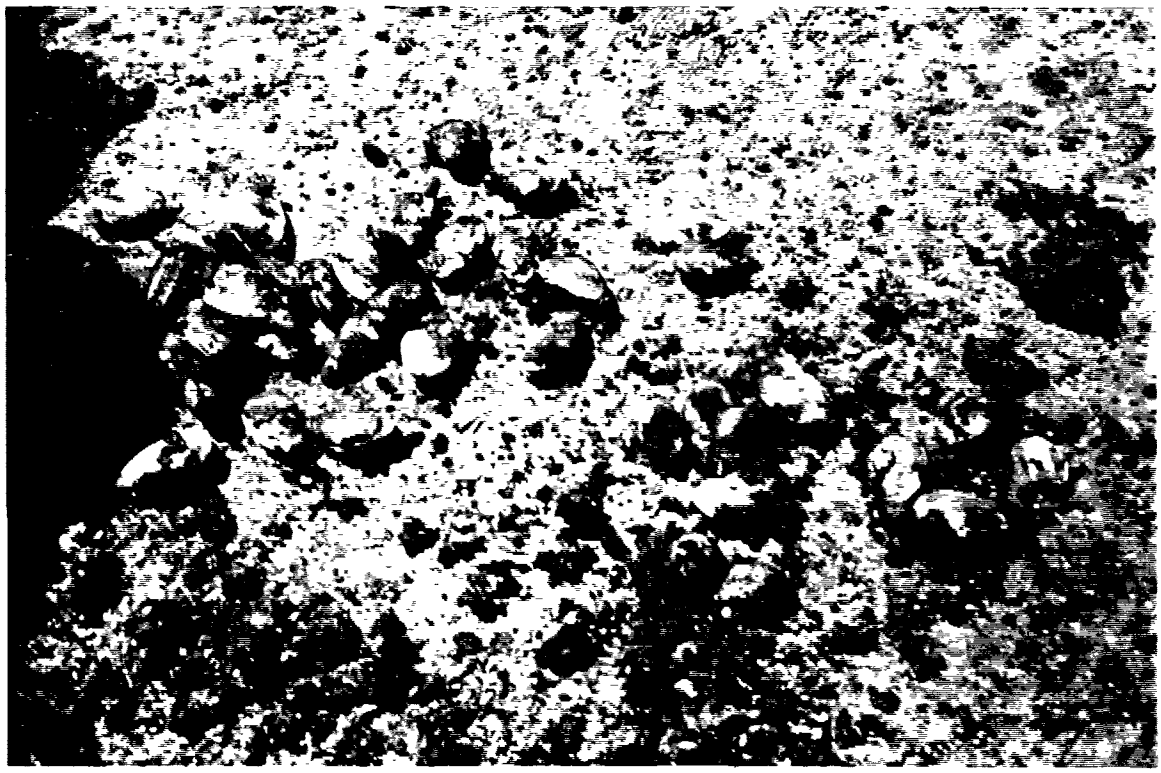
Aquaculture and Management of the Soft-Shell Clam *Mya arenaria*.



H.K. Rask, January 1999.

Massachusetts Department of Food and Agriculture Technical Report
100 Cambridge St., Boston, MA 02202

This is a manual describing aquacultural methods that can be used for the large scale culture and management of soft-shell clams (Mya arenaria). The same methods can be used either in the private sector or for municipal management purposes. This manual is based on many years of trial and error experimentation in different locations in Maine and Massachusetts. The methods are based on the biology and behavior of clam larvae and the newly set seed, which can be caught and protected with aquaculture netting, if siting is done properly. Seed can be grown on the site, or transplanted in a different area for final growout. The project was funded by the Massachusetts Department of Food and Agriculture, 100 Cambridge St., Boston, MA.

Biology

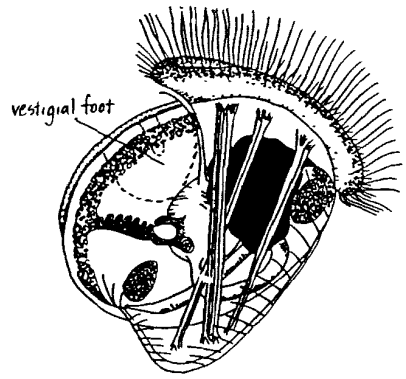
Clams spawn in early spring when water temperatures rise. The actual time of spawning will vary, since clams high up in the tide zone will warm up faster than those in a subtidal area. Thus, spawning can occur for an extended time within a given harbor or river system. This provides for a steady supply of larvae during the summer. In some cases, setting seems to continue throughout the summer until September.

Clam larvae are planktonic, and will drift around for about two weeks prior to setting. Larvae are moved by currents and tides, but can also swim. Swimming is generally up or down, bringing the larva either into or out of the current. As larvae prepare to set, they actively react to certain environmental conditions. For example, the larva has the ability to dig in and set if the conditions are right, as well as swim along hoping for a better site. Even small clams can continue to move for a few weeks after they have set. Once the clams have set in their permanent location, however, they do not move again unless transplanted. The clam may live a few inches below the surface, and in some cases, as much as 18" down. Clams mature in two years, and are harvestable in two to three years, depending on their density.

This approach to clam culture is based on the behavior of the larvae at setting, with the focus on creating a habitat the provides for good survival and growth of the small clams after they set. This includes both sediment improvement and predator control. The methods were developed from many observations, over several years in many different locations. The procedure involves managing an environment which favors clams over other species at all phases of their life cycle. This means providing a site conducive to setting, as well as managing the site afterwards to provide for good growth and survival.

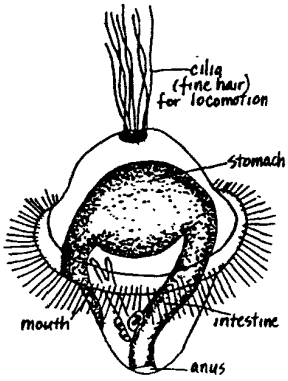
The Life Cycle of the Clam

EARLY VELIGER

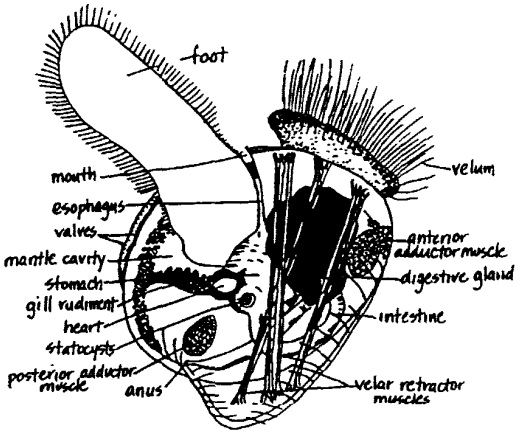


24 to 26 Hours

2 to 10 Days at 70°F



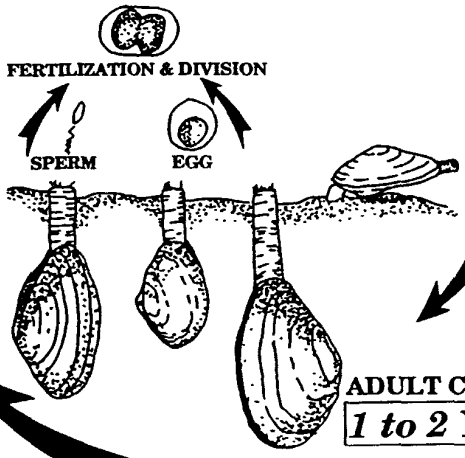
TROCHOPHORE



LATE PEDOVELIGER

Metamorphosis

6 to 12 Hours

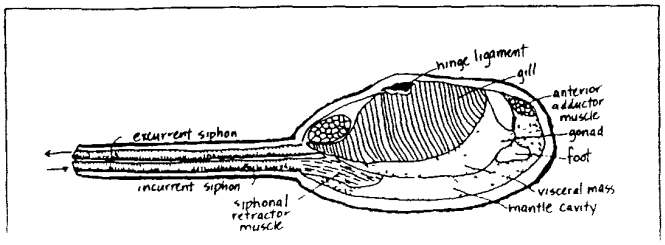


JUVENILE CLAM

ADULT CLAMS

1 to 2 Years

Start here



Clam management

Clams have been studied and managed for well over 100 years, since they have always been an important resource in coastal towns. Many things have been tried, such as plowing the flats with oxen (1898), harrowing the flats, hydraulic cultivation of the flats to improve sediment quality, harvesting seed with a seed harvester for later transplanting, and using netting to protect the clams from crabs and other predators. All of these methods work to some extent, but require labor.

Until the recent development of private aquaculture it was very difficult for one or two people (usually shellfish wardens or researchers) to put in the labor needed to successfully manage a town wide aquaculture experiment. The testing of different methods was almost always done by enterprising shellfish wardens, especially in Maine and Massachusetts, with excellent success considering the limited manpower available. Truly large scale projects, in which hundreds of acres are intensively managed, can rarely be done by a small number of people in a municipal setting. Private aquaculture, however, has set the stage for this to occur. In some towns there are close to 100 people working privately licensed grounds, every day. The income from these areas can exceed the total landed value from the wild fishery, and is the result of a level of management that would be impossible for one person (often a part-time shellfish warden with several dozen other responsibilities) to do alone. If the labor can be found, the methods can be used on a town wide level, with or without the presence of private aquaculture licensing.

Although clams can be grown in a hatchery, using standard hatchery methods, the methods described below are focused on catching and managing naturally occuring sets. These methods are low cost, effective, and easily replicated. Hatchery seed, if purchased, can be handled in the same manner, but adds additional costs and may not be necessary if natural sets can be caught.

Methods

Clams can be caught to some extent simply by putting out a flat net in a good area. This works if the area is already a reasonably good setting area, since the seed is likely to set in the vicinity anyway. The netting in this case serves to protect the seed from small crabs and other predators. This is the lowest cost option, but is not always effective. Note that nets are standard equipment for shellfish farmers, and methods for installing and maintaining them have been worked out. Nets are usually dug in about 4-6" around the edge, and held down with lengths of rebar before being backfilled. Flat nets must be watched for accumulations of sand, which can bury the net and kill the crop, especially in an active or exposed area.

Figure 2. Flat net, 25' x 100', Eastham, MA. This net has not been dug in (notice edge of net on surface), but is held in place with 10' lengths of 1/2" rebar, overlapped 4" at each joint. These are held down with 12" rebar U-hooks (a 24" piece of 1/4 round bent into a U, and used as a staple). U-hooks are set approximately every 3'.

An improvement over a flat net is to raise the net a few inches off the bottom, either with a frame or with a series of small floats tied to the net every 6' (Figures 3 and 4). For floats, small lengths were cut from 6' styrofoam "Fun Noodles", and attached to the net with heavy duty cable ties. The floats were the least expensive method, since an entire net can be held up for less than $5.00. They are also light, and easy to carry.

Methods for raising the netting were developed first because the flat nets were burying under shifting sands. When this occurs, the sand must be swept or shoveled off the net, in order that the crop underneath does not get smothered.

Frames can be made from PVC or bent rebar, and serve to hold the net 2"-10" off the bottom. PVC Frames with 90 degree elbows are easy to put together and hold up adequately in calm areas. These do not hold up in faster currents, however, where rebar is generally used. Raising the nets prevents crabs from reaching through the net to get at the small seed, and also serves to trap quite a bit of new sand, since the raised nets act like a snow fence, catching sand otherwise being moved by currents. These raised nets, in effect, create small artificial sand bars,

made of clean coarse sand, perfect for clam seed. Flat nets can also do this, but often bury if they become too effective. The size of the netting is also important, since a smaller mesh will catch more sand, and also more seed. Smaller meshes, however, also foul faster, and will reduce current flow.

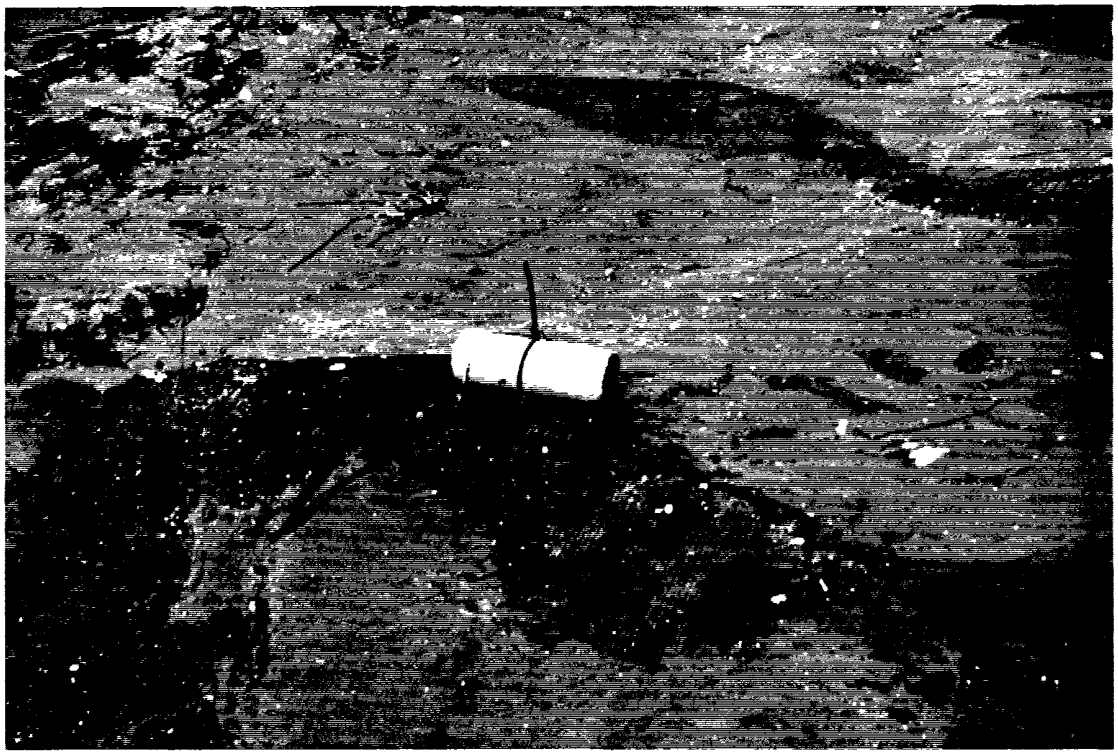


Figure 3. Styrofoam float attached to net using cable tie. Float is about 5" long, spaced at 6' intervals. Note the new sand burying this portion of the net, even with flotation.

Although hatchery seed is available, the cost is generally around $5.00-8.00/1000, depending on size. Hatchery seed does "just as well" when transplanted (there is still a loss), but the initial cost is much higher than the equipment used to catch the natural sets, and the seed is generally smaller. Further, some areas catch such a set that thinning is needed, with densities under the nets over 2000 per square foot. The supply of seed in these areas is not the limiting factor in production, and these sites could be used as a seed source for neighboring areas in the town. Our materials consistantly catch natural sets and allow for the accurate measure of seed clams. Clams are then thinned and transplanted at appropriate planting densities.

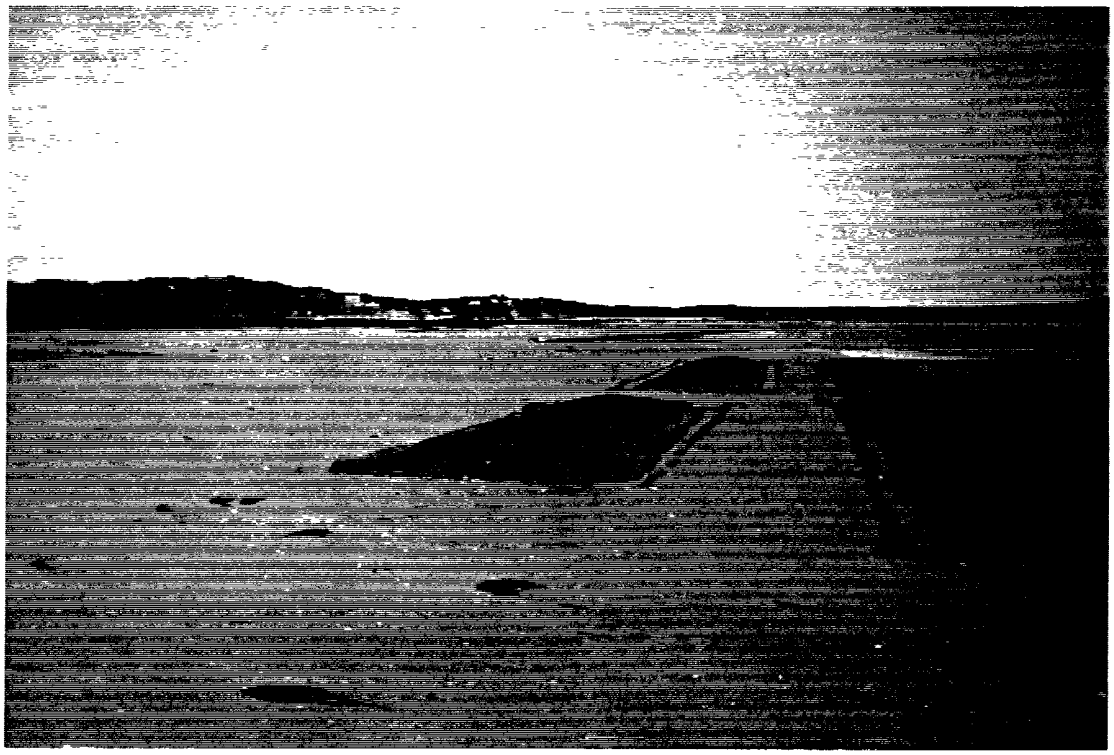


Figure 4. "Clam Tents", Wellfleet, MA. Nets are run with the current, and are held 8-10" up. Frame pieces are 3-4' apart. Similarly designed hardware exists for nursery row covers used for the overwintering of perennial plants. Nets held cross-current tend to catch more sand, silt, and floating debris. Strong currents can also cause chafing of the net on the frame.

Clams can be caught using any number of netting materials commonly used in aquaculture, as well as in trays, cages, and other containers, with or without sand in them. The nets are set out in late April and May, and can still catch a set in June. The netting serves to slow down water movement, catch drifting sand, as well as protect the newly set clams from predation. Floating wooden trays lined with window screen, and floating or raised boxes fill with clean sand will also catch natural sets. These cost more to make and maintain, but can be used to test an area on a small scale.

Of all the netting materials used, a black woven 1/6" mesh Aquanet (Cissel Mfg Co. Lakewood, NJ) proved to be the best. Clams were also caught under most other netting types (3/8" Tenax, and 1/2" polypropylene bird net), but there is a distinction between enhanced setting, and enhanced survival of normal setting rates, caused simply by protecting the clams from predators. These are two different things. Many areas would not catch a single clam unless netting was used, other areas get a reasonable set which is later attacked by predators and does not amount to much.

The woven net is a smaller mesh size than is normally used for hard clam culture, is very strong, does not tear easily, holds up to debris and abrasion caused by extreme currents, and curiously, has less fouling problems than larger mesh size netting made from nylon (mono) instead of polypropylene. Larger mesh size (1") does not provide the same amount of hydraulic resistance, and is used the second year to protect transplanted stock.

Figure 5. Clam production in Barnstable Harbor, MA, approx. 40/ft. Netting is 3/8" Tenax.

After working with various types of nets for several years, it became apparent that the problem was not always in catching the set, but in growing it out at the right densities. Successful sets often produced several hundred clams per square foot, and often well over 2000 per foot. These numbers are not supportable to adult size. Generally, a site will accomodate 25-50 adult clams per foot. depending upon the number of smaller seed clams present. Clams needed to be thinned to approximate these densities. Overcrowding causes not only slower growth, but often death, decay, and the destruction of an entire area because of resultant anoxia. Areas receiving only a "light" set are often preferable, since clams will grow faster, and there are no thinning problems.

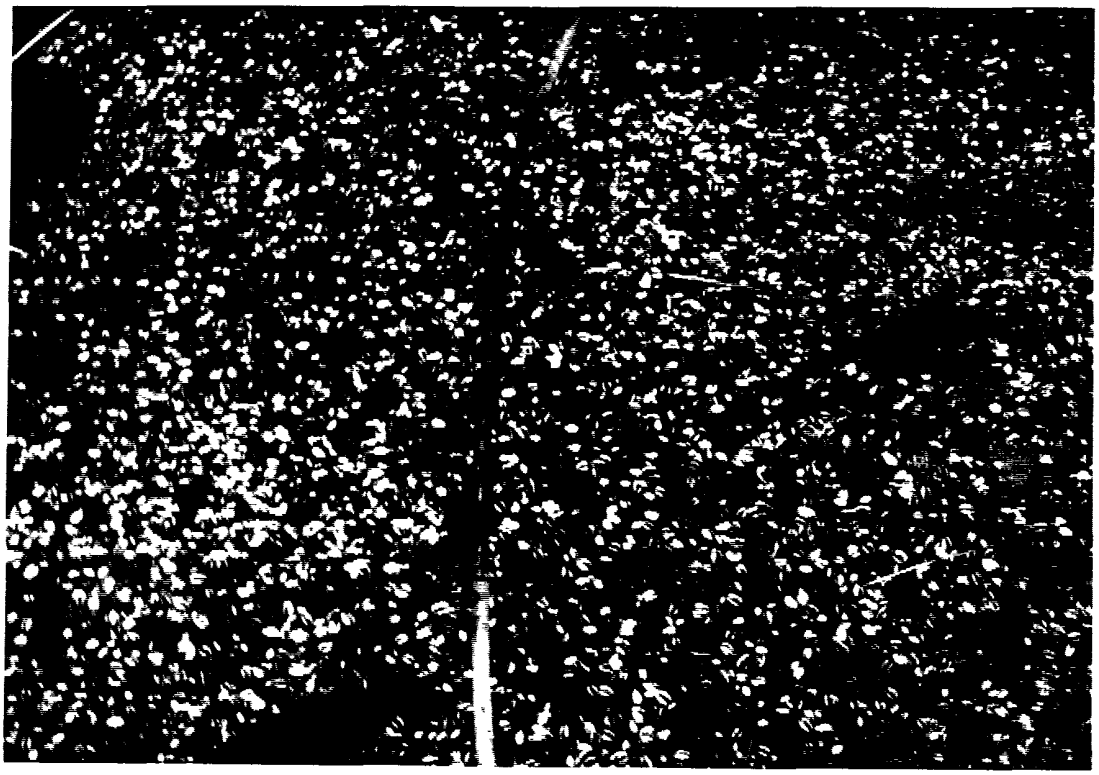


Figure 6. Heavy set of seed clams washed to the surface under a raised net. Much of this is dead shell. Live densities still exceeded 500/square foot, and the site must be thinned to provide for the best growth. Overcrowded sites show slow growth.

In many instances, clams were thinned to about 20 per square foot, and then the area caught another set on top of the larger clams the following year. A heavy set on top of an existing set significantly slows growth of the larger clams, even though the smaller seed will still grow very fast.

Thinning

Several methods described above have consistantly been successful in catching a set, including a flat net directly on the bottom, a flat net with small floats attached to keep the net slightly elevated, and nets supported by rebar or PVC framing to keep them up off the bottom. These are the most cost effective methods. Many nets can be made in advance, and quickly set up. However, in a good year, several hundred to well over 1000 seed per square foot can be caught. These will not do well unless thinned.

The thinning problem was solved by the using mesh bottom nursery trays under the nets. The trays were used because elevated nets alone caught such a set that thinning and reduced growth was a problem. The trays can easily be picked up and moved. The trays have also been used successfully for the nursery culture of hatchery seed, as well as oysters.

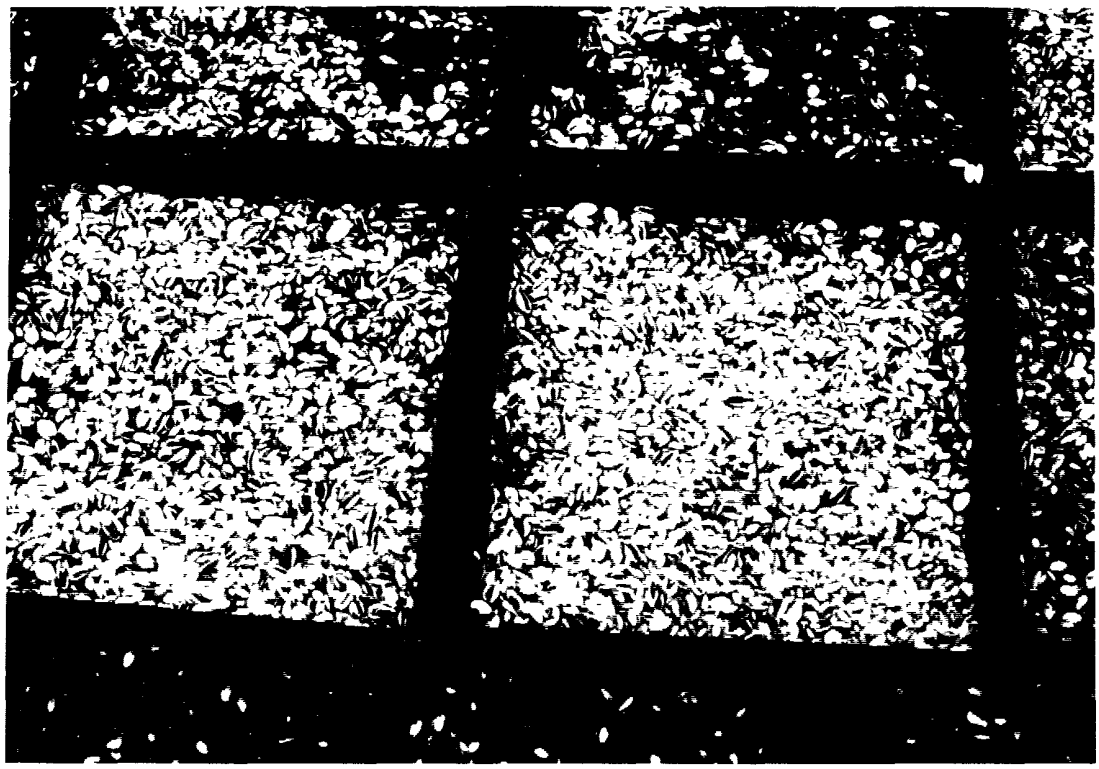


Figure 7. Polyethylene nursery trays filled with clam seed.
Traps were made using polyethylene nursery trays (15" square, 5" deep, with 1/4" mesh on the bottom, available from Anderson Die Mfg, Portland, OR). Trays have a mesh bottom, which allows sediment to be sifted out, while retaining the seed.

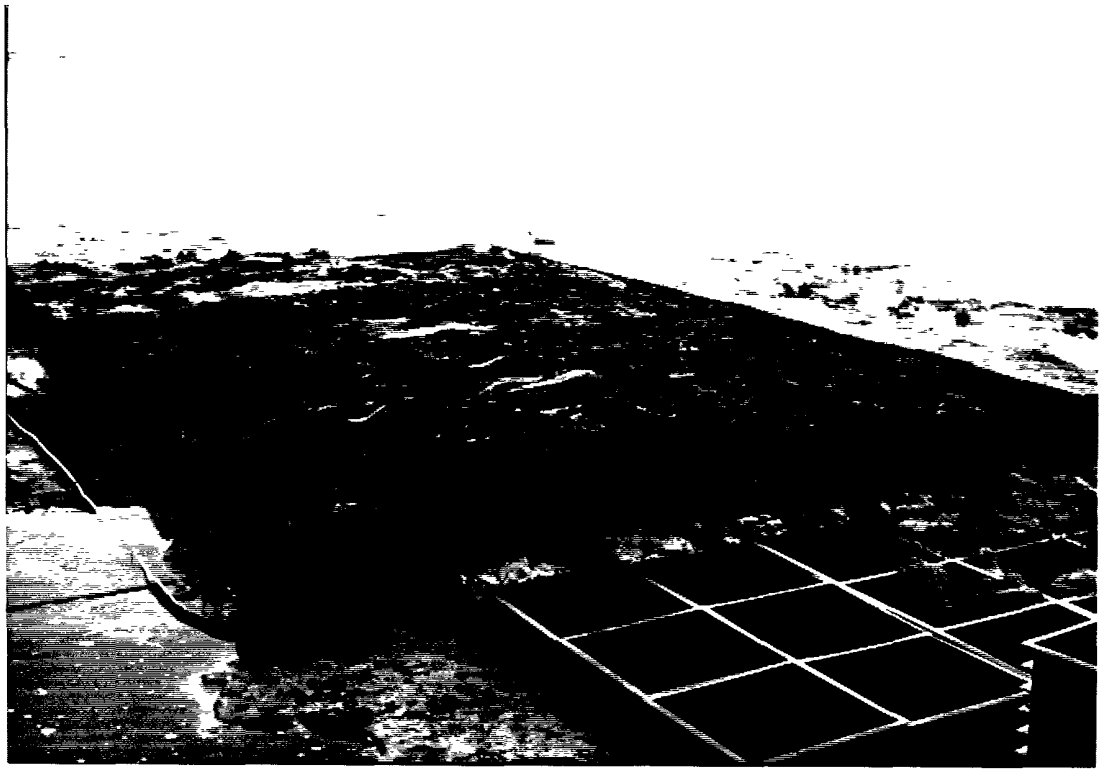


Figure 8. Use of tray system in setting up clam tent.

About 250 trays are set out directly on the bottom, and filled with (on-site) sand shoveled into them. Any predators found during this process are removed from the site. Trays are set in 35 rows of 7 across. A 50'x 12' piece of netting is pulled over the assembly, the entire edge of the net being put into a trench about 6" deep, and anchored with rebar U-hook staples (1/4" round, 24" pieces bent double to form a U). The entire perimeter of the net must be securely held, not only to hold the net, but also to keep out crabs and other predators. The entire set takes about two hours to install with two or three people. The site is checked the next day and again the day after to ensure that the net is stable and that currents have not moved sand away from or on top of the new net. Since the trap is a slightly raised obstacle, it is vulnerable to wave action and strong currents. Sand usually settles into the net within a few days and stabilizes the entire trap.

Figure 9. Trays are filled with sediment from the site. Netting is brought to the site in a bag, and one end dug in and backfilled. Note the rebar staples used in holding the net. The entire net can then be pulled out of the bag, covering the trays. Both sides are then dug in and backfilled.

Clam seed starts to become visible in late June. If there is a successful catch, seed needs to be thinned in early to mid-July, or overcrowding and resultant death will occur. Densities of over 1000/square foot were normal catch rates, with higher and lower setting often seen. The setting density problem is compounded because the set often takes place over an extended period of time during the early summer. This is because clams spawn at different times based on the temperature at their location: clams in deeper water will most likely spawn later than those very high up on the flats. In late summer, all sizes of seed can be found under the nets, ranging from 2 mm to 30 mm.

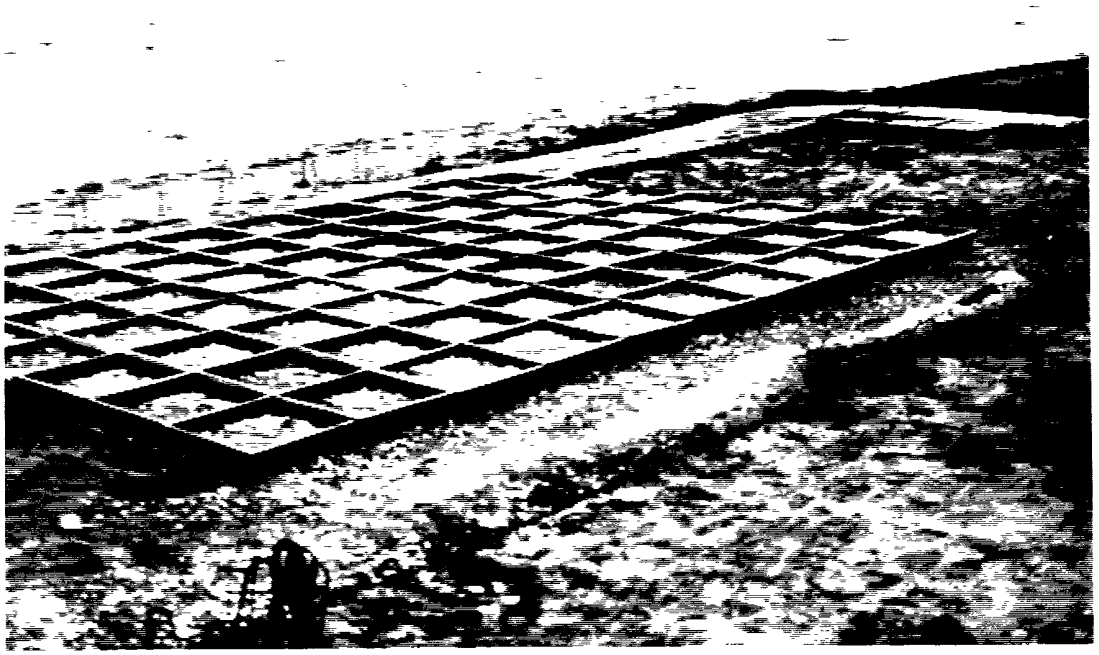


Figure 10. Clam seed in trap after top net has been removed. Seed can be counted and thinned simply by picking up the trays and replanting them accordingly. This site provided enough seed for four additional 12x50' runs when transplanted. Note seed along edge of net as well as in trays (see Fig. 11).

Clam seed is counted, and replanted as soon as it becomes noticably abundant. This is generally at the 8-12 mm size. Seed is replanted at about 100 per square foot, allowing for transplant losses and predation, hoping for a 50% survival rate. Although some of these clams will be ready to harvest the following year, the following year's set can also land on top of this crop, resulting in another batch of seed. These are transplanted when the adults are harvested.

Figure 11. Clam seed in trap after trays have been removed and transplanted. These clams set between the trays and the edge of the net. This net is simply pulled back into its original position, and stapled back down (after trays have been removed).

Seed is transplanted directly onto new ground that has been scarified with a garden rake or shellfishing tools. Smaller clams (under 30 mm) dig in immediately as they are covered by the rising tide, with an almost complete success rate. Larger clams, closer to harvestable size, often have trouble digging in, and survival rates are much lower. The seed is covered with 1/2" aquaculture netting immediately, which is trenched and anchored around the perimeter as described above. This is especially important during the transplant phase as predation can be ferocious. As long as the seed is growing in the nursery trays, predation is limited since the trays themselves prevent much predator movement. For example, if a crab gets under the net and into a tray, it generally stays in that one 15" square.

The seed under normal conditions will dig in on the first rising tide. New growth can be seen within two weeks. The type of netting used depends on the degree of exposure and extent of predation. In some locations, crabs are the primary problem, in others, many clams are lost to ducks and geese puddling on top of the run. Again, the transplanted seed does not have to be moved to an area close to where it was caught. Many excellent growing areas exist, that simply would not catch a natural set. In some cases, this might be due to the lack of adult broodstock in the area.

Figure 12. Transplanting. Trays are washed free of sediment and counted. Trays are carried by hand to an adjacent bed that has been hand raked free of predators. Trays are dumped out onto the new area, and hand raked smooth. Target planting densities are 100 per square foot (generally one tray of 900 seed per yard). Area is then covered with netting. Original net is put back into place.

As the clams grow the following year, they often catch an additional set in the season immediately prior to harvest. This causes many more clams to be present than were initially planted. Such high densities reduce growth rates, but in extreme conditions can cause mortalities in clams smothered by those above them. If this happens, worms and other scavengers move into the site. Such an area must either be renovated or allowed to be fallow prior to replanting. Generally, the turnover caused by harvesting will accomplish this. Hydraulic harvesting definitely will, since the sediments are washed free of mud and organic matter. In either case, bed rotation could be an option to consider if sediment quality is questionable. Although seed is caught on "new" ground, previously devoid of shellfish, large crops of clams often create their own environment by attracting predators and detritivores. Populations of worms and other invertebrates often move into the clam beds. Some growers prepare their seed beds by hydraulically pumping the ground to clean it prior to planting. This aerates the sediment, and can improve the sediment quality for setting. Crop rotation is used for agricultural crops for exactly the same reasons.

Siting

Clam setting is influenced by a number of factors, any of which can alter the effectiveness of the traps. Clam larvae are planktonic, and are moved around by winds and tides. At the same time, the larvae will actively seek a suitable place to set. The larvae can swim, crawl, test out a possible setting location and then move; the larvae can even move several times before finally choosing a permanent location. Larvae are sensitive to sediment grain size, currents, bottom chemistry, the presence of other clams, as well as predators and anoxic muds.

The initial siting of clam nets is key to success. Although the nets promote setting, in addition to protecting the newly set seed from predators such as crabs and moon snails, some locations do not catch a set at all. Many sites are obviously good, due to the presence of multiple year classes of clams. Others may not set at all unless nets are used because of predators. These are excellent setting areas, but survival of the seed is very low because of predators. Other sites may not set because of current velocity, tidal height, sediments, or some other reason. Some locations do not catch a set, ever, with or without netting or any other method.

One goal of these test plot experiments was to be able to go into a new area, evaluate it by walking the site, and set the plots accordingly based on information from other sites. This was not always successful in terms of catching a set, but always valuable in terms of learning something new. In most cases, the best success rate was found in areas quite high up in the tide line, near the edge of the grass, or within about 12" of this elevation. A 12" elevation difference can mean hundreds of feet away from the grass, but this tidal height was consistantly better than lower areas in the same vicinity. This is noted only as an observation, since clams were also caught in all types of locations. Also, some areas seemed ideal for clams, had a long history of productivity, but were currently barren. These areas had been fished out, had not seen a natural set in years, and obviously did not have much if any remaining broodstock. Traps in some of these sites performed miserably, with next to nothing in them. Transplanted shellfish, however, grew well once moved to these areas. These sites are of interest, since the lack of setting could be due to a number of different reasons, one of which being that the area simply did not get a good set in the year the traps were put out. One year of data is inadequate in terms of concluding that the area isn't a good setting area; some areas only get a good set one year out of five, but still repopulate with clams. The lack of adequate adult broodstock and a number of other theories have been discussed for about 100 years, and are well summarized in Belding (1930).

Economics

This method is a very low cost way to grow clams if a suitable site has been located. The only costs are the initial purchase of netting and hardware. If the site can be proven to be a good setting area, with subsequent acceptable growth and survival rates, then additional expenditures are justified. The method as well as the site suitability can be evaluated for about $200-600/50'plot, with a normal depreciation rate of three years on equipment, 2 years on netting. The use of the nursery trays is only justified if thinning or moving the seed is intended. The trays add the extra cost, as well as additional labor, but more than pay for themselves if there is a heavy set to move. In any case, small scale test plots can quickly and inexpensively be set out.

Initial startup costs are much lower than for other species commonly grown in aquaculture, since the site can be evaluated without losing thousands of dollars on seed that does not survive. No hatchery seed is required, and cash flow in the business is generally better. Maintenance is substantially less than it is for hard clams or other crops, since the growing areas are generally higher up in the tide zone and fouling on the netting is reduced by the increased amount of air exposure.

Figure 14. Netting covering second year crop. Note green and brown algal growth. This amount of fouling is normal, and does not significantly reduce water flow. Subtidal nets, however, can become completely covered.

The costs of one 12x50' trap, including nursery trays is about $600, including hourly labor. Costs are itemized below. Note that all materials are usable for at least two seasons. with the nursery trays having a 3-5 year usable life span.

Netting: (1/6", woven polypropylene, 12'x 50'	$ 65
Rebar staples (1/4" round 12" U hooks,100 @0.35	35
Nursery trays (250 @ $1.80)	450
subtotal materials/unit, with trays:	550
subtotal materials/net without trays.	100

Once a site has been identified as a good setting area, the use of the trays may become justified. This could be of interest to towns wishing to expand their clam production area, but which are no longer getting good natural sets in areas known to be historically productive. The use of the $1000 in gear outlined above has caught over 700,000 seed (hatchery value at $8/1000 of $5600). After the seed was moved from the site and transplanted in adjacent beds, the original nets were put back down to protect any seed that remained after transplanting. Harvest of this 50' section alone (after transplanting) yielded about 1000 pounds, and the area still has a heavy crop of seed in it from a subsequent set.

We feel that our original expense for materials, which are still in use, was more than justified simply in the value of the seed produced. However, the primary cost involved is labor in harvesting and thinning. In 1998, test traps were installed in a number of different locations, in cooperation with interested growers and municipalities. The amount of labor required to install the plots and to handle the crop remains low unless there is a crop to work on. If this becomes the case, then the labor inputs are warranted. Adults clams are dug by hand, with a plunger, or hydraulically, with undersize clams transplanted into adjacent flats, also under netting. These transplanted seed tend to grow very fast, since they are in new ground with no other clams or predators present.

Given a method that works, the limiting factor is how to provide for enough labor to make it work on a large scale. This goes back to early experiments with netting done in Maine in the 1950's. Netting was used to protect a good natural set if one was found. Few people ran the numbers to think about what this might mean. For example, one or two dedicated wardens might put out the netting and grow a crop, which could possibly be worth $10,000-20,000. (!) When the crop was ready, forty or so (or more) commercial harvesters would dig the crop (a yield of less than $500/person). This is a fantastic rate of return for the amount of effort on the part of the people putting out the net. When it is divided up between everyone in town, it barely pays for commercial license fees in 1998. However, if forty growers did the same thing on forty different plots, this could bring in about $800,000.

Aquaculture and Management

The methods described here can be used by anyone. For a town to undertake a stock enhancement program, as described here, would be called "management". If a private grower does the same thing, the is "aquaculture". There is a huge difference in the perception of these terms. Growers are managing a small area, using proven methods which could be expanded to a larger scale opportunity if the labor were available. Towns, generally, do not have this level of labor available.

Aquaculture is an economic opportunity in many locations. In towns with privately licensed aquaculture, the landed value of product increases and jobs are created. The towns still have a wild fishery, and there is a minimum of actual conflict. In many areas, however, this is politically not an option. Even without the benefit of private aquaculture licensing, the same methods are still usable if a reliable labor force can be found.

One 50' trap can provide enough seed for several 50' growing runs. If the transplanted clams are protected from predation, survival is generally good (well above 50%). Clams will reach harvestable size in about two years, and can provide a reasonable return for the amount of time and material invested. The limiting factor in doing this on a large scale, however, is labor. Most towns simply do not have the labor or budget available to put out and manage a large number areas. Private aquaculture can accomplish this, since each grower can be fully responsible for their own site, and benefits directly from the product they grow.

On a relatively small scale privately managed area, an annual return of about $15,000 is realistic. Some growers realize a better return through direct marketing. These methods are not only usable, but are already in effect. At the same time, private aquaculture is not a reality in many locations. A system that allows municipalities to use these methods on a large scale without allowing aquaculture licensing seems to be of interest in many towns, although the economic development potential of private licensing is greater. In short, there is opposition to private aquaculture licensing in many areas, regardless of the value of such an industry to residents.

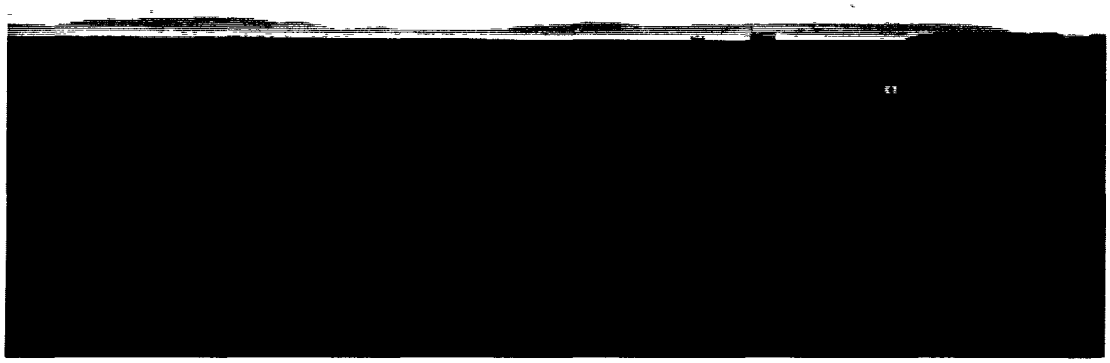


Figure 15a. Approximately 60 acres of previously "unproductive" ground, currently in use for clam culture.

Figure 15b. View of one acre used entirely for soft-shell clams.

Summary

Soft-shell clams seed can consistantly be caught using seed traps placed on suitable grounds. These areas are usually high up in the tide zone, and generally within a one to two foot elevation of the grass line on the edge of the marsh. The traps may be hundreds of feet away from the grass, but the direction of exposure and height on the tide has critical effects on the success of the traps. Small traps can be set out quickly and inexpensively to monitor the suitability of a new site. A wide variability between sites also exists, and sites should be tested on a small scale to determine site characteristics. A site can often be improved by hydraulic pumping or hand digging; both serve to turn over the bottom and increase sediment grain size. Hydraulic gear can be used for harvesting of adults, which also improves the plot for the following year. Seed can also be transplanted using hydraulic seed harvesting equipment developed in Maine.

The nets serve a number of different functions. First, water velocity under the net is decreased, providing larvae a chance to settle out. More importantly, the nets serve to create new sand bars, since sand also drops out of the water column as water velocity slows. This provides clean coarse sand for the new larvae to set in. This clean sand is also devoid of predators, since it just accumulated on the spot. The environment is clean of predators, clean of decomposing organic matter, and ideal for the small seed. If the seed clams do end up under a net, survival is further enhanced by the protective netting which keeps out crabs, moon snails, and birds. The traps not only catch the set, but also enhance the survival of the small seed.

Once a set has been caught, the seed can be counted and thinned. Exceptionally heavy sets can be thinned using small nursery trays designed for plant propagation, but these are not necessary to catch the set. Seed clams can readily be transplanted to another growing area, which does not have to be close to the setting area. This can provide a seed source for areas that would otherwise not catch a set under any circumstances. Hatchery seed can also be used, with good success although the cost is greater.

Also, many concepts for clam management have been discussed or attempted in the past, that fit into the management of either a private area or an entire town. Much can be learned from existing information, especially in Maine and the Maritimes where clams are the primary inshore shellfish product. A more regular discussion between growers and managers throughout the region would be beneficial to all.

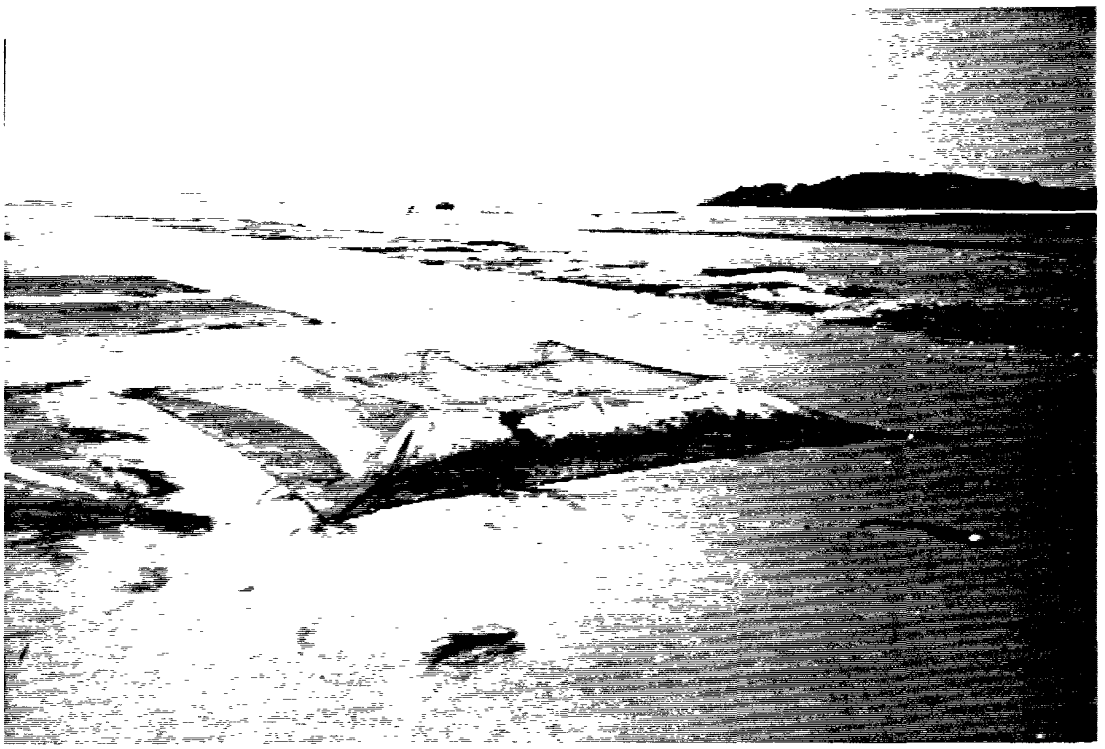


Figure 18. Small scale experimental frame (14x14') using rebar. Note row of netting along inshore edge, which are plots that have already been harvested.

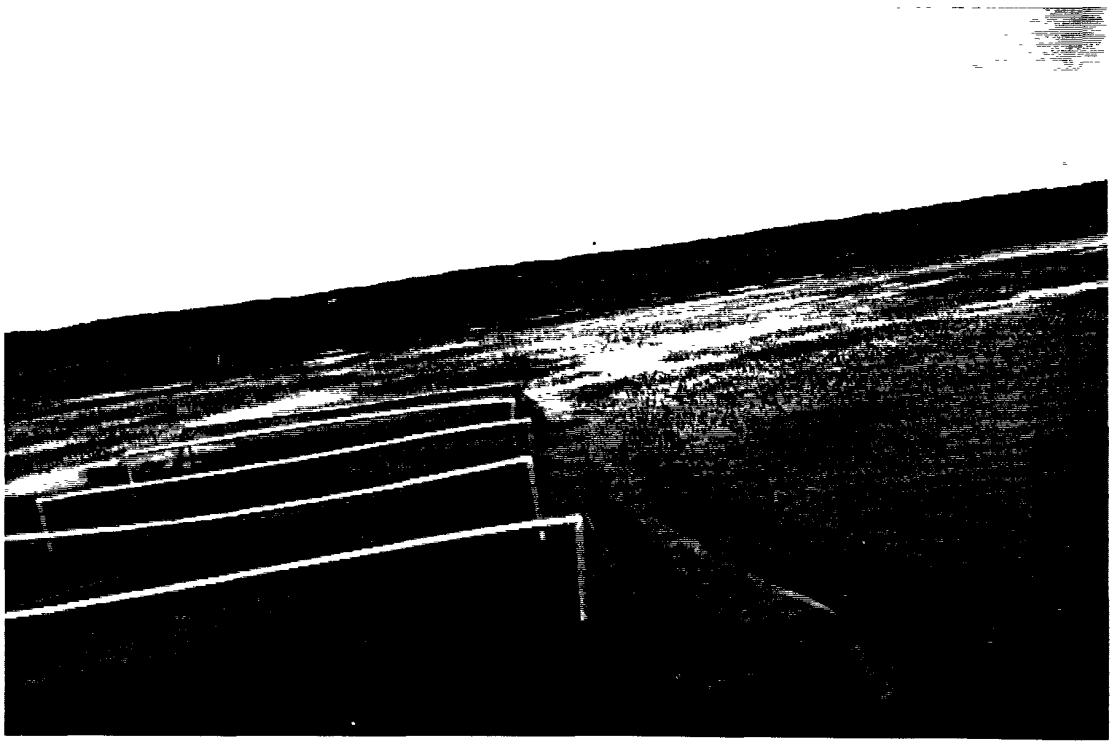


Figure 19. Experimental frame using PVC and 3/8" Tenax netting. Netting is held down using 10' lengths of 1/2" rebar. PVC is lightweight, inexpensive, durable, but not well suited for extreme conditions.

Figure 16. 100' clam tents using rebar for supporting bows.
Netting is 1/6"mesh, commonly used in nursery cages.

Figure 17. Small scale experimental tent, using 1/6" orange netting.
Rebar can be covered with hose to prevent chafing.

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