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Seventh Conference for Shellfish Growers:

Clam and Oyster Farming

Conference Record

March 3-4, 1997 - Olympia, Washington

Terry Nosho, Organizer/Editor

Sponsor

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SEA GRANT PROGRAM
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Alaska Sea Grant Program
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WSG WO 98-01

Terry Nosho, editor; Nancy Blanton, Kris Freeman, Nancy Lerner, copy editors; Vicki Loe, graphic designer. Illustration of oyster concepts for Yves LeBorgne's summary by Sandra Noel.

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Contents

Forward

The "Conference for Shellfish Growers" has been sponsored since 1991 by the Washington Sea Grant Program. The annual event is intended to be an educational forum for the shellfish industry and a tool to facilitate information sharing between industry members locally, regionally, nationally, and internationally. It also provides interaction opportunities for industry, researchers and agency representatives. Conference attendance has been 220 persons in each of the past two years. Of these, about 90% of the attendees are from industry. This is probably the largest annual gathering of shellfish industry members in North America. The success of the meetings is largely due to direct grower participation, and the willingness of researchers and agency personnel to share their knowledge with the industry. Washington Sea Grant Program will continue to sponsor this conference so long as relevant topics can be identified.

This year the conference dealt with Manila clam culture, geoduck culture, aspects of oyster farming, and updates on selected species with culture potential. I wish to provide the reader with the following thoughts on how and why the subject material was developed.

Discussions on various aspects of Manila clam farming have been presented on numerous occasions at this and other meetings. However, a program that incorporates seed production, nursery methods, the most recent farming advances and experiments, and market preparation, had never been developed. All the salient presentations were made by industry members because they are the ones innovating in a practical manner. The one exception was Harrison Brecee, a student of the North Carolina Sea Grant Program. His work on "U-Rake Clam Farming" in North Carolina may be applicable in the Pacific Northwest because the general public only has access to well-worked recreational beaches, and people like to dig clams. They may be willing to pay by the pound if given the opportunity to enjoy digging in productive areas.

Of the four presentations in the oyster farming session, two dealt with experimental aspects, while the two other papers discuss Connecticut's substantial oyster industry. My question was "How did the state of Connecticut restore its oyster industry in an urban sea?" The reviews presented by John Volk, Conn. Dept. of Agriculture, and Bill Green, Township of Guilford, revealed a large and vibrant Connecticut industry that was restored through a state seeding program and an active water quality program resulting from state and local cooperation. In fact, water quality has been restored to the extent that recreational and commercial fisheries exist within the boundaries of the townships. This is unheard of in the Pacific Northwest.

Wild geoduck fishery quotas and increased Asian demand for live product have resulted in market prices that justify further research and development. In essence, the high market prices for high quality product has created an opportunity for the industry and the industry is responding. Several hatcheries have been involved in the various aspects of broodstock handling, seed production, and nursery methods, while growers have been conducting farming experiments. Although not without problems, preliminary results have been encouraging. The potential is there for the industry to take a commanding position in development and marketing. Aquaculture of geoducks will set the market standards if high quality products can be supplied consistently. This session essentially combined the collective experience of the industry to date and should serve as valuable reference material for others.

The potential of new species always interests the industry. This year, the focus was on scallops (pink and rock) and sea urchin roe enhancement. From a culture standpoint, sea urchin roe enhancement seems very promising. However, longer-term pink scallop culture offers great potential because of the price scallop meat commands and the volume consumed in world markets. In future conferences we will continue to address developments with new species or provide updated information whenever relevant.

This workshop record is a compilation of papers and summaries supplied by the speakers. For your convenience and for further information, a list of conference speakers and attendees is provided in the appendix. I hope that everyone who attended the conference enjoyed it, and that this publication will be useful.

Terry Nosho

Acknowledgements

On behalf of Washington Sea Grant Program, I wish to express our profound gratitude to the many people who contributed to this meeting. I extend a special thank you to the conference speakers who took time from their normal course of activities to share their knowledge and experiences with us, and for the extra effort they gave in helping to produce this publication.

Recognition goes to the Conference Planning Committee and the Washington Sea Grant staff. Planning members from industry include Brady Engvall, Jim Donaldson, Dave Nisbet, Bill Taylor and Lee Wiegardt. I greatly appreciate their thoughts and ideas, but most importantly, they let me know if I have a suspect idea. Much time and effort was expended by WSGP staff. Teri King and Steve Harbell not only helped at the meeting, but also provided valuable input during the programming phase, and Susan Hester efficiently handled the registration process. A special note of gratitude is extended to Nancy Blanton, Kris Freeman and Vicki Loe, WSGP Communications, for developing and distributing news releases, designing and producing conference materials, editing work, and producing this conference record. Also, I wish to acknowledge WSGP management for sponsoring speakers from around the country and the world. These speakers have contributed greatly to success of the conferences.

I would like to thank Little Skookum Shellfish Growers and Taylor Shellfish Farms for their generous donations of oysters, clams and mussels. Those who attended the conference were treated to these delectable shellfish at the reception. Special gratitude goes to Ralph Schley, NORPLEX, who provided a wonderful hospitality gathering.

In addition, I am indebted to the shellfish industry for supporting these conferences, and to individual growers too numerous to mention here who have provided insights on matters important to them and to the industry. These conferences are a reflection of their input and cooperation.

Finally, the conferences could not have been developed and carried out without the advice and support of Dr. Kenneth K. Chew.

Terry Nosho

Opening Statement of Manila Clam Culture Session and Remembrance of Arnold Waring

Ken Chew, Director, School of Fisheries, University of Washington

Manila clam farming is important not only in the Pacific Northwest, but also in many parts of the world. In the past 20 years, this ubiquitous clam has been introduced and cultured in temperate and even sub-tropical areas. In Italy, France, Great Britain and other countries, Manila clam stocks are growing from hatchery production or natural spawning. Some of the new techniques in Manila clam culture were developed in our area through early research by students at the University of Washington. Subsequently, these techniques have been refined by the shellfish growers to suit their own needs. Today, we will be hearing from several people who are involved with Manila clam culture, and about the techniques they have implemented to maximize the harvest of this important commercial clam under their own beach conditions. This clam is the most important in terms of total value for the state of Washington, with a harvest close to 10 million pounds in 1995 alone, as recorded by the Washington State Department of Fish and Wildlife.

Most of you who know Arnold Waring will feel as I do, that a little something is missing in this particular Shellfish Growers Workshop today. As a matter of fact, we will miss Arnold at any of our shellfish meetings for quite some time in the future. Arnold died on Monday, January 13th of this year at the age of 83. Out of those years, he spent 50—more than half of his life—being involved with and supportive of the shellfish industry. You might say he was truly the "Oyster King." I knew Arnold in the late 1950s and, of course, many of you knew him even longer. In his earlier years, he was active with the National Fisheries Institute. He founded Coast Oyster in the mid-1940s, and later became the manager of the United Oyster Producers Cooperative. Throughout all these years, he served diligently and helped during a time of difficulty to hold the Pacific Coast Oyster Growers Association (PCOGA) together as president for, I don't know how many years. He was always sensitive to the young students who were coming up the ranks. When he was at the helm helping to organize the PCOGA-Pacific Coast Section at the National Shellfish Association meetings, he would say, "Let's work out something for the students who are presenting papers and give them a break with registration or whatever to bring them here." Some of you in the audience have been recipients of some of this help, although you may have forgotten. Thus, it would be very appropriate and fitting at this time to take a moment of silence to honor Arnold, who may have left us in the physical sense, but is still with us in spirit.

Manila Clam Culture

- Seed Production
- Manila Clam Farming
- Processing and Distribution

Basic Methods of Seed Production

Jim Donaldson, Coast Seafoods Company, Quilcene, Washington

There are two basic types of molluscan larval hatcheries. One is a seed production facility that produces relatively small numbers of larvae, usually less than a billion total of all species combined, and concentrates on production of single seed of oysters, clams or scallops. The other is a larval production facility that produces large numbers of larvae and little or no single seed, but sells larvae extensively to others who set and grow seed to plantable size. All hatchery systems for algal culture, broodstock conditioning, larval rearing and larval setting can easily be adapted to suit the culture of any molluscan species and the form or product desired. The following is a brief general description of the systems currently employed in the industry for both Manila clams and single Pacific oysters, the two most dominant species presently cultured in the Pacific Northwest.

Algal Culture

Algae are generally cultured either by using the batch method in open-top culture vessels or by continuous-flow culture in enclosed plastic bags. Many hatcheries use a combination of the two methods. The bag culture method produces dense, high-quality algal cultures, but does not provide enough total algal cells to feed large volumes of larvae or seed. Continuous-flow bag cultures work well in small-scale hatcheries but are really an intermediate step toward open-top tank cultures in larger hatcheries. Most open-top algae culture systems use metal halide lighting, although some rely solely on natural light.

Algal diets are available for use as a supplement to cultured algae and can be fed to a variety of molluscan seed. Most hatcheries culture three or four species of algae and feed with different combinations of algal species, depending on the form of animal cultured. The following is a list of the most popular species currently in use. They are useful for all species in varying degrees.

Thalassiosira pseudonana (Clone 3H)
Skeletonema sp.
Isochrysis galbana
Chaetoceros calcitrans
Chaetoceros gracilis
Pavlova lutheri
Testraselmis suecica

Broodstock

Broodstock clams and oysters require a healthy environment to convert their stores of glycogen into gametes for spawning. Many papers document the importance of broodstock nutrition in producing high-quality eggs and, subsequently, quality larvae. It is important that broodstock receive an adequate quantity and quality of algae during the entire broodstock holding process. Most hatcheries feed mixtures of the algal species they culture, rather than a single algal species, to provide the best nutritional balance to broodstock.

Broodstock can be held or conditioned to spawn in either a flow-through environment or a static environment. There are advantages and disadvantages to both. A flow-through provides a healthy environment if flow rates, food levels and temperatures are maintained at adequate levels. However, this system is expensive to operate unless the energy and food in the effluent is reclaimed. Adequate monitoring for flow, food and temperature can also be laborious.

Static tank broodstock conditioning is the most common method in use. It requires stock to be held at specific densities or biomass per volume of medium, with water changes and sanitation every two or three days. It is generally much easier to control a static environment for temperature control and feeding than a flow-through environment. The main disadvantage is the loss of the entire stock if only one of the animals releases spawn into the water. However, this disadvantage can be controlled with proper attention to the system.

Rearing Larvae

Larvae can also be reared in either a flow-through or static environment. The traditional method is static tank culture where larvae are stocked at prescribed densities at various stages of development. Tanks are drained and cleaned and larvae are graded at regular intervals. The advantage is a relatively stable environment with a continuous production of competent, ready-to-set larvae.

The flow-through larvae culture method requires a continuous flow of sea water into and out of the culture vessel. This method originated in Europe and is really a modification of the upwell system of culturing single oyster seed in high densities. The advantage over static tank culture is that much higher densities can be achieved. This enables hatcheries to culture large numbers of larvae in large facilities or save considerable space by culturing smaller volumes in small hatcheries. The disadvantages of flow-through systems include the continuous monitoring that is required to maintain food, temperatures and flow rates at the proper levels and the problems that can occur when larval densities are high during the most sensitive stages of an animal's life cycle. Clam and oyster larvae are physically tough but chemically sensitive and their reaction to stress while being reared can often be catastrophic. In a flow-through system where densities are higher, losses can be more catastrophic than in lower density static tank systems.

Setting Clams and Single Oysters

A traditional upwell/downwell system can be used to set both clams and single oysters. They are generally set with the water flowing down onto the screen. The flow is then changed to move up through the screen once the larvae have settled and new shell growth has begun, which usually takes about a week. Both clams and oysters are washed daily and graded every week to two weeks. Clams will grow to the 1410 screen size (or 2 to 3 mm) in six to nine weeks after setting, while Pacific oysters will reach the same size in three to five weeks.

Both clams and oysters can be grown to any size in an upwell system but it is most efficient to move them out of a land-based upwell at 2 to 3 mm and into a FLUPSY (Floating Upwell System) or a tray-based floating raft system where they can rely on the algae present in natural waters. Clams generally reach the plantable 3600 screen size (6 to 9 mm) two months after being put into a secondary nursery system, but the growth rate will vary considerably depending on the area and season. Single oysters are initially put into 1/4-in mesh grow-out bags or trays at the 5000 screen size or 9 mm+.

The following talks in this session will elaborate on some of the aforementioned systems and will allow us all to reach an understanding of the state of the art in Manila clam culture.

Spawning and Larviculture Methods for Manila Clams

Brian Williamson, Taylor Shellfish Farms, Quilcene, Washington

To produce good viable eggs, broodstock are conditioned from four to six weeks at 21°C in trays placed in tanks. The process involves filling the tanks with ambient sea water, placing the broodstock into the tanks, and elevating the temperature one degree per day until 21°C is reached. The broodstock are then taken out of the conditioning trays and put into separate bags containing about 40 clams each. Rinse off the bagged clams with fresh water and leave to dry for 1 to 1 1/2 hours. Then suspend the clams in 150 l drums filled with ambient sea water for another 1 to 1 1/2 hours. Make sure the animals are pumping well. Then move the clams and suspend them in another set of 150 l drums filled with 28°C water for 45 minutes to an hour. It is possible they may begin spawning before inducement with sperm; however, sperm does work best and should be added if necessary. Be patient, talk dirty, and play good soft music.

When you start seeing spawn, be sure several clams are spawning. Viable eggs will be round, have an intact outer membrane and plenty of yolk. After spawning, the larvae are put into tanks with 25°C water for overnight holding, then I have a smoke. The larvae will advance to the straight hinge or D-stage within 16 to 20 hours after fertilization. There is no feeding during this period.

The steps involved in getting the larvae through to set are as follows:

Day 1 (after straight hinge stage)

I feed the larvae TX, a flagellate, at 20,000 cells/ml. Cell densities are kept at these levels by monitoring three times a day with a coulter counter.

Day 2

Monitor and adjust feed.

Day 3

Use split screens of 100, 80, 70 and 45 mm mesh to change larvae. The 100 mm mesh screen is used as a cleaner. Place sorted larvae into tanks filled with 19°C water by mesh size. Bring food cell count up to 30,000 per ml.

Day 4

Add diatoms to diet (food mixture is 80% TX, and 20% 3H, CC or CHGRA). Good healthy clams should hold on a 70 to 80 mm mesh screen.

Day 5

Adjust feed mixture to 40,000 cells/ml with a 50-50 flagellate to diatom mix.

Day 6

Size-out larvae at 125 to 130 mm length using a microscope. Screen with 100 mm mesh. Larvae are reared at a density of 75 million per tank or 2.5 to 3 larva/ml. Change water every three days.

Day 7 and 8

Maintain feed and watch larvae.

Day 9

Change water with a 130 to 140 mm screen and put larvae back into 19°C water.

Day 10 and 11

Maintain feed and watch larvae.

Day 12

Screen with 160 mm mesh. Screened larvae are near set size. Put them into downwellers. Return the smaller larvae to the tank.

Day 14

All larvae should now be setters. We have seen that when larvae of this age are still small, about 150 mm, they will swim for days and eventually drop out and die. I have seen best results using TX and CHGRA throughout the larvae cycle.

Setting and Nursery Applications

Don Dahman, Dahman's Shellfish Co., Shelton, Washington

Our company has been setting Manila clam larvae and planting seed for seven years. In that time, we have learned just about every way there is to kill clams. I believe we have learned from our mistakes, but even so, there is no guarantee of setting larvae on a consistent basis.

During our first two years of operation, we bought all of our larvae at a cost of $100 per million. For the next three years, we began spawning clams and raising half the larvae we needed and buying the other half. In the past two years, we have been producing all of our larvae in our hatchery. We used to spend $30,000 to $40,000 per year purchasing larvae; now we buy none.

The hatchery/nursery is a closed system in which we spawn, set and rear juvenile clams and oysters until they are ready for the outdoor FLUPSY. The system consists of spawning tanks, larvae rearing tanks, setting tanks, and downwelling/upwelling units. The water is recirculated and uses a bio-panel to maintain water quality. Algae are grown in a separate system that uses filtered ambient sea water. We feed a mixed diet of flagellates and diatoms. The FLUPSY consists of a set of six containers. Each container measures 3 ft. x 3 ft. x 4 ft. deep. This "six-pack" requires 400 gpm flow per container for optimal use. Clams are sorted once per week. Keep in mind that a bed of clams 2 ft. deep in the containers becomes 3 ft. deep when fluidized.

After spawning, larvae are put into high-density rearing tanks. The average density in most hatcheries is 1.5 to 2.0 larvae/ml. We hold 35 larvae/ml in our high density larvae tanks. The basic design of the tanks was developed in the United Kingdom by John Bayes, Seasalter Shellfish, Ltd. We are starting the fourth modification of this larvae tank design.

When ready, larvae are taken to the setting trays. Setting usually takes three to five days. The set clams then go to the upwellers where they are fed until they reach 1.5 to 2.0 mm. At that size the clams are taken outside to the FLUPSY. There, it takes about six weeks for the clams to reach an average plantable size of 8 mm. Recovery from larvae through the FLUPSY ranges from 100% to nothing. But, on average, we get about 30% of each lot to plantable size.

We plant the ground at a density of 50 to 200 clams per square foot, depending on the seed size and what is in the ground. The planted ground is protected by covering it with 1/4-in. mesh netting. The netting is left on all the time at some locations. At other areas we net for only nine to ten months.

In the beginning, our goal was to get a yield of 2 lb./foot/year from the plantings. However, we have realized an average yield of 5 lb./foot/year for the whole farm if everything is done right. I have seen a sustained yield of 9 lb./foot/year from some grounds.

Planting, Growing, and Harvesting Manila Clams

By Brett W. Bishop, Little Skookum Shellfish Growers
Shelton, Washington

Preparing a Planting Bed

Substrate for planting a bed of clams should be clean and gritty. A mixture of sand, gravel and shell fragments dominated by sand is best. Mud and silt are acceptable in varying amounts during the different stages of a clam's life cycle.

When planting seed of 10 mm or less, the water-to-substrate interface should be free of mud or fouling organisms that could form a cap on top of the beach.

In areas that don't receive a wave battering, clams do well in pure sand. Clams can also grow well in pure gravel ranging in size from pea gravel up to rocks 3/4 in. or larger.

I have noticed that the voids between the rocks in pure gravel tend to fill up with very fine sediments. These sediments come from the ground below working up, or from silt settling out of the water column. It is better to add your own washed sand mixture to the gravel at the beginning. That way, there are no voids for silt to fill.

Seed Size

In my experience, the larger the planted seed, the better the survival. The other obvious benefit of using large seed is that it is closer to harvest size. However, seed should spend enough time in the ground to take on the characteristics of a beach-grown clam. The time, labor and costs of growing larger seed are substantial, but worth it. Planting larger seed (between 8 to 15 mm) increases survival more than enough to compensate for the labor and costs involved.

There are different methods of growing seed to fit different scales of operation. Floating Mexican trays and small-mesh seed bags on racks are relatively inexpensive and work well. FLUPSIES and nursery buildings are practical for larger volume operations.

Another method of growing seed is to build a sink float holding a submerged sand bed, which protects the bed from the sun and predatory fish.

Planting Methods

Begin with a clean beach with a gritty surface. Figure out the limits of the area to be planted. Determine upper and lower tide zones suitable for clams. To grow clams and oysters on the same beach, it is generally better to use the high ground for clams and the lower ground for oysters.

Add a skin of gravel or sand, if needed, to achieve a clean surface for clams to dig into. Seed with water over the beach when practical to do so, preferably on an incoming tide. The water cushions the impact of the falling clams, provides insulation from temperature extremes, and lets clams dig in and disappear immediately.

Early spring seeding has the advantage of fewer predators; many predators multiply in the summer and fall. Foremost among them are crabs and perch.

The ideal method is to use an on-site seed nursery system of some sort, and then plant straight onto a freshly dug patch of beach. Seed that is held in the same water it will be planted in is already acclimatized to the local conditions. In addition, the seed spend only a few hours out of the water before planting. This eliminates stress on the animals.

Webbing, if maintained, will increase the survival of seed clams, sometimes dramatically. The finer the mesh, the better the protection provided, but the more quickly fouling occurs. Ideally, first use a fine mesh at planting time. Then switch to a larger mesh, like 3/8 in., when fouling starts to occur. Growers rarely take the time and trouble to do this.

Webs can be held down with lead line and stakes, by stakes alone, or by digging a trench and burying the outside edges of a web. Sew interior seams tightly enough to keep crabs from squeezing in.

When a grower seeds a recently dug bed using seed from an on-site nursery system, then covers it with net, the grower increases the chances of reaching as thick a clam density as human endeavor will allow.

Fouling and Remedies

Lots of things can go wrong after planting. Low salinity events kill clams. Freezes below 25°F kill clams. Temperatures rising into the 90°F range kill clams. The grower has to accept this as a part of the burden of cultivating Manila clams. I have made a list of some problems that the grower can remedy. The same clean beach that is so attractive to the seed clams is also attractive to a succession of other species. There are many places in southern Puget Sound where any clean patch of gravel, shell or web will catch a set of barnacles, mussels or seaweed. The grower needs to artificially hold this organic succession at the clean beach stage.

When a net is being buried by sand, silt or brown slime, the grower needs to remove the stuff from the top without harming the clams below. Hand labor always works; you can use a five-gallon bucket and gloves with maybe a hard rubber dust pan to scoop off the layer of muck. Float the web above the surface with floats of some sort.

Some beaches catch heavy sets of mussels or barnacles. These organisms should be removed before they form a mat that caps off the substrate. A dredging fork or something similar works well to skim off the junk and leave the rest.

Seaweed and the brown slime grow seasonally on webs and on the open beach. Usually, if one waits a while, something happens all by itself to reduce the slimy stuff. If the slime does start to choke off the substrate, the web should be taken up and replaced, or maybe pressure washed; I haven't tried that one yet.

Oysters can be a fouling problem, too. You'd be lucky to have a problem like that.

Engineering a Bed

Clams are setting and growing extremely well in the old Olympia oyster dikes in south Puget Sound. Built as artificial tidepools, most of these dikes no longer function as such. With boards broken and concrete walls breached, the flat gravel terraces that remain are ideal for Manila clams. The skeletal dikes also help anchor and support the banks of the bay and prevent new channels from forming.

As growers work their beds ever more extensively, they need to offset the sloughing and settling process that occurs each time a bed is dug. On the banks of a bay, a grower should protect against landslides and erosion from above the tideline. The grower also needs to limit the size of the channels and flood plains of rivers and creeks where they meander destructively back and forth across clam beds.

After seeing the terraced fields and hillsides of Asia, I believe that Manila clam cultivation would benefit from this type of approach. In Little Skookum Bay, steep banks in some parts of the narrows are constantly sloughing away into the water and onto the beds. The beds slough downward each time they are hand dug. If stepped terraces were built and filled to the proper grade with sand and gravel, the erosion problem would be slowed and superior clam beds would result.

In places where siltation occurs on flat or concave beds, most of the time a little bit of contouring will eliminate the problem. Put a slight crown on a section of flat bed. Take a shallow swale full of mud, put a trough down the center, and watch the ooze slide downhill with the outgoing tide.

In some flat or gently sloping areas, particularly areas that are barren of natural set clams, the grower needs to build "planter box beds" to raise the bed that critical inch or two above the water table. Cedar wood or concrete walls would contain a slightly-raised, crowned bed of perfect substrate. The walls should be buried to a depth of about four inches to deter moon snails and crabs. Webbing is easy to apply and service over such a structure. Sediment washing off the bed accumulates in the access ways between beds and flows down into catch basins at the bottom where it can easily be removed.

In some places affected by severe tidal velocities, deflectors can shelter a bed. Old shucked oyster shell makes a perfect construction material. A low dike or wall will protect a flat bed from forming new channels.

Existing beds can be perfected by adjusting the relative amounts of sand, gravel and shell. Too much rock can make a beach too hard to dig. Too much sand can make the surface move around too much. Shell is nice to have because it makes the ground more porous, but it is not essential.

Harvest Techniques

Dry digging is performed on exposed beaches using a hand-held "potato fork." Under water one uses a "dredging fork," a hand-held, modified pitchfork with many tines. In both cases the digger takes only the mature clams and carefully leaves the seed clams to dig back into the bed and keep growing.

Blanket digging or row digging is the most beneficial method of harvesting clams. It turns over the entire bed and yields all of the mature clams.

Digging the same bed yearly, or even several times each year, aerates the bed and allows moon snails and oyster drills to be removed before they get out of control. Barnacles on rocks can be turned upside down or buried.

Harvest Timing

It is best to wait until the tide before they are to be processed and shipped to dig the clams. If one has to hold clams over, it is best to do so in the water. Some growers hold clams in sink floats; some leave them low on the beach in net bags; some use refrigerated upland depuration tanks. Depending upon the season, with summertime being the worst, clams stress out after being dug. The longer they are out of the ground, the shorter their shelf life.

Final Remarks

Bringing the Manila clam over here from Japan was one of the finest things the old time oyster growers ever did. This clam inhabits a greater range of elevation than the native clams. It also reproduces in huge volumes, has a long shelf life, and looks and tastes superb.

Intertidal Bag Culture of Manila Clams

Joth Davis, Ph.D, Baywater, Inc., Bainbridge Island, Washington

In the Pacific Northwest, culture of the Manila clam (*Tapes philippinarum*) has historically relied on the harvest of clams that occur naturally, with natural replenishment occurring as larvae settle out onto suitable substrates. In recent years, hatchery production of seed clams has allowed artificial replenishment of beaches. Replenishment and enhancement efforts have included seeding over sections of beach covered with netting to exclude predators, adding seed clams to wild populations to enhance overall productivity on natural clam beds, and gravelling of beaches to encourage natural clam settlement.

In addition, the use of Vexar plastic shellfish bags (ADPI Enterprises, Philadelphia, PA) to enclose seed of suitable size until they have grown out and can be harvested has been successful under some culture conditions. This method has been used exclusively to grow out Manila clam seed on intertidal beaches at Thorndyke Bay in north Hood Canal. This method works in this location because of the suitability of the sand substrate and the relatively protected nature of the intertidal beach. A stainless steel frame slightly larger that the outer dimensions of the clam bag (30 in. x 18 in.) is laid onto the beach and the lower lip pressed into the sand to provide a template for substrate removal. Sand is removed from within the frame by shovel and the material added to an empty clam bag. Sand is removed within the frame to a depth of approximately 4 inches. Four hundred seed clams having a shell height of 3/8 in. or greater are added to the bag, and the bag is clipped shut using stainless steel hitch pins. The bag is then rolled into the rectangular depression and the frame removed. The entire upper side of the bag is thus exposed and protrudes above the level of the beach by about one inch. Approximately 12 to 15 bags an hour can be comfortably deployed in this manner by one worker.

In this location two years are required to raise 3/8 in. seed to harvestable size (1.5 in.). Harvest consists of lifting the bags free of the substrate and washing out the sand, leaving washed clams in the bag ready to purge and bring to market. Costs associated with this type of clam culture are described below, based on 20% coverage of the available area. In this system, small seed are first deployed in small mesh Vexar bags on intertidal shellfish racks and grown to the appropriate size prior to seeding out into bags for beach culture.

Production Costs on a per Acre Basis	
Vexar Bags (2000)	$7,000
Bag Preparation	$1,000
Bag Development	$2,000
Seed Costs (800,000)	$3,600
Nursery Costs (100 bags)	$1,000
Harvest Costs	$2,000
Total Costs of Deployment	$16,600

Production capabilities using bag culture are based on the size of the clam harvested. At a rate of 15 lbs. per bag, approximately 30,000 lbs. may be harvested per acre, and at a rate of 20 lbs. per bag, approximately 40,000 lbs. per acre may be harvested.

A critical component in the husbandry phase of culture includes preventing sand from covering over the upper mesh surface of the bags. If sand is allowed to overcover the bags, high clam mortalities will result. In addition, red rock (*Cancer productus*) and Dungeness (*Cancer majister*) crabs may settle out of the water column as late instar larvae and grow up inside individual bags to predate upon young clams. In the absence of predators, an initial stocking of 400 seed clams per bag will result in uniformly high returns of adult Manila clams.

In addition to Manila clams, other clams recruit into the bags during the growout period. Butter clams (*Saxidomus giganteus*), eastern soft-shelled clams (*Mya arenaria*), horse clams (*Tresus capax*) and native littlenecks (*Protothaca staminea*) are commonly encountered. In addition, heart cockles (*Clinocardium nuttallii*) often recruit into clam bags as well.

If juveniles of these species of clams and cockles can be produced in the hatchery to provide a reliable supply of seed, then the aquaculture potential for these species may be enhanced using Vexar growout bags on suitable substrates.

Developments with Mechanical Clam Harvesters

Dave Mitchell, Madrona Shellfish Ltd., Errington, B.C., Canada

Increasing production and labor costs for current manual harvesting practices has renewed interest in British Columbia in the development of mechanical harvesting methods for Manila clam farms. Two designs for mechanical clam harvesters were developed in B.C. in 1996: a fully operational harvester built by Mid-Isle Marine Ltd., and a smaller working prototype built by Madrona Shellfish Ltd.

These prototypes are the first applications of mechanical clam harvester technology in B.C. that do not use pressurized water to separate clams from beach substrates. Earlier so-called "hydraulic harvesting methods," developed for the wild clam fishery, were found to be environmentally destructive (Adkins et al, 1983) and are prohibited. Both the Mid-Isle Marine and Madrona shellfish mechanical harvesters use a sifting method that more closely mimics the current manual harvesting practice.

The criteria for the Madrona Shellfish harvester project was to develop a small, maneuverable clam harvester that could easily be operated by one or two persons. A track drive was considered important for weight distribution and traction. For the sake of economy, the harvester was built using the chassis and motor from an 8 hp track-driven snowblower. A set of rotating tines was designed to separate the clams from beach substrates and deposit them on the beach surface. Hydraulic motor drives controlled both the propulsion and digging systems. This harvester was field tested in August 1996 and successfully separated clams from the beach substrates with very little clam breakage (estimated at 1% to 2%). However, the propulsion system did not prove to be adequate, primarily because of insufficient clearances under the chassis and between the track-drive and the digging mechanism. It is believed that this problem can be overcome in the future with the use of a somewhat larger track-drive system.

The Mid-Isle Marine Ltd. clam harvester prototype consists of a series of chain-mounted buckets that remove the top 15 cm of beach substrate and deposit it on a screen that sifts the clams by size. The clams roll off a screen into a tote and gravel falls back onto the beach in the harvested track. The harvesting mechanism is mounted on a trailer that is towed behind a tractor. Preliminary testing in the spring of 1996 showed that the digging mechanism efficiently sorted clams from beach substrates. Unfortunately, the configuration of the trailer-mounted harvester proved too heavy for the soft-gravel/mud on which it was tested, and required that sheets of plywood be placed under the wheels of the tractor and trailer to prevent it from becoming stuck in the beach. In spite of this, the success of the digging mechanism warranted further evaluation. As a result, more extensive testing was undertaken in the summer of 1996, sponsored by the B.C. Ministry of Agriculture, Fisheries and Food. This testing was considered essential to determine whether the mechanical harvester harvested clams with a minimum of breakage, left beach substrates in an acceptable condition, and caused minimal clam seed damage and other environmental impacts.

To meet these objectives a study was designed to compare mechanical clam harvesting with traditional manual harvesting by conducting quantitative clam population density surveys before and after harvesting. The surveys would enable comparisons on relative harvest efficiencies and on the survival of seed clams that pass through the harvest process. In addition, evaluation of beach substrates before and after harvesting was undertaken to determine environmental impacts (substrate evenness and appearance, macrofauna, interstitial pH). Results from the mechanical and manual harvesting treatments were compared with reference to unharvested (control) areas. Each of the three treatments consisted of three replicate plots (nine plots total), each 17 ft. x 100 ft. in size and assigned using a randomized block design. The plots had previously been seeded with clams and were covered with protective netting.

Results of the study (Mitchell, 1996) showed that the mechanical harvester removed market size clams from the beach with an efficiency similar to manual harvesting (81% vs. 88% respectively). Clam breakage as a result of mechanical harvesting was measured at 1.5% versus an estimated 1% to 2% for manual harvesting. The number of small clams (length $\leq$ 32 mm) remaining on the beach after harvesting was not significantly different ($P > 0.05$) between the three treatments (mechanical vs. manual vs. control), ranging from 494 to 608 small clams per m^2 (most in the 15 to 28 mm size range). Both mechanical and manual harvesting left the beach in a level condition without large furrows, mounds or other adverse environmental impacts (e.g. mud shrimp *Upogebia* present; no change in beach interstitial water pH). The additional labor associated with maintaining traction in the mechanical harvester (i.e. placing plywood under the wheels) did not result in an overall savings in labor in this study in comparison with manual harvesting. However, in spite of the traction problems, the machine harvested a 17 ft. x 100 ft. plot in an average of 0.5 to 1.0 hours, compared with 6 person-hours for manual digging.

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Basic Methodology of Manila Clam Culture in France

Yves LeBorgne, SATMAR, Gatteville-Phare, France

At SATMAR we produce 50 million larvae at the straight hinge stage in the hatchery during March of the year. Of these, 40 million larvae are set at 160 µm screen size and then held in downwellers for one week at 20 C. Using a screen size of 180 µm, we get 30 million post set clams from this prenursery phase of the operation. The juveniles are allowed to grow to a size of 600 µm and then they are transferred to an upwelling nursery system in April. This will result in 20 million clams at about 2 mm size by the end of May. During the June-September period clams remain in the nursery where they will reach 6 mm. Feeding is enhanced by adding *Skeletonema.*

In October, the clams are placed into 4 mm bags and placed into ponds for overwintering through February. After a period they are transferred to 6 mm bags and remain in the ponds—no food is added. About 18 million clams are available from this phase of the operation. If there is a demand for clam seed, we have additional production on the same pattern (e.g. for the European clam *Ruditapes decussatus*).

We plant in June at a density of 400 clams/sq. meter with the use of a planting machine. All seeded ground is covered with 5 x 5 mm netting. The netting is periodically cleaned by brush and is removed and destroyed by October. Then, the clams are allowed to grow one year without netting. Harvesting is done with a machine converted from carrot harvesters.

Overall, we realize a 70% survival from plant to harvest. In other terms, we harvest 10 mt for every million seed planted at 10 mm. SATMAR has been planting 12 million seed per year, and harvesting 120 mt or 264,000 pounds per year. In 1998 SATMAR will plant 18 million seed.

Results From a "U-Rake-It" Clam Farm

Harrison R Bresee III, North Carolina Sea Grant, Raleigh, North Carolina

The "u-rake-it" clam farm concept evolved as an idea for providing extra income for commercial fishermen (who were already producing clams in a mariculture operation) by drawing on the flourishing tourism industry found in many coastal areas. The idea is very similar to the common "pick-your-own" vegetable farms that are frequently found in the country. With a grant from The National Coastal Resources Research and Development Institute (NCRI), the North Carolina Sea Grant Program and Hatteras Village Aquafarms worked together in the summer of 1995 to set up a "u-rake-it" clam farm on Hatteras Island, N.C.

Our objectives were:

1) Establish a "u-rake-it" clam facility.
2) Develop a marketing program.
3) Develop educational products to inform tourists about shellfishing and aquaculture.
4) Develop a manual and a video.
5) Obtain biological and behavioral data on the clam *Mercenaria mercenaria.*

Results were definitive. The business proved to be popular with customers. Ninety-five percent of the customers were vacationing. Seventy-nine percent said they had never been clamming before. Eighty-two percent of the customers surveyed said they would return. Ninety-nine percent said they would recommend the facility to others.

The business made money. With a total labor cost of $10,904 (two full-time employees at $1,817 a month each), income before taxes was $2,954 for the three-month season. Investments were minimal. Assuming the operation already had a successful mariculture operation, only $15,545 in direct expenses and $14,602 in indirect expenses (for a total of $30,147) were accrued. Total net revenue was $33,890.

Sorting, Packaging and Shipping Manila Clams

Austin Docter, Taylor Shellfish Farms, Shelton, Washington

Taylor Shellfish Farms' processing facility receives Manila clams from Taylor operations and outside sources. The product is brought to the plant where it is unloaded, weighed, tags checked (certified dealer, approved waters and date), and the general quality assessed (off species, cleanliness). If the product has been purged it is delivered to the processing line. If it hasn't been purged, it is sent to the sink floats. We require that clams be washed off and be reasonably clean when they are received. At delivery, clams will be processed for shipping or refrigerated at 45° F and processed later, according to the time-temperature matrix outlined in the NSSP Manual, Part II, Appendix F.

Clams are washed by placing them on a brush roller, which performs several functions— scrubbing, high pressure washing, and spreading the clams for grading. From the brush roller, the clams drop onto a three-deck roll grader that sorts them into large, medium (regular) and small sizes. The grader has size adjustment and counter rotation features.

The clams are then accumulated for intermediate storage. This step gives the processor the ability to run one size or mix clam sizes when packaging. Storage containers have a 400 lb. capacity. They are placed on a sloped and padded floor. Interior netting softens the clams' fall. Clams must be processed within two hours during this phase.

Next, the clams are rolled onto a conveyor for inspection and packaging. During inspection we check for cleanliness and look for broken, weak or dead clams; rocks; and off-species such as littlenecks, butter clams and cockles. The conveyor spills to the packaging chute where the clams are weighed in 5-, 10- and 25-lb. containers. A tag providing harvest, shipper, and destination information is strapped to the outside of each box. Gel ice is placed into each package at 1.5 lb. per 25 lb. of clams. The clams are stored in a cooler (45° F) until shipping. An important point here is that they cannot be out of refrigeration for more than two hours.

Our quality control program includes post-packaging inspection where we check weights, product temperature, quality, tags, size and consistency, and refrigeration temperature. We also do fecal count testing by sending daily samples to a private lab and weekly samples to the state lab.

We use several sources to ship clams. Taylor refrigerated trucks are used for local deliveries and deliveries to Sea-Tac Airport. Outside refrigerated truck lines (coast to coast LTL) are used to deliver less than truckloads anywhere in the United States. Also, orders are sent by UPS, Federal Express or are picked up at the plant. Trucks are checked for temperature (45° F or less).

Oyster Farming

The Economic Benefit of Connecticut's Oyster Farming Industry

John Volk, Connecticut Department of Agriculture, Milford, Connecticut

Connecticut's oyster farming industry is the nation's leader in terms of the value of oysters produced and ranks among the top three states in production volume. The economic impact of oyster culture to Connecticut's economy is significant. More than $40 million in annual farmgate sales is generated, creating more than 400 industry jobs. Annual harvests exceed 700,000 bushels (over 175 million oysters). More than 40,000 acres of oyster farms are under cultivation and more than $200 million is contributed annually to the state economy (estimate uses standard economic multipliers). The outlook is promising for continued industry growth and export opportunities.

Overview

Background

Oyster farming has been an important Connecticut industry for more than a century. Peak industry harvest occurred during the 1890s. During that time, more than 2,000 Connecticut citizens were employed by 600 firms and annual harvests approached 2 million bushels. Connecticut could boast of having the largest fleet of steam-powered oyster vessels in the world. Connecticut was also the leading producer of seed oysters in the Northeast, supplying the New York, Rhode Island and Massachusetts industry with oyster seedlings.

After World War I, the industry went into steady decline and by the early 1970s had nearly died out. The primary cause of the decline was pollution resulting in oyster harvest prohibitions, loss of market, reduced production and lack of seedlings. By 1972 Connecticut harvest levels were less than 33,000 bushels.

As water quality began to improve, so did the oyster industry. With a few farming operations still in place, the industry began rebuilding itself.

Current Status

Connecticut oyster farmers now produce the highest-value oyster in the country and are second only to Louisiana in quantity produced.

Through sound farming techniques such as the removal of silt, cultivation, planting of shell (cultch), transplanting of seed and predator control, Connecticut shellfish farmers have significantly increased their yields per acre and produce an oyster famous nationally for its consistent size, shape, flavor, hardiness and quality. Annual harvests now exceed 700,000 bushels valued at more than $40 million wholesale.

Oysters are farmed by 32 firms on leases and grants off the Connecticut coastline of Long Island Sound using extensive bottom-culture methods. These firms employ approximately 320 people and operate 71 vessels. Oyster seed is obtained by the firms through planting cultch (shell) on their leases and grants or by purchasing seedlings harvested by seed oystermen licensed to work the public grounds. There are approximately 125 seed oystermen operating 77 boats. Seed sales alone generate $300,000 to $700,000 annually. Additionally, in Connecticut there are 45 firms engaged in wholesale oyster sales and distribution; they employ approximately 270 persons.

CONNECTICUT SHELLFISH INDUSTRY PROFILE

Number of firms engaged in shellfish cultivation	32
Approximate number of boats	71
Approximate number of employees	320
Number of seed oystermen	125
Number of seed boats	77
Number of additional firms engaged in wholesale shellfish sales and distribution	45
Approximate number of employees	270

State And Industry Partnership

The recent explosive growth and success of Connecticut's oyster farming business are primarily due to cooperative efforts between state government and the oyster industry.

Cultch Program

The continued availability of seed is critical to the stability and future of the industry. Therefore, to foster industry growth, in 1987 the state legislature established a program with the Connecticut Department of Agriculture (CDA) to purchase cultch (shells) for planting on the state's public seed oyster beds (Gen. Statute 26-237a). The planting of cultch improves the overall condition of the oyster beds and provides a surface for the oyster spawn to attach to and grow. The cultch is distributed and planted by boats and volunteers from the oyster industry. The oyster larvae settle on the cultch in late summer and the thumbnail-sized oysters are harvested by licensed seed oystermen in the fall and spring. Oystermen sell the seed to the aquaculture industry leaseholders for growth in deeper, clean water where the shellfish will be harvested for market three to four years later.

The cultch program was established with an initial bond authorization of $1.3 million in 1987. Subsequently, an additional $4 million was bonded over the past few years. In addition to the bond authorizations, the oystermen harvesting seed from the restoration areas pay a 10% assessment on the sale value of their harvest. The money is collected by the Department of Revenue Services and deposited in the cultch program fund to help sustain the program. To date, more than 3,000 acres of state beds have been restored with approximately 5,250,000 bushels of shells.

The success of the CDA's cultch program in restoring public oyster beds has received national acclaim as a triumph of state government and industry working together for economic development and job creation. To quote a recent aquaculture industry publication, "Connecticut is a prime example of a state that has invested a modest amount of funds towards managing and improving its natural resources and reaped huge rewards in terms of jobs and revenues that exceed their investment many times over."

Leasing of Shellfish Grounds

The CDA leases shellfish grounds through competitive bids. This program permits oyster farmers to obtain underwater lands in Long Island Sound for planting, cultivating and harvesting their crops. Through proper care and investment in their leases, the industry has perpetuated and greatly enhanced the oyster resources in the sound. Presently, more than 46,000 acres are farmed by the industry.

Licensing, Monitoring, Inspections

The nation's shellfish industry has faced a difficult marketing challenge in recent years because of negative publicity about water quality and the safety of oysters. Health problems associated with oysters produced in other states, particularly along the Gulf of Mexico, have caused market price decline and reduced consumption. However, Connecticut oysters continue to be in high demand and sell for twice the price of any other oyster in the marketplace. The reason for this lies in the reputation for quality and the outstanding safety record that has been established by the Connecticut industry and the CDA's shellfish sanitation program.

To assure safe shellfishing areas for commercial and recreational harvesters and to maintain certification with the U.S. Food and Drug Administration, the CDA licenses and inspects all commercial shellfishing operations. The agency carries out detailed shoreline surveys and fastidious water quality monitoring to protect public health and the credibility of Connecticut-grown shellfish in the interstate and international marketplace.

Recently, Tallmadge Brothers, Inc., Connecticut's largest oyster company, contributed more than a half million dollars toward the construction of the CDA's aquaculture testing laboratory on the shoreline.

Marketing and Export

The CDA works closely with Connecticut's oyster farming industry in the competitive arena of marketing, promotion and export— equally important to production and quality assurance.

Recent efforts by the CDA have successfully linked Connecticut oyster producers to several major regional and national supermarket companies. The department's linkages with federal programs have resulted in grant funds to assist in developing export opportunities. Negotiations with Asian and European markets are underway. Connecticut oysters have recently been enjoyed by potential clients in Japan, Malaysia and Chile.

Added Economic Benefit

Using standard economic multipliers, it is conservatively estimated that Connecticut's oyster farming industry contributes more than $200 million to the state's economy annually. Additional jobs and revenue are generated by use of support trades and services associated with the oyster farming industry. These include purchases of fuel, boats, trucks, equipment and supplies, as well as maintenance and repair needs.

The oyster industry has major capital investment in the ownership and operation of shoreside processing facilities.

Oysters, as they move through the wholesale and retail distribution chains, generate considerable revenue. Finer restaurants routinely sell Connecticut oysters for more than one dollar apiece.

Recreation and tourism are multimillion dollar industries in Connecticut. Both are positively impacted by the state's oyster industry. Virtually all of Connecticut's recreational shellfishing programs have been assisted by the industry in restocking shellfish populations and creating harvest opportunities.

Because of the strict federal standards that are required to market shellfish, the oyster industry has diligently pursued water quality improvements in Long Island Sound.

These efforts ultimately contribute to the quality of the shoreline experience enjoyed by visitors and residents alike.

Situation Outlook

During the next decade, aquaculture activities such as oyster farming are expected to be among the top 10 growth industries in the United States. The CDA and the oyster industry presently have the necessary programs and infrastructure in place to foster continued growth in this environmentally sound business. Logistically, Connecticut is ideally located to respond to national and international markets. The potential for export opportunities offer great possibilities.

Municipal Shellfish Programs in Connecticut

Bill Green, Guilford Engineering Department, Guilford, Connecticut

Guilford, Connecticut, which was settled in 1639, was probably typical of most small New England coastal towns. Local laws governing shellfish resources were adopted and repealed, it seems, on a monthly basis. During town meetings, debates over shellfish issues often became heated. The importance of shellfish to public and private interest was recognized early in Guilford's history. Archival land records reveal a somewhat humorous but serious chronology of the townspeople's concerns regarding shellfish. Excerpts from town records are as follows:

1648 - First reference to shellfish: local mollusk shells used in mortar.

1753 - First legislation regarding oysters.

1766 - General assembly authorized towns to make laws regarding shellfish.

1775 - Fear of extermination; a law enacted forbidding the transport of oysters out of town.

December 15, 1775 - Law changed to allow one to carry out of town as many oysters as one horse could conventionally bear.

1791 - Voted, that in case of sickness, one could take oysters from closed grounds with a permit.

1828 - Beginning of oyster culture; voted that anyone might lay down oysters and clams below the high water mark and they become his property.

October 2, 1876 - Selectmen are authorized to lease town grounds for five years. Vote 802-39.

October 14, 1876 - Vote repealed by vote 116-53.

January, 1877 - Law reinstated by vote 57-49.

February, 1877 - Law repealed vote 197-28.

1887 - Fear of oyster extinction; $250 appropriated to enforce the oyster law and a committee was appointed to report on the protection of oyster and other fisheries.

1879 - Town voted to make all shores free to inhabitants for taking long clams (steamer clams).

January 28, 1882 - Appointment of oyster grounds committee and two constables to enforce shellfish laws.

1984 - Guilford Shellfish Commission was appointed.

Background

Through the 1930s and 1940s, the State Department of Health issued permits to take shellfish from polluted water to clean water for purging, subsequent to public sale. From the 1940s to the 1970s, Connecticut's coastal water quality was generally poor and recreational shellfishing was not permitted. In the mid-1970s, the Oyster Grounds Committee of Guilford, appointed by the Selectmen, actively pursued certification of one or two bays for recreational harvesting.

In 1982 the state law was changed to allow the conversion from an Oyster Grounds Committee to Shellfish Commission, which would be responsible for writing management plans for local shellfish resources.

In 1988 the FDA and ISSC changed guidelines for the standards for shellfish sanitation in growing areas, and for processing and distribution. Connecticut did not meet the new requirements. Following a lengthy legislative process, the state shellfish program was transferred from the state health department to the CDA, Division of Aquaculture, under the direction of John Volk.

After the transition, communities desiring to maintain their Shellfish Commission were required to rewrite management plans, produce action plans and enter into a Memorandum of Understanding (MOU) with the Aquaculture Division. As a legal instrument, the MOU was very specific as to the responsibilities of all interested parties. Guilford's success, as with other communities, was only possible through the support and cooperation from the Board of Selectmen, the Health Department, the Police Department, the Water Pollution Control Authority, the Shellfish Commission, and commercial and recreational shellfishers.

The Commission

In 1982 Connecticut enacted laws to encourage towns to create shellfish commissions and write management plans regarding their local shellfish resources. Today all but three or four of Connecticut's 36 coastal communities have shellfish commissions. Typically, as determined by the town's charter, commissions are composed of five regular and two alternate members who generally serve four years. Communities with commissions operating under the guidelines of a MOU are authorized under state statutes and town ordinances to manage local shellfish resources.

Guilford's monthly meetings are called to order in a public forum by the chair. The meeting is attended by commissioners, Health and Water Pollution Control personnel, and the public, which is usually commercial and recreational fishermen. A regular agenda would include a public forum, bills and correspondences, treasurer's report, subcommittee and warden reports, as well as old and new business.

The commission sets policy with respect to federal, state and local standards. Responsibilities of subcommittees within the commission include: managing leases and agreements, water sampling and data collection, assessment of shellfish resources, overseeing recreational and commercial activity, participating in commission-driven aquaculture programs, encouraging outreach for high school internships and general accounting and bookkeeping.

Recreational Shellfishing

Recreational grounds are opened and closed depending upon the availability of resources and in strict accordance with the protocol of the MOU. In the town of Guilford, population 21,000, more than 500 recreational permits are sold annually. Proceeds from permit sales go directly to the commission's account, which allows the commission to operate its programs independently from the town budget. Revenues are used to purchase seed and mature shellstock, for transplanting programs, internships, printing costs for signs, maps, brochures and permits, public educational forums and salaries for wardens and clerks.

Recreational fisheries include oysters (*Crassostrea virginica*), steamers (*Mya arenaria*), mussels (*Mytilus edulis*), hard clams (*Mercenaria mercenaria*), and in some eastern Connecticut areas, bay scallops (*Argopectin irradians irradians*). Habitat restoration and enhancement projects continue to expand to meet the growing popularity of the recreational fishery.

Commercial Fisheries

At regular monthly meetings, commissioners are faced with a variety of tasks that affect commercial fisheries. They might review co-management agreements, review leases and consider new applications presented by fishermen. Lease applications are advertised by legal notice in the local paper and acted upon in accordance with the management plan. Sizes of leased grounds vary from 5 to 100 acres. Payment for leases is usually in the form of cash; however, a "share" of the shellfish harvested may be taken in lieu of cash. Transplant or "put and take" programs are often negotiated through a bartering system. When available, shellfish resources are taken from restricted town waters for transplanting. Commercial harvesters agree to help in the process in return for a share of the shellfish harvested and transplanted. Bids are usually 60/40, with the harvester retaining the larger portion. In other cases, when town-owned resources are not available, the commission contracts to buy the necessary amount of shellfish to meet the recreational demand.

Competition for locally-controlled shellfish ground has grown due to improved water quality. The demand for shellfish combined with the decline in the finfishery has caused a number of fishermen to retool and convert to shellfishing. As a consequence, the increase in harvesters has placed a greater demand on the local volunteer commissions and the state's aquaculture bureau.

Summary

To maintain local control of shellfish resources each town must be vigilant in its responsibilities or relinquish control to the state. A loss of home rule would likely close the fishery due to state budgetary constraints and lack of staff to fulfill the laborious tasks that were performed by local volunteers. The present successes of local commissions is due also to the close working relationships and cooperation among state and local agencies, as well as recreational enthusiasts and commercial shellfish interests.

Survival of Juvenile Oysters in a Rain-Down System

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Kitt's Oysters Limited, Ladysmith, B.C., Canada

The rain-down system for rearing newly-set single oysters was developed by Seasalter Shellfish (Whitestable) Limited, Great Britain and was introduced to us by Dahman's Shellfish Co., Shelton, Wash. The system takes the unusual approach of keeping juvenile seed oysters in suspension through an airlift in a plastic cylinder. The benefits compared to an upwelling system include: (1) algal food is more efficiently used; (2) water flow requirements are lower; (3) less maintenance is required; and (4) survival and growth rates are higher.

We conducted an applied research project to ascertain that the rain-down system does improve the survival rate compared to traditional upwelling systems. Specifically, our objective was to undertake a comparative statistical assessment of survival rates among three densities of stocking in the rain-down system (Treatment 1 = 0.5 million larvae set, Treatment 2 = 1 million larvae, and Treatment 3 = 1.5 million larvae) of the rain-down system and one density in our current commercial upwelling system (Treatment 4 = 1 million larvae set).

An analysis of variance performed on the data of four replications (four different sets) of the above four treatments showed that differences in mean results among the treatments means are statistically significantly ($P << 0.01$). Tukey's multiple comparison test at the one percent level of significance shows a difference between means from each pair of treatments except for Treatment 3 and Treatment 4.

The results indicate that the rain-down system does improve survival rates compared to traditional upwelling rates and that stocking densities affect survival rates in the rain down system.

The Science Council of British Columbia provided financial assistance and students at Malaspina University College assisted with sampling and collecting of data for the experiment.

The following tables summarize study survival data (mean percent) and an analysis of data variance.

ANALYSIS OF VARIANCE

ANOVA

Source of Variation	SS	SS	MS	F	P-value	F crit
SET	5238.495	3	1746.165	239.7085	7.15E-40	2.718785
TREATMENTS	1330.857	3	443.619	60.89873	1.34E-20	2.718785
INTERACTION	1084.283	9	120.4758	16.53858	5.40E-15	1.999116
ERROR	582.7628	80	7.284535			
TOTAL	8236.3978	95				

MEAN PERCENT SURVIVAL

	TREAT 1	TREAT 2	TREAT 3	TREAT 4
SET 1	17.205433	14.798633	5.4484167	14.041617
SET 2	8.7470833	7.9307667	4.99495	4.8312
SET 3	30.636667	25.1357	27.6425	24.183433
SET 4	29.9838	19.62605	12.237617	7.57575
TREATMENT AVERAGE	21.64325	16.87279	12.58087	12.658

Oyster Chub System Commercialization Project

Skip Kemp, North Carolina Sea Grant Program
Atlantic Beach, North Carolina

The aim of this project was to scale-up research and development of the chub oyster grow-out system and to determine its economic feasibility. The project was a partnership between the Sea Grant program and industry oyster growers.

The chub system is probably more appropriate for large scale operations than for growers producing small quantities. Slow oyster growth and high mortalities encountered during the course of the project were unexpected based on results from previous testing and contributed to poor harvest results. Of the 200,000 oyster seed distributed to partners, 50 bushels were reported harvested. Reported selling prices ranged from $26 to $45 per bushel. A significant development from the project was the observed superior performance of triploid versus diploid oysters. The chub system will undoubtedly continue to be refined and altered in the search for appropriate N.C. oyster culture methods.

Other accomplishments are as follows:

1. Funding of several North Carolina Fishery Resource grant proposals to develop off-bottom oyster growing systems were based on this work.
2. The Blue Ribbon Advisory Council on Oysters developed recommendations using the results of this project.
3. Several community college and high school educational programs in North Carolina have incorporated into the curriculum chub technology as an oyster-growing method.

Procedures

Participants

Industry partners paid a registration fee of $200 to participate in the project. A memorandum of agreement was signed by the partners and Sea Grant detailing the responsibilities of both parties in the project. Sea Grant was responsible for providing oyster seed in chubs and technical advisory assistance; partners were responsible for providing labor and reporting results. The project manager helped all partners with applications to the N.C. Division of Marine Fisheries (DMF) for the required water column research and demonstration amendments to the leases and endorsed the projects as an educational sponsor. Each proposal described work to be attempted and included drawings of the site. Applications went through the public hearing process and all were approved by DMF. Renewals were applied for separately after two years from date of first issuance by individuals who chose to continue their research with oyster culture.

Kevin Wissel, a graduate student at Duke University Marine Laboratory's new Coastal Environmental Management curriculum, used oyster chub grow-out research as the basis for a master's project. He designed several experiments to be conducted simultaneously with the project and contributed labor. All data collections and analyses during the first year and one-half of the project were conducted by Mr. Wissel. After his departure from the project, the partners continued to provide information on the system's commercial feasibility.

Student volunteers also participated in the assembly of chub links. Students in the Environmental Biology class of Carteret Community College (Morehead City) received lab credit for time spent working on the project. Students in the new Oyster Mariculture curriculum of Dixon High School (Snead's Ferry), a collaborative program with Coastal Carolina Community College (Jacksonville), worked on the project as a class activity. Also, oysters and chubs were donated from the project to both institutions for their continued studies.

One partner, Jim Swartzenberg, used preliminary results of this project as the foundation for a Marine Fishery Resources grant proposal to continue developing the chub system as a commercial oyster culture method. That study is ongoing; however, preliminary results are promising. The 1996 hurricanes delayed the project's examination of the commercial economic feasibility of the chub system. Results will be reported separately by Mr. Swartzenberg. Those results will more accurately reflect the true economic feasibility of the chub method because of the larger scale of operation.

Seed

Oyster seeds were purchased in late February and early March 1994 from Harbor Branch Oceanographic Institution, Ft. Pierce, Fla. Two shipments of 2 to 4 mm oyster seed (total 400,000 seed) were received. The seed was put into onshore raceway nurseries at the Sea Grant mariculture demonstration facility for growing to a larger planting size.

High mortality and slow growth of oyster seed occurred in the raceway nurseries. An upweller nursery was subsequently built and used for the remainder of the project. Subsequent telephone conversations with persons associated with Harbor Branch indicated that the seed may have been the slower growers of a group.

One hundred thousand 3 to 4 mm triploid oyster seed were purchased from Harbor Branch in August 1994. Because of the diploid mortality experienced in the nursery, and the expectation of running short of seed to supply project partners, additional oyster seed were purchased to make up for the expected shortfall. Seventy-two thousand 7 to 15 mm oyster seed were purchased from Carolina Cultured Shellfish, Harkers Island, N.C. in September 1995 (seed from Maryland stocks). Seed were transferred to the project nursery. Some partners bought additional seed on their own to stock more chubs or experimental grow-out cages of their own design.

Larger seeds were transferred from the on-shore nursery to floating chubs and cages for holding. Grow-out chubs were stocked when enough seed were available to justify a project workday.

Chubs

The primary chub mesh used for the project was selected based on favorable results from previous tests. A bulk order was placed with Norplex Inc., Kent, Wash., the sole supplier of the selected mesh. Dimensions of the material we received were slightly different from the material previously tested. In addition, the product quality was inconsistent, causing greater waste than necessary. When contacted about this, the company explained that the mesh was not a standard product and required a special cutting; also the cutting die required constant adjusting during the mesh's manufacture. This caused the variation from material previously used and the problems with quality control. Other chub materials were purchased from ADPI Co., Internet Inc., and Nalle Plastics Co. for comparison purposes and for additional experiments.

A major development of the chub system was changing from a ladder configuration to a link configuration. Comparing costs of materials and expected assembly times for the two configurations on paper showed a significant savings by using links. A new workstation was built to allow dual assembly line construction of chub links. Links were also approved by the project partners as a better method.

The length of individual chubs was modified from the original design. Longer chubs developed problems with seed oyster washing into one end and requiring periodic leveling of the oysters. Chubs were shortened so that oysters would collect underneath floats rather than wash into the ends of chubs.

Project workdays were used to complete chub assembly. Notices were sent to project partners announcing upcoming workdays. Participants sieved oyster seed by size group and constructed chub links. Chub link construction consisted of measuring and cutting stabilizer ropes, floats and mesh, measuring and stocking oyster seed, and clipping chubs to ropes.

Assembled chub links were kept at the Sea Grant Research Sanctuary in Bogue Sound until distributed to partners' sites. Chub links were identified by treatment type for testing.

Anchored longlines and marker floats were installed by the project manager at each of the 10 partners' sites. Links were distributed equitably to project partners with each receiving 20,000 oyster seed in chubs. Chub links were delivered between August and November 1994. This was a much later stocking date than anticipated.

Mr. Kevin Wissel conducted follow-up sampling for test data in mid-September and early December 1994.

Tests

Kevin Wissel designed several tests to occur simultaneously with the oyster chub ladder project. It was anticipated that these tests could be accomplished without compromising the economic nature of the project. Following are the tests included in the master's project. Detailed results of tests are found in Mr. Wissel's thesis (1995. Wissel, K. "Oyster Mariculture in North Carolina." Master's thesis. Duke University Marine Laboratory, Beaufort, NC).

Site – 12 sites
Density – 3 densities (high, medium, low)
Mesh size – 3 mesh sizes
Mesh type – 3 mesh types
Salinity – high and low salinity sites
Control – chubs without floats placed on bottom
Seed size – large and medium seed sizes
Wave energy of site – high and low energy sites

A brief description of test results follows. Detailed analyses may be found in the master's thesis.

Tests showing no significant differences:

(1) Large seed– low versus medium density
(2) Medium seed– low versus medium density
(3) Medium seed– medium versus high density
(4) Mesh diameter– no effect at the densities tested.

Tests showing significant differences:

(1) Medium seed– floating versus bottom culture
  Floating seed grew faster.
(2) Medium seed– low versus high salinity area
  Seed in two low-salinity sites grew faster than seed in two high-salinity sites.
(3) Medium seed at low salinity– medium versus high density
  Medium-density seed grew faster than high-density seed at one low-salinity site.
(4) High wave-energy site versus low wave-energy sites
  Oysters grew faster at two high-energy sites than at three low-energy sites.
(5) Site salinity differences
  Fouling was more severe at high-salinity sites than at low-salinity sites.
  Survival was greater at low-salinity sites.

Results

Seed

Oyster seed suffered high mortality and slow growth in the demonstration raceway nursery. Mortality was caused by the silt accumulation over small seed in raceways. The silt and crowded conditions caused slow growth of the seed. Construction of an upweller nursery solved the problem.

Oyster seed continued to grow more slowly than expected. The volumes of water pumped in the upweller were insufficient for maximum seed growth for the numbers grown. Poor seed quality was also suspected as an additional cause of the slow growth. Subsequent telephone conversations with Harbor Branch associates indicated that the seed shipped to us were probably left over from several cullings and may have been slow growers. These same conditions were suspected for the triploid seed and the Maryland seed.

The large number of sites made it difficult to stock and plant seeds evenly at all sites as they reached proper size. A project objective was to distribute seed equitably to all partners. In addition, tests required simultaneous delivery for validity. The result was that oyster seed were held in high densities far longer than they should have been. This situation also contributed to slower growth. The net result of the combination high initial mortality and slow growth was that chubs were placed on partners' sites much later than desired and the stocked oyster seeds were smaller than desired.

Chubs

Problems with mesh quality control were slight. Sections of the tubular mesh where the die had malfunctioned were discarded. The diameter of the mesh was slightly less than expected. To compensate, chubs were made shorter with smaller floats.

In the interest of continuing the search for best materials, several new mesh and flotation types were tested. Material from ADPI (product #OSN-1) has proven to be the most durable of the lightweight meshes tested. It has a bar mesh size of 9/16-inch that stretches to 1 1/8-inch mesh. This requires particularly large seed oysters that will lay flat in the chub and not become enmeshed in the chub material.

The conversion from chub ladders to chub links was a breakthrough in construction efficiency. All partners approved of the new configuration. The chub link assembly method is a simple procedure. Project partners and volunteer students could master the techniques after a few minutes of instruction.

Three people using two workstations could assemble a chub link with 1000 oysters every 5 minutes. One person stocked oyster seed and flotation into chubs. Two others measured mesh and clipped chubs to the stabilizer ropes. A fourth person moved chubs and supplied components to the assembly line crew. Chub ladder assembly requires more labor and is not as fast as links. Also, longline fields for holding links were less costly than longlines required for ladders.

Grow-out

To reiterate, the purpose of this project was to move the oyster chub system toward commercial scale and attempt to evaluate the economic feasibility of the system. Biological measurements were taken in September and December 1994 by Kevin Wissel for use in his master's thesis. Further sampling by the project partners was scattered and not consistent. Repeated follow-up calling was unsuccessful in obtaining additional data except from a limited number of partners. A printed survey was also mailed to partners to obtain additional data but again only a limited number responded.

From those telephone calls and mail surveys it is estimated that 50 bushels of oysters were harvested form the original seeding. Of the oysters reported sold, a price range of $26 to $45 per bushel was indicated.

Discussion

Seed

Results of this project indicate that the quality of the seed is a critical factor in successfully growing oysters. Seed quality is certainly a major factor in other traditional farm crops. Poor seed quality caused a major delay in stocking grow-out chubs for this project. This will likely delay expected harvest dates by as much as one year. And it probably contributed to the high mortality rates experienced. The problem is especially notable because the same supplier provided the seed that grew and survived well in previous tests.

To address the problem of seed quality it is important to know what factors constitute good quality. Some desired traits of agricultural seed are: fast growth, high yield, disease resistance, environmental tolerance, nutritional content and marketability. Oysters should be bred for these same qualities. But is it possible to tell whether a particular batch of oyster seed is good quality? What tests can be done to determine seed quality? And what is the earliest point in the life of an oyster that these traits can be determined?

Some hatcheries claim to routinely discard slower growing larvae and only grow or sell the better performing seed. Many hatcheries have unreliable performance and keep as much of the larvae as they can. This way they are assured of having more seed to sell without regard to its quality or subsequent performance. By improving the success of hatchery techniques, the latter group could spawn more times, cull slow growers and still end up with desired numbers of higher quality seed.

Triploid oysters seemed to be the preferred seed by oyster growers who continued the project on their own. Although no formal data was collected regarding the differences between triploids and diploids, the growers noted several advantages of triploids. Triploids seem to grow with more uniformity of size than diploids and the shape of triploid shells appears to be more rounded. The triploids appear to be fatter and of more marketable quality throughout the year than diploids, including in-season and out-of-season harvests. The triploids appear to survive better than diploids.

Seed costs are by far the largest cost in producing oysters, especially considering that large oyster seed are needed to stock chubs. Future work should look at ways to reduce seed costs. Seed collected from wild settlement is used in some oyster growing areas but we need to develop effective ways to collect wild seed so that it can then be cultured in off-bottom systems. On-shore pumped-water nurseries can be efficient ways to grow clam seed to larger sizes for planting, but we still need to perfect cost effective ways to culture oyster seed to the larger sizes required of the chub system.

Chubs

The new link configuration has replaced ladders as an assembly method. Operating procedures have been established for assembly lines. Mesh selection has been narrowed to a few acceptable types. Proper stocking densities, times and seed sizes are still being developed. The best type and quantity of flotation also remains in question.

Fouling remains a major problem with off-bottom oyster culture. A drying routine was used to control fouling in the development study. Several prototype drying devices have been built. None have been adopted by growers and no drying device has been used by partners to control fouling in this project. A simple, cost-effective device needs to be developed for drying chubs. When oysters are grown in mesh bags on racks, fouling is effectively controlled in areas where there is a high tidal amplitude that allows regular drying of the mesh. In subtidal cultivation, drying the mesh is not possible and mechanical solutions must be developed. Fouling severity is highly dependent on growing area. The higher-salinity growing areas generally were plagued with more severe fouling problems than lower-salinity areas.

Costs of the System

The chub system has not yet proven to be an economically feasible method for growing oysters in North Carolina. However, these experiences have stimulated a renewed interest in oyster cultivation in the state. The link configuration significantly lowers the system costs over those of the ladder configuration. Continued feasibility by other projects are ongoing. Figure 1 shows a description of the costs of the chub system as used in this project.

Figure 1. Costs of the Chub Link Oyster Culture System

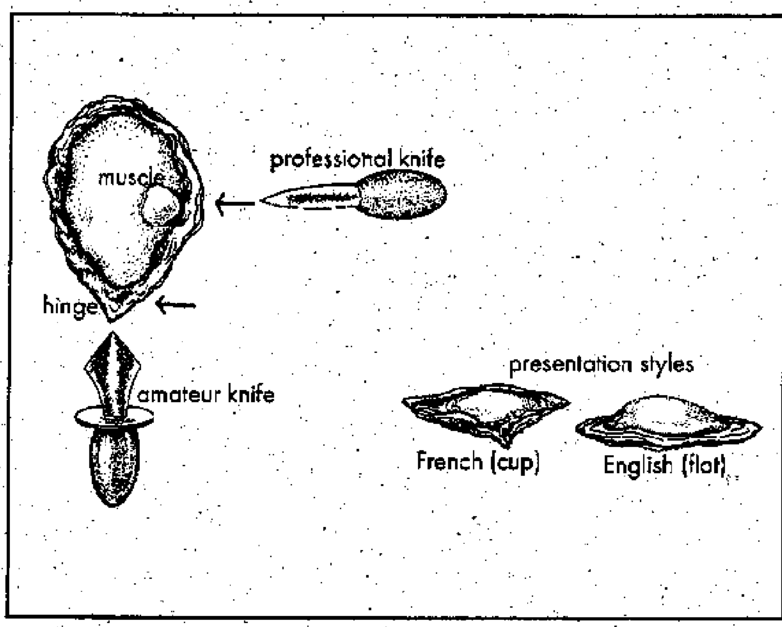
Materials	Amount	Size	Price	Total
Oyster Seed	100,000	25-35 mm	$35/1,000	$3,500
Chub Mesh	6,000 ft	9/16 inch	$0.09/ft	540
Floats	4,000	2" x 2" x 12"	$0.12 ea	480
Rope	6,000 ft	1/4 inch	$0.02 ft	120
Clips	6,000		$0.02/ea	120
Longline	400 ft	1/2 inch	$0.50	200
Anchors, buoys				200
Miscellaneous				400
Total				**$5,560**

Special thanks and acknowledgment to Kevin Wissel for assistance with this project.

Diagrams of Oyster Opening Methods Used in France

Yves LeBorgne, SATMAR, Gatteville-Phare, France

Traditional



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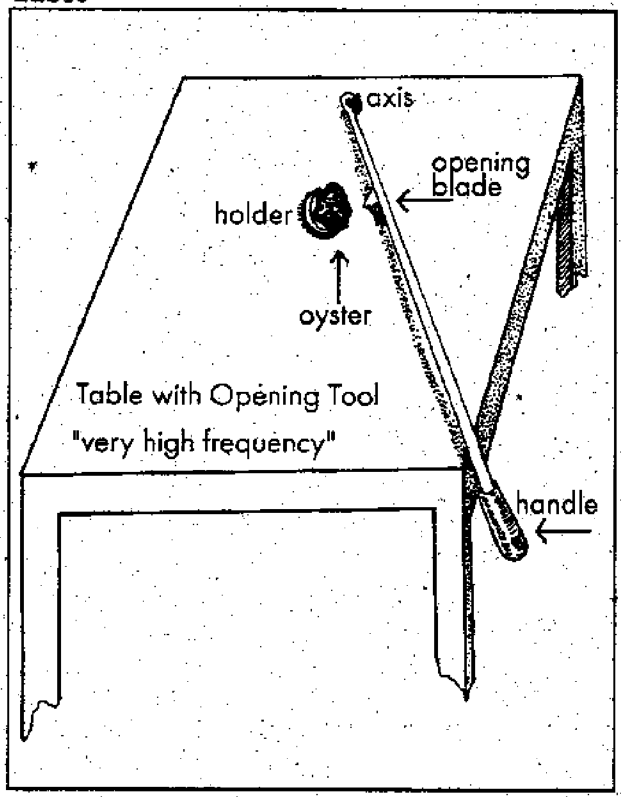
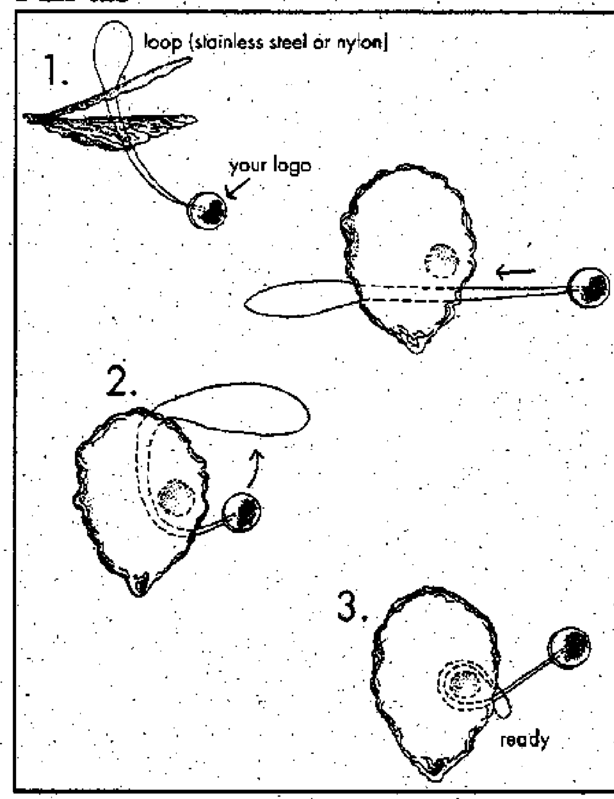


Pull-tab



Discussions of Selected Species

Larvae sampling and setting experiences with pink/spiny scallops

Raymond RaLonde, School of Fisheries and Ocean Sciences/Sea Grant Program, University of Alaska, Anchorage, Alaska

Alaska has 56 permitted aquatic farms using 219 acres of tidelands for shellfish culture. Since passage of the 1989 Aquatic Farm Act the industry has grown from a single farmer to its current development with over $5 million of inventory now under cultivation (Figure 1). Currently, Alaskan aquatic farmers can purchase only Pacific oyster seed from shellfish hatcheries in Washington. Major problems now facing the Alaska shellfish culture industry are access to reliable, high-quality oyster seed and diversification of production.

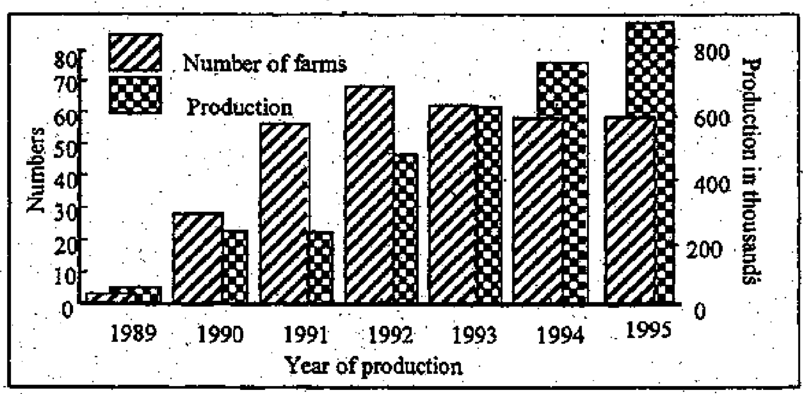


Figure 1. Growth of oyster farming in Alaska based on farmer permits and production.

Culture of shellfish species other than Pacific oysters is not feasible because the state prohibits importing species other than oysters, and the state lacks a shellfish hatchery to produce the seed. Along with shellfish seed production, research and development is necessary to produce an in-state oyster broodstock and technology to culture other species for production on Alaska aquatic farms. As a partial solution to these problems, $3.2 million was appropriated from Exxon Valdez litigation funds to construct a Mariculture Technical Center and shellfish hatchery in Seward. Construction is now underway and the facility is expected to be completed in April 1997.

Of the alternate species being proposed for development, scallop is a preferred option for aquatic farmers. Initial investigation into scallop culture in Alaska began in the mid-1980s from a State of Alaska/Japan cooperative program to attempt capture of weathervane scallop (*Patinopectin caurinus*) spat from the wild by application of a technique successfully used in Japan for collection of Japanese scallop spat (*Patinopectin yessoensis*). With help from the Overseas Fisheries Cooperation Foundation of Japan, the Alaska Department of Fish and Game conducted a project around Kodiak Island starting in March 1987. Completed in 1989, the project was not successful in collecting weathervane scallop spat, but captured primarily spat of the smaller species of pink (*Chlamys rubida*) and spiny (*Chlamys hastata*) scallop spat (OFCF 1989).

As a result of failures, the project was expanded to southeastern Alaska in the summer of 1987 with distribution of spat collection equipment to Yakutat, Sitka, and Ketchikan. This report summarizes the results of scallop spat collection and growout in Sitka Sound from 1987-1989. With little manpower and funding, the studies were conducted as separate, but related, projects over a three-year period. Activities include collection of spat, analysis of plankton to estimate scallop larvae setting, and spat growout studies (Table 1).

Table 1. Schedule of activities of the Sitka Sound Scallop Study

1987	Preliminary scallop collector study
1987	Beginning of the growth study
1988	Targeted scallop collector study
1989	Larva sampling study
1989	Completion of scallop growth study

Preliminary scallop collection, collector assembly

The spat collection equipment, called a ren, consists of nine collection bags attached vertically to a rope anchored to the bottom of the sound with sand bags and suspended via a submerged buoy (Figure 2).

The collector bags are nylon 80 cm x 40 cm with 3 mm mesh size and attached at approximately 1-meter intervals along the line. The bags are filled with plastic netting to give loft to the bag, creating a "pillow" effect. During this study we use monofilament gillnet material and Netron, a stiffer polyethylene netting.

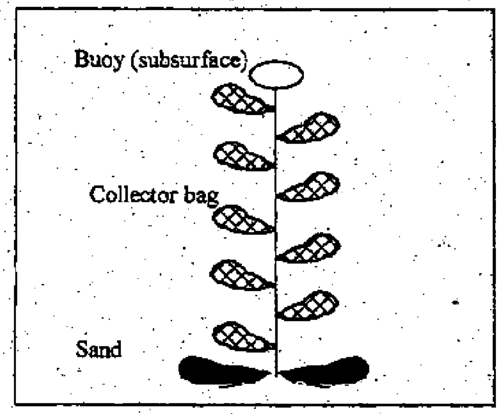


Figure 2. Ren collector assembly.

Spat collection during 1987

- Initial sites for the study beds in the area
- Ease of access
- Salinity over 28 ppt

Collectors were assembled into rens having six collectors each, and placed adjacent to the purple hinge rock scallop beds in the southern Sitka Sound area at Deep Inlet, Leesoffskaia Bay, and Nothoroughfare Bay (Figure 3). The collectors were placed in each location at three different times: June 30, July 12, and July 31, 1987.

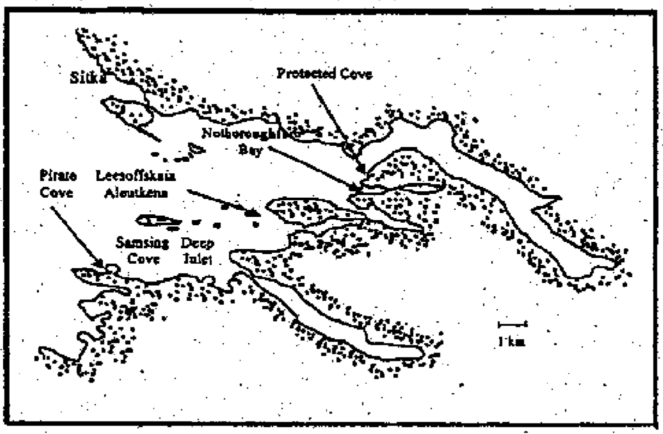


Figure 3. Sites selected for scallop studies in Sitka Sound, 1987-88.

The first series of three rens were retrieved in November 1987. A total of 411 scallops were collected, predominately spiny and pink scallop. Average size of the scallop spat was 4.3 mm, S=.88 (n-30). Survival from the initial retrievals was very low, and we did not retrieve the remaining rens until May 10, 1988. At that time only two rens were located at Leesoffskaia and Nothoroughfare Bay. Approximately 1,120 scallops were recovered. The average size was significantly larger than spat collected in the fall at 7.7 mm, S=1.8 (n=30). Survival of these larger spat was very good, nearing 95%+. Spat were outplanted to determine growth potential. Initially, 50 spat were placed in clean collector bags with a single bag placed in each chamber of a lantern net. Three lantern nets were prepared in this manner and anchored in Aleutkena Bay.

Continuation of spat collection in 1988

In 1988 several modifications of the study were implemented as more collection gear became available. Two additional sites were added at Pirate Cove and Protected Cove. Nothoroughfare Bay was dropped as a sample location, and, in order to better estimate scallop spat set timing, deployment of the rens was initiated earlier on May 2. A total of 17 rens were deployed as follows: two at Pirate Cove, six at Deep Inlet/Samsing Cove, six at Leesoffskaia/Aleutkena, and three at Protected Cove. The rens were retrieved on February 15, 1989, and April 12, 1989.

Again, spiny and pink scallop were the predominant species collected (Table 2). Survival was not significantly different than the February 15 and April 12 retrieval dates.

Table 2. Scallops collected in the Sitka Sound Scallop Project during the summer of 1988.

	Species			
Location	**Pink**	**Spiny**	**Purple Hinge**	**Total**
Pirate Cove	48	222	27	297
Deep Inlet	169	1119	68	1356
Leesoffskaia	67	508	16	591
Protected Cove	191	1130	82	1403
TOTAL SCALLOP				**3647**

Average size of the spat was 11.75 mm. Fouling was troublesome, particularly from early deployment (Figure 4). Mid-summer deployment of rens captured significantly more spat than those deployed in the spring and early summer.

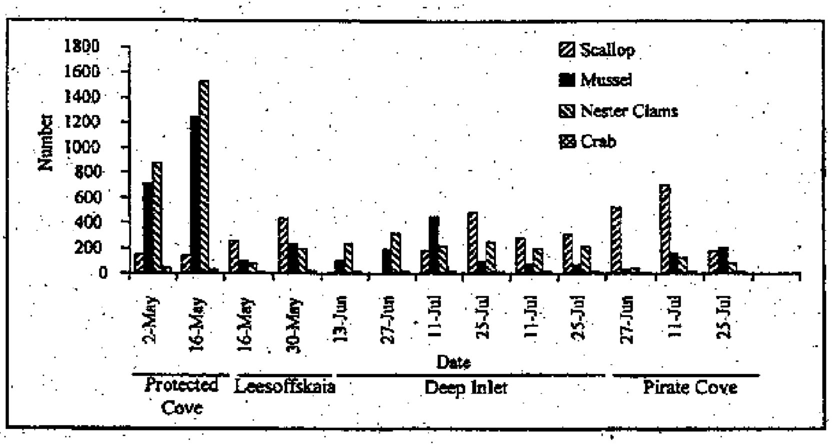


Figure 4. Results from scallop collectors from Sitka Sound, Alaska, 1988.

From the spat collection results, it appeared that the best spat collection and reduced interference from fouling occurred when rens were deployed in mid-summer.

An additional part of this 1988 study was to determine if depth of collection was significant in capturing scallop spat. To determine the effect of depth, the water depth the bag was measured by scuba diving and using a depth gauge. The number of scallop spat from each bag were counted. Results indicate that the best depth for collection was between 6 to 10 meters (Figure 5) (Coulthorpe 1988).

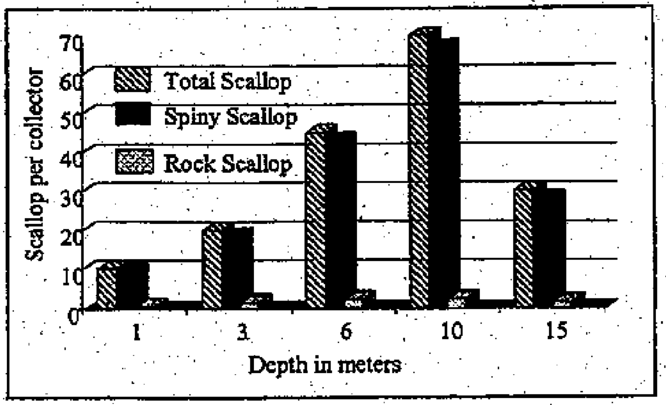


Figure 5. Depth ranges for scallop collection.

Continuation of the study, 1989

In 1989, the project was expanded to include collection and analysis of bivalve larvae samples to attempt prediction of setting time and enable more precise deployment of collectors. Beginning June 16, 30-meter vertical tow plankton samples were collected using a 50 mm size plankton net. Monitoring plankton differed for each study site based on access. Severely stormy weather during the summer of 1989 did not allow us to access the sites nearest the open ocean, thus limited plankton data was obtained from Pirate Cove and Samsing Cove.

Subsamples were taken using 1 ml volume Hensen-Stempel pipets. General zooplankton composition was recorded by counting individual organisms. This was done to assess the prospects for invertebrates such as crab and starfish settling in the collector bags, causing loss of spat from predation. Bivalve larva were separated from the sample, placed in a counting chamber, and examined with a microscope equipped with a video camera unit that projected an image of the sample on a television monitor. The larva were identified by type: mussel, clam, and scallop. The television monitor was calibrated with a stage micrometer so larva length could be measured. These lengths were then converted to actual measurement in microns.

Knowing that scallop larva set when they are approximately 250 mm, the rens were to be deployed when the larva reached approximately 220 mm in length. Length frequency data was collected from two areas in an attempt to determine set timing and the relative numbers of bivalve larva that were above or below 220 mm. Distinctly different patterns occurred between the two sites. At Protected Cove, the initial number of larva above 220 mm was quite high on June 16, but dropped by greater than 80% by July 8 (Figure 6).

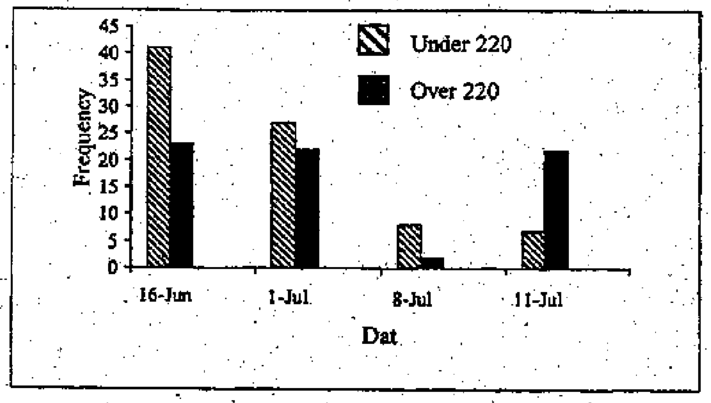


Figure 6. Length frequency of scallop larva above and below 220 mm at Protected Cove, Sitka Sound, Alaska.

At Leesoffskaia no such drop in larger scallop larva occurred. An abundance of larger size scallop larva were evident during the entire sampling period (Figure 7).

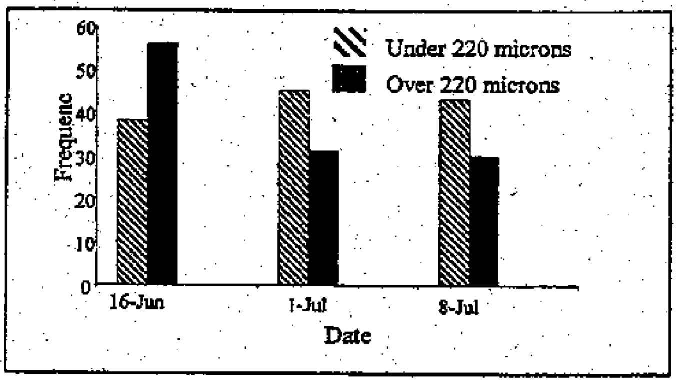


Figure 7. Length frequency of scallop larva above and below 220 mm at Leesoffskaia, Sitka Sound, Alaska.

On the first date of plankton sampling, June 16, an abundance of larger size (greater than 220 mm) scallop larva were captured. At that point we decided to deploy all collectors at all sites immediately. Within 5 days all the collectors were deployed. Unfortunately, the results of the 1989 spat collection were not quantified. The collectors were recovered and empirical estimates of the results were noted by the investigators. There did appear to be a pattern of success. In order of most-to least-successful collectors, the most obvious observation was the massive spat captures that occurred at the Leesoffskaia site with more than 500 spat retrieved per bag. Protected Cove had far fewer spat than Leesoffskaia even though the sites are in close proximity (approximately 2 km apart). Moderate numbers of spat (less than 300 per bag) were collected at the Pirate Cove and Samsing Cove sites.

An apparent correlation may exist between the Leesoffskaia site and the large number of spat collected in the area. Leesoffskaia was the only site where large scallop larva (greater than 220 mm) persisted. All the other sites had decreasing numbers of larger scallop larva starting at July 1.

Results of growout study

For growout, approximately 50 spat were placed in clean collector bags and each bag inserted into a chamber of a lantern net. The spat were grown out to approximately 25 mm then removed from the collector bags and placed directly into lantern net chambers at a density of 50 scallop per chamber. The lantern nets were anchored at Leesoffskaia and grown from October 1987 to March 1989. Measurements of shell height (from the hinge to the opposite shell margin) were measured approximately every six months. Water temperature during the growout period were considerably cooler than occurred in more southern latitudes (Figure 8).

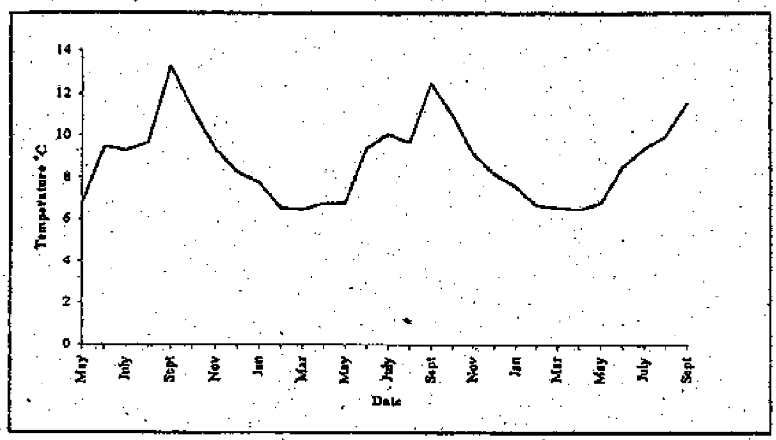


Figure 8. Surface water temperature of southern Sitka sound during scallop growth study, May 1987-September 1989.

The scallop grew very well, and were significantly larger than that reported from wild populations (Figure 10). As an example (Bourne and Harbo 1987) reported that a five-year-old spiny scallop reaches approximately 75 mm in shell length. After 18 months of lantern net culture, a number of spiny scallop reached that size, although the average size was 60 mm. Pink scallop grew more slowly, while purple hinge rock scallop grew fastest.

The growth of pink and spiny scallop also appeared to level off by the end of their second year, while rock scallop growth rates continued. One interesting feature of rock scallop growth is the difference in shell mass and morphology from that of wild-grown scallop. In a lantern net culture operation, the shell is far less massive, and takes on the ribbed appearance associated with scallops and lost in wild scallops.

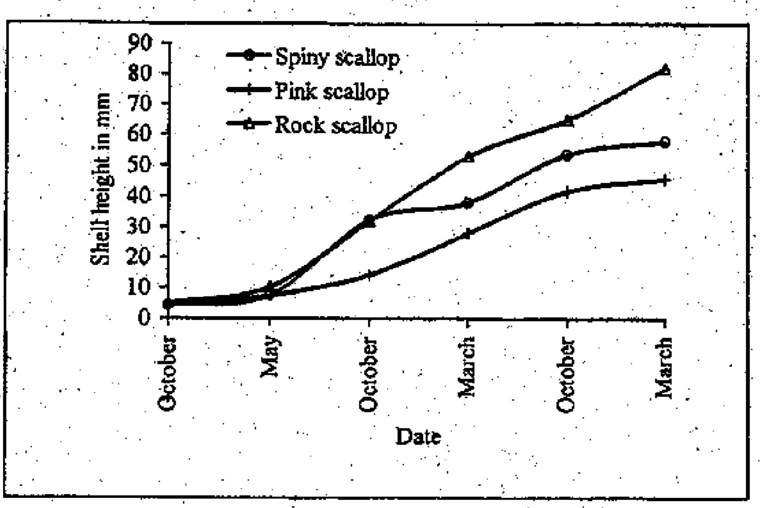


Figure 9. Growth of scallop at Leesoffskaia in southern Sitka Sound, Alaska.

Conclusions

We were unsuccessful capturing wild spat of the weathervane scallop. A small number of purple hinge rock scallop spat were captured, but not enough to make the process economical. The predominant species captured were spiny scallop, and we could increase the capture of this species by estimating the time of spat set and subsequent appropriate deployment of the collection tens. Attention to scallop larva size in the plankton monitoring (greater than 220 mm) may increase the chances of successful capture of spiny scallop. Fouling can be minimized with proper timing of collector deployment. Deployment of the collection bags in a longline system at a depth of 6 to 10 meters will increase spat collection.

Growth of the scallop was definitely improved above that of wild populations, but with pink and spiny scallops, growth decreases significantly at about 60 mm in shell height, the average size we achieved at the end of two years of growout. Purple hinge rock scallop can achieve 80 mm in shell height at the end of two years of cultivation and growth continues to increase after the two year growout period.

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Preliminary Trials for Red Sea Urchin Enhancement Using Prepared Artificial Diets

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The red sea urchin, *Strongylocentrotus franciscanus,* is one of the most valuable fishery exports in California. This fishery was developed to supply a strong Japanese market for uni, the male and female gonads of the urchin which appear as five skeins of reproductive tissue inside the lateral margins of the shell. Uni value is highly dependent on quality, and ranges from $6/kg to $200/kg based primarily on color, size, texture and flavor. Worldwide, fishery production has been fairly steady at 60,000 mt, but this harvest rate is not sustainable and has been maintained by the sequential depletion of new stocks to meet the strong demand for high-value product.

Six species of urchins are harvested in Japan, and throughout the 1970s the commercial catch fluctuated around 25,000 mt. In the 1980s, harvests declined to around 20,000 mt, and then in 1991 dropped drastically to around 14,000 mt where it remains today (Hagen 1996). This decline created an enormous demand for high quality uni, and urchin stocks throughout the world were aggressively harvested to satisfy this market.

The California fishery experienced tremendous growth in the mid- to late-1980s, but by 1991 was beginning to exhibit classic signs of over-harvesting. California production declined from 30.5 million lb. in 1988 to 6.7 million lb. in 1993. The catch per unit effort declined from 800 to 300 lb./hr between 1988 and 1995. During the same period there was a decrease in the average size of urchins harvested.

While urchin resources continue to decline throughout the world, demand remains high. The Japanese annually consume 7,000 tons of processed uni, of which 5,000 tons are imported, representing 40,000 to 45,000 tons of live animal harvest. The French provide the second largest market for uni and consume about 1,000 tons/year. With this great demand for a declining resource, interest has risen in improving fisheries, aquaculture, and enhancement of adult urchins to improve gonad quality.

Some of the factors contributing to the decline of the Japanese fishery are habitat loss, poor recruitment, and limited available natural food. To counter this, the Japanese are developing artificial reefs, improving soft bottom substrates, and cultivating algae in areas with suitable urchin habitat that lack adequate food resources. There are also hatchery programs designed to overcome poor recruitment through the release of juvenile seedstock. While these programs should stabilize or improve the fishery, aquaculture of urchins to market size is unlikely to succeed because of the low net value of the animals on a whole weight basis. As a result of this, considerable interest has developed in enhancing uni quality in adult urchins through supplemental feeding with kelp and formulated diets. In California, there are numerous urchins that occur in barren areas with little available food and, as a result, have poorly developed gonads. If the gonad quality of these urchins could be improved, they would provide a substantial contribution to the fishery.

The goal of supplemental feeding is to increase urchin value by improving gonad yield, color, texture and taste. This "feed lot" concept can be conducted in land-based systems, floating ocean systems, or ocean-based bottom net pens. Each system has different advantages and disadvantages in terms of cost, permitting, access, water quality, stocking and harvesting. In order to test the feasibility of the enhancement concept, preliminary trials were undertaken to evaluate two artificial diets against a kelp control diet.

Experimental Trials

Red sea urchins were captured in Bodega Bay, Calif., near the mouth of Tomales Bay, in an area that consistently produces low quality uni. Animals were held in outdoor 8 m x 1 m x 1.5 m concrete raceways for two months after harvest to allow for incidental post-harvest mortality. They were subsequently separated into 1 m^3 raceway sections using welded plastic mesh partitions prior to being fed the experimental and control diets at ad-lib rates. Animals were stocked at 12/m^2 with a water flow of 5 l/min. Ambient water temperatures varied between 12°C and 15°C.

Two experimental diets were tested. One was a kelp-based formulation developed by Dr. John Lawrence and the other was a fish meal-based diet developed by the Mexican company, PROESA. The Lawrence diet was fed as small pellets approximately 8 mm in diameter and 4 mm thick, while the Mexican diet was formulated into discs approximately 4 cm in diameter and 8 mm thick. The Mexican diet was broken into small irregularly shaped pieces prior to being fed. Both diets exhibited good water stability. The giant kelp, *Macrocystis pyrifera,* was used as a control diet. Animals in one treatment were not fed but were able to graze on the mixed algal growth occurring on tank walls. Results from this group were used to evaluate the effects of incidental grazing on gonad development. Animals were fed three times per week for a two-month period. They were then measured, weighed, and their gonads dissected for weighing and grading.

Results and Discussion

Animals in all treatments had increases in gonad weight and index, defined as the gonad weight divided by the total animal weight and expressed as a percentage. Table 1 presents data on gonad index and grade for each of the experimental treatments and control. There is no significant difference in gonad index between any of the fed treatments.

TABLE 1. Mean urchin weight, diameter, gonad index and quality

diet treatment	Mean weight (g)	Mean diameter (mm)	Mean gonad index	Uni grade, % A/B/C
WILD (initial)	485.0	103.0	7.0	22/45/33
KELP	454.4	104.6	9.6	11/89/0
MEXICAN	442.0	102.2	10	78/22/0
LAWRENCE	438.8	102.42	9.9	67/22/11
NO FEED	454.4	102.82	8.5	22/45/33

Supplemental enhancement of red sea urchins using kelp and formulated diets results in increases in gonadal index and uni grade. On average, gonad weight increased in the neighborhood of 1g/wk in all fed treatments. The observed increase in the gonad index of the unfed controls most probably resulted from their grazing the abundant algal turf that grew in the concrete raceways. This increase in gonad index of unfed animals was approximately one-half that observed in the fed animals.

There were observable differences in the final gonad color and this is reflected in the degree of variability in grade and the percentage of uni in the highest A grade category. Animals collected from the wild and unfed controls were observed to have a higher degree of variability in their gonad colors and resulting uni grade. The range in uni grade is similar in the unfed animals to that observed in wild urchins harvested in areas without abundant kelp, both of which presumably grazed on mixed algal turf. The best grades were observed in the two formulated feed treatments and the kelp diet, followed by the no feed trial and the wild condition at the beginning of the trials.

Supplemental feeding of red sea urchins increases their market value in a relatively short time. This practice can also improve the fishery by allowing divers to access the resource when seas are calm and safer diving conditions exist. The practice of holding urchins for a period and enhancing their uni weight and grade would also allow harvesters to supply markets with a better product on a more consistent basis. This is particularly important during the December holiday season when demand and price often peak. Coincident with this peak, California divers must contend with high seas and winter storms.

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Geoduck Culture

Geoducks and the Washington Department of Fish and Wildlife

Hal Beattie, Washington Department of Fish and Wildlife, Brinnon, Washington

Harvest History

Prior to 1970, geoducks were strictly an intertidal recreational harvest species. In the late 1960s, diver-biologists from the Washington Department of Fisheries, now the Washington Department of Fish and Wildlife (WDFW), discovered and documented vast reserves of sub-tidal geoducks. In 1970, the commercial fishery for subtidal geoducks began.

WDFW assesses subtidal populations of geoducks for number, size and quality. Geoducks are a sedentary natural resource and as such the Department of Natural Resources (DNR) manages the sale of sub-tidal tracts fished by the commercial geoduck fishery.

Geoduck Facts

- Geoduck distribution: Baja, California to Alaska, from +3 foot tidal height to -400 feet deep.
- Geoducks can live for more than 100 years
- Once harvested, geoducks stocks are slow to repopulate—about 50 years on average. The allowable harvest in Washington state is about 3 million pounds per year, equivalent to 2% of harvestable population.
- Most geoducks are unavailable for harvest, living either in closed areas or in waters too deep for divers.
- Geoducks start sexual reproduction at 4 to 5 years old. They spawn periodically from March to July, with each female producing about 40 million eggs over the season.
- Geoducks grow to a weight of about 2 pounds in five years and reach maximum size in 15 years.
- The average weight of geoducks harvested from Puget Sound is just under 2 pounds, however geoducks can reach weights of more than 14 pounds.

Geoduck Culture

- Geoduck culture began on a small scale at Point Whitney in the 1970s.
- Commercial scale culture started in 1982 under a memorandum agreement between the Department of Fisheries and the Department of Natural Resources. The goal of the project was to double the subtidal commercial harvest of geoducks in 10 years. By 1987, the hatchery was producing 6 million geoduck seed per year. These seed were planted without protection into subtidal areas.

Culture Facts

- Geoducks start life as swimming larvae only 80 mm long.
- They swim, eat and grow for 25 days.
- At a size of 400 mm they sink to the bottom and crawl around, much like a snail, eating whatever they can find growing on and between grains of sand.
- By 6 weeks of age, at a size of 1.5 to 2 mm, they have developed a siphon. At this point they dig into the sand and begin filter feeding.
- In another 6 weeks, they grow to about 8 mm in length—a good size for planting.

Factors That Affect Geoduck Growth

- Food level—natural algae production
- Currents—strong currents bring in food
- Temperature—geoducks grow well at water temperatures of 55°F to 65°F but will be stressed at continuous temperatures above 70°F
- Substrate type—silty sand is best

Goal of Intertidal Geoduck Planting

- Make more geoducks available to recreational diggers

How WDFW Began Planting Geoducks on Beaches

There are few public beaches with geoducks readily available for the recreational digger. In 1990, WDFW diver/biologists discovered very low survival rates among the unprotected geoducks planted in subtidal areas. Experiments revealed that predators such as crab can get to geoduck seed even when the seed is buried several inches deep. WDF&W staff Brady Blake and Hal Beattie invented a method for protecting newly planted geoducks: place the vulnerable seed inside of short pieces of plastic pipes stuck into the sand. This technique became known as the tube method.

In 1991, Brian Hovis, biologist with Washington State Parks and Recreation, invited Beattie and Blake to test the tube method on beaches in four state parks. Test results in 1992 from the four beaches showed an average overall survival of 40%. By 1993, the planting techniques were being adopted by commercial interests in Washington state and British Columbia.

Hatchery Rearing Of The Geoduck Clam (*Panopea abrupta*)

Richard Poole, Lummi Shellfish Hatchery, Bellingham, Washington

This paper describes methods used to rear geoducks. Most techniques are modified from those used in oyster and clam culture. For the information in this paper, the author relied heavily on the experience of other hatcheries, particularly the Washington Department of Fisheries and Wildlife (WDFW) laboratory at Point Whitney. Geoduck larvae have been reared at the Lummi Shellfish Hatchery on several occasions. Juveniles were produced by two different methods, both of which will be described.

Hatchery rearing of the geoduck clam is a relatively new venture. WDF&W (formerly the Washington Department of Fisheries or WDF) has been involved in a program of geoduck enhancement since 1981 using hatchery techniques developed for oyster and clam culture. An original goal of the enhancement project, conducted in cooperation with the Department of Natural Resources (DNR), was to double geoduck landings in Puget Sound. It was estimated that reaching this goal would require planting 30 million geoduck seed per year. Funding for the project was to be provided by lease fees paid by divers harvesting geoduck on DNR tracts.

In 1983 the WDF&W Point Whitney Laboratory produced millions of geoduck larvae from stock taken from various locations, mainly in south and central Puget Sound. Two years later a sand-substrate nursery was completed and the lab was successfully producing geoduck juveniles for planting in Puget Sound. By 1988 the number of seed planted increased to 7.5 million juveniles. Seed was broadcast over selected areas of Puget Sound and was also planted on state beaches. It was anticipated that the seed would dig in and survive. However, observations indicate that less than 0.5% of the planted clams survived.

WDFW geoduck enhancement efforts were reduced for two reasons: (1) low returns and (2) problems rearing larvae and seed after the 1988 production success. In 1996, efforts were made to produce stock from specified areas. More than 100 broodstock geoducks from any one location are required for a viable larval culture. Several attempts to rear larvae were aborted because of a lack of spawners present in the sample harvested. WDF&W biologists did note that geoducks spawn multiple times each year.

Reduction of hatchery efforts to maintenance levels is unfortunate. Market demand for geoduck is currently very high. The present market in Washington is for live geoducks, Number 1 or Number 2 in quality. (No processing occurs in the state.) The aquaculture industry is well suited to meet this demand. Planted geoducks reach market size in three years and have excellent market characteristics such as white color, uniform size and ready availability. Present aquaculture efforts could use millions of geoduck seed for grow-out.

Hatchery Production of Geoduck Larvae

Geoducks can be reared in the hatchery using procedures that have been developed for oysters, clams and other species. The Lummi Tribal Shellfish Hatchery has been rearing clams and oysters since 1969 for planting on Lummi tribal grounds and for sale to other growers (Figure 1). Using standard procedures, marine algae CHGRA, CC, 3H, SK3, *Isochrysis* and *P. lutheri* are grown for feed; broodstock is conditioned and spawned; filtered sea water of a proper temperature is placed in fiberglass tanks for culturing the larvae; the cultures are changed, sorted and cleaned on a regular basis (usually three days) until the larvae are ready for metamorphosis.

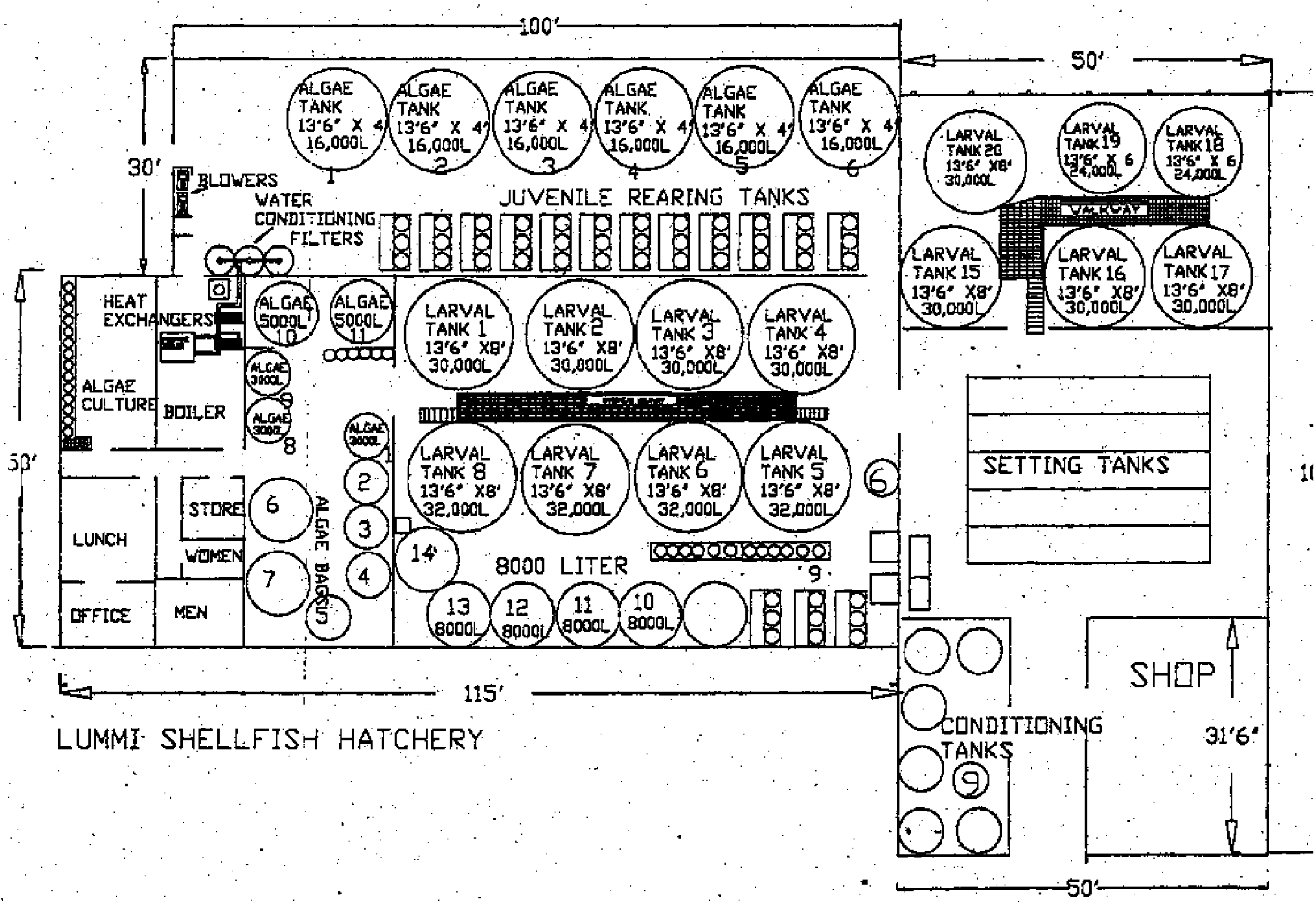

Figure 1. Lummi Shellfish Hatchery showing algae systems, larvae rearing and juvenile rearing in the 14,000 square foot facility.

Collection of Broodstock

Adult geoduck clams can only be taken by commercial permit and under personal license limits set by WDFW. It is also possible to obtain special harvest permits issued by tribal fisheries. Stock for the Lummi Shellfish Hatchery is taken from central Puget Sound near Skiff Point by commercial divers and transferred to tanks at the Lummi Shellfish hatchery. Careful selection and handling of the adults is required. Any tears or breakage leads to mortalities, usually sooner rather than later. So will lifting geoducks by the neck (siphon) or other rough handling. Because the combined weight of the animal's body, shell and included water is so great, lifting animals by the siphon will break siphon muscles, killing the animal.

Broodstock were selected by the following criteria: (1) young and in obvious good health, (2) white in color, (3) no torn membranes or broken shells, (4) transported to the hatchery within 24 hours of harvest and (5) harvested from a central location. Broodstock geoducks are transported in a van and are packed in single layers in wet blankets to minimize exposure to wind and chilling conditions. Harvesters should avoid temperature extremes that may result from leaving the moist blankets exposed to evening temperatures near or below freezing.

Properly collected animals will survive quite well in the hatchery without any special holding or restraining devices, such as rubber bands or sand. If the animal is intact, the membranes that normally keep it together appear to be adequate. Healthy animals will have siphons withdrawn into a short compact mode. If the siphon extends and droops, the animal is in trouble.

In 1997, broodstock was collected on January 23 to determine if it was possible to condition geoducks out of season and produce juveniles early in the year. Early conditioning is already used in the oyster industry. Early production of oyster seed results in fast spring growth; the seed acts as if it were set in the fall.

Conditioning of the Adults

Broodstock was hung in plastic baskets in 32,000 liter tanks at 12°C for two weeks. Examination of three adults (one female and two males) at the beginning of the two-week period indicated that the female was just beginning to form eggs and the males had active sperm. Food was added to the tanks daily in large quantities (excessive amounts of pseudo-feces are produced if the animals are overfed) and water changed every three days.

Small compartments, approximately the same size as the clams, were made in the baskets using 3/4-inch PVC pipe. Long-term contact with slats in the bottom of the baskets used to hold broodstock sometimes causes ulcers to develop on the feet of the geoducks. Small nitex mesh was added to the bottom of the compartments in an attempt to reduce this problem. During 1996 broodstock trials, clams housed in large buckets of sand also developed blackening of the foot caused by low circulation. Putting holes in the buckets reduced this problem. Holding geoducks in sand had other drawbacks. The sand was contaminated and brought in unwanted animals. It was difficult to handle the heavy buckets and a crew of several people was required to change the tanks and move the adults when spawning occurred.

During the 1997 conditioning trials, water temperature was increased to 17.5°C on February 7 and feeding increased. Water was colored with CHGRA, SK3 and *Isochrysis* to the point that the bottom of the eight-foot-deep tank was not visible. A small spawning occurred the next day and the adults were removed to another tank. This first spawning was light, producing approximately 7 million larvae. The adults spawned again February 13 and produced 30 million larvae. The adults were then removed and water from the spawning tank siphoned to an adjacent 32,000 l tank to dilute the eggs and sperm and allow development to proceed without excessive handling of the eggs. (A similar procedure is used for manila clams. Dilution is accomplished by further siphoning, if necessary. Fresh filtered sea water at 18°C is added to the tank to fill it to the top.)

The adults were moved to cold water (7°C) because no tanks with warm water were available. This temperature drop caused severe stress and more than 30 of the animals died. Examination of the morts showed they were still in spawning condition with eggs and sperm present. Examination also showed that more males were present than females. However, sufficient females were available to provide large quantities of eggs. The geoducks that survived the transfer to cold water pulled their siphons into healthy, retracted positions.

Sea Water System

With the sea water system, water for the shellfish hatchery is taken from a shallow six-foot intake in a 700-acre saltwater pond adjacent to the facility. Two 25 hp cast iron pumps supply both the fisheries and shellfish operations through PVC lines. Water temperature at the intake ranges from 0°C in the winter to 25°C in mid-July. Salinities range from 15 to 30 ppt. Water is filtered in three multi-media pressure filters through pea gravel, sand and anthracite coal. Water is heated by Pyrex glass and titanium plate heat exchangers powered by two modulating propane gas boilers (900,000 Btu and 500,000 Btu). Hatchery water can be mixed to provide any temperature from ambient to 30°C. Temperature adjustment is manual and temperatures may fluctuate when tanks flows are changed. Hatchery drainage goes to a pond and adjacent tidal area. Air is supplied by a 10 hp blower.

Algae Culture

The basic system is open batch culture. Starter cultures are maintained in autoclaved 1000 ml flasks and changed every one to seven days, depending on the species and situation. Changing diatoms daily appears to rejuvenate the cultures at times when large quantities of algae are required. Total annual hatchery algae production is 151,800 l. At maximum capacity, the hatchery uses 42,000 l per day. The hatchery does not have a centrifuge to harvest excess algae and tanks may be dumped if algae are too old. Most of the cultures are used in three to seven days depending on the species. *Isochrysis*-type algae may be held longer.

Algae tanks range from 3,800 to 17,000 l in size. They are chlorinated with 90 ppm chlorine (12.5% chlorine from a 15 gallon carboy) and allowed to stand overnight. The tank is de-chlorinated with equal amount of sodium thiosulphate and allowed to aerate for two to four hours. Then nutrients and one or two carboys of algae inoculant are added. All cultures use the f2-nutrient solution. Silicate is not added to *Isochrysis*, T-Iso or *P. lutheri* (all the non-diatoms). Carbon dioxide is not added to the cultures. The cultures are continuously and heavily aerated and are lit by metal halide or cool white fluorescent lamps.

Cultures are fed by pumping the algae to the large culture tanks with a stainless steel pump and 1 in. vinyl hose. The amount of algae to be added to the tanks is measured by pumping time. With 30 million cells per ml in the culture, approximately 25,000 cells per minute per ml are added to the 32,000 l tanks. Algae culture densities vary from species to species, with the diatoms CHGRA, SK3 and CC producing culture densities that usually range from 1.0 to 3.0 million cells per ml. Iso, T-Iso and *P. lutheri* culture densities are usually less than 1.0 million cells per ml. Due to limited personnel, counts are not made on a regular basis. Water coloration is judged by eye, based on experience. During the later larval stages of oysters and clams, tanks are fed twice a day, early in the morning and late in the day. This schedule has produced good results. According to WDFW, geoducks should be fed at lesser rates and early cultures should not be fed more than 10,000 cells per ml. Feeding concentrations can be increased to 15,000 cells per ml and above later in the larval cycle.

All of the cultures are enhanced with f2 nutrient medium as described by Guillard (1975). Nutrients are made in five-gallon carboys, sterilized and placed on shelves for use. Nutrients are made several times a week. Vitamins are kept in the refrigerator until use. All of the nutrient stock solutions are made in high concentration to near saturation.

Larval Culture

Geoduck larvae are cultured in the same fashion as the oyster and clam larvae. Tanks used for larval culture range in size from 8,000 to 32,000 l. Tanks are filled with 18°C water from the heat exchangers and the larvae are added. Feed is added daily at the required rate and according to larval size. Small larvae less than 150 mm are fed *Isochrysis*, T-ISO, SK3 and CC. Larvae over 150 mm are fed additional species including 3H and CHGRA.

In 1996, the first spawning of geoducks occurred on March 14 with a second spawning March 20, a third spawning April 4, and a fourth spawning on April 18. In 1997, the first spawning occurred February 7 with additional spawning on February 13. Eggs measured 75 mm.

Following the 1996 spawning, we observed that straight-hinge larvae, reared at 16° to 17°C, were purplish in color by 24 hours of age. They reached a size of 125 mm by March 23, 10 days later. The 1996 cultures were from a mixed spawn and it was difficult to determine the exact sequence of rearing sizes. On March 29 the larvae ranged in size from 100 to 190 mm and were reddish-brown in color. Shells were thin and easily broken. Larvae of 15 mm can squeeze through an 88 mm screen. Larvae are siphoned onto screens with water above the screen to avoid direct impact of the larvae against the screen. By April 10, 1996 some of the larvae reached 350 mm and were crawling. By April 13, all larvae reached 350 mm, On April 15, 1.5 million were transferred to an upwell/downwell system as shown in Figure 1.

During the rearing, some erosion of the cilia by bacteria was noted. Clean food is very important; food can be a source of contamination. Feeding was heavier than recommended by WDF&W biologists and often exceeded 25,000 cells per ml. Larvae that went to the bottom were not recoverable due to contamination from detritus and assorted bacteria.

Setting of Geoduck Larvae

Juveniles are pedal palp feeders, according to the literature. Experiments with downwellers and upwellers indicate that setting in downwellers results in high survival through metamorphosis. A substrate of sand and ground oyster shell is an effective medium for juveniles up to 5 mm.

At the WDFW hatchery in Brinnon, the nursery was designed for over/under flow that provided interstitial flow in the sand to prevent loss of oxygen. The 12 ft x 80 ft raceways used for rearing the juvenile geoducks required large quantities of sand and gravel. Food for this system was taken from the lagoon at the station. In addition, algae was reared in the hatchery. The system was highly successful and produced over 6 million clams in 1987. Harvest of the clams in this system required large equipment: fish pumps for removal of the clams, and sand and dump trucks to remove the sand. Seed was held in upwellers for up to two days after harvest (separation from the sand).

At the Lummi Hatchery we have had good success without using any substrate while employing other principles of the WDFW grow-out operation. Flow was applied both to the bottom of the cylinder with a small aquarium pump at 475 gph and by airlift to the top of the cylinder to give maximum circulation and cleaning (Figure 2). The design was intended to reduce dependence on substrate for rearing. Setting without substrate goes very well in the downwell mode of the upwell/downwell box. In 1996 we grew clams to 10 mm+ in this system. We began to experience mortalities due to warm weather in late June when pond temperatures reach 23°C.

The rearing success of juveniles raised in plastic and paper tubes (4 in. to 6 in.) and under netting has ranged up to 80% using larger seed classes. We have some indication that small seed (2 to 10 mm) can also be placed in tubes with net covers with good success and seed as small as 1 mm have been successfully planted in tubes with net covers. If these smaller sizes prove viable, the cost of hatchery seed will be reasonable and geoduck farming will become a reality. Even if seed priced at $0.25 each suffer 90% mortality, the seed cost per adult animal is only $2.50 compared to an average final market value ranging from $7.50 for a 1.5 lb. animal to about $15 for a 3 lb. animal. Seed that is reared to 15 to 20 mm will cost more and still be subject to some mortalities.

Currently, hatcheries can grow seed of 2 to 10 mm with good success. However, some hatcheries don't have the facilities to grow seed to a larger size which growers may prefer. A secondary grow-out system would be needed to produce larger seed.

Configurations for grow-out nurseries include sand-filled swimming pools, sink floats, lantern nets, and floating upwell boxes (with or without sand). Using these methods, juveniles can be grown to much larger sizes, increasing planting success. However, as stated before, seed costs will increase substantially as the size of the seed increases.

Demand for geoduck seed has increased dramatically with the success in culturing geoducks intertidally. The potential for a large and highly valuable industry is just around the corner, but requires seed to be successful. Present hatchery production is far below volumes needed to meet demand.

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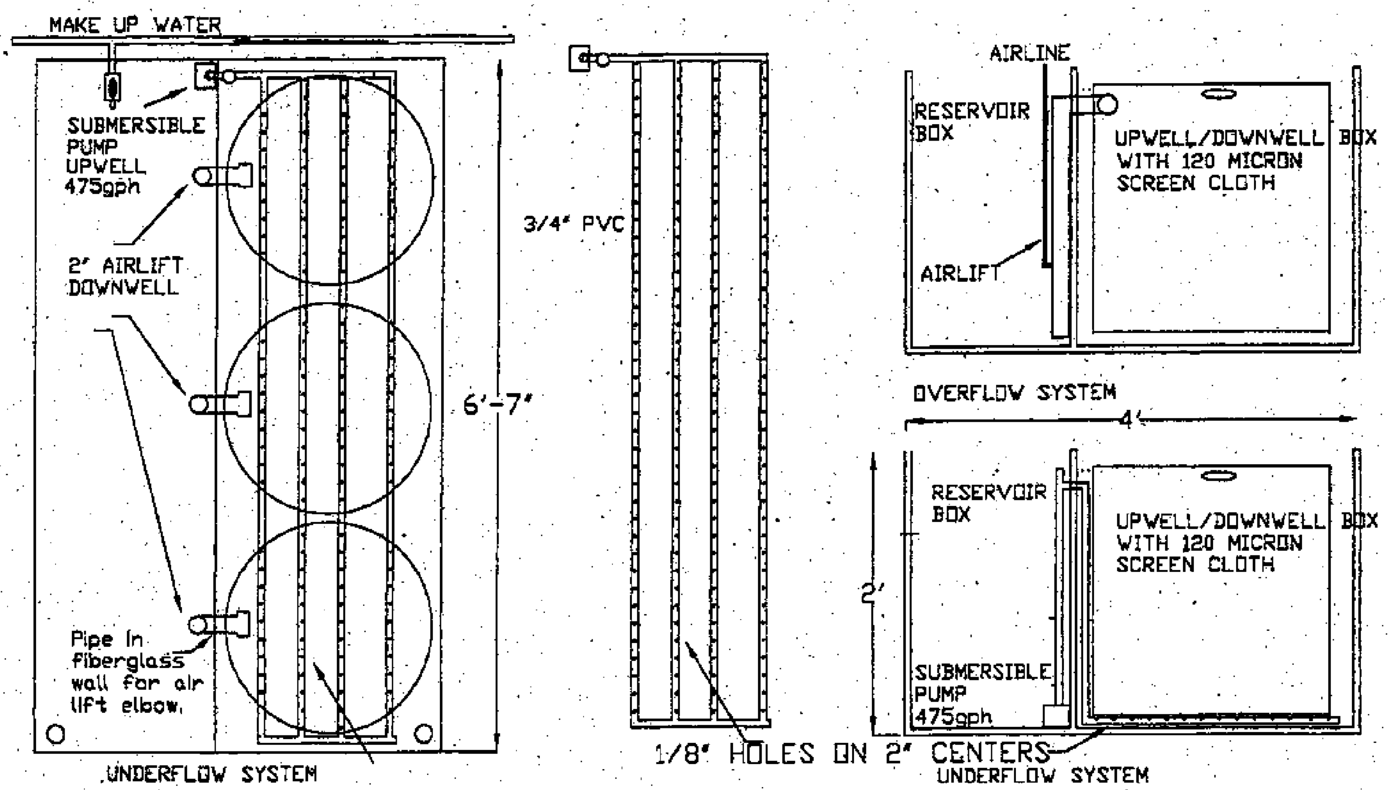

Figure 2. Fiberglass rearing box for geoduck clams 4-10 mm with over/under circulation.

Geoduck Planting and Grow-Out Trials

Brian Phipps, Taylor Shellfish Farms, Shelton, Washington

At Taylor Resources we have been commercially planting and harvesting geoduck clams for five years this October (1996). We receive the seed from the Taylor Hatchery when it is 3 to 6 mm in size. So far we have found that smaller seed seem to dig in a little faster than larger seed.

Car Cover Method

After we receive the seed from the hatchery we have two methods of planting. One is with car cover and the other is with tubes. Car cover is the fastest way to plant geoducks. There are different sizes of car cover that you can use: 1/4 in., 1/2 in., and 3/4 in. mesh. To plant seed and use car cover, we trench ditches 6 inches deep around the edges of the net. After making the trench we rake the ground to create little furrows. This helps get any leftover crabs and makes little valleys for the seed to settle into.

For 1/4-inch mesh or larger, you can lay mesh down, bury the edges, then plant the seed straight through the net. For smaller than 1/4-inch mesh, you have to lay the animals down first, then carefully pull the net over them and bury the edges.

We experienced several problems with car cover. If you plant on a windy day, the animals may be blown onto a section of the cultivated area. This results in too many animals in one area and they will not grow as fast as you want them to. Netting also rips in really bad weather. Another time, we had geoduck necks get caught in the netting and the constant pull actually pulled them out of the ground. Survival using car cover has been hit and miss. Sometimes we plant and get good survival. Other times we plant and get lousy survival.

Planting with Tubes

The next method of planting is with tubes. Tubes are time-consuming. You have to individually cut your pipe into 9- to 10-inch lengths and push them into the ground. They are pushed about 7 in. deep so that 2 in. of the tube are above ground. We plant 43,560 tubes per acre; each tube is planted with three to five animals depending on tidal level. After the animals are put into the tubes, a mesh is placed over the top of each tube to keep out predators such as crabs, moon snails, fish and anything else. Tubes take a lot of man hours to cut, store, and install, but are the most successful way of planting we have found so far.

Harvesting

Now, you may ask, how are we going to harvest? We have tried two methods. One is by digging with a shovel and the second is by using a pump. Using a shovel is time-consuming, plus you break a significant amount of geoducks this way. You also leave a big hole in the ground that takes time to fill back in. In addition, you cannot replant the ground until the holes have been completely filled.

The second way to harvest is by pumping water to liquefy the sand and break the suction of the geoduck. Then you can pull them right out of the ground with little or no breakage. After harvesting with the pump, we have found that we can re-seed the ground sooner. The pump also cleans the ground of unwanted material such as oyster shells and debris.

At Taylor Shellfish Farms, our goals for 1997 are to plant 2 million seed and to harvest 12,000 lbs. But by the year 2000, we hope to harvest 2.5 million lbs.

Planting Experiment at Dahman's Shellfish Co.

Don Dahman, Dahman's Shellfish Co., Shelton, Washington

Last summer, our company planted 11,000 geoduck seed clams. We punched holes in the sand with a steel rod and dropped one clam into each hole. The density was one animal per square foot. It sounds simple enough, but it took nine of us two days to complete the plant. The only immediate problem observed in the area was moon snails. We haven't had a chance to assess the outcome yet, but it looks promising from casual observations.

We bought broodstock to condition, spawn and produce larvae. This experience taught us the following:

- Collecting enough females is a major problem. We bought a total of 200 animals for broodstock and found that only 11 were females.
- Geoducks are dribble spawners.
- Larval rearing and setting are currently inconsistent.
- Feeding larvae the proper amount of food is critical. If you over-feed the larvae, they will die. Keep algae cell densities on the low side.
- Geoduck necks don't always "show" on the grounds during February and March. Apparently, many of the geoducks retract their necks during this period and will not "show" again until April or May. The time period seems to depend on the area.

Geoduck culture provides an opportunity for existing shellfish farms to expand and diversify operations. Geoduck culture also allows the use of marginal areas unsuitable for farming oysters and clams. However, growers must be patient and consider that it will take four to five years to produce a crop.

Overcoming Political Resistance

Eric Gant, Fan Seafoods Ltd., Courtney, British Columbia, Canada

When I consider all of the factors that have reduced my productivity over the years, both as a fisher and as an aquaculturist, the one factor that stands out is political resistance. The resistance to our project in Canada came from individuals within four basic groups—government, industry, natives and environmentalists. This resistance can be broken down into three basic types—the reasonable, the neurotic and the corrupt.

In such a short presentation it is not possible to provide a comprehensive description of all the ways we use to overcome the political resistance to our operation. But the following will give you some insight.

We dealt with the legitimate concerns of the environmentalists by targeting natural beds for reseeding that, as fishers, we knew had been mined down over the years because of mismanagement by the Department of Fisheries and Oceans (DFO). We are seeding these beds only to a density that we think is the same as the original natural density. We are also seeding a permanent fringe around the working area of each site which will add to the natural spawning biomass. We are leaving a large buffer zone between the beds, and are trying to fit into the natural ecology of the sites. For example, we don't trap away the predators. Whenever we can't be invisible to the eye, we try to be pleasing to the eye. We have refused to be politically pressured into accepting small sites on the grounds that we can't be environmentally sound and financially feasible unless we have enough area. We've spent a great deal of time, money and energy responding to legitimate environmental concerns. Then we proceeded with our work regardless of the remaining resistance.

Fishers have three legitimate concerns. The first is over the limited amount of coastal area. We are dealing with this concern by helping the fishers move from a fishery based upon the "guesstimation" of natural recruitment to a culture-based fishery which requires less area for them to become more productive. The second concern is what to do about residual natural stocks on prospective aquacultural sites as they are rolled out of the common resource and into private tenure. We have resolved this by relinquishing any claim to the residual natural stocks. In addition, we have recommended that the fishers' association be allowed to purge-fish these stocks through a low-bid process outside the regular management plan of the fishery. We have also recommended that profits from the purge fishing go into a generic fund to deal with problems that are common both to aquaculture and to culture-based fisheries, such as how to cooperatively market the increased amount of stocks, which is the third concern of fishers.

Of course we ran into problems putting these solutions into place. Opposition came from some of the fishers who wanted to maintain their monopoly over world supply and from some individuals within DFO who wanted to perpetuate their own mindset and existence at the expense of the whole. Simple exposure of individual corruption has proven to be an effective tactic in dealing with these people. This requires working from within for extended periods of time in order to properly define the various forms of neuroses and corruption that exist within their organizations. Money can also be an effective tool when used properly, not only when dealing with the corrupt but also with the neurotic.

The most effective approach we've found in dealing with political resistance is, first of all, to realistically define the type of resistance you are encountering. Do this before you decide upon your response. Reasonable resistance should be welcomed into your perception as an opportunity to improve upon your operation. Neurotic and corrupt resistance deserves to be dealt with ruthlessly, regardless of the status or capability of individuals causing the problem.

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