

Chapter 5: Seed Collection and Larval Monitoring

Mussel spat or seed collection is arguably the most important aspect of mussel culture. Growers may have the option of either growing their own seed or purchasing seed and in some cases this may be the most cost effective way of obtaining seed. Without a reliable seed source a mussel farm cannot produce consistent quantities of product annually. Consequently, considerable effort is placed on obtaining large quantities of seed. This has been accomplished through the use of larval monitoring to determine the best time to deploy collectors and through the deployment of large numbers of spat collectors all around the province.

Collector Designs

Newfoundland mussel farmers utilize a variety of spat collector designs. All surveyed growers used polypropylene rope with a weight attached to the bottom as their collection material while some also used socking material. Collector rope length and width varied; some farmers used old rope; new rope or a combination of both. The most obvious difference in collector design in the surveyed farms was the type of weight used. These weights ranged from a rock placed inside a small amount of socking material, to a small cup of concrete, lead weights, or nails. The method of attaching the collector to the mainline also varied. Some tied each individual collector to the mainline with a short length of twine while others wove the collector lines through the mainline.

The rock weight collector type was the most common, utilized by 64% of surveyed growers. The collector is constructed by tying a knot in the bottom of a small piece of socking material (60 cm length) and placing a small rock in the sock. The sock is then tied to a length of polypropylene rope (usually 9 mm (3/8")), with twine or by passing the sock through the collector followed by a half hitch. A drawback with this collector type is the short life span of the rock weight, which falls off after an average of 3 years (Gardner and Coombs 1997). In addition, collecting the rocks and attaching them to collectors also constitute considerable labour costs.

Only two growers surveyed used the concrete cup collector design (Figure 5.1). To build this collector the end of the collector rope is then placed in a styrofoam cup filled with concrete using only sand for mix. The concrete is allowed to set and then the cup removed to be reused. This creates collectors with very permanent weights that are expected to last 10 years. Building these collectors may be time consuming unless many cups are used at once (several hundred).

Nail weight collectors simply use a galvanized nail, which is pushed through the collector rope (Figure). The nail is typically 15 – 20 mm (6" to 8") long to generate the necessary weight. Nail weights are expected to last 10 years but are expensive to purchase (12 for \$1.35-Home

Hardware, Grand Falls-Windsor). The advantage of nail weights is that they are very easy to attach to collector ropes such that many collectors can be made in a short period thus reducing labour costs. Nails have certain disadvantages however in that they may rust and the sharp points may pose a risk to workers as collectors are handled. Few growers are using this technique.

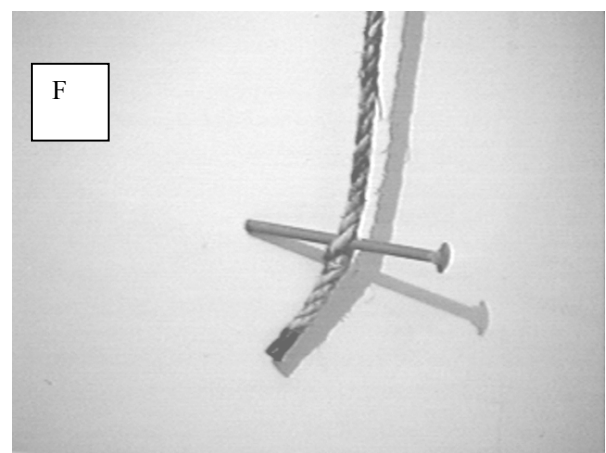
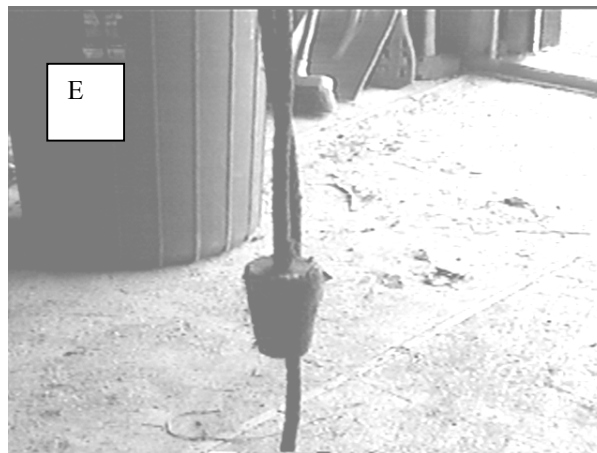


Figure 5.1: (A and B) Rock weights collectors, (C and D) method for attaching rock weights to collector ropes (socking is inserted through collector rope, followed by a clove hitch), (E) concrete cup collector weights, (F) nail weight collectors.

Lead weights are simply tied to the bottom or flattened around the end of the collector. These weights can be purchased or can be formed from scrap lead by certain growers. This method may be costly if the leads are purchased and would require extensive labour to manufacture.

A fifth type of collector composed of just socking material tied to the mainline was also utilized. This collector employs a rock for a weight, which is placed in the bottom of the sock and then kept in place by tying a knot in the sock (Figure 5.2). According to growers, socking material employed for collectors could only be used for one to two years before it is no longer useable. This means that new material must be bought or waste material from harvested socks and tied on to mainlines on a yearly basis.

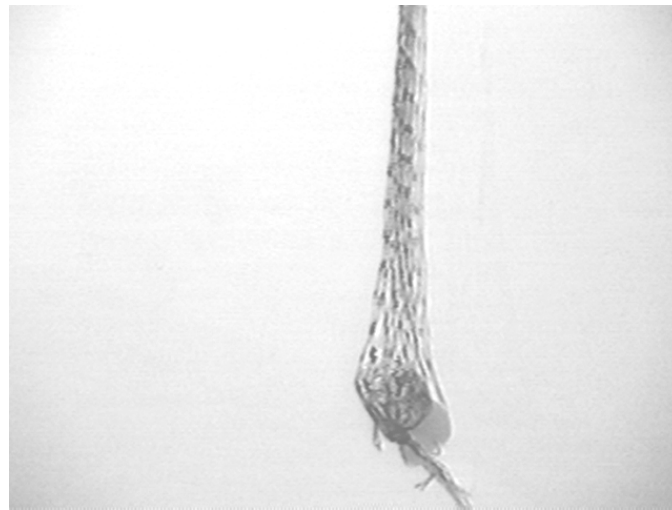


Figure 5.2: Socking material collector.

Lead rope may also be used for weighing collectors. In this case the lead rope is tied in a continuous line to the bottom of the collectors (Figure 5.3). Each collector line would be tied or woven through the mainline. This method was utilized by only one grower who was unable to estimate labour costs in construction and as such this collector design will only be utilized in the material portion of the cost analysis.

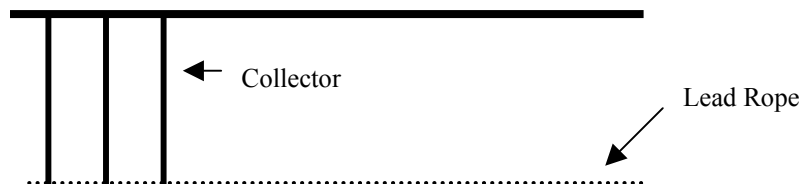


Figure 5.3: Continuous collector using a complete line of lead rope along the bottom.

A final type of weight for collectors involved stringing rope along the bottom of all the collectors on a line (Figure 5.4). One grower was using 9 mm (3/8") polypropylene rope along the bottom as additional collection area. At intervals along the twine rock weights were tied on. This allows one weight to weigh down many collectors. This system reduces the number of weights but requires extensive preparation tying all the collector bottoms together. The system may be more difficult to handle and may tangle more easily.

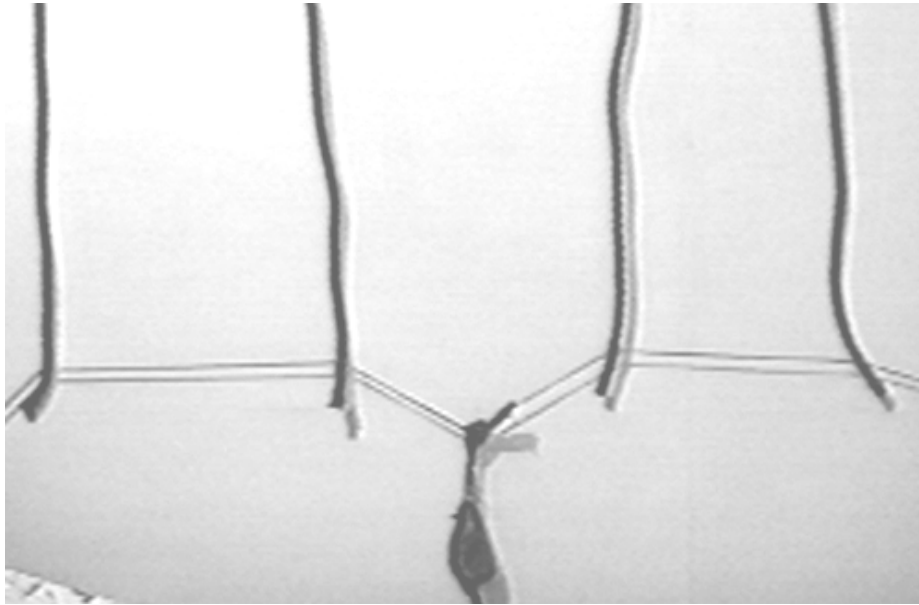


Figure 5.4: Collector design using twine or polypropylene rope for a bottom line to which weights are attached at intervals.

One grower looped the collection rope between the top and bottom line in a truly continuous system. Another looped the collectors without using the bottom line. During harvest, the collector line could be cut from the top and/or bottom and then hauled through an automatic seed stripper (Figure 5.5). A seed stripper has been developed by Atkinson & Bower and is currently in use in Nova Scotia.

Collector Attachment

A common method used to attach collectors involves tying a single collector, usually 2 m long, to the mainline using twine. The collector is cut during harvest and completely removed for stripping. The collector must then be retied to the mainline after stripping, resulting in increased yearly labour cost.

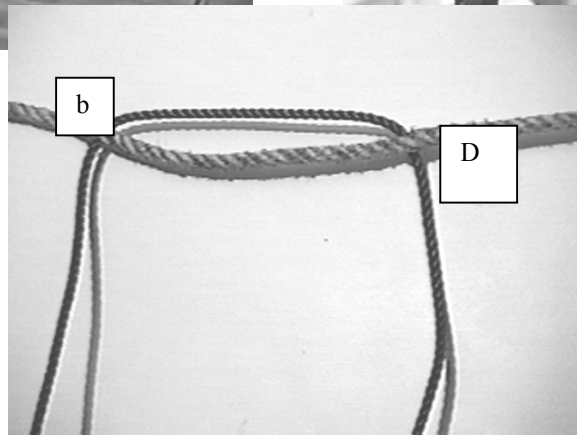
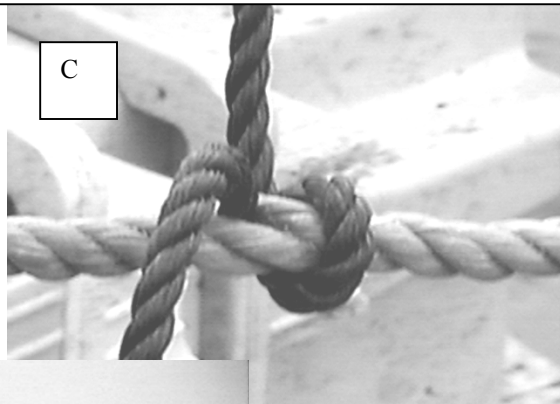
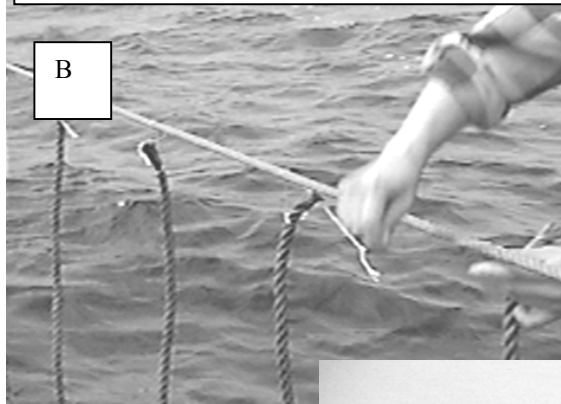
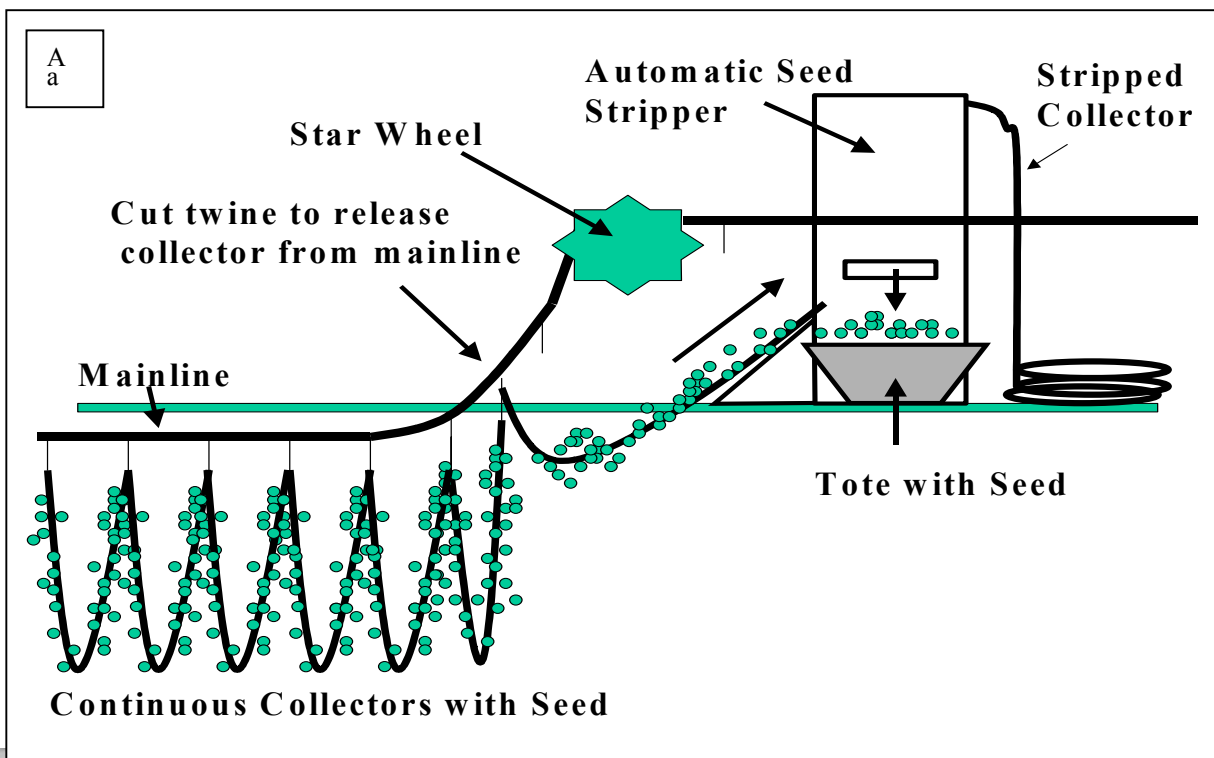


Figure 5.5: (A) A flow diagram of continuous collectors using an automatic seed stripper. Collector attachment methods: (B) tied with twine, and woven through mainline; (C) single and (D) double.

In the second method, the collectors are woven through the mainline and are more permanently attached and are not removed during stripping. This can be accomplished by tying a single collector through the mainline or by weaving a collector 3.9 m long through the mainline in two locations about a 30 cm apart. This creates two, 1.8 m long collectors that are permanently attached to the mainline. The weights are added after the collector rope is woven through the mainline. After all the collectors on the mainline are stripped, the entire mainline is pulled out of the water and allowed to clean off on the beach. After several weeks on the beach the mainline with collectors still attached is simply pulled back out into the water and attached to the anchor lines to begin collecting spat. This reduces the labour cost associated with retying individual collector ropes to the mainline. Weaving the collector lines through the mainline also prevents slippage and bunching of collector lines on the mainline.

Collectors tied to the mainline with twine do not have to be cut for removal. They can be harvested in the same way as those woven through the mainline. Twine tied collectors appear to work more smoothly on star wheel systems (Figure 5.6) as there are no loose ropes to get tangled in the star wheel but the twine will weaken over time causing the collector to break off.

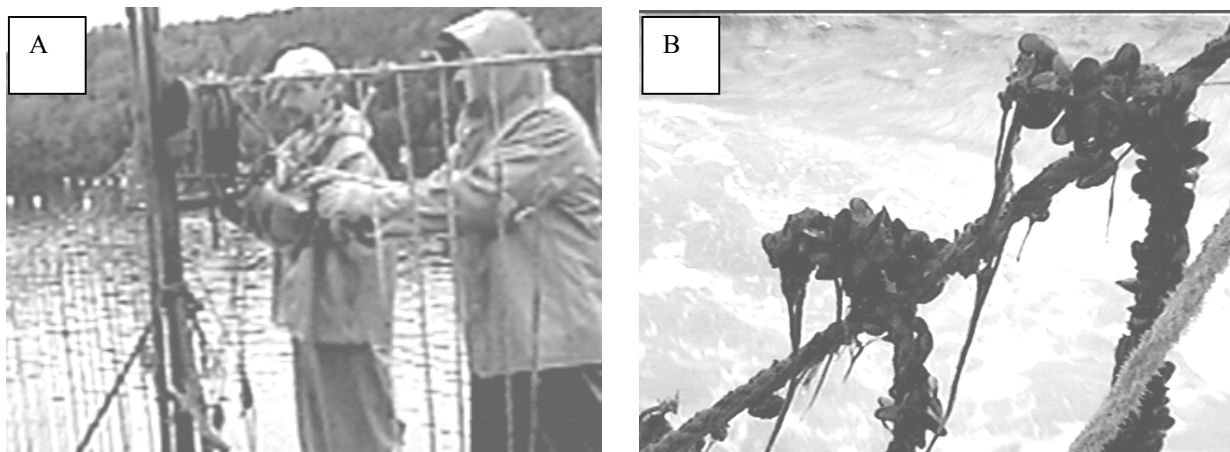


Figure 5.6: (A) Collectors tied to the mainline with twine being retrieved using a star-wheel. Note the smooth surface of the collector attachment to the mainline. (B) Collectors woven through the mainline and tied, note the collection on the loose end from the knot.

Cost Efficient Collection Practices

In a NAIA sponsored project, Gardner and Coombs (1997) compared the cost efficiencies of two collector types, one using lead weights and the other rock weights in socking material and found the former to be superior in terms of overall costs (including labour and capital). The current analysis compares the cost efficiencies of the six collector designs observed on the 13 farms surveyed in 1997.

A comparison of the labour cost (estimated by the grower) and material cost (from IMP and Home Hardware) to make and deploy 10,000 collectors suggests that collector design made entirely of socking material had the lowest cost at \$2,898.58 (Appendix 1, Table A1). The remainder of the designs had costs ranging from \$5,779.15 to \$7,726.00 for 10,000 collectors. Additional costs in labour and materials for collectors occur after the start up year (Appendix 1, Table A2). The socking material collector must be bought and tied each year resulting in the highest cost per year after the start year. The rock weight collector that must be retied to the mainline every year results in a significant labour cost and both rock weight designs must have weights replaced every three years, thus long term costs for these types of collectors are higher than the more permanent weight designs.

If collector costs are extended over a ten-year period, a marked superiority in the nail weight, the concrete cup and the woven rock weight collector is suggested (Figure 5.7). These costs do not include any seed harvesting costs, float cost, mainline or anchoring costs. The least cost efficient collector design in the cost analysis included the most common design, the rock weight collector retied to the mainline each year and the least expensive initially, the socking material collector. A grower that utilized either of these types would spend \$10,000-\$15,000 more over the ten year period than a grower that utilized any of the collectors that were woven through the mainline.

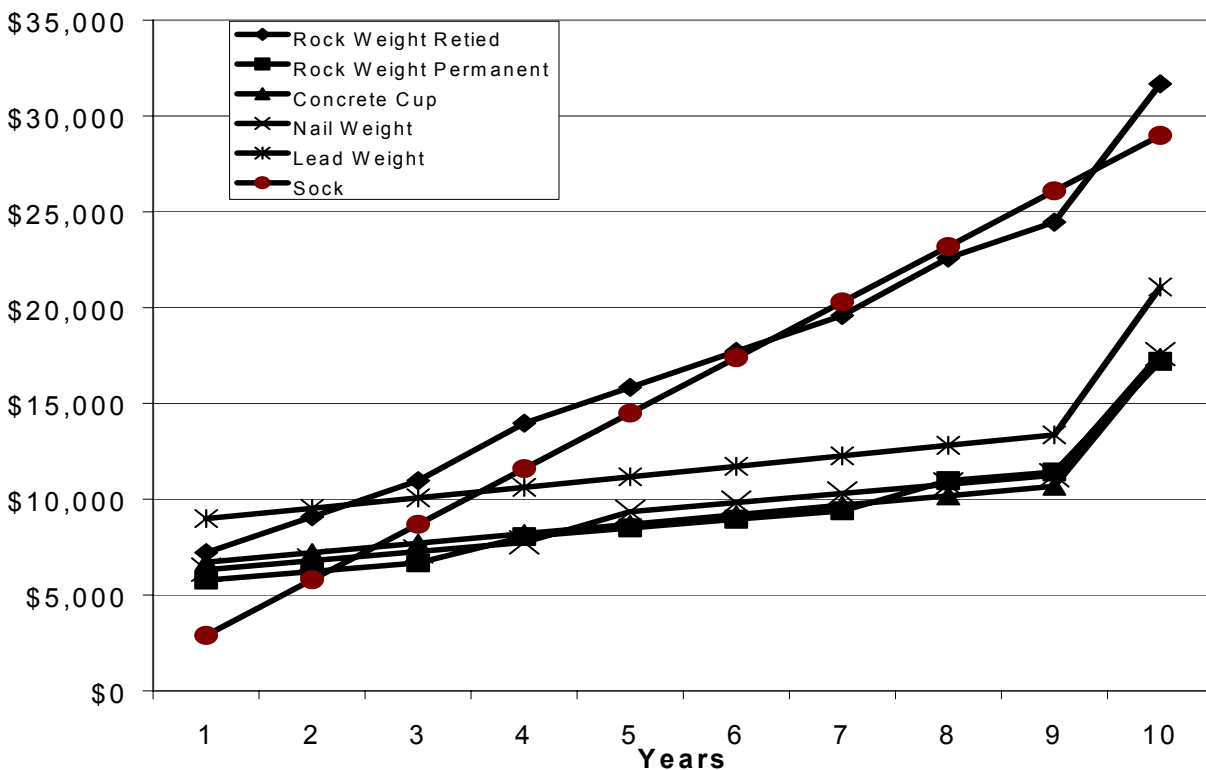


Figure 5.7: The cumulative cost (labour and materials) of six collector designs used in the Newfoundland mussel aquaculture industry for a hypothetical 10,000 collector farm over a 10 year period. Estimates do not include float, anchor or mainline costs or the costs from seed harvesting. See Appendix 1 for additional details.

Collector Deployment Practices

There are a number of considerations involved in collector deployment regarding when, where and how many collectors to deploy. The timing of collector deployment is critical for obtaining a reliable seed supply. Larval monitoring methods have been developed to address the timing of collector deployments and are detailed in Chapter 10. Just prior to deployment, old collectors should be permitted to dry out on the shore for a week or more to kill any remaining fouling organisms. If this step is excluded heavy fouling on collectors could result, reducing seed settlement and retention.

The location of collector deployment in a farm is also crucial to successful seed collection. Many growers using shore-to-shore lines initially experience good spat collection when the farm is in the developmental phase, but as the farm develops and more lines are added, seed collection becomes highly variable. Growout mussels and lines will affect water circulation patterns in enclosed sites such that placing collectors at various locations in the site often will not yield improved seed collection. There are three reasons for this. In enclosed inlets with restricted circulation, the growout lines may substantially alter current flow patterns thus affecting the location of settling mussels. Secondly, growout mussels are known to filter considerable volumes of water while feeding. In many cases this water contains larval mussels that would normally settle on collectors. The mussels are not cannibalistic by choice but by circumstance. Finally, the site may simply be unreliable with respect to long term seed supply.

The location of collectors on a farm also has important consequences for farm production. Recent evidence suggests that seed mussels (less than 20 mm shell length) filter approximately twice as much water as larger market size mussels of equivalent weight (Mooney et al. 1999). The smaller mussels are faster growing and require more food than larger mussels on a per weight basis. The consequence is that a kg of small mussels will consume approximately twice as much food as a kg of large mussels. If a farm is located in a protected inlet with limited current flow, the seed collectors could be consuming a large portion of the available food, thereby slowing the growth of production mussels. Most mussel farmers anticipate a yield of about two socks per 180 cm (6 ft) collector. Using this assumption a 10,000 sock farm would require 5,000 collectors. However the 10,000 collectors are potentially filtering the food requirements of 10,000 newly deployed socks. If these collectors are not carefully located on the farm impacts on production lines could be severe, particularly on sites using shore-to-shore mainline layouts in sheltered inlets with limited water exchange. One way to reduce the impact of seed collectors on growout mussel production is to deploy the collectors in areas that are not in the path of the food flow to the growout lines (Figure 5.8). This may be impossible in shore-to-shore farm designs in sheltered inlets and consequently, growers may have to consider separate seed collection and growout sites to optimize production. On sites with parallel line mooring, seed collectors may be placed in an area away from growout mussels in an effort to reduce the effect of one on the other.

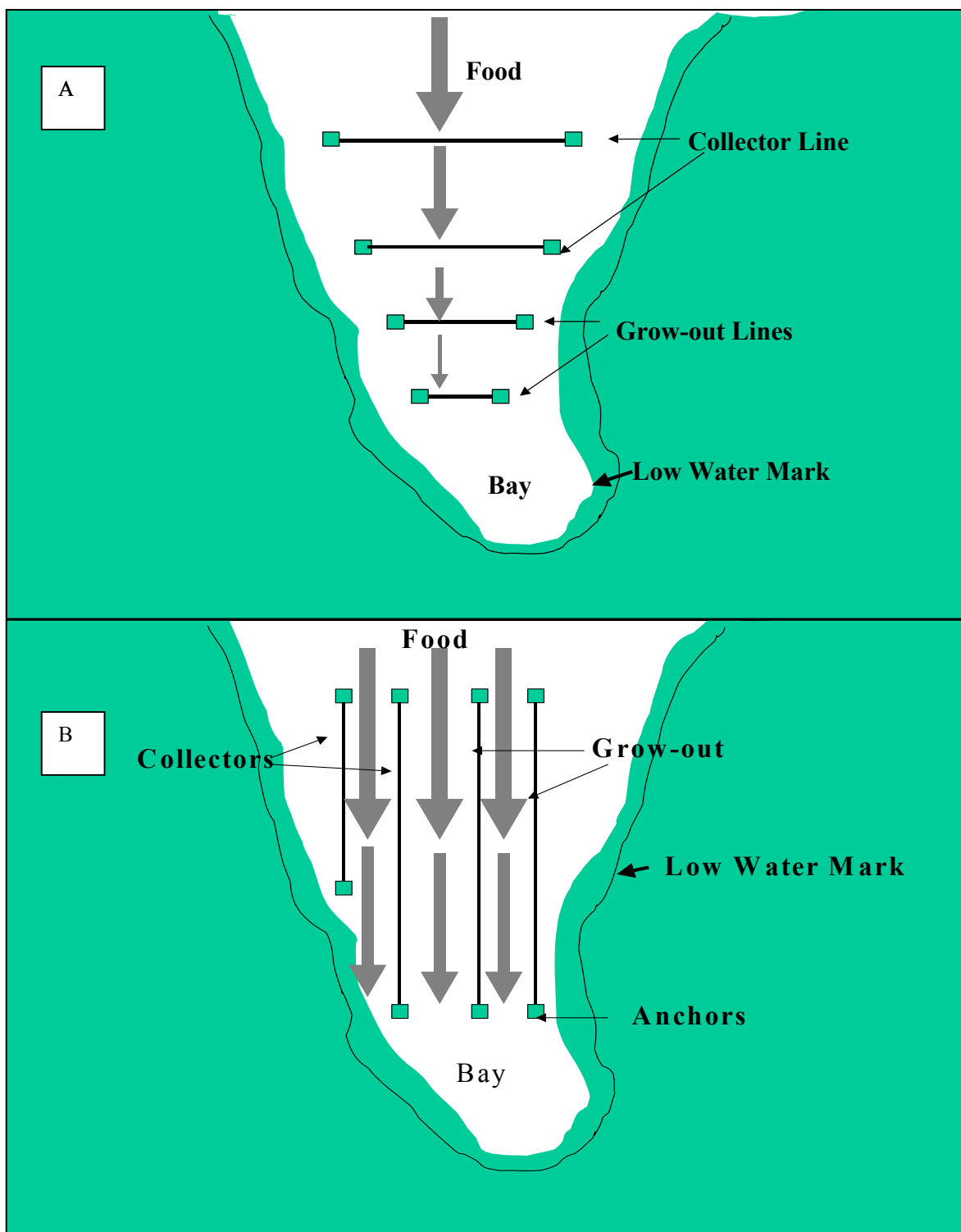


Figure 5.8: Food attenuation throughout a (A) shore to shore mainline mussel site with collectors located at the front and (B) a parallel mainline site with collectors located on the side.

Purchasing seed from other growers is an alternative that eliminates the collector location and timing problems indicated in the previous section. The drawback is that the grower must rely on others for his/her seed requirements and must have cash available to make the necessary seed purchases. This drawback is becoming less of an impediment to the creation of growout-only sites as more and more seed-only sites are identified and developed and as growers develop reliable cash flow cycles.

A direct cost comparison of growing one's own seed compared to purchasing seed (Figure 5.9) suggests a lower seed cost of \$61,000 (total costs over 6 years for a 10,000 sock per year farm) for the mussel farmer by growing the seed vs. \$80,000 for buying. These numbers can vary depending on the size of seed used and the collection performance. If the sock to collector ratio is 2:1 then the cost of growing the seed may be reduced by up to 50%. If the seed size is smaller then the number of socks per tote increases and purchasing the seed becomes more cost effective.

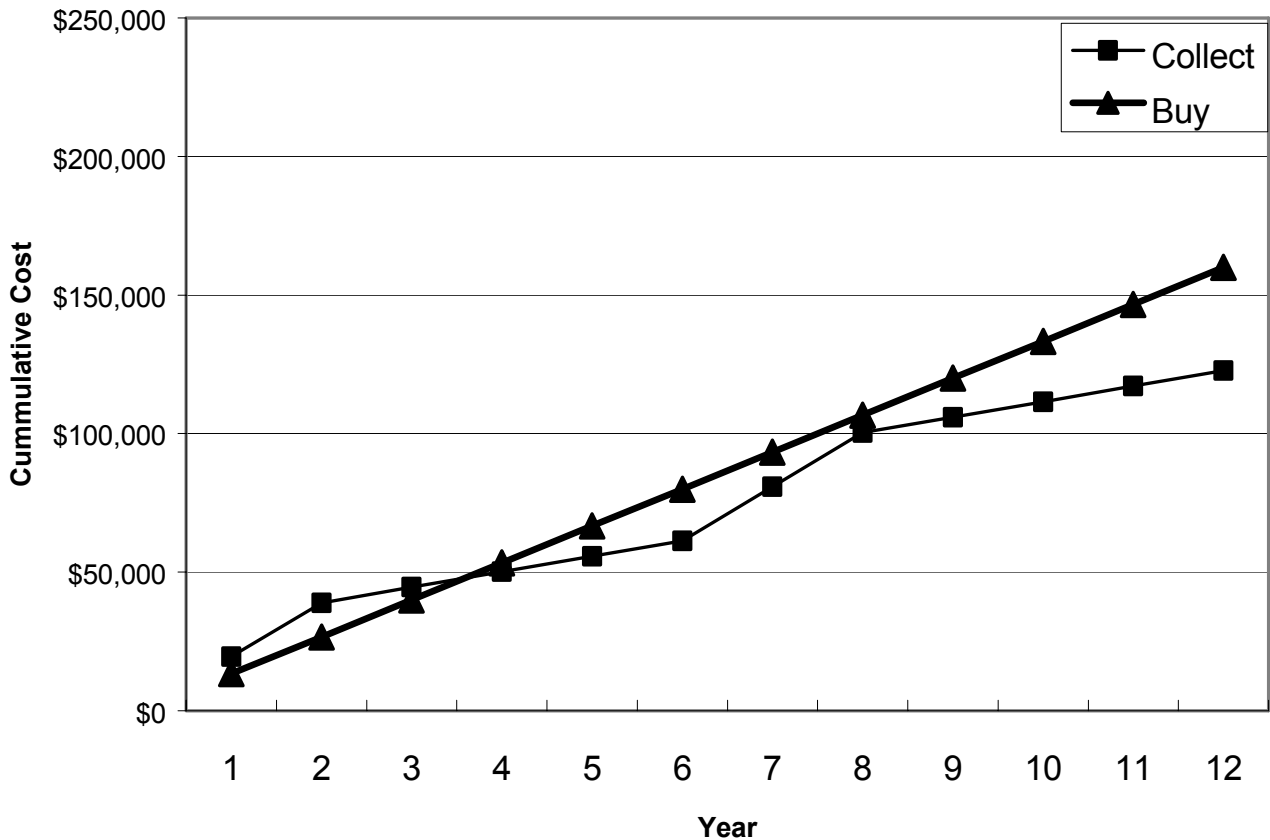


Figure 5.9: A comparison of the cumulative costs associated with purchasing seed or growing one's own over a 12 year period for an hypothetical 10,000 sock per year farm. This assumes a 1:1 sock to collector ratio, 15 socks per tote pan and a seed cost of \$20 per tote. For additional assumptions see Appendix 1, Table 1B.

Even though there may be little to no direct cost saving in buying seed compared to growing one's own, there are real benefits. Purchasing seed allows the grower to develop a site faster. The grower can deploy socks in the first year of operation without having to wait the full year to produce the necessary seed from collector deployment. This will generate revenue a year earlier than the collection scenario. In addition purchasing seed will allow 15-20 % more space on the farm site for growout. This will increase annual revenue by 15-20 % assuming this area can be successfully utilized for growout. If we assume a 10,000 sock per year farm, by purchasing seed an additional 1,500 socks can be deployed on the same site. The comparison of the two scenarios suggests that the farm that purchases seed breaks even with regard to seed costs in year 3 following initial startup compared to year 4 for the collection farm (Figure 5.10). The farm that purchases seed will outperform (with regard to revenue-seed costs) the collection farm by \$140,000 over a 6 year period. An analysis performed by the Marine Institute of MUN (Rideout 1997) suggested purchasing seed remains competitive to collecting even if seed costs reach as high as \$1.06/kg (\$0.50/lb)

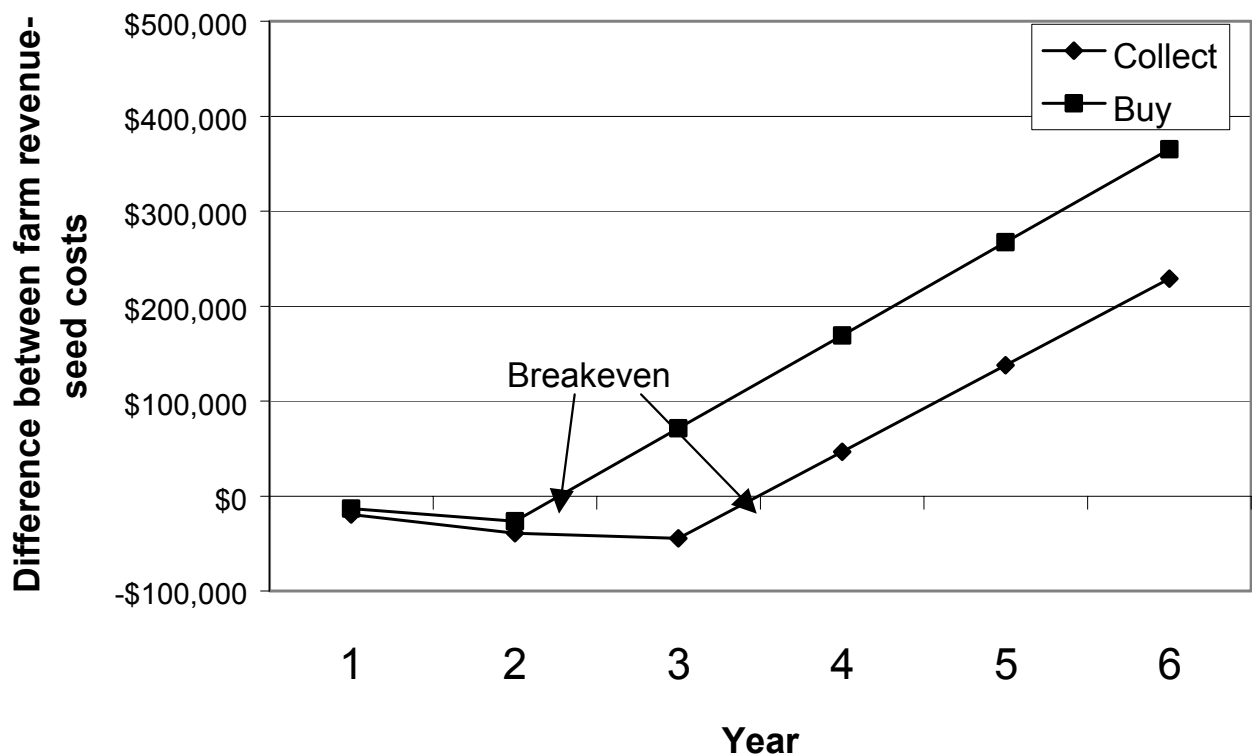


Figure 5.10: The difference between cumulative revenue and cumulative costs for a mussel farmer that collects seed compared to one that purchases seed. This assumes a 1:1 sock to collector ratio, 15 socks per tote pan and a seed cost of \$20 per tote. For additional assumptions see Appendix 1, Table 1B. Breakeven is described with regard to seed costs only, and is defined as the point where cumulative revenue equals cumulative seed costs.

The decision to purchase seed should be made only after the grower is confident he/she can secure a reliable seed supply from seed farms that has shown to perform well at their own site. Finally, purchasing seed is subject to obtaining a permit for transfer, following the appropriate testing to ensure the seed does not contain potentially harmful organisms such as toxic dinoflagellates.

Chapter 6 Socking Practices

The socking of mussels is probably the most important husbandry event in mussel aquaculture. Simply put, socking is the placement of mussel seed from collectors into mesh tubes or socks, which are then tied to longlines to grow to market size (Figure 6.1). Socks in Newfoundland are typically three to four meters in length and are placed approximately 0.5 m apart on the longline.

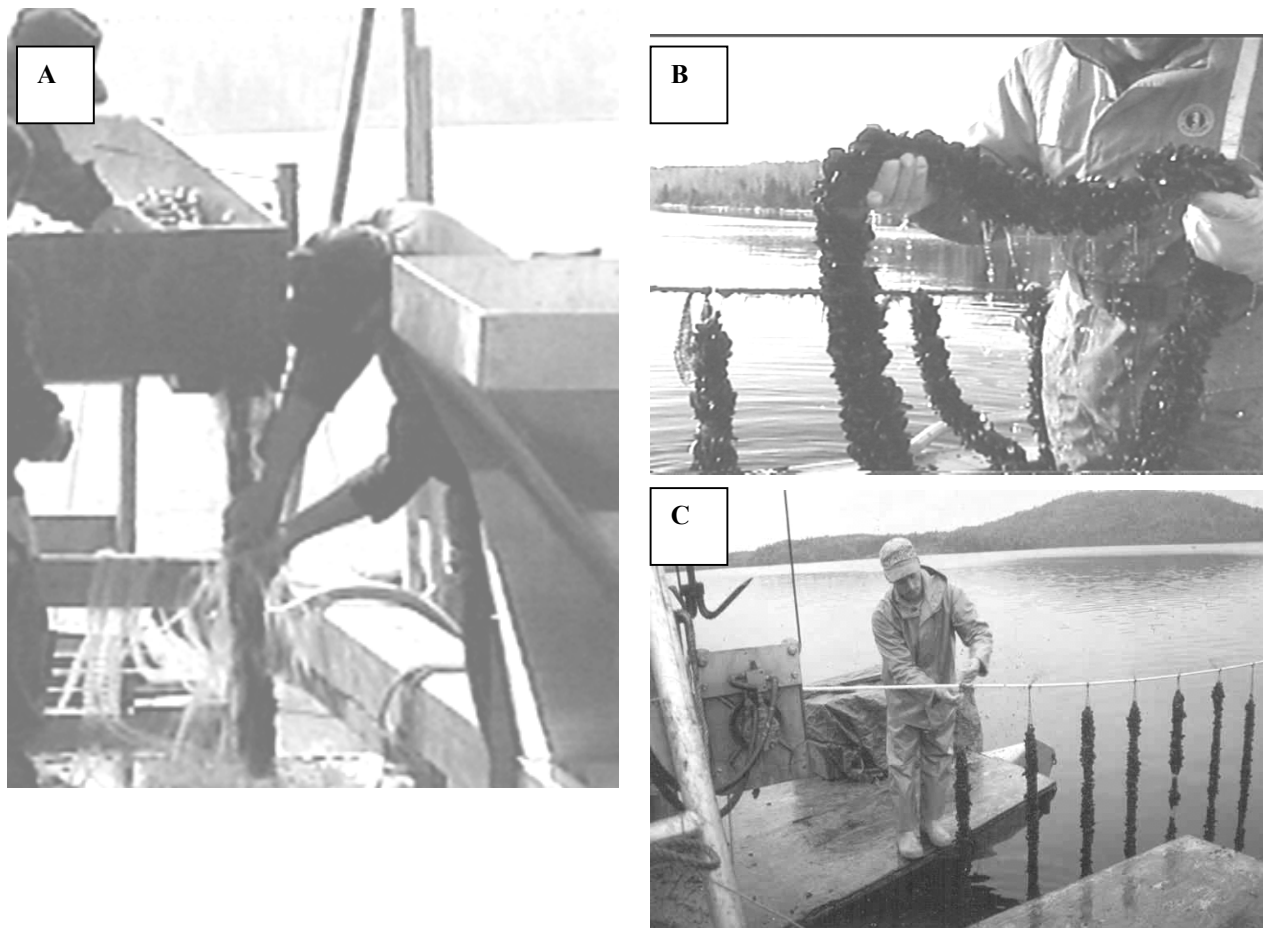


Figure 6.1: (A) Socking on a two-tube table, (B) socks on mainline, (C) deploying socks on a mainline.

Socking allows the grower to adjust animal density, size grade, remove predators and keep basic inventory. Consequently, the use of proper socking practices is paramount to achieving maximum mussel production. Current socking practices in Newfoundland tend to be aimed primarily at achieving an initial socking density of greater than 200 animals 30 cm (per foot) of sock. This trend seems to be changing to lower densities in the range of 150-200 mussels per 30 cm of sock (for larger seed, approximately 30 mm shell length) as new socking materials with narrow tube diameters and graded seed becomes available. It is recognized, however, that the

most appropriate initial socking density is highly dependent on site conditions, and in some cases higher initial densities are needed to reduce or avoid problems with secondary set.

Although socking gives the grower considerable control over the mussel product, it also entails substantial cost. Direct labour costs on Newfoundland mussel farms were estimated at \$2.42 per sock (Gardner and Coombs 1997). The majority of this labour (\$1.51/sock) is derived from the stripping and socking of mussels. This value is an average of the well established farms and does not demonstrate the considerable variation in efficiencies of socking techniques used in Newfoundland mussel farms.

In any type of aquaculture operation, including mussel culture, the goal is always to reduce costs. The following analysis is intended to provide an indication of the variability in socking practices and to suggest an optimum socking practice that could provide maximum yield and quality for minimum cost.

Socking Efficiencies

Most of the growers surveyed in 1997 and 1998 utilized homemade socking tables to sock mussels, although some had purchased aluminum tables. Most socked on barges and immediately attached the socks to mainlines for grow-out although many growers who are using seed graders are now socking on land and transferring socks in tote pans to the lines. Three of the growers surveyed allowed socks to stay in tote pans in the ocean for 24 hours to permit mussels to develop byssal threads prior to attachment to mainlines. Of these three, one grower socked on land and the other two on a large enclosed floating platform.

The number of socks filled per day per person varied considerably among the surveyed growers (22) in 1997 and 1998 (Figure 6.2). Socking performance ranged from 225 socks per person day to 30 socks per person day with an average of 108. These values included both the retrieval and stripping of seed and the attachment of socks to the mainline. This is marginally lower than the PEI industry values, which are in the order of 200-250 socks per day (R. Gallant, 1998. pers. comm.). One PEI grower is able to sock an average of 400 socks per person day using a six person crew. Two of the crew ran the sock table; one ran the declumper-grader and three were supplying seed and hanging socks (Gordon Deveau 1997. pers. comm.).

A cost comparison of socking performances assuming a 10,000 sock farm and a labour cost of \$80 per person day, indicates the inefficiency of current Newfoundland socking practices (Figure 6.3). In some Newfoundland farms the number of workers on the surveyed farms was variable with little indication that the higher labour force improved socking performance. When an increase in workers does not increase production efficiency then the economy of scale of the current technology has been reached. The only option at this point is to improve the technology or techniques being used (Colander and Sephton 1996).

, the Newfoundland average socking labour costs were \$4,207 higher than the PEI average.

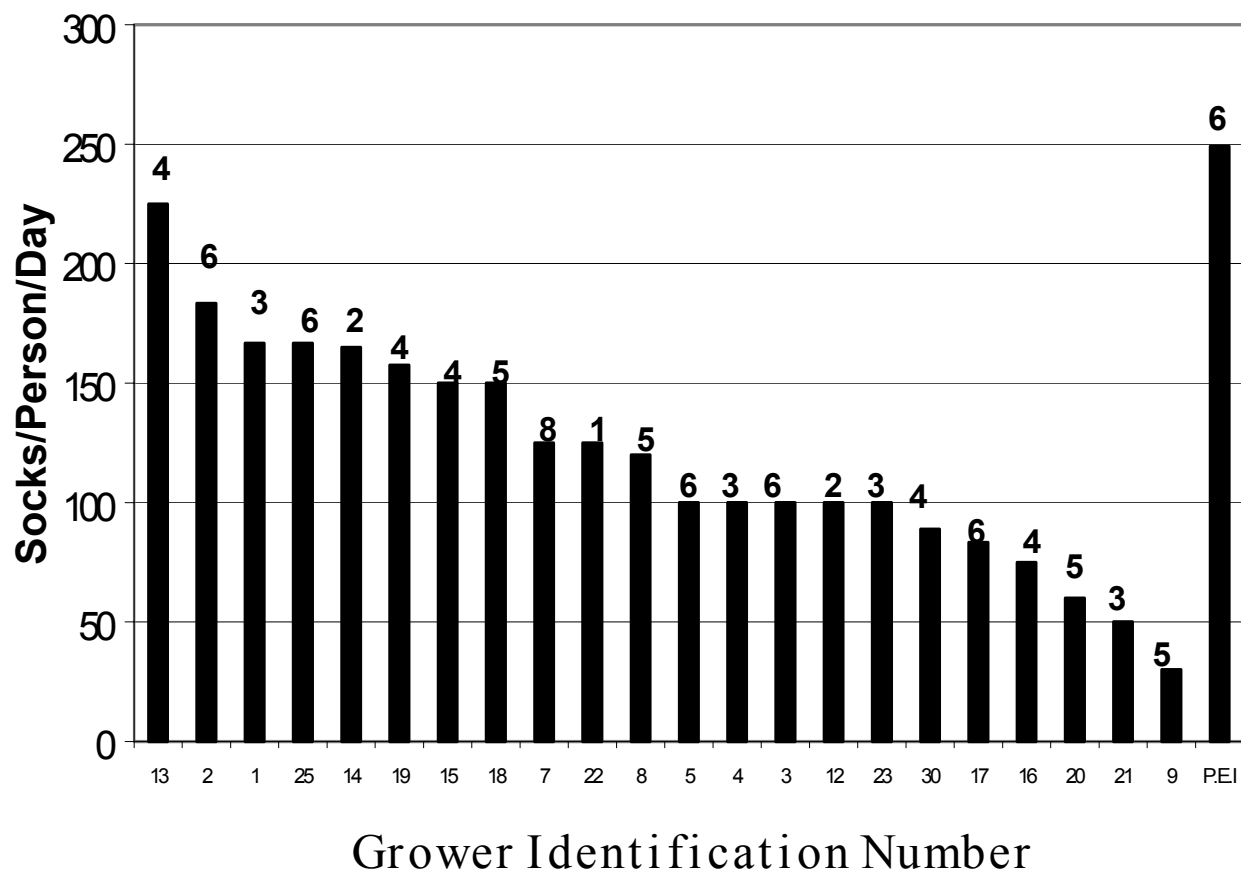


Figure 6.2: The number of socks filled per person day at 22 commercial mussel farms. Values are based on an eight hour day and include the stripping of seed and the deployment of socks. All information is based on the 1997 and 1998 NAIA-Marine Institute Mussel Extension Service Survey. Numbers above each bar represent the number of people involved in the socking process. The PEI value was provided R. Gallant, 1998. pers. comm..

The difference in socking labour costs from the most efficient Newfoundland grower to the least efficient for the hypothetical 10,000 sock farm was \$26,311. Using the same assumption The differences in socking efficiency between PEI and Newfoundland operations is likely a result of more efficient husbandry practices in PEI. These include the use of de-clumped, graded seed, reduced socking densities, better socking table designs and more efficient seed harvesting and sock deployment methods. These considerations will be elaborated upon further in upcoming discussions.

New Socking Techniques

Many Newfoundland growers are now using mechanically graded seed (Figure 6.4) along with new table designs and socking techniques. Many of the current socking tables are inefficient and may be redesigned to hold more mussels and water to generate a higher pressure, thereby increasing socking speed. This may also be improved by placing the socking tube at the bottom

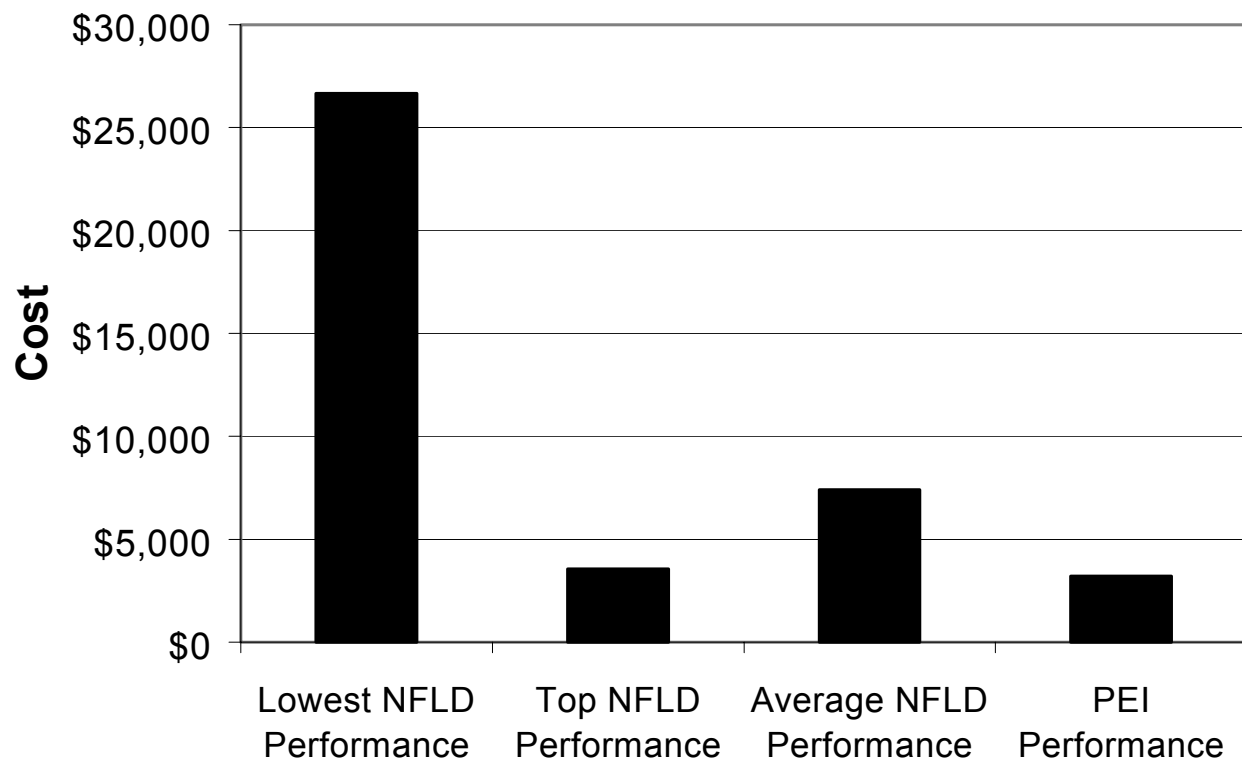


Figure 6.3: The labour costs associated with stripping seed, socking and tying socks to mainlines for the best, worst and average Newfoundland performances of 12 surveyed growers. Values are based on a 10,000 sock deployment using a labour cost of \$80 per day per person. PEI socking performance is derived from R. Gallant (pers. comm. 1998).

of the table rather than the end. Having the tube more vertical may increase flow speed (particularly with graded seed) and make it easier to unclog as the motion is up and down rather than horizontal. Moreover, double gated tables (Figure 6.5) are currently the standard in the Maritimes and new designs could easily incorporate these features to reduce labour and increase efficiency (socking table designs can be seen in upcoming sections).

Graded seed appears to be the key to increasing socking speed. A comparison of socking speed on the same table using graded and ungraded seed revealed a two-fold increase in the number of socks per person day (Figure 6.6). With a two tube socking table and a four person crew (two socking, one feeding and one tying on) a total of 100-125 three meter socks per hour can be deployed. With large seed this would require about 10 tote pans which can be graded in approximately seven minutes and in a 10 hour day would allow the deployment of 900-1,200 socks. This assumes the seed was already stripped or two extra people were stripping seed. This yields an average of **150-200** socks/person day with a six-person crew (three socking, one tying and two getting seed).

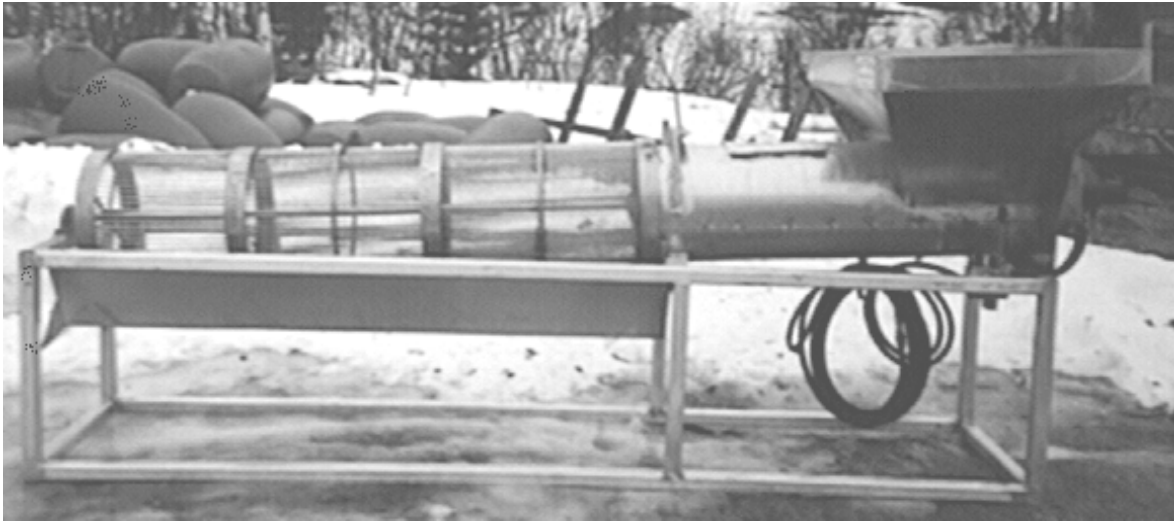


Figure 6.4: A small de-clumper grader used in socking experiments and for demonstration to Newfoundland growers. The device is 3 m long and weighs approximately 180 kg. Depending on seed source, its capacity ranges from 1000 to 1800 kg per hour.

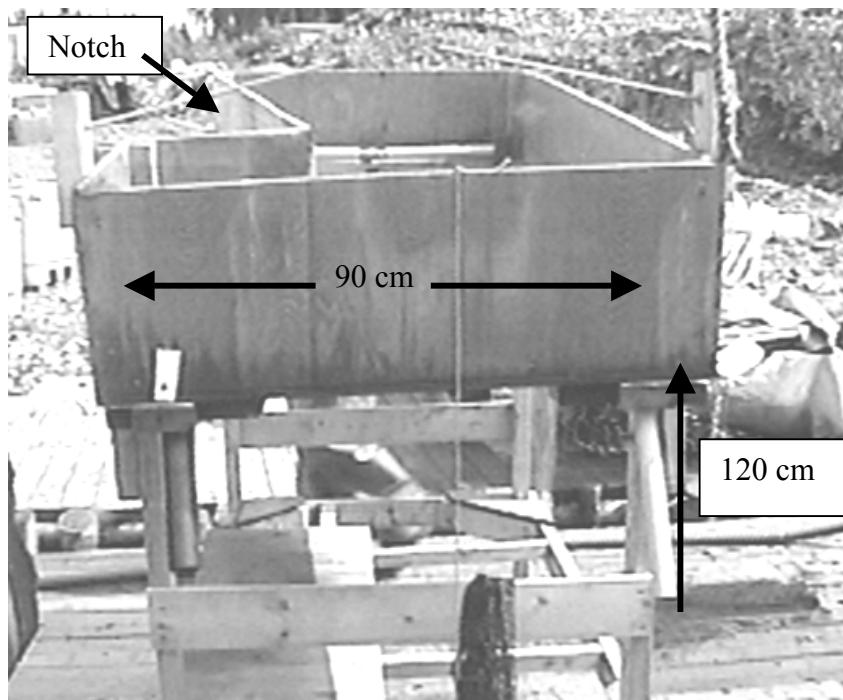


Figure 6.5: Three person socking table with vertical tubes. The table is designed with a notch to allow one person to feed two sock tubes.

Ungraded seed is slower to sock, and much slower if the byssal attachment is heavy. A three person table cannot be utilized for ungraded seed as one person is required to feed one tube. This automatically makes your crew size five people, two people for each socking tube and one person tying the socks to the mainline. During experimental trials approximately 30-40 socks per hour per tube could be socked when the mussels were manually de-clumped. In a 10 hour day a five person crew could sock between 400-700 socks if the seed was already stripped. This results in a socking efficiency of only **57-100** socks per person day with a 7 person crew (four socking, one tying, and two getting seed).

A different socking method that uses a 7 m long sock and graded seed is currently in use by one grower. In this method, as the sock is filled, one end of the sock is tied to the mainline, and on completion of the sock the other end is also tied to the mainline. This generates a 6.5 m long loop (Figure 6.7). This method can produce the equivalent of 100-125 three meter socks in one hour with three people. This technique requires only two people to work the table and one person to tie on. Using the same assumptions as in the other socking methods, 200-250 socks per person day can be achieved. With current barge designs only one person can tie socks on at a time, creating a bottleneck and a maximum of approximately 1,000-1,200 socks per day for a 5 person crew (two socking, one tying, and two getting seed). If this problem can be solved a two tube socking table using the loop technique described above could sock the equivalent of an estimated 2000 3m-socks per day with a 7 person crew (three socking, two tying, two getting seed) or 285 socks per person day. It is unknown if looped socks have yields similar to standard socks and there may be increased breakage using the looped method. In addition, looped socks may have to be spaced farther apart on the mainline requiring more site area than standard sock deployment methods.

Mechanical seed graders are a relatively new technology to Newfoundland. With this technology new techniques and table designs must be utilized to maximize production. Seed harvest technology seems to represent a major bottleneck in the socking process. Some growers require 1 hour to remove 10 pans of seed while others can strip and grade 50 pans in a one hour and 30 minutes (Figure 6.8). The slower systems tend to have a work area only on the front of the barge while the faster systems utilize the whole barge. One of the most efficient systems is to haul the mainline and collectors completely across the middle of the barge. The line is suspended on two star wheels so that the collectors can move along the wheels easily. The seed is then stripped off the collectors into pans on the floor of the barge. Excess seed on the barge floor is shoveled into tote pans to be graded later. The system also works well if the star wheels are mounted on one side of the barge (see barge designs in Chapter 7)

If the system is set up properly, two people can operate the stripping process on the barge. The hauler is turned on slow and both people can strip at once. The star wheels remove the necessity of manually handling the full collectors as they enter the barge and the stripped collectors as they go out over the end.

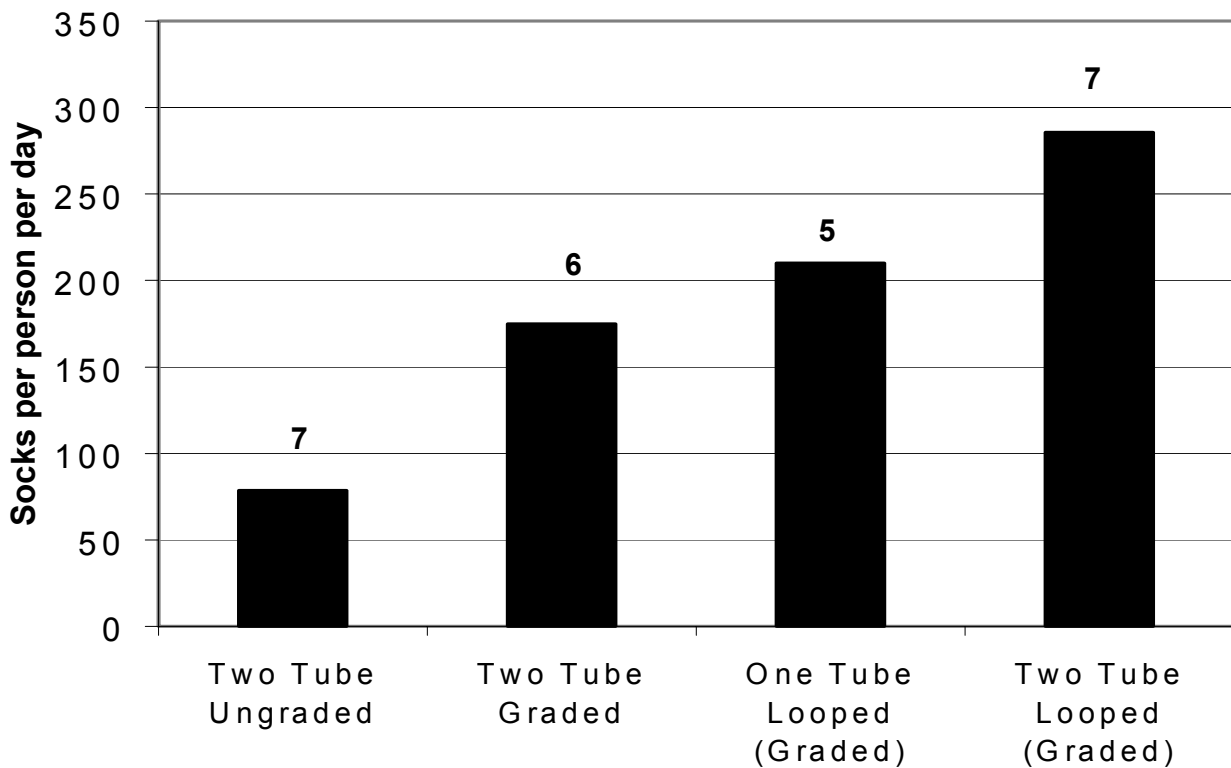


Figure 6.6: The number of socks filled and deployed per person day (assuming a 10 hour day) using four socking techniques, based on Newfoundland mussel grower interviews and on direct timings of the socking process. The numbers above each bar represents the number of workers required for each technique and values include the time required to strip and grade seed. The PEI average is 200-250 socks per person day for a six person crew.



Figure 6.7: Socking attached to the mainline in a loop.

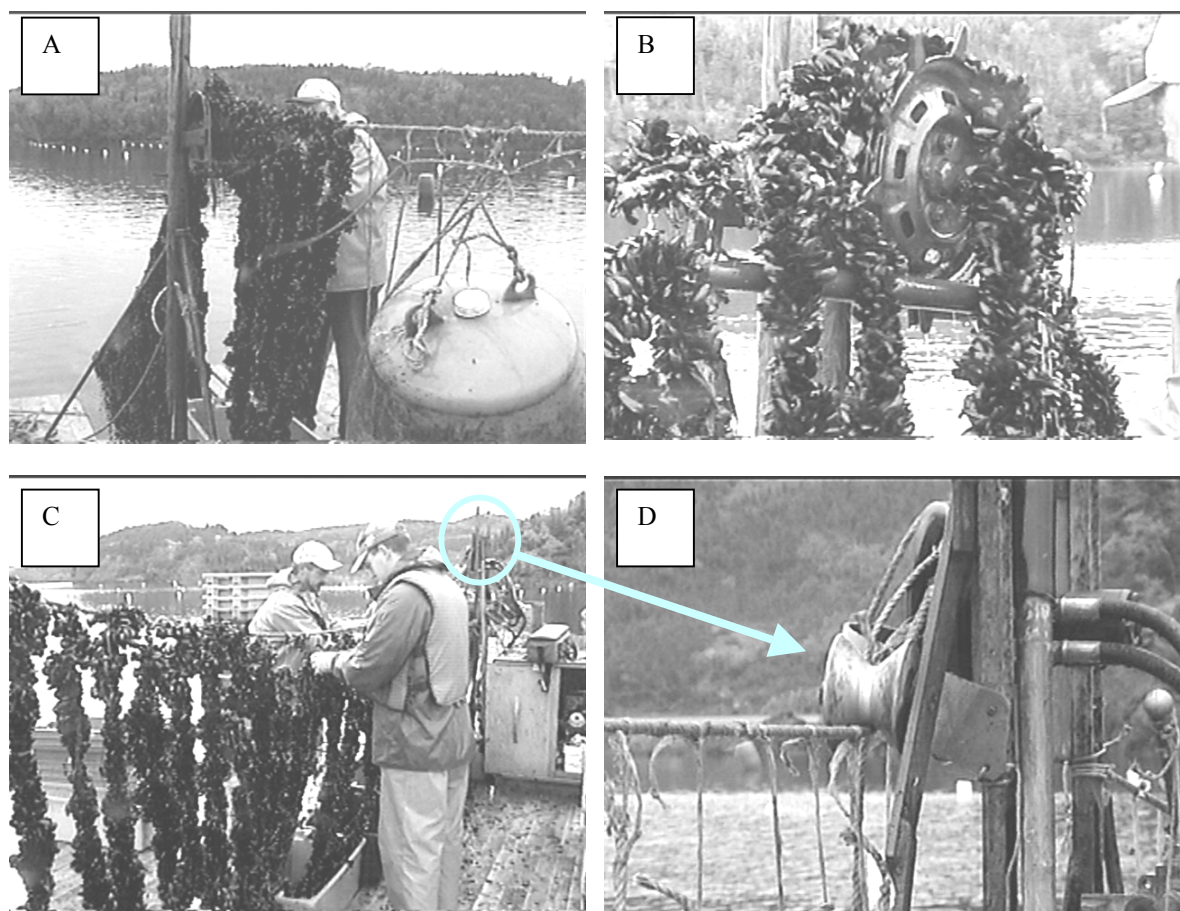


Figure 6.8: Barge design that allows fast easy removal of seed. (A) Seed being pulled up and over a star wheel, (B) home made star wheel, (C) stripping seed to the middle of the barge, (D) rear hauler wheel.

Socking Material

A variety of socking material brands and designs are available for today's mussel grower. Historically the diamond shaped mesh, extruded polyethylene socking was used almost universally in Newfoundland. These are more commonly known as the Dupont, Spanish and Italian brand names. Recently other brands such as the Irish Square Mesh socking and Fukui socking have also been used (Figure 6.9). There have also been very small-scale uses of biodegradable cotton mesh using a rope core in continuous socking trials.

It is imperative that the appropriate socking material and mesh size be utilized with graded seed. The most suitable socking material for the mechanically graded seed appears to be the Irish Square mesh. In field trials for the large grade seed (about 30 mm shell length) the 6.5 cm TML Irish Square mesh sock had a 12 % mussel loss at thirteen months after initial deployment

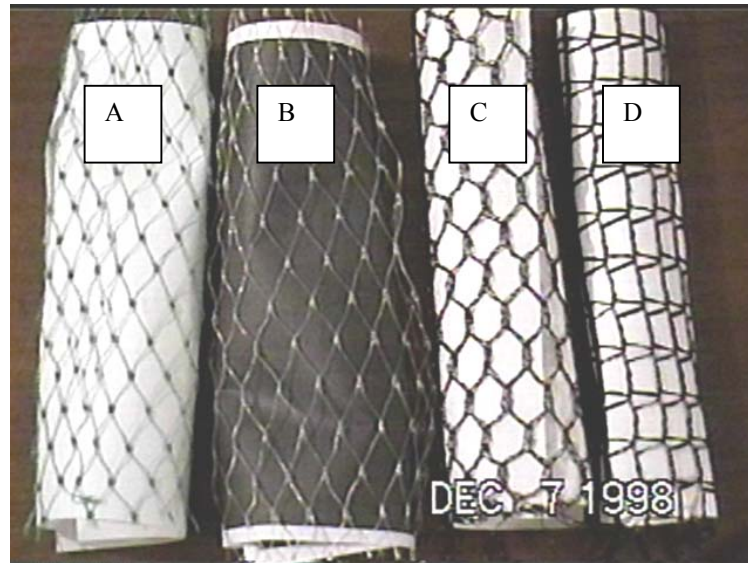


Figure 6.9: Socking brands. (A) 17 mm Dupont, (B) 20 mm Spanish, (C) 20 mm Fukui, (D) TML Irish Square Mesh.

(Figure 6.10B). This compared to 66 % for Spanish (20 mm mesh), 33 % for Dupont (17 mm) and 37 % for Fukui (20 mm). The Irish TMM socking also had better seed retention ability for medium sized seed (initial shell length of about 22 mm) at 38 % loss (Figure 6.10A). This compared to a 49% rate for Spanish (15 mm), 50% for Dupont (14 mm) and 56% for Fukui (15 mm). The 10mm mesh Spanish and the 10 mm mesh Fukui also seem to retain seed very well (data not shown). It should be noted that these results apply to one specific farm and set of husbandry practices, however, similar findings have been reported by several commercial mussel producers in Newfoundland. More information will be forthcoming as the socking experiment is finalized.

Current socking techniques must be modified to use the graded seed. The sock has to be filled tightly, otherwise the seed will fall out. The best method of deployment uses the least amount of handling. Tie the sock right on the mainline as it is filled. If socks are placed in pans, seed loss may occur, particularly in the Dupont, Spanish and the Fukui brands. One of the newer problems in socking mussels is using seed that is too small for a particular mesh size. Prior to mechanical grader use little seed was lost from the socks during or shortly after deployment because the mussels were clumped together via byssal attachment. With the introduction of mechanical seed graders, separated seed of discrete size groups are now available. With no byssal attachment, undersized, loose seed will fall through the socking as it is handled.

Measurements by the Marine Institute on mussel socking mesh size and seed retention for Fukui and Irish square mesh socking suggests that the mussel sizes typically used in these socking materials are much smaller than allowed by the physical characteristics of the sock. For example, the mean mussel length retained by Fukui 15 mm mesh was 39.04 mm, and 61.13 mm for 20 mm socking (Table 6.1). Unfortunately, growers normally place mussels of 20-30 mm shell length

Table 6.1: Average and maximum mussel sizes that could be pushed through a variety of mesh types and sizes.

Sock Type	Mean mussel length (mm)	Maximum mussel length (mm)	Mean mussel width (mm)	Maximum mussel width (mm)	Mean mussel height (mm)	Maximum mussel height (mm)
Fukui 6 mm	28.38	29.7	14.91	15.5	9.43	10.4
Fukui 10 mm	35.17	39.2	18.01	19.6	12	14.4
Fukui 13 mm	40.34	44.8	19.97	21.7	13.61	14.8
Fukui 15 mm	39.04	41.7	19.69	21.7	13.27	14.2
Fukui 20 mm	61.13	68.3	30.51	27.2	21.61	24.9
IrishTMM 4.5 cm	32.95	36.3	16.17	19.0	11.11	12.3
Irish TML 5 cm	38.32	40.3	19.76	20.6	12.98	14.0
Irish TML 6.5 cm	45.78	55.7	23.16	27.8	15.9	19.5

in 15 mm socking and 25-40 mm shell length in 20 mm socking. Supplier information sheets are partially to blame as they suggest a range of mussel sizes to be used for a particular mesh size. For example, mussels of 24-64 mm shell length are suggested for 20 mm Fukui socking. If graded seed is used, even with mussels of approximately 40 mm shell length (very large seed) heavy losses may occur. Growers can check appropriate mesh sizes by pushing mussels through the selected mesh. If the mussels just fall through then a smaller mesh size is required. Mechanical seed graders can produce up to four size grades of seed and consequently a variety of mesh sizes will be required to match seed to mesh size.

Of further note is the variety of mesh shapes that are available in socking material. Currently there are square, hexagonal and diamond shaped meshes available in traditional style socking material. These shapes may influence the size of seed to be used and should be tested by the grower for appropriate seed size prior to socking.

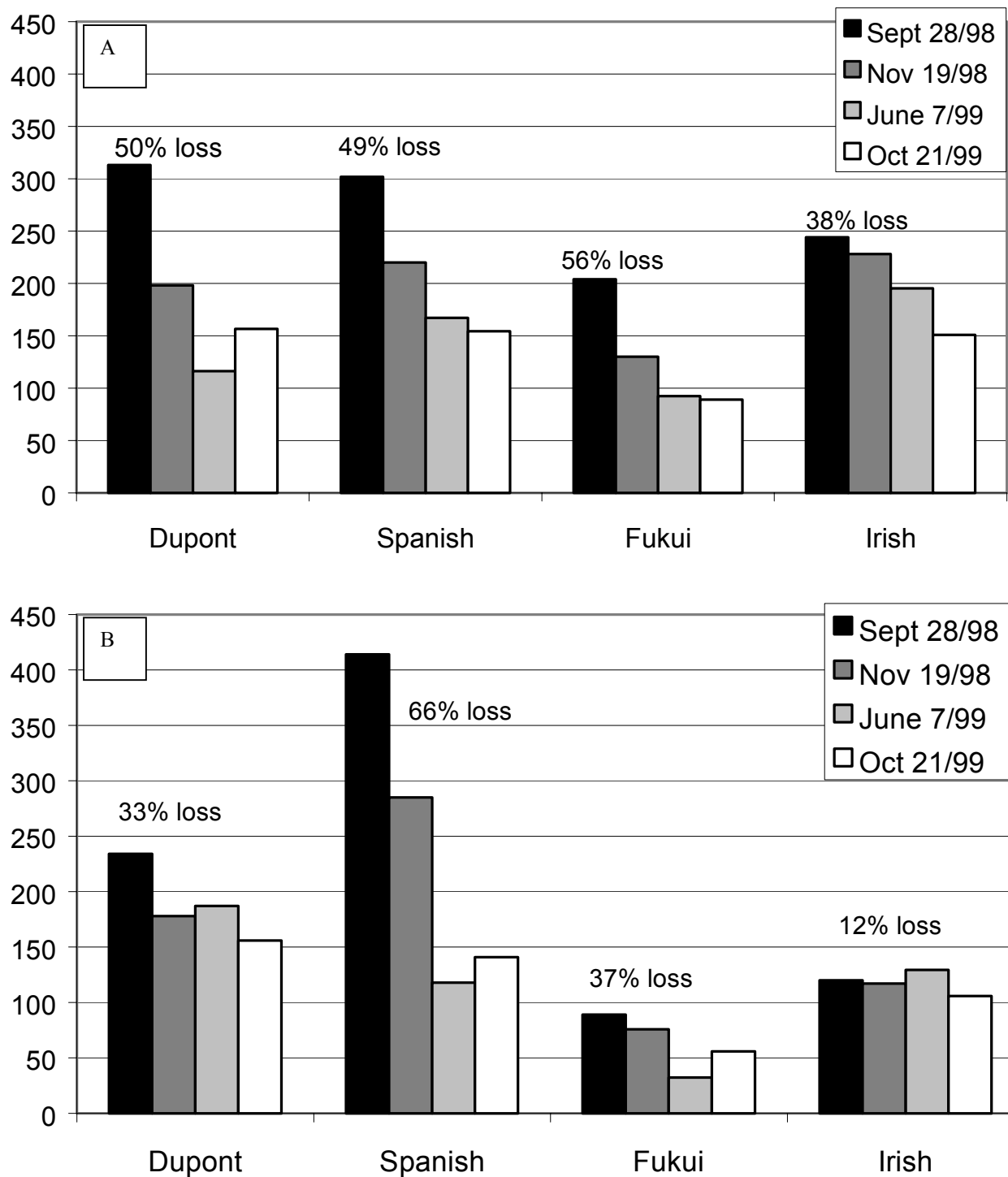


Figure 6.10: Changes in mean mussel density per 30 cm of sock for four sock brands from deployment in September 1998 to final sampling in October 1999 at Cap Cove, Trinity Bay. Socking material had an approximate mesh size of (A) 15 mm, medium seed (15-25mm shell length) and (B) 20 mm large (25-35mm shell length). Values are derived from the mean density from three socks per treatment. Percent seed loss is based on the difference between initial and final sampling densities.

Socking Density

A comparison of mean mussel length to mussel density per 30 cm of sock suggests that mussel density is inversely related to shell length (Figure 6.11). This same pattern occurs wherever mussels are cultivated in suspension (Frechette 1993, Mallet and Myrand 1995). This implies that as the mussels get larger there is less space available on the sock and some mussels are forced off. This drop off caused by space and/or food limitation is called “Self-Thinning” and is a well known principle in land based farming (Frechette 1990, 1994, 1998)

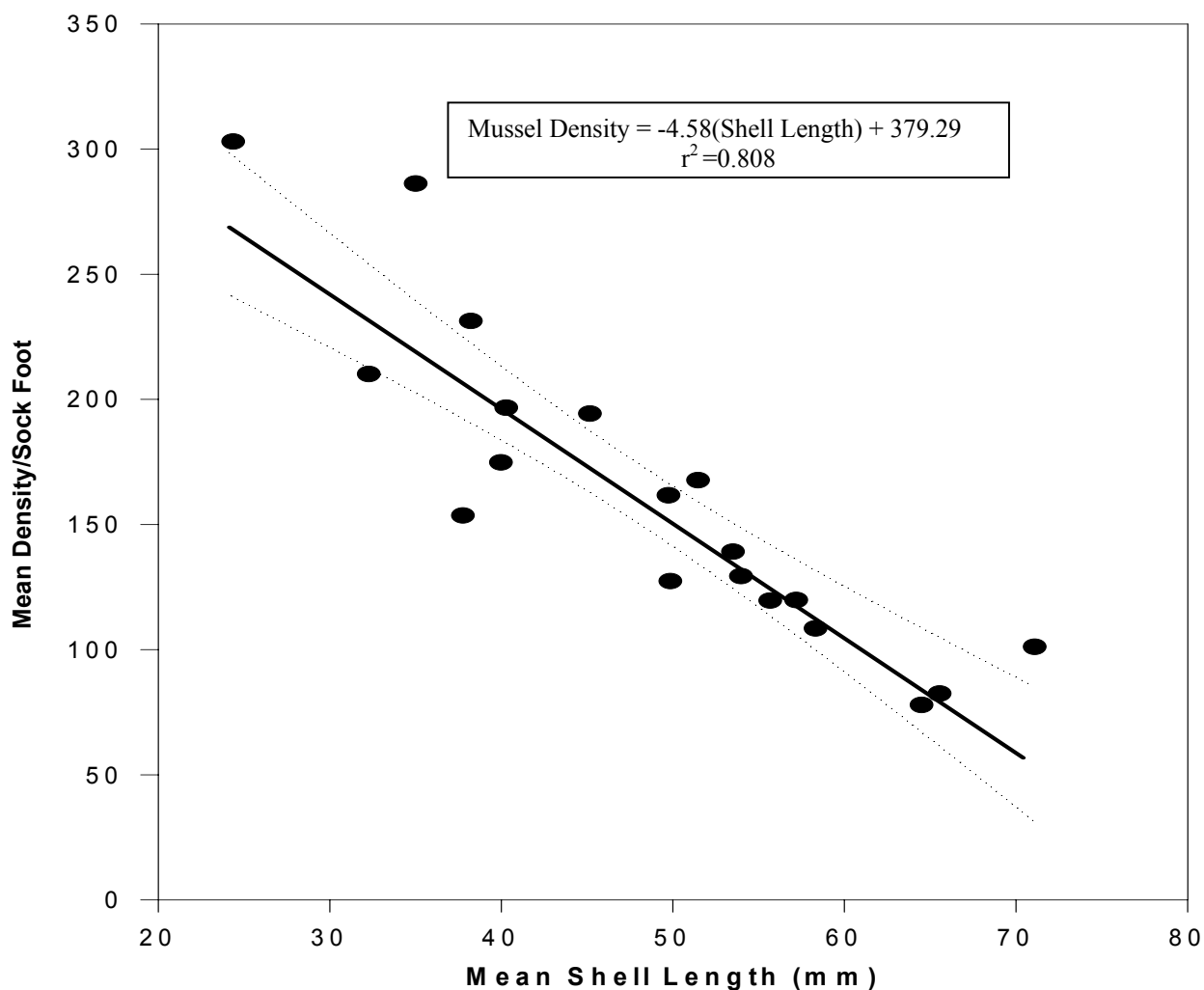


Figure 6.11. Relationship between mean mussel density per 30 cm sock and the mean shell length (mm) of socked mussels from nine commercial grow out sites in Newfoundland. Sites were sampled in the fall of 1997.

As shell length increases to market size (assuming a mean size of 55 mm and 85-95 % of the mussels are greater than 50 mm shell length) a 30 cm length of sock can hold a maximum of approximately 127 mussels. This of course is dependent on food and current conditions at the site and higher or lower numbers do occur at harvest time. This means that the average socking density of 197 mussels per 30 cm of sock, for the 8 growers that supplied newly socked samples resulted in a loss of 79 mussels per 30 cm of sock. If mussels are permitted to grow to a mean shell length of 60-65 mm, then the density drops to 89-100 mussels per 30 cm of sock. This results in a loss of 97-115 mussels per 30 cm of sock, approximately half the original density (based on ungraded seed).

A number of factors are responsible for the decline in the number of mussels per 30 cm of sock over the growout period, including self-thinning, type of equipment (floats, socking material), whether lines are at the surface or submerged and site environmental characteristics (water flow, food, and wave action). Of these, site characteristics, initial socking density and husbandry techniques are likely to have the greatest influence on the number of mussels that are lost from socks over the growout period. It is worth mentioning that mussel producers in other areas of Atlantic Canada obtain harvest densities of 60 to 80 mussels per 30 cm (mean size of 55-60 mm shell length) of sock/rope regardless of the initial density (Broom 1992, Mallet and Myrand 1995).

Current practices in other areas of Atlantic Canada include socking densities in the range of 125-275 mussels per 30 cm of sock, using graded seed (Mallet and Myrand 1995, Gordon Deveau, 1997, pers. comm.). Deciding on an appropriate density for Newfoundland is difficult because of the wide range of environmental and growing conditions. Consequently the environmental conditions of the site, the production capacity, the secondary set potential, the size of the seed, the desired harvest size and the type of socking material to be used must be considered to predict a socking density for a particular site.

Environmental conditions and thus production capacity ultimately dictate growth rate and yield on a site. Lower capacity sites may generate faster growth by lowering socking densities. If socking densities are lowered too much an increase in fouling may occur causing the mussels to be displaced and result in lower yield. Higher capacity sites may be capable of using heavier socking densities and generate large yields per sock (20-30 kg). If the density is too heavy not only is seed wasted but there is also a risk that the mussels will be too heavy for their own byssal attachment and peel off the sock. In addition heavy socking densities may cause slower growth and lower meat yields. Therefore it is important to be very careful when adjusting socking densities.

Another consideration is secondary set. Secondary set may be reduced or avoided by increasing initial socking densities, and reducing the space available for mussel spat to settle. If a site is subject to second set, it may be wise to start with higher initial socking densities rather than risk losing the entire crop.

Acceptable harvest size and yield will also play a role in determining appropriate socking density. If smaller mussels (50-55mm) are desired then a higher socking density is in order to generate the necessary sock yields. According to the model (Figure 6.11), mussels of average

size 50-55 mm will require 127-155 mussels per 30 cm at harvest time to generate approximately 11.7 kg (25 lbs.) per sock. If a larger size is required, 55-65 mm then 82-127 mussels per 30 cm of sock is required at harvest time. The model only predicts the number of mussels that must remain at harvest time and not initial density. The model then can only act to suggest a minimum initial socking density. Obviously the grower would sock at higher initial densities to allow for potential losses from environmental conditions.

Mechanically graded seed requires that socks be filled tight and that seed size be better matched to socking mesh sizes to prevent initial seed loss. Consequently, the type of socking material used will dictate initial socking density. Attempts by the grower to reduce socking density by not filling a sock will typically result in huge losses of seed. Growers must therefore choose a sock that provides a density that best suites the particular needs of the site and the grower.

Although specific recommendations on initial socking densities for the Newfoundland mussel industry would be premature general guidelines follow. For medium size grade seed (20-30 mm shell length, second grade on most graders) an estimated 200-300 mussels per 30 cm is suggested. This density can be achieved using a 4 cm (1.5") socking tube with the Dupont 14 mm (blue), Spanish 15mm and Irish TMM (4.5 and 6.5 cm diameter) socking materials. For large grade seed (25-35 mm shell length, third grade on most graders) an estimated 150-250 is suggested. This density may be achieved using the Dupont 17 mm or Irish TML (6.5 cm and 7.5 cm diameter). The largest seed that should be socked (35-40mm, mean shell length, last grade on grader) should use an initial density of 125-175 mussels per 30 cm of sock. This density may be achieved in the Irish TML socking (6.5 and 7.5 cm diameter). All sock type suggestions are based on the study of the four types of socking indicated in Figure 6.9, other sock brands (i.e., Italian) were not considered and may be suitable. **These suggestions are meant only to provide general guidelines, and growers should determine what works best for them. Any testing should be done on a limited scale in the event that the new density proves less viable than historic levels. If unsure of initial socking densities, growers should experiment at a small scale with three to four densities (150-400 mussels per 30 cm of sock) and determine which is most suited to their particular site conditions.** It is recommended that Irish square mesh be used for any density testing because four tube diameters can be purchased in the same mesh size. The tube size differences can be used to generate consistently different trial densities.

A study on socking density is now in the analysis phase and when completed, should provide a more precise optimum density range for a variety of site conditions.

Once an optimum density is determined for a particular seed size, the next logical step is to ascertain the most appropriate seed size to sock. Mussel collector data from the NAIA Larval and Spatfall Monitoring Program indicated that in the spring of 1997, 12 out of 19 sites had mussel spat with a mean length greater than 15 mm and three sites had seed greater than 20 mm. The remaining sites had mean mussel sizes between 10 mm and 15 mm. The mean seed density at these sites was between 800-1000 spat per 30 cm of collector. If mussels are socked at this time of the year (i.e., spring) using an initial density of 200 mussels per 30 cm of sock, approximately three 3 m socks could be generated per 1.8 m collector. This is approximately double the current ratio obtained by using large seed socked in the fall. One grower in 1998

socked mussels (about 10-15 mm shell length) in the fall of the same year that the mussels set. He stated that 700 3m socks were filled from only 14 pans of seed, with 8 collectors per pan. That is a sock to collector ratio of 6.25:1.

Average mussel densities are low on collectors after one year. For example, at one site sampled in November the mussels (1 year old) on the collector had dropped to a mean density of 408 per 30 cm of sock (NAIA-Marine Institute Mussel Extension Service Survey, 1997). If initial socking densities of 200 mussels per 30 cm of sock were used at this time only 1.63 socks could be filled per collector. This suggests that the later the socking time the lower the mussel density per 30 cm of collector. The self-thinning principle applies equally to both socks and collectors.

If mussels were socked earlier in the year at this site when densities were higher on collectors (assuming seed size is greater than 10 mm) then the number of socks per collector is expected to double. Similarly, if seed is purchased early in the year when the mussels are typically small the grower should realize about double the number of socks for the same weight of seed. From this approximately 20 socks could be filled from one tote by socking early in the year.

Overall, if a mean socking density of 200 mussels per 30 cm of sock is used, a considerable saving in mussel seed costs could result from socking small seed in the spring vs. large seed in the fall. For a 10,000 sock farm this saving could amount to \$10,000 (Table 6.2), or about half the cost of socking in the fall with larger seed. Unfortunately it is unlikely that all sites will be able to sock in the spring and those sites which have secondary sets may experience problems from reducing socking density. If a spring deployment of socks is considered by growers, care must be taken not to sock the seed too close to their spawning time in June or July. It would be best to have early socking completed before the end of May to early June at most sites. Moreover care must be taken to avoid long periods of mussel exposure to sun, rain, and wind.

Table 6.2. The seed cost associated with socking at a density of 200 mussels per 30 cm and in the spring versus the current method of fall socking. An initial socking density of 197.3 mussels per 30 cm, was derived from a survey of 8 Newfoundland mussel growers in 1997. Costs are based on a 10, 000 sock farm using a cost of \$20 per tote of seed.

	Socking Density (Mussels/foot)	Socks/Tote	No. of Totes Needed	Cost of Seed
Fall	197.3	10	1000	\$ 20,000.00
Spring	200	20	500	\$ 10,000.00

There are additional benefits to socking smaller seed earlier. The first is that mussels will reach market size sooner. Reducing mussel density (from collector to sock) earlier in the year will present the mussels with improved access to space and food potentially resulting in improved

growth (shell length and meat yield) and thus growout times. MacMillian (1990) suggested that mussel lines that had density reduction produced higher marketable yields than those lines that did not.

Secondly, with the higher sock to collector ratio, fewer collectors will have to be stripped and thus fewer pans handled. One grower required 70 pans of seed in late fall using large seed to generate 700 socks. This same grower, as indicated above, required only 14 pans to generate the same number of socks using smaller, younger seed. Handling 70 pans of seed instead of 14 requires a considerable amount of extra labour, deck space and grading. Each pan is moved a total of at least three times, from the barge to the grader, from the grader to the table, and from the table to be tied on the mainline.

The Case for Seed Grading

Grading in aquaculture is a common tool to keep similar sized individuals in the same growing location. Grading typically results in faster growth, a more uniform sized product and a more consistent high quality product. It will also likely produce higher yields per site than ungraded mussels. Grading is commonly practiced in all commercial mussel industries elsewhere.

There was no mechanically graded seed used in 1997 by the surveyed growers, however, 1998 saw the use of new seed graders in Newfoundland (see Graders in Chapter 7). A number of commercial growers do grade their seed manually, but this requires clean seed free of fouling and second set, a narrow size range of seed and seed with relatively little byssal attachment. Seed sources such as these can be located but are rare and only the experienced mussel farmer is able to use this type of seed efficiently.

The new mechanical seed graders were either one of several PEI grader designs or a new design created by Fab Tech Industries (Appendix 2) in Newfoundland. These graders generate up to four size grades of mussels (shell height: 4.5 mm (3/16"), 9.5 mm (3/8"), 12.5 mm (1/2") and greater than 12.5 mm). These grade sizes can be custom made if the grower desires.

Newfoundland mussel farmers harvest mussels of a variety of sizes and consequently receive varying yields from processors. The key is to limit the size range at harvest so that optimal yields are obtained. Only a few of the more experienced growers are able to do this on a consistent basis. In our survey, for example, the average yield per tote of nine growers was 29 kg (64 pounds) per tote and ranged from 16-34 kg (36-75 pounds) per tote. If the 30% overpack deduction by the processor is ignored then the weight of harvest size mussels per tote was in the range of 21-44 kg per tote. Some of the growers suggested that a tote pan contains 45-54 kg (100-120) pounds of mussels. This means that 10-24 kg (22-53 lbs.) of material is considered non-market mussels. According to our survey a mean of 11.32 % (n=8, s=4.39%) of the total weight consisted of empty shells and fouling. The remainder, 4-19 kg (9-43 lbs.) were undersized mussels. This represents a huge loss of potentially marketable product and results in considerable extra floatation and maintenance costs. Seed grading whether done manually or mechanically, should ensure that the harvest size mussels are a more uniform size resulting in a

lower percentage of undersized mussels at harvest. It is noteworthy that the most experienced mussel farmers surveyed rarely obtain yields lower than 43 kg (95 lbs.) per tote pan before overpack is considered and they average 32-34 kg (70-75 lbs.) per tote after 30 % overpack is incorporated into the yield.

A comparison of the size distribution of mussels sampled during initial sock deployment indicates a wide variation of sizes in ungraded seed compared to the graded seed at one site in Trinity Bay (Figure 6.12). It is obvious that mechanical grading can reduce seed size ranges in socks at deployment, but does this uniformity continue through to harvest? After 13 months in sock at the site in Trinity Bay both the graded and ungraded seed demonstrated increased uniformity of mussel sizes within the sock. The graded seed had only a marginal increase in uniformity while the ungraded seed was nearly twice as uniform at 13 months compared to initial deployment. The graded seed was more uniform in size after 13 months in sock than ungraded seed.

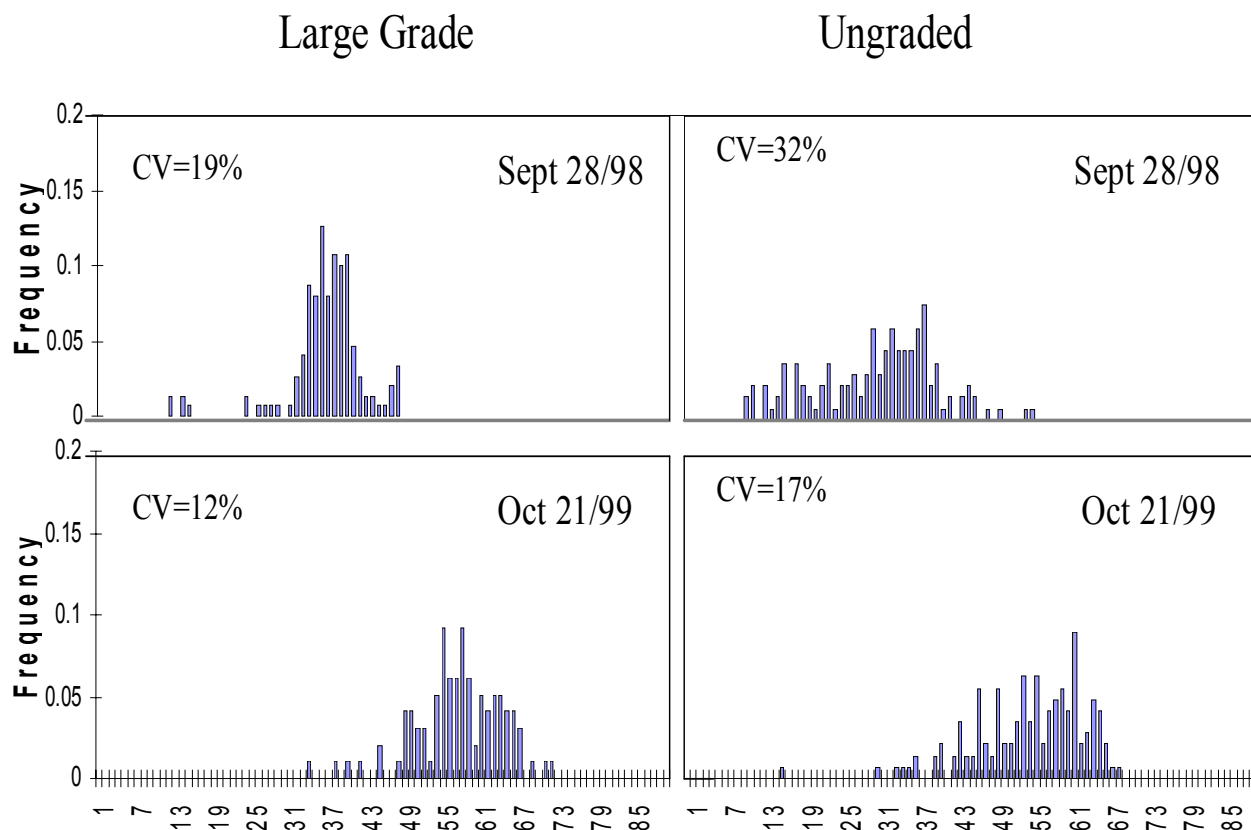


Figure 6.12: A comparison of relative frequency of seed sizes in ungraded and graded seed using Irish square mesh TML (6.5 cm diameter) socking. Ungraded seed and large grade seed were socked and sampled on September 28/98 and sampled again on October 21/99 at Cap Cove, Trinity Bay. Variability of seed sizes is indicated by the Coefficient of Variation (CV) for each treatment at the beginning and end of the experiment.

The increases in uniformity demonstrated by the ungraded seed may be attributed to the greater initial mussel seed density (120 mussels per 30 cm for graded and 214 mussels per 30 cm for ungraded) for the ungraded mussel socks. The greater the initial density the greater the potential self-thinning. With increased self thinning many of the smaller mussels initially present may have been lost. It is likely that graded seed at other sites will demonstrate higher uniformity throughout the growout cycle resulting in higher quality product at harvest.

Mechanical seed grading may increase growth rate by separating the fast growers in the population from the slower growers, allowing all mussels better access to food and space. For example, medium grade seed (about 24 mm shell length) socked in Irish square mesh socking at the Trinity Bay site had an average growth rate of 0.074 mm per day over a 388 day period. This compared to 0.06 mm per day for ungraded seed from the same seed source. The large grade (about 35 mm shell length) had a slightly lower growth rate of 0.053 mm per day for the 333 day period. This is expected as larger mussels typically grow at a slower rate with respect to shell length. In fact, survey results suggested that mussels around the island typically grow 30-35 mm in the first year, 15-20 mm in the second year and about 10 mm in the third year (refer to Chapter 1).

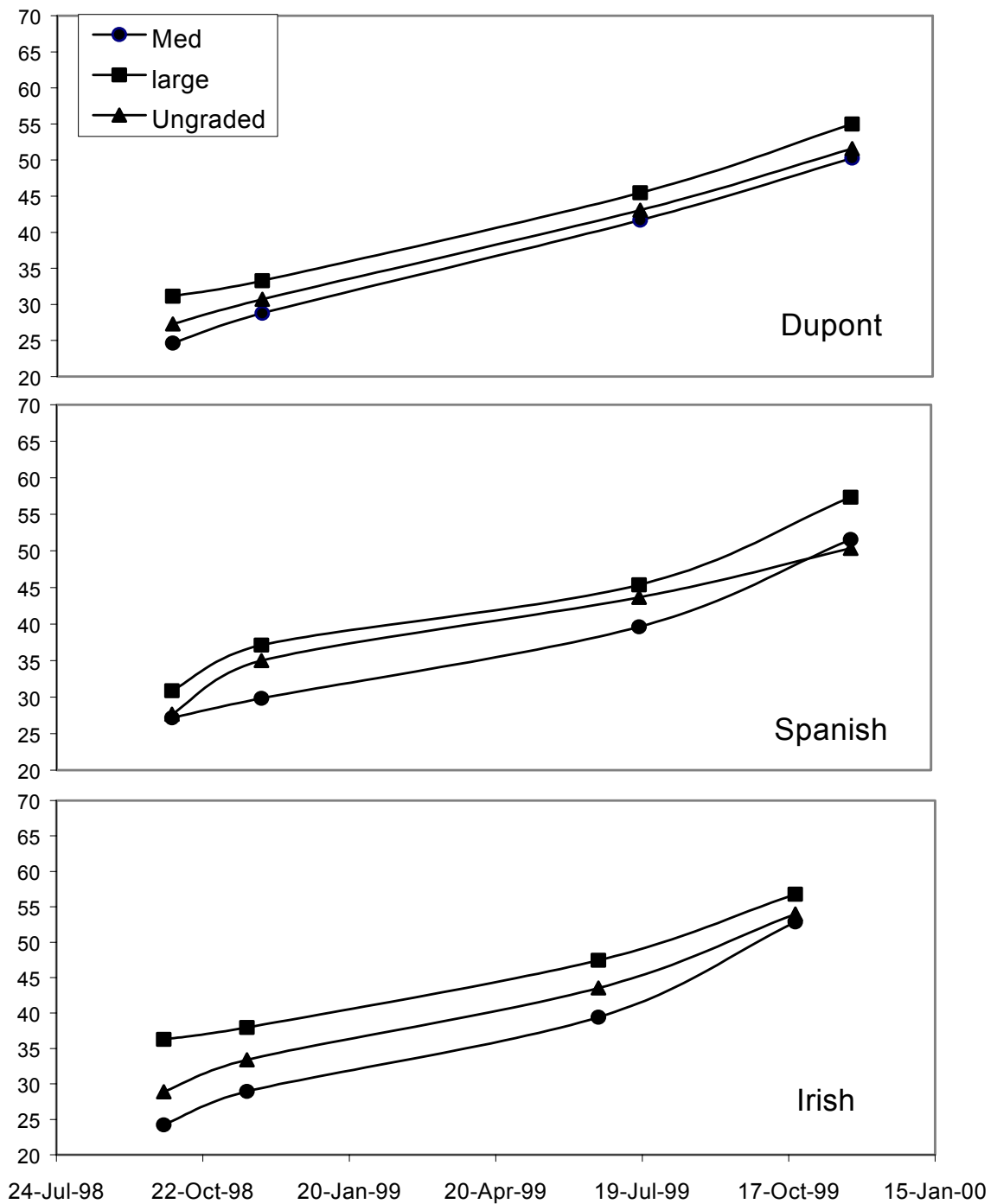
The large grade seed was 3- 6 mm larger on average than the ungraded seed at initial deployment and remained 3-7 mm larger 13 months later depending on sock brand (Figure 6.13). The medium grade seed, which was 3-5 mm smaller on average than the ungraded seed, met or surpassed the mean size of the ungraded seed after 13 months. The indication then at this site is that by separating the larger mussels from the smaller the grower can exceed the mean size of ungraded seed by approximately 5 mm, which from a growout perspective can represent six months of growth. Additionally, size grading has allowed medium sized mussels to reach a size that is equivalent to ungraded seed.

Even if increases in growth are not substantiated, by placing the largest mussels together in a sock the grower should shorten time to harvest compared to ungraded seed that would contain many smaller mussels. Upon completion of the ACERA socking experiment, information concerning yields and growout times will be available for graded and ungraded seed.

Mussel Growth

Loo (1992) suggested that high food quality during the spring phytoplankton bloom was resulted in increased food absorption efficiencies by mussels, even in water with temperatures of -1°C . This suggests that there is no limiting effect of temperature on mussel growth. In fact, the spring bloom may be the period of maximum growth. Loo and Rosenberg (1983) reported that mussel biomass doubled during the spring bloom in Norway. In Newfoundland waters, Sutterlin et al. (1981) indicated that mussels doubled their shell length from March to August under high density (culture nets), with the fastest growth period during May and June. This March to August period represents approximately 75 % of the growth of the mussels for the year (Figure

6.14). This is comparable to the growth pattern (Mallet and Carver 1989) of mussels in Nova



Scotia that have a peak growth period between June and October. This is likely also due to the

Figure 6.13: A comparison of mean shell lengths (mm) of large (30-35 mm mean shell length) and medium (24-27 mm mean shell length) size graded seed and ungraded seed from the same

seed source socked on Sept 28/98 and sampled on June 7/99 in Cap Cove, Trinity Bay. Data are presented using three sock brands, Dupont, Spanish and Irish Square Mesh socking.

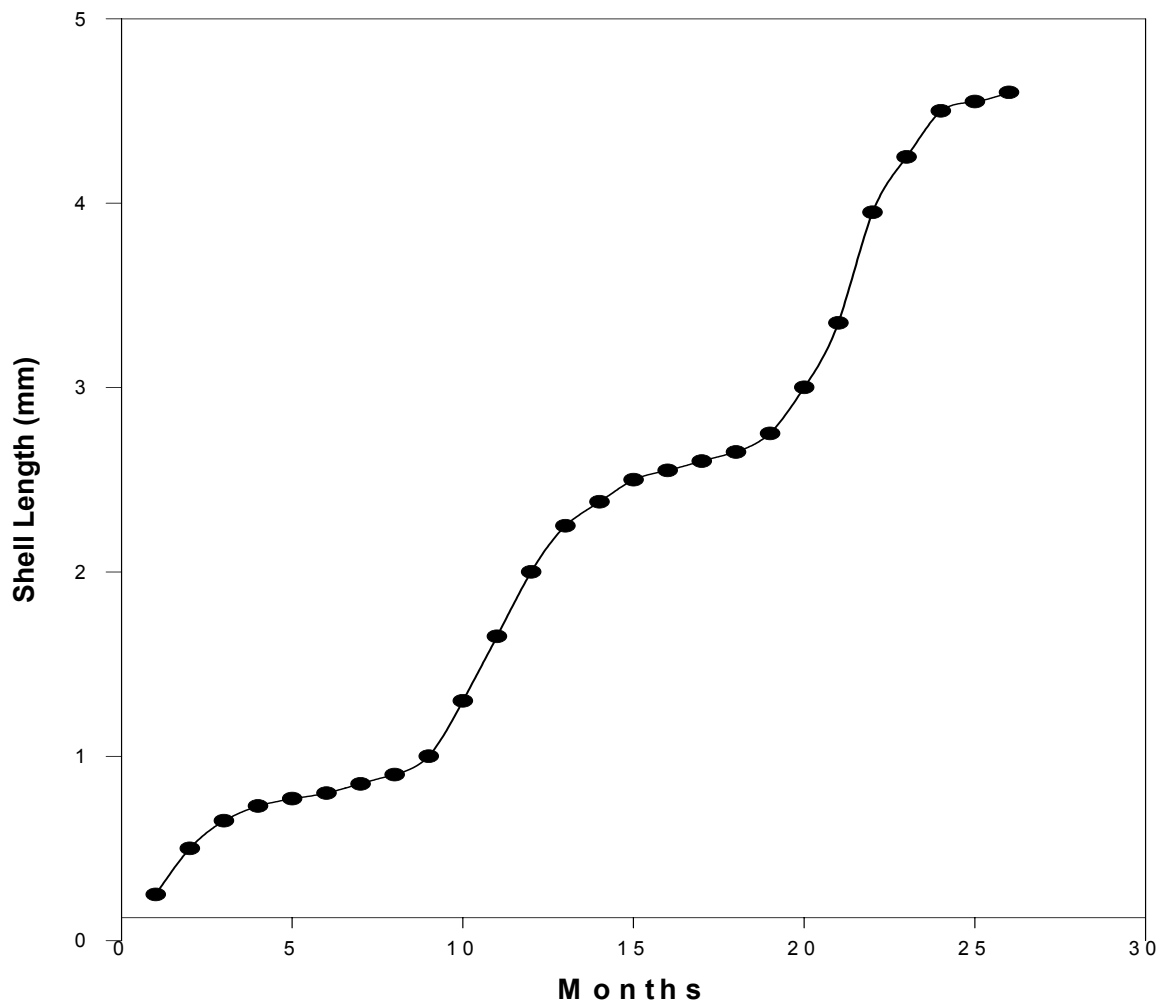


Figure 6.14: Mussel growth pattern over a 25 month period. Adapted from Sutterlin et al. (1981). The first data point begins in August. The period of maximal growth occurs from April to August and is indicated by the shaded areas.

presence of the spring phytoplankton bloom. In the Mallet and Carver study, virtually no growth occurred between October and December, but increased between December and April, when the spring bloom occurred again.

The practice of socking from September to December causes the mussels to grow at high densities on collectors during the optimum growth period from May to September in their first year. By socking earlier in the season, mussel densities could be reduced during the prime growth period potentially resulting in increased growth.

To test this theory, an experiment was initiated at a commercial mussel farm in Trinity Bay. Socks were deployed in late June and again in late September using the same seed source to determine if early socking times increased mussel growth. Mussel seed size was small in the spring (approximately 12 mm shell length) relative to normal Newfoundland standards (i.e., 20-40 mm) and had to be socked in 10 mm or smaller mesh. Initial seed densities in the three sock types utilized in June were high, ranging from 500-1,900 mussels per 30 cm of sock. When compared to the fall deployment (socked at lower densities ranging from 200 – 500 per 30 cm of sock) the spring treatments had approximately 4 mm larger mean mussel sizes in two of the three types of socking as of October 21/99 the final sampling date (Figure 6.15). The contradicting results are likely due to the high initial socking density of the spring treatment (1,900 mussels per 30 cm of sock) and the relatively low initial seed density of the fall treatment (215 mussels per 30 cm of sock).

Of further note, the length of Newfoundland mussels socked in June was similar to that of mussels in Nova Scotia socked during the same time of the year and sampled in December (Mallet and Carver 1989). This suggests that reducing mussel density by socking during the initial part of the spring bloom provides more high quality food per individual and improves growth to the extent that Newfoundland grow out times are comparable to those of Nova Scotia. If this proves true more Newfoundland growers could harvest mussels after only 12-18 months of growout in sock, reducing the sock year classes to two instead of the usual three. With only two year classes, there would be more space available to expand annual sock output.

If we refer to the 10,000 sock farm example, under current practices the site has a capacity for 30,000 socks, 10,000 newly socked, 10,000 socks of 12 plus months, and 10,000 socks of 24 plus months. By reducing growout time such that all mussels are harvested before 24 month, the need for a third year class is eliminated. This means approximately one third of the site space is now available. If utilized this space could allow the addition of 5,000 socks for each of the two cohorts now in use. This new practice would result in a harvest of 15,000 socks per year rather than 10,000, assuming all other things are equal (e.g., that the production capacity is not exceeded)

If growers are going to sock earlier in the season it is recommended that they wait until the majority of the mussels reach the 9 mm (3/8") grade on the mussel grader (use a 12-13 mm mesh sock). This will allow at least some size grading during the socking process. Many areas should reach this growth stage by late June. Some areas may reach this stage late in the fall of the same year as collectors are deployed. Regardless of growth benefit, under no circumstances should mussels be socked if water and or air temperatures are high. Socking during warm air and water

conditions can result in mussel kills in the newly deployed socks, often to the extent that the entire sock deployment is lost. Socking is not recommended when water temperatures are greater than 14-16°C at most sites. In addition it is best to avoid socking immediately before mussels have spawned and for some time following spawning to allow the animals to recover. This will limit many sites to socking times in May and early June and in late September to December.

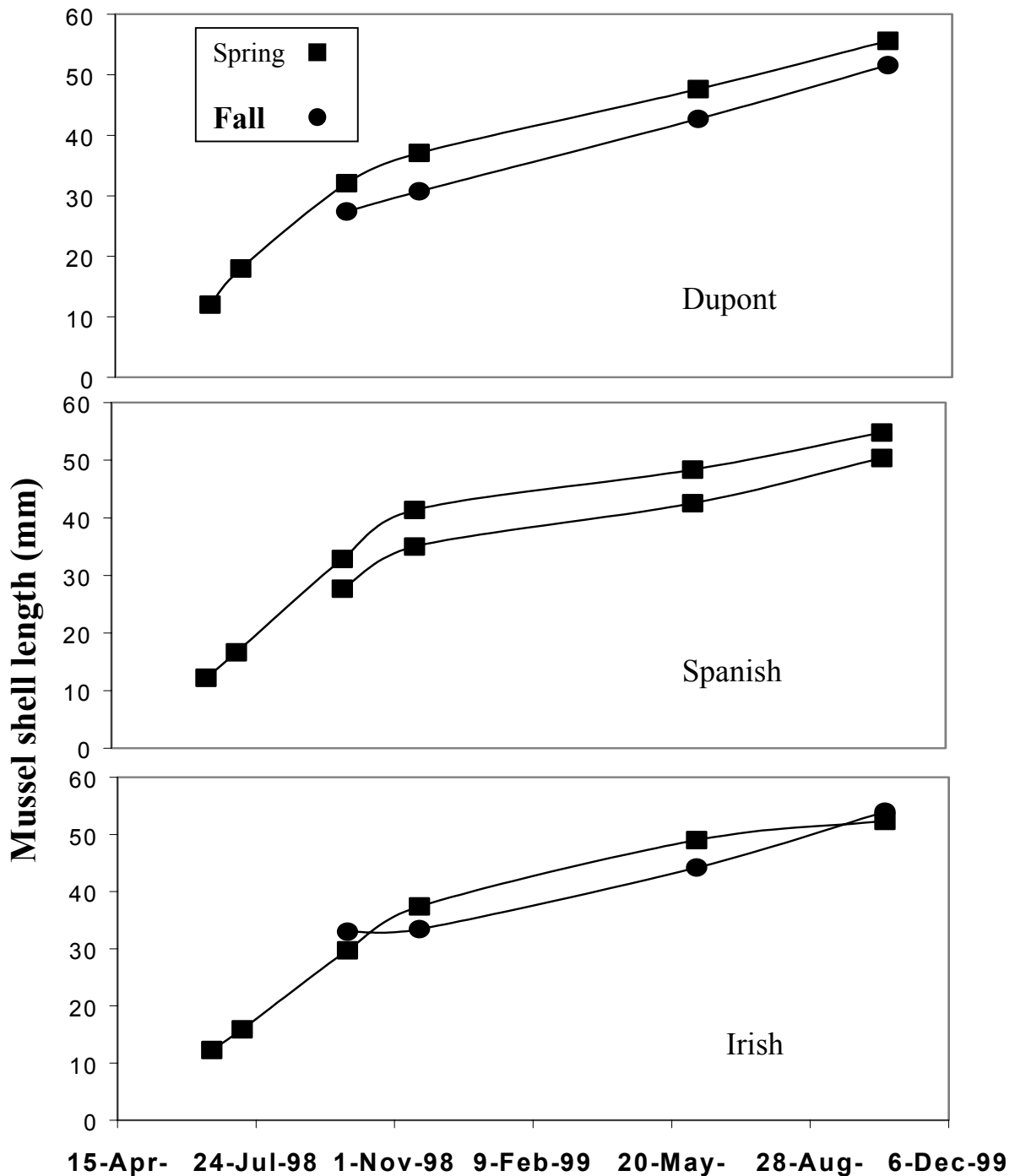


Figure 6.15: A comparison of mean mussel shell length (mm) for mussels socked on June 22/98 and mussels socked on September 28/98 at a commercial mussel farm in Trinity Bay, Newfoundland. Mussel lengths were averaged using 150 mussels from each sock types (Dupont, Spanish and Irish) per sampling period.

