Karney, 1991) to the development of a successful and cost effective sea scallop aquaculture technology.

APPROACH

Literature Search and Consultations

The hatchery and field culture techniques for Placopecten attempted in this project were relatively untested in this country. The only reported hatchery work on sea scallops conducted in the United States was in 1992 and 1993 by Brian Beal, Samuel Chapman, and Thomas Duym in a project entitled "Sea Scallop (Placopecten magellanicus)Aquaculture in Maine" funded by the National Coastal Resources Research and Development Institute.

The majority of the culture work for Placopecten has been conducted and reported by Canadians. Researchers at Memorial University's Marine Sciences Research Laboratories were largely unsuccessful with early attempts to collect spat on artificial substrates along the Newfoundland and Labrador coasts in the late 1960's. In 1971, using Japanese advisors and methods, a joint federal and provincial study including spat collection and grow out was conducted in Newfoundland. Growout methods proved successful but spat collection was unreliable. By the early 1980's hatchery methods were being experimented with at several government and university laboratories. Successful hatchery methods were reported in the late 1980's. Concurrently, spat collection methods were improved and areas with commercial quantities of sea scallop sets were identified.

The spat falls, however, remained highly variable. By 1995 cultured sea scallop product in Atlantic Canada was expected to exceed 500 tons. (Couturier et al., 1995). The 27. January, 1995, issue of Atlantic Fish Farming carried an article about the announcement of a commercial scale sea scallop hatchery in Newfoundland. The new facility was producing seed for growers in 1995 and 1996.

A number of scientific papers about the culturing of sea scallops has been assembled and reviewed in preparation for the culture work proposed in this project. Dr. Sandra Shumway of Long Island University and Dr. Michael Dadswell of Acadia University provided the bulk of the reprints. A list of these publications is attached as Appendix 1.

Information contained in Chapter 7 "Aquaculture of the Sea Scallop" by Parsons and Dadswell, part of the "Synopsis of the Biology of the Sea Scallop, Placopecten magellanicus" by Shumway (in preparation) was particularly helpful in developing the spawning and larval culture protocol. A progress report to the National Coastal Resources Research and Development Institute for a project entitled "Sea Scallop (Placopecten magellanicus) Aquaculture in Maine" by Brian Beal, Sam Chapman, and Thomas Duym, detailing their culture efforts in 1992 was also extremely valuable.

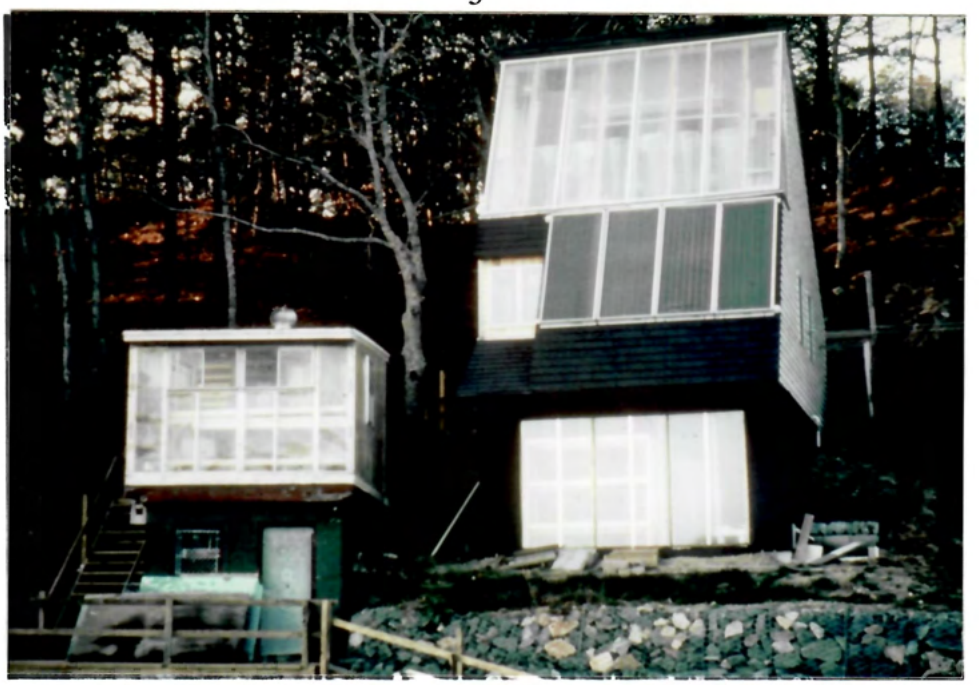
Brian Beal, Sam Chapman, and Dwayne Shaw of Maine, and Mike Dadswell of Nova Scotia were consulted by phone regarding their knowledge and expertise in Placopecten aquaculture. Their suggestions were incorporated into the culture methods. Duncan Bates, who field cultures sea scallops in Nova Scotia with Dr. Dadswell, shared his field culture expertise in return for training in hatchery techniques. Mr. Bates worked at the MVSG hatchery between 21. April and 1. May, 1995, and consulted with Frank Dutra, the project's Offshore Field Culture Investigator, on Nantucket on 2. May.

The Principal Investigator, Hatchery Technician, and Offshore Field Culture Investigator attended "A Workshop on Developing Sea Scallop Aquaculture in Massachusetts" on 24. July, 1995 at the Cape Cod Community College (program attached as Appendix 2). The workshop provided an opportunity to consult and share information with sea scallop culturists, most notably, Canadian pioneers Mike Dadswell, Sam Naidu, and Jay Parsons. Cage and spat bag designs were discussed. The Principal Investigator attended the Gloucester Fisheries Forum on 14.-15. September, 1995, which provided additional opportunities to consult with the leading Canadian sea scallop culturists.

Walter Rhee, who studied scallop culture at the University of Washington, offered insights on visits to the hatchery on 7. April and 15. June and supplied spat bags for the field culture of juvenile scallops.

John Thomson, of the Tasmanian Scallop Enhancement Project, shared his knowledge of ocean scallop culture techniques during two visits on 18. April and 20. May.

On 15. and 16. May, several female sea scallop broodstock, held in raceways in the hatchery, were found dead. These were delivered to Dr. Roxanna Smolowitz, of the Laboratory for Marine Animal Health, at the Marine Biological Lab in Woods Hole for inspection. The scallops suffered from Trichodina brachaeitis, a ciliate infestation of the gills, common to sea scallops held in captivity.



Hatchery culture investigations for the sea scallop were conducted in the Martha's Vineyard Shellfish Group's solar hatchery.

Phytoplankton Culture

In preparation for the hatchery culture of the sea scallops, phytoplankton food cultures were started. Stock cultures of Isochrisis galbana (Tahitian strain), Chaetoceros neogracili, Thalassiosira weissfloggi, Tetraselmis maculata (TTM strain), and T. striata were worked up using the Milford method.

At the Martha's Vineyard Shellfish Group Hatchery, phytoplankton is routinely cultured in a third floor greenhouse next to the larval conicals. We experienced some difficulties with the algal cultures, especially the warm water T- Iso, as the greenhouse had to be kept cool to maintain the 15° C water temperatures for the sea scallop larvae. The quahog, bay scallop, and oyster larvae we normally grow are cultured at a temperature of about 23° C. In the cooler than normal greenhouse, C. neogracili grew much better than T-Iso and was the primary larval food. We partitioned the greenhouse with reflective mylar to separate algal and larval cultures. This allowed the algae to be cultured at temperatures higher than the sea scallop larvae would tolerate.

Cultured phytoplankton was fed to the developing larvae and post set juveniles for a period of about 55 days. Stock cultures of the five phytoplankton species were maintained over the entire course of the project in preparation for a second spawning and culture scheduled for the fall of 1995.

The fall spawning was canceled when ripe broodstock could not be located. In lieu of a second spawning, attempts were made to ripen broodstock in the hatchery. Cultures of the five phytoplankton species were worked up into 4 liter, 19 L, and 220 L cultures using the Milford Method. In addition, 220 L Kalwall cultures of indigenous phytoplankton were cultured using a modification of the Wells-Glancey Method. These cultures were fed to broodstock in an effort to ripen their gonads.

Broodstock Acquisition and Conditioning

For the spring spawning

In anticipation of the grant award in early February 1995, we obtained 14 sea scallop broodstock in December 1994 and January 1995 from Tom Osmers, a local fisherman. These sea scallops were caught about three miles south of Martha's Vineyard and kept in a bottom cage tied to the hatchery pier in Lagoon Pond. Salinity in Lagoon Pond is constant at about 30 parts per thousand and during the period Dec-Feb the pond was at times ice covered. About 20 adult sea scallops were received from Richard Dickey of Cape Cod Resource in Orleans, MA on March 6, 1995. These were caught in October 1994 in Cape Cod Bay loran bearings 44070 and 13014 by Captain David Dutra and held in Truro Aquaculture Project cages until delivery to the Vineyard on March 6 in water (4.5° C) in a cooler. These were transferred from the cooler to a bottom cage off the pier in Lagoon Pond. William Dupaul of the Virginia Institute of Marine Science was contacted in January and agreed to provide ripe broodstock in March/April from the Virginia coast if northern stock was not ripe.

On March 3, one female sea scallop from south of the Vineyard was brought in from the cage off the pier and put in a raceway of flowing ambient (4°-5° C) seawater in hopes that it would open so that the gonad could be visually inspected for degree of ripeness. The gonad appeared swollen with pink eggs and an attempt to spawn the sea scallops was scheduled for the following week. As the sea scallops appeared to be ripe, no effort was made to condition broodstock for the spring spawning.

For the fall spawning

Efforts to collect ripe broodstock for the fall spawning were not successful. Inquiries were made to the New Bedford fleet, a fisherman out of Gloucester, and researchers in Maine and Nova Scotia.

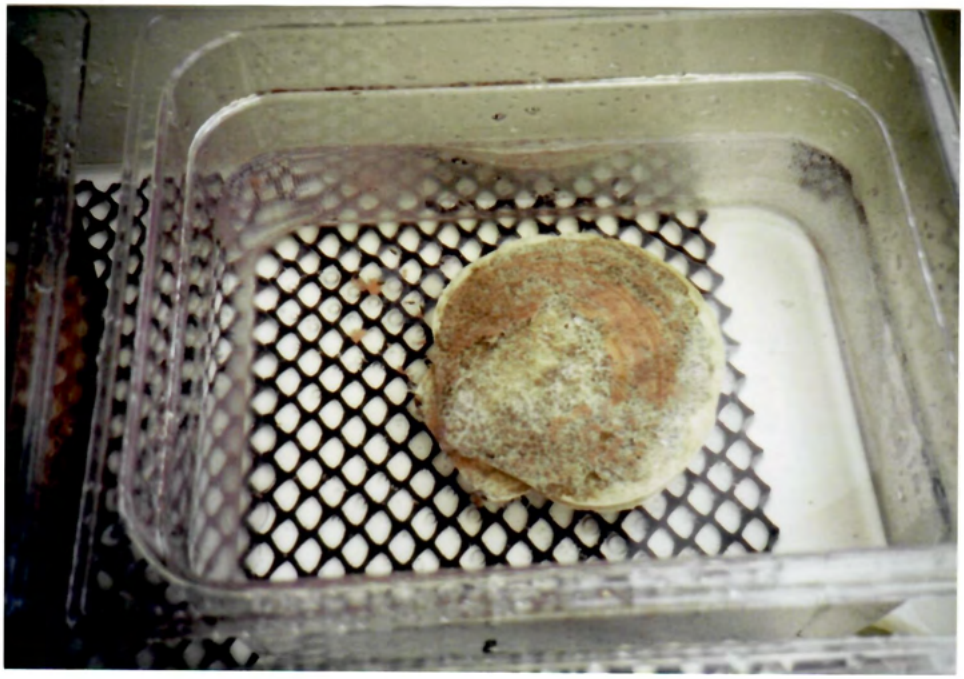
During the middle of November, eleven spent broodstock, collected from Cape Cod Bay by the Truro Aquaculture Project, were transferred to raceways of flowing seawater at the hatchery in an attempt to ripen them artificially. Beginning on November 29, approximately 15 L of cultured phytoplankton (T. weissfloggi, - approximately 87,000 cells/ml; Tetraselmis sp.., - approximately 236,000 cells/ml; and Wild cultures) were drop fed daily via a hospital I.V. to the 11 animals held in a flow of ambient seawater. Upon the suggestion of Canadian researchers, an attempt was made to lengthen the photoperiod of the broodstock. Starting on December 8, a 75 watt incandescent bulb, set on a timer for 12 hours on and 12 hours off, illuminated the broodstock in the raceway. No attempt was made to alter the ambient water temperature which fell steadily from 8° C on November 29 to 2° C on December 31. The scallops were observed to actively feed throughout the period. Gross visual examination of the gonads in late December showed some development of the gonadal tissues, however, the animals remained far from ripe.

The effort to artificially ripen broodstock sea scallops continued until 8. March, when the broodstock were flown to the Nantucket hatchery for an attempted spawning. Throughout the period, the broodstock were held in a flow of ambient water, and drip fed about 15 liters of cultured phytoplankton daily. During the month of January, they were fed cultures of Tetraselmis (sp..) at approximately 190,000 cells/ml and Thalassiosira weissfloggi at about 110,000 cells/ml. During January, the ambient temperature fell from a high of 3° C on 1. January to a low of about -1° C on 12. January and rose to 3.5° C on 31. January. The photoperiod provided by illuminating the broodstock with a 75 watt incandescent bulb was increased on 15. January from 12 hours to 18 hours. The broodstock were observed for degree of ripeness by gross visual examination on 31.

January. We recorded three ripe females, seven ripe males, and one male that appeared not to have ripened.

The broodstock remained in the raceway conditioning system with a similar feeding regime until 8. March. Ambient water temperature fell in mid February to a low of -0.5° C, rose to 3° C at the end of February, and fell again to 1.5° C on 8. March. Despite the visually apparent ripe condition of the broodstock, the sea scallops failed to spawn readily at the Nantucket hatchery. The important culture technique of conditioning sea scallop broodstock for spawning clearly needs further investigation. The broodstock scallops conditioned on Martha's Vineyard and others from Cape Cod Bay were finally successfully spawned on Nantucket on March 22, 1996 after two unsuccessful previous attempts.

Spawning



Eggs released by the lone female appear as orange clumps in the upper left of the spawning dish.

On March 9, 1995, 24 sea scallops were selected for spawning- 10 males and 2 females from the area south of the Vineyard (MV) and 10 females and 2 males from the Cape Cod Bay (CCB) collection. The scallops' shells were brushed under a flow of fresh water to remove fouling and transferred to plastic spawning dishes (2 per dish) filled with seawater (30ppt) filtered to 1 micron at 5° C. After about an hour, the water in the dishes was changed and the water temperature raised over the course of about half of an hour to 12°-13° C. Within a half hour one female (MV) began releasing eggs. Interestingly, this was the female that had been moved to the raceway of flowing ambient water on March 3. Some of the egg solution was droppered into the dishes with males and the water temperature was raised to 15° C. Within ten minutes a male (MV) released a small amount of sperm. Some of the sperm solution was droppered into all dishes as an added stimulus. The water temperature was raised to 17° C and than dropped to 14° C. The female scallop continued to release eggs for about an hour . The temperature was raised to 15°C and lowered to

12°C in about half hour intervals for about another 2 hours until 5 males (2 CCB and 3 MV) released copious amounts of sperm. The eggs released by the lone female were fertilized with sperm from the males and counted. We recorded just over 7 million eggs (about 70 microns in diameter) most of which appeared fertilized as evidenced by polar bodies. Attempts were made over the next 5 hours to stimulate egg release from the remaining females. Sperm was introduced to the dishes and the temperatures were fluctuated to the extremes of 10°C and 20°C to no avail.

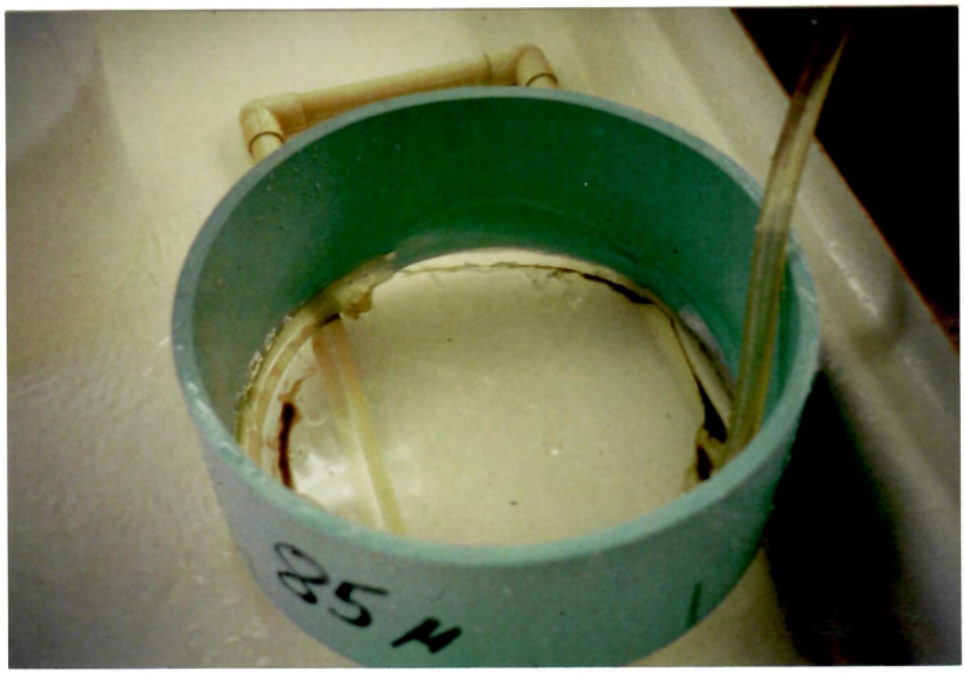
Principal Investigator Rick Karney droppers sperm solution into the spawning dishes as an added stimulus.

Larval Culture

The 7 million eggs from the lone female were put into a 400 liter larval conical filled with 1 micron filtered, aerated, sea water at 12° C. After several hours the eggs appeared to settle in pink clumps on the sides of the bottom cone of the conical. The bottom clumps were still visible 30 hours after fertilization but were gone, and larvae were observed in suspension after 48 hours. At 48 hours the tanks were drained for the first time. About 3 million scallops remained. They were, however, still ciliated blastulae and trochophores. We did not observe straight hinge veligers until the second drain down on Day 4.

Normal larval culture protocol included a daily feeding with a drain down and sizing every other day. The conicals were drained by attaching Tygon tubing to the bottom of the conicals, opening a valve, and draining the culture water through plexiglass sieves which retained the larvae and let old culture water and wastes pass. Following every drain down, the conicals were cleaned with a Wescodyne solution, rinsed with fresh and filtered seawater, and then refilled with filtered, heated seawater. After sizing the larvae by pouring them through a series of plexiglass sieves with decreasing sizes of nylon mesh, the larvae were equally redistributed in three 400 liter conicals of 5 micron bag filtered water heated to about 15° C(range 13°-17°C). They were fed a diet of Tahitian

Isochrisis and Chaetoceros neogracili. A chart of the larval culture food regime including algal species' volumes and densities is attached as Appendix 3. By Day 9, over 2.5 million were still alive and the largest veligers measured 100 microns shell height. They grew about 5 microns per day and by March 30th (Day 21) about 2 million had survived with the largest measuring 170-180 microns.



Larval cultures were drained down through fine mesh sieves which retained the larvae.

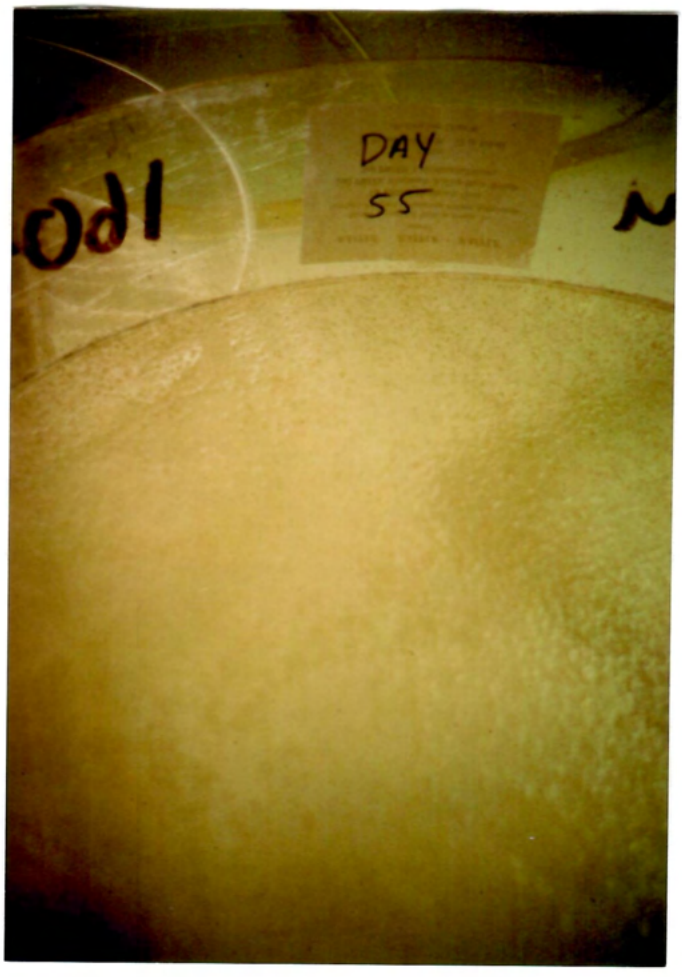
On the April 5th(Day 28) draindown, 90,000 sea scallop larvae were retained on a 183 micron sieve. The largest measured 250 microns shell height, and some were clearly pediveligers. The larvae were observed to contain heavy stores of lipid globules. The 90,000 larvae were moved to two 130 micron mesh, 18" diameter downweller sieves in a 2,000 liter Kalwall tank, with the downweller flow provided by an airlift. The downflow sieves were constructed from cast acrylic tubing and various sizes of Nytex screening. The units were aged in flowing seawater for about a week prior to use. The remaining larvae (1,215,000 caught on a 150 micron sieve, and 200,000 retained on 130 and 85 micron sieves) were resuspended in the three 400 liter conicals.

We successfully took 1,350,000 pediveliger larvae to set systems between Day 28 and Day 38. On Day 32 the first, fully set, crawling juvenile was noted from a sample of the first scallops moved to the set sieves on Day 28. Many juveniles were byssally attached to the bottom and sides of the first downweller sieves on Days 36 and 37. On average, it took the eyed pediveligers about a week to undergo the metamorphosis to set juveniles. Vorticella-like fouling was observed on the set sieves about a week after deployment. The larvae and set scallops were removed from the sieves by air drying and gentle brushing with paint brushes. The sieves were cleaned with Wescodyne, and the scallops returned to the clean sieves. Lack of space resulted in placing as many as 330,000 setting scallops on one 18" diameter sieve. We observed more mortality in these

densely planted sieves compared to the first set shellfish, which were placed on the sieves at a density of about 100,000 larvae per sieve.

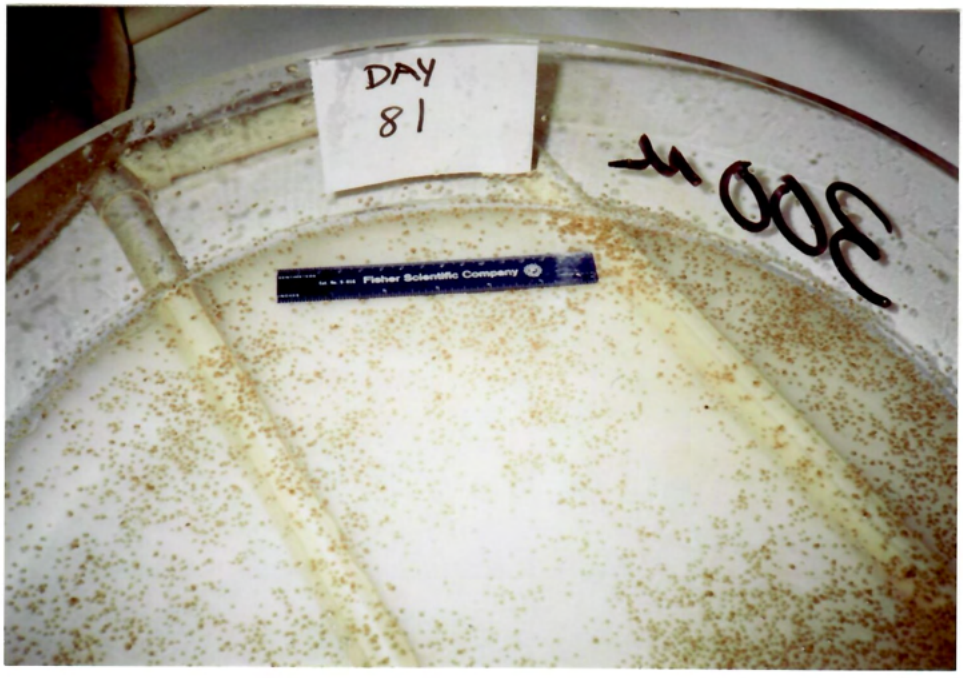
Land Based Nursery Culture

Newly set sea scallops on downeller sieves received a trickle flow of ambient seawater filtered through 10µ filter bags.



Newly set sea scallops byssally attached to a downweller sieve.

Set scallops were removed from biofouled sieves by air drying and gentle brushing.



Juvenile sea scallops 81 days from spawning.

On Day 40, a sieve with the most developed sea scallops was moved out of the closed system setting tank at approximately 15°C to a slow flow of 10 micron bag filtered seawater at 8°C. These were observed to be sluggish and not strongly attached the following day. On Day 43, the largest animals were observed to have reached about 400 microns and had some Vorticella biofouling. On the following day, more scallops were moved to ambient (9°C) flows of 10 micron water to reduce the density in the limited, heated water system. On Day 47, scallops on the colder (10°C) flowing water were noticeably smaller (350 microns) than those on the recirculated (15°C) water (400 microns).

By Day 60, all scallops were moved to flowing water (10 micron) with the largest scallops measuring about 750 microns. On Day 64, the sea scallops were distributed on 13 sieves with a bag filtered (25 micron) flow of about six liters per minute per sieve, at 12°C. On Day 73, the largest seed measured about 2mm. By Day 79, the scallops were spread onto 16 sieves with the largest on ten 300 micron sieves with a flow of 50 micron bag filtered water at 16°C. On Day 83, scallops retained on windowscreen mesh were moved to upweller silos in order to thin the crowded downweller sieves. The growth data is graphically depicted in Appendix 4.

Inshore Field Culture

Due to the slow growth of the seed, field culture methods were changed. Oriental style 1mm plastic spat collection bags were purchased, filled with sanded monofilament and fiberglass windowscreening, and used to field culture the 2mm seed. Some field culture cages originally planned to be used for the inshore field culture were assembled. The seed scallops were placed in the bags, and the bags then were placed in the cages. Culturing the scallops in the bags would facilitate the movement of the small seed to the offshore field culture systems.

On June 8th (Day 90), 89,080 2mm seed scallops were moved from upweller silos in the hatchery to four 1mm mesh spat bags filled with monofilament to provide surface area for attachment. The density was 22,270 scallops per bag. Ambient water temperature was 18°C. The bags were placed in a nursery cage anchored in Lagoon Pond off of the hatchery.

Between Day 96 and Day 110, another 416,080 2mm seed scallops were transferred to 24 spat bags in the field. Densities ranged from 11,350 to 31,714 scallops per bag. Crumpled sheets of windowscreening were substituted for the monofilament in some of the bags assuming that the seed would be easier to detach from the screening than the tangled monofilament. Water temperature on Day 110 reached 20°C.

On June 29th (Day 111), the first bags set out on Day 90 appeared fouled and crowded. The four bags were emptied into four windowscreen mesh cages that were 6 feet long, 2.5 feet wide and 1 foot deep. The scallops ranged in size from 3 - 6 mm. Few mortalities were observed despite the crowding and increasing water temperature. All other bags were rinsed with a strong flow of seawater to remove silt and fouling.

On July 3rd (Day 117), the last of the sea scallops (15,944) were moved from the hatchery to a bag in a field cage. The water temperature was 20 ° C. A total of 519,000 2 mm seed were successfully transferred to inshore field culture systems.

As we produced more seed scallops than our field culture budget could grow out, we requested that the excess sea scallop seed be provided to interested growers at no cost except for reports of their culture activities. We budgeted enough field equipment to grow out about 125,000 10mm sea scallop seed at a deep water site in Westport, Massachusetts. We received requests for sea scallop seed from David and Judy Dutra of the Truro Aquaculture Project, Tobin Store, who proposed

growout in Cape Cod Bay, Richard Taylor from Gloucester, Richard Krauss of Aquaculture Research Corporation, and Ian Emery in Maine. We received permission to distribute the seed to any growers who had obtained all the necessary local, state and/or federal government permits.

Successful transfer of the seed sea scallops to the planned offshore Buzzards Bay grow out site of the Southeastern Shellfish Association in Westport was frustrated by seemingly endless delays and broken promises from regulatory agencies. Likewise, all the other potential growers were having difficulty getting their permits. None of the possible off shore culture sites were able to be timely permitted, resulting in the in shore field culture having to be extended through most of July.

On the 6th and 7th of July, ambient water temperatures at the Lagoon Pond inshore culture site reached 21.5 - 22° C and the first substantial seed mortalities were observed. The largest 7mm seed in cages were observed to be stressed as evidenced by withdrawn mantles and some mortalities were noted. The seed scallops were hastily moved to makeshift bottom cages at a cooler water site (19° C) off Menemsha Beach in Vineyard Sound. On 14. July after a week at the Menemsha Beach site where the water temperature was recorded to be 19° C, more mortalities were observed. Heat stress before and during the transfer from the Lagoon Pond site is believed to be the major cause for mortalities. However, spider crab predation and biofouling of the bags were also suspect. Mortalities were higher in the bags stuffed with window screen when compared to those with monofilament. The bags could not be adequately cleaned at this new site located and hour's drive from the hatchery.

With water temperatures at the Menemsha site continuing to rise and all potential offshore growers still stymied by regulatory authorities, efforts were made to find a legal site in cold water to relocate the stressed sea scallop seed. On 24. July, a letter was secured from Marguerite Holoway, the Shellfish Constable of the town of Truro, who kindly agreed to accept the seed scallops and provide a legal limbo for the seed in Cape Cod Bay until the offshore growers could get their lease sites approved.

Juvenile sea scallops (3-6mm) were cultured in 1mm mesh Japanese spat bags.

Offshore Field Culture

Design of the bottom growout system by Frank Dutra, Offshore Culture Investigator, was finalized with the assistance of local lobster trap manufacturer Robert Ketcham. Delivery and construction were slated for the middle of July. A design and construction workshop was held for the trainees in the MVSG Aquaculture Training Program on 18. July followed by a trial deployment at the Menemsha site on 19. July. Trainees later completed construction of six vinyl coated wire (1-1/2" mesh), 27"x27"x54", 18"x18" tier bottom units.

On 29. July, with a water temperature of 22° C at Menemsha, transfer operations under the direction of Frank Dutra were hastily commenced at 10:00 AM. Prospective scallop farmer and draggerman David Dutra captained the eastern rigged dragger F/V Richard and Arnold which would carry the seed scallops and crew from Menemsha to the Cape Cod Bay site in Truro. The bottom units and bags of seed scallops were quickly emptied into a chilled sea water bath by a crew of five on the Richard and Arnold. Emptying, stripping and sorting of the 1 mm mesh bags was carried out during the seven hour steam to the growout site. Heavy losses, presumably due to thermal stress were noted. Weather conditions at the Cape Cod Bay site were deemed too rough to safely begin stocking operations prompting a trip to Provincetown Harbor, where David's wife and partner Judy joined efforts at 10:00 PM. Stocking densities were volumetrically determined (20 scallops/ml) to equally distribute the remaining 90,000 scallops evenly between the 75 tiers available. Over 80% of the 519,000 2mm scallops transferred to the inshore culture systems were lost during the month of July when regulatory delays prevented transfer of the seed stock to cold water growout sites. Tired MVSG employees, aquaculture trainees and newly christened scallop farmers David and Judy Dutra were briefed in volumetrics and stocking protocols. The crew stocked 130 2.5mm mesh pearl nets (600 seed/net) and ten 18" x 24", 1/8" mesh plastic bags (1200 seed/bag) and quickly returned the seed to the chilled bath. Elevated water temperatures within the harbor necessitated a return to the growout site by Captain David Dutra and Offshore Culture Investigator Frank Dutra at 2 AM.

Frank, David, and Judy Dutra, and M.V. Aquaculture Pogram Trainee Jeff Clements distribute seed sea scallops into pearl nets prior to stocking the Cape Cod growout site.

Moderation of the sea conditions and the return of daylight allowed deployment at the site to begin at 8:00 AM on 30. July. Bottom units were loaded with either two pearl nets/tier, secured overhead to maximize flow and service area, or one rigid 18" x 24" bag/tier. Fully loaded bottom units were secured to an anchored main line separated by a distance of 50' with a bridle and gangion arrangement similar to that used in the lobster trawl industry. Trawl floats were added to the top of each unit to ensure the proper alignment of the cages on the sea floor. An experimental gangion release was attached to one of the units for the same purpose. The bottom tier of each unit was left empty to avoid mortalities associated with excessive siltation. Loran bearings were noted at each end of the main line to facilitate retrieval by a diver or grapple. The substrate conditions were reported to be a coarse gravel/small cobble type at a depth of 65'. The site is known to have supported a population of sea scallops in the past. Transfer of the seed sea scallops to the offshore culture site was successfully completed by 12 PM on 30. July.

David and Frank Dutra prepare to deploy a bottom cage with plastic mesh bags at the deep water Cape Cod growout site.

With declining surface water temperatures in September (17° C on site), tending operations commenced aboard the Richard and Arnold at 11:00 AM on 29. September -- 61 days following the initial deployment in Cape Cod Bay. Trainees from the MVSG Aquaculture Training Program (NOAA) and the Nantucket Aquaculture Program (NOAA), and program directors Richard Karney and Frank Dutra (Offshore Field Investigator for the project) joined Dave, Judy and Bob Dutra aboard the Richard and Arnold. Anticipating normal growth rates reported for the species and a possible doubling in the volume of the scallops, an additional five cages with 75-3/16" plastic mesh bags were brought along. Upon arrival on the growout site, the original five bottom units were brought aboard for routine monitoring, grading and thinning. Weather conditions were ideal with calm seas, light winds, and seasonably warm air temperatures.

Pearl nets from three bottom units were emptied into containers of ambient sea water while the 75-3/16" mesh bags were prepared for stocking. Fouling of the 2.5mm mesh pearl nets was almost entirely absent and predation restricted to a relatively low number of small crabs and starfish which may have gained access prior to their onsite deployment. It was decided to reuse the existing pearl nets due to their excellent predator protection properties and lack of fouling experienced thus far. Other predators noted on the exterior of the bottom units included two crab species, lobster and starfish. Competitors within the nets consisted of numerous tunicates and several other bivalves, including a number of bay scallops.

The contents of 25 pearl nets were randomly sampled to determine growth, survival and volume for optimal stocking densities. Sizes ranged from 12 to 22 mm with a mean of 16mm. A survival rate of 66% yielded a total of 60,000 scallops which were equally divided into ten bottom units with 50% returned to the pearl nets and 50% to 3/16" mesh bags. Sieving/grading operations were suspended due to shell frailties, "biting" amongst cohorts, and the relatively small size range. Due to the space and time constraints, a total of three cages were restocked with the remaining two units scheduled for later tending by the Dutra family. The Richard and Arnold and its crew returned to Provincetown at 6PM on 29. September, 1995.

A pearl net sampled on 11.November showed good survival of the seed sea scallops.

In preparation for reducing the density of the field cultured sea scallop seed, 240 3/16 inch mesh ADPI bags were ordered in early November. On November 10, fishermen from the MV Aquaculture Training Program, accompanied by trainers, joined field investigator Frank Dutra and Judy and David Dutra of the Truro Aquaculture Project, to assemble the ADPI bags, and field growout cages. On November 11, a site inspection was conducted on the Cape Cod Bay growout site, to sample the seed for growth and survival, and to thin some of the seed into new growout bags. Survival was good, with little evidence of recent mortality or predation, however, scallops were observed to have escaped from some of the culture bags that had not been properly fastened. Random samples of the seed ranged between 9.8 and 32.2 mm, with an average shell height of 22.4 mm. There was no difference in the seed grown in 2.5 mm mesh pearl nets compared with 1/8 inch mesh ADPI plastic bags. During the period from the last sampling on September 29 (range = 12-22 mm; average 16 mm), the seed grew at a rate of about 3 mm per week.

With the exception of a random sampling of one bottom cage for growth and survival by Captain David Dutra on 17. March, no field activities were attempted during the abnormally stormy winter months. Sea scallop size was estimated to be between 25 - 35 mm, with no apparent signs of mortality or overcrowding. The sea scallops were evenly distributed within the growout containers maintaining their relative spacing through byssal attachment as observed with juvenile bay scallops under similar conditions. The tending vessel F/V Richard and Arnold was in dry dock prior to the 15th, and deteriorating weather conditions prohibited a planned voyage on the 19th and 20th of March. The Offshore Field Investigator logged 20 hours in consultation and gear work, as well as attendance at a meeting of the Sea Scallop Working Group in lieu of the planned excursion. Additional consultations were conducted either by phone or in person on approximately a weekly basis.

During the course of consultations with the Dutras, a growing concern over scallop seed supplies for planned expansion efforts by the Truro Aquaculture Project during the 1996 growing season was expressed. Perspective suppliers were unable to produce for various reasons, including spawning difficulties. It was decided that the Offshore Field Investigator could best serve the Truro Aquaculture Project by attempting to rear a limited number of scallops at Nantucket Harborlife's facilities with the experience gained the previous year at the Martha's Vineyard Shellfish Group's spawning. Broodstock scallops obtained from the MVSG and Cape Cod Bay were successfully spawned on Nantucket on March 22 after two unsuccessful previous attempts. The larvae had attained D stage by the end of March. Approximately 10,000 .75-1.5 mm seed were eventually delivered to the Truro site on 13. June. A primary field nursery system suitable to small seed and culture conditions at the Truro was designed and constructed. The system minimizes labor costs and hazards of thermal stress associated with land based nursery culture systems. The Offshore Investigator spent 40 hours in the preparation of spawning and rearing facilities in an inactive section of Nantucket Harborlife's lab for this project.

A preliminary meeting was held on 3. April, 1996, with a representative from a mold injected plastics manufacturer to discuss design criteria for a rack and tray grow out system suitable for bottom culture of sea scallops. This product is deemed of particular importance to the Truro Aquaculture Project's continuing success because of concerns over right whale entanglement with any type of suspended culture array. In addition, the present unavailability of an off-the-shelf unit has necessitated many hours of labor devoted to the construction of vinyl coated wire cages, which seriously conflicts with the farming/fishing schedules of the operators. Unseasonable weather conditions and conflicts of schedule prevented any further field investigations during the month of April.

On site inspection and grading operations were commenced during two trips in May. Fouling and predation were negligible, with the exception of two tiers out of thirty sampled. Specimens of 3"

starfish were found in two of the original pearl nets, apparently overlooked as juveniles during stocking operations.

A density dependent growth and survival relationship was observed between scallops stocked at two different densities. A random sample of animals held at .69/ square inch on 19. May yielded an average shell height of 38.35 mm with an overall survival rate of 96%. Animals held at 1.67/ square inch sampled on 22. May yielded an average shell height of 35.03 mm with 90.5% survival.

Further grading of overcrowded animals continued in June, with a recommendation of .18 scallop/ square inch for the majority with several other densities established for comparison, contingent upon a September thinning. Time constraints allowed for only the most crowded of animals being thinned before the operator began his summer fishing season on 15. June. The highest density remaining is now .69/ square inch.

Preparations were made on Nantucket for the transfer of 10,000, 1-2 mm scallops from the March spawn. These were volumetrically stocked at approximately 1,000 per tier in 1.5 mm mesh polyester spat bags with vexar substrate inserted to prevent collapse of the fine mesh and provide resettlement sites for the evenly distributed juveniles.

A follow up meeting was held with the plastics manufacturer including an on site inspection of the existing systems.

Spat collection bags were deployed on site to determine the feasibility of this practice in Cape Cod Bay.

All operations were finalized on 13. June, to be resumed in September when declining water temperatures allow for further thinning.

Land Based Juvenile Culture

A sample of sea scallops retrieved from the Truro Aquaculture Project growout site on 10. November, 1995 measured an average shell height of 22.4mm.

A sample of about 500 sea scallops was retrieved from the Truro Aquaculture Project growout site on November 10, 1995 and held in raceways of flowing ambient seawater in the hatchery. This cohort sample allowed for a monitoring of the sea scallops' growth over the winter months. A random sample measured on November 14 gave an average shell height of 22.4 mm. By December 18, a random sample averaged 27.2 mm; growth averaged about 1 mm per week.Some of the seed was distributed to five of the fishermen in the MV Aquaculture Training Program for experimental growout on their lease sites.

We continued to follow the growth and survival of a small sample of about 100 of the seed scallops over the course of the winter. Throughout the period, they were held in a raceway of flowing ambient seawater in the hatchery. A sample of 30 measured on 16. January (water temp. 0° C) gave an average of 31.2 mm with a range of 20.0 -40.0 mm. A sample of 30 on 14. February (water temp. 0° C) averaged 30.8 mm with a range of 14.8 - 38.2 mm. On 14. March (water temp. 2.5° C) the total group of 110 scallops was measured and gave an average of 31.8 mm with a range of 14.0 - 42.5 mm.

A sample of 106 measured on 12. April (water temperature 5° C) gave an average of 34.7 mm with a range of 14.3 - 47.1 mm. On 16. May (water temperature 12.5° C) the entire group was measured again and gave an average of 40.5 mm with a range of 19.1 - 51.5 mm. A final measurement was taken on 14. June (water temperature 19° C). At that time, they averaged 43.1 mm with the largest at 55.0 mm and the smallest at 24.9 mm. The growth data is graphically presented in Appendix 4.

Outreach and Data Dissemination

Throughout the project, every effort was made to share the insights from our investigations.

Copies of quarterly reports have been sent to Michael Dadswell, Sandra Shumway, Ron Smolowitz, Harlyn Halvorson, Frank, Judy, and David Dutra.

On November 7, Mr. Karney presented a slide show of sea scallop culture methods to the fishermen in the MV Aquaculture Training Program, in preparation for their work at the Truro site on November 10 and 11.

Mr. Karney is an active member of the Sea Scallop Working Group of the University of Massachusetts Dartmouth's Policy Center for Marine Bioscience and Technology, attending meetings in Hyannis on November 17, December 15 and March15. A slide presentation of the successful sea scallop culture work carried out under this grant was presented at the November 17 meeting.

Slide presentations of the sea scallop project were presented at the NMFS Milford Aquaculture Seminar on 27. February and the Massachusetts Shellfish Officers Association annual meeting on 21. March. The Principal Investigator presented a paper entitled "Hatchery and Field Culture Techniques for the Giant Sea Scallop, Placopecten magellanicus" for the 88th National Shellfisheries Association meeting in Baltimore in April.

The Principal Investigator has provided photos to illustrate this sea scallop project for inclusion in an article that appeared on the first page of Aquaculture News and another article which appeared in the 1996 Spring/Summer issue of "Nor'easter, Magazine of the Northeast Sea Grant Programs ."

The Principal Investigator is part of the technical support group for the Westport Sea Scallop Enhancement Project funded under the NMFS Saltonstall - Kennedy grant program. In support of

the project, he attended a technical planning meeting of the group on 15. March and 19. December, and hosted a meeting on the Island on 24. March where local lobstermen and draggermen, unhappy with the siting of the project south of the Vineyard, met with the Principals of the project and agreed on an adjacent site acceptable to all parties. A letter was sent by the Biologist to the New England Fisheries Management Council in support of this pioneering aquaculture project in the EEZ on 30. January.

The Biologist answered questions regarding sea scallop culture for Bill Mook of Mook Sea Farms, who is conducting experimental culture of this species under NMFS funding.

Mr. Frank Dutra disseminated information about the sea scallop culture project on the internet and fielded numerous phone inquiries.

Project Management

Richard Karney, Shellfish Biologist and Director of the Martha's Vineyard Shellfish Group, Inc., was Principal Investigator for the project and, as such, supervised all aspects of the project. Mr. Karney administered the grant providing all legal assurances, authorizing all expenditures, and preparing all progress reports.

Mr. Karney conducted the literature search and corresponded with sea scallop culture consultants from Canada and Maine. Elizabeth Scotten, MVSG hatchery Technician, and Mr. Karney performed the tasks associated with the hatchery production and culture of seed sea scallops including phytoplankton culture, obtaining and conditioning broodstock, spawning, larval culture, land based nursery culture, and inshore field culture. With the assistance of fisherman trainees in an aquaculture training program, Mr. Karney and Ms. Scotten constructed the lab culture units (downweller sieves) and several inshore field culture units (nursery cages).

Frank Dutra, Director of Shellfish Aquaculture and Enhancement for the Nantucket Research and Education Foundation, was the Offshore Culture Investigator for the project. His responsibilities included the design, construction and deployment of the offshore field culture units, and supervision of the offshore culture of the sea scallops. Frank Dutra provided offshore culture expertise to David and Judy Dutra, dba the Truro Aquaculture Project, who performed the day to day tasks associated with the culture of sea scallops at the deep water growout site in Cape Cod Bay in Truro. Field culture units were constructed by the Dutras with the assistance of the MVSG Aquaculture Training Program participants. Frank Dutra was responsible for gathering growth and survival data for the sea scallops cultured at the Truro site and provided draft reports of the offshore field culture investigations. He was also responsible for a second spawning on Nantucket for the Truro Project in March of 1996, and the subsequent delivery of 10,000 .75-1.5 mm seed.

Diane Leonard Bookkeeping provided secretarial and bookkeeping services for the project. Fulchino and Co., accountant for the MVSG, conducted an audit.

FINDINGS

True to the original proposal, the project adapted and transferred hatchery and field culture methods for bay scallops to a successful demonstration culture for the giant sea scallop. During the project, sea scallops were successfully spawned and cultured in the hatchery, in a land based nursery system, floating inshore nursery cages, and bottom cultured in cages on a deep water site in Cape Cod Bay.

Starting with just over seven million eggs, we swimmingly took 1,350,000 pediveligers to set

systems during a larval culture period which lasted almost forty days. These were cultured in both upweller and downweller land based nursery culture systems. A total of 519,000 2mm seed were successfully transferred to inshore culture systems which included Japanese style spat bags and floating nursery cages. Over 80% of the 519,000 2mm seed scallops were, however, lost due to heat stress during the month of July when regulatory agency delays prevented the scheduled transfer of the seed stock to the cold water offshore growout site.

The 90,000 surviving scallops were hastily transferred to pearl nets and plastic mesh bag growout units in late July. Two months later, at the end of September, 60,000 seed scallops remained (66% survival) and averaged 16mm in shell height. The observed mortality was not recent, and is suspected to be the result of the heat stress before and during transfer from the inshore site.

When examined on 11. November, the offshore cultures showed little evidence of recent mortality and had grown to an average of 22.4mm. At the time of the final monitoring in May, the least dense cultures averaged 38.35mm with a survival rate of 96% from the September baseline. Seed scallops cultured at a higher density grew to an average of 35.03mm with a 90.5% survival from September.

The most significant problem encountered during the project was the difficulty of securing the required permits for the offshore culture sites. By early July, we had successfully produced over one half million 2mm seed, ready to be stocked in culture units offshore. The amount of sea scallop seed we produced exceeded the capacity of the offshore culture units budgeted in this project, and we planned to distribute the surplus seed to additional offshore growers. We had hoped to expand the scope of the project with data from additional offshore culture operations. Unfortunately, all of the enthusiastic potential offshore growers found it impossible to secure the necessary permits to allow them to begin offshore culture investigations. Over 80% of the sea scallop seed died of heat stress in inshore waters while potential offshore growers were frustrated in their attempts to secure permits from the regulatory bureaucracies!

All of the seed would probably have died, had we not found a "loophole" in the regulatory tangle that allowed for a legal transfer of the dying, heat stressed seed to a colder deep water site. On 24. July, a letter was secured from Marguerite Holway, the Shellfish Constable for the town of Truro, who kindly agreed to accept the seed scallops and provide a legal limbo for the seed in Cape Cod Bay until offshore growers could get their lease sites approved. Massachusetts Shellfish Constables have carte blanche to culture seed shellfish on up to 20 acres in their respective towns.

The only other problem encountered in this project was our inability to secure ripe broodstock for a scheduled second spawning attempt in the fall. In lieu of the second spawning, we attempted to artificially ripen a number of adult sea scallops during the fall and early winter of 1995. Following a couple of months of supplemental feedings with cultured phytoplankton and manipulation of photoperiod, the scallops did ripen and were eventually spawned at the Nantucket hatchery. This attempt to condition sea scallops for spawning was, however, preliminary and further investigation is needed to refine the process.

EVALUATION

Original Project Goals

The goal of this project was to develop hatchery and field culture methods for the giant sea scallop. The new sea scallop production technology was to be patterned after successful bay scallop culture methods. We proposed to adapt hatchery and nursery culture methods developed by the MVSG over the past 15 years to a successful pilot production project for sea scallops. Likewise, we

proposed to use a variation of an experimental growout system that has proved promising in field trials with the bay scallop on Nantucket for the offshore culture of sea scallops in this project.

The success of this pilot production project for sea scallops can be measured by both the quantity and quality of giant sea scallops produced. More specifically, the success of our efforts are a function of the survival and growth of the sea scallops we cultured.

Two modifications were made in the proposed project statement of work over the course of the investigation. The offshore field grow out site was changed from the intended deep water lease area of the Southeastern Shellfish Association at the mouth of Buzzards Bay to an alternative deep water lease site of the Truro Aquaculture Project in Cape Cod Bay. This change resulted from the difficulties encountered by the offshore growers in securing the necessary permits from the regulatory agencies. The Truro Aquaculture Project, like the Southeastern Shellfish Association, is comprised of commercial fishermen, so the change in no way altered our original intent that commercial fishing interests be directly involved in the project.

Our inability to locate ripe broodstock in the fall of 1995 precluded a scheduled second spawning and culture attempt. The success of the spring culture, however, provided ample opportunities to test our culture methods, and meet the planned objectives of our investigation. Further, in lieu of the second spawning, we conducted a preliminary investigation to artificially ripen a number of sea scallop broodstock. Conditioning broodstock for spawning is an important component of hatchery culture technology and our investigation provided information supportive of the project's goals.

Over the course of this investigation, we successfully achieved the goals and objectives which we set out to meet. Using time tested culture methods for the production of bay scallops, we successfully produced over 50,000 38mm sea scallops from fertilized eggs. This successful pilot production of sea scallops provides a methodology that can be utilized for both stock enhancement or private aquaculture of sea scallops. The production technology developed in this project may one day be used to restore overfished natural stocks and/or provide alternative employment and new business opportunities for fishermen in the Northeast.

Information, Products and Services

The development and demonstration of hatchery and field culture methods for sea scallops accomplished over the duration of this project has generated information, products and services beneficial to the area's fishing industry.

Information -- The sea scallop culture information developed in this project provides a manual for the hatchery and field production of sea scallops. The information made available includes:
1) a bibliography of scallop biology, culture, and management,
2) methods used to ripen sea scallop broodstock for spawning,
3) methods successfully used to spawn sea scallops,
4) methods to culture sea scallop larvae,
5) a feeding regime for larval sea scallops including species, cell densities and volumes,
6) methods used to maximize survival of setting larvae,
7) land based nursery culture methods for post set juvenile sea scallops incorporating downweller sieves and upweller silos,
8) successful methods to field culture small juvenile sea scallops in spat bags and nursery cages,
9) methods for the deep water cage culture of juvenile scallops using pearl nets, plastic mesh bags and bottom cages,
10) growth data for all phases of the hatchery and field culture of sea scallops.

Products -- 1) Over 90 thousand seed sea scallops were produced and provided to the Truro Aquaculture Project for experimental culture. In July, over a half million 2mm seed were made available to the industry, but could not be used due to the inability of the offshore growers to obtain all necessary permits.
2) A cage design for the field culture of sea scallops has been developed. Preliminary efforts to design a plastic rack and tray growout system suitable for bottom culture of sea scallops were undertaken when the Offshore Field Investigator and Principals of the Truro Aquaculture Project met with a manufacturer of mold injected plastics.
3) A primary field nursery system for sea scallops has been designed and constructed with materials readily available to the aquaculture industry, minimizing labor costs and the potential hazards of thermal stress associated with land based systems.

Services -- 1) Commercial fishermen David and Judy Dutra, dba as Truro Aquaculture Project, have received aquaculture training over the course of their participation in the project.
2) Likewise, fishermen trainees with the MVSG Aquaculture Training Program received hands-on aquaculture training through their participation in all aspects of the hatchery and field culture investigations of this project.

Benefits to the Fishing Industry

The information, products and services resulting from this project all support the development of a sea scallop culture technology which can be used to help restore natural depleted beds through stock enhancement efforts, or be used in the development of aquaculture ventures that can provide alternative employment opportunities for fishermen displaced by the collapse of natural offshore stocks.

Every effort was made to share the information, products and services resulting from the project. Copies of quarterly reports were provided to both prospective growers and persons in the academic community involved in scallop aquaculture work and aquaculture policy development. These included David and Judy Dutra of the Truro Aquaculture Project, Dr. Mike Dadswell of Acadia University and the Great Maritime Scallop Trading Company, Sandy Shumway of Long Island University, Dr. Harlyn Halvorson of the Sea Scallop Working Group of the University of Massachusetts Dartmouth's Policy Center for Marine Bioscience and Technology, and Ron Smolowitz of the Westport Sea Scallop Enhancement Project.

The Principal Investigator presented a slide show of sea scallop culture methods to the fishermen in the MVSG Aquaculture Training Program. The fishermen trainees also received hands on aquaculture experience through their participation in the construction and deployment of the offshore field growout units.

Slide presentations of the sea scallop project were presented at the Gloucester Fisherman's Forum, the Sea Scallop Working Group, the NMFS Milford Aquaculture Seminar, the Massachusetts Shellfish Officer's Association Annual Meeting, and the 88th Annual National Shellfisheries Association Meeting.

The Principal Investigator has provided photos to illustrate this project for inclusion in articles which appeared in "Aquaculture News" and "Nor'easter, Magazine of the Northeast Sea Grant Programs". The Principal Investigator is part of the technical support group for the Westport Sea Scallop Enhancement Project, a pioneering aquaculture project in the EEZ, funded under the NMFS Saltonstall-Kennedy Grant Program.

Further, the Biologist shared sea scallop culture information with Bill Mook of Mook Sea Farms,

who is conducting experimental culture of the species under NMFS funding.

The pioneering culture efforts for sea scallops initiated in this project provide an important foundation for future sea scallop culture endeavors which are key in reversing the crisis of supply in the Northeast fishing industry. Sea scallop aquaculture holds great promise to both provide the means to replenish wild stocks through seeding efforts and to provide alternative employment and new business opportunities for displaced fishermen. Hatchery culture techniques discovered during the course of this investigation may be used by public shellfish managers to facilitate stock enhancement programs. Stock enhancement will result in increased harvests for fishermen. Hatchery and field culture innovations should both prove valuable to private aquaculture ventures. Private aquaculture ventures, in turn, will offer fishermen alternative employment opportunities. Further, any increase in seafood product supply made available through the application of the new sea scallop aquaculture technology promises to revive the supporting seafood handling and processing industries devastated in the wake of restricted harvests.

Need for Government Financial Assistance

The Martha's Vineyard Shellfish Group, Inc. is a locally funded, non profit corporation managing inshore species under the jurisdiction of local municipalities. Local tax dollars support our hatchery and field production of economically important inshore species. Local tax dollars will not be appropriated for production of species not under municipal management or control. Federal funding was required to transfer our successful aquaculture methods for inshore species to the sea scallop.

CONCLUSIONS

The project successfully met its goal to develop and demonstrate hatchery and field culture methods for the Atlantic sea scallop. We transferred and adapted successful hatchery and field culture methods for the bay scallop to the sea scallop. We demonstrated and documented a culture methodology which resulted in the production of 50,000 38mm sea scallops from fertilized eggs over the course of a year and a half. During this pioneering effort, we directly involved members of the commercial fishing industry. We shared our findings with the fishermen, provided training in aquaculture techniques, and supplied seed sea scallops and culture cages to fishermen attempting to grow sea scallops.

As became perfectly clear during this project, the development of sea scallop aquaculture is severely hampered by the regulatory process. It is nearly impossible to secure permits to conduct experimental operations, let alone any production scale operations. Streamlining the regulatory environment is probably the single most important thing that needs to be done. A mechanism that allows and expedites the permitting of experimental and pilot scale culture operations is crucial to the development of sea scallop aquaculture!

As with any technology, the sea scallop culture methods developed and described in this project can stand to be refined. This pioneering sea scallop production project was preliminary by nature. Although it was not within the scope of this project to conduct an economic analysis of the methods, clearly, the methods employed in this experimental effort were labor intensive. The slower growth of this species when compared to the bay scallop resulted in lengthy larval and land based juvenile culture periods. Future work should investigate the possibility of bypassing much of the land based juvenile culture, by moving set scallops into the field in spat bags shortly after they metamorphose. Savings in labor may more than compensate for any losses. Preliminary work on such primary field nursery systems was attempted in June of 1996, but the success of these systems has yet to be determined.

Although we were successful in our attempt to artificially ripen sea scallop broodstock, the effort was preliminary and shotgun, involving far too many variables to clearly determine which treatments were significant. A reliable means of artificially conditioning sea scallops to spawn will be crucial to any production scale culture of sea scallops. The low temperature requirements of sea scallop larvae limit the times of the year in which they can be economically cultured inshore. Manipulation of broodstock gonad development would ensure a source of eggs and sperm in the fall and winter months when ambient water temperatures are more conducive to culture, but broodstock is not normally ripe.

Established Japanese field culture methods for scallops incorporating suspended pearl and lantern nets may not be easily transferred to the United States. Conflicts with navigation and fear of entanglement by endangered whale species preclude these traditional culture methods in many areas. The bottom cage culture techniques employed in this project are more likely to be allowed in this country. Prototypes designed after cages used for bay scallop culture on Nantucket, although adequate, are far from perfected. Much work needs to be done to increase the efficiency in both the production and handling of the cages. An inexpensive plastic cage for the efficient field culture of sea scallops does not yet exist and will be necessary before any operation reaches commercial scale. The time and labor required to open and reseal the prototype cages during thinning operations, for example, would prove far too uneconomical for a large production operation. Refinements made to closure systems of bottom cages have recently been successfully developed on Nantucket with bay scallops, resulting in substantial labor savings, but have yet to be tried at the Truro site with sea scallops.