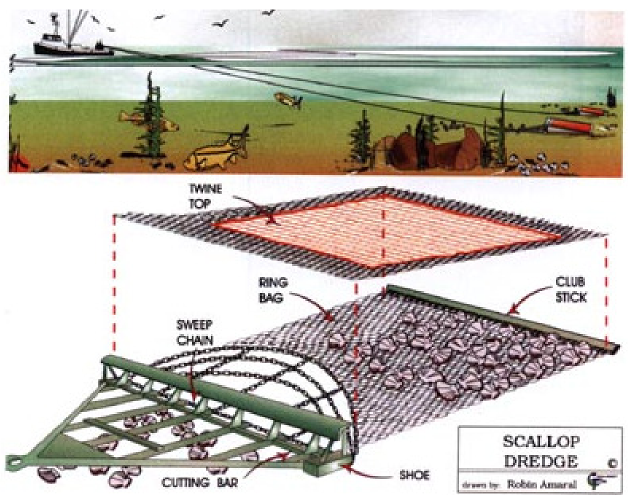
Sea Scallop Enhancement and Sustainable Harvesting

The Seastead Project



The New Bedford style scallop dredge, with top removed for illustration. Drawing by Robin Amaral.

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II. Abstract

The Seastead Project has been a three year effort to demonstrate sea scallop, *Placopecten magellanicus*, resource enhancement off the coast of Massachusetts. The objective of this project was to enhance sea scallop production using the existing Massachusetts fishing industry base by developing a)means to transport scallops live, b) methods to grow-out transplanted scallops on the bottom and in the water column, c) criteria for managing scallop grow-out areas, and d)means to identify potential grow-out areas. The emphasis was to develop and demonstrate the technology to enhance sea scallop production, on a sustainable and environmentally sound basis, using the existing New England fishing industry and infrastructure.

III. Executive Summary

Seastead is a collaboration between scientists and the sea scallop fishing industry to examine potential scallop enhancement/production strategies. After 30 months of effort all required permits had been secured for the first aquaculture research area in U.S. federal waters. The twenty-four square-kilometer area is located 15 kilometers south of Martha's Vineyard, Massachusetts, USA, and is now closed to mobile gear and dedicated to researching culture and enhancement strategies. The site, with average depths of about 30 meters, has been marked by large lighted yellow buoys. The site is in an open ocean location subject to large waves and strong currents.

The site has been stocked with wild-caught scallops. Approximately 40,000 scallops, ranging in shell height from 40-100 mm, were placed in bottom cages, suspended nets, and loose on the bottom in 1997. The scallops were monitored for growth and mortality. In 1998, an additional 80,000 scallops, ranging in shell height from 50-140 mm, were direct seeded on the bottom. The scallops seeded on the bottom were monitored using an underwater video camera sled. The scallops in the cages were hauled and measured. Sub-samples of all groups of scallops were evaluated for health and condition at times during the project. Data was collected to allow for an economic analysis of the culture strategies.

The biggest obstacles the project has overcome, and with great success, were regulatory and social. The project was in part responsible for (a) the formation of the Sea Scallop Working Group in Massachusetts, (b) the formation of an Aquaculture Committee within the New England Fishery Management Council, (c) developing scallop industry awareness of enhancement/area management strategies, and (d) establishing the first working aquaculture site in federal waters.

The project results indicate that bottom seeding of scallops into grow-out areas is a very viable option for managing scallop production.

IV. Purpose

A. Identification of problem

The New England fishing industry is facing hard times. The fish and shellfish resources the industry depends upon are seriously depleted. Proposed conservation measures will restrict catches at levels that will put many fishermen out of business and any remaining fishermen will be operating at lower levels of production. The ripple effects on the economy, including processors and suppliers, will be devastating. The value of the sea scallop industry to Southeastern Massachusetts easily exceeds half a billion dollars annually in good years. This could all be lost quite suddenly.

The decline of the scallop resource has been blamed on overfishing, usually thought of in terms of harvest removals. However, there are other fishing impacts that play significant roles. Frequent towing over the bottom impacts the productivity of the scallops and other species in ways we don't understand clearly. There is non-catch mortality to scallops caused by the dredge while on the bottom (ie, mechanical damage, sediment suspension effects, etc). There is the loss of value and spawning potential by harvesting small scallops. Existing management options can only address these problems by decreasing fishing effort which will reduce employment and most likely lead to the consolidation of the industry in the hands of a few. A much better approach would be to expand the resource base.

There are possible alternative opportunities for the men and infrastructure that compose the fishing industry of southeastern Massachusetts. One of the most promising is sea scallop (*Placopecten magellanicus*) aquaculture and resource enhancement. Many of the prerequisites for success exist. There is a large supply of small scallops, the infrastructure is in place, the unit value is high, and the market is established. Most importantly, the scallops can be reared on naturally occurring feed. The potential is vast, however, much will need to be accomplished to make sea scallop resource enhancement and aquaculture a reality in this geographic area. In the interim, there needs to be a logical progression from today's wild capture fishery to one of husbandry.

This project reviewed the current status worldwide of scallop aquaculture and examined the possible approaches that can be used in southeastern Massachusetts to raise sea scallops for market. Problem areas were identified and the approach to solve these problems were enumerated. What follows is a summary of what the review uncovered.

Background

Scallop culture, as practiced today, was pioneered in the Mutsu Bay region of Japan (Aoyama, 1989). The scallop fishery in that area was subject to significant fluctuations in abundance; a factor common to most scallop fisheries including sea scallops. In 1935, Japanese researchers started on a program to overcome the fluctuations in scallop abundance. The early scientific efforts concentrated on ways to collect scallop spat; the stage in the scallop's life, after the planktonic phase, when it settles to the bottom.

By 1953, local fisheries cooperatives were collecting spat to re-seed fishing grounds. In 1955, they started to hold the spat for short periods of time before re-seeding in order to increase scallop survival. In 1964 a breakthrough occurred in spat collector design that significantly increased the number of spat collected. The increase in spat availability lead to improved methods to hold large numbers of scallops in captivity until fully grown (Ito and Byakuno, 1989). Today seventy percent of Japan's scallop harvest is cultured. The harvest is stable from year to year and is an order of magnitude larger than the previous wild harvest fishery. There are over 1900 scallop harvesting firms in the Mutsu Bay region alone and many other regions also produce cultured scallops.

Since the 1970's, countries in all parts of the world have begun scallop culture operations based on the Japanese model (Kirk, 1979; Paul et al., 1981; Reyes, 1986; Naidu and Cahill, 1986). Some depend on collecting spat, others use hatcheries to produce the spat. Canada has been working on culturing the sea scallop and is on the verge of successfully starting an industry based on culturing. While the world moves forward creating jobs and wealth through aquaculture and resource enhancement, the United States finds itself importing cultured scallops.

Culturing

Scallop culture operations depend on obtaining a large supply of spat, commonly called seed. Two sources of seed are hatcheries and spat collecting devices. Hatcheries usually collect sexually mature scallops from the wild population and spawn them in captivity. Scallops are easily induced to spawn by raising the water temperature (Gruffydd and Beaumont, 1972; Costello et al., 1973; Ito et al., 1975). There are variations in the rearing techniques, and different levels of difficulty, depending on the species of scallop. The Canadians are successfully spawning sea scallops in hatcheries and rearing them through the spat stage (Naidu et al., 1990).

The Japanese, however, have found that hatcheries are expensive to operate when compared to wild spat collection. Their culturing system depends on setting out spat collectors. The spat collectors consist of submerged longlines to which onion bags, stuffed with monofilament netting, are attached. The small swimming scallop larvae pass through the mesh of the onion bag and attach to the monofilament netting. After a month or two they detach but are now too large to pass through the onion bag mesh so they collect inside the bag.

Success of spat collection depends on locating the collectors at the right time and place.

The Japanese have developed an efficient system for timing collector placement utilizing plankton surveys, oceanographic buoys, gonadal indices, and the blossoming of cherry trees (Ozaki et al., 1991). They usually harvest significantly more spat then they can utilize. An interesting consequence is that they select the largest spat, which are the fastest growing, for the culturing operations. There is some indication that this selective process has shortened the time needed to culture the scallops to market size (Ito and Byakuno, 1989). The Canadians have tested spat collectors but have not yet attained the large catches as seen in the Japanese fishery (Naidu and Scaplin, 1979).

Intermediate culture

Scallop spat usually range in size from a few millimeters to about 15 mm depending on the species and holding time. This size scallop, if placed on the bottom, suffer high mortality. Therefore most culture operations hold the scallops, in an intermediate culture phase, until the scallops are about 20-30 mm in size. The most common method of holding utilizes strings of specially designed pearl nets attached to arrays of submerged longlines. Holding the scallops in these nets, up off the bottom, reduces predation and provides better feeding conditions enhancing growth. The Canadians have held sea scallops for one year in the intermediate phase with success (Naidu et al., 1990). Occasionally cleaning of the nets is required during this period.

On the west coast of South America a culturing system was utilized that bypassed the spat collection and intermediate holding phases. Divers harvested scallops of intermediate size and brought them into shallow water where the scallops were held in corrals until grown to market size (Costello, 1985). This method has now been replaced with hatchery reared seed stock.

Final culture

Final culture, or grow-out, can be conducted in a number of ways. Two general categories are cage culture and bottom culture (sea ranching). The most common form of cage culture utilizes a specially designed lantern net; a cylindrical cage of netting with about ten compartments stacked one on top of another. A specific quantity of scallops are placed in each compartment and the nets then placed on longline arrays. After a period of time, about one year, the scallops are thinned and usually placed into a larger mesh lantern net. There are many variations to this theme such as a scallop house (or pocket net) where each scallop has its own individual compartment (Dix, 1981). Other hanging culture methods include ear hanging where the scallop is tied to a string by means of a hole drilled in the hinge, or ear, of the shell. A third method involves gluing scallops to a hanging rope (Cropp, 1985). Obviously, these methods are very labor intensive.

The least expensive method of grow-out seems to be bottom culture (Frishman et al., 1980). Bottom culture does not require expensive nets or labor. The scallops are released onto appropriate bottom to grow to market size and, in some cases, the bottom has been cleared of predators such as crabs and starfish. Upon reaching market size the scallops are harvested by dredges or divers. Appropriate bottom is defined both by ecology and legal/regulatory constraints. The bottom needs to be suitable for scallop growth and have minimal amounts of predators. The bottom should not be in conflict with other users. The bottom can be leased to individual operators who would own the scallops they seed. Another approach, commonly called resource enhancement, involves government supported seeding of common grounds.

Canadian efforts

It is most appropriate to review what is publicly available on the Canadian efforts to raise sea scallops on the east coast. Canadian efforts on sea scallop culture began in Newfoundland in 1971 with the invitation of two Japanese experts to set up an experimental operation. Work also began at this time, at the Memorial University of Newfoundland, to produce seed scallops in the laboratory. In 1975, the Canadian government's Department of Fisheries and Oceans became actively involved in attempts at sea scallop culture, testing various techniques of spat collection and the impact on growth. By 1986, investigators succeeded in rearing scallop larvae in the laboratory through metamorphosis. There is evidence that some of the scallops caught in Newfoundland are from stock enhancement efforts (Naidu et al., 1990).

Large scale production of spat is underway at the Magdalen Islands Experimental Hatchery in Quebec, at the Marine Sciences Research Laboratory in Newfoundland, and at the Aquaculture Research Station in Halifax. One hundred thousand 1.0 mm seed scallops have been produced and transferred to the open sea for growth trials in Quebec. Scallops can reach spat stage in the laboratory in five weeks at 15 degrees C. Scallops do well in 5-15 degrees C but succumb to temperatures above 21 degrees C.

In one Canadian operation, at the end of the intermediate grow-out phase, the two year old scallops were placed into lantern nets. Survival in the lantern nets was estimated to be between 60-75 percent in years three, four, and five. Cages can be cleaned during grow-out with high pressure hoses. In Newfoundland, commercial size scallops have been grown in four years in cage culture vs six years in the wild. Ear hanging has been tried but there are problems with fouling. Bottom culture is less expensive than other methods and the scallops reach commercial size within 3-4 years of transplanting.

The Canadians have found that the choice of a suitable site, for each phase of the aquaculture operation, is critical for success. Limiting factors include disease, toxins, water temperature, and predation.

Southeastern Massachusetts

This project had a limited geographic range, limited time, and a single species focus, *Placopecten magellanicus*. The work that was accomplished will certainly have wide ranging application into other geographic areas and species. However, successful scallop culture is site specific and thus there is a need to focus the research and development effort.

The fishing infrastructure that may most directly benefit from this project includes primarily the New Bedford scallop fleet and the coastal fishing fleets from Cape Cod north to Scituate. The project focused on the technology needed to culture scallops away from the crowded, and possibly polluted, coastal zone. One of the key design considerations was to use the existing scallop industry infrastructure; personnel, vessels, and ports. The scallops that were to be used for stocking are those that are normally taken as bycatch in the commercial scallop fishery; ie, often culled back overboard (40-60 mm shell height). However, ring size changes in the fishery eliminated this source of seed. Consequently, the project relied on directed seed harvest. The project also examined how to hold and transport these scallops live to the Seastead test site.

Problem areas

Project personnel conducted an extensive literature search in order to identify potential problem areas in shifting from a wild capture to a husbandry based scallop fishery. The following is a brief synopsis of what were the major anticipated problems in addition to those of biology and engineering associated with rearing scallops.

1. Site Selection

This project planned to compare two types of grow-out technology; off-bottom culture (arrays) and bottom culture (lanes). The first problem was to determine where to locate the test site. Since the highest priority of this project was to test equipment and procedures in a relatively exposed location the site location task was not overly difficult. A site was needed where a specially designed lantern net array could be moored and then compare its operation to scallops placed nearby on the sea bottom. A site was chosen that was relatively close to New Bedford (fishing), Marthas Vineyard (hatchery), and Woods Hole (science) but still exposed. Fishermen were surveyed to find a place free of most fishing activities. From our combined experience we know the area is not heavily traversed by surface traffic. Bottom water temperature data was checked to confirm that the location did not exceed 18 degrees C in the peak summer months. Finally, scallops have been in the area in the past and are present more often in the heavily used areas to the east and west of the proposed site. However, in the future, sites will need to be chosen to maximize scallop growth and survival and this will require extensive experimentation and user interactions.

2. Seed source

Ultimately, efforts will need to be made to locate the best sites for spat collectors to determine if this methodology is appropriate for Southern New England. Currently, plankton sampling performed by the National Marine Fisheries Service (NMFS) does not separate out sea scallop larvae from other bivalve larvae. There also is no routine examination of sea scallop gonad condition. Spat collection was not a major aspect of this proposal, but its potential can not be ignored. Basically, the existing research capabilities of NMFS and others would need to be reoriented or augmented to support scallop culture activities. There is reason to believe that high concentrations of scallop spat are seasonally present in the area (Merrill, 1965; Merrill and Edwards, 1976). Spat collectors were to be set out at the project test site in the appropriate seasons to confirm the presence of scallop spat and other co-spawner activity however this activity did not take place due to problems in a related project. We were also planning to work closely with the Marthas Vineyard Shellfish Group on their attempts to produce seed scallops, but their project was completed before we received our permits.

For the purposes of this project we decided to take the approach of using wild caught intermediate size scallops (40-60 mm) or larger depending on availability. This approach was used in Japan and Peru when these countries first started their scallop culture industries. Research has shown that scallops above 30 mm in shell height have a much higher chance of survival in bottom culture operations. In effect, this project bypassed the seed problem in order to test water column culture vs bottom grow-out technology.

3. Legal

The project needed to address legal problems associated with setting up a system that would allow a degree of exclusivity to a scallop grow out site. Much has been written about these problems, but little had been done to provide workable solutions needed to support the technologies presented by this project. One approach would be to have the government, both at the state and federal level, identify aquaculture zones in which simplified leasing arrangements can exist. A major part of this project proposal was to propose model law to set up such zones and to issue experimental leases. However, the granting authority (NMFS) decided this was not an appropriate activity for federal funds. Our efforts in this area were funded by the participants.

Competing uses and environmental parameters needed to be addressed from the legal/regulatory standpoint to get the project underway. This resulted in the development of an Scallop Fishery Management Plan (FMP) Amendment by the project team. In Japan, fishery rights are given to fisheries cooperatives to conduct aquaculture operations in designated areas (Ozaki et al., 1991). Our project was to test this concept by having eight commercial scallop companies share the test site defined in the Amendment. The difficulties in getting permits from NMFS limited this activity. A lengthy discussion of the legal/regulatory aspects of this project will be presented in this report because of the importance to future aquaculture and enhancement efforts..

4. Oceanography

There is very little information available about the oceanographic conditions in potential culture areas. The Massachusetts Division of Marine Fisheries has some bottom water temperature monitoring stations in state waters, designed primarily with the lobster fishery in mind, that could be expanded to support scallop culture operations. There are other sources of data that need to be examined. After examining what is available, this project may propose a real-time network of oceanographic monitoring stations. Such information would benefit not only this enhancement/culture project, but also other activities.

B. Objectives of the project

1. Provide alternative economic opportunities for the New Bedford scallop industry.

   The New Bedford scallop fleet is currently overcapitalized - too many boats fishing too depleted a resource. This project planned to demonstrate alternative usage for scallop vessels as tenders in open-ocean grow-out activities. The project also planned to work towards methodology to expand the resource base which in turn should support a larger industry.

2. Develop techniques for the optimal management of a scallop grow-out area

   This project planned to develop and demonstrate new, alternative techniques for improving scallop utilization. Today's practice of repeatedly dredging an individual scallop until it is large enough to shuck is both inefficient and wasteful. Their growth cycle is disturbed, they are smothered in sediments, and dredge and handling-induced mortality may take a high toll. Controlled harvesting in seeded areas, where most scallops are of known and near uniform size, minimizes the above effects. In this project's approach, scallops would be harvested once prior to seeding and once to keep. This reduction in dredging effort on individual scallops and over these controlled-fishing sites is the key to improved growth, better survival, and the restoration of the scallop resource.

3. Develop techniques for the capture, holding, transportation, and seeding of small scallops.

   Essential to the previous goal is the development of methods to hold, transport, and seed undersized scallops. Scallops need circulating, oxygen-rich water and thermal stress must be avoided. This project planned to demonstrate cost-effective systems for holding live scallops and ways to effectively seed a grow-out site.

4. Propose a legal/regulatory regime (model law) for scallop operations.

   The development of commercial-scale culture and grow-out operations is discouraged in this region due to a complicated regulatory framework and unclear policies. This project planned to explore the problem and identify changes or new legislation that would foster beneficial growth in near-shore and off-shore waters.

5. Identify potential scallop grow-out sites in New England.

Scallops, like other filter feeders, are attractive to culture due to the lack of an artificial feeding requirement. In both suspended and on-bottom situations scallops offer excellent potential to commercial growers. They are, however, sensitive to temperature and nutrient availability and siting of grow-out activities will be critical to the success of a venture. The project planned to explore the region for potential grow-out locations based on environmental conditions, conflicting use, and local regulations and infrastructure.

V. **Approach**

A. Detailed description of work performed

This section of the final report is organized chronologically, as a series of quarterly reports, to give the reader a feel for the progression of the work performed. Much of the accomplishments achieved by the project were related to how the process developed to allow the work to take place. The findings section is organized by subject areas.

From November 1, 1995 **To** December 31, 1995

This project has not begun the field work (site preparation) as planned for this quarter due to delays in the Council process. Since this is the first venture of its kind in federal waters there has been much review and discussion. However, significant progress has been made. The project proponents have prepared an Amendment to the sea scallop FMP to allow exclusive use of the project site. This Amendment was approved by the full Council in December for public hearing which will take place on January 19, 1996. The Council will vote later in January on the amendment. If the amendment is approved by the Council it will take about four months for final implementation. This means the project may have exclusive use of the site by late May, 1996. This may not be the best time to seed the site and thus changes to the project plan may have to be made. In all likelihood we will need to have a project extension due to the delays.

A meeting was held on December 19, 1995 in Fairhaven among project participants. There was much discussion on the most appropriate way of capturing the seed scallops for the initial seeding, especially due to the Council delays and new ring size requirements. The general opinion was that it might be best to have one vessel dedicate itself to harvesting the scallops for initial seeding by using special gear on an identified seed bed (peanut pile). We plan to pursue this option by first discussing the idea with the sea scallop industry advisors committee of the Council. Initial contact was made with a number of suppliers of equipment that can be used for the live transport part of the project. Specifications will be developed shortly for the initial purchase of two systems for trial.

We will soon formalize the project technical committee as the Sea Scallop Working Group (SSWG). We plan on inviting all government funded sea scallop aquaculture projects to participate on this panel. One major goal would be to work jointly on bottom cage designs.

From January 1, 1996   **To** March 31, 1996

The project is moving forward at a snail's pace but the most amazing and significant fact is that the project is moving forward step by logical step. On January 19, 1996 a public hearing was held on Scallop Plan Amendment #6 which is the authorization for the project to proceed. While there were some objections voiced by Marthas Vineyard fishermen over the project site, there was overwhelming written comment support for the project to proceed. On January 25, 1996, the New England Fishery Management Council voted to approve Amendment #6 making this the first time an aquaculture type project has been approved for federal waters; a significant milestone for marine aquaculture in this country. NMFS staff, NOAA General Council, and Council staff placed finishing touches on the document for the Federal Register. If all goes according to plan final approval to proceed may be available by June 1, 1996. This entire process to date has taken a significant amount of time and resources and puts the field work about six months behind on the planned time line.

We are still under significant pressure to reach an accord with the Marthas Vineyard fishermen on the site location. Since it will be very important to the future of aquaculture efforts to demonstrate that these activities can co-exist with most types of traditional fishing activities we have decided this issue must be addressed by the project. It falls under our goal of identifying future aquaculture sites and user issues. On March 24, 1996, at the urging of the NMFS Regional Director and local politicians, a meeting was held on Marthas Vineyard with about 16 fishermen plus project participants. A consensus was reached that if we moved the site slightly to the southeast there would be broad active support for the project among all users of the area. We are now proceeding to see if this can be accomplished without impacting the new June 1, 1996 time line. On February 11, 1996 the Army Corps of Engineers renewed our permit until January 13, 2000 or to 18 months after scallops are seeded into the area. Preliminary discussions with the COE indicates a slight move of the area would not be a problem.

Press coverage of the project has been extensive including supporting editorials in some of the regions newspapers including the Providence Sunday Journal. Project participants have been requested to give presentations at many conferences and the AP wired the Council approval nationally.

While site approval has dominated this project this quarter, other work has been accomplished. On January 19, 1996 a meeting was held in Woods Hole concerning the collection and analysis of economic data for the project. Present were project and NMFS economists.

On February 6, 1996, a two day trip on the F/V Westport was made to the site for the purposes of conducting a side-scan survey of the area. A series of transects were made at 1/4 mile spacing and the data was plotted to make a bottom contour map showing sediment type. Control was provided by a differential GPS system purchased for the project. Arrangements have been made with the Marine Biological Laboratory in Woods Hole to charter their small vessel to conduct biological collections at the site in April. Underwater video mapping of the site will be undertaken during April/May as well.

A meeting was held in Hyannis with members of our technical Advisory panel (SSWG). Many of the members have their own sea scallop projects planned or underway. We agreed to work together in designing and building underwater cages for sea scallop culture.

The delays to the project (site approval) have made us rethink how we should collect the initial seed for stocking the project site. To get the project back on track we feel we should conduct a dedicated seed collection cruise as soon as possible after final approval. This will require a special experimental permit from NMFS according to NOAA attorney Joel MacDonald. A letter was written to the New England Council requesting that this be discussed at the March Scallop Plan Development Team (PDT) meeting. At that meeting general criteria for experimental fisheries were discussed but specific requests were not reviewed. We plan to submit a specific experimental fishery request to collect seed to the NMFS Regional Director in the next few weeks.

From April 1, 1996 **To** June 30, 1996

On April 8, 1996 a letter was submitted from Westport Scallop Corporation to the NMFS Regional Director requesting an Experimental Fishery Permit in order to harvest, transport, and seed small scallops. On June 3, 1996 a response was received from Harold Mears, Chief, State, Federal and Constituent Programs Division, requesting additional information. This information includes revisions to the scope of work to be conducted under the S/K grant. These revisions are currently being written.

On April 12, 1996 a meeting was held in New Bedford with draggermen, lobstermen, and scallopers. A consensus was reached on a new site location for the experiment with promises of active support for the project by the attending fishermen. The coordinates of the new site, were submitted to the Council. The Council on the advice of General Council rescinded the original Amendment for the project in order to go out to public hearing with the new coordinates. The public hearing was held in Wareham on May 17, 1996 and received all favorable comments. On May 23, 1996 the Council's Sea Scallop Sub-Committee met and voted to recommend the Council approve the new Amendment and on June 6, 1996 the Council voted approval. The Amendment is now on its way to being published in the Federal Register. The Council approval process has taken nearly two years but this has not been a waste of time. Much has been learned in the process. On June 26, 1996 project participants Cliff Goudey and Ronald Smolowitz were requested to meet with Council staff and Corps of Engineers to propose a process based on our experiences.

Several technical presentations were made during this quarter. Ronald Smolowitz made a presentation at the Aquaculture coalition meeting in Boston on April 29, 1996 and Cliff Goudey made a presentation at the Offshore Aquaculture Conference in Portland on May 10, 1996. On May 17, 1996 the Sea Scallop Working Group (also our Technical Review Panel) met in Hyannis to receive a presentation by Dr. Miriam Barbeau on the state of sea scallop bottom seeding experiments in Canada. Some of the revisions to the S/K Grant are based on this information, and information collected at the Offshore Aquaculture Conference.

The project, while almost a year behind schedule, still has not suffered any serious set-backs. We have received, or at least have not been denied, all permits needed albeit at a snail's pace. During this process we have greatly increased the awareness at a national level of the problems confronting offshore aquaculture and resource enhancement. With the continued support of NMFS and the Council we will hopefully enter our field phase by October.

From July 1, 1996 **To** September 30, 1996

The project this quarter, like previous quarters, has primarily been waged on the paperwork front. A plan for the new site has been resubmitted to the Army Corps of Engineers and we expect no problems with its approval. An experimental fishery request was submitted to NMFS to cover the harvesting, transport, and seeding of the initial group of scallops. In addition, changes to the scope of work and budget were submitted to the project office including a request for time extension. A request to retain scallops for scientific study was denied by NMFS siting the FCMA definition of scientific research as only that being conducted from scientific research vessels. At a meeting in the NMFS Regional Office (September 30, 1996) the request was resubmitted as an experimental fishery. The long and arduous process has provided a wealth of material to define the roadblocks to aquaculture in federal waters. Ronald Smolowitz and Cliff Goudey were requested to present this information at a public hearing on the National Aquaculture Plan on September 20, 1996. The final report will provide extensive documentation of the problems and propose solutions.

Progress has been made on some other fronts. Two small vessels have been lined up for site work including a biological survey using bay scallop rakes. A Marthas Vineyard fishermen has been found that will be able to build the scallop cages. Live scallops were brought in by the NOAA ship Albatross for our tagging work and transferred to the WHOI Coastal Research Lab tanks. A sea-going technician, with a degree in biological oceanography, has been hired to assist in field operations.

From October 1, 1996 **To** December 31, 1996

Paperwork issues still dominated the project this quarter. Amendment Five to the Sea Scallop FMP was approved authorizing the closed area for the purposes of this project. This is an historical first for aquaculture in federal waters. We now have to wait for the regulations to be promulgated by NMFS. We have not received the experimental fishing permit from NMFS to allow us to collect small scallops with a lined dredge. The Corps of Engineers is reviewing our new site plan but is awaiting feedback from NMFS Habitat Division. The Grants office has approved our time extension request and project changes.

We chartered the F/V Teresa M, a 42' fishing vessel from Marthas Vineyard, to survey the test site with an underwater camera provided by the NURP Program. The bottom was found to consist of areas of hard sand, silty sand, and sand with rocks present. This preliminary survey will be followed up by biological sampling once the permit situation is resolved. Another side-scan sonar survey will also be conducted.

The Woods Hole Oceanographic Institute donated four large navigation buoys to the project that will be used to mark the test site corners. The 60" spherical buoys, with attached light towers, were transported to Westport Scallop Corporation facilities in Fairhaven by MIT Sea Grant truck. The USCG has been contacted and we foresee no problems with the buoy design. The buoys will be sandblasted and painted by unemployed fishermen. We plan to use old scallop dredges to anchor the aquaculture tract marker buoys in place (swords into plowshares).

From January 1, 1997 **To** March 31, 1997

Westport Scalloping Corporation's three year effort to demonstrate sea scallop farming off the coast of Massachusetts has finally moved into the field stage. This S-K project, known as Seastead, is a collaboration between scientists and the sea scallop industry to examine potential scallop enhancement/production strategies. After 30 months of effort all required permits have been secured for the first aquaculture area in U.S. federal waters. The nine-square-mile area is south of Martha's Vineyard and is now closed to mobile gear and dedicated to researching culture strategies. The site, with average depths of about 30 meters, has been marked by large lighted yellow buoys set by the F/V Concordia. The buoys were donated by the Woods Hole Oceanographic Institution and overhauled by fishermen in Fairhaven.

Plans now call for stocking the site with wild-caught scallops sometime in early May, 1997. The scallops will be placed in cages, suspended nets, and loose on the bottom. The scallops will be monitored for growth and mortality. The project managers have been actively soliciting the participation of researchers and industry who have an interest in using the protected site to test equipment and strategies that would further the project goals. A number of research proposals have been generated by this activity.

Significant progress has occurred in the project's supporting activities. Several hundred live scallops have been caught and transported to the WHOI Coastal Research Lab where they are being held for tagging/mortality studies by Dr. Dale Leavitt. Losses have been under 5% in thirty days of holding. Cliff Goudey contacted Riverdale Mills Corporation which then donated plastic coated wire for the construction of fifty large scallop bottom cages. Fukui North America is putting together a proposal for a suspended scallop culture system for the Seastead site. The Project's legal advisor, Attorney Ken Riaf, has been putting together a detailed analysis of the regulatory process to assist in resolving scallop site selection issues.

The Project's economists, Dr. Hauke Kite_Powell and Dr. Porter Hoagland, have worked on two aspects of the economics of scallop farming operations: the market for scallops in New England and the cost structure of vessel operations. Using data on historical scallop landings and prices, they have developed simple models that capture seasonal variations and market responses to changes in landing volume. Historical vessel cost data provide information about fixed, variable, and crew wage costs for trawlers and scallop dredgers in various size ranges. Both market and vessel economic models are useful to the financial and operational planning of full_scale scallop farming operations, and vessel cost data are useful to economic analysis of offshore mariculture operations for other species as well.

The project manager, Ronald Smolowitz, up until this quarter has been fully involved in getting the project permits in place. Now his efforts have shifted to reviewing an extensive amount of literature on scallop harvesting and transport strategies in preparation for the next phase. Dr. Dale Leavitt and Ron Smolowitz have drafted the detailed bottom seeding research plan. Cliff Goudey has been arranging for the side scan and video surveys of the site. We are in the process of developing a mailing list of all interested parties, especially fishermen, in order to distribute a newsletter to keep everyone informed of project activities.

All in all, the project is moving along at a slow and steady pace. The project has received a significant amount of press coverage, nationally and internationally, for toppling barriers to offshore marine aquaculture. Where sea scallop resource enhancement and aquaculture were mocked by most just two years ago, these concepts are now entering main stream management discussions. The Sea Scallop Working Group, which acts as the Technical Advisory Panel for the Seastead project, has received recognition as an effective approach for aquaculture development. Now that we successfully completed the initial phase of the project we look forward to the technical challenges ahead.

From April 1, 1997 **To** June 30, 1997

Significant progress has been made this quarter. Three dedicated project trips were conducted during the quarter; one using the F/V Contender and two using the F/V Westport. The first trip on the F/V Contender was for the purpose of conducting a side scan sonar survey of the Seastead site, however, equipment problems prevented the accomplishment of the objective. A second trip, using the F/V Westport resulted in a successful side scan survey of the site. In addition a series of biological samples were taken and the bottom was filmed using a video camera.

The third trip, on the F/V Westport was for the purpose of collecting scallops to transport to the Seastead site for seeding the bottom. Approximately 35-40,000 sea scallops were harvested, transported, and seeded on the site. Scallop on deck holding strategies and tagging techniques were tested. Over 300 scallops were tagged by drilling holes in the hinge and inserting various types of tags.

Forty-eight scallop bottom cages were constructed out of the wire mesh donated by Riverdale Mills. We are in the process of trying to determine the best method for providing ballast and keeping the cage floor up above the substrate. A meeting was held with representatives of Fukui North America and Coastal Aquaculture Supply for the purpose of designing an open ocean lantern net array using Japanese nets. This would be in addition to our planned large net array.

A total array price of about $6000 was quoted. We will be assessing where we stand on our budget and may submit a request to modify the budget in order to test the Japanese equipment.

We will be requesting a time extension in either case due to the late approval for the project site (February 13, 1997).

Initial trials have been conducted to assess the survival of small scallops that are being harvested, handled, and transported on deck of the fishing vessel. To date three attempts have been made to assess sea scallop survival. For Trials One and Two, the scallops were harvested during the last tow of a trip by a commercial scallop vessel (F/V/ Westport) and held on deck in a fish tote with running seawater. In both cases the scallops were held on deck for approximately 18 hours before being transported to the Rinehart Coastal research Laboratory (RCRL) at Woods Hole Oceanographic Institution, a two hour trip by truck. At the RCRL the scallops were placed in a seawater table with flow_through seawater and held for over two months to monitor survival.

From July 1, 1997 **To** September 30, 1997

We are going to use this quarterly report to summarize where we are in the project based on the original work plan categories. Progress this quarter will be emphasized in each section.

1. Final permitting of site

All permits necessary for the site have been obtained. This includes the Army Corps of Engineers permit and the NMFS Experimental Fishing permit. The latter permit took over 30 months to obtain because NOAA attorneys decided it required an amendment to a Fisheries Management Plan; a very long and time consuming process. This makes the Seastead site the first permitted aquaculture area in the US EEZ. A special experimental permit application and procedures was designed and implemented for vessels operating within the site and experimental permits were issued to the F/V Westport and F/V Concordia for project operations outside of the site. There is a permit problem involving the harvest of seed scallops during commercial trips that needs to be addressed; we plan to address this issue next quarter.

2. Grow-out array design and construction

Three different moored grow-out arrays have been designed. The first system, consisting of forty-eight bottom grow-out cages, has been constructed out of vinyl coated steel wire provided free by Riverdale Mills. The cages were deployed this quarter in three strings of ten, nineteen, and nineteen cages, marked by high flyers at each end. The cages have two shelves which were stocked with scallops, ranging in size from 40 to 120 mm shell height, at varying densities. The stocking took place in August after a long steam in which the scallops were subject to warm water temperatures. The scallops were in hard shape by the time they were placed in the cages. The second system, a 20 unit lantern cage longline, has been designed by Coastal Aquaculture Supply and has been purchased using Fukuii nets. All the longline components have been acquired and will be ready for deployment in October. The third system, the large-scale lantern nets, has been designed by project participants and components will be acquired in the immediate future.

3. Vessel modifications

All modifications to the F/V Concordia and F/V Westport have been made. The F/V Concordia successfully deployed three large corner buoys and the F/V Westport has been modified to transport large numbers of live sea scallops. In all likelihood additional scallop vessels will not be utilized due to the difficulty in getting permits.

4. Site preparation

Three large picket buoys have been constructed and deployed to mark three of the site corners; the forth corner being marked by a USCG navigation buoy. The buoys are painted yellow and contain radar reflectors and lights. Additional lane markers will not be used due to concerns about marine mammal entanglement. The site has been surveyed with a side-scan sonar and a composite map drawn. Biological samples have been taken using a lined scallop dredge to provide a biological baseline. An underwater camera has been dropped on stations throughout the site and video recordings made of the bottom.

5. Scallop harvest, transportation, and seeding

Samples of several hundred live scallops were brought in from regular fishing trips throughout the fall and winter. The scallops were transferred by truck in coolers without water. These scallops were held alive at the WHOI Coastal Research Center with relatively low mortalities. Based on what we learned from these trips , a dedicated seed harvesting trip was made in May and 40,000 seed were transported to the Seastead site. The scallops were harvested using short tows, carefully dumped on deck, and immediately transferred to deck pens and totes that were continuously sprayed with sea water. Upon arrival at the Seastead site, the scallops were dumped overboard, a sub-sample being tagged, along a 400 foot transect. Our work to date indicates that we should be able to transport 400,000 scallops to the site this fall. The biggest obstacle is the distance we need to travel to transport the scallops from harvest areas located on the Northeast edge of Georges Bank to our site. Nearby seed areas all lie within the groundfish closed areas. Transport problems include warm surface water temperatures this year right through the end of September. Harvesting scallops using commercial practices also results in shell edge damage.

6. Monitoring of bottom grow-out sites

The data from the May 20-21 benthic survey of macrofauna at the Seastead site has been processed. Sub-samples of the seed scallops have been sent to LMAH and were necropsied and evaluated histopathologically. Other samples sent to WHOI were used to obtain indices of physiological condition. On August 25th we searched for the seeded scallops using dredge mounted video cameras. While some scallops were spotted it was extremely difficult to make useful observations with this approach. Problems included sediment suspension and inability to operate at slow speeds. We designed and plan to fabricate a low cost camera sled that can be towed by a smaller vessel. We will use TUGOS system components for the sled video system. We have also made arrangements to use an ROV provided free by the NURP Program which will require one of the project participants to be trained as an operator.

7. Site harvesting

No harvesting has been accomplished from the site.

8. Economic analysis

The model to develop the economic evaluation of sea scallop aquaculture has been completed using vessel information provided by several New Bedford scallop companies. The model will be utilized towards the end of the project when field data is available.

9. Site evaluation

A significant amount of information and data has been collected for the purposes of describing potential sea scallop grow-out sites. We are working with UMASS Dartmouth on a Geographic Information System (GIS) that can be utilized for this purpose.

10. Legal regime

A complete record of the process we have completed to get the site has been kept and is undergoing analysis. We are actively participating with the New England Council in providing information that they can use to set up a system for aquaculture site/project evaluation.

11. Project reporting

The project has received national attention and over a dozen formal and informal presentations have been made nationally on the project's progress. We have helped form the Sea Scallop Working Group which has become a major forum for the exchange of aquaculture information.

In summary, the permitting process has delayed this project 30 months. Difficulties in finding seed beds that we would be allowed to harvest and warm water temperatures have caused further delays. We are now poised for a major effort this fall when all gear will be in place and water temperatures will allow for seed transport. The major weak link in the project is the lack of resources for a strong site monitoring program, however, we are working on developing partnerships with other scientific researchers that should enhance our monitoring capabilities.

From October 1, 1997 **To** December 31, 1997

We requested a no cost extension for this project for one year. The request was approved.

We also requested an experimental fishing permit to allow us to take 1500 bushels of scallops from the Nantucket closed area to stock the test site. We need a nearby source of seed and that seems to be the best choice. The permit request is under review.

On October 8, 1997, a site visit was made using the F/V Dragon, a 35' lobster boat. We pulled up three cages on each of the three strings that were filled with scallops on September 19, 1997. As previously reported, the scallops that were placed in the cages were in hard shape for a number of reasons. They were harvested during commercial tows and transported a long distance when surface water temperatures were high. As expected, the mortalities were high as reported on the attached raw data logs. Few predators, such as large starfish and crabs, were found in the cages. A slight amount of algae growth was found on the outside of the cages but not on the inside shelves. On the positive side, all three cage strings are still intact at the end of the quarter even after some severe weather. The remaining live scallops looked in good condition. A cage check is planned for January, 1998. We should also have our camera sled in the water next quarter.

A longline was set out on the site that contains twenty Japanese lantern nets. The design of the longline string was based on recommendations from Japan. One of our cooperating vessels making a routine check on the way back from a trip reported the longline array looked like it had been dragged through because the submerged floatation buoys were bunched up on the surface. A subsequent check did not find the longline array. There are very strong wind and current conditions on this site which make it an excellent test for hardware. It seems this longline array might have flunked.

We had a project meeting to review the results of our economic model. The project economists presented the results in New Bedford to a panel consisting of cooperating fishermen and scallop processors. The economist will now refine their work based on these discussions. We are also working on a newsletter and mailing list to start disseminating some results now that the field work is underway. Our technical panel, known as the Sea Scallop Working Group, has been routinely kept informed of our progress. We are currently preparing a requested paper for the World Aquaculture Meeting in Nevada in February on the project.

From January 1, 1998 **To** March 31, 1998

Our request for an experimental fishing permit to allow us to take 1500 bushels of scallops from the Nantucket closed area to stock the test site was reviewed by the New England Fishery Management Council at their February meeting. The Council members reached consensus that the request should be approved by the Regional Administrator. To our knowledge the permit request is still under review at NMFS.

On January 8, 1998, a site visit was made using the F/V Dragon, a 35' lobster boat. The NOAA weather report indicated 15 knots and 2-3 foot seas. Upon arrival at the site we found that the tide, running against the wind, caused wave heights of 5-6 feet at the site. Each of the three strings were missing one of the two high flyers marking the string ends. On string one, the remaining high flyer was on the up-tide end. This meant that if we over-hauled the gear, working one cage on the deck at a time, we would drift over the remaining bottom cages resulting in fouling the string.

We decided to haul the entire string to get to the down-tide end to replace the high flyer. This was a mistake. The lobster boat was too small and the weather was getting rougher. We managed to get the entire string on deck but could not open and examine the individual cages. We replaced the high flyer and reset the string with plans to re-haul the string from the down-tide end.

The weather prevented us from re-hauling the gear. While on deck we visually inspected the cages and found that many scallops were still alive and healthy looking. We particularly looked into one of the cages we inventoried in October and did not see any additional mortalities (empty shells).

On March 22, 1998, we revisited the site on the F/V Westport with the idea of replacing all the missing high flyers and conducting a full inventory of all the cages. This winter had been very windy and this day was not an exception. The lobstermen that we work with indicated that they had lost many of their buoys in a recent blow so we felt an urgency in getting out to the site. Upon arrival we found that all our high flyers were missing and we could not recover the strings. At this time we have made arrangements with a lobsterman to grapple for the cage strings at the first opportunity. The positions of the strings are very accurate and we do not expect problems with their recovery.

The above experience, coupled with the loss of the Japanese lantern nets, has lead us to re-examine our design concepts for the large array. We are now considering a system based on mussel sock strings suspended from rings made of plastic pipe sections. The open ocean is particularly rough on surface buoys. Large, expensive buoys, such as our corner buoys, can be designed with long service intervals. Typical fishing gear markers, such as high flyers, need frequent inspection and still fail on a routine basis. We suspect that in a secure aquaculture site, free of mobile gear encounters, no surface markings would be required.

On other fronts our veterinary pathologist (Dr. Roxanna Smolowitz) has set-up the equipment and procedures for examining sea scallops. Our economists have completed their model to evaluate sea scallop aquaculture. Project participants and the Sea Scallop Working Group lead in putting together an all-day session on sea scallop aquaculture at the World Aquaculture Conference in Las Vegas during February. The project also received extensive national and international news coverage this quarter.

From April 1, 1998 **To** June 30, 1998

A significant amount of field work was accomplished this quarter; much of it unplanned searching for lost gear. When the Westport Project reached a compromise with the area fishermen on a choice of location, the site we accepted was considered "dead bottom" that was basically not fished. We are beginning to find out that this area has extremely harsh environmental conditions related to wind, tidal currents, and depth. It makes for an excellent testing ground for offshore hardware.

We made several trips looking for our lost cage arrays using grappling gear and our new camera sled. We did not locate the gear but did acquire video footage of the grounds we were to seed with scallops. On June 5-6 the F/V Westport went into the Nantucket Lightship closed area on a seed collecting trip authorized by NMFS. We caught a total of 500-700 bushels of scallops in three ten minute tows and one six minute tow. While in the closed area we also replicated two NMFS 1997 Sea Scallop Survey Stations. We used the two fifteen foot drags; one with a partial liner. The weather was bad, blowing 40 knots plus with 20 foot high seas, greatly limiting our time and capabilities. The intended purpose of our attempt at replication was to determine if the same scallop bed can be relocated months later.

The scallops were transported to the Seastead Site at night on deck sprayed with water. The vessel took severe pounding and only made six knots into the wind and sea. On arrival at the site the next morning the scallops were shoveled overboard while the vessel drifted along a single transect previously video surveyed. The F/V Sandra Jane, already on site with the video sled, proceeded to follow the F/V Westport and video taped the newly settled scallops.

The F/V Westport also conducted a short dredge tow south of the location we seeded the scallops in May 1997 and caught ten scallops that were most likely from the May 1997 seed drop. The F/V Sandra Jane towed the camera sled in that area and sited more scallops. Interestingly, during the search we found that in an area that we have towed repeatedly, and examined with video cameras, and found to be sand, was now a boulder tow. The boulders were clean of any organisms. The winter storms must of moved the sand away to expose the rocks.

On June 17, 1998 we went to the Seastead Site on the F/V Isabel S to survey the recent scallop seed drop with the camera sled. The scallops were found to be right where we left them. Very few mortalities were observed. Most of the scallops had righted themselves and were settled into the bottom. There was no observed increase in crabs or starfish from previous video surveys.

While towing the camera sled we snagged a line. We hauled the line up and found one of our missing cage arrays. All nineteen cages were hauled and the contents emptied into bags to bring back to port for detailed analysis and measuring. There were many live scallops that had definite growth added since being towed up and placed in the cages last year. The string had one cage that was totally destroyed and the next three abutting cages were obviously cut open and had the scallops removed. We are almost certain that the cage array was towed through, most likely by a clam dredge or scallop drag, and the cages deliberately robbed. Keep in mind, there is nothing worth fishing on this site; no fish, no scallops, no clams.

With the limited funds and time available we are going to focus on monitoring the newly seeded scallops, locating the May 1997 scallop seed bed (which seems to have moved south), finding the two remaining cage arrays, and analysis and report writing. The preliminary results seem to indicate that scallop seed can be transported successfully to reseed new grounds.

From July 1, 1998 **To** September 30, 1998

During this quarter we made an effort to retrieve the remaining two lost cage strings. We hired Dr. Arnold Carr and the R/V Aphrodite to conduct a side scan sonar search of the Seastead site. In addition, we conducted an underwater video survey of the seeded scallop beds.

To survey the seeded scallop bed we lowered a video camera and drifted over the site. Numerous scallops were observed along the previously defined transect. The scallops were recessed into the bottom. Very few clappers were observed and no signs of increased levels of predators were observed, however, this is a difficult observation to quantify.

We located a string of our cages with the side scan sonar and marked the position. The vessel we were on was not capable of retrieving the gear. We notified the F/V Westport of the location of the string. On returning from a scallop trip the F/V Westport attempted to grapple the string with a light hand-held grapple. They snagged the string and managed to get one cage up to the surface before the grapple line failed. Subsequent attempts to retrieve the string using grapples on the main wire failed. It is important to note that the side-scan images of the string indicate that the string was dragged across the bottom.

Three major sections of the final report have been completed. Economists Drs. Porter Hoagland and Hauke Kite-Powell have completed their analysis of the economics of sea scallop farming. Attorney Ken Riaf and Project Manager Ronald Smolowitz completed their review and analysis of procedures for permitting sea scallop aquaculture in Federal waters. Veterinary Pathologist Dr. Roxanna Smolowitz has completed her health analysis of transplanted scallops.

We plan one final video survey of the transplanted scallops before ending the project's funded field work.

From October 1, 1998 **To** December 31, 1998

On November 14, 1998, the F/V Isabel S conducted a video survey of the seeded scallop bed. The bottom topography had changed significantly from the previous surveys. What was flat sand bottom now had significant sand waves, as much as 4-6 inches in height. The scallops were observed to be in excellent condition. There was no signs of mortality or empty shells. Many of the scallops were seen to swim in front of the cameras. Very few crabs were seen. Some of the star fish present were seen on top of scallops but there was no indication of successful predation taking place. The scallop densities seem to be the same as in the previous surveys. There was no indication that the bed was spreading out or moving in any particular direction.

B. Project management

This project was managed by Soren Henriksen, president of Westport Scalloping Corporation. Captain Henriksen has 45 years in the scallop business as a captain and boat owner in New Bedford and Alaska. In 1984 he spent 6 months in Peru establishing a successful scallop aquaculure program in cooperation with the University of Lima. He was be responsible for management of the vessels and grow-out site operations.

Captain Edward Welch, also of the Westport Scalloping Corporation, assisted Captain Henriksen in managing the field operations of the project. Captain Welch was the skipper of the F/V Westport during all of the project operations.

Technical assistance to the project manager was provided by Ronald J. Smolowitz, a consultant in fisheries engineering and an expert in scallop harvesting. Mr. Smolowitz was a NOAA Corps Officer for 20 years and during that time was involved in a wide range of fishing industry projects. Since leaving the NOAA Corps, he has engaged in numerous projects and collaborations on fishing and appropriate technology. He was involved in the literature search, the development of the experimental plans, the *in-situ* observations and specimen analysis, and the data analysis. He also interfaced with the LMAH, Richard Karney, Dale Leavitt, and others on the biological and growth aspects of the project. He was responsible for project reporting.

Also assisting the project manager was Clifford A. Goudey, project director for the Center for Fisheries Engineering Research. He is an expert in fishing gear and offshore aquaculture systems. He dealt with engineering issues associated with the grow-out site, the suspended array, and harvesting gear. He designed and seen to the fabrication of the lighted picket buoys. He was responsible for the water quality instrumentation, video observation equipment, and other underwater gear. He shared responsibilities for data analysis and project reporting with Mr. Smolowitz. Cliff lead in writing the engineering section of this report.

Several aspects of this project were accomplished by persons and organizations not in the employ of Westport Scalloping Corporation. In addition to the consulting by Ron Smolowitz and the involvement of Cliff Goudey of MIT, both described above, several subcontracts were issued to individuals as follows:

Kenneth M. Riaf, attorney, 6 Tolman Avenue, Gloucester, MA 01930. Ken assisted the project manager in dealing with legal and permitting issues. He was responsible for evaluating areas in New England as potential sites for controlled scallop grow-out and array locations. He wrote the Appendix on site selection issues.

Dr. Roxanna Smolowitz, veterinarian, UPenn Laboratory for Marine Animal Health, Marine Biological Laboratory, Woods Hole, MA 02543. Roxanna, a veterinary pathologist, was a member of the technical advisory panel and also provided veterinary support to the project; primarily by performing necropsies on scallop mortalities and assessing the condition of survivors.

Dr. Dale F. Leavitt, biologist, Southeastern Massachusetts Aquaculture Center, Massachusetts Maritime Academy, Buzzards Bay. Dale was a member of the technical advisory panel and provided biological support to the project primarily by conducting biochemical analysis of the scallop meats through the project period. Dale lead in writing the biology section of this report.

Dr. Hauke L. Kite Powell and Dr. Porter Hoagland, Woods Hole research Consortium, WHOI, Woods Hole, MA 02543. Hauke and Porter were the project economists responsible for the collection and analysis of economic data to determine the viability of sea scallop aquaculture and resource enhancement. They wrote the economic analysis section of this report.

One of the goals of this project is to build the infrastructure in southern New England to support a scallop culture industry thus all the contract work was kept local where possible.

All the project participants that have been identified by name were a part of the formal technical advisory panel that came to be known as the Sea Scallop Working Group lead by Dr. Harlyn Halverson. The SSWG provided most of the communication and project outreach efforts.

VI. Findings

A. Actual accomplishments and findings.

Securing the Seastead Site

Fisheries regulations have become extremely complex during the last decade in the Northeastern United States. In 1987, it simply took a one paragraph letter from the Regional Administrator, sometimes issued the day the request was made, to allow a research project to take place in Federal waters (see correspondence section). More recently, very formal public procedures have been set up, that can easily take six months, to allow the same sort of research activities to take place (obtaining an experimental fishing permit). Experimental fisheries usually entail the "relaxing" of an existing regulation to allow accomplishment of a research goal.

What was different about the Seastead project proposal was that there would be a need for some restrictions on the activities of some fishermen; for example, no towed gear over the seeded site. In the eyes of the NOAA General Council, this required an Amendment to the Sea Scallop Fishery Management Plan (FMP) since more restrictive regulations require public process. A complete Amendment would not have been necessary if there were frameworking procedures within the existing scallop FMP for special management areas.

The Council staff did not have the time (more correctly, the priority) to work on writing the Amendment. The Seastead project participants offered to do the work; the first time the private sector wrote an FMP Amendment. Project participants completed the draft Amendment which was then refined by the professional Council staff.

The Council had no set procedures for dealing with reviewing and approving the Seastead project. Presentations were made before several Council Committees before the full Council was able to vote to send the proposed draft to public hearing. The public hearing part of the process turned up two real issues. The first was that there was an important tow for small draggers within the chosen site that did not show up in the NMFS data base. Secondly, there was a fear on the part of the lobstermen that fish in the vicinity of the site that the seeded scallops would attract dredge vessels and gear conflicts would result.

After a number of informal discussions between project participants and the various industry sectors, a new location was chosen that received full support of all parties concerned. The Amendment was re-drafted and finally approved through the system. Complete documentation of this process can be found in the Appendices to this report.

The major accomplishment here was the first set of regulations for managing an aquaculture site in Federal waters. Additionally, a process was established for reviewing and approving future aquaculture proposals.

Army Corps of Engineers Permit

The Fisheries Management Council process concerned itself with the management of the marine living resources in the project area. The Council does not issue an aquaculture permit. The only federal permit required by the Seastead project was from the COE. The Rivers and Harbors Act requires the Army Corps of Engineers (COE) to issue a permit for any activities requiring the placement of physical objects into the navigable waters of the United States. The COE permitting process thus wanted to determine that the Seastead project did not unduly interfere with navigation and that the gear placed into the water would not fail and become a risk to navigation. The COE checks with other agencies of government to make sure there are no problems related to water discharge/water quality, habitat impacts, and introduction of non-indigenous species. This was a straight forward process which can be followed in detail in the Appendices of this report.

The major accomplishment of the Seastead project in this area was to get a process established between the respective agencies to allow for an expedient early review of aquaculture proposals.

Experimental Fishing Permits

The approval of Sea Scallop Amendment Five, establishing the Scallop Experimental Fishing Area (SEFA), was followed by the development of regulatory procedures by NMFS for access into the site by allowed gear and experimental activities (see Correspondence Appendices). The procedures for requesting the SEFA Experimental permit and the issuance of the permit were straightforward and relatively expedient. The greatest difficulties were the lead times associated with the notification requirements. Placing burdens on researchers, and eventually aquaculture site operations, in order to control wild capture fisheries is a major problem area that will have to be addressed in the near future.

The greatest obstacle to this project was the need to get experimental fishing permits for work outside of the SEFA (Seastead site). During the project period NMFS initiated new formal procedures for obtaining experimental fishing permits that greatly lengthened the process. This was compounded by all the issues related to access into the groundfish closed areas. The limitations imposed on the project greatly restricted the amount of work we hoped to accomplish.

The main accomplishment and finding related to experimental fishing has been the identification and documentation of the difficulties with the existing procedures. There is further discussion of this topic in the Evaluation section of this report.

Sea Scallop Working Group (SSWG)

The genesis of the Seastead project was the frustration felt by some members of the sea scallop industry, notably Captains Soern Henriksen and Malvin Kvilhaug, with Amendment Four. They commissioned Ronald Smolowitz to conduct a literature search on scallop culture focusing on the potential for New England which was completed in December, 1993. This lead to a meeting in Congressman Studd's office in Hyannis on January 11, 1994 to organize an effort to develop a sustainable sea scallop industry based on enhanced production techniques. A number of initiatives set their roots from this meeting. Participants agreed on a coordinated approach and complimentary sea scallop proposals were generated (including this Seastead project) and many were funded. The Policy Center for Marine Bioscience and Technology (PCMBT) was encouraged to focus on sea scallop culture in their efforts to foster aquaculture development. Dr. Harlyn Halvorson of the PCMBT took the lead of what is now referred to as the SSWG.

The SSWG has met on numerous occasions (see Appendix) fostering communications and information exchange. The SSWG acts as the Technical Monitoring Group for the Seastead project. The SSWG generated a Blueprint for Sea Scallop Aquaculture in Massachusetts and has actively worked towards the identified goals.

Council Aquaculture Committee/Policy

Project participants have been heavily involved in the Council process to establish policy and procedures for aquaculture in Federal waters. A considerable portion of the evolution of this process has been directly related to the Seastead project. For example, in response to policy questions raised by the Seastead project, the Council hired a consultant (see Brennan Report summary in Appendix) to examine policy issues.

Aquaculture policy in Federal waters is being addressed on two levels; locally and nationally. The project participants, because of the project's experience, have been asked on numerous occasions to give oral and written testimony on policy questions at the national level. One of the major accomplishments of the project, albeit indirect, has been to give federal aquaculture policy issues a sense of urgency.

Engineering

General Design Approach

An important part of this project has been the development of hardware suitable for use in sea scallop culture. This hardware ranges from buoys to mark the location of the approved experimental area to cages for the controlled growing of animals to equipment for reliably observing the growth and dispersal of seeded scallops.

Paramount in the development of this hardware has been two goals: cost effectiveness and maximum compatibility with fishing industry capabilities. This approach has driven the project towards the adaptation of existing hardware and methods rather than the intellectually_tempting approach of initiative a blue_sky design.

The result has been a series of hardware items that have, in most cases, served the purposes of the project well. More important, they represent solutions that are understandable by the project's industry participants as well as non_participating fishermen. In general, there remains opportunities for both major and minor improvements to these project developments. The essential point is that those next steps can be readily made by industry as the practice of sea scallop culture is undertaken commercially.

Experimental Area Picket Buoys

In our application for the experimental sea scallop area, the Corps of Engineers stated a requirement for buoyage to mark the location of the site. In order to meet the requirements of the U.S. Coast Guard for such "privately maintained" aids to navigation, they needed to be lighted, have a radar reflectors, and be painted yellow. The lights needed to be amber (yellow) and offer a flash visible for 4 miles every 4 seconds. A buoy was required on each corner of the 3_mile by 3_mile site. As noted on the revised_location site plan (Figure 1), the northwest corner buoy became redundant with the existing USCG lighted whistle buoy R "2" and was not required.

The buoy design is based on the use of a 60" diameter steel sphere of a type that is in common maritime use. Spheres, already adapted with ballast and tower were obtained from the WHOI Buoy Laboratory scrap yard. Rust was removed and they were painted. The final configuration is shown in Figure 2. Lights (Figure 3) and air_zinc batteries were obtained from Automatic Power, Inc.

A cylindrical battery pack housing was developed which would allow the needed air circulation while protecting the batteries from splash and occasional, momentary submergence. This housing is pictured in Figure 4 and is made from an off_the_shelf polyethylene container with a cover
band_clamped on. The dual requirements of air circulation and protection from sea water were

met with a lower compartment that can tolerate occasional short_term flooding from an over_washing wave.

To anchor the buoys on station, old New Bedford_style scallop dredge frames were used. These steel frames weigh 2,000 to 3,000 pounds in air. Mooring chains of a length 1.6 times the depths were made up from 3/4" and 5/8" galvanized chain.

Bottom Grow_out Cages

One form of culture to be evaluated in this project was bottom culture in cages. This method of sea scallop production offered a relatively low_cost approach to contained culture. Through containment, movement and "possession" of the scallops controlled, as it mortality by predators.

We based our cages on the ubiquitous lobster trap, both in design and construction materials. We obtained PVC coated 14 gauge wire mesh, 1" x 1", from Riverdale Mills, a local manufacturer (the two rolls of material were donated to the project, enough for all 50 cages.) Fabrication to the design shown in Figures 5 and 6 was done by a lobsterman from Fairhaven, Mass.

Assembly methods were as practiced for mid_sized lobster traps, except for the lack of entrances. The hinged opening for scallop handling was located on one of the long sides. It hinged from the bottom and in practice, the door was tie_wrapped to prevent or detect tampering.

The cages were arranged in typical lobster_trawl fashion, with 10 fathom of main line between each cage. Gangion lines 6_feet long lead to each cage. The trawls, two of 20 cages and one of 10 cages, were fitted with buoys at each extreme end. A high_flier was used on the eastern ends of the three trawls.

The recovery and growth rates are reported in the main portion of the report. In general, the method proved troublesome in that all the surface buoys were lost before the first scheduled recovery for maintenance and growth measurements. Numerous efforts at grappling were unsuccessful. However, during one of our observation sled surveys aboard the F/V Isabelle S, a main lines was noticed and subsequent maneuvering snagged it on the shoe of the sled. The trawl was recovered and we thereby obtained growth and survival data from 20 cages.

At a later date, grappling from the F/V Westport hooked a second mainline and it was brought to the surface. However, it parted before retrieval could commence. Further grappling attempts at that location have been un_rewarding.

We have concluded that the cage approach is technically sound except for the hardware used for the surface buoy and line. Standard industry practice proved inadequate for the extended periods of soak time combined with the harsh exposure of the site.

Suspended Scallop Array

The evaluation of the off_bottom culture of sea scallops using a large_scale scallop grow_out array was an objective of the project. The approach was to be similar to suspended lantern nets used in Japan for oyster and scallop culture, but scaled up to be compatible with servicing by a typical scallop dragger.

Figure 7 shows our initial concept which included ten grow_out units, each supported by an independent spar buoy. These units were to be arranged in a line array that was kept taut by four opposing anchors, a pair or spherical floats and underwater tom weights. Figure 8 is a plan view of the array, revealing the anchor arrangement.

The scale and robustness of this approach raised the concern of marine mammal specialists at NMFS and an alternative approach was developed. Figure 9 is our alternate design. Here, the large_scale suspended grow_out units are moored individually, suspended in the water column by
a cluster of trawl floats with a pick_up line running to a small surface buoy. This approach eliminated the entangling potential of the previous array, particularly its anchors and the horizontal main line.

As this design became more refined, the preliminary economic modeling was occurring. Initial results of this model revealed a very poor economic return for the use of this suspended array approach due to high labor and capital costs. Therefore, we decided to seek information on the biological implications of suspended culture without investing project funds into the costly hardware of our large_scale plan.

A modest_sized, midwater lantern net array was purchased from a commercial aquaculture supplier. This system is pictured in Figure 10. The design and the specifications were developed by the manufacturer with an understanding of the site. The system was installed and loaded with scallops by the project industrial partner. No trace of the system was ever seen again.

Towed Observation Sled

An important element of the project was the observation of the seeded scallops placed in the experimental area. Three things needed monitoring: dispersal, growth, and predator activity. Several options were considered as shown in the following observation option matrix

Option	Pro/Con
SCUBA	Ability to search for and study individual animals. Depth complications, safety issues, cost.
ROV	Ability to search for and study individual animals. Operator skill required, expensive, careful handling required.
Drop camera	Cheap, simple. No isolation from vessel motions, variable field of view.
TUGOS	Some lateral track control, fore and aft views. Operator skill and careful handling required, variable field of view.
Towed sled	Simple, fixed camera height, very robust, operates like dredge. No position control other than vessel track.

Based on this analysis, we opted for a towed sled. Our design is presented in Figure 11 and dimensional views are presented in Figures 12 and 13. The sled was fabricated in a New Bedford welding shop. A Gates underwater housing was purchased along with a Sony Hi_8 handycam. For real_time viewing, two B&W cameras and underwater housings were used, both mounted facing forward. A spare tether from the TUGOS system is used with this sled.

We found real_time viewing is essential for the operation of the sled from a large vessel. This is because the vessel movements dominate the movement of the system with its small size and low towing resistance. The persistent tidal currents at the experimental area required us to adjust vessel speed based on the course relative to the current. Tow speeds of 1.0 to 1.5 knots are ideal for surveying sea scallops and this typically required jogging the vessel in and out of gear based on information from the surface video monitors.

During periods of slack tide, hands_off recording can be done without the video tether. Deployed from a smaller craft, the resistance of the sled and tow cable allows similar, no_real_time_view operation, minimizing the logistics associated with the sled operation.

Biology

The overall objective of this portion of the program was two-fold. First, we proposed to evaluate the biological potential for relaying sub-adult scallops from sites of high recruitment and low productivity to sites with low recruitment. Second, we propose to evaluate the productivity of sea scallops cultured using a variety of culture techniques compared to scallops left in the wild. Several studies were conducted to assess this potential, including

1. A comprehensive survey of the site selected as the SeaStead Scallop Culture site, located as described in previous components of this final report.
2. Three studies to assess the mortality associated with relaying scallops caught using commercial New Bedford style dredges to other sites in proximity.
3. Two studies to investigate the degree of damage that one could expect using conventional dredges that would contribute to the mortality defined in #2.
4. A preliminary measurement of a gonad/somatic and an adductor muscle/somatic index.
5. A baseline estimate of wild sea scallop population growth within the areas that served as a source of the relayed scallops used in this experiment.
6. Two experiments measuring the growth of sea scallops when cultured using a bottom ranching technique.
7. An evaluation of sea scallop growth when cultured using bottom cage technology.

The schedule for completing each of these activities is included in Table B-1. The results of each of these components comprising the biological studies component of the S/K funded program are included below.

Site Survey

Objective: Following the acquisition of permits allowing us access to the SeaStead Sea Scallop Culture Area, we required an overview of the habitat contained within the nine square mile culture area. Therefore, the first objective was to evaluate the bottom composition and the predominant flora and fauna that currently existed on the site.

Methods: To assess the bottom habitat of the SeaStead Sea Scallop Culture site, two different technologies were used. In October of 1996, a video camera mounted on an aluminum frame was borrowed from the National Undersea Research Program (Groton, CT). The camera in frame was mounted such that it provided a real-time view of a one-quarter square meter quadrat when it was deployed to the bottom and setting on the bottom sediment surface. The system also had the capacity to record the bottom views on an 8mm digital video recorder for later analysis. Four video transects were completed following dividing the culture site into four equal square sections, one video transect in each section.

The second bottom survey technique was to conduct a systematic assessment of the bottom within the culture area using a 15 foot New Bedford style scallop dredge that had been lined with a 38mm nylon mesh bag. The scallop drag was deployed from the F/V Westport and was hauled at approximately 4 knots for 5 minutes. The catch from the dredge was retrieved to the deck and sorted with the major species retrieved, enumerated, and measured. The nine square mile scallop culture site was divided into nine one square mile sectors and one dredge sample was retrieved from each sector.

Results: Video observation of the bottom indicated that the bottom across the entire Sea Scallop Culture Site was a medium to coarse sand with very small occurrences of hard substrate (boulders or rock cobble). The depth across the site ranged from 15 to 18.6 fathom (27-34 meters) and the bottom sediments were moderately rippled, indicating a degree of bottom current or other form of impact from water movement. There was virtually no algae noted in the video transects, consistent with what one would expect from a sandy bottom. The fauna was dominated by the sand dollar (*Echinarcus sp.*) as observed in the video transects.

The dredge samples retrieved from the nine tows conducted on 20-21 May 1997 also indicated the fauna associated with the culture site was consistent with what could be expected for a sandy bottom (Table B-2). The site is predominantly covered by sand dollars, where catches ranged from one-half to six bushels of sand dollars retrieved from a five-minute tow. Other species of interest during our survey were

1. known scallop predators, including
    a. *Asterias sp.* sea stars (3 to 200 per tow)
    b. *Cancer sp.* crabs (0-41 per tow),
    c. lobster (1 in one tow), and
    d. predatory *Busycon sp.* gastropods (1 in two tows plus a few egg cases);
2. commercially important fish species, including
    a. skate (5-29 individuals per tow),
    b. flatfish (3-25 individuals per tow), and
    c. monkfish (0-5 per tow);
3. sea scallops (0-11 per tow).

Accomplishments: The bottom of the Sea Scallop Culture Site was surveyed and characterized in terms of the bottom composition and predominant flora and fauna. The site is comprised of a sandy bottom dominated by sand dollars. Included are low levels of known scallop predators, including sea stars, lobsters, crabs, and predatory snails. The site does support a very small population of naturally recruited scallops (average 2.8 individuals per five-minute tow).

Relay Mortality

Objective: To meet the overall objective of measuring the success of relaying small scallops from areas of high recruitment to permitted culture areas, it was necessary to measure the degree of mortality associated with harvesting and moving scallops to the relay site. Sea scallops are generally considered to be relatively fragile with respect to handling and we needed to assess the degree of handling they could withstand without causing significant mortality.

Methods: The method of choice to harvest the small scallops was to utilize a commercial size New Bedford style scallop dredge that was lined with a small mesh liner to retain the smaller scallops. Scallops were retrieved in a 15-foot New Bedford dredge following short tows (5-10 minute duration) using a commercial scallop dragger. After the scallops were landed on deck they were immediately sorted out of the pile and held in flowing seawater in fish totes held on deck and in the shucking house. Following the completion of deck loading, usually finished within a twelve-hour period, the boat departed for the culture site without hesitation. Therefore the total elapsed time between harvest and reintroduction into a natural habitat was 24-36 hours.

Initial trials were conducted to assess the survival of small scallops that were harvested, handled, and transported on deck of the fishing vessel. To date three attempts have been made to assess landed sea scallop survival (Table B-1). For Trials One and Two, the scallops were harvested during the last tow of a trip by a commercial scallop vessel (*F/V Westport)* and held on deck in a fish tote with running seawater. In both cases, the scallops were held on deck for approximately 18 hours before being transported to the Rinehart Coastal Research Laboratory (RCRL) at Woods Hole Oceanographic Institution, a two hour trip by truck. At the RCRL, the scallops were placed in a seawater table with flow-through seawater and held for over two months to monitor survival. Trial Three was an attempt to harvest scallops from an area with a known population of smaller "peanut" scallops. This was a directed fishery where the dredge was lined with a small mesh liner to retain the smaller scallops. The scallops were landed and held on deck in fish totes with running seawater. They fishing effort took about twelve hours and the steam to the relay site was another twelve hours. The final transport to dock was another two hours and a final two hours elapsed in relaying the experimental scallops to the RCRL. In total, a maximum of twenty-eight and a minimum of fourteen hours passed between landing the sea scallops on deck and deploying the scallops in the flowing seawater tables at RCRL.

At the RCRL, the scallops were initially measured to determine the size frequency distribution (Figures B-1 & B-2). The sea scallops were observed for varying amounts of time and the valves of dead animals were removed. The total number of dead animals was determined for each trial and percent survival was calculated (Table B-3).

Results: The scallops retrieved in Trials One and Two were of a size that could support commercial harvesting (Table B-3 & Figure B-1). The mean valve depth for scallops harvested in Trial One, measured from the umbo to the leading edge of the valve, averaged 85.9mm ($\pm$6.9) (Table B-3). The size frequency distribution (Figure B-1) is relatively symmetrical about the mean although a small shoulder can be discerned on the larger end of the size distribution. The scallops harvested in Trial Two were slightly larger, mean valve depth of 98.5mm ($\pm$8.6) but the size frequency distribution indicates two size cohorts with a smaller peak at approximately 86mm valve depth and a second larger peak at approximately 103mm valve depth.

Trial Three was an attempt to harvest scallops from an area with a known population of smaller "peanut" scallops. This was a directed fishery where the dredge was lined with a small mesh liner to retain the smaller scallops. As can be seen in Table B-3 and Figure B-2, smaller scallops were harvested. The mean size for the scallops caught in Trial Three was 70.7mm

(±9.2). The size frequency distribution suggests a single cohort of sea scallops within this population, although this area was being commercially fished at the time of collection and the fishery may have removed the larger scallops.

The survival rate of the scallops relayed to RCRL during Trials One and Two was very good, 95.9% in Trial One and 91.5% in Trail Two.(Table B-3). A very small percentage of the harvested scallops died during transport and there was no ongoing mortality observed following the initial losses. The results for Trial Three were different. Survival was 71.2% one week after harvest but the mortality continued for a period after the initial handling period where handling induced mortality was expected to occur, thus differing form Trials One and Two. After two weeks, scallop mortality had reached 57.7% of the harvested scallops. Although data was not collected, the sea scallop mortality for the combined animals held at the RCRL following the initial die-off eventually stabilized. The scallops were held at the RCRL through most of the summer and no significant mortality was observed until late August when water temperatures approached the upper lethal maximum, about 22 degrees Celsius.

Accomplishments: Overall the results of the three Trials was very encouraging. Sea scallop survival following harvest and relaying fell within acceptable levels during these experiments. Survival was very good during the spring sampling events and may be correlated with lower surface water temperatures. Sea scallops are very sensitive to higher temperatures during handling (M. Dadswell, personal communication) and most of the handling of scallops in commercial grow-out facilities in Canada is scheduled when the ambient water temperature is relatively constant from the bottom to the surface, i.e. spring and fall. Even under the most stressed conditions where both the surface water temperature during the relay interval and the ambient water temperature at the laboratory were approaching the upper limit for the bivalve, survival was approximately 40%. This closely corresponds to the survival rate of 40% observed by the Gloucester Aquaculture Project with respect to wild scallops that were relayed into cages for experimental grow-out (NFIG funded - R. Taylor, unpublished data). With a more sophisticated seawater delivery system and a temperature controlled scallop-holding facility on-board the fishing vessel, sea scallop survival approaching 80-90% during the relay interval may be attainable.

Extent of dredge damage in relayed scallops

Objective: During the mortality studies above, it was observed that many of the scallops that were dying during the observation interval of Trial Three had damage to the valve and/or had a disarticulated or broken hinge ligament. It is suspected that damage to the hinge area during harvest causes a significant portion of the sea scallop mortality subsequently observed. If shell and/or hinge damaged leads to an increase in mortality, then it is necessary to assess the extent of shell damage that occurs during harvest of wild sea scallop juveniles for relay. These type of data were collected and analyzed during Mortality Trial Three (May 1997) and during a NOAA sea scallop survey cruise aboard the *R/V Delaware II* in August-September 1997 (Table B-1)

Methods: The sea scallops that were transported to the RCRL in May 1997 for the mortality study in Trial Three were subjectively evaluated with respect to overall condition at two times during the fifteen day study. When the scallops were initially placed in the seawater table, the scallops were assessed as to whether they had damage to the valve or hinge. Nine days later, the dead scallops were removed and were matched to the damage evaluation from the initial observations. At this point, the remaining scallops were subjectively evaluated as to their health status. During this evaluation the sea scallops were judged to be either in good, fair, or poor condition. Six days later, the mortalities were again removed and the dead individuals were matched to the subjective evaluation from the previous sampling interval.

To develop an estimate of the amount of damage inflicted on small scallops harvested using a conventional scallop dredge a follow-up experiment was undertaken. The follow-up experiment was conducted in conjunction with a sea scallop research cruise supervised by Drs. Idoine and Han for the Northeast Fisheries Science Center aboard the *F/V Delaware II* during 26 August to 2 September 1997. The objective of the cruise was to sample and tag a population of scallops sampled from a transect across the northeast peak of Georges Bank. To accomplish this, sea scallops were collected in the NMFS standard 8-foot scallop dredge at a large number of stations. At each station the dredge was deployed for approximately a 5-10 minute tow and the contents were loaded onto the deck. The scientific crew would subsample the catch and retain those scallops that they considered appropriate for measuring, tagging, and releasing back at the collection site. As an addendum to this study, I surveyed all of the scallops sampled by the science crew and retained those scallops that had damage to the valve or hinge area. These sea scallops were measured and the extent of the valve damage was evaluated and recorded.

Results: The results of the assessment of the damage in the scallops harvested using a lined dredge on 26 May 1997 is presented in Table B-4a. A total of 8.9% of the landed sea scallops were damaged with either a broken valve or a disarticulated hinge. Of those 19 damaged individuals, 17 (89.5%) died within nine days of landing and 100% of the damaged scallops died by fifteen days post-harvest. The mortality of damaged sea scallops represented 15.5% of the total mortality measured during the fifteen-day interval.

A comparison of the size frequency distribution of the dead sea scallops to the size frequency distribution of the total landed population suggests that the mortality is disproportionately distributed to the smaller sizes of the population, based on the shape of the distribution curve (Figure B-4). A comparison of the average valve size of the different subsets of the landed sea scallops indicates that there is no significant difference between the average sizes of the four subsets (Table B-4b).

Given that the damage inflicted during the harvest of sea scallops lead to 100% mortality in Trial Three, it was considered important to evaluate the degree of damage expected in a routine harvest situation. The NOAA/NMFS Sea Scallop cruise of Aug.-Sept. 1997 provided the opportunity to investigate that aspect of scallop harvest. On the whole, damage to sea scallops harvested using a small dredge towed for short periods of time was approximately 9.7% of the total catch (Table B-5). The extent of damage to the harvested sea scallop population ranged from 1.2 – 21.0% (Table B-5). A plot of the size frequency distribution of the damaged sea scallops compared to that of the total landed population suggests that the larger scallops were damaged to a proportionately larger degree than the smaller sea scallops (Figure B-5).

Accomplishments: Damage to the valve or to the hinge area of a sea scallop during harvest will result in mortality. With the functioning of the valve or the hinge ligament compromised the sea scallop may not be able to position the valves appropriately for feeding and would be unable to move by swimming. Additional damage to the soft tissue may have also occurred during the trauma that impacted the hinge ligament. Therefore, it is imperative that scallops that are being harvested for relay be caught using short duration tows that minimize the potential damage while in the dredge.

The size frequency distribution of the damaged scallops, relative to the total landed population, provides conflicting information. In Trial Three, the size of the damaged sea scallops was skewed to the smaller side of the total population. This led us to initially speculate that the damage was predominately occurring in smaller sized scallops. Subsequent data, collected during the NOAA-NMFS Sea Scallop Cruise, contradicts this observation. During the research cruise, the damaged population is skewed to the right or toward the larger end of the harvested scallop population. Further investigation into the development and strength of the hinge ligament relative to the size of the scallop and the stresses experienced during harvest is warranted.

Given that shell and hinge damage inflicts 100% mortality to the damaged population, it is important that a less damaging harvest strategy be developed. With some attention directed at preventing valve and hinge ligament damage, the overall survival rate of sea scallops could be expected to increase to over 90% for scallops relayed out of areas with high concentration of small scallops.

Gono-somatic and other physiological indices

Objective: Valve growth and soft tissue growth are frequently not coupled in bivalve mollusks. Therefore it is important to evaluate the relative increase in soft tissue mass and, more importantly, the adductor muscle mass when studying scallop growth. Sea scallops are harvested and processed to retrieve the large adductor muscle and the overall size of that component is the most important measurement when considering the economic viability of sea scallop culture. With that in mind, we conducted a baseline evaluation of the various indices of condition that may be applied to monitoring sea scallop growth and performance during the various aquaculture scenarios developed in this study and in other studies.

Methods: Twenty-five scallops were randomly selected from the sample returned to RCRL and measured for the following parameters:

1. Valve length, width, and depth: measured using a Vernier caliper,

2. Live weight: the whole scallop weight measured using a single pan balance,
3. Wet soft, wet meat (muscle), wet gonad, wet viscera, and wet shell: the scallop was shucked and the component parts were separated from each other, blotted dry, and weighed on a single-pan balance,
4. Dry meat, dry gonad, dry viscera, and dry shell: each component was weighed on the single-pan balance following drying in a 60°C oven for 48 hours,
5. Calculated dry soft: the sum of the items described in # 4 above, excluding the dry shell,
6. Soft %DM, gonad %DM, meat %DM, and viscera %DM: percent dry matters calculated as the dry weight of the component divided by the wet weight of the component multiplied by 100,
7. Wet meat – wet soft ratio and wet gonad – wet soft ratio: indices calculated by dividing the wet weight of the component by the wet weight of the total soft tissue,
8. Dry meat – dry soft ratio and dry gonad – dry soft ratio: indices calculated by dividing the soft weight of the component by the soft weight of the total soft tissue,
9. Dry soft – dry shell ratio: an index calculated by dividing the dry soft tissue weight by the dry shell weight and multiplying the quotient by 100.

Results: Three indices may prove to be important in monitoring the health and productivity of the sea scallops held within an open-ocean culture system. These are

1. the meat/viscera index, calculated by dividing the wet or dry weight of the adductor muscle by the wet or dry weight of the total soft viscera,
2. the gonad/viscera index, sometimes called the gono-somatic index, calculated by dividing the wet or dry gonad weight by the wet or dry weight of the total soft viscera, and
3. the traditional bivalve condition index calculated by dividing the weight of the total dry soft viscera by the dry weight of the shell and multiplying the quotient by 100.

A summary of these three indices and other parameters that were measured on this population of sea scallops collected during the 26 May 1997 trip is presented in Table B-6.

Depending on whether you are using the wet or dry measurements, the meat/viscera index was between 42.8% (wet) and 50.4% (dry). In other words, the adductor muscle comprised approximately 50% of the total visceral mass in the sea scallop. The gonad on the other hand, represents about 15% of the total visceral mass (17.3% wet or 10.2% dry). The average overall condition index was approximately 13.8 ($\pm$3.2) for the same population of sea scallops.

A second use for these data is to produce a means to estimate the total soft tissue or the muscle mass in sea scallops without destructively removing the scallop from the cultured population. To accomplish this we plotted the wet soft tissue or the muscle mass against the valve depth of the scallops measured in this component of the study. The plots were then fitted, using best-fit methods, with a logarithmic model to describe the relationship between muscle mass or soft viscera mass and the size of the scallop. These data are presented in Figure B-6. The relationship between soft tissue and scallop size is best described as:

$$\text{Soft Tissue Wet Weight} = 47.6*\text{Ln(valve depth)} - 177.3 \qquad (r2 = 0.9076) \qquad (1)$$

The relationship between adductor muscle mass and scallop size is best described as:

$$\text{Adductor Muscle Weight} = 15.6*\text{Ln(valve depth)} - 56.7 \qquad (r2 = 0.8868) \qquad (2)$$

Accomplishments: The indices reported in this study were measured on a range of scallops that were harvested in late spring (May). In looking at the gonad/viscera index, one would expect, if these values were tracked year-round, that one would see a cycling of the gonad mass where the index would increase as the sea scallops approached reproductive activity and then would decline to a low point immediately following spawning. Careful monitoring of these data would permit the culturist to monitor gonadal development and the cycle of reproductive activity in their product. These data would be very important if the scallop is being marketed as a “roe on” product, as is in demand in the European market.

If the scallop is being marketed in the traditional U.S. market, as the adductor muscle only, then it would be important to monitor the meat/viscera index to monitor the growth and development of the adductor muscle relative the overall growth of the scallop. This relationship, between muscle growth and scallop growth, can also be monitored by using the graphical relationship between muscle mass and valve size, as is represented in Figure B-6.

The classical condition index can potentially define the general physiological state of the scallop, provided that the data are ground-truthed with respect to the performance and survival of the cultured scallops. This has been investigated in the soft-shell clam (Leavitt 1996) and other bivalves (Leavitt unpublished data) and the relationship between soft tissue weight or other tissue component and some indicator of bivalve size does allow one to generate specific observations on the health and performance of the bivalve. The one caveat is the need to generate adequate baseline information to be able to interpret the data collected. The data collected in this study provides a first attempt at investigating these relationships in cultured animals.

Growth of wild scallops

Objective: In order to assess the overall performance of sea scallops held within different aquaculture technologies, we needed to generate an estimate of the growth potential of the scallops if they were left undisturbed at the wild harvest site. By knowing the growth potential of the wild scallops, we have a reference point for comparing the performance of the cultured scallops to that of the wild scallops to evaluate the efficacy of relaying and holding scallops under manipulated conditions.

Methods: Data on a population of sea scallops were collected from a NOAA Sea Scallop Assessment Cruise (Cruise #9705). Two samples of the population were collected on 6 August 1997 (Tows 239 & 240) and the size frequency distribution was measured. The Sea Stead Project repeated the same tow tracks approximately one year later and the size frequency distribution of the sampled population was again measured. The change in the mean valve depth of one cohort of sea scallops sampled in consecutive years permits us to estimate the growth rate of the cohort when left undisturbed under natural field conditions.

Results: The size frequency distribution of the sea scallop population at the NOAA Sampling Sites #239 & #240 are represented in Figure B-7a. A single cohort (labeled cohort A – Figure B-7a) of sea scallops was selected from the 1997 data and the mean valve depth of scallops from both sampling stations was compared (Figure B-7b). Because there was no difference in scallop size of the selected cohort between the two stations (Table B-7), it was assumed that the cohort was from the same recruitment event, probably from the previous year (1996), and the data were combined.

The combined data compared between 1997 and 1998 indicated that the single cohort of sea scallops had grown 32.3mm in valve depth over the course of 302 days (Table B-7). The average daily growth increment was 0.106mm per day.

Accomplishments: The growth data indicate that the sea scallops at the wild collection site grew well over the course of the year. They increased in valve depth from 64mm to 96.4mm, representing a 50% increase in size over the 302-day interval. In terms of marketable product, using Formula #2 derived above, the meat count (number of scallop meats per pound) decreased from 54 meats/lb. to 31meats/lb. This represents a significant increase in the production of marketable product. These data will provide a basis for comparison to evaluate the scallop growth rate of animals held under aquaculture conditions at the SeaStead site.

Bottom Ranching

Objective: There are a variety of methods that can be applied to culturing the sea scallop and the objective of the SeaStead Project was to evaluate as many of these technologies as could be deployed at the site. The first technology considered was the least intensive system available – ocean ranching. The tactic employed in ocean ranching is to relay the scallops to the culture site where they are deposited on the bottom with no restraint from emigration or protection from predators. Ocean ranching is the least complicated in terms of equipment and technology, relying solely on a means to hold live scallops on deck with a minimum of stress. The SeaStead Project proposed to evaluate ocean ranching as a technology for culture of the sea scallop.

Methods: Two separate ocean ranching experiments were conducted during the course of the project. The first attempt occurred during 25-26 May 1997 where 61 bushels, equivalent to approximately 38,000 individual scallops, were harvested at a site near Stellwagen Bank and relayed to one location within the SeaStead permitted area. Of these 38,000 scallops, seventy-five were measured and tagged with individually numbered tags and one-hundred and ninety-seven were measured and marked with colored nylon tie-wraps, totaling approximately 1% of the total number of scallops deployed. A second subsample of approximately one-bushel of scallops (619 individuals) was measured to generate a size frequency distribution for the deployed scallops. The ranched bed of scallops was left undisturbed for nine months and then followed by a number of unsuccessful attempts to collect some of the deployed scallops. The bed was eventually rediscovered and a small number of the deployed scallops were recollected and measured.

Based on our experiences with the initial attempt at ocean ranching, a second experiment was conducted using scallops collected on 5 June 1998. In the second attempt, five hundred-bushel, equivalent to approximately 150,000 scallops, were relayed to a site within the SeaStead zone. A subsample was measured to provide an estimate of the size frequency distribution of the deployed scallops. The protocol for the second bottom ranching experiment increased the frequency of the observations on the relayed bed of scallops to ensure the bed could be tracked over time. A subsample of the ocean ranched scallops was collected by dredge and measured on 2 August 1998 to determine if any growth could be detected in the population.

Results: Because the bed of relayed scallops was left undisturbed for the first nine months, it was difficult to find the bed for subsequent sampling. As a result of this difficulty, the bed was sub-sampled at a very small level after 374 days. Although the number of scallops collected after 374 days at the SeaStead site during the first bottom ranching experiment was very small (ten individuals), the average valve depth of the ranched scallops had increased from 70.1mm in May 1997 to 89.5mm in June 1998 (Table B-8 and Figure B-8a). This represents an overall growth of 19.4mm or a daily growth rate of 0.052mm/day.

The second bottom ranching experiment resulted in a more successful tracking of the relayed bed. The strategy employed for tracking the second ranching experiment was to place a video observation sled on site during deployment and again within a week after the initial deployment. Observation on the relayed bed was continued whenever the opportunity arose where the limitation was the accessibility to the commercial scallop dragger and the video sled at the same time.

The second ocean ranching bed was sub-sampled after fifty-eight days to measure the size of the deployed population. The size frequency distribution of the scallop population as measured at the time of deployment and at fifty-eight days post-deployment is represented in Figure B-8b where the mean valve depth at time 0 was 107.9mm whereas after fifty-eight days it was 106.4mm (Table B-8).

Accomplishments: Sea scallops were deployed in an ocean ranching situation at the SeaStead sea scallop culture site on two occasions. They were subsequently sub-sampled after 374 days in experiment one and after fifty-eight days in experiment two. The daily growth rate of the scallops in experiment one was 0.052mm/day, approximately one half of the rate observed in the undisturbed population (0.106mm/day). Because the number of scallops collected during the second sampling event was very low (ten individuals), the data collected may not represent the entire range of the relayed population and the observed growth rate may not be accurate.

The second ocean ranching experiment has resulted in the researchers being able to track to relayed scallop bed more carefully using video cameras. Unfortunately the duration of the second experiment has been very short with the second sample being collected only fifty-eight days post-deployment, resulting in no observable growth in the population. This population will continue to be monitored and more data will be collected after a longer time interval in the future.

This project has demonstrated that relaying sea scallops and deploying them in an ocean ranching situation is biologically feasible. The scallops can be tracked and monitored and scallop growth can be demonstrated. More extensive experimentation will need to be developed to monitor ranched populations to assess the overall survival and growth, thereby allowing the culturists to develop a more complete assessment of the biological and economic feasibility of ocean ranching of sea scallops.

Bottom Cages

Objective: A more intensive method to raise sea scallops is to house them in some sort of predator exclusion apparatus, such as a wire mesh cage. To test the concept of culturing scallops in bottom cages, scallops were relayed from a wild population into cages constructed of one-inch plastic coated wire mesh. The cages were deployed on the bottom at the SeaStead scallop culture site. During the grow-out interval in the cages the scallops were assessed for mortality and growth.

Methods: Scallops were relayed from the wild population to a series of three trawl lines of cages with each line consisting of ten to twenty cages. The design and construction of the cages is described elsewhere in this report. The cages were stocked on 19 September 1997 and deployed. On 19 October 1997 three cages from each line were sampled for mortality within the caged population and the size frequency distribution of the initial population was measured on a the sub-sample of scallops in the nine cages. The cages were left on-site for 236 days after which one string of cages was recovered (1 June 1998) and all of the scallops or empty valves in the cages were measured.

Results: Two parameters were monitored as an evaluation of the efficacy of bottom cage culture, mortality and increase in valve depth (i.e. growth). The most pressing issue was scallop survival in the cages. Immediately following the initial stocking of the bottom cages, there was an extensive mortality. By the time of the first sample, 19 days after initial stocking, mortality rates ranged from 43% to 97% with the average mortality observed in the cages sampled being approximately 75% (Table B-9). Following this initial wave of mortality, scallop mortality was relatively low, ranging from 7% to 9.5% in the two cages that were sampled both on 8 October 1997 and 1 June 1998.

The growth of the caged scallops was measured by comparing the size frequency distributions and the mean valve depths of samples of the caged scallop populations between 8 October 1997 and 1 June 1998 (Table B-10 and Figure B-9). Scallop growth averaged 21mm over the 236 day sampling interval resulting in a daily growth increment of 0.089mm/day.

Accomplishments: As was noted in the laboratory experiments on scallop survival following relaying, stress or damage due to handling sea scallops during relaying results in significant mortality to individuals within a population. The mortality that was observed in the cage experiment (average of 78.2% mortality) was the highest noted for all of the experiments undertaken in this study. As was stated above, there is a great need for research to be conducted to address the development of a less damaging method to harvest scallops destined for relay and an effort must be put forth to develop appropriate technology for transporting live scallops aboard commercial fishing vessels. Correcting these two issues could probably result in a decrease in the overall mortality to below 20% for relayed scallops.

Those scallops that survived the relaying and deployment in the bottom cages performed relatively well. They grew from 68.5mm to 89.5mm for a total growth of 21 mm in 236 days. This translates to a daily growth increment of 0.089mm/day. This growth approaches the growth noted for the population of scallops left untouched in their native habitat (0.106mm/day). With more control on handling stresses and on issues such as stocking densities, which were not carefully controlled in the current cage experiments primarily due to extensive mortalities, coupled with a better understanding of the environmental requirements of the sea scallop, we conclude that sea scallop culture could become a viable form of bivalve mollusk aquaculture within the Exclusive Economic Zone in U.S federal waters.

B. Significant problems

There were some significant problems that severely handicapped this project. The first and greatest was the extreme amount of time and effort it took to get the experimental site approved. In many ways this was not a waste of time because we accomplished a tremendous amount of groundbreaking for future research and aquaculture /resource enhancement efforts. It did however subtract from the scientific and technical work that should have been accomplished by this project.

The second major problem was the significant restrictions placed on the project by NMFS Fisheries Management authorities. They effectively prevented the project from harvesting seed by preventing access to potential seed beds in the groundfish closed areas. When we did locate a seed bed during a fishing trip, with a NMFS observer onboard, they refused to allow a liner to be placed on the dredge. When closed area access was finally approved at the end of the project, they restricted the fishing time to the point we could not scout for seed beds even with a NMFS scientist onboard.

The NMFS requirements for seven day notification before going out to even check the scallop site and the prohibition on mixed trips frustrated any attempt to conduct the project in an economically viable manner, i,e,, using vessel time efficiently. This greatly limited the amount of time available to the project personnel to conduct in situ research.

A final problem, though not completely unexpected, was the fact that a mobile gear vessel towed through the site destroying all three bottom cage strings and possibly the lantern net array, We suspect the vessel was a clam dredger. We knew there was a high likelihood of this type of gear conflict which will need to be taken into consideration in projects of this nature.

C. Additional work needs

We are only at the initial stages of making scallop resource enhancement a reality so there are significant research and management problems to be addressed. We now have a research site established for at least the next two years. The site is marked and there are two beds of seeded scallops within the site. At a minimum, the beds should be monitored on a regular basis.

VII. Evaluation

In our project proposal we listed 14 questions to be answered to evaluate the project impacts. We will now go through those questions and provide answers.

1. Do we gather sufficient information on scallop transport, seeding, predators, and their control to proceed properly in subsequent phases of the project?

We gathered a significant library of information on scallop culture, transportation, seeding and predator control. This information was augmented by a scallop workshop put together by project team members at the World Aquaculture Conference. This information allowed the project to proceed though we were not permitted to practice predator control on bottom seeded beds.

2. Are we able to satisfy the regulatory and permitting requirements of the U.S. Army Corps of

Engineers, the U.S. Coast Guard, the Management Council, NMFS, and other agencies with respect to our chosen site?

We satisfied all regulatory and permitting requirements of the above mentioned agencies.

3. Is the moored, suspended scallop grow-out array serviceable and does it survive the weather it is exposed to during the project duration?

As we progressed through the project planning stages, waiting for permission to work the site, it became apparent that we did not have the resources for the proposed large array system. In addition, the preliminary economic analysis coupled with marine mammal concerns made this approach seem less promising. We opted to test the off-the-shelf Japanese lantern net array and this did not survive the site conditions.

4. Are the modification done to the two New Bedford scallop draggers judged by the captain and crew to be proper and sound?

The modifications to the vessels for the purposes of transporting scallops were easily accomplished and any operational problems were solved.

5. Are the live transportation units we develop capable of keeping large quantities of scallop alive for transport and seeding?

We tested several types of containers for transporting scallops. However, scallop transport needs to minimize handling of large quantities of scallops. In the end deck loading was the best solution given that transport can occur in cold water temperatures and at night.

6. Are we able to successfully harvest small scallops and seed the bottom and load the array?

We did not harvest scallops as small as we would of desired due to the problems stated in the report. We did harvest enough scallops for bottom seeding and loading cages.

7. Do the cooperating vessels see sufficient incentives to seeding their lane and do they adopt a sense of ownership and the associated responsibilities?

We did not use the scallop vessels as initially planned because of the difficulties in getting permits. In addition, new ring size increases eliminated any bycatch availability for seeding.

8. Is the growth of seeded scallops within the grow-out lanes sufficiently greater than on the fishing grounds to make this approach to resource utilization attractive?

We did not accomplish enough work to answer this question. The advantages of transporting scallop seed to new areas are complex and deal with many issues beyond growth rates.

9. Do the growth rates found in the suspended array justify the capital costs and labor associated with them?

Regarding bottom cages; no.

10. Do we identify a sufficient number of suitable scallop grow-out sites in New England to allow the allocation of all fishery participants their own grow-out areas without significant negative impacts on competing fisheries?

We did not identify specific sites but did focus on the issue of criteria for the purposes of identifying sites.

11. Do we develop model law to facilitate the growth of sustainable scalloping?

We helped to establish the procedures and developed fishery management plan materials that are now in place to allow aquaculture to move forward.

12. Is our report readable and does it properly convey the findings of the project?

Yes.

13. How widely do we disseminate the report? Do those who want the information get it?

The Sea Scallop Working Group has widely disseminated the progress made by this project as reported in this report..

14. Finally, is our approach taken seriously by the industry and those who manage it?

The scallop industry is now moving forward with a plan to manage scallops using a rotating area management system as we proposed including areas for seed harvest and seeding. This last question and answer sums up the success of this project.

APPENDIX A

Engineering Drawings

Coonamessett Farm

and

Biological Data

APPENDIX I

Aquaculture Policy Development

SeaStead Project

Coonamessett Farm