Technical Report

SUBMERGED COASTAL OFFSHORE MUSSEL AQUACULTURE SYSTEM (SCOMAS): A MULTIDISCIPLINARY APPROACH

Walter Paul and Mark Grosenbaugh

MITSG 01-11

MIT Sea Grant College Program

Massachusetts Institute of Technology
Cambridge, Massachusetts
02139

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NOAA Grant No.: NA86RG0074

FINAL REPORT

for the

MIT Sea Grant College Program

Project Title:

Submerged Coastal Offshore Mussel Aquaculture System (SCOMAS): A Multidisciplinary Approach

Reporting Period:

September 1999 through September 2000

by

Walter Paul

Woods Hole Oceanographic Institution

November 20, 2000

Project Update

MIT Sea Grant College Program

Return to: Richard Morris E38-300 292 Main Street, Cambridge, MA 02139 (617) 253-7042

Please Read Instructions Before Completing

PART I - PROJECT IDENTIFICATION INFORMATION

Investigator: Walter Paul, Mark Grosenbaugh Grant Period: September 1999 through February (September) 2000

Institution: Woods Hole Oceanographic Institution

Address: WHOI, MS #9
Woods Hole, MA 02543-1053

Sea Grant Funding:

Initial Year: $ 37,500
Second Year $ 37,500
Subsequent Years: ( ) $

Theme Area: Offshore Aquaculture, Mooring Technology, Numerical Modeling, Submerged Longline

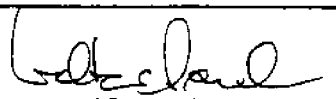
Project Title: Submerged Coastal and Offshore Mussel Aquaculture System (SCOMAS), a Multi-Disciplinary Approach

Project Number: MIT P.O.#: 5700000750, MIT Tracking No: 02216794

PART II - DOCUMENTATION

ITEM (*Place an X in appropriate blocks)*	None	Attached Previously	To be furnished
Name and degree candidacy of all students Theses or student reports, two copies plus abstract of each	x		
Information on patents and inventions	x		
Publication citations, plus two reprints of each paper	x		
Publicity, key correspondence, other relevant material	x		

Current matching funds: $25,000 per year. Sources: Blue Gold, The Woods Hole Group, Fukui North America, Woods Hole Oceanographic Institution discretionary funds, DorMor Anchors.



Signature of Principal Investigator

Date: November 20, 2000

PART III - RESULTS, ACCOMPLISHMENTS & BENEFITS
Please summarize your results, accomplishments, and benefits in up to five pages. *Please see separate file*

Submerged Coastal and Offshore Mussel Aquaculture System (SCOMAS)
A Multidisciplinary Approach

Final Report for the MIT Sea Grant College Program

Walter Paul and Mark Grosenbaugh
Woods Hole Oceanographic Institution
October 1999 through September 2000

Part III: Results, Accomplishments and Benefits

SUMMARY: This report summarizes the activities and findings during the final period of a two year effort to study the grow-out of mussels offshore. The site of the experiment was the "Buoy Farm" of the Woods Hole Oceanographic Institution (WHOI), a charted test area 9.5 nautical miles southwest of Gay Head, Martha's Vineyard. A submerged longline mooring system was deployed in October 1998, and the growout harness was suspended from the longline in December 1998 and June 1999. The mooring was retrieved in June 2000, and the project work was completed during the summer of 2000. The year 2 (September 1999 until September 2000) at sea activities consisted of four visits to the site. The entire harvest yielded approximately 3,000 lbs. of mussels. An additional similar amount of mussels fell back into the ocean during retrieval operations before the supporting harness could be raised on board of the service vessel[1]. The retrieved mussels were 2 to 3 inches in length and of exceptional taste and meat quality[2]. Delicious two inches long market size mussels had grown in 10 to 12 months, 3 inch mussels took about 18 months and could have been harvested at an earlier time. Presentations about the mussel project were made during two workshops, and a professional videotape was prepared about the progress of the mussel growth and the harvesting effort. The experiment is considered successful, it provided a wealth of information and significant harvest. The mussel larvae seed themselves on the ropes in the water by attaching with their byssus arms to the lines, eliminating the need for seed mussel collection and deployment. It was also found that the mussels weed out other growth on the lines as they grow in size. Both the mussels' self-attachment to the growout harness, and the mussels' ability to generate a monoculture on the lines should be significant cost savers for a commercial mussel production. The feasibility to grow mussels offshore in waters south of Cape Cod seems to have been established. The warmer summer water temperatures may accelerate the growout process. The project raised commercial interest to deploy a series of longlines at the site.

1.0 Background Information, What Was Done

This project is part of three funded research contracts at WHOI, which focus on the biological, economic and engineering aspects of a mussel grow-out project offshore. Support for the biology effort funded a Massachusetts Aquaculture Grant (MAG). The WHOI Sea Grant College Program provided assistance to the Marine Policy Center at WHOI for the economic support and help with the permit application process, and the MIT Sea Grant College Program supported the engineering development for the mussel growout system.

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[1] The in water mussel weight increases three times once the mussels are raised above the water. The byssus strings of some mussels can not support the weight increase once the hanging ropes are raised out of the water, big mussel clumps fall back into the sea. Spaced cross bars have to be added to become part of the growout ropes, they would support the mussel weight and reduce losses when the lines are retrieved.

[2] Some of the mussels harvested from several socking loops contained pea crabs, small crabs that seem to originate from seed mussels that were scraped off a rock near Plymouth, MA. The mussels that had attached themselves on the rest of the socks and growout ropes were pea crab free. Pea Crabs in mussels, although harmless and edible, reduce the market price of the mussels.

Activities During Year 1, March 1 1998 through September 1999: The long-line mooring was modeled, designed, its components selected, procured, prepared and assembled. The system was deployed in October 1998, after a permit for its installation was obtained from the US Army Corps of Engineers. Activities for this project started earlier in 1998, with permit application and some work at the buoy farm in order to expedite the project. The grow-out harness was suspended from the long-line in December 1998 and early June 1999. A side-view of the deployed system is shown in Figure 1. Heavy growth of grass-like hydroids settled on all ropes over the winter of 1998-1999, containing thousands of tiny mussels. At the end of the 1999 summer the mussels had grown to about 1 cm in length and were starting to take over space held by the hydroid growth. The weight of the suspended grow-out harness increased significantly, and extra floatation was added in August 1999 to support the added weight. Hurricane Floyd did not damage the system, as a diver inspection a few days later found out (September 1999). For further details see the year one progress report (1)[3].

Activities During the Second Year of the Project, September 1999 through September 2000.

At the end of the 1999 summer significant mussel growth was observed during site visits in August and September, but the mussels were too small for human consumption. During the winter the mussels had grown to market size.

On the first site visit in 2000 in early March the crew on board the RV *Asterias* stripped over 500 lbs. of mussels from several socking loops of the growout harness in an exhausting 5 to 6 hour effort. The mussels had grown to a market size of approximately two inches in length, see photos in (2)[4]. The crew did not attempt to recover the much heavier 92 ft long growout ropes.

A harvesting cruise was conducted on April 20, 2000, using the modern 100 ft long fishing trawler *Nobska* based in Woods Hole, owned and operated by Matt Stommel. The vessel has eight independently operating winches, including three powered overhead net reels and a bow thruster. Matt suggested an easier and faster way to raise the mussel loaded up to 300 lbs. heavy growout ropes on board[5]. Over 1,000 lbs. of mussels were harvested in record time. All socks and vertical growout ropes were redeployed. It took the *Nobska* and its captain and four people on deck two hours to raise, inspect or harvest, and redeploy the entire harness.

The FV *Nobska* made a retrieval trip to the site on June 15, 2000. The trip was conducted to get the entire gear to shore in order to allow inspection of all mooring hardware, replacement of any worn out components, and getting the gear ready for redeployment. First the western DorMor anchor was broken easily out of the soft clay at the site with and raised with its nose first by the

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[3] (1) Paul, W., and M. Grosenbaugh: *SCOMAS Mussel Project Update*, Progress Report for MIT Sea Grant, Woods Hole Oceanographic Institution, September 1999.

[4] (2) WHOI proposal #OE10547.00 to MIT Sea Grant submitted March 27, Rev. April 13, 2000.

[5] The growout rope was secured to a lead line from the aft net reel, located right over the stern. This reel served to wind up a mussel loaded rope or sock. First the weight of the hanging rope was transferred to the lead line from the winch. The mussel line was then cut from the longline just above its connecting point with the net reel lead line. The mussel carrying rope was hoisted out of the water and spooled onto the net reel, and later lowered on deck for removal of its payload. This is a rapid and almost effortless process, lasting an average of only 4 minutes per line, eliminating the slow strenuous and hazardous task to raise the heavy mussel lines out of the water by hand. For redeployment Will Ostrom, senior mooring technician at WHOI, found and procured special hardware called grommet hooks. A matching pair of grommet hooks allows quick connect and disconnect of two line ends without splicing or cutting. One grommet hook was spliced into a short rope end that was secured to the longline with the other end. The other grommet hook was spliced into the upper end of the growout rope or sock. Once the two lines are without tension, the hooks can be engaged or disengaged quickly, a significant time saver.

marker buoy mooring's ground wire. On the anchor rope very heavy mussel growth (up to 18 inch thick) was found and recovered. More mussels were found on the undisturbed ends of the longline on each side, see Figure 2, pulling off the large quantities of mussels from the ropes was quite a challenge. The east DorMor anchor had to be broken out of the ground in the direction of its anchor-line pull, the west anchor was pulled out by its nose. A 20,000 lbs. load cell was put into a loop of the trawl wire and the breakout tension was measured at 8,200 lbs. tension, about twice the anchor weight in water. Both anchors were retrieved on deck without incident, see Figure 3. Again a lot of mussels were scraped off the undisturbed end of the longline and the east anchor line, and over 1,000 lbs. of market size mussels were brought back by the *Nobska* - see Figure 5 - and given to the Woods Hole public. The entire site operation took under three hours thanks to the versatile gear and winches of the FV *Nobska,* and the skill and efficient collaboration between the ship crew and the WHOI mooring technicians on deck guided by the ship's captain, Matt Stommel, and Will Ostrom from WHOI.

Onshore Longline Inspection: Most of the mooring system, in particular the longline and its hardware, was inspected on shore near the end of the summer 2000. On a few spots near the center of the longline some slight damage and wear was found, but mostly the line, after removing the marine growth through power-washing, looked almost new[6]. A section of the line will be tested to destruction to determine its residual breaking strength. After re-splicing the longline, all ropes and connecting hardware can be reused in a future deployment.

2.0 Accomplishments and Benefits:

The effort consisted of the modeling, design, and construction of a longline mooring system with a suspended mussel growout harness, its deployment, servicing, harvesting, and retrieval at sea, and onshore inspection after the sea test. This mooring system was deployed in order to determine if offshore mussel growth was feasible and happening at a rate that it might become a form of offshore shellfish aquaculture. A side view of the deployed system is shown in Figure 1, a detail of the anchor line mooring in Figure 5. A list of the ship trips to the buoy farm in conjunction with this project is found in Table 1. Ship visits (10) to (13) are part of the year 2 efforts. Table 1 does not include separate ship visits to deploy and exchange four guard buoys at the corners of the site, this had to be done annually in order to protect the scientific moorings and instrumentation at the buoy farm.

Assessment of Objectives: Of the nine objectives listed in the proposal six were reached. The objectives met are:

1. Engineering and overall feasibility
2. The design of a survivable and serviceable structure to grow mussels offshore
3. The engineering design enhancement through improved hydrodynamic modeling
4. The multi-disciplinary task of the project with close collaboration of the team pursuing the economic, biological, and engineering components of the effort.
5. Determination of geometric drivers to optimize serviceability of the submerged longline at sea from a surface vessel
6. The successful at sea deployment, servicing, and retrieval of the system, which was recovered with little signs of wear after 19 months at sea.

[6] In some areas there were flat spots at the suspension points of some of the heavy growout ropes, and near the center of the longline there was an area frequently "stabbed" by the grapnel hook used to find the longline and pull it to deck height for servicing. One 10 inch section had significant surface wear from rubbing over a sharp edge probably during servicing, this will be cut out and the ends respliced.

The following objectives were not reached or dropped:

7. The close cooperation with Blue Gold, our industrial partner, ran out due to financial difficulties of the mussel processing firm and its relocation in 2000 from New Bedford to Canada. In-kind assistance had to be sought elsewhere, in particular for some of the ship charter and diving services. Financial aid was of $50,000 was received from discretionary funds of the Woods Hole Oceanographic Institution, diver services were donated by Steve Aubrey from Aubrey Consultants. The Marine Policy Center and the Coastal Research Center at WHOI donated ship charter on two occasions to visit the site, and Mark Grosenbaugh allowed us to piggyback three times to conduct work at the test site, and to exchange guard buoys.
8. Monitoring of the submerged longline through sensors. This work was never budgeted, no opportunities became available to perform this work, however sea state and currents were monitored in one of Mark Grosenbaugh's tests in 1999, current records taken at the buoy farm are available from earlier tests.
9. The "Mature the engineering design" objective was discarded (motherhood statement)

Event #	Date	Event Description	Name of Vessel
(1)	03-18-98	Six Spat Collector buoy moorings deployed, sea floor samples taken with Young van Veen clamshall grab, drag test with DorMor anchor conducted	FV *Melissa & Vanessa*
(2)	06-28-98	Dive trip to determine O_2 content, CTD, and nutrients at the site	RV *Mytilus*
(3)	09-21-98	Diver cruise to check mussel growth, only few were found	RV *Mytilus*
(4)	10-14-98	Mussel longline mooring deployed in bad weather	FV *Alpha & Omega*
(5)	10-17-98	Revisit to reposition the longline, 2 spat collector moorings retrieved, one stored in sea water, one dried out onshore.	FV *Alpha & Omega*
(6)	12-05-98	Four 92 ft spat collector ropes (2 ropes were lost at sea) suspended from longline, begin of growout experiment	FV *Alpha & Omega*
(7)	05-28-99	Inspection of mooring, heavy growth (hydroids) found on all lines. Attachment of first socking loop to longline	RV *Connecticut*
(8)	06-02-99	Suspended almost all socks on longline, some filled with seed mussels from rock near Plymouth, MA, some empty	RV *Asterias*
(9)	08-26-99	Diving along longline, heavy mussel growth now dominant flotation added to counter increased mussel weight	RV *Asterias*
(10)	09-27-99	Diving cruise along mooring after passing through of Hurricane Floyd, system undamaged	Boston whaler from WHOI
(11)	03-21-00	Inspection cruise, led to recovery of 500 lbs. of market size (~ two inches long)	RV *Asterias*
(12)	04-20-00	Harvesting cruise. 1,500 lbs. Of mussels retrieved, another ~1,000 lbs. dropped from the long-line into the ocean	FV *Nobska*
(13)	06-15-00	Retrieval cruise. In 2 ¾ hours entire system retrieved, and ~1,200 lbs. of mussels harvested from anchor ropes	FV *Nobska*

Table 1: List of Sea Activities to support Mussel Farm Deployment, Monitoring, and Retrieval

New Research: No new research direction was taken during the course of the work

Major Problems: Major problems were of financial nature, there was no real problem with the technical tasks of the effort. The dropout of the industrial partner Blue Gold was difficult but was overcome thanks to additional and new support (see above under 7.). In general contracts with

significant ship charter require a sufficient cushion in the budget to cover the uncertainties of doing work in the ocean like weather days, unscheduled inspections after storms etc.

Significant Effects of this Effort on Marine Business: The project received commercial interest. The owners of two small firms in Rhode Island, Mr. Bill Silkes of American Mussel Harvesters Inc., and Todd Corayer of Block Island Shellfish Farm, are looking for a suitable site near Block Island to set up a mussel farm. In addition Bob Garrison, a mussel farmer from Nantucket is working on a permit for a site in Nantucket Sound to address the increasing demand for mussels. These people would like to adapt the mooring designs developed under this contract to build their own systems.

The charter of the FV *Nobska*, which was used for the major harvesting and the system retrieval effort in April and June 2000, resulted in an unscheduled side effect: The vessel's owner and operator Matt Stommel came forward with a plan to invest in a mussel farm with 30 longlines. He would provide the growout moorings and hardware and perform the deployment, servicing, harvesting, and retrieval operations at sea. This farm would be located at the WHOI Buoy Farm site. If funded WHOI would support his effort with engineering, biology, and permitting assistance, and provide the guard buoys. Mr. Stommel would keep the right to sell the mussels, and will without charge deploy, service, exchange, and retrieve the guard buoys. Porter Hoagland from WHOI's Marine Policy Center recently prepared and submitted a permit request to the Army Corps of Engineers for this planned effort. A top view of the proposed installation is shown in Figure 6. WHOI will apply for funding for a two-year support contract, and will assist in getting some funding for the mussel farm hardware. Beyond the engineering, economic analysis, and biological efforts, water quality monitoring around the site and related scientific studies would be of interest. Mr. Stommel's plan is considered a significant development and would help to introduce and check out the offshore mussel aquaculture on a considerably larger scale. We are encouraged by this development and hope that this project will be permitted and can be funded.

3.0 Conclusion

The mussel growout experiment has proven that a significant new source of protein can be accessed in the coastal offshore waters south of Cape Cod by deploying submerged mussel growout harnesses. The natural growout time seems to be in the nine to twelve month range for smaller cocktail sized mussels. Twelve to eighteen months seem to be required to grow larger size mussels. The submerged deployment of long-lines as support moorings for suspended mussel culturing eliminates the worst effects of surface waves and makes the system components survivable for a number of years. The mussel growth was overwhelming and led to the proposal by Matt Stommel, a commercial fisherman, to build and install a significant number of longlines to prove the principle. This is a significant opportunity to conduct mussel aquaculture offshore as a small commercial enterprise. The incentive comes from a highly experienced commercial fisherman who sees an alternative to offshore fishing in the establishment and operation of a musselfarm, first on a small scale. Experience gained in the completed effort indicates that significant simplifications and cost savings are possible through the pragmatic experience of commercial fishermen. The charted and permitted Buoy Farm site for the experiment eliminates one major roadblock to this plan. In this pioneering effort research funds would serve as needed help to learn more about biology, engineering, legal issues and the permitting process of such an endeavor. Research support would complement the practical experience and skills of the operating personnel to come to grips with a simple but complex process of understanding one segment of open ocean aquaculture.

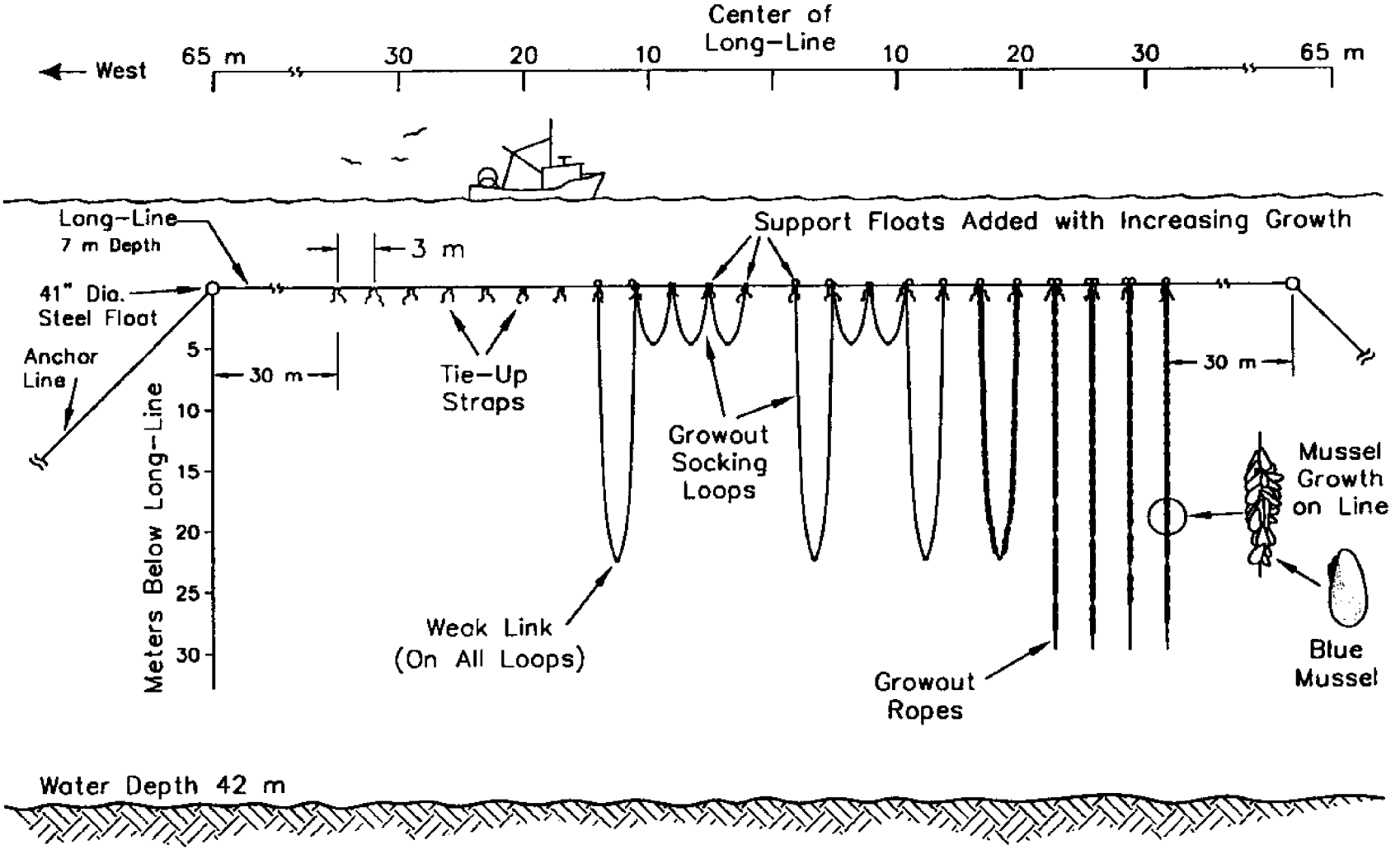

Figure 1: Side View of the SCOMAS Long-Line Mooring with Suspended Mussel Harness

Figure 2: Raising ropes covered with up to 18 inches of mussels was much more than expected and made harvesting the mussels a challenging task.

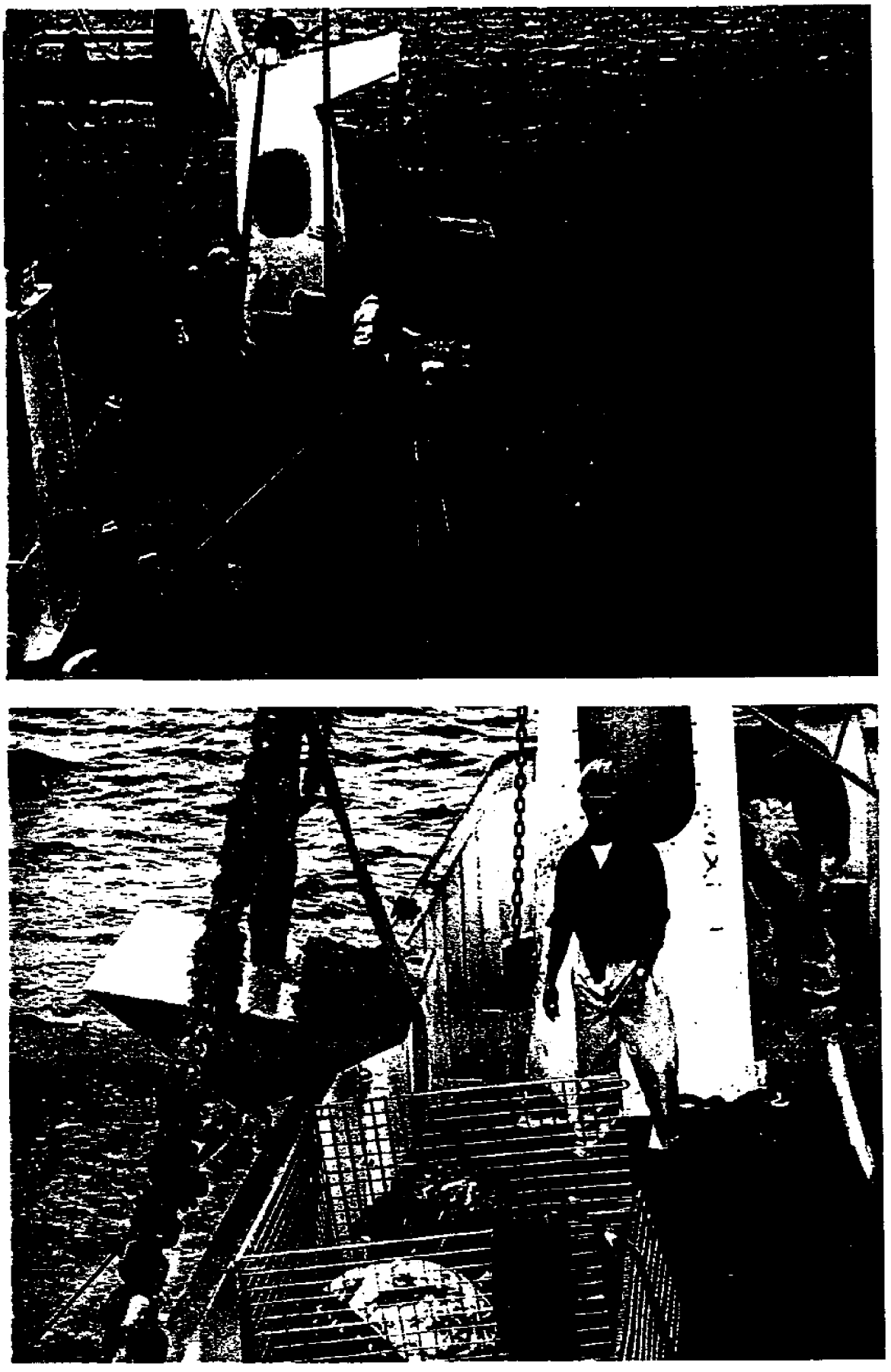

Figure 3: Two 4,400 pound DorMore anchors held the longline system in place for 19 months. Recovery of the anchors took place in June 2000. Over 8,000 pounds of break-out tension was measured when pulling the last anchor.

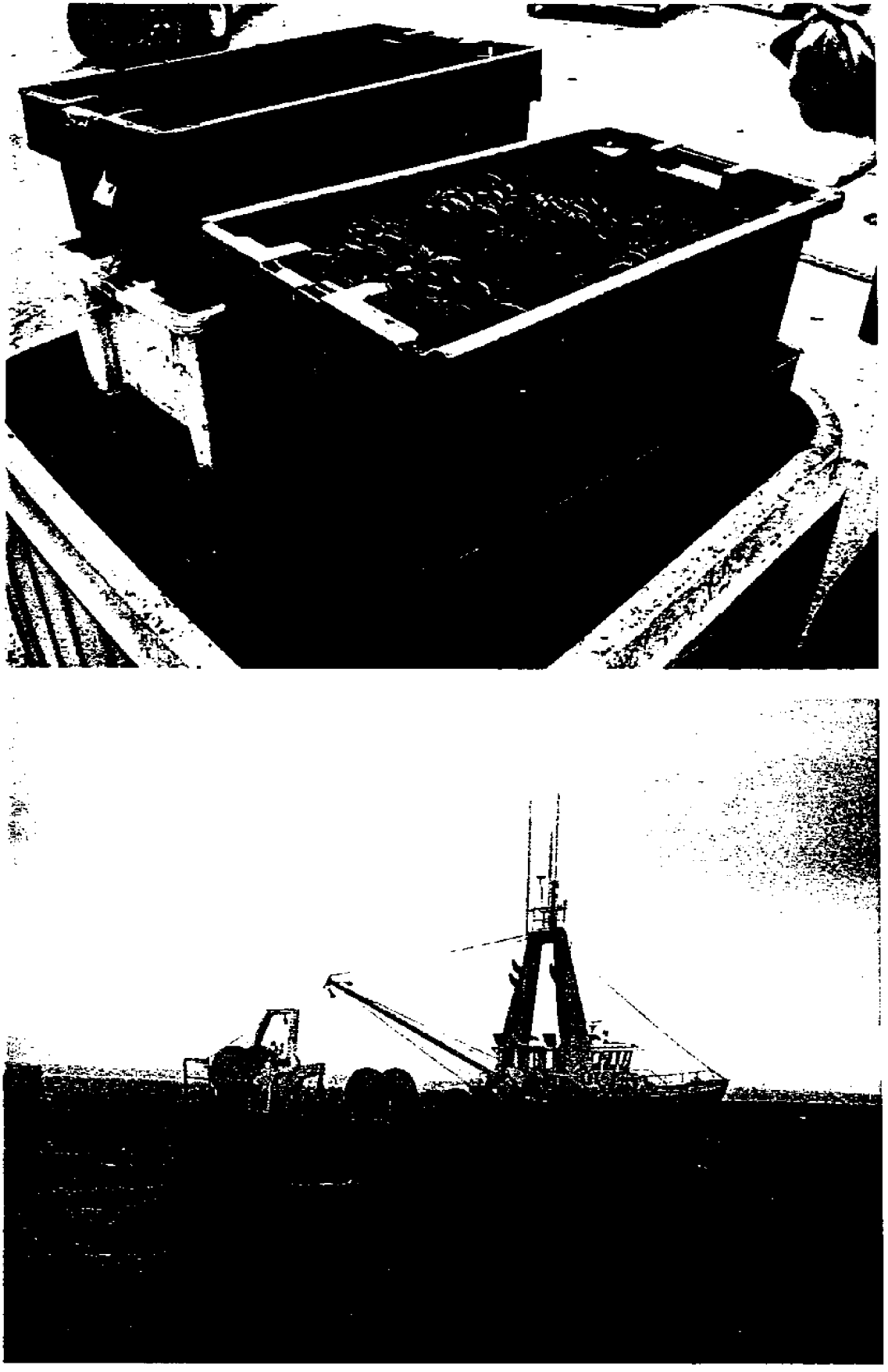

Figure 4: During recovery of the SCOMAS system over 1,500 pounds of large, delicious mussels were recovered from the anchor lines alone. Two earlier harvesting trips, resulted in 500 and over 1,000 pounds of mussels collected, and large mussel quantities lost which fell back into the sea. The lower image shows the FV *Nobska* after unloading of mussels and special gear leaving, the WHOI pier.

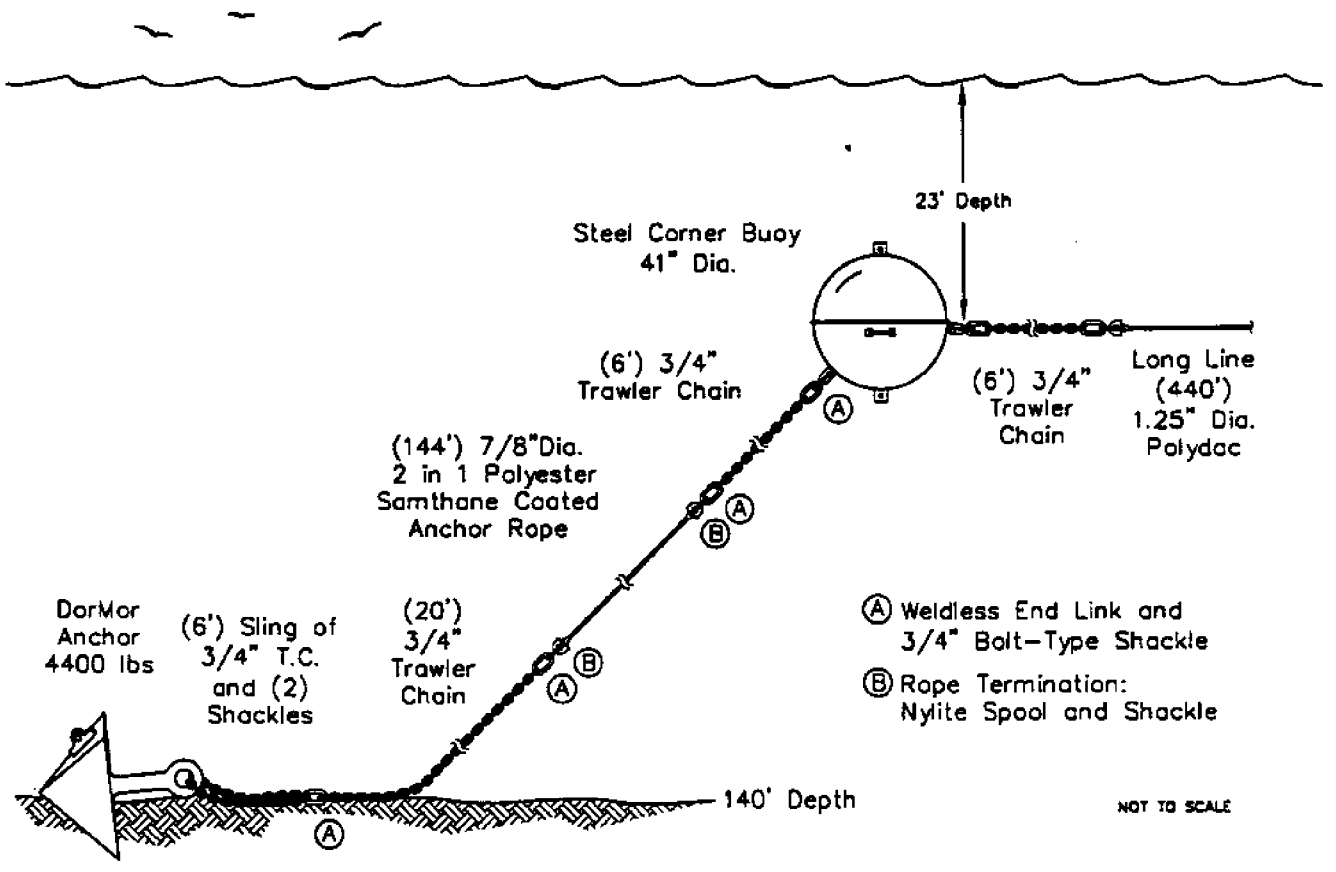

Figure 5: Anchor and corner buoy mooring detail.

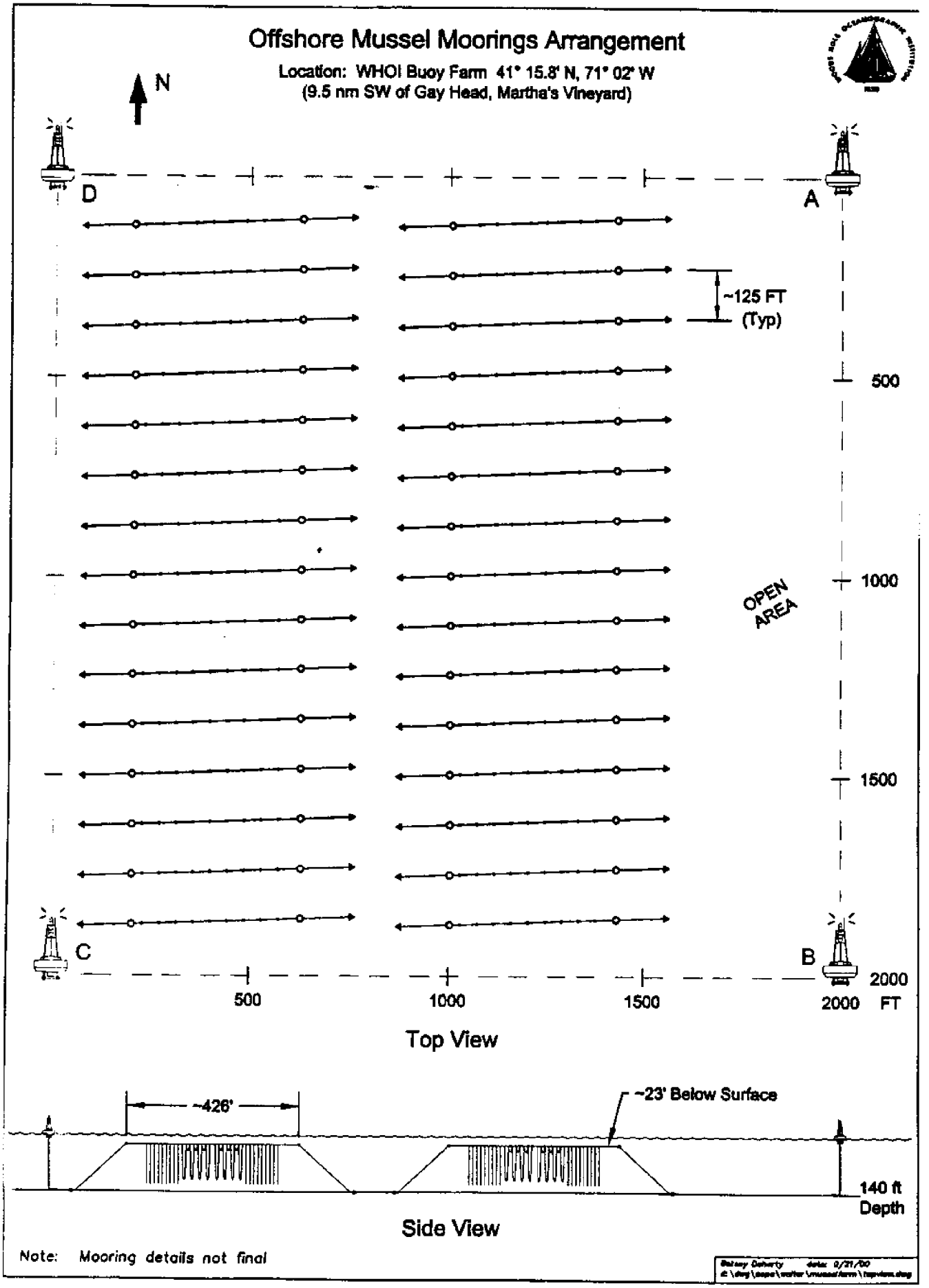

Figure 6: Top view of proposed mussel farm at the WHOI Buoy Farm Site.

PROJECT SUMMARY FORM

Sea Grant Institution: ***Massachusetts Institute of Technology***

ICODE: ***2500***

Project Title: Submerged Coastal and Offshore Mussel Aquaculture System (SCOMAS), a Multi-Disciplinary Approach

Second year of a two year project.

Project Number: 5700000750

Revision Date:

Project Status: Concluded, but ready to start in expanded scale, if funded

Initiation Date: 05-07-1998

Grant Number: 02216794

Completion Date: 02-28-2000, actual early summer 2000

Sub Program:

Principal Investigator: Walter Paul
Affiliation: Woods Hole Oceanographic Institution
Affiliation Code:
Affiliation: Woods Hole Oceanographic Institution
Affiliation Code:

Months effort per year: 1.1

Associate Investigator 1:
Affiliation:
Affiliation Code:

Months effort per year:

Co-principal Investigator: Mark Grosenbaugh

Months effort per year: 1.0

Associate Investigator 2:
Affiliation:
Affiliation Code:

Months effort per year:

FY Beginning March 1, 2001 Sea Grant Funds: *none*

FY Beginning March 1, 2001 Sea Grant Funds:

FY Beginning March 1, 2002 Matching Funds:

FY Beginning March 1, 2002 Matching Funds:

FY Beginning March 1, 2003 Pass-Through Funds:

FY Beginning March 1, 2003 Pass-Through Funds:

Related Projects: Support of Mussel Biology and Marine Policy and Economics of SCOMAS offshore mussel project, funded by a Massachusetts Aquaculture Grant and WHOI Sea Grant respectively.
Also: Modeling, Engineering Analysis and Monitoring of Offshore Fish Pen Systems (Paul, W., M. Grosenbaugh, J. Irish), University of New Hampshire Open Ocean Aquaculture Subcontract to WHOI Sept 1999 through August 2001
Also: Reducing the Risk of Open Ocean Aquaculture Facilities to Protected Species (Paul, W., H. Kite-Powel, K. Vonder Heydt), funded by Woods Hole Oceanographic Institution Sea Grant College Program, start March 2000, I year

Parent Projects: None

Sea Grant Classification:

Keywords: Offshore Aquaculture, Long-Line Mooring, Hydrodynamic Modeling, Shellfish Culturing

Objectives:

1.) Determine engineering feasibility of cultivating blue mussels (*mytilus edulis)* within offshore waters west of Martha's Vineyard, Massachusetts in the Exclusive Economic Zone (EEZ).
2.) Establish the engineering design for a survivable and serviceable structure for mussel grow-out project in unprotected waters. Provide means to minimize entanglement risk for marine mammals.
3.) Develop improved hydro-mechanical modeling of submerged long-lines to understand the response to ocean currents and waves.
4.) Collaborate with biologists and economists who monitor biological growth and health of the mussels, and economic viability of mussel growout aquaculture offshore.
5.) Determine geometric drivers to optimize serviceability of the submerged longline from a surface vessel.
6.) Deploy, maintain and service submerged long-line system with suspended mussel grow-out harness, and retrieve unit at end of program
7.) Conduct project in close collaboration with Blue Gold, a mussel processing firm in New Bedford, MA, our industrial partner
8.) Monitor submerged longline through sensors
9.) Mature the engineering design

Methods:

- A submerged long-line mooring was designed , which is serviceable from a surface vessel
- Numerical Modeling was conducted to aid in the design and estimation of mooring forces and sea state response.
- The mooring components were selected, using the most suitable materials and constructions with proper safety factors and terminations to survive a planned two year deployment. The components were procured and assembled, and weak links installed at the bottom of socking loops to eliminate the chance of marine mammal entanglement.
- Chartering of commercial fishing boats for deployment, most servicing, and retrieval.
- Monitoring of mussel growth by the biology team funded under Massachusetts Aquaculture Grant
- Inspection and assessment of mooring component wear after system retrieval

Rationale:

- The SCOMAS system sought to exploit the natural presence of food for mussels in offshore waters west of Martha's Vineyard
- Mussel grow-out experiment to be conducted in a submerged mode to reduce wear, tear, and dynamic loading from surface waves, and to reduce the risk of airborne predators and human interaction.
- Engineering design to be supported by customized numerical modeling to understand the system's response under ocean current and wave forcing, aiding in the selection of reasonable safety factors for mooring components and hardware.
- Engineering design also includes selection of most suitable rope and hardware components and investigation of geometric optimization of long-line mooring system geometry to optimize serviceability from surface vessel without affecting mooring stability and payload.
- The design also incorporates weak links that would rupture if marine mammals would swim into the mussel socking loops. The weak links would break under a tension of 100 to 200 lbs.
- Project was a collaboration with separately funded biology and marine policy contracts to cover separately: (1) the mussel biology (growth, predation, commensals) and (2) permitting and economic analysis, in particular cost projections
- Results of this collaboration provided input into the engineering, related biology, permitting and economics know-how required for future mussel long-line enterprises to encourage starts of new mussel aquaculture projects offshore

Engineering, biological and economic advice for this project was provided by our commercial partner Link Murray, president of the mussel processing firm Blue Gold Inc., and by the prime developer of commercial offshore mussel farms in Canada, Dr. John Bonardelli, formerly of GRT Aquatech in Quebec Province. Matt Stommel, owner of a local fishing vessel, developed easier methods of servicing and harvesting the longline and suspended mussel harness at sea while contracted by program to work at the mussel farm site.