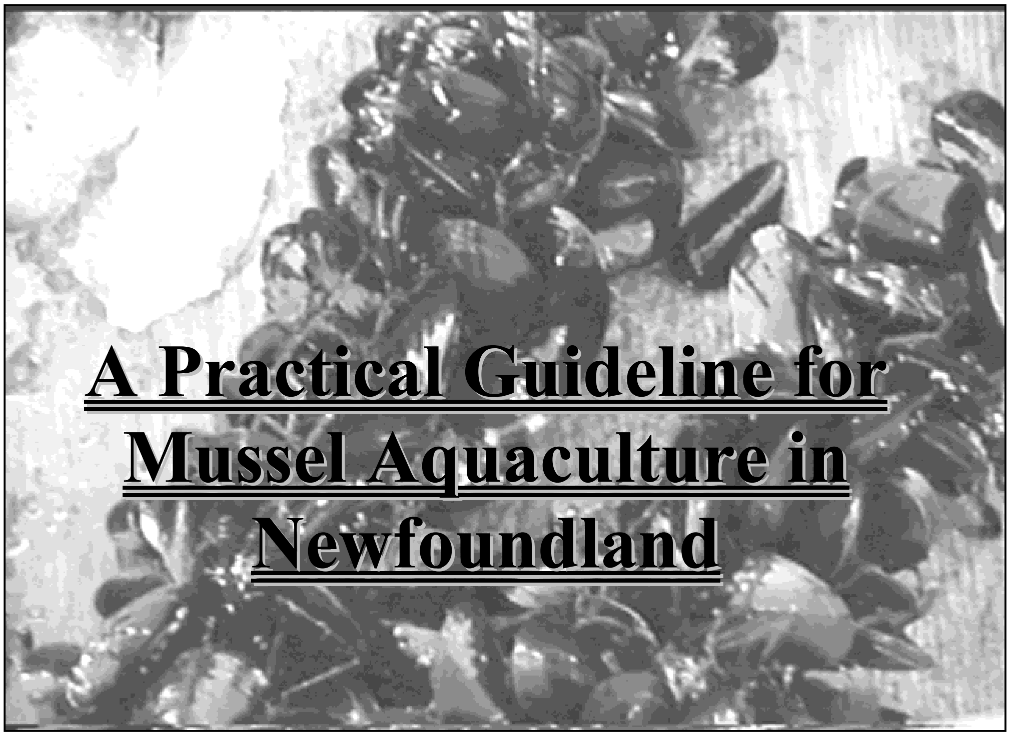

# A Practical Guideline for Mussel Aquaculture in Newfoundland

**Developed for the Newfoundland Aquaculture Industry Association**

**by**

**The Marine Institute of Memorial University of Newfoundland**
**Centre for Aquaculture and Seafood Development**
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## Foreword

The Newfoundland and Labrador mussel culture industry has been in existence for more than 15 years, and recent interest in commercialization has increased. A number of impediments to full industry commercialization were identified by the Newfoundland Aquaculture Industry association through extensive consultation with mussel producers in 1996 and 1997. The following constraints, not in any particular order, were seen as items for "Immediate Priority" in alleviating the constraints:

Seed availability for mussel culture – larval and spatfall prediction
Assess production capacity of shellfish sites
Enhance mussel farm growth and production
Assess seed source and farm production
Collect baseline data on the health of mussel populations
Examine causes of mussel drop-off and mortality
Access to working capital for farm expansion
Producer training and skills upgrading
Access to product marketing
Access to new sites and water quality testing

Items one to six are being addressed by a comprehensive, multiyear program jointly sponsored by the Canadian Centre for Fisheries Innovation (CCFI) and the Newfoundland Aquaculture Industry Association (NAIA). The program began late in the fall of 1997. Funding for the program is provided by the Canada/Newfoundland Economic Renewal Agreement-Aquaculture Component (ACERA), the Atlantic Canada Opportunities Agency (ACOA), CCFI, and the Marine Institute of Memorial University. Items seven to ten are being addressed separately by the NAIA and other provincial and federal government departments.

The following manual entitled "A Practical Guideline for Mussel Aquaculture in Newfoundland" provides a version of current and proposed industry practices in Newfoundland. The information was generated from various sources, including preliminary farm site surveys, producer surveys, NAIA sponsored projects, and provincial government statistics (Department of Fisheries and Aquaculture). All information pertaining to individual farm practices remains confidential, as requested by growers. As such, names, places and site information are excluded from the manual.

The general purpose of the manual is to provide brief descriptions of how the current mussel industry operates and to offer some suggestions for improvement in production efficiency. The goal is to assist with improvements in overall husbandry and operating practices for the benefit of the industry. The idea is not necessarily to advocate one method of practice over another, as various producers are at different levels of development. The decision on which practices to adopt remains, as always, with individual growers.

The information contained herein is incomplete, as a limited number of producer and site surveys were performed. Given the limited information, conclusions and comments in the manual are tentative at best. Suggestions for improvements or additions to the manual are welcomed, and should be given to project personnel.

Cyr Couturier
ACERA Mussel Program Manager for NAIA and CCFI

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After two years of measuring, weighing, late night phone calls, cold wet early mornings, thousands of kilometers and long hours in front of a computer screen the "A Practical Guideline for Mussel Aquaculture in Newfoundland" is finally complete.

The following individuals spent a considerable amount of time gathering and providing information for the manual and we acknowledge their contribution: Christa Linthorne, Danielle Nichols, Steve Canning and Tony Clemens.

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**Most importantly, we gratefully acknowledge the valuable contributions of all the commercial mussel growers in the Province for freely allowing prolonged interview sessions. Special thanks goes out to the Newfoundland mussel growers who donated their valuable time for site surveys and encouraged many of the photographs presented in this work. These mussel growers are listed below in no particular order.**

| | |
|---|---|
| Brad Clarke | |
| Alvin Hodder | Farewell Mussel Farms Ltd. |
| Terry Mills | Thimble Bay Farms Ltd. |
| Geoff Ball | B & B Forest Products Ltd. |
| Job Halfyard | Sunrise Fish Farms Inc. |
| Derrick Caines | Drac Bay Aquaculture Inc. |
| Juan Roberts | Badger bay Mussel farms Ltd. |
| Mat Diamond | |
| Joe Keating | Bae Sea farms |
| John Carter | Conaqua |
| Lloyd Fudge | Cross Bay Mussel Farms Ltd. |
| Ed Sheppard | Northeastern Shellfish Ltd. |
| Herb Noel | Noel Brothers Mussel farms |
| Colin Adey | B & C Mussel Growers Ltd. |
| Rick Pippy | Shells and Fins Inc. |
| Clayton Matthews | |
| Jim Ward, Joe Wiseman: | Atlantic Ocean Farms Ltd. |

The extra efforts made by Joe Keating, Geoff Ball and Rick Pippy are especially noted for their contributions of time and equipment to set up socking experiments on their sites.

In addition, Jim Ward, Juan Roberts, Terry Mills, and Alvin Hodder acted as the industry review board for the development of the practical guideline.  Their advice and critiques enhanced the practical nature of the guideline.

**Finally, thanks must go out to the funding agencies that supported this endeavor.  These include the Aquaculture Component of the Canada/Newfoundland Economic Renewal Agreement (ACERA), the Canadian Centre for Fisheries Innovation (CCFI), The Newfoundland Aquaculture Industry Association (NAIA), and the Marine Institute of Memorial University.**

## A Practical Guideline for Mussel Aquaculture in Newfoundland

## Introduction

One of the common comments of growers in the Newfoundland mussel aquaculture industry is that they learned how to grow their mussels by trial and error or simply from years of experience. In addition, they expressed a concern that detailed information on the best available grow out methods is lacking. Consequently new growers entering the industry may encounter the same difficulties as the original entrants. The fact that these growers are successful is a credit to their ingenuity, but the end result from many individual trial and error attempts is a variety of husbandry techniques and equipment. These techniques and equipment have varying successes and efficiencies. Most of the estimated 1700 metric tonnes of product available in the year 2000 and again in 2001 will come from a few select growers that are utilizing proper husbandry techniques and technologies. To further increase province wide production these successful practices must be past on to other growers. As a developing industry, an attempt must be made to determine the best techniques and equipment to maximize mussel production and minimize expense to allow the industry to be competitive in the market place.

To achieve this goal, a three-year study into mussel industry practices commenced in the fall of 1997. This study is designed to analyze current mussel husbandry practices and equipment in an attempt to develop practical guidelines that will provide detailed instructions and suggestions to optimize production from Newfoundland mussel farms.

The following is the end result of that study, a "how to" guide which has been reviewed and approved by some of the most successful mussel growers in Newfoundland and Labrador. It describes many of the techniques and practices used in the Newfoundland mussel industry and makes an attempt to suggest some of the more efficient practices that can be easily adapted to any mussel operation.

## Chapter 1: Industry Overview

Background information on mussel aquaculture site production in Newfoundland is perhaps the most important planning tool for grower expansion plans. Information on the relative size of mussels among sites might reveal if a site is viable for development. Production information may determine if a certain site is being underutilized or if growth problems are likely to occur from expansion. Finally, total industry production and sales information are extremely valuable to predict if mussel supply will meet demand or if a surplus condition exists now or in the future. This information will allow the grower to control sock deployment based on expected future need. A survey of 18 existing commercial farming operations was undertaken in 1997 to 1998 by the Newfoundland Aquaculture Industry Association (N.A.I.A.) and the Marine Institute Mussel Extension Services Program to gather this background information and to present it in a fashion that would be useful to the developing mussel industry in the province.

**Baseline Mussel Growth**

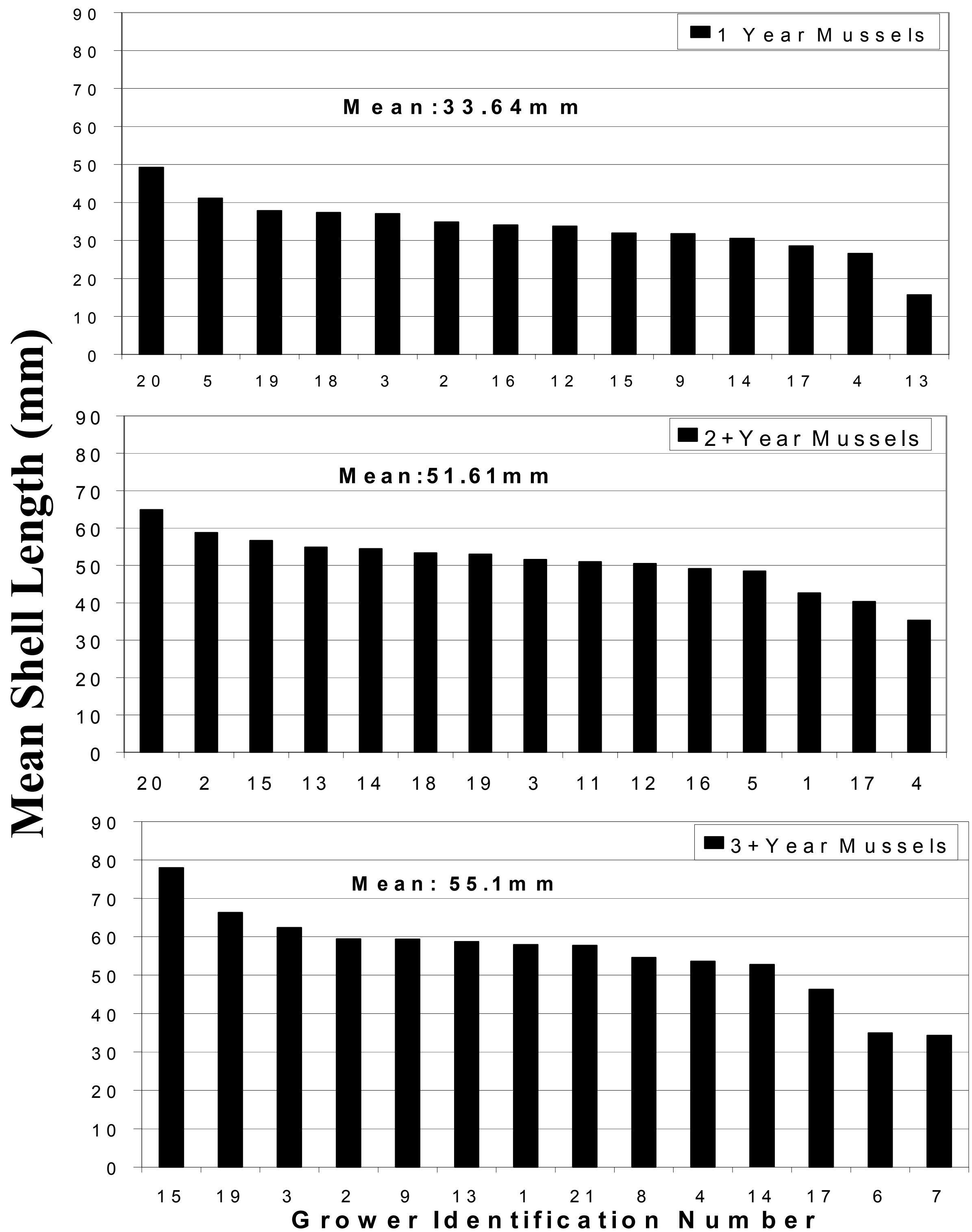


Figure 1.1: The mean shell length of 1, 2 and 3 year + mussels from 14 to 15 Newfoundland mussel sites. All shell lengths were derived from a sub-sample of 150 mussels from 3 socks located at different locations on each site. Sites were sampled from September to November in 1997 and/or 1998 by the NAIA-Marine Institute Mussel Extension Program.

Newfoundland mussel aquaculture is based primarily on a three-year production cycle at present. It typically requires one year for seed to grow to a suitable size on collectors followed by two years in socks to reach a market size approximately 50 mm to 75 mm (2" and 3") in shell length. This growth period varies dramatically among sites. One year old plus (12-15 months) mussels ranged from 15 mm to 49 mm shell length among 14 sites sampled with a mean of 33.6 mm (Figure 1.1). Two year old plus mussels (24-27 months) which have been in the sock for a little over one year were on average 52 mm in shell length and ranged from 35.3 mm to 64.9 mm in mean shell length among sites. Three year plus mussels (36-39 months), now in sock for two years reached a mean size of 55 mm and ranged from 34 mm to 78 mm in average shell length among sites. The considerable difference in the lengths of mussels among the sample sites indicates a very site-specific growth. These growth differences may result from a variety of site characteristics particularly environmental conditions like temperature and food supply. Other possible influences may include stock genetics and the husbandry practices of the grower. The grower can control the later two, seed may be brought into a site and husbandry practices can be modified. Some sites, which have multiyear seed and sock grow out periods, may have to be dropped if improvements in husbandry and stock do not improve conditions.

## Production Capacity

Production capacity is the optimum volume of mussels that a site can produce on a sustained basis. Generally, a value of 3,500 kg/ha of marketable product annually is accepted by lending agencies for the creation of business plans. Current thinking is predicting this value to be lower at 3,000 kg/ha (Paul Strickland, ACOA, 1998 pers. comm.). The standing crop of marketable mussels per hectare for the 15 farms examined by the N.A.I.A. and Marine Institute Mussel Extension Service was between 11,732 kg/ha to 341 kg/ha in 1997 and 1998 indicating huge

differences in production efficiency (Figure 1.2). The largest production per hectare value was more than twice that of any other farm. Many of the lower values came from farms that had recently received commercial status and were not at full production or from existing commercial farms that received expansion requests for new water area. This high volume of unused water gives the appearance of low production potential. As the sites are developed average production per hectare should increase. The extent of this increase is dependent upon a variety of conditions including site environmental characteristics, husbandry techniques, and mussel stock.

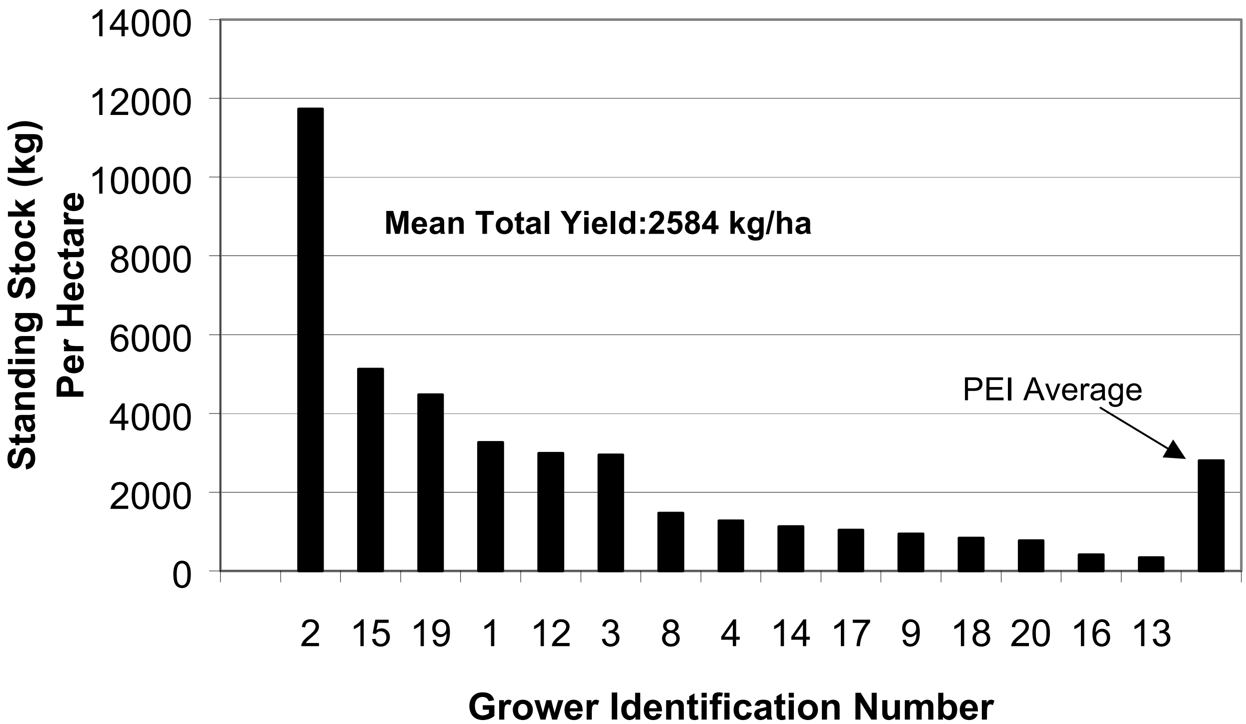



Figure 1.2: The standing stock of marketable product at 15 commercial mussel sites. Production estimates were derived from the N.A.I.A.-Marine Institute Mussel Extension Inventory Survey and were divided by total site area to determine production per hectare. Production for grower 18 and 19 was derived from 1997 data and the remainder from 1998 data.

The mean standing stock of marketable product per hectare, 2,584 kg/ha observed during the Mussel Extension Survey, was comparable to the PEI average of 2,800 kg/ha (Anonymous 1997) and will likely increase as under utilized sites are developed. There was also a general increase in standing stock from 1996 to 1998. This is largely based on a poor historic sales resulting in an accumulation of product at many sites.

The considerable standing stocks of some of the growers far exceeds the widely used value of 3,500 kg/ha as an average production volume for Newfoundland growers. This suggests that 3,500 kg/ha may be an underestimate resulting from inefficiencies at the farm site. Consequently, improved grow out practices may increase production levels beyond currently accepted values. Production capacity though, will ultimately vary depending on site characteristics with some sites capable of higher yields than others.

Presently, studies on production capacity are being completed by the Marine Institute, which will allow a more accurate prediction of a site's maximum production capacity.

Until production capacity models can be completed, determining a marketable weight per sock may be a simple method to predict production yields (see Chapter 10: Monitoring). Typically a two year old sock would represent the best indicator of harvest yield, as most sites require 24 months in sock for a high percentage of the mussels to reach market size (50 mm shell length). This yield can vary dramatically (Figure 1.3) among sites. The highest marketable yield per sock from the 1998 survey was 2.38 kg per 30 cm of socking or 22.61 kg (49.74 lbs.) of marketable product per sock of approximately 3 m length. The average was 1.21 kg per 30cm of sock or approximately 11.5 kg (25.28 lbs.) per sock. A new or existing grower may determine his/her own sock yield per 30 cm of sock and compare to 1998 values. Comparisons may reveal relatively high or low performance at sites indicating potential husbandry problems or site quality issues.

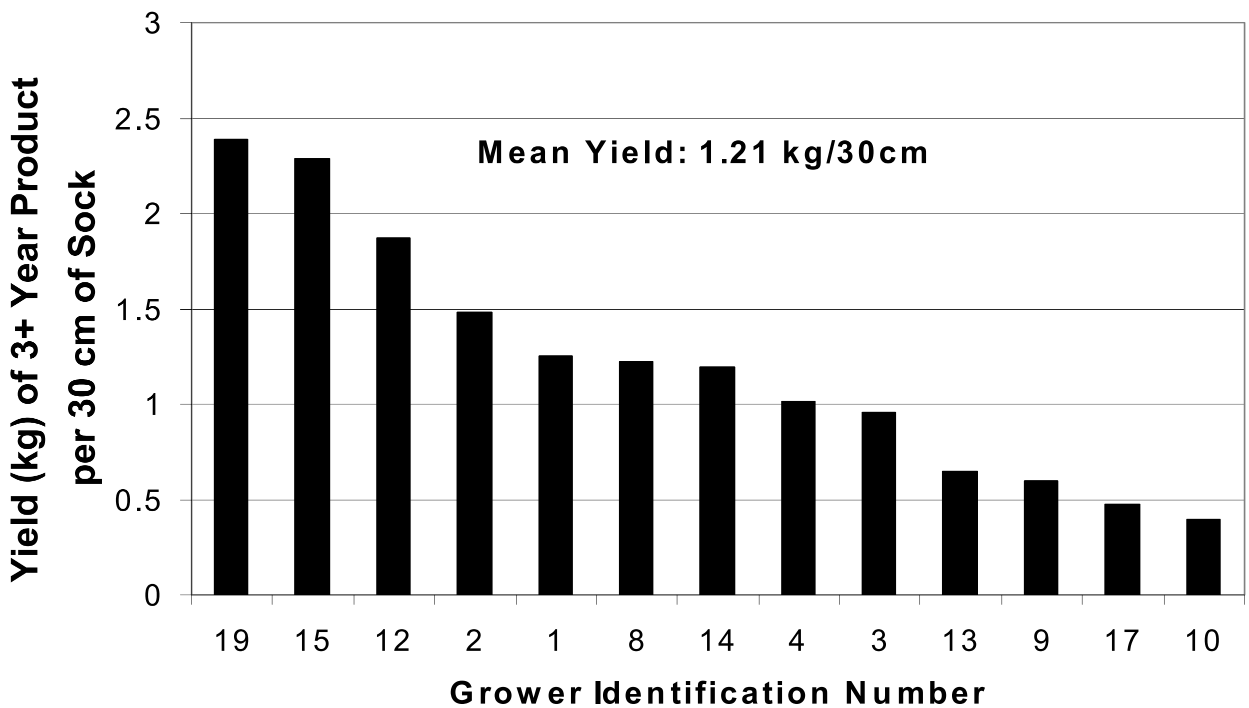



Figure 1.3: The Marketable Yields (weight of mussels greater than 50mm shell length, minus 30% over-pack) per 30cm of sock using 3 year plus mussels (24-30 months in sock) from 12 mussel aquaculture sites in Newfoundland. Estimates are derived from N.A.I.A.-Marine Institute Mussel Extension Service site inventories in 1997 and 1998.

Current Industry Status

Newfoundland farmed mussel sales were static from 1992 to 1996. The combined sales of commercial farms did not exceed 500,000 kg from 1992 to 1996 (Figure 1.4). In 1997 however, sales from the commercial mussel farms increased to nearly 750,000 kg and had reached 1,700,000 kg in 1999 (DFA preliminary estimate, Fred Hutcheson, pers. comm. 2000). The available product has generally been double the sales volume from 1992 to 1998. The quality of this available product was questionable and may have contributed to the low sales volumes for this period.

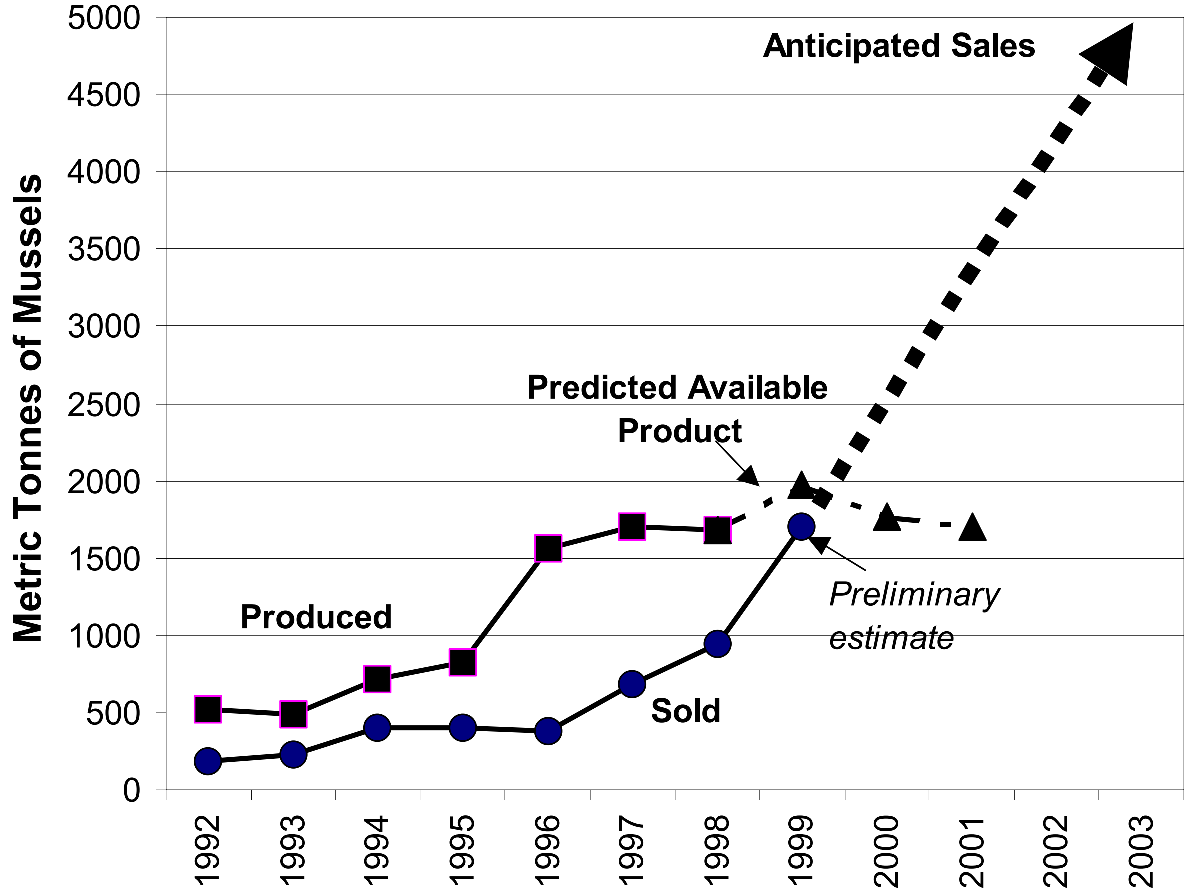



Figure 1.4: The annual mussel sales and production for Newfoundland commercial growers. Predicted production is based on the N.A.I.A.-Marine Institute Mussel Extension Service Inventory from 34 commercial mussel farms. All socks deployed prior to 1997 were not included in the predicted available product in 1999. Sales volumes and production volumes from 1992 to 1998 are based on DFA 1998 annual statistics. Anticipated sales to 2003 are based on personal communication, Dave Coffin, DFA 1999.

Based on the apparent improvement in sales and marketing it is necessary to predict both future production and sales. If a 24 month sock grow out period is assumed (Hutcheson, DFA 1997 pers. comm.), the total production of commercial farms is predicted to be 1978 metric tonnes in 1999, 1772 metric tonnes in 2000 and 1700 metric tonnes in 2001. (Derived from 1998 N.A.I.A-Marine Institute Mussel Aquaculture Extension Program Survey). There was a considerable surplus of market size product in 1999, which was not sold in 1998 that was not included in the 1999 prediction. The marketability of this surplus may also be questioned as it is composed of a high percentage of older (3-5 year) product and may be oversized or have substandard appearance. In addition the volume of this product that remained in 1999 was very difficult to ascertain due to losses from heavy ice damage. This volume of product (approximately 1200 metric tonnes) would suggest a large increase in available product for 1999 and yet the number off socks deployed in 1997 (Figure 1.5) does not reflect this value. Consequently the older product was removed from the 1999 available product prediction.

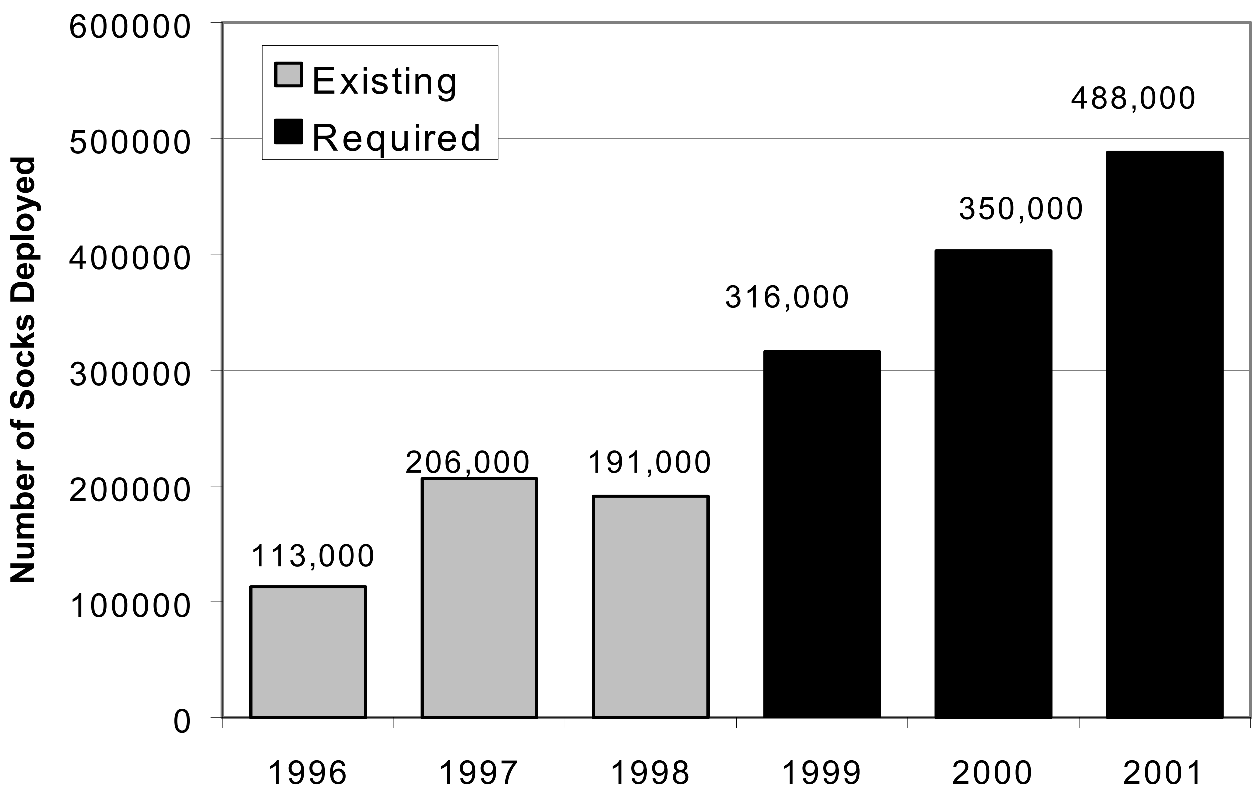



Figure 1.5: The number of socks deployed by the 34 commercial mussel grower in Newfoundland from 1996 to 1998 and the predicted deployment required to reach 5000 metric tonnes by 2003. Information is based on the Marine Institute Mussel Extension Service Survey and DFA Annual Statistics 1998.

Once this surplus is eliminated estimates are based on the assumption that all product available from the previous year has been sold. If market growth trends continue a potential lack of supply could develop in the year 2000 and continue into 2001. A lack of supply will likely result in lost markets and a stall in the growth of the Newfoundland mussel industry. In addition, to meet predicted future sales expectations (5000 metric tonnes by 2003, DFA 1999, pers. comm.) an estimated 316,000 socks are required to be deployed in 1999, approximately 125,000 more than 1998. This trend must continue to 2001 to see a total of 488,000 socks deployed. The implementation of appropriate husbandry practices should also result in increased yields on a per sock bases reducing the number of socks, costs and grow-out area required to reach projected production levels.

In order to reach this goal the grower, lending agencies, government and extension services must cooperate such that monies, leases, permits and techniques/technologies are available in a timely fashion to allow optimum development as the specific conditions of a site demands. As sales improve, the creation of cash flows will increase farm equity, placing the grower in a better position to lever loans from a variety of lending agencies forging a more positive expansionist attitude.

## Chapter 2: Mussel Culture Biology

Blue mussels comprise the largest species group of marine mussels cultivated worldwide. These mussels have been cultivated for over 700 years beginning in France, then throughout Europe and more recently in North America. The blue mussel species *Mytilus edulis* has been studied extensively since the early 1900s since it is an important component of shallow marine ecosystems around the globe. The general biology of mussels has been reviewed extensively before and the reader may wish to refer to some of the more interesting publications on the subject at some future time (see Field 1922, Bayne 1976, Gosling 1992A). Some of the more recent work has focussed on biological, ecological and physiological aspects of this and related species under culture conditions. The following section summarizes, in a general way, some of the more important biological aspects as they relate to the cultivation of mussels in Newfoundland and Labrador.

### Species

There are two species of blue mussel cultivated in Atlantic Canada: *Mytilus edulis* and *M. trossulus*. Both species have been identified in varying proportions from culture sites in every Atlantic province and Quebec. In spite of suggestions from a number of growers, there is no reliable way of distinguishing the two species simply by shell color or shape (Gosling 1992B). Both species may display shell coloration ranging from dark blue to light brown and shell shape may range from almost round to elongated, almost 'banana' shaped. The external shell characteristics vary according to the environment the mussels are grown in, the culture densities, and even strain or seed stock. More reliable methods of distinguishing between the two species are available but these require killing the animal for genetic determination or extensive measures of internal shell features, which are complicated at best.

Both mussel species appear to thrive well under similar environmental conditions. Small research trials in the Canadian Maritimes have suggested that *M. edulis* has more desirable production characteristics in culture (better survival, faster growth, more meat and stronger shells), however, this has been shown for very few sites and stocks. At a recent workshop sponsored by the NAIA the consensus among researchers was that both species are commercially acceptable and viable. Moreover, it was agreed that there are both good and poor performing stocks of both species, and that growers should evaluate seed stocks at their sites before deciding on which stock or species is most appropriate for their conditions (Mallet and Carver 1999).

### Reproduction

Blue mussels attain sexual maturity (adulthood) within their first year of life, often spawning at 8 to 10 months of age. Mussels may be as small as 15-20 mm when they first spawn. The sexes are separate, with ripe females showing a light to dark orange coloration of the gonad and males displaying a paler, creamy coloured gonad. An average size adult female mussel (5-6 cm) may produce in excess of five million eggs per year while males produce billions of sperm (Seed and Suchanek 1992). The spawning adults release their gametes (eggs and sperm) into the surrounding water and fertilization occurs externally to the animal (Figure 2.1).

A variety of factors have been suggested as spawning triggers for mussels, including temperature thresholds, temperature changes, storm surges, tide changes, food supply, and even mechanical shocks. Of all of the available evidence, food and temperature appear to be implicated most often in the spawning behavior of mussels. There is good evidence that mussels spawn at temperatures as low as 5°C in the Maritimes, Quebec and in Newfoundland (MacNeill et al. 2000) when food supply is increasing which suggests that temperature may not be the primary cue for spawning in blue mussels. Regardless of what triggers spawning in mussels, both food and temperature conditions must be suitable for larval development to occur, and generally temperatures above 10°C are considered to be adequate for *Mytilus* sp.

Mussels may spawn anytime from May until October, however, June through August are the main spawning periods in Newfoundland. There may be one or several spawning periods within a season. Complete spawning of a group of mussels may be rapid and extend over a few short weeks or it may be protracted over months, with trickle spawnings. Not all mussel stocks in an area spawn at the same time, and this will depend on when the appropriate spawning cues are received by the mussels. Some growers have noted differences in the spawning times of wild and cultured mussels in the same inlet, and this is likely due to differences in the readiness to spawn by these mussel groups. The intensity and rapidity of spawning is likely related to the strength of the spawning cues: if these are weak, trickle spawnings are more likely. In general, Newfoundland mussels have one main spawning season over a relatively short period of a few weeks to a month. In 1999, two major spawning periods, one in spring and the other in the late summer, were observed at a number of sites in Newfoundland indicating good environmental conditions during the spring and summer (Seed and Suchanek 1992).

It is a good practice to monitor spawning events in cultured mussels at growout sites on a regular basis. This can be easily accomplished by determining cooked meat yields on mussel samples taken from production lines. The methods for determining meat yields are provided in detail in Chapter 10, and will not be repeated here. A rapid decline in cooked meat yield indicates spawning. Regular meat yield determinations are also useful in assessing the general condition of mussels on a farm, which gives an indication of when mussels are at their peak condition and of highest quality.

Following spawning, mussels generally undergo a recovery period, which varies by site and location. Mussels are essentially weakened or stressed following spawning as they may lose up to 40 % of their body weight over a short period of time. The degree of stress in post-spawning mussels is related to the amount of body reserves built up prior to spawning, the environmental conditions at the site (low food and warm temperatures are stressful), and the particular seed stock. In more severe cases, mussels may detach themselves from socks or collectors or even experience direct mortality (i.e., summer mortality).

The causes of the drop off or mortality are not well understood. Regardless of the explanations for mussel stress, **it is imperative that mussels not be handled to any extent until sufficiently**

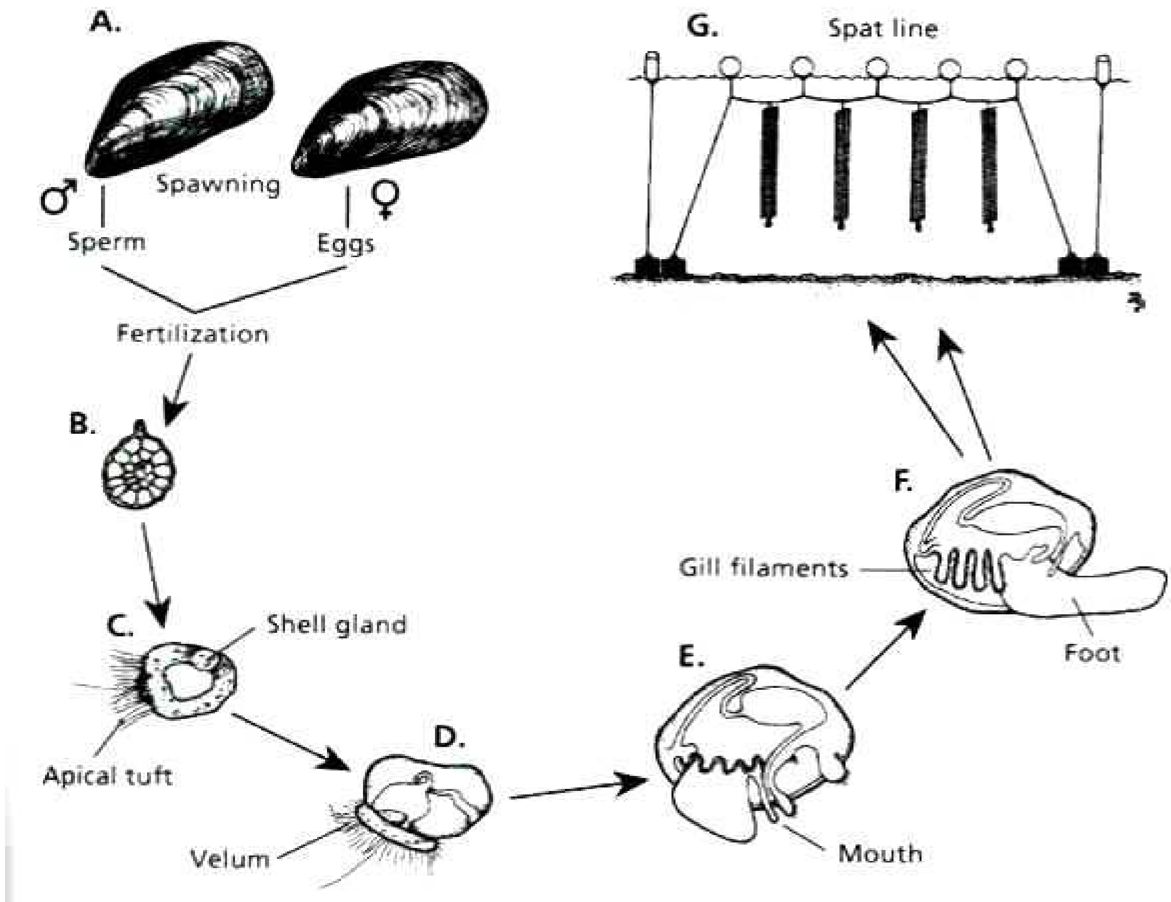



Figure 2.1: Life cycle of the blue mussel, *Mytilus edulis*, adapted from Sutterlin et al. (1981) and Mallet and Myrand (1995). A) Adult mussels, D) D-stage larva (ca. 100 µm shell length), E) pediveliger larva (ca. 250-300 µm in shell length), F) recently settled and metamorphosed spat (ca. 350 µm in shell length)(no swimming organ or velum).

**recovered.** This applies equally well to seed mussels less than 30 mm in length as it does to harvest size mussels above 50 mm in size. Thus, care must be taken to avoid stripping collectors and socking seed mussels until they are in reasonably good condition. Spawning may occur as early as June so care must be taken when contemplating spring socking. A number of mussel growers have experienced severe losses first hand in newly socked mussels that were likely in a post-spawning stress period in early July. The following is recommended as a guide in assessing mussel condition prior to socking or harvesting:

Beginning in early spring, open a few mussels at random and examine the degree of 'fullness' (see Figure 2.2). If done on a regular basis (e.g., every two weeks) changes will be noticeable and the timing of these changes can be determined.
Perform regular meat yield determinations beginning after ice break up.
Conduct a meat yield or assessment of fullness on larger seed if contemplating a spring sock deployment.
If mussels show evidence of spawning, by either of these methods, do not sock or harvest until mussels have recovered sufficiently. As a guide, an increase of 10 % in meat yield from the post-spawning minimum is recommended.

## Larval and Spat Development

Following spawning, mussels will develop into planktonic, shelled larvae (free swimming) that are at the mercy of currents (Figure 2.1). The larvae are called veliger larvae and swim with the help of an organ called the velum. At this stage, they are about 100 µm in size or 1/250 of an inch. Typical swimming speeds are in the range of 2 mm per second. The velum also serves as a food-gathering organ for the growing veliger larvae.

When temperature and food conditions are favorable the veliger larvae will continue to grow until they reach the 'pediveliger' stage (Figure: 2.1). This stage is characterized by the appearance of a foot and an eyespot. The first pediveliger larvae begin to appear in the water at sizes above 200 µm and most blue mussel larvae will be at the pediveliger stage when they are larger than 250 µm in size. The time to develop from first feeding veliger to pediveliger is temperature dependent: at 11°C this will take 3 to 4 weeks and at 17°C about half this time (Bayne 1976). Please refer to Chapter 10 and Appendix 4 of the Guide for details of larval monitoring.

At the pediveliger stage, mussel larvae begin to search for a suitable substrate to settle upon. Filamentous substrates seem to be preferred (Field 1922) but just about anything solid will do if the larvae come into contact with it. Fortunately for our purposes, polypropylene rope is an ideal substrate for mussel settlement. Mussel pediveligers may settle, swim away, and resettle several times before deciding upon a location to attach. The pediveliger will use its foot to crawl on the substrate and tiny sensory cells at the tip of the foot provide information to the larva about the type of substrate. Settlement and metamorphosis may be delayed for up to 10 weeks if a suitable substrate is not available (Bayne 1976).

Once a suitable substrate has been located, the larva will undergo a major reorganization of its organs, including shedding of the velum and production of gills. This transformation is termed metamorphosis and it is not reversible. The newly metamorphosed larvae now begin to resemble the adult form and are termed 'spat'. Spat attach themselves to substrates by secreting tiny hairs known as byssal threads. These threads firmly secure the spat to the substrate or collector but can be shed very rapidly if the spat decides to move away for some reason.

Figure 2.2: Adult male (top) and female (bottom) mussel showing high degree of 'fullness'. Photo courtesy of S. MacNeill.

Mussel spat are extremely mobile. They may use their foot to crawl over substrates in search of better locations with less crowding and more food. The smaller spat up to 3 or 4 mm are capable of secreting a specialized byssal thread many times their body length that has a flattened disc on the end that acts like a parachute drogue. These spat are able to take advantage of water currents and drift around the water column until they come into contact with another suitable substrate. This byssal 'drifting' may be quite common in areas with high spat settlement densities, and it may occur anytime up until the spat reach a size of about 4 mm. Some cases of byssal ‘drifting’ have been noted in spat up to 8 months following initial settlement. This might provide an explanation for the sudden appearance of mussel seed in the spring noted by several mussel growers in Newfoundland and it would account for the occasional appearance of 3-4 mm mussels in larval plankton tows noted by others. The resettlement of mussel spat following initial settlement has been termed secondary settlement in the literature.

Mussel spat will continue to grow on collectors until they reach a sufficient size for socking. As mentioned above, young, small mussels are very active. Recent trials at the Marine Institute and Ocean Sciences Center at Memorial University suggest that mussels less than 10 mm in length are much more active than mussels greater than 10 mm in length (S. Macneill, pers. comm.). These observations may explain in part why there is a considerable drop in the numbers of mussel spat on collectors from June to the fall each year at most mussel sites in Newfoundland (Macneill et al. 2000).

As mussels grow in size and age, the levels of activity decline and crawling behavior diminishes substantially. General observations by growers and researchers suggest that after a size of about

30 mm mussels are much less likely to crawl around on a substrate and will tend to be quite slow crawling out from socks. The same observations have been made on continuous mussel growout lines in New Zealand and Canada. This suggests there is an upper size limit for socking seed after which mussel performance may be reduced. **The recommendation would be not to sock mussels larger than 30 mm if at all possible**; however, in practice this is not possible at many Newfoundland sites.

## Mussel Feeding

Mussels feed on natural food particles in the water by filtering the water over their gills. An average 50 mm mussel weighing 1 g dry weight of tissue will filter 2 liters per hour or about 50 liters per day (Mooney et al. 2000). If there are 1,000 mussels on a 3 meter sock, each sock then is capable of filtering 50,000 liters of seawater per day. Finally, if there are 1,000 socks on a line the amount of water filtered would be equivalent to 50 million liters per day! In addition to this, smaller seed mussels filter considerably more water for the same weight of tissue - as much as 2 to 3 times. If the same calculation is made for a 20 mm, 0.1 g dry weight seed mussel, an average collector with 8,000 mussel spat will filter approximately twice the volume of water that a standard mussel sock. It is obvious from the foregoing that it may not require too many mussels in a small inlet with limited exchange before the incoming food supply is outstripped, and the site has exceeded its useful production capacity. Moreover, it can be easily shown that placement of seed collectors in front of growout socks could reduce the food supply to the production mussels substantially and thereby slowing growth. These factors are currently being examined in greater detail by a NAIA sponsored project being undertaken by the Marine Institute of Memorial University, and the study is expected to be completed in 2000.

Environmental monitoring studies at several Newfoundland mussel farms over the past 6 years suggest that the diet of mussels changes seasonally in quantity and quality but that it consists for the most part of phytoplankton. Mussels are capable of ingesting a fairly wide range of food sizes ranging from 2 to over 200 µm but for the most part the diet likely consists of particles smaller than 50 µm in size. Mussels are omnivores - that is they will consume just about anything they can fit in their mouths, not only plant material. There are indications that in areas of high mussel concentrations on mussel farms that larval mussel abundances have declined in some areas and the suggestion is that the adult mussels are consuming the larvae. This however still remains to be confirmed.

## Growth and Survival

A variety of environmental and biological factors will influence the growth and survival of mussels in culture. These include: food quantity and quality, mussel stock and species, salinity, temperature, physiological condition (spawning, post-spawning, etc.), culture density and husbandry practices. Many of these factors are discussed earlier in this chapter and in other chapters of this Guide, so will not be reiterated here. Instead, some general information will be provided on environmental factors most likely to influence growth, survival and performance of mussels on culture sites.

Temperature is an important variable in the growth and survival of Atlantic blue mussels. For instance, optimal temperatures for growth are in the range of 5 to 20°C, however growth can be significant even at temperatures as low as 0°C if sufficient food is available (Loo 1992, Mallet and Myrand 1995, Hatcher et al. 1997). Some Newfoundland growers have observed considerable growth in their mussels in early April and May when there is a major pulse of food from the spring phytoplankton bloom and temperatures are generally below 5°C. In fact, at some sites this is the period of most rapid growth during the year.

Growth rates of mussel shell and tissue do not occur simultaneously, but rather shell growth precedes tissue growth, sometimes by several weeks (Hilbish 1986). The main reason for this is so that the shell will have enough space to accommodate the new tissue growth. Thus, it is quite common to see an increase in shell length in mussels without an actual increase in total mussel weight or tissue. This has obvious implications for mussel harvest quality with respect to meat yield. Only by conducting regular meat yield sampling will mussel farmers become familiar with these patterns on their sites.

Shell growth rates in Newfoundland mussels vary by season, site stocking density, mussel size and site. Smaller mussels generally grow a little faster than older mussels but this is site dependent. A survey was undertaken in 1998 at a number of commercial mussel farming operations on the island (C. Brown, pers. comm. 1999) and shell growth rates ranged from 0.02 mm/day to over 0.1 mm /day over a growout cycle (24 to 36 months). Farms with the most rapid shell growth (0.08 to 0.11 mm/day) tended to be the farms with the longest history of development and the most 'efficient' husbandry practices. Those with with lower growth rates (less than 0.05 mm/day) either had over-stocked the sites, or site environmental conditions were deemed marginal, or the seed stock was performing poorly for one reason or another. Average growth rates of 0.08 mm/day are considered relatively good over a 24 month mussel production cycle in PEI and Nova Scotia (Mallet and Myrand 1995) and a number of Newfoundland sites compare favorably with these figures.

Simple measurement of shell growth rates in culture mussels can provide indications of a site's suitability, the seasonal variation in growth, whether it is over-stocked or if the environment has changed in the area or if there is a mussel health issue to contend with. It is a useful tool in farm management for forecasting production harvest. **It is recommended that mussel farms incorporate shell growth measurements in their regular site monitoring routine.**

Natural mortality in cultured mussels is generally very low, below 20 % from socking to harvest in most cases (Sutterlin et al. 1981). Losses on socking material are often not related to "mortality" per se but rather to drop off. Drop off generally occurs if one of the following conditions are met: 1) socking densities are too high to support the growth or weight of the number of mussels on the sock, 2) extensive fouling occurs on socks, or 3) the mussel's byssal attachment weakens. All conditions have been observed at one time or another on various farm sites in Newfoundland. Avoiding major drop off from culture socks requires careful observation by the farmer of the conditions at the site and the behavior of the mussels he or she is culturing.

For instance, the strength of byssal thread attachment changes seasonally in mussels, generally weakening in the post-spawning period. Mussel farmers should therefore avoid excessive handling of lines during these periods but only careful assessment at each site will allow the farmer to determine if there is likely to be a problem with drop off related to byssal attachment strength. Byssal attachment strength also varies in mussels according to current speeds at the site, the degree of shaking on a line, salinity levels and so on (Price 1982, Mooney 1997).

Similarly, the optimal density of mussels per sock will vary by site, depending on food and current conditions, and so a farmer should undertake trials at 3 or 4 different initial socking densities when he/she is first testing a new site or area.

Finally, periodic mass mortalities do occur in some mussel stocks. They do not always occur every year and appear to be related to the health or stress levels of the mussel and environmental conditions at the time of the mortality events. These mortalities generally occur in the post-spawning period in late summer and are referred to as "summer mortality". The precise causes are unknown but it is generally agreed that susceptible mussels are stressed somehow and this is compounded by higher than usual temperatures combined with low food levels. Summer mortality events have been observed at temperatures above 22-24°C in PEI, 20-22°C in Nova Scotia and the Magdalene Islands and 18-20°C in Newfoundland.

## Mussel Health

Mussel health is a catch-all phrase to indicate the general health status of mussels. If mussels are stressed in some fashion, there will usually be some indication in the animal. The key for the mussel farmer is to know what is 'normal' and what is 'abnormal' in his or her stock.

The first step is to have a reasonably good understanding of the anatomy of a mussel. Experienced mussel farmers will be able to recognize the major soft tissues of the mussel, including the foot, mantle/gonad, gills, and the digestive gland or gut. Familiarization with the normal appearance of these tissues throughout the year is essential for a complete understanding of the mussel stock's health. If unsure, a mussel farmer can contact any one of the extension specialists NAIA, the Marine Institute or the Department of Fisheries and Aquaculture for advice on mussel anatomy.

Some indicators of problems with mussel health include:

light coloration of the gut, especially if for prolonged periods (indicates low food or animal is not feeding for some reason)
separation of the gill filaments (these should be in a 'sheet' like manner)
presence of worm-like or other creatures around the gills and tissues (may indicate a potential parasite and samples should be provide to a shellfish health expert for analysis)
unusual patterns or inclusions in the mantle (may indicate parasite or environmental concerns)
unusual gaping or water loss in mussels when out of water (may indicate low reserve levels or presence of disease/health concern)

If in doubt, contact a shellfish extension specialist for advice and assistance.

## Conclusions

Mussels are interesting creatures. It is up to the farmer to understand the biological limits and capabilities of the animals he or she is growing. By doing so he or she can use this to their advantage in everyday farming practices.

# Chapter 3: Basic Mussel Farming Activities

Newfoundland mussel farming is based entirely on the long line system. This system typically involves the deployment of a length of polypropylene rope across a bay or cove to which mussel seed collectors and socks are attached (Figure 3.1). The ropes are anchored at least 3 m below the low water mark (now 40m from the shoreline) using eyebolts, which are drilled into the bottom or using a variety of anchors. This shore to shore mainline setup appears to be changing to a line setup that is parallel to the shore (Figure 3.2). The benefit appears to be a decreased strain on the line from current and ice, more uniform product quality and easier maintenance of navigational channels

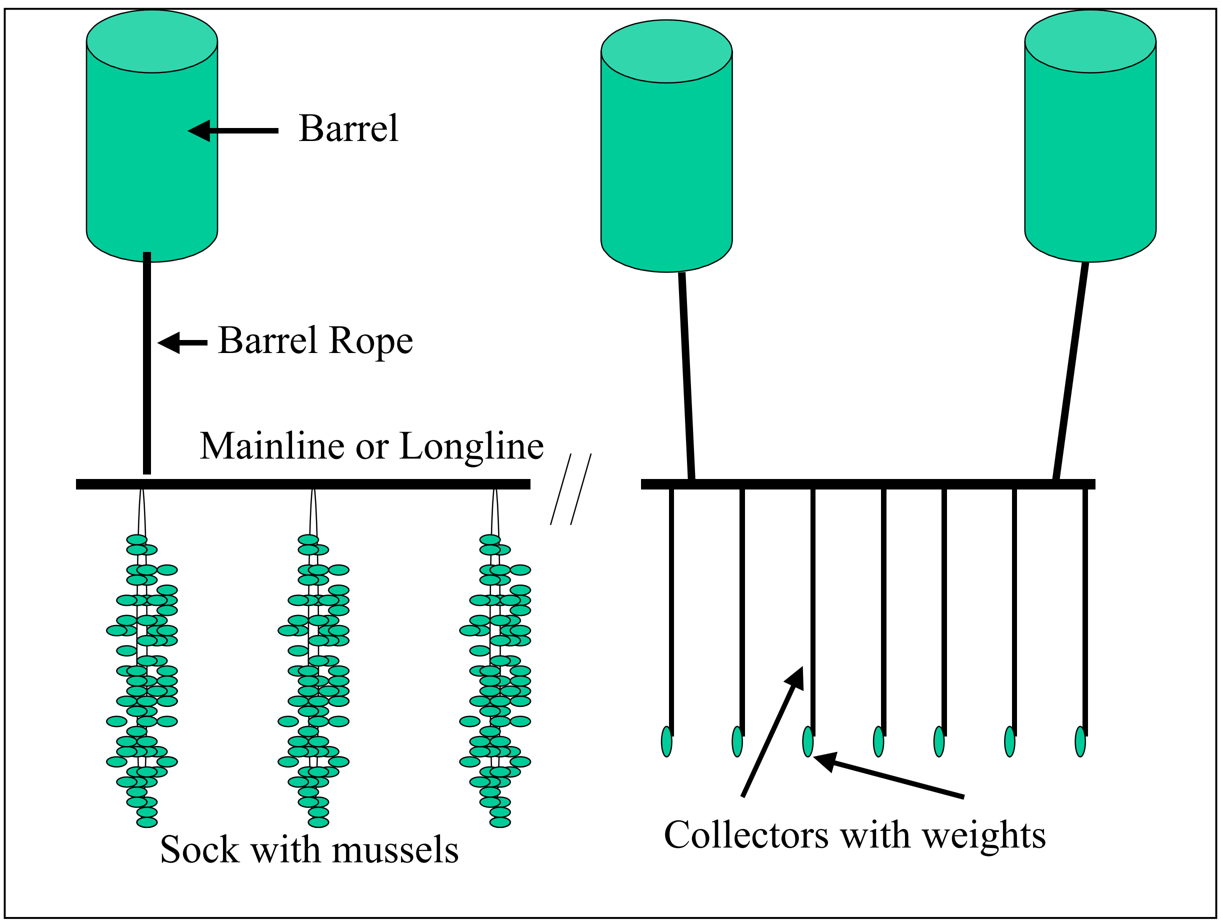



Figure 3.1: Typical mainline (longline) with mussel socks or collectors using barrel floatation.

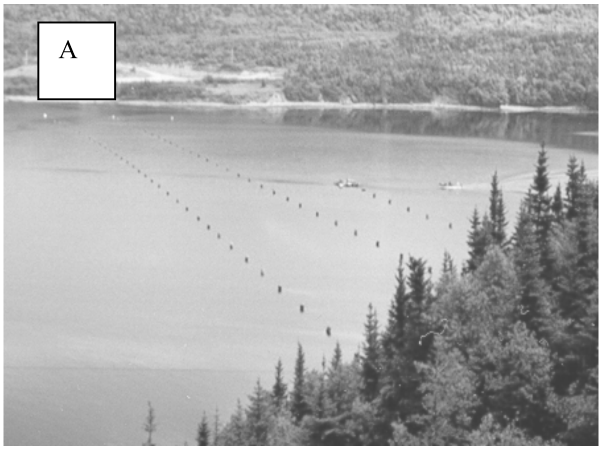




Figure 3.2: (A) Mainlines perpendicular to the shore using 45 gal barrels for flotation (photo courtesy of Sean Macneill), (B) parallel to the shore (C. Coutureier).

After a mainline is setup mussel seed collectors are deployed usually at 30 cm (1ft) intervals along the line. The collector is basically a 2 m to 3 m polypropylene rope with a small weight on the bottom, although some growers use other material like socking material (Figure 3.3). The mussel larvae settle out naturally and attach to this rope often in huge numbers (10,000 to 100,000 per collector). Typically the mussel seed is left on the collector for one year at which point it has grown to a length of 15-30 mm. The seed then goes into the next stage of operation, socking.

Socking involves the placement of seed stripped from collector lines into mesh tubes called socks. This is usually done by placing the seed into a socking table, which is constantly supplied with water. More commonly today, the seed is being declumped and size graded by hydraulic seed graders. The table has a tube or multiple tubes, which the sock can be threaded over (see Chapter 6).

A knot is tied in the sock and the mussels, powered by water pressure, are allowed to flow into the sock. Typically 30 cm of sock is left unfilled to allow the space necessary to tie the sock to the mainline. The socks are usually tied using a rolling hitch or clove hitch (Figure 3.4). Sock spacing is typically 0.45 m (1.5') on the mainline.

Floatation for the Newfoundland mussel farm is usually in the form of a 200 l (45 gallon) plastic barrels that are tied every 25 to 30 socks along the mainline. A smaller 0.4 m (16") diameter round float is becoming more and more popular, especially for collectors.

After the socks have been in the water for 18-24 months the mussels will have reached a market size of 50 mm or 2". This grow out period depends on the specific characteristics of the site.

Some sites may have longer growing periods than others. The mussels can then be harvested when the quantity of meat (meat yield) is high enough, and sold to a processor. Harvesting

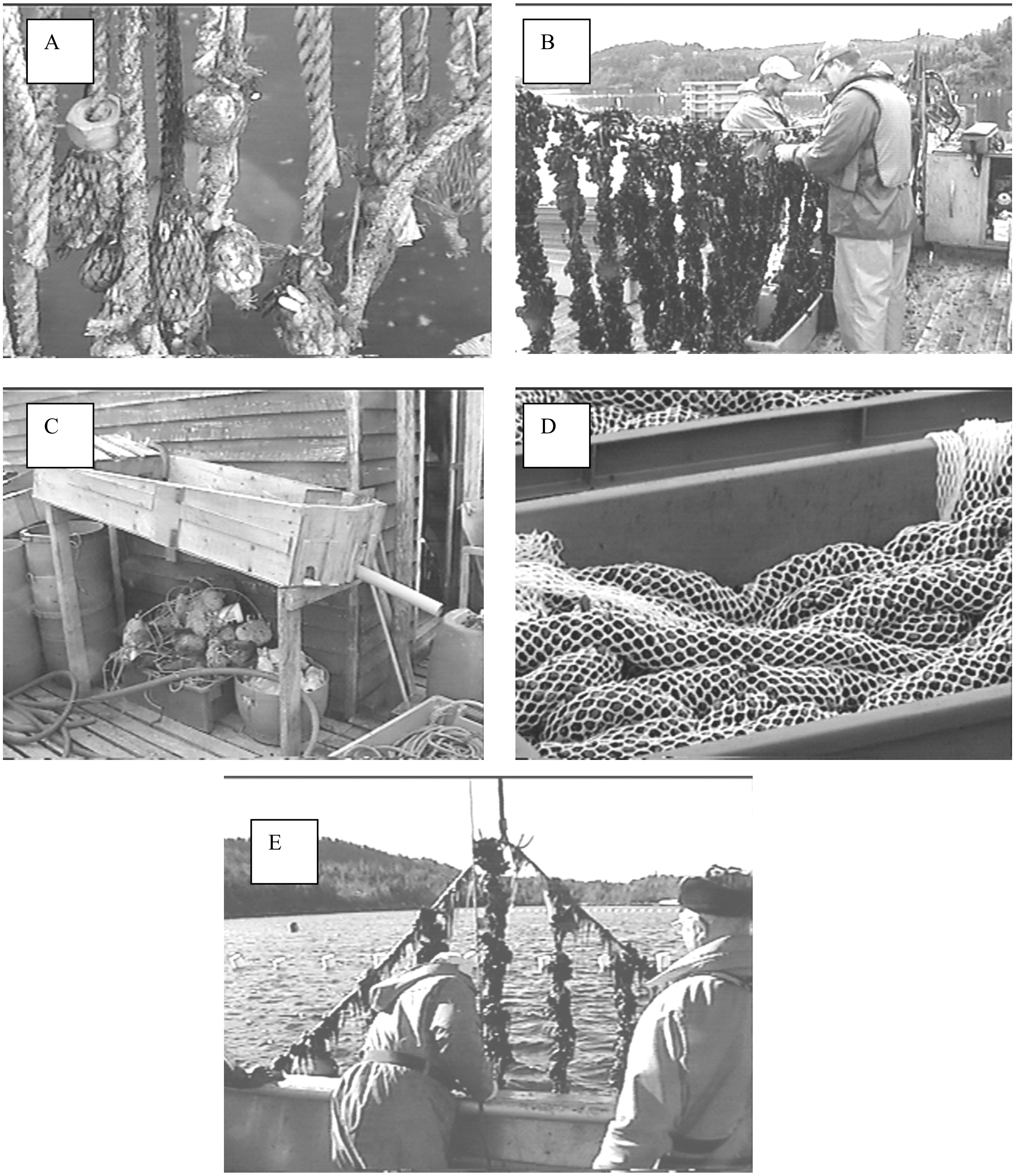



Figure 3.3: (A) Collector ropes with a variety of weights (B), collectors being stripped (C), wooden socking table (D), filled socking and (E ) market size mussels on socks.

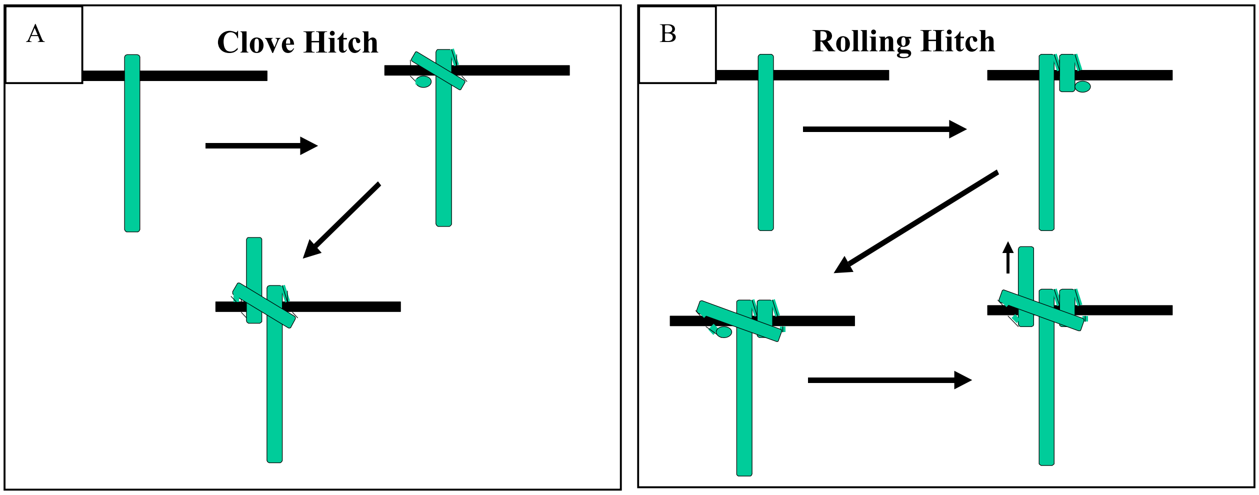



Figure 3.4: The main knots used for float and sock attachment (A), clove hitch (B), rolling hitch.

usually requires a barge or large boat with hydraulic equipment to handle the heavy socks, which now can reach 45 kg (100 pounds) or more at some sites (Figure 3.5). Technology and techniques are also available to allow harvesting through the ice in the winter when the mussels are often in top condition. As the industry develops and secondary processing increases, winter will likely become the main harvesting season.

Figure 3.5: Recently harvested mussels on work barge (photo courtesy of Sean Macneill).
The following chapters will discuss in detail the techniques and technologies that are used in the Newfoundland mussel aquaculture industry.

Chapter 4: Site Design

The new or expanding mussel farmer has a variety of options to choose from when deciding how to set up the mussel site. These include the type of anchorage, mainline setup and float types, as well as the location of collectors and sock year classes on the farm.

Mainline Systems

Perhaps the most important site design decision is how to deploy and anchor mainlines within the site. Typically Newfoundland mussel growers use a shore to shore mainline system which completely crosses a bay or cove (Figure 4.1). In this case each mainline is usually anchored separately. The lines on the outside of the site will have more food available than lines on the inside due to mussel feeding as the water passes inward. This may cause different growth rates within the site. When mussel farming began in Newfoundland this shore to shore system was the easiest to use as mainlines could be tied to trees or to steel eyebolts in large rocks on the shore. These anchorage systems are termed "shore-fasts". With new regulations, this activity is no longer permitted. The Department of Fisheries and Aquaculture regulations stipulate that shore-fast systems must now be at a depth of 3 m below the low water mark (Notice to Aquaculturists, DFA, December 29/1997). The Canadian Coast Guard will not approve shorefast moorings. Shoreline channels are generally required on the majority of sites with a typical spacing of 40 m from the low water mark. The requirement and size of the channels is determined on a site specific basis (Paul Nippard, Canadian Coast Guard 1999. pers. comm.). This has effectively eliminated the creation of new shore-fast systems.

Another option is to drill large rocks (500-2,000kg) on the shore and insert an eyebolt, then pull the rock into the water to the necessary depth. This will require a large boat or barge and hydraulic equipment.

Another type of system involves deploying mainlines parallel to the shoreline and current within the bay (Figure 4.1). This will reduce the drag on the lines from the incoming current and may reduce the chances of ice damage. The lower drag may reduce line breakage, which can cause severe losses in product. By placing lines parallel to the current, the mussels on the inside of the cove will likely receive more food than if the system was shore to shore. In addition, parallel systems are generally much easier to navigate through. Parallel systems require true anchors rather than shore-fast systems as the anchor is usually deployed in the middle of a bay or cove in deep water.

A third deployment strategy used by a small number of Newfoundland mussel farms is the use of cross-lines (Figure 4.2). These are a set of lines anchored either in a parallel or shore to shore system to which the mainlines are attached. This system usually uses a shore to shore set up of cross-lines and has the mainlines parallel to the shoreline. This gives the benefit of a reduced number of anchorage points with the lower drag of a parallel system. An added benefit of the

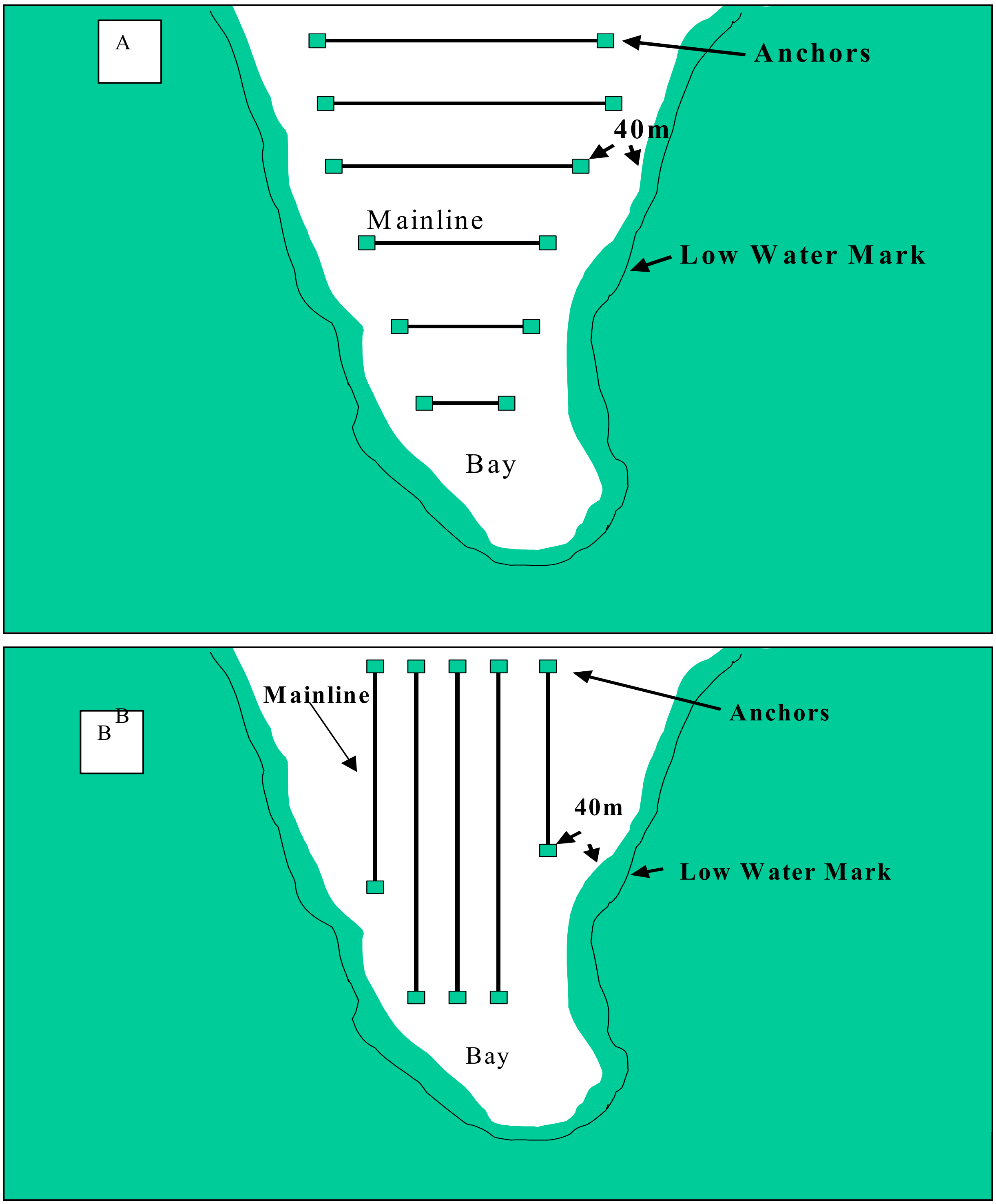



Figure 4.1: (A) shore to shore mainline system and (B) parallel mainline system. All new sites must typically leave a 40 m boundary between equipment and the low water mark (Paul Nippard, Canadian Coast Guard, 1999 pers. comm).

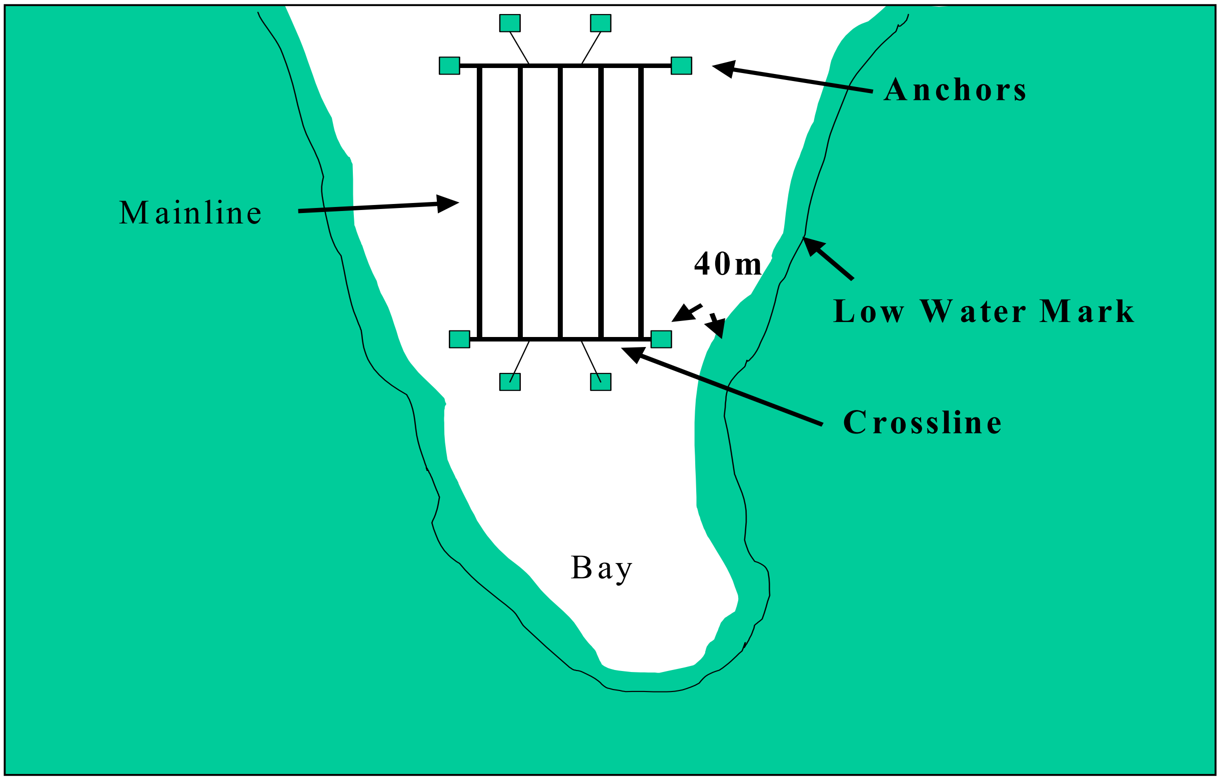



Figure 4.2: Mainline system using cross-lines.

cross-line system is that mainline spacing can easily be adjusted simply by retying the mainline at any point along the cross-line. The other systems would require the movement of an anchor.

Anchorage Systems

A variety of anchorage systems are in use in the Newfoundland mussel aquaculture industry. The anchor types are predominantly steel eyebolts, which are embedded into the shore or large rocks (Figure 4.3). Gardner and Coombs (1997) suggested that the shore-fast method was more cost effective than underwater anchors but gave no indication as to the type of anchor only that it had a higher material and labour cost. Regardless of cost, growers are required to move these eyebolts under water, which may require divers. Parallel systems may require the use of divers to insert anchor bolts into the seafloor, which may be very costly and only works if the seafloor is rocky.

A less costly alternative is the use of rock, concrete or steel anchors. Rock anchors are simply large rocks with an eyebolt, which are hoisted onto a barge and brought to the appropriate location then lowered to the seafloor. These require a large barge with a crane or other system to handle the 500-2,000 kg rocks. Steel anchors are the typical ship type anchors that are welded its weight in water so a significant weight is required. One Newfoundland grower surveyed

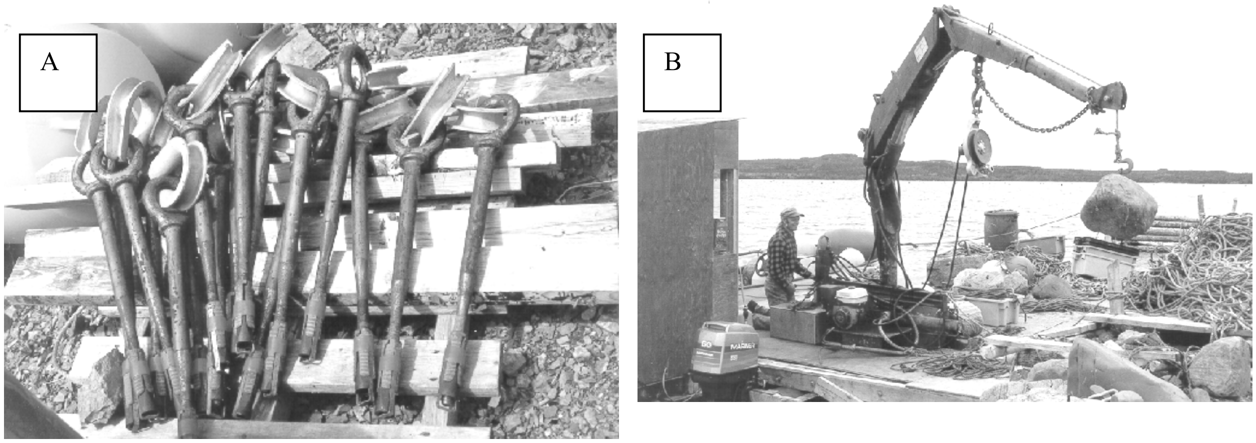



Figure 4.3: (A) Eyebolts, (B) rock anchor with an eyebolt. Photos by Sean Macneill.

together from scrap metal. These may be expensive but do not require the weight of rock or of concrete anchors (steel only looses 1/7 of its weight in water). A problem with steel anchors is that they may pull loose and have to be reset, which may cause mainlines to tangle. Concrete anchors are constructed using a wooden frame. The cement is poured into the frame and an eyebolt, chain or polypropylene rope loop is added for mainline attachment. Concrete loses 2/5 was using one 272 kg (600 lb.) block and one 590 kg (1,300 lb.) block tied together on each end of a 400 m mainline. The longer the line the heavier the anchor that is required. Concrete and rock anchors work very well in muddy bottoms but much extra weight is required for rocky bottoms.

A special mud design for concrete anchors produces much greater holding power using the suction of the mud (Figure 4.4). The anchor is larger at the base than at the top producing a pyramid-like shape. As the anchor sinks into the mud the sloping sides become covered creating a downward force by the mud on the anchor creating the suction. New Zealand growers use a similar system called a wedge anchor which has the sloping side on only one side of the anchor. The eyebolt or other attachment is also located right on the the sloping side.

If concrete anchors are to be used, it is imperative that as little water as possible and enough hardener is added to the mix or the concrete will crumble after only a short period in the salt water.

**of** Concrete anchors may be the easiest anchors to use especially for the beginning mussel grower. It is relatively inexpensive and can be mixed in any container without mechanical aid. Eyebolts require special drills, which are expensive to rent, and may not be readily available. Rock anchors require a natural abundance of appropriate size rocks as well as the drill. Relatively heavy concrete anchors can be made by connecting two small anchors together by a small length of rope. This will allow the beginning mussel farmer to handle heavy anchor systems without the need for a barge or hydraulics. Typically a plastic sheath flexible tubing is placed over the rope where it is tied to the anchor to prevent chaffing but is not necessary when using large diameter rope of 19 mm or 25mm (3/4" to 1").

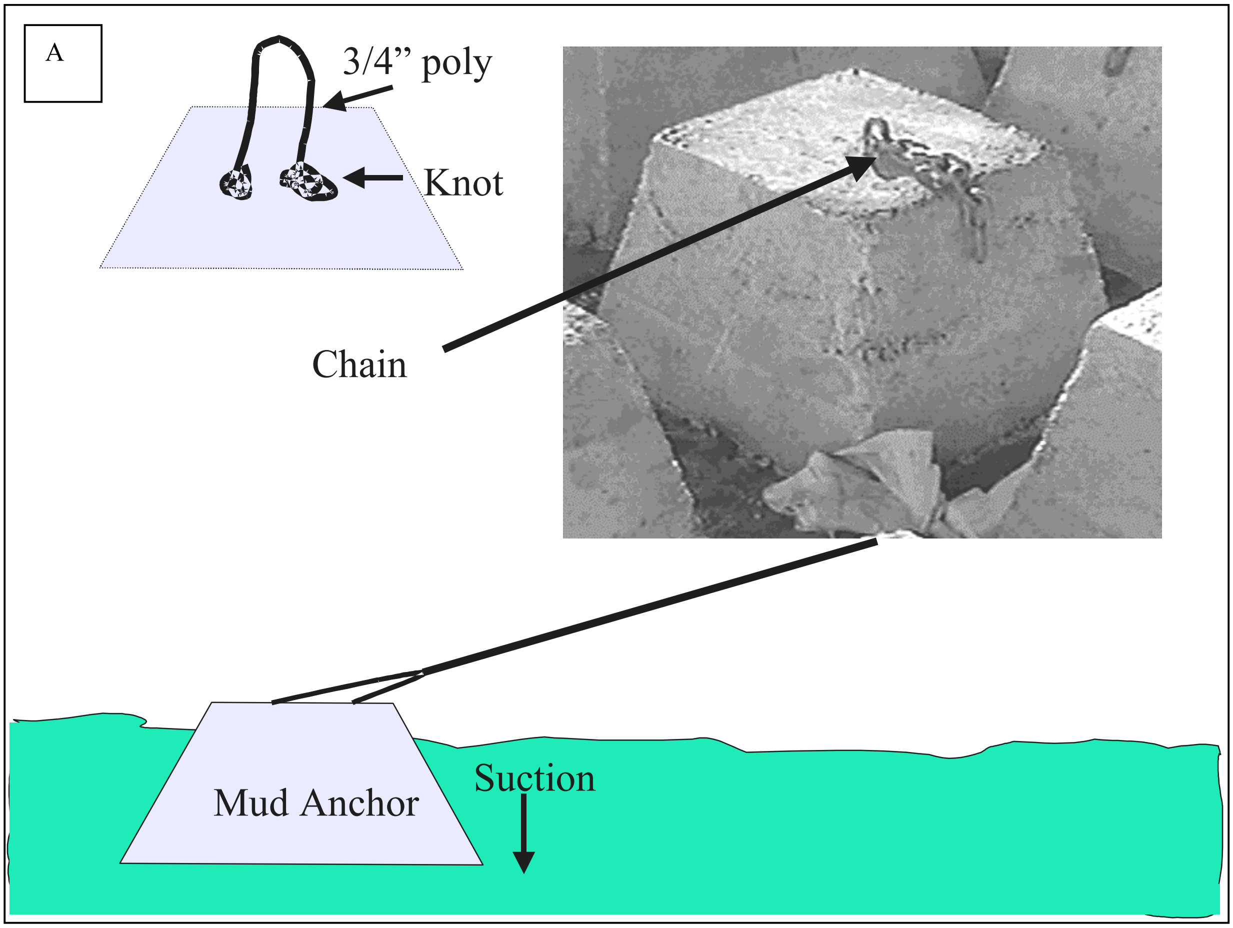



Figure 4.4: (A) Concrete mud anchor and (B) New Zealand wedge anchor system. Attachment may be in the form of chain, eyebolts or rope loops set in the concrete. Mud anchors must be given time to sink into the bottom to obtain maximum holding power.

Handling a 272 kg (600 lb.) anchor can be made easier by creating two 141 kg (300 lb.) anchors, which are connected together by a rope (Figure 4.5). Rope, steel or chain loops can be placed in the concrete while it is hardening to allow easy attachment of anchor lines (Scarratt 1993).

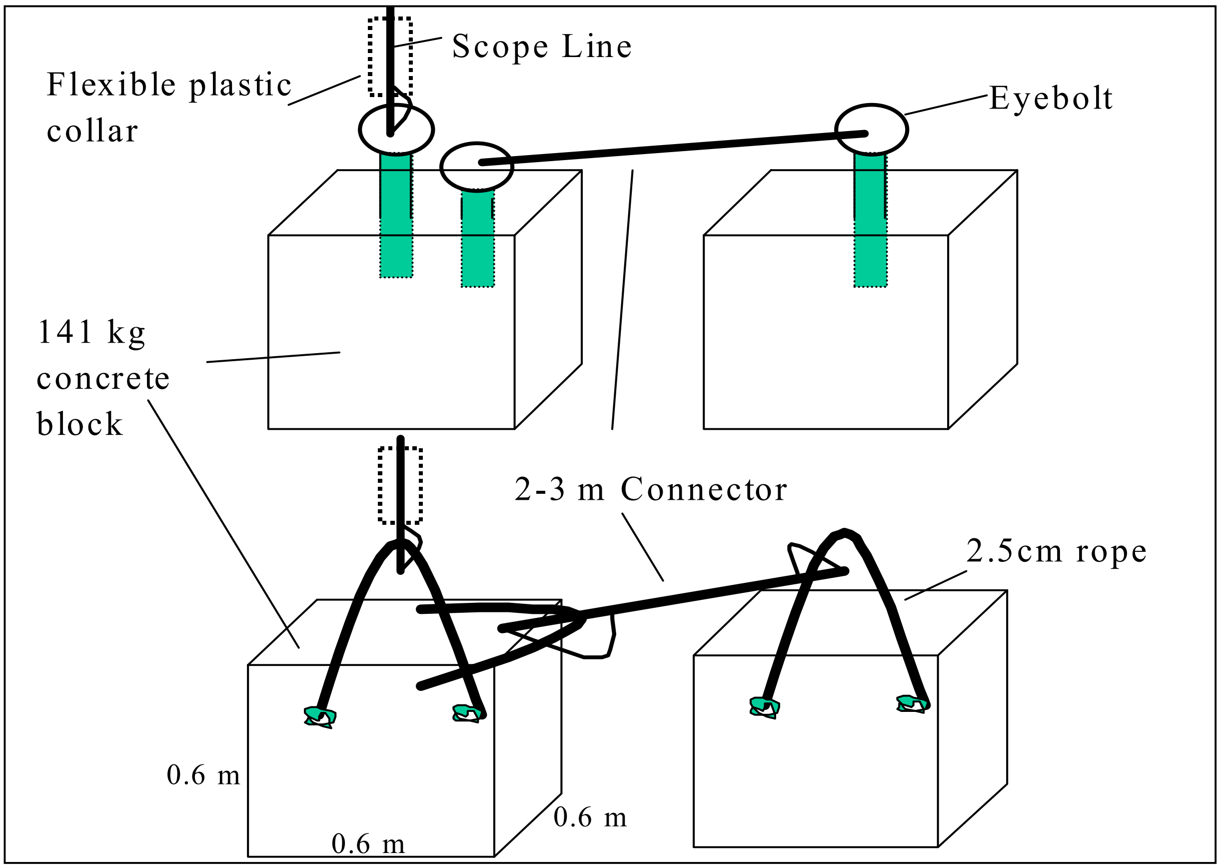



Figure 4.5: Easy to handle concrete anchor design. Total Anchor weight estimated as 272 kg.

This concrete anchor design is so versatile that 200-300 kg concrete anchors can be set on the ocean floor by a small open boat (7m (20ft)). This may be of considerable importance to growers that are in the first 1-4 years of operation and may not have purchased or built a barge capable of handling heavy anchors. Even for established growers, a test line may be set up in a new site without having to relocate a barge. The method is relatively simple (Figure 4.6), starting with the construction of 141 kg concrete block anchors. These anchors are connected together by a short rope. Each block is tied to one side of the boat at the shore with the connector line loose underneath. The boat is then driven to the location where the anchor is to be deployed with the anchors submerged in the water on either side of the boat. The blocks are then cut away and lowered together using the anchor line that is tied to the lead block. The anchor rope would be run under the boat rail to more easily control the descent of the anchor. An alternative deployment method involves using two 7 m boats (Figure 4.7) which are connected by a 10 cm X 10 cm (4” X 4”) or larger timber (J. Negrijn 2000, pers.comm.). The timber is strapped to the

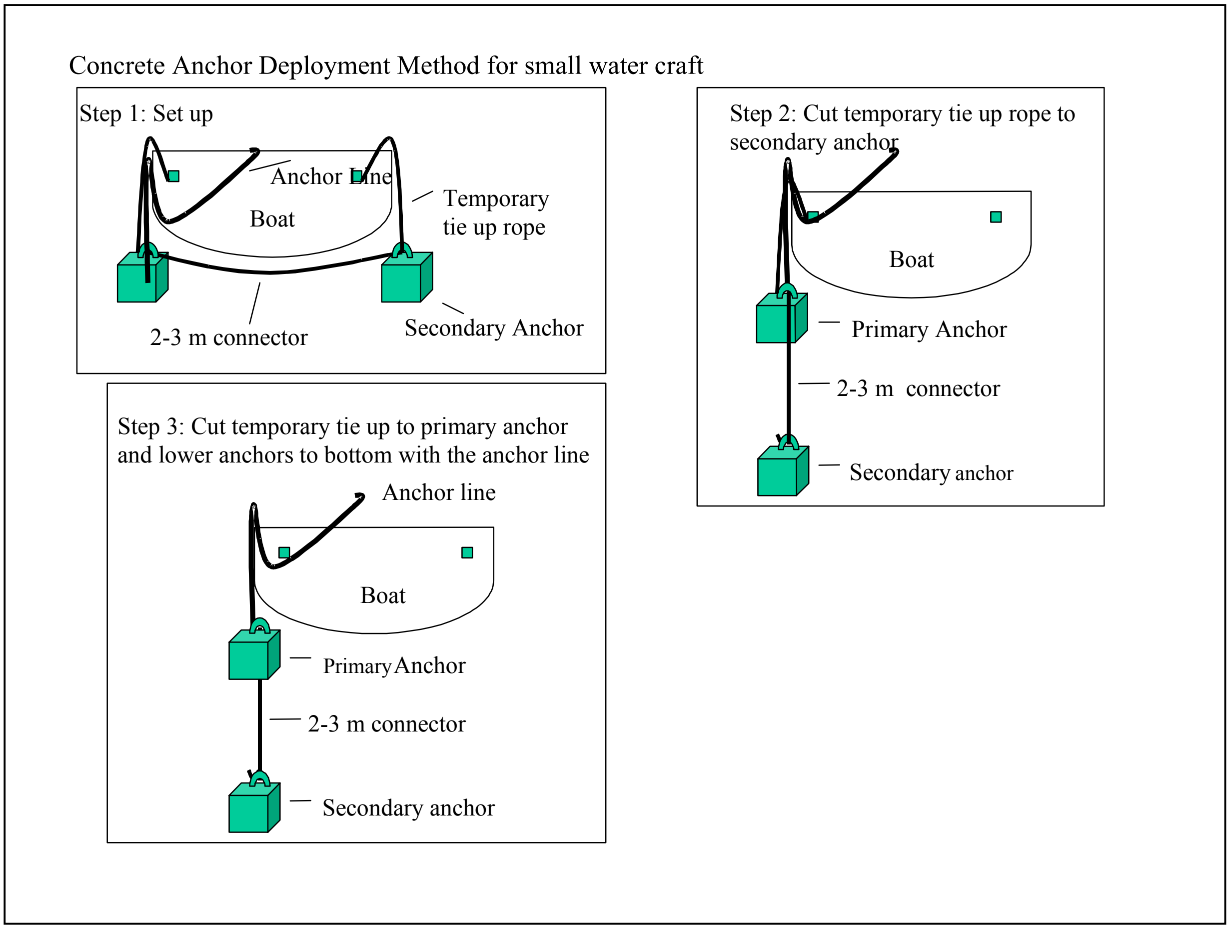



Figure 4.6: Small anchor deployment technique using a small open boat.

two boats and the anchor is suspended from the timber. Upon reaching the appropriate location the temporary line connceting the anchor to the timber is cut and the anchor dropped. Anytime these methods are used in small boats extreme care should be taken and deployment should occur under only the best weather conditions. Also, do not transport the anchors inside the boat then try to lift them out by hand this is very dangerous and may result in injuries and/or capsizing the boat.

When two sets of these anchors are down, a mainline can be connected to the anchor line and tightened. Only short surface mainlines (100 m) should be used with this system, as longer lines will likely cause the anchors to slip. Submerged lines my be longer (up to 200 m) as there is less wave action and consequently less strain on the anchors

It is of the utmost importance that enough weight is used for anchorage, especially for surface lines, which have more drag than submerged lines. If an anchor slips the ensuing tangle may be

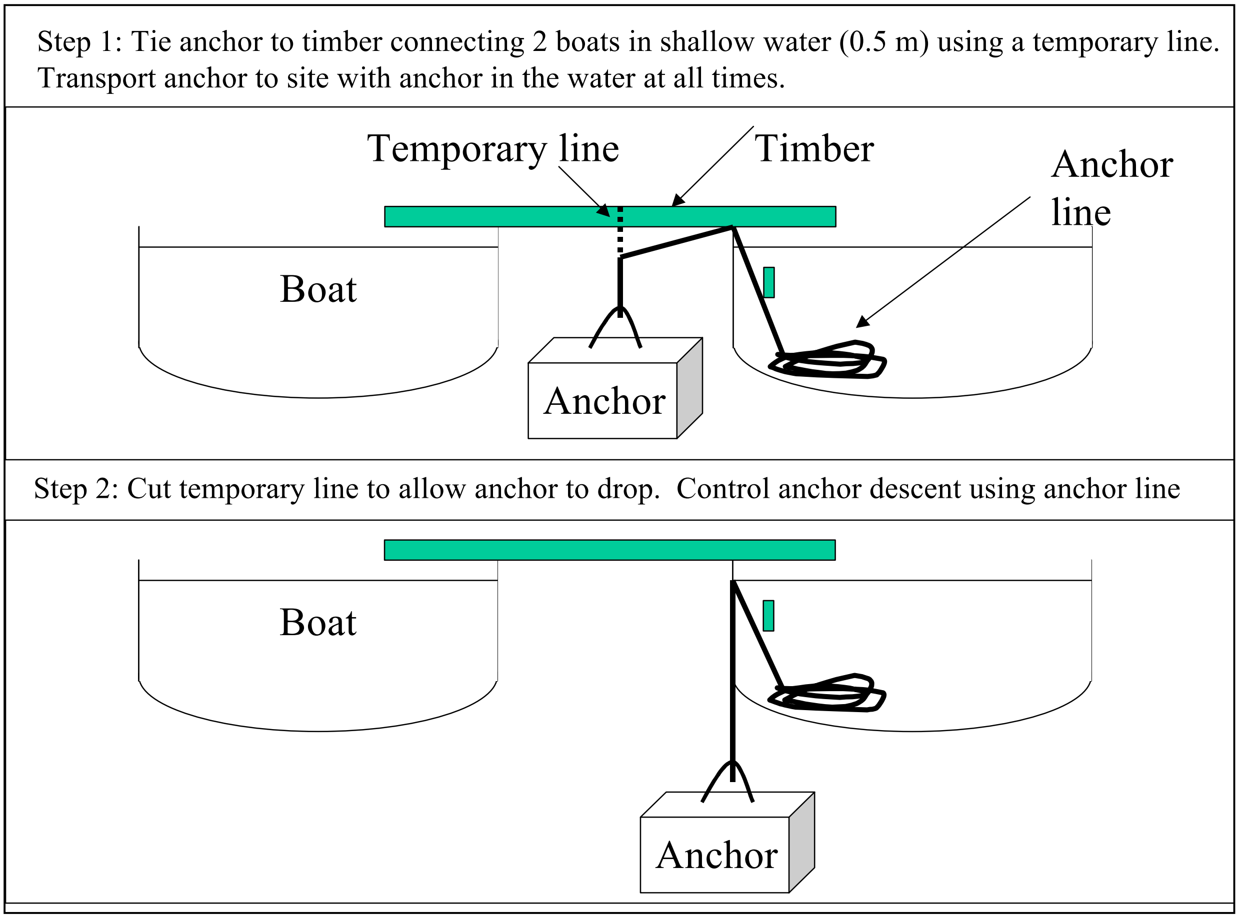



Figure 4.7: Anchor deployment technique using two small open boats (7m)

extremely costly. In addition to heavy weight for anchors, a sufficient length of line to the first float (scope line) must be used. This length is typically three times the depth of the water that the anchor is in. Mud anchors should also be deployed for as long a period as possible before they
are used. This allows the anchor to sink into the mud and generate the suction force before tension is placed on the anchor.

Rope

Various brands of rope are being utilized for mussel culture in Newfoundland. The most common type is the 13 mm (½') and 14 mm (9/16") polypropylene rope. This is used for both anchor lines, cross-lines and mainlines. 9mm (3/8") polypropylene is also commonly used for collector ropes and for tying floats to mainlines. Other types including polysteel and nylon are also in use but at much lower levels due to higher costs. These materials are suggested to have better characteristics such as greater strength and lesser stretch than the polypropylene. Its use in mussel farming though has been limited in Newfoundland.

Another specialty rope is the ice boom rope. This may be very heavy manila ship rope or 50 mm –75 mm (2"-3" ) polypropylene (Figure 4.8). Some growers use multiple lines of 16 mm (5/8") polypropylene, which have been loosely twisted around each other. These ice booms are stretched from shore to shore across the mouth of the mussel farm and often hold back huge quantities of ice.

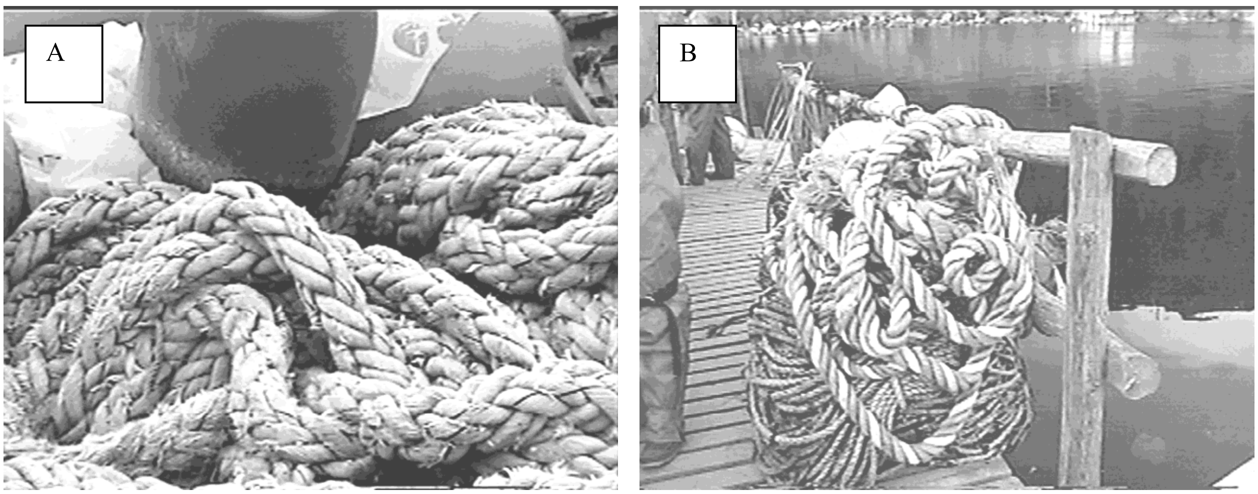



Figure 4.8: Ice boom rope, (A) manila and (B) polypropylene.

Ice boom engineering can be relatively complicated, especially when trying to determine the necessary rope size. This requires the identification of ice pressure on the boom from wind, ice volume and currents. The actual dimensions of the boom though can be calculated using a simple formula (Figure 4.9). A single span boom described by Cammaert (1997) for a 300 m wide channel was composed of 76 mm (3") diameter polypropylene rope, which was attached to 35 three meter long logs. The logs were used for extra ice adhesion. The boom was secured by a 10 m length of chain to two eye bolts on either end. This boom was designed to withstand 15 metric tonnes of pressure. None of the Newfoundland growers surveyed used logs in the construction of ice booms. In addition, ice booms are typically attached from shore to shore on an angle to force the ice into the shore.

For an up to date report on ice boom design contact Shawn Robinson at the Department of Fisheries and Aquaculture 709-637-2960.

Any grower wishing to deploy an ice boom should contact the Department of Fisheries and Aquaculture for advise and the Canadian Coast Guard well in advance as ice booms will require the formal approval process.

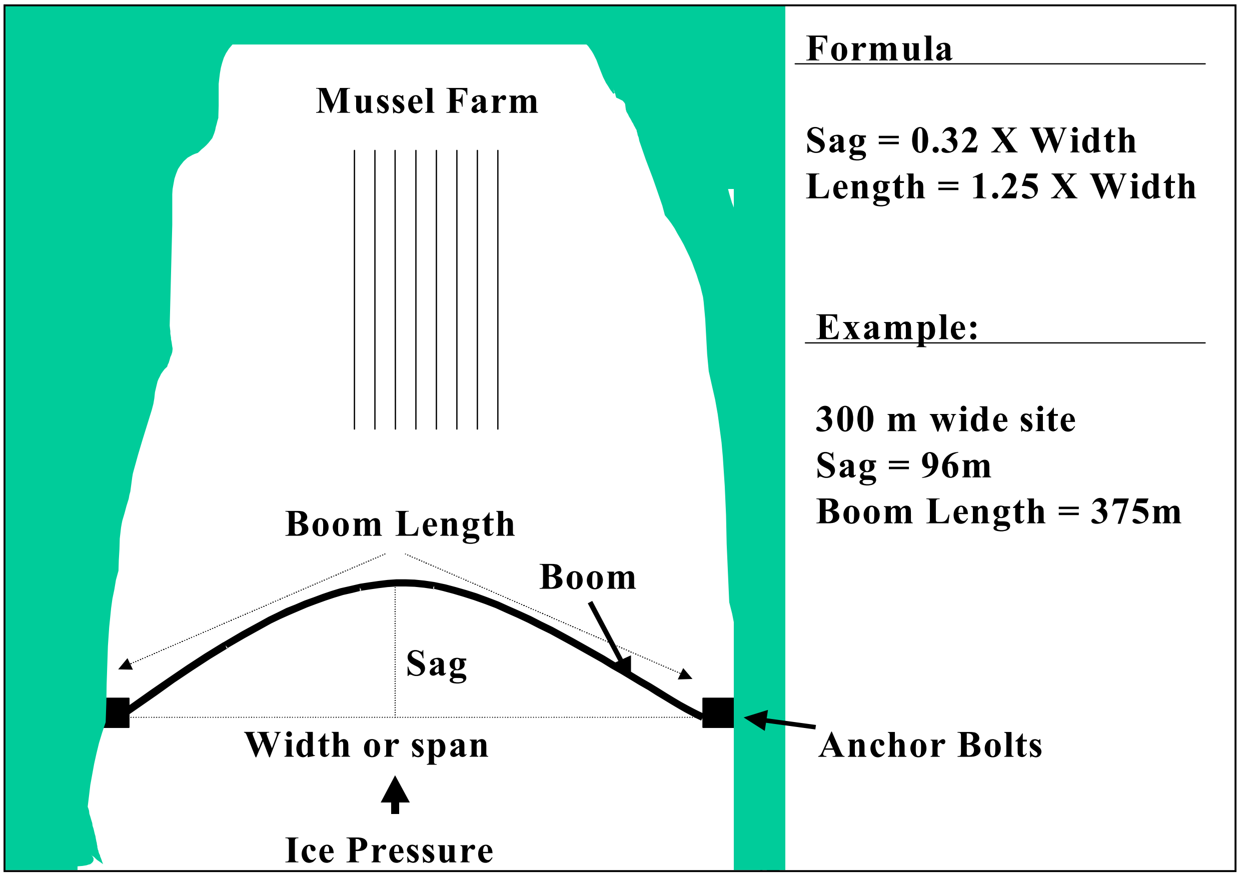



Figure 4.9: Single span Ice boom design with formulas for calculating boom length and sag. Based on Cammaert (1997).

Floats

Newfoundland mussel growers use a large variety of floats. These range from specially designed 200 l (45 gallon) aquaculture barrels, the 0.4 m (16") and 0.3 m (12") pressurized hard plastic spherical buoys and styrofoam lobster floats to used soft drink containers, 20 l (five gallon) buckets and plastic bottles (Figure 4.10). By far the most prevalent float is the 200 l aquaculture barrel. These are being used for both socks and collectors although the 0.4 m pressurized spherical float seems to be replacing the barrel in popularity for collector flotation.

Typically two barrels are sufficient to hold 25 to 30 socks at harvest size which may exceed 1000 kg (weight in air). Many growers use 50-60 socks between two barrels and then add an

additional barrel as the mussels grow. The total weight (including fouling, undersized mussels etc. in air) of two year old or older mussel socks supported by two barrels varied considerably among the surveyed Newfoundland mussel growers. It ranged from 1097 kg to 368 kg with a mean of 668 kg of mussel product between barrels (Figure 4.11). This variation among growers may be based
on the number of socks deployed between barrels, sock length, growth conditions and

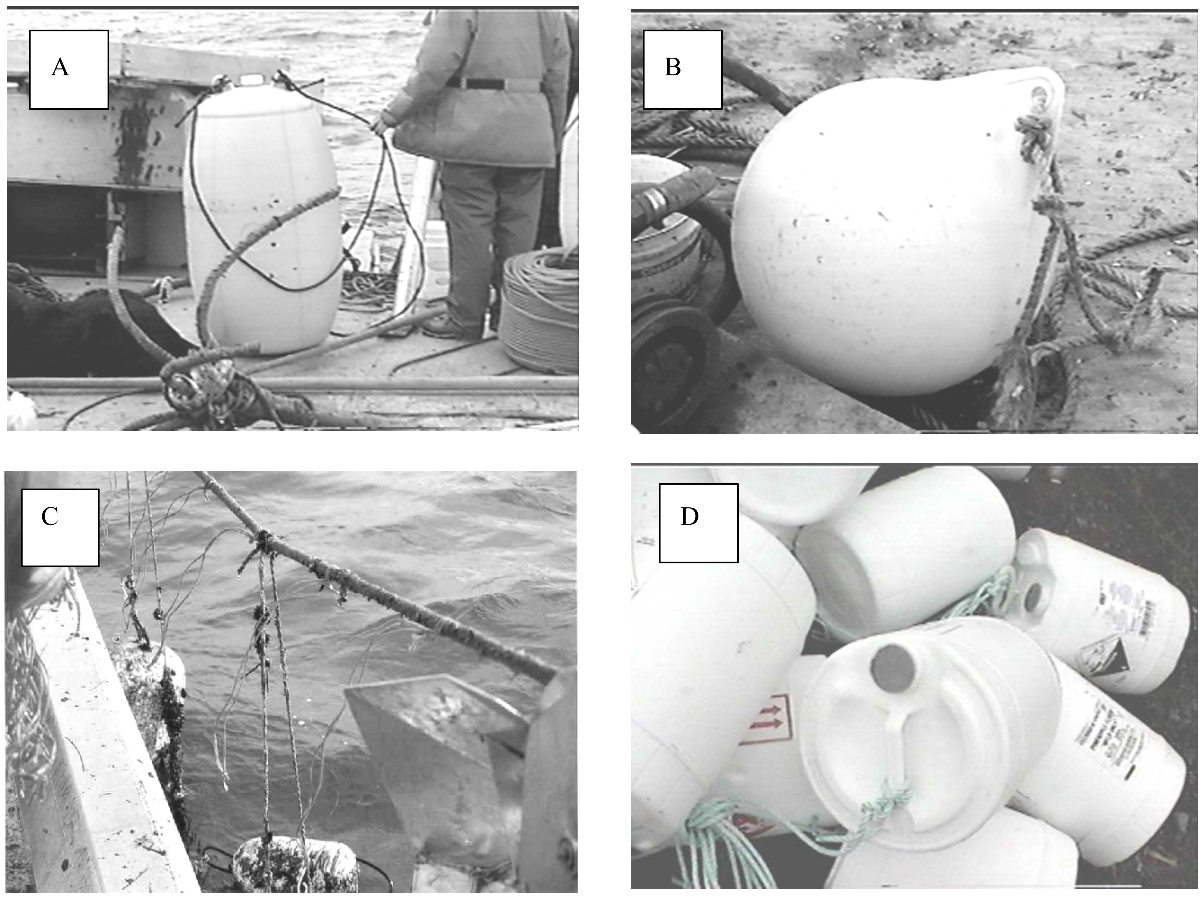



Figure 4.10: Various types of floats used in Newfoundland Mussel aquaculture. (A) barrels, (B) 0.4 m pressurized floats, (C) styrofoam floats, (D) concentrate containers.

environmental conditions at the site. The extent of the difference among sites may indicate a potential inefficient use of barrels at some Newfoundland sites. Growers with low production between two barrels may find it beneficial to experiment with longer sock length or increasing the number of socks between two barrels.

Typically 50-60 collectors are deployed between two barrels at Newfoundland mussel farms. Initial this number may be doubled with the grower placing a barrel in the middle at a later date as required. These large barrels provide high levels of floatation but are placed up to 15 m apart for socks and often farther for collectors. This may generate a large sag in the line placing mussels at much different depths and potentially allowing them to touch bottom in shallow areas where they may suffocate in the mud or be consumed by predators. Barrels are also very susceptible to wave action and may shake mussels off socks and collector lines in rough seas, so are best used in protected areas.

The 0.4 m pressurized float is becoming more popular with growers, particularly with collector floatation. These floats are much more versatile than the 200 l barrels and have sufficient

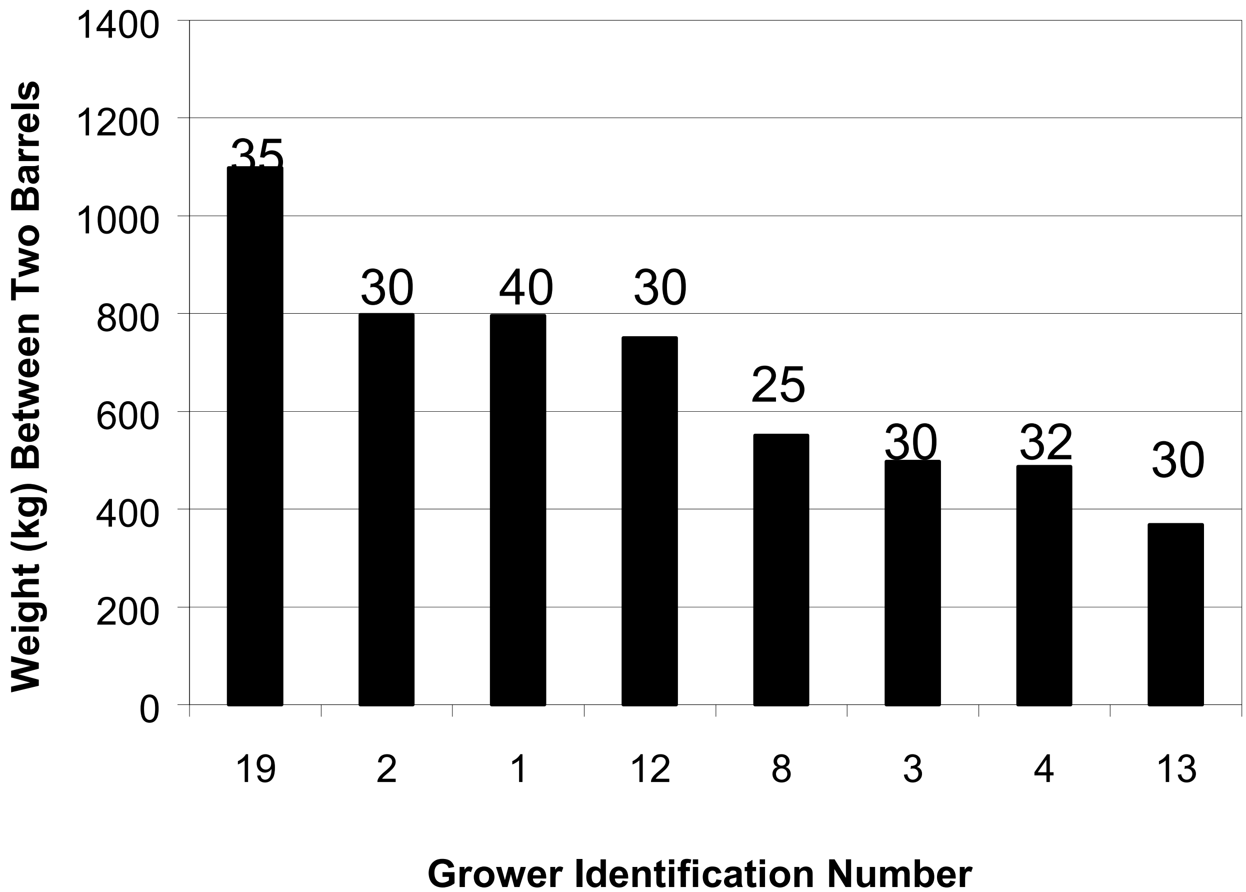



Figure 4.11: The total weight (kg) of mussel socks supported between two 200 l (45 gallon) barrels on a mainline system. Weight was based on mean total sock weight of 2 year plus socks weighed in air. Numbers above bars represent the number of socks between barrels at each sampled site in the fall of 1997 and 1998.

floating power to suspend both collectors and socks. Usually 25 collectors are placed between two floats although some growers use many more and add floats as the mussels grow. 0.4 m

float usage for collectors has multiple benefits over the barrel floatation. It will reduce the sag between the two floats, reduce wave action (Figure 4.12) and allow the collector line to be submerged. In addition it is cheaper to use the 0.4 m floats for collector lines. 50 collectors will require two barrels vs. three 0.4 m floats (2 floats for every 25 collectors). Barrel cost is approximately $40-$45 per barrel vs. $11-$15 per float depending on purchase location and shipping. Assuming 50 collectors are between two barrels, a total of 3 barrels would be required per 100 collectors. The same quantity of collectors would require five 0.4 m floats. At the above costs 16" float usage generates a saving of $ 45 per 100 collectors. On a 10,000 collector farm this savings may exceed $4000 in floatation costs.

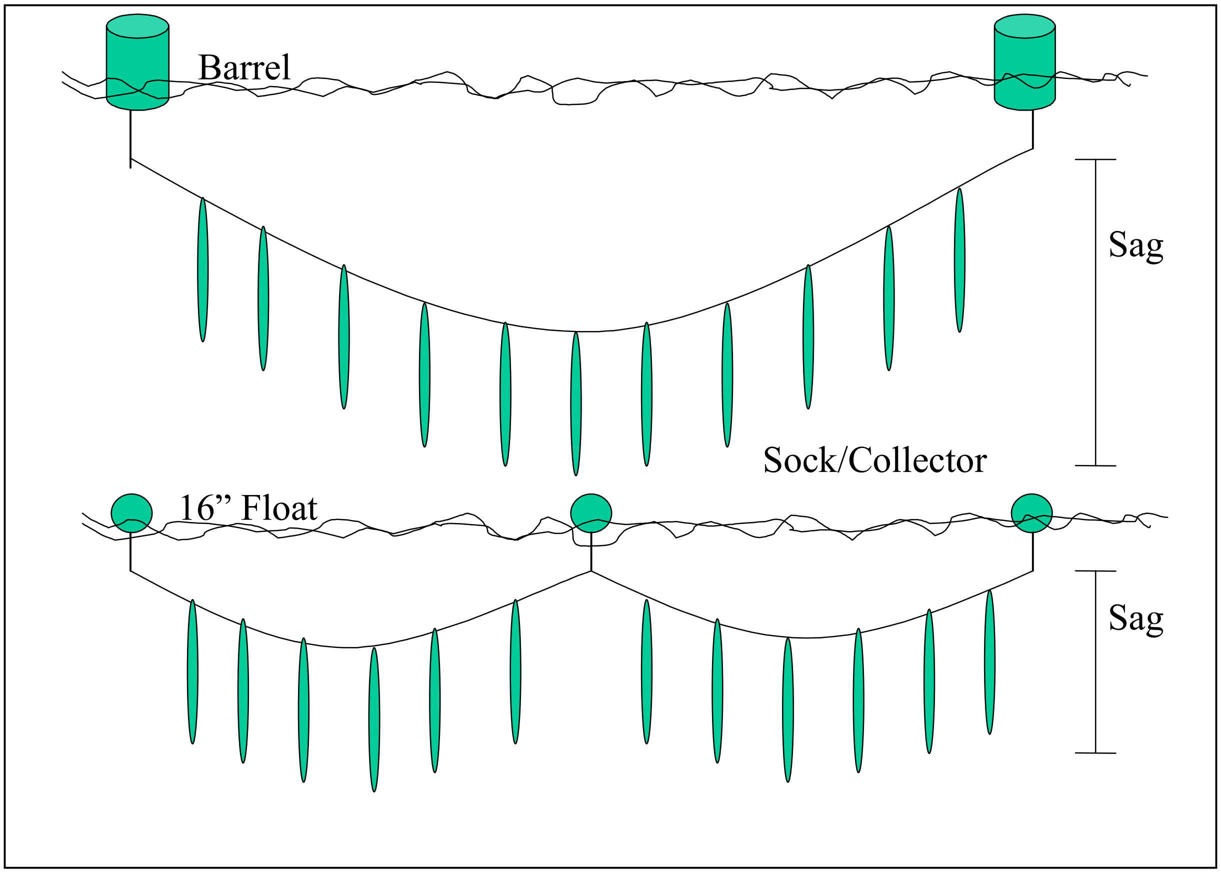



Figure 4.12: Comparative line sagging using barrels and 0.4 m floats, assuming 50 collectors between barrels and 25 between floats.

0.4 m floats may also be used for sock floatation although few Newfoundland growers are using this practice. Two 0.4 m floats can suspend approximately 6-8 socks at harvest size. From a capital cost perspective this is more cost effective than barrel floatation using 25-30 socks between two barrels. If we assume 6 socks between two floats a total of 9 floats would be required for 48 socks. This is a cost of $99-135 vs. $120-145 for three barrels. The smaller pressurized floats also give the grower the option of sinking the entire farm below the surface. This reduces wave action on the socks and collectors and may become important in the future where potential conflicts over the aesthetics of surface floats may exist. Labour costs associated with barrel handling however are lower as there are approximately 3 times less floats that have to be tied on when dealing with sock lines.

Styrofoam floats have not been used to a great extent in the Newfoundland industry but are quite prevalent in PEI. Several growers are planning to incorporate styrofoam floats to their operation, particularly where lines and floats have to be submerged. Because of their small size they are easily sunk with ballast weights. The larger 0.4 m floats require a significant amount of ballast weight to submerge the float particularly at the first year of socking when the socks are of a relatively low weight. Styrofoam floats become waterlogged after 2-3 years of use but may be dried over a summer. A new type of styrofoam float on the market (Dave Champion, IMP 1999, pers. comm.) claims to have superior water resistance to the ordinary styrofoam float. Several growers will be tested this float in 1999. Styrofoam floats however, have higher labour costs associated with tying floats to mainlines because of the numbers required, which may be one float every sock or two depending on sock weigh and float size.

Canadian Coast Guard requires that all sites be approved under the Navigable Waters Protection Act (NWPA). All sites are assessed individually with the approved site size, location and the required markings outlined on the NWPA documents issued to the grower. Perimiter markings consist of an arrangement of yellow cautionary buoys typically placed at 60 m intervals. Some of these buoys may be required to carry reflective tape (10cm wide strip completely around the float) and cautionary lights. The extent of the reflective tape required is not fixed nor is the number of cautionary buoys and a mussel grower should review their NWPA documentation to determine site requirements. If growers require clarification with respect to their requirements they can contact Canadian Coast Guard (Paul Nippard, Canadian Coast Guard, 1999, pers. comm.) The 0.6m cautionary buoys are very expensive ($250-$350) and are ubiquitously replaced by yellow 200 l barrels which are inexpensive by comparison ($40-$45). The tape may be purchased separately. Other colored floats may be required if a navigation channel is necessary through the site. These floats also must be 0.6 m and must be red on the right side of the channel and green on the left side proceeding from the seaward direction (Figure 4.13). Channel markers may require reflective tape based on the specific navigation characteristics of a site. The grower should contact the Canadian Coast Guard for the requirements for individual sites. All buoys must conform to the Private Buoy Regulations under the Canada Shipping Act.

The Canadian Coast Guard has a video available that shows the coast guard requirements for mussel farms. Growers may contact Dan Shea (709-772-2284) at the Canadian Coast Guard to obtain a copy of this video.

Submerged Lines

Only two of the surveyed growers submerged their lines (including floats) below the surface. This requires the use of small anchors, usually a 12 to 20 l to (3-5 gallon) bucket of concrete or a sandbag (sandbags are considered environmentally unfriendly and are not encouraged) that are tied at intervals to the mainline (Scarratt 1993). The length of the rope on these small anchors is sufficient to submerge the entire line, floats and all below the surface (Figure 4.14). The floats would have to be able to withstand the water pressure of being submerged and be small enough to be sunk with the small anchors. A 0.3 m or 0.4 m hard plastic float or styrofoam float are preferred. Large barrels simply would require too much ballast to sink and would compress from the water pressure. 0.4 m hard plastic floats, although pressure resistant, have considerable

floating power and require a significant amount of weight to submerge. The pressurized hard plastic floats are designed to withstand 10-12 m depth but will collapse if they sink below this. If
floats collapse the entire line may sink to the bottom. Styrofoam floats will rarely collapse and consequently represent the safest floatation method for submerged lines

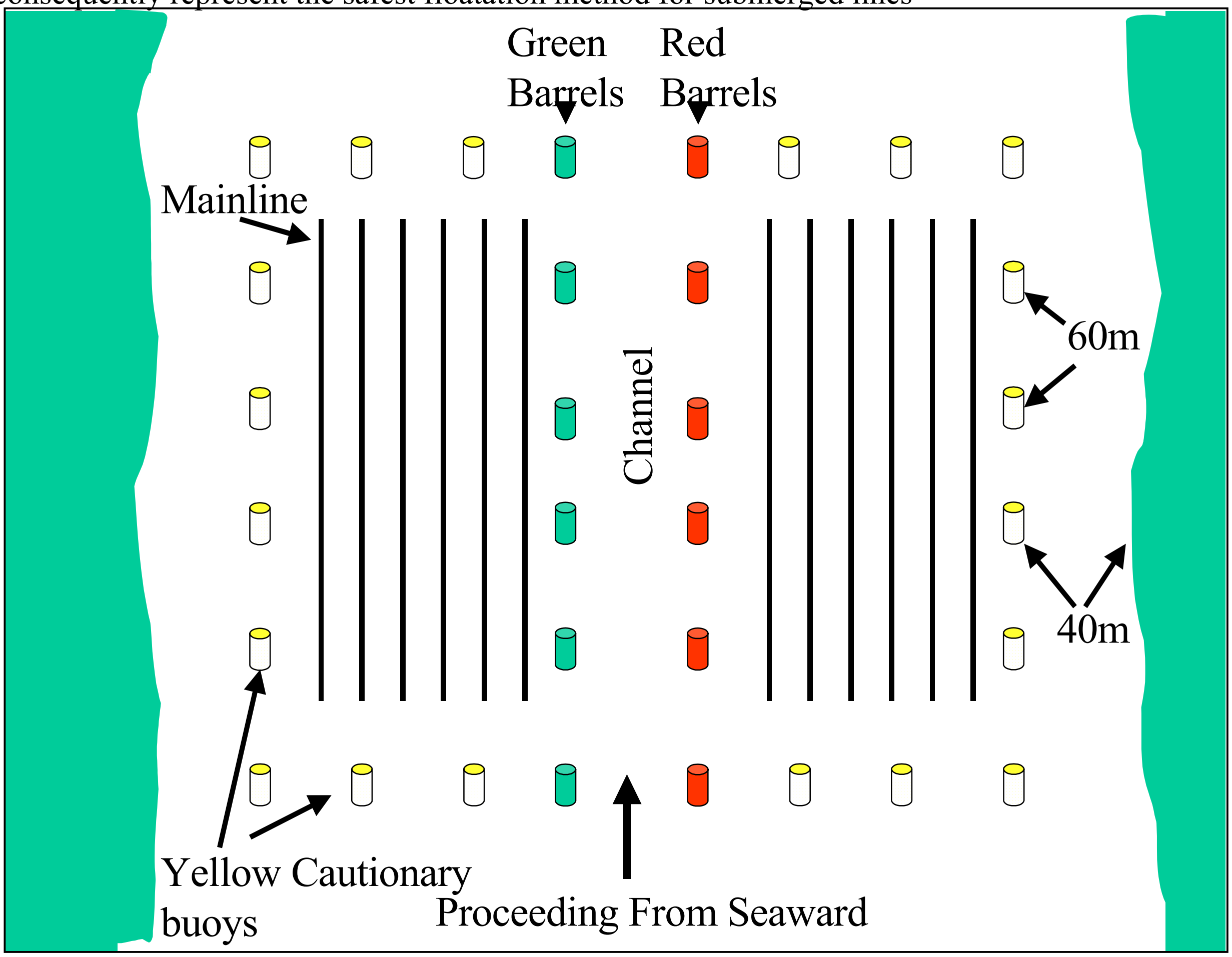
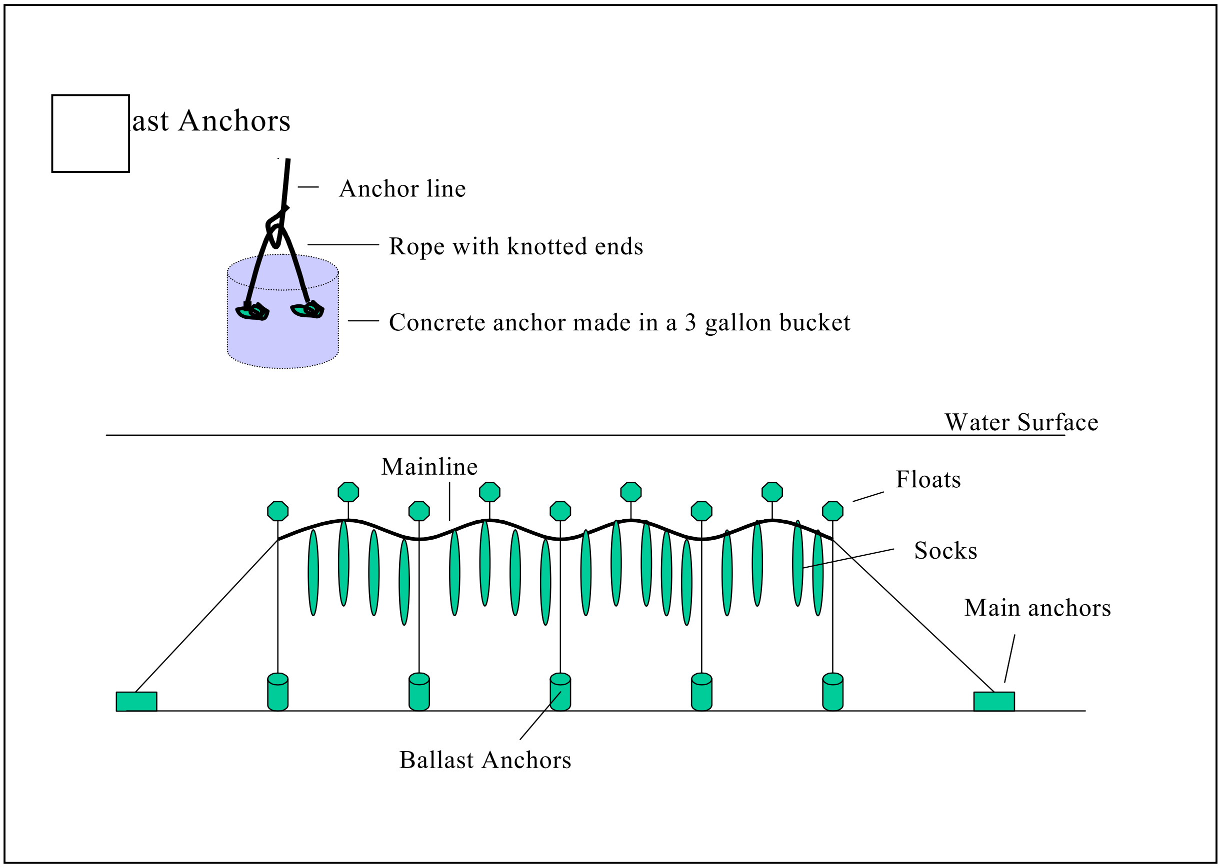



Figure 4.13: Typical site layout indicating placement of yellow cautionary buoys, and red and green channel markers.

The benefits of submerging floats include aesthetics, preventing drop off, improving yields and avoiding ice. Sinking also reduces the wave action on the lines preventing the mussels from being shaken off (Scarratt 1993). Pack ice can flow over the top of lines that have been submerged to a sufficient depth and thus ice damage is minimized**.** In areas with highly variable depths, care should be exercised such that lines are not sunk unevenly and touch the bottom where they may be more susceptible to moralities.

Unfortunately, using submerged lines has and added cost. Ballast anchors are required in very large numbers. The materials and labour needed to make these anchors is not insignificant. There is also an added labour cost in attaching the anchors and removing them during harvest. The costs of product and equipment losses from ice damage and wave damage may exceed the costs of sinking lines



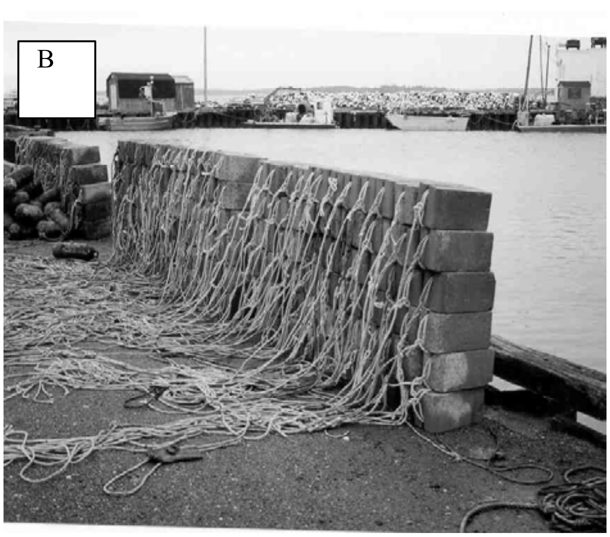




Figure 4.14: (A) Ballast anchors, and a mainline submerged using ballast anchors, (B) cinder blocks used as ballast, (C) Con crete buckets used for ballast.

If a mussel grower intends to use submerged systems he/she should contact the Canadian Coast Guard with the details of their plan to make sure that all navigation requirements are met.

**Site Layout**

The location of collectors and sock year classes on surveyed farms tended to vary. Collector lines were generally separate from sock lines but not in all cases. Sock year classes each socked with a variety of seed sizes tended to be mixed together. In addition, some growers tended to sock mussels of different sizes on the same line. Mussels that fell through the socking material were collected in tote pans and then re-socked in a smaller mesh size then placed on the same line as the larger mussels. If seed grading was used all seed size grades were usually deployed on the same line. These practices could potentially result in lower harvest yields. The smaller seed will not reach the same size at harvest as the larger seed, assuming mussel density and food availability is similar. Since these socks are on the same line, some or all of the smaller mussels may be harvested with the larger mussels because the socks are mixed together. The result is a lower market yield from the harvest.

Proper site layout is just an extension of the size grading process. Mussels of similar sizes should be located in the same area. Collectors should be located together and separate from sock lines. Each year class of socks should be in a separate section. While socking, seed of the same size should be placed on the same line(s). To further improve the situation, all the socking should occur during the same period if financially and physically possible. By socking in different months a wide variety of mussel sizes is generated. Under current practices socking the entire farm at one time may be difficult but with the use of seed graders and improved socking efficiency the entire socking for a farm may only require a few weeks.

# 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.

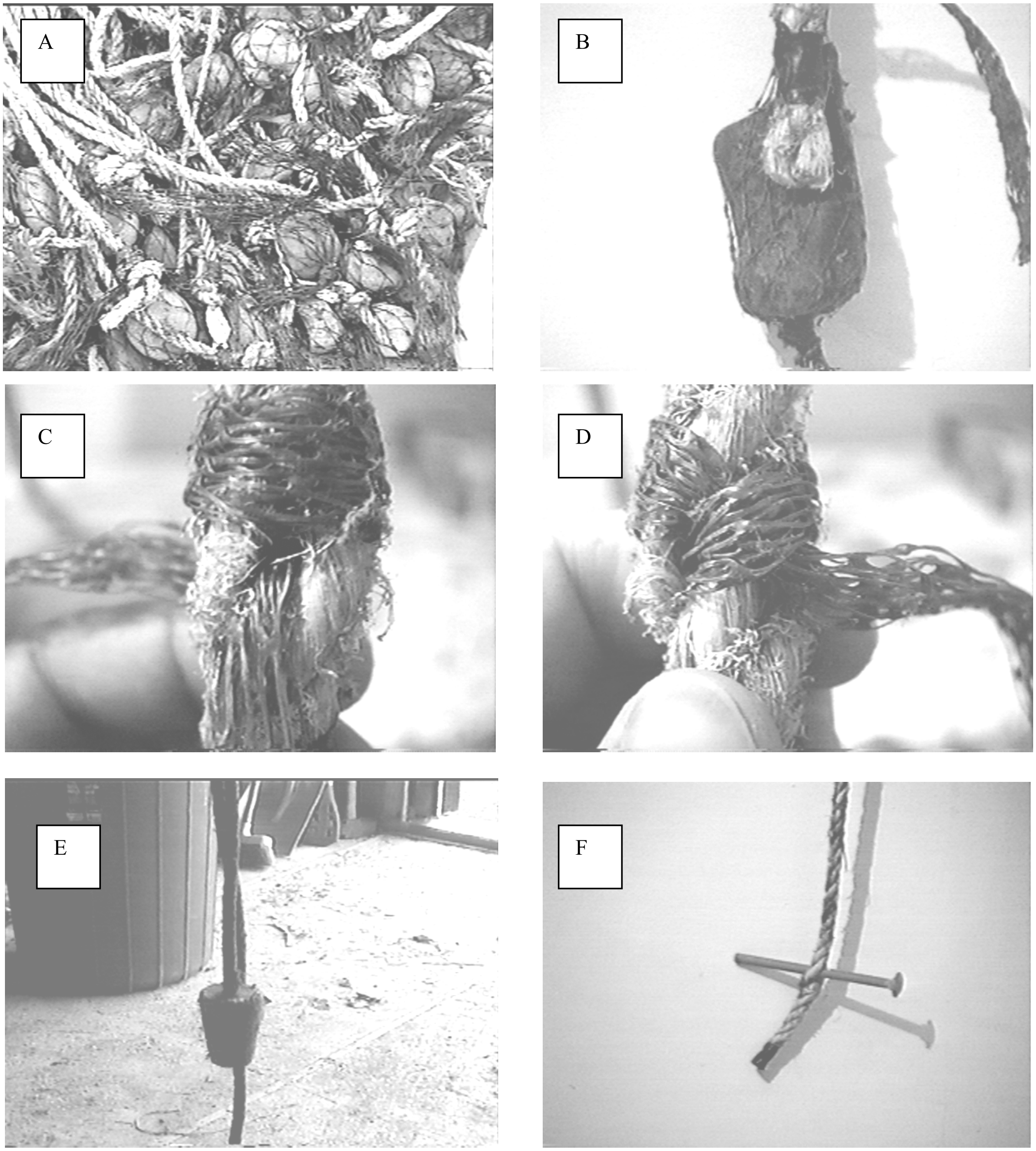



Figure 5.1: (A and B) Rock weights collectors, (C and D) method for attaching rock weights to collector ropes (socking is inserted through collector rope, followed by a clove hitch), (E) concrete cup collector weights, (F) nail weight collectors.

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.

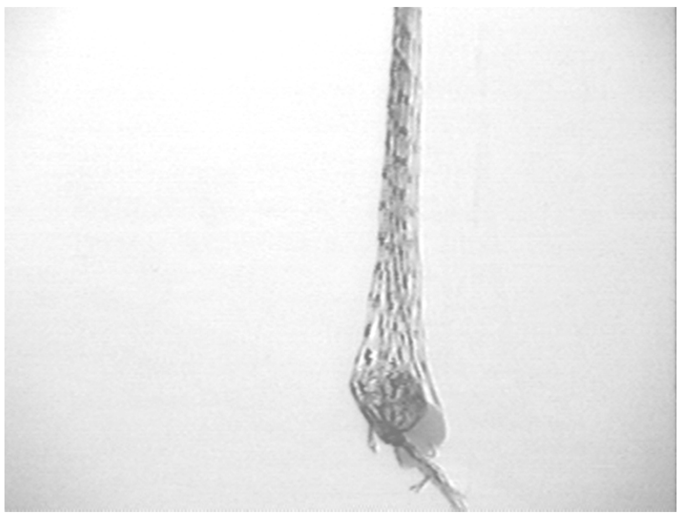


Figure 5.2: Socking material collector.

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.

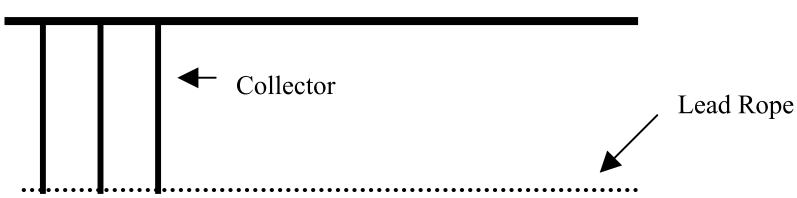



Figure 5.3: Continuous collector using a complete line of lead rope along the bottom.

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.

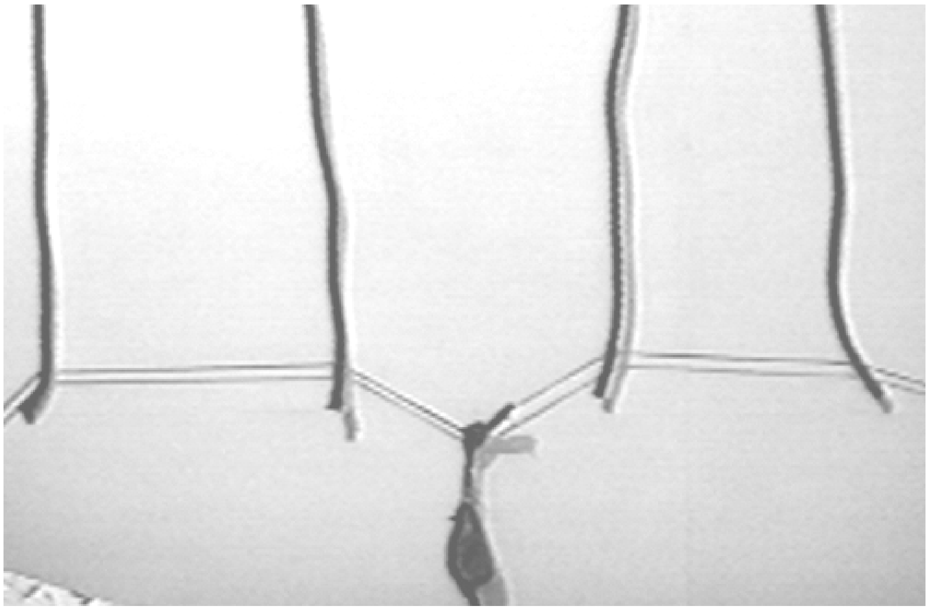


Figure 5.4: Collector design using twine or polypropylene rope for a bottom line to which weights are attached at intervals.

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.

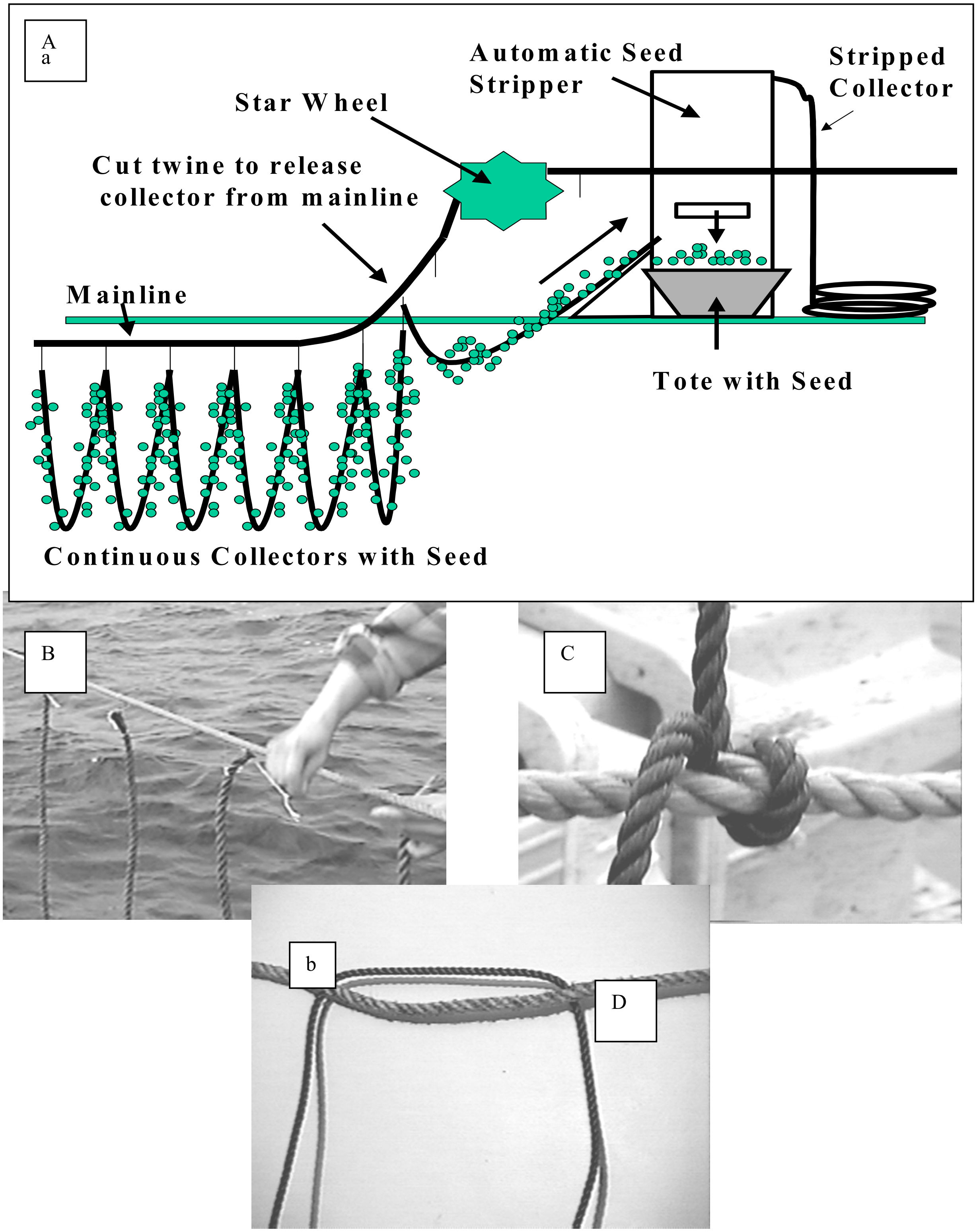



Figure 5.5: (A) A flow diagram of continuous collectors using an automatic seed stripper. Collector attachment methods: (B) tied with twine, and woven through mainline; (C) single and (D) double.

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.

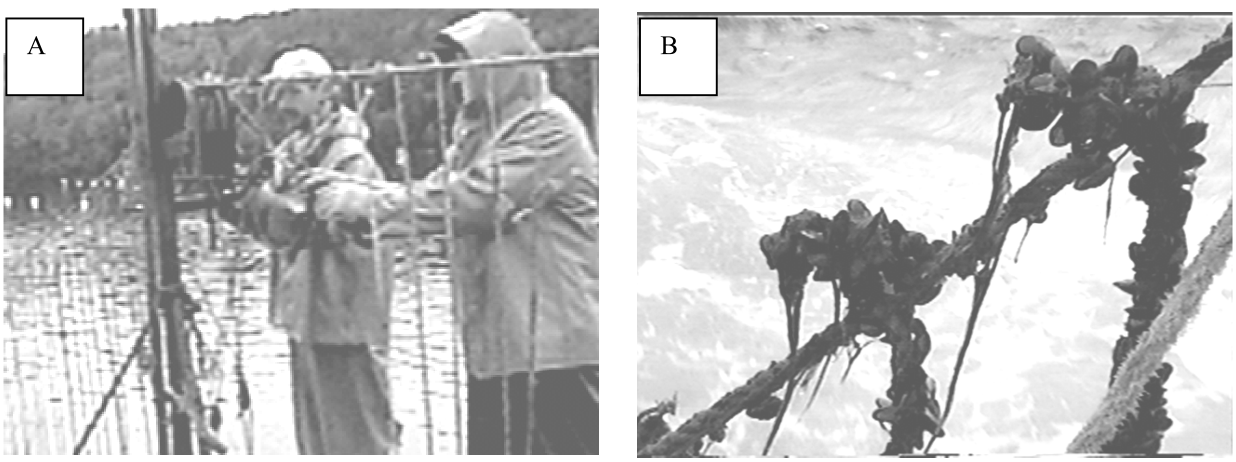



Figure 5.6: (A) Collectors tied to the mainline with twine being retrieved using a star-wheel. Note the smooth surface of the collector attachment to the mainline.  (B) Collectors woven through the mainline and tied, note the collection on the loose end from the knot.

## 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.

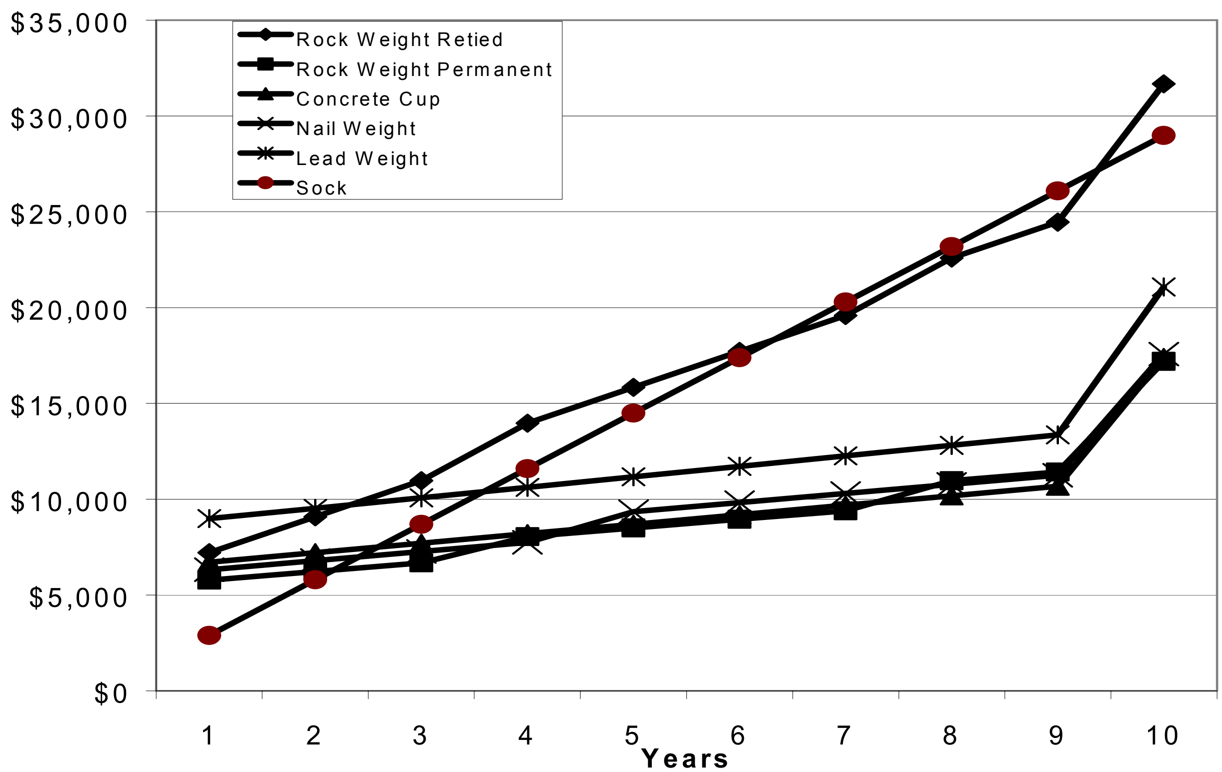



Figure 5.7: The cummulative cost (labour and materials) of six collector designs used in the Newfoundland mussel aquaculture industry for a hypothetical 10,000 collector farm over a 10 year period. Estimates do not include float, anchor or mainline costs or the costs from seed harvesting. See Appendix 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 currrent flow, the seed collectors could be consumming 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 otimize 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.

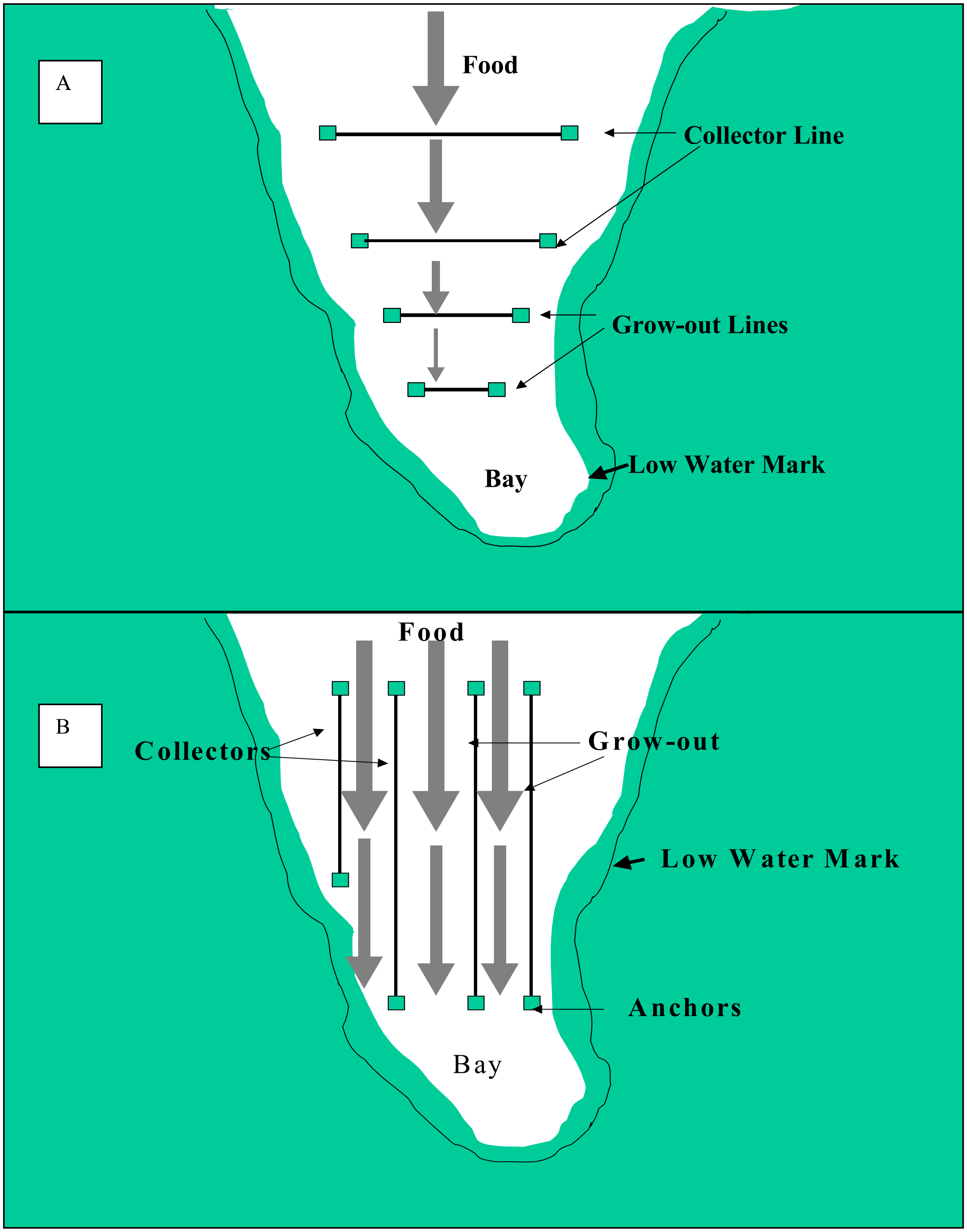



Figure 5.8: Food attenuation throughout a (A) shore to shore mainline mussel site with collectors located at the front and (B) a parallel mainline site with collectors located on the side.

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.

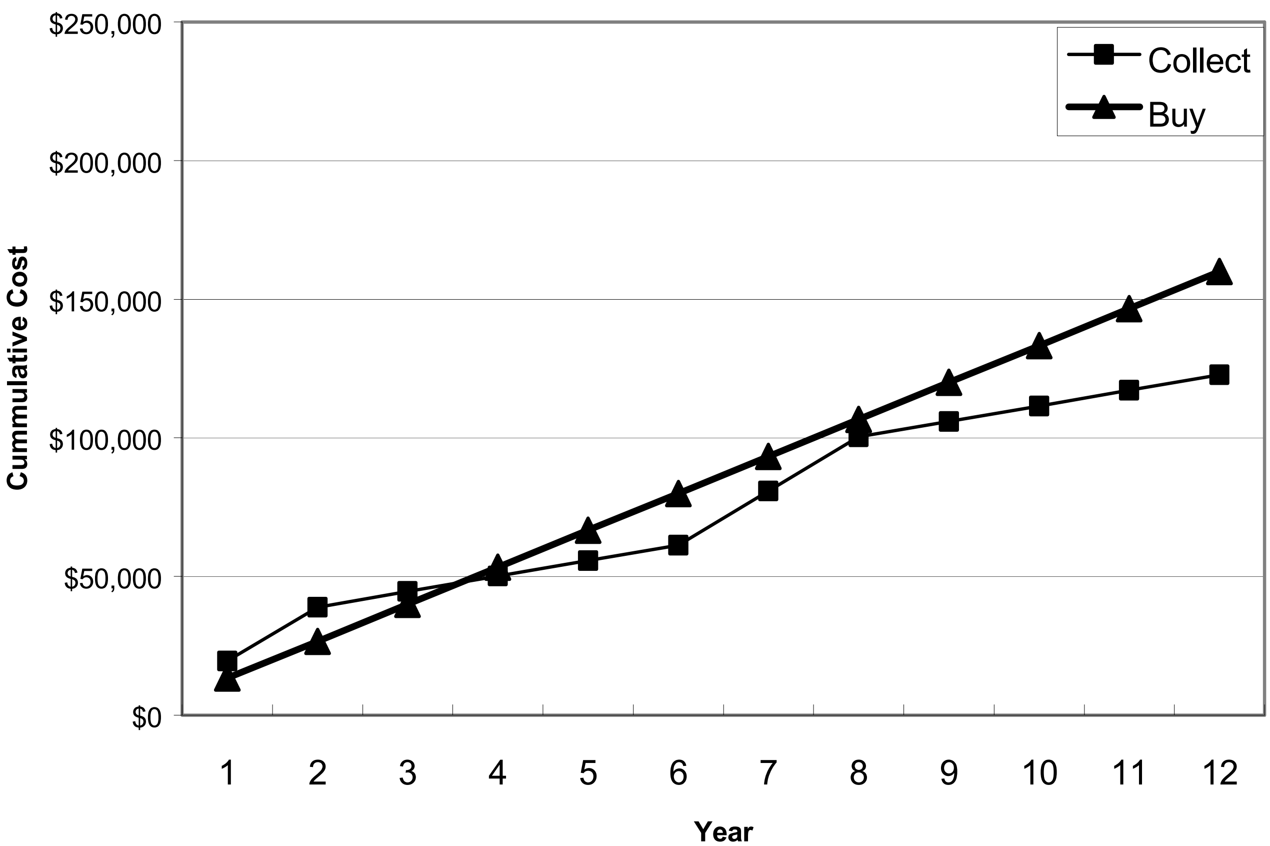



Figure 5.9: A comparison of the cumulative costs associated with purchasing seed or growing one's own over a 12 year period for an hypothetical 10,000 sock per year farm.  This assumes a 1:1 sock to collector ratio, 15 socks per tote pan and a seed cost of $20 per tote.  For additional assumptions see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

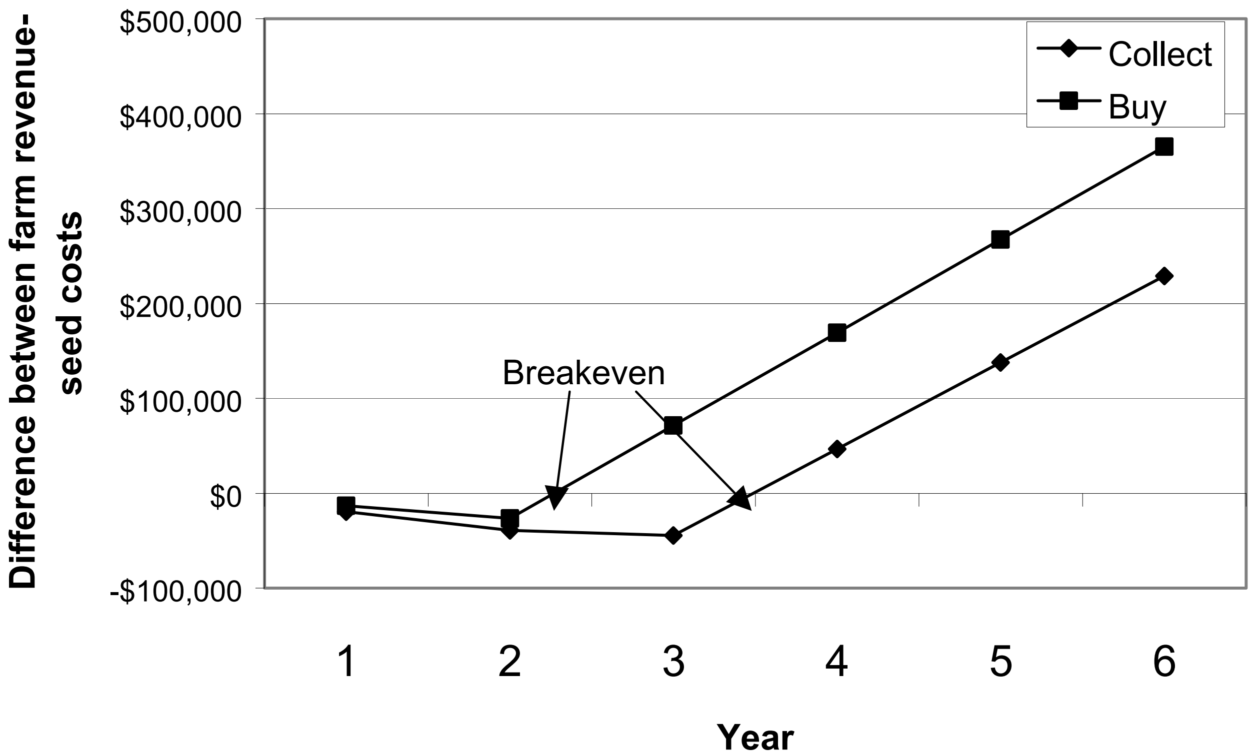



Figure 5.10: The difference between cumulative revenue and cumulative costs for a mussel farmer that collects seed compared to one that purchases seed. This assumes a 1:1 sock to collector ratio, 15 socks per tote pan and a seed cost of $20 per tote. For additional assumptions see Appendix 1, Table 1B. 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.

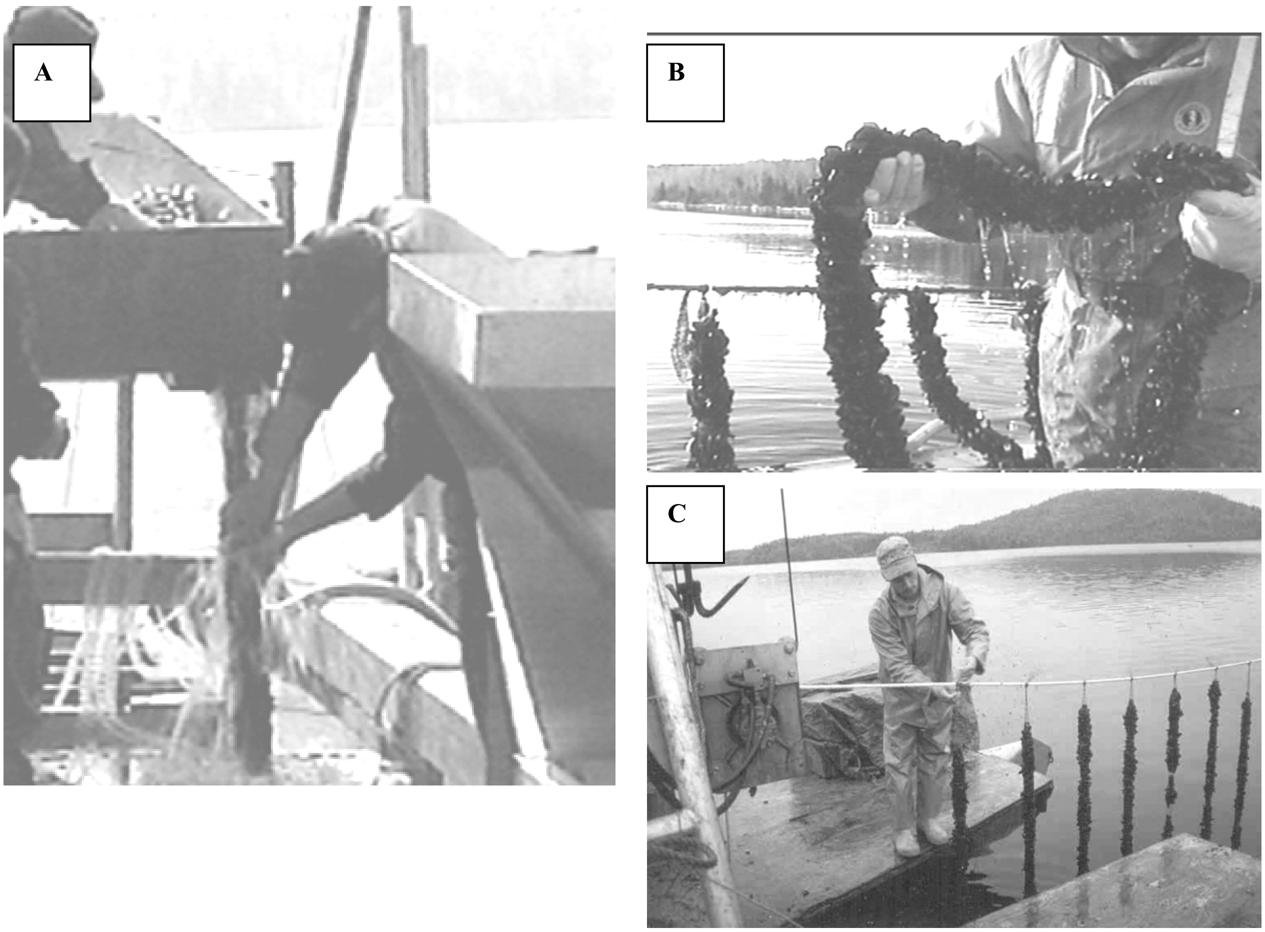



Figure 6.1: (A) Socking on a two-tube table, (B) socks on mainline, (C) deploying socks on a mainline.

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.

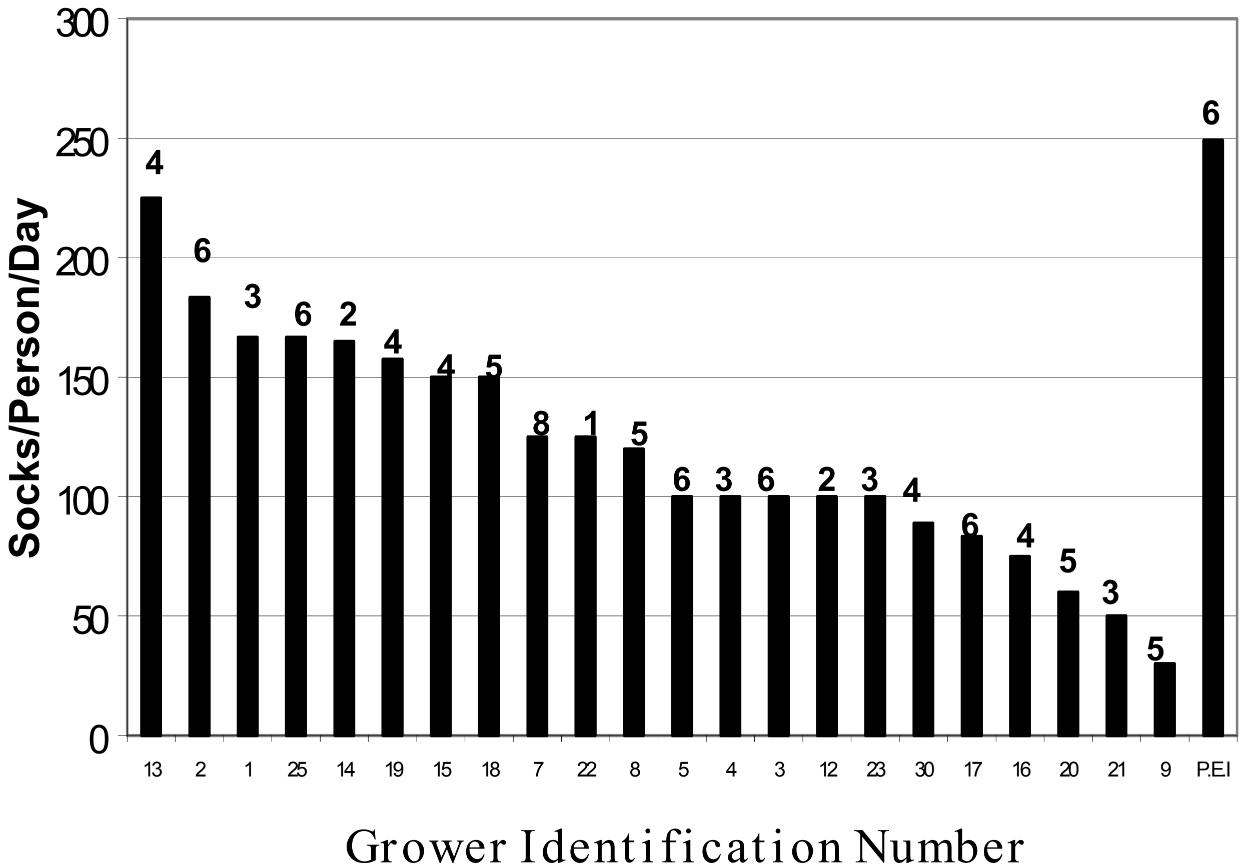



Figure 6.2: The number of socks filled per person day at 22 commercial mussel farms. Values are based on an eight hour day and include the stripping of seed and the deployment of socks. All information is based on the 1997 and 1998 NAIA-Marine Institute Mussel Extension Service Survey. Numbers above 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

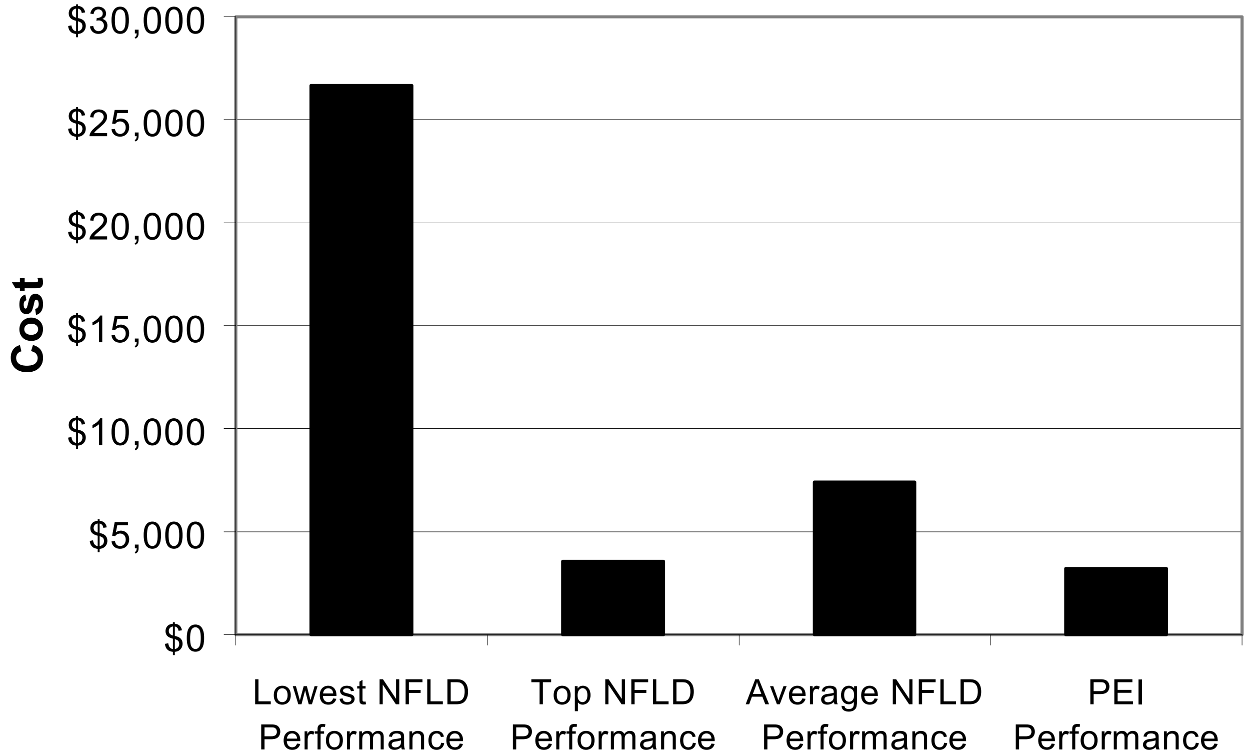



Figure 6.3: The labour costs associated with stripping seed, socking and tying socks to mainlines for the best, worst and average Newfoundland performances of 12 surveyed growers. Values are based on a 10,000 sock deployment using a labour cost of $80 per day per person. PEI socking performance is derived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

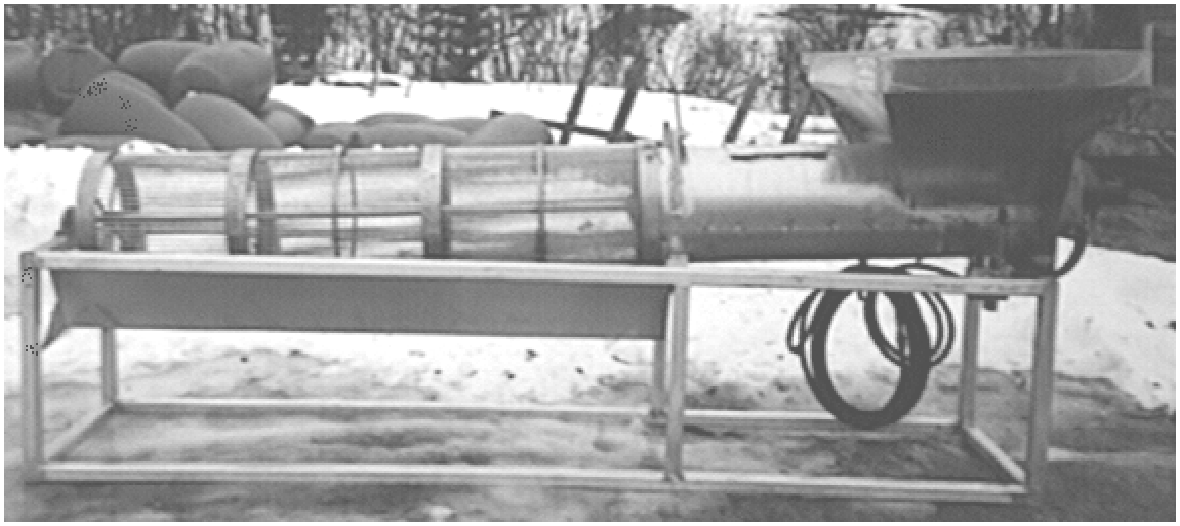


Figure 6.4: A small de-clumper grader used in socking experiments and for demonstration to Newfoundland growers. The device is 3 m long and weighs approximately 180 kg. Depending on seed source, its capacity ranges from 1000 to 1800 kg per hour.

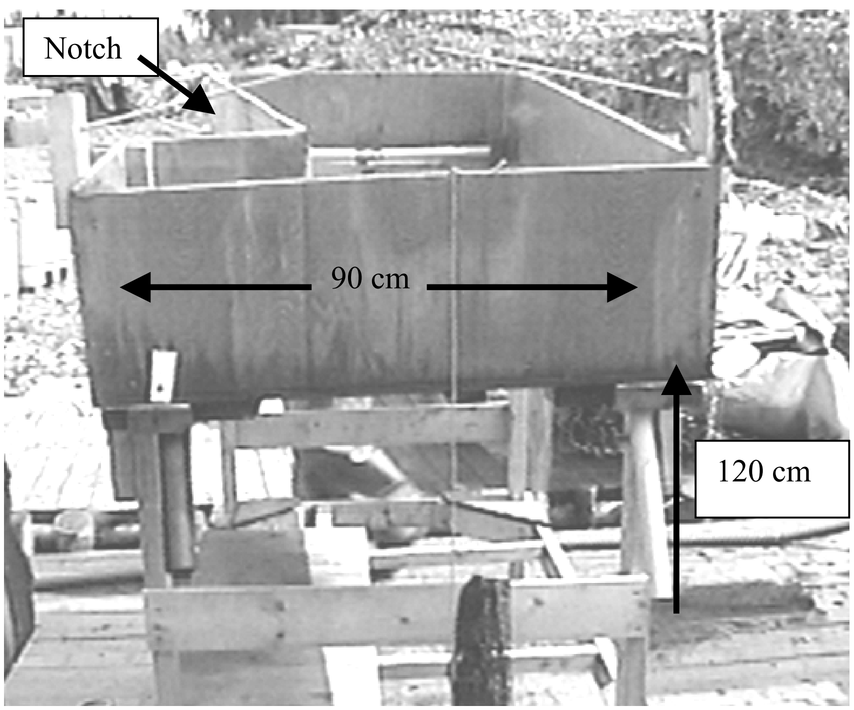



Figure 6.5: Three person socking table with vertical tubes. The table is designed with a notch to allow one person to feed two sock tubes.

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.

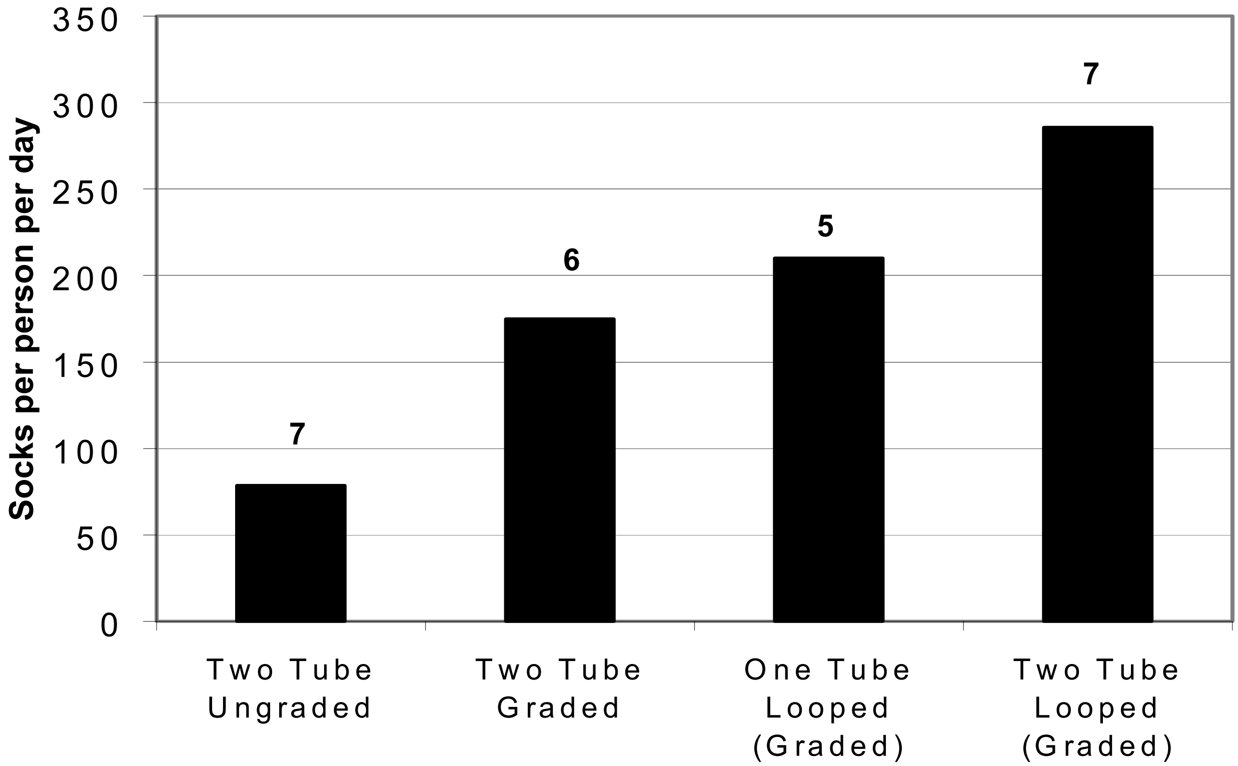



Figure 6.6: The number of socks filled and deployed per person day (assuming a 10 hour day) using four socking techniques, based on Newfoundland mussel grower interviews and on direct timings of the socking process. The numbers above each bar represents the number of workers required for each technique 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.

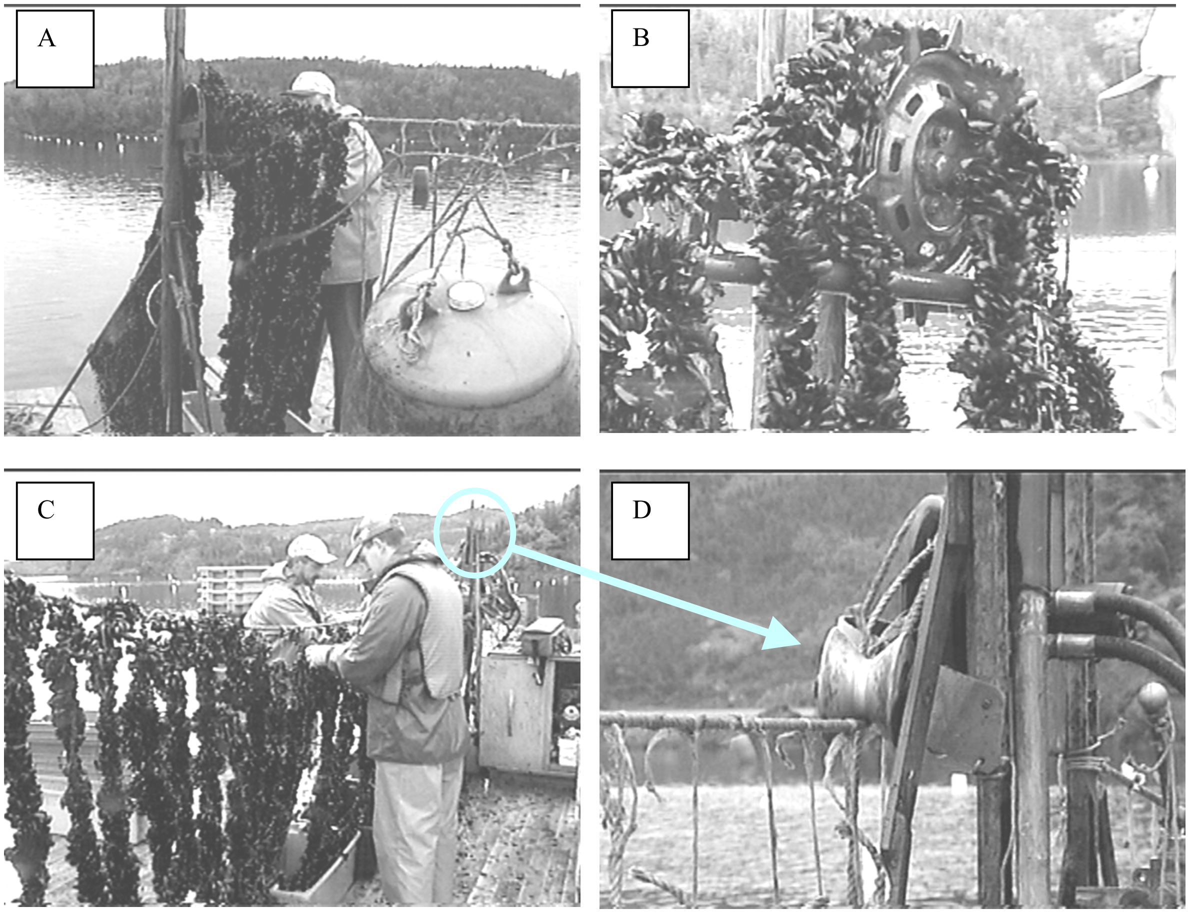



Figure 6.8: Barge design that allows fast easy removal of seed. (A) Seed being pulled up and over a star wheel, (B) home made star wheel, (C) stripping seed to the middle of the barge, (D) rear hauler wheel.

**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

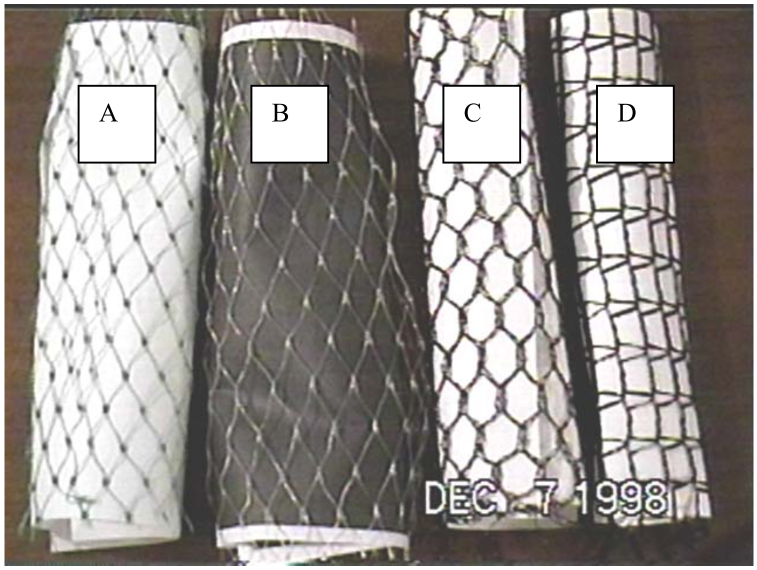



Figure 6.9: Socking brands. (A) 17 mm Dupont, (B) 20 mm Spanish, (C) 20 mm Fukui, (D) TML Irish Square Mesh.

(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.

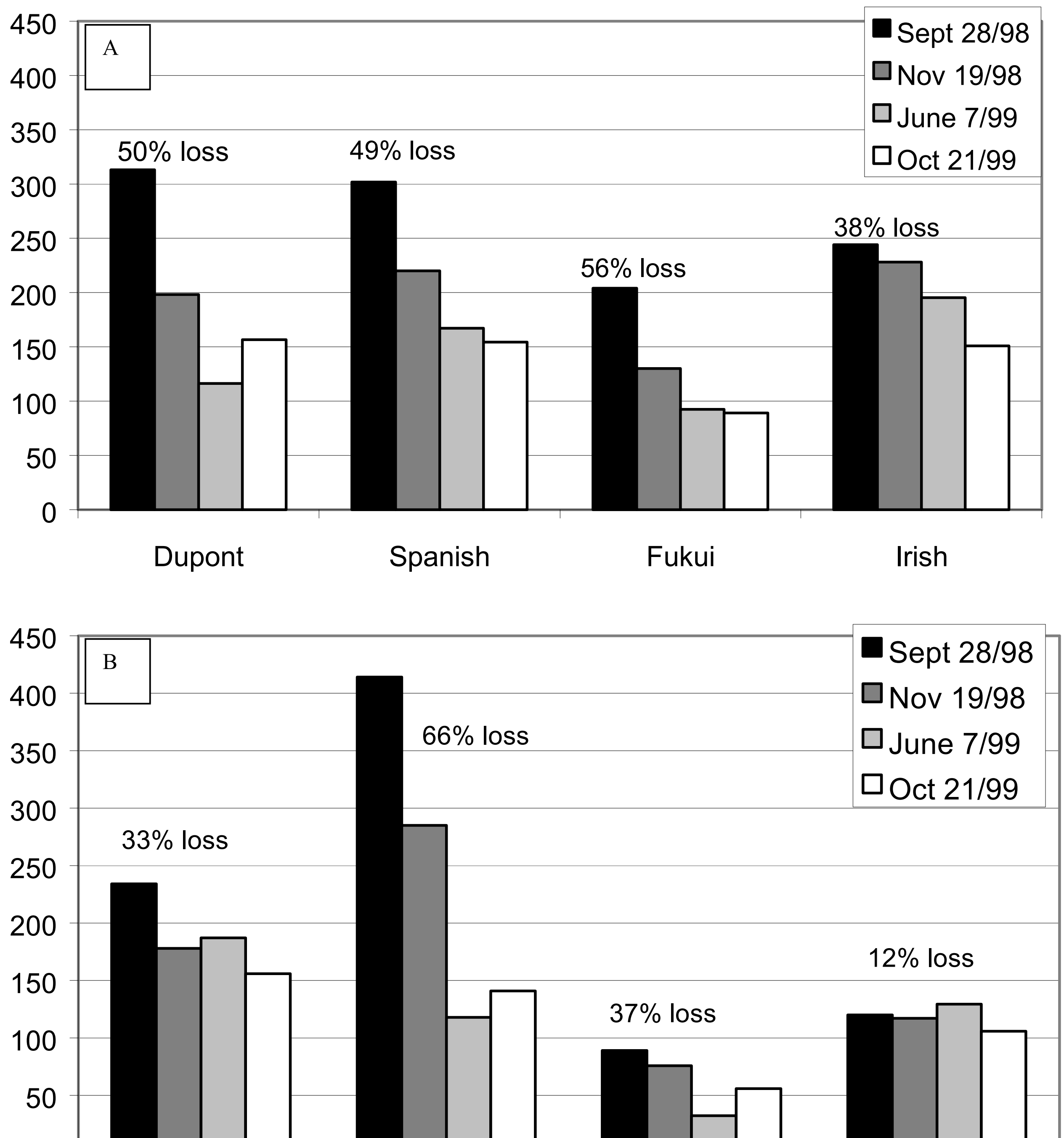



Figure 6.10: Changes in mean mussel density per 30 cm of sock for four sock brands from deployment in September 1998 to final sampling in October 1999 at Cap Cove, Trinity Bay. Socking material had an approximate mesh size of (A) 15 mm, medium seed (15-25mm shell length) and (B) 20 mm large (25-35mm 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)

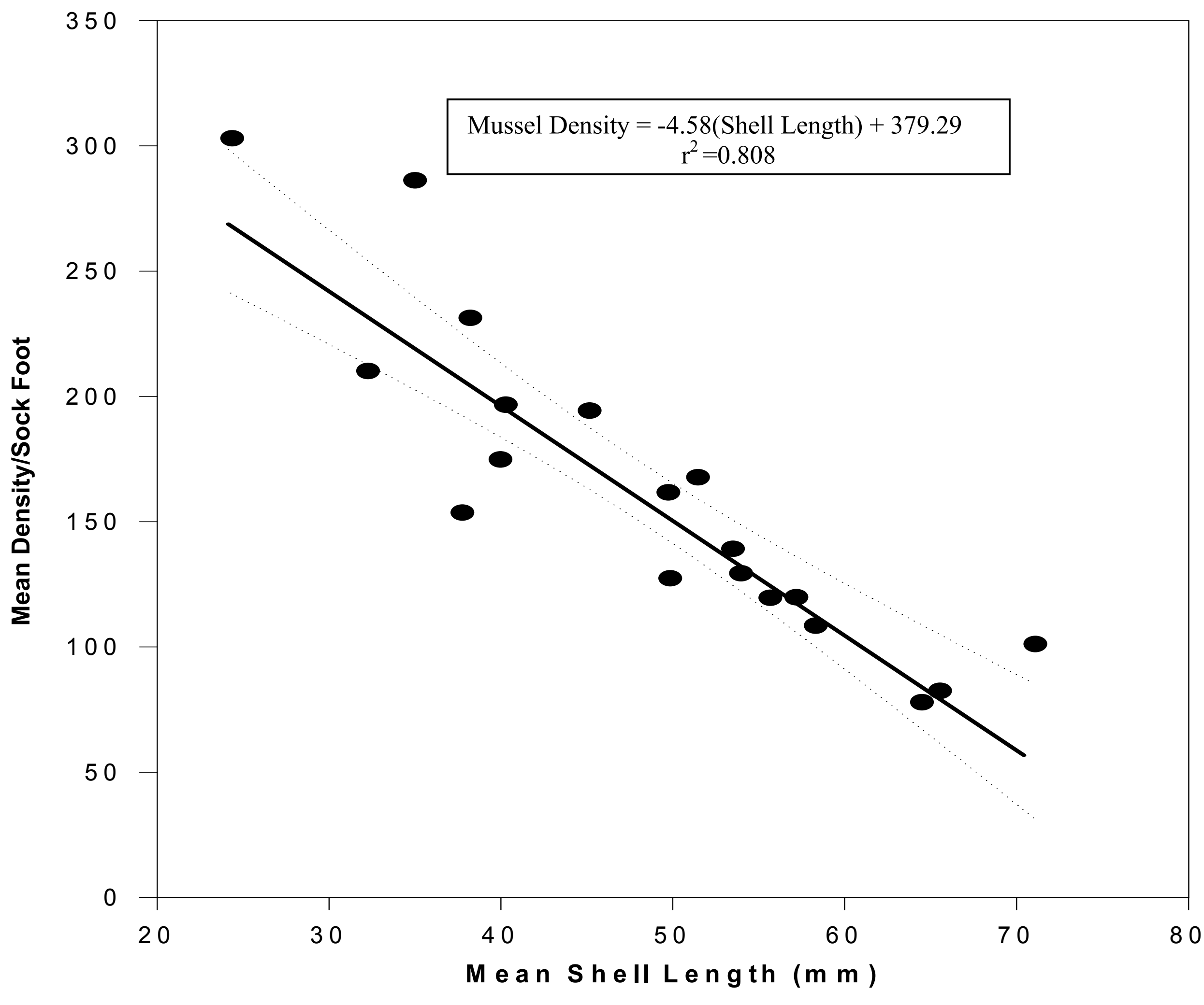



Figure 6.11. Relationship between mean mussel density per 30 cm sock and the mean shell length (mm) of socked mussels from nine commercial grow out sites in Newfoundland. Sites were sampled in the fall of 1997.

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 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 indicted 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.

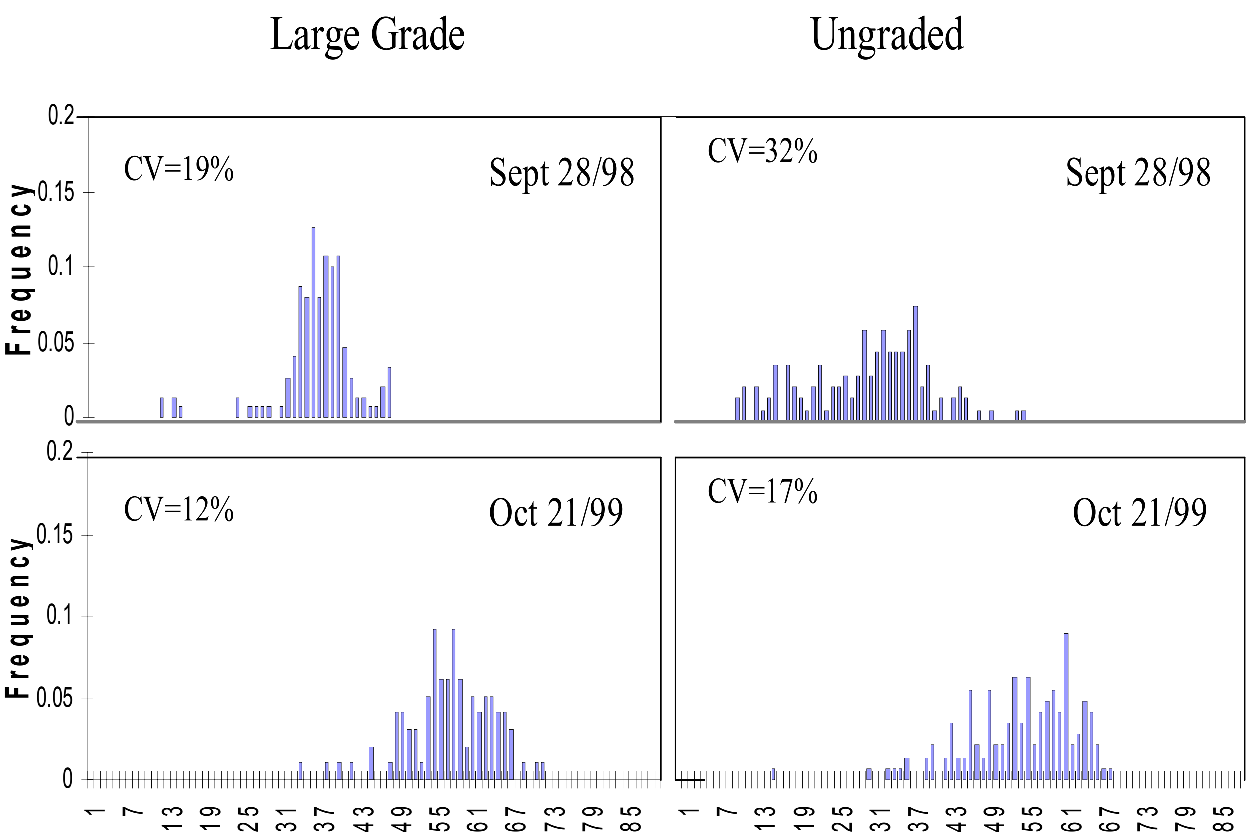



Figure 6.12: A comparison of relative frequency of seed sizes in ungraded and graded seed using Irish square mesh TML (6.5 cm diameter) socking. Ungraded seed and large grade seed were socked and sampled on September 28/98 and sampled again on October 21/99 at Cap Cove, Trinity Bay. Variability of seed 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).

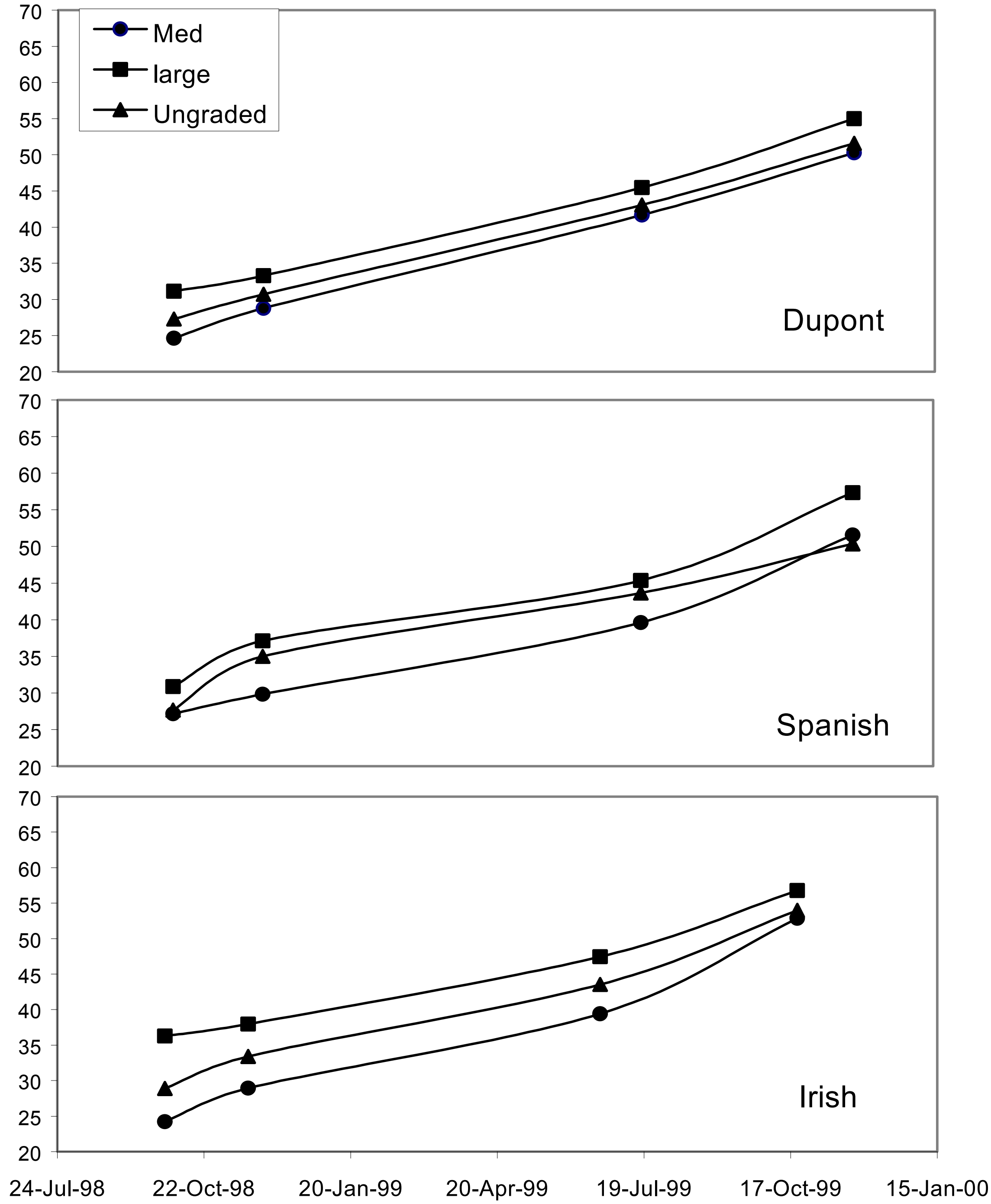
The large grade seed was 3- 6 mm larger on average than the ungraded seed at initial deployment and remained 3-7 mm larger 13 months later depending on sock brand (Figure 6.13). The medium grade seed, which was 3-5 mm smaller on average than the ungraded seed, met or surpassed the mean size of the ungraded 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 $^{0}$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.

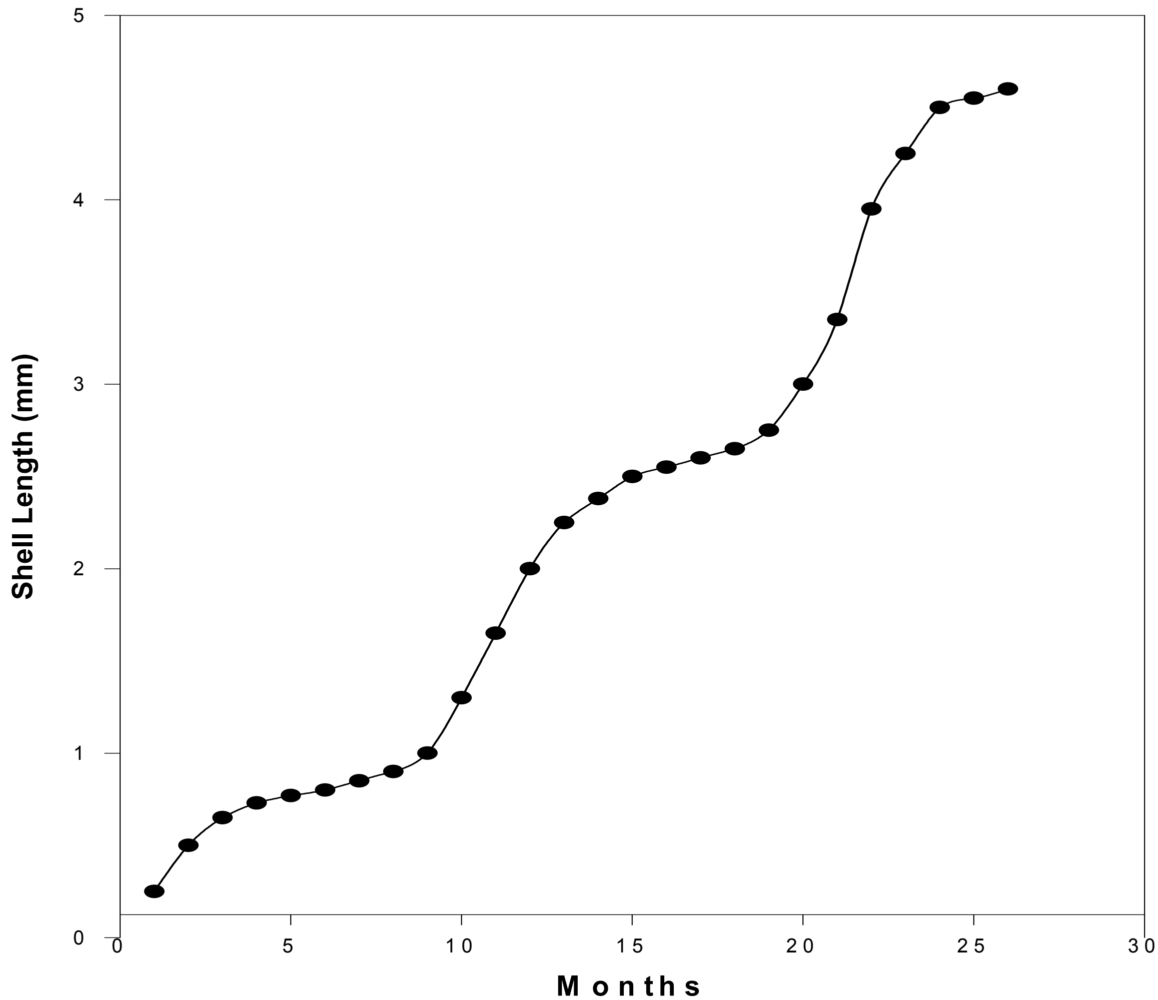



Figure 6.14: Mussel growth pattern over a 25 month period. Adapted from Sutterlin et al. (1981). The first data point begins in August. The period of maximal growth occurs from April to August and is indicated by the shaded areas.

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.

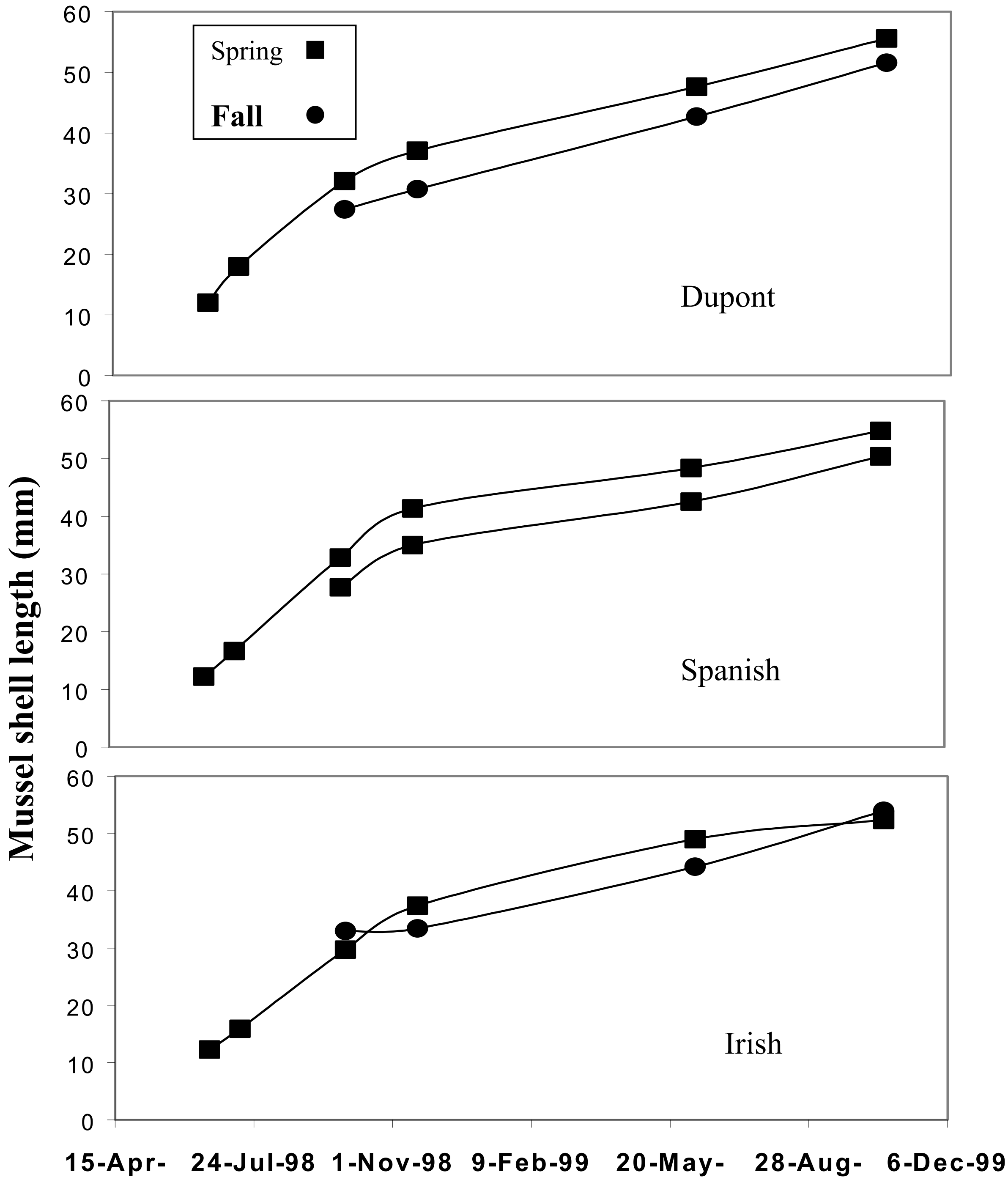


Figure 6.15: A comparison of mean mussel shell length (mm) for mussels socked on June 22/98 and mussels socked on September 28/98 at a commercial mussel farm in Trinity Bay, Newfoundland. Mussel lengths were averaged using 150 mussels from each sock types (Dupont, Spanish and Irish) per sampling period.

# Chapter 7: Mussel Farm Equipment

The typical equipment employed by the surveyed growers consisted of a small open boat with a motor, a barge with hydraulic hauler, and a socking table with a water pump. The barges often had outboard motors. Some growers also incorporated cranes and/or winches into the equipment mix. New equipment like hydraulic seed graders and socking machines are also becoming more common in the Newfoundland mussel aquaculture industry.

Barges

Most of the surveyed growers used barges to work their mussel farms (Figure 7.1). Those that did not used small open boats. The barges were much more efficient, safer and comfortable to work on than the small boats. One grower did purchase a large aluminum flat bottomed boat from PEI that had most of the characteristics of a barge (Figure 7.2). There were four types of barges that were utilized by the surveyed growers. These were: the aluminum pontoon, the wooden frame pontoon filled with styrofoam, the fiberglass pontoon and barrel floatation barge. The aluminum pontoon had to be purchased at considerable expense to the grower resulting in barge costs of approximately $ 25,000 to $30,000 for a 10 to 15 m (30-45 ft) long barge. Although expensive, the life expectancy is much longer for the aluminum barge.

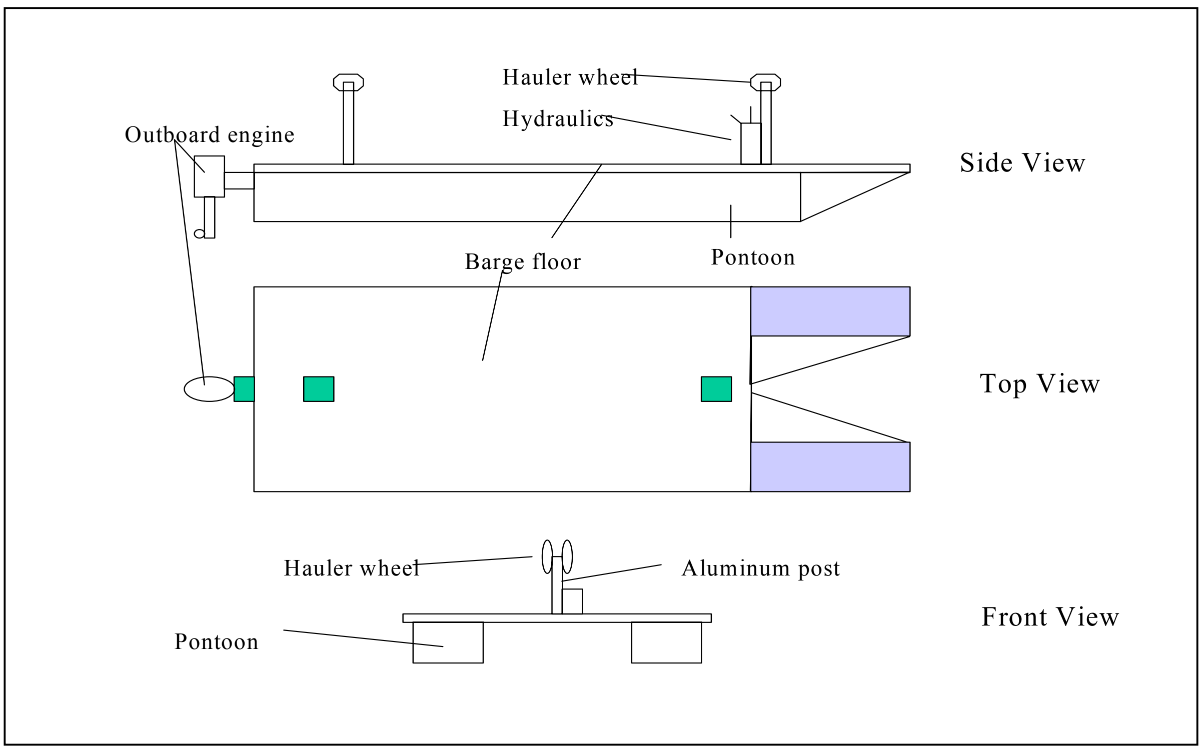


Figure 7.1: A diagrammatic representation of the typical Newfoundland barge. Most barges are 10-12 m in length and 4-5 m in width.

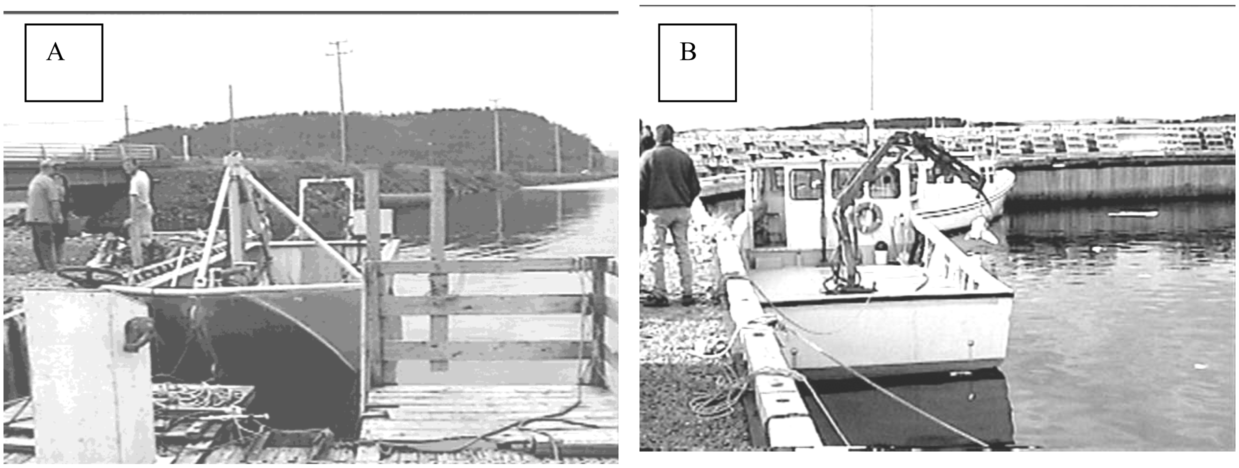


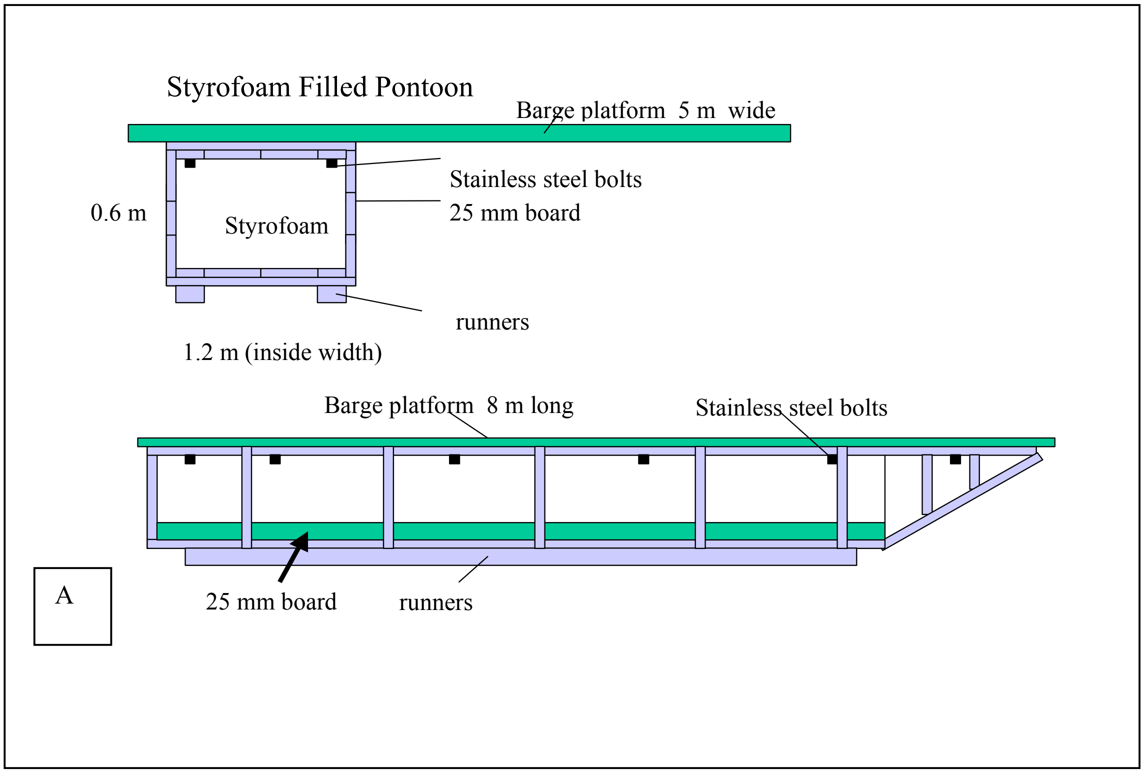

Figure 7.2: (A) Flat bottomed aluminum work boat with hydraulic crane and hauler, (B) boat with center mounted boom commonly used in PEI mussel culture.

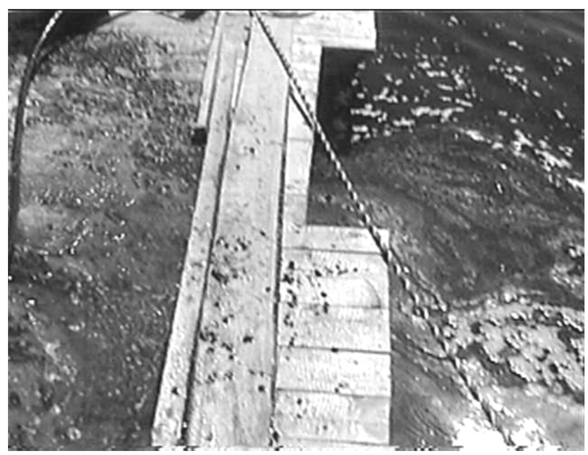
Considering the high start up costs in mussel farming, for the first two to three years a mussel farmer may want to build his/her own barge. This can be accomplished relatively cheaply since most growers already own or have access to the tools required to build a barge. Two barge designs, the styrofoam filled pontoon and the fiberglass over wood pontoon barges, appear to be the most economical barges for the developmental mussel farmer

## The Styrofoam Filled Pontoon Barge

The Styrofoam Filled Pontoon Barge is constructed using 2.5 cm (1") board that is nailed or screwed to a two by four or board frame (Figure 7.3). The completed frame is then filled tightly with sheets of styrofoam insulation. If the frame is placed on the outside, then the inside area can exactly match the area of a styrofoam sheet. The sheet can then simply be slid snuggly into the frame. The styrofoam provides the floatation and thus sealing the pontoon is not necessary. The pontoon size can vary but one grower that used this design suggested a width of 1.2 m (4 ft) and a depth of 0.6 m to 0.9 m. Pontoon length depends on the desired space on the barge but a length of 8 m (24 ft) is considered small.

The pontoons should be constructed such that the barge platform can be connected to the pontoons by stainless steel bolts. This allows for the removal of a pontoon should repairs be necessary. A runner can be screwed or bolted on the bottom of the pontoon to allow the barge to be hauled up on a slipway for over wintering. One grower that used this barge design suggested that he could build it for less than $2000 (material costs).  This does not include labour costs and



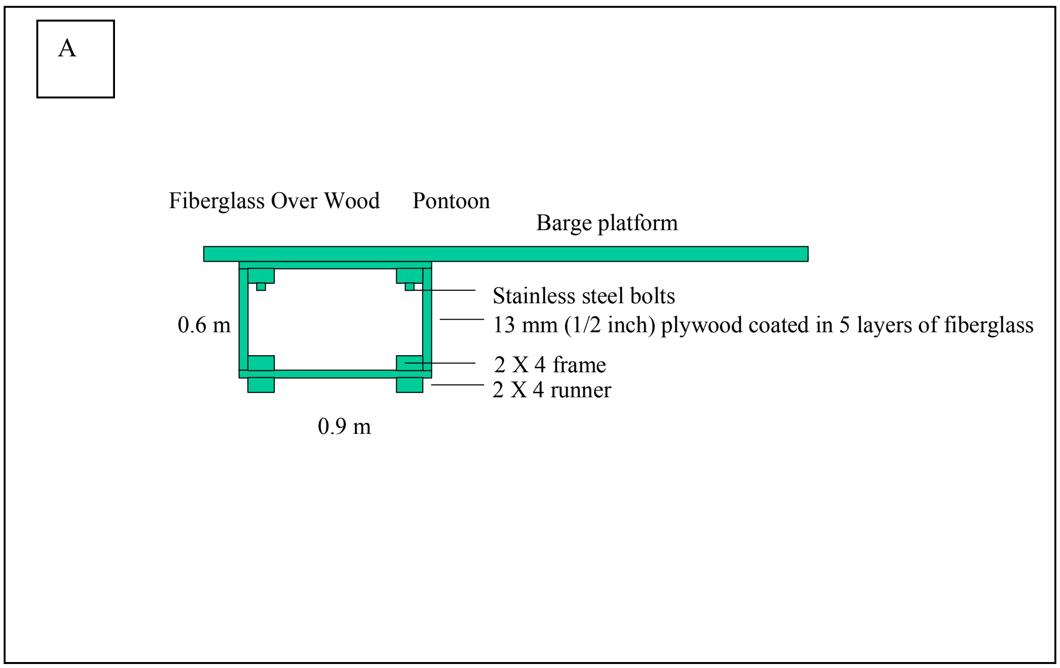
hydraulics.

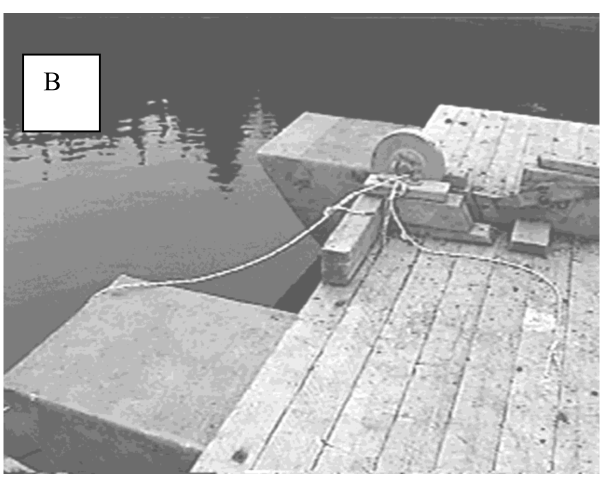
Figure 7.3: (A) The styrofoam filled pontoon design, (B) small styrofoam filled pontoon barge, (C) styrofoam filled pontoons protruding  from the front of the barge.

The Fiberglass Over Wood Frame Pontoon Barge

Solid fiberglass pontoons can be constructed by many of the fiberglass boat companies but these tend to be more costly.  A less costly alternative is to construct a wooden pontoon and then coat it in fiberglass (Figure 7.4).  The pontoon frame is constructed from two by four and then coated in 6-13 mm (¼  to ½ “) plywood.  This shell is then coated in five layers of fiberglass (Fiberglass thickness recommended by L. Squires, Sea Serpent Boats 1998, pers. comm.).

The pontoon is constructed such that the barge platform can be attached via stainless steel bolts.  Runners may also be added to the bottom of the pontoon to allow the barge to be hauled up for the winter.  The grower that used this type of barge estimated material costs at less than $2,000 for materials.  This does not include labour and hydraulics.



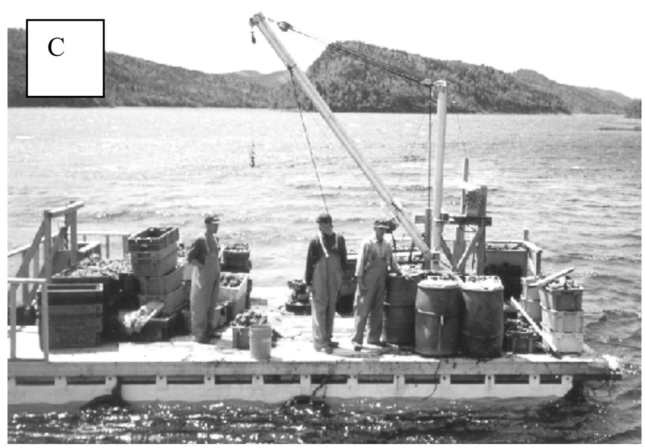



Figure 7.4: Fiberglass over wood-frame pontoon design (A), picture (B), commercially made fiberglass pontoon (C) (photo by Sean Macneill).

The Barrel Floatation Barge

Barges that utilized 200 l plastic barrels for floatation were the most common type used by the surveyed growers. In all cases a wooden framework was constructed beneath the barge platform to hold the barrels in place (Figure 7.5). The number of barrels employed depended on the size of the barge and often barrels would cover most of the bottom surface of the barge rather than just the sides like a pontoon. An 8 m long barge would require <u>at least</u> 22 barrels, 11 on each side.

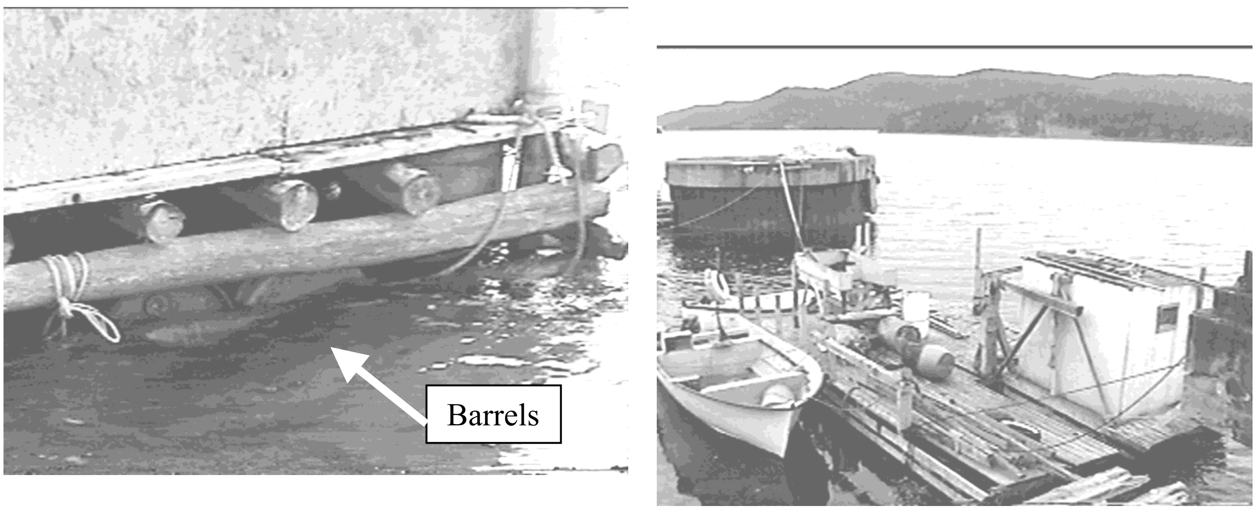



Figure 7.5: Barges that use barrel floatation.

These barges tend to be very slow based on the poor ability of the barrels to break the water. By inserting a plywood plane at the front of the first barrel barge speed may be increased. Another disadvantage is that barrels often leak and need to be replaced. A 8 m long barge would have a barrel cost of at least $1,000 at $40 a barrel.

Commercially Designed Pontoon Barge

There are commercially designed and manufactured pontoons available to the mussel grower. These tend to be primarily aluminum although some plastic, steel and fiberglass pontoons have been developed. There are several aluminum pontoon barges in use in the Newfoundland mussel industry (Figure 7.6). The grower may wish to build the platform for the barge to reduce costs rather than purchase it with the pontoons. These systems tend to be very costly resulting in total barge costs exceeding $20,000. However, they offer large work areas (at least 50 % more surface area) and have a much greater life expectancy.  Costs also include custom hydraulic systems.

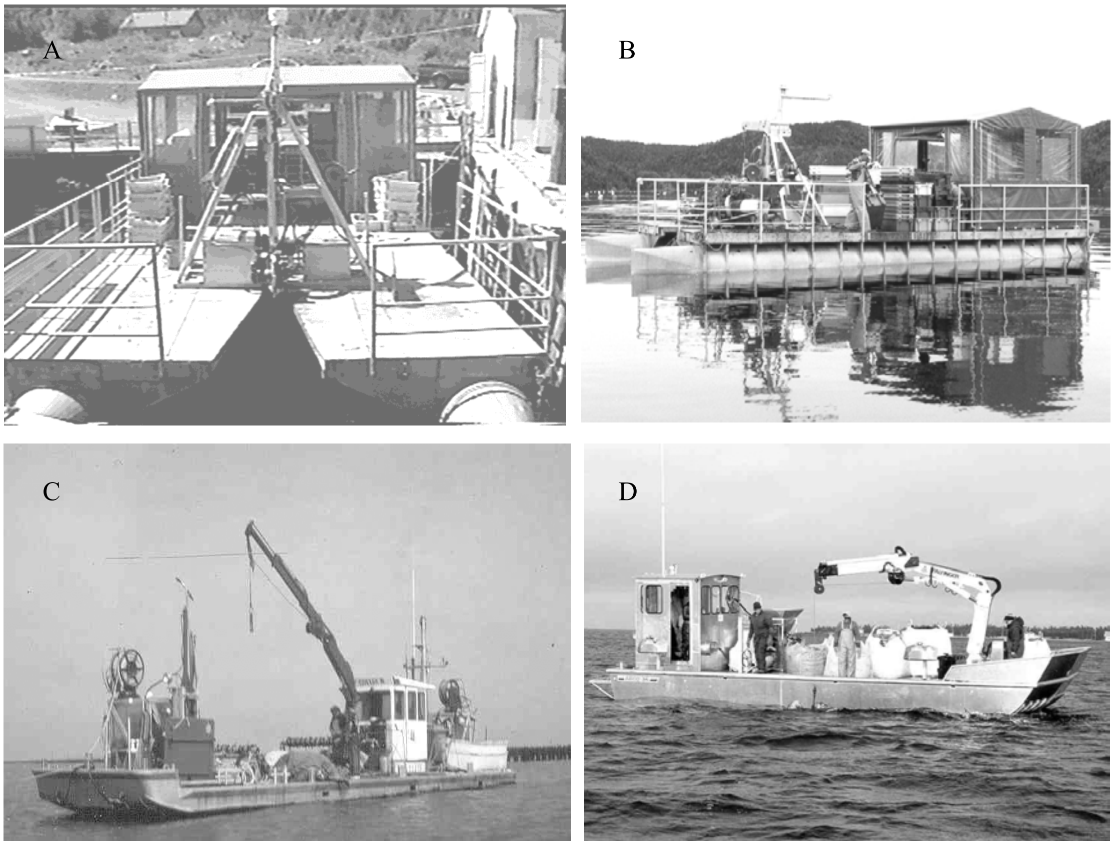



Figure 7.6: (A and B) Newfoundland aluminum pontoon barges, photos courtesy of Sean Macneill, (C) barge from France and (D) barge for Ireland (photos courtesy of Cyr Couturier.

Although large aluminum barges require larger initial costs compared to the smaller wooden types they will likely be required for long term commercial production.  Increased efficiencies in labour,  harvest volumes and durability  from the aluminum barges will make them more and more attractive to developing mussels businesses.

Barge Platforms

Once the pontoons or barrel frames are constructed the barge platform must be built and attached.  The platform frame may be built out of wood or metal (steel or aluminum) depending on availability and cost (Figure 7.7).  Extra framework is used near the front of the barge to provide more strength to the base of the hydraulic hauler.

Once the frame is completed, plywood, one 25 mm board, 5 cm X 15 cm (2" X 6" ) boards may be used to create the barge floor. The 8 m long barge of previous examples would require 12 sheets of plywood. This area may then be coated in fiberglass if the grower desires. Typically a notch is created at the front of the barge to allow a work area that allows socks and collectors to remain hanging in the water. After completion the barge platform is mounted on the pontoons using the stainless steel bolts jutting from the pontoons.

## Haulers and Winches

The heavy sock lines require winch or hauler systems to allow the grower access for maintenance and harvesting. These may be simple hand winches to very expensive hydraulic winch/hauler systems.

Many new growers that have not invested heavily into equipment often use a simple hand or trailer winch to haul up heavy lines (Figure 7.8). These are inexpensive at approximately $50 and very powerful. Hand winches although useful have several drawbacks. They are slow and require manual labour and there is a limit on the load they can handle (two tonnes). Thus hauling up several lines may be both physically draining and very time consuming.

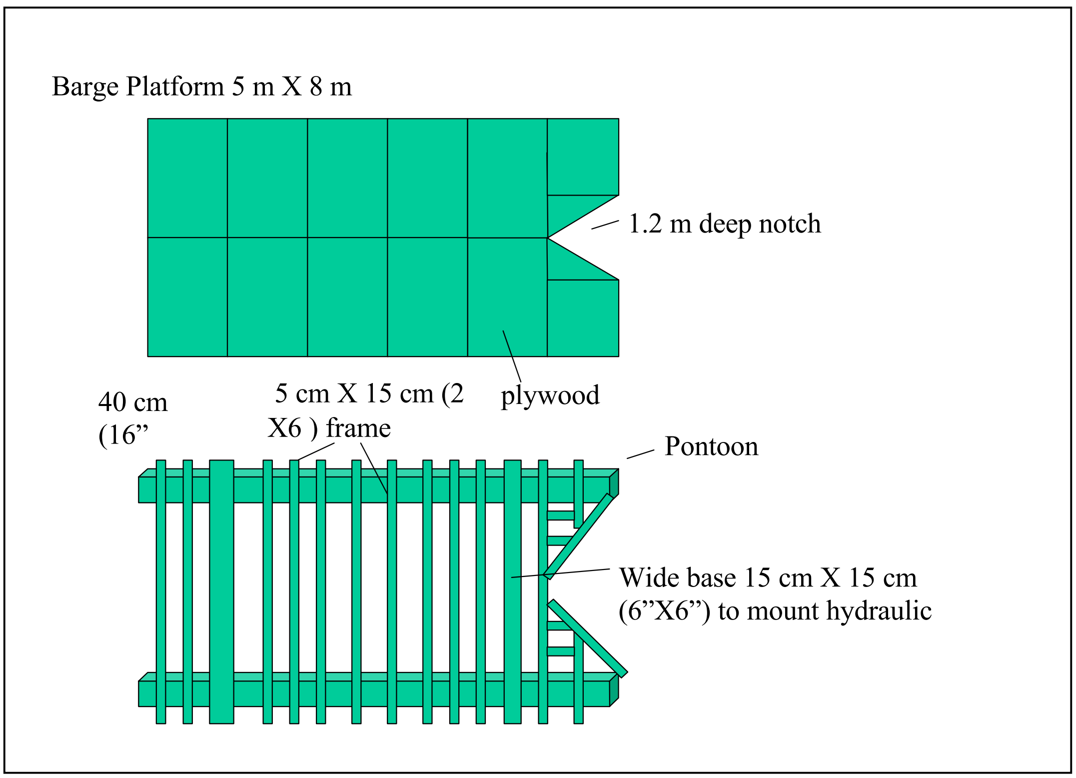


Figure 7.7:Typical barge platform design and flooring.

Figure 7.8: Simple hand or trailer winch used to haul mainlines to the surface. This system may be suitable for line maintenance or inspection but is not advised for commercial scale harvests.

As financing becomes available the mussel grower usually purchases a hauler wheel or builds one. The hauler wheel is normally powered by hydraulics but an electric motor can be used and hand powered models have been used in Newfoundland (Figure 7.9). Wheels typically have notches or teeth that grab the line. A simple wheel will haul the mainline but will not allow the passage of socks, collectors or floats. The socks or collectors must be cut off before they reach the wheel or manually lifted around the wheel. Consequently using this type of wheel limits the work area to the front of the barge. It also causes the grower to drop the mainline each time a different section of the line must be reached which is time consuming increases labour costs and may result in some loss in product.

A more versatile type of hauler wheel is the sta wheel. This wheel has raised extensions that cause the wheel to resemble a multi-pointed star (Figures 7.10 and 7.11). As a sock or collector approaches the wheel it is deflected to the side by a metal bar (sock deflector). The sock lies between two points of the star and is rotated with the wheel until it clears the hauler. This system allows the grower to move along a line of socks without having to detach and then reattach to the mainline. This results in the best mussels on the line being harvested because the difficulty in bypassing

smaller mussels is virtually nonexistent. An additional benefit to the starwheel system is that the grower can now use the entire length of the barge as a work area.

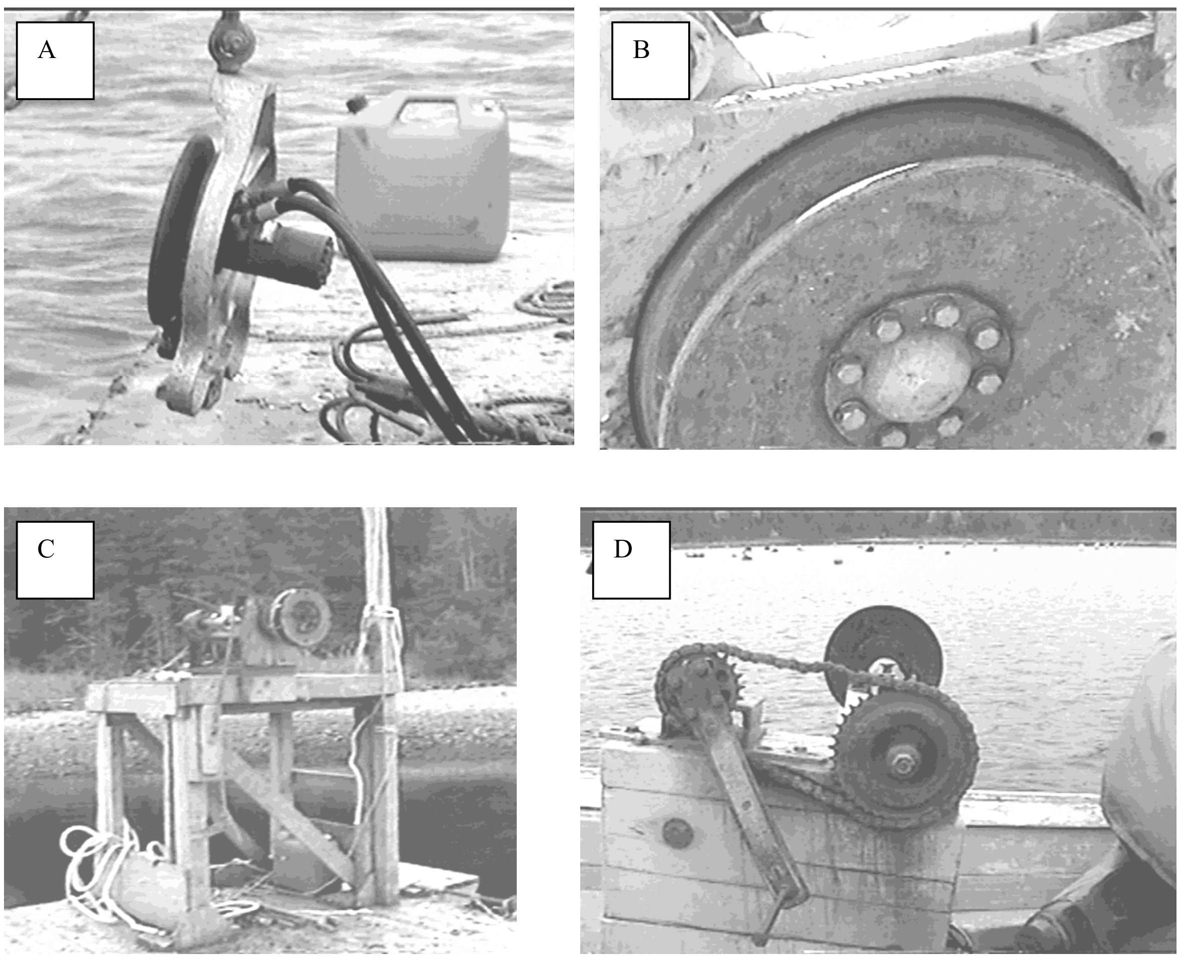



Figure 7.9: Simple hauler wheels. (A & B) Hydraulic, (C) electric, (D) hand powered.

Some growers add a crane and/or winch to lift the mainline up until it can be placed on the hauler wheel (Figure 7.12). These crane systems may be simple aluminum shafts or large booms that have been removed from boom trucks, or specialty booms designed for marine use

Barge layout

Once the barge has been assembled and the hauling system purchased the layout of the barge must be decided upon.. Most growers with barges used aluminum or steel posts to mount the hauler wheel. Some growers made these posts telescopic to lift socks or collectors high into

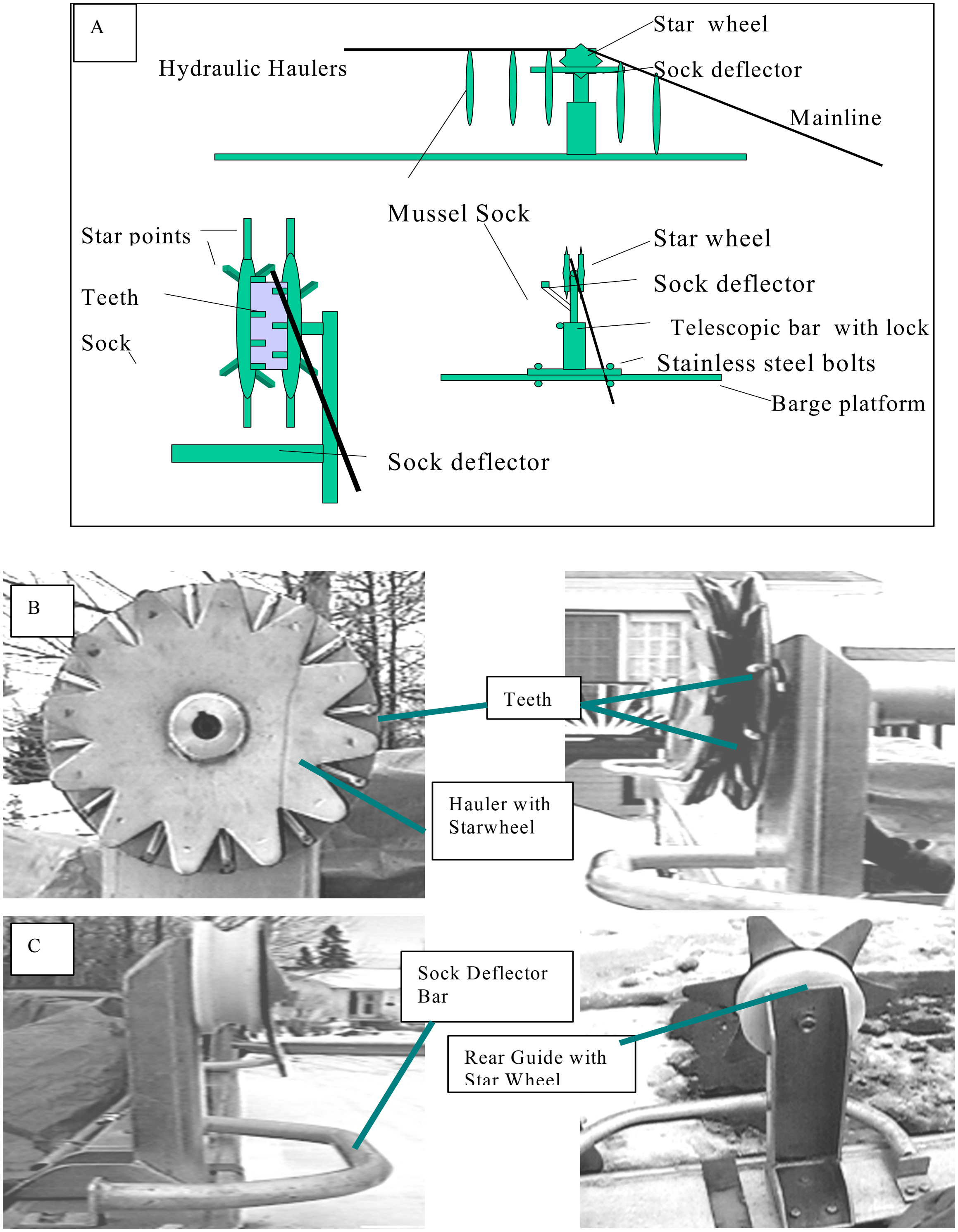



Figure 7.10: Star-wheel diagrams and photos. (A) Diagram of a starwheel in operation, (B) hauler wheel with star wheel and sock deflector, (C) rear guide wheel with star wheel

wheel and sock deflector.

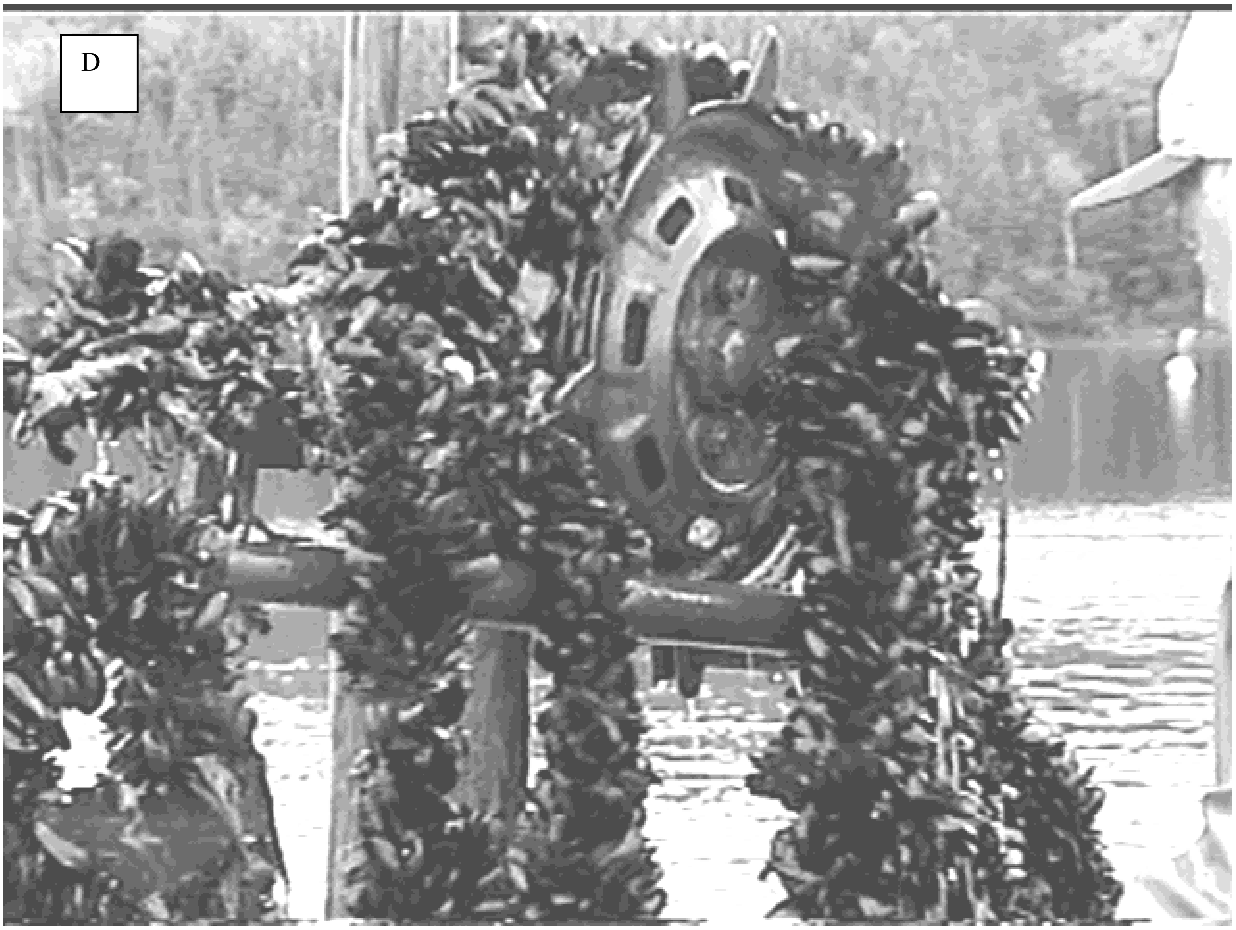



Figure 7.11: A homemade starwheel and deflector bar used to harvest collectors.  Star wheel was made from an old tire rim.

air.  Typically a post is placed in the center of the barge at both the  front and rear of the barge to allow the mainline to pass completely over the barge (Figure 7.13).  The hauler may be placed at either the front or the rear of the barge.  This system allows the grower to haul seed or market sized product directly over the barge where it can be stripped into tote pans.  The total area of the barge may be utilized with this system assuming a star wheel is used.   If a simple hauler wheel is used the work area may be limited to just the front area of the barge.  A disadvantage is that the mainline is at chest height or higher across the middle of the barge.  This may restrict movement and equipment placement on the barge.

Another alternative is to mount the hauler wheels along the side of the barge. This also allows a large area of the barge to be utilized (Figure 7.14).  The grower though must physically lift the socks or collectors in over the side of the barge to strip them.  Consequently workers can only work on one side of the line compared to either side if system were through the center of the barge.

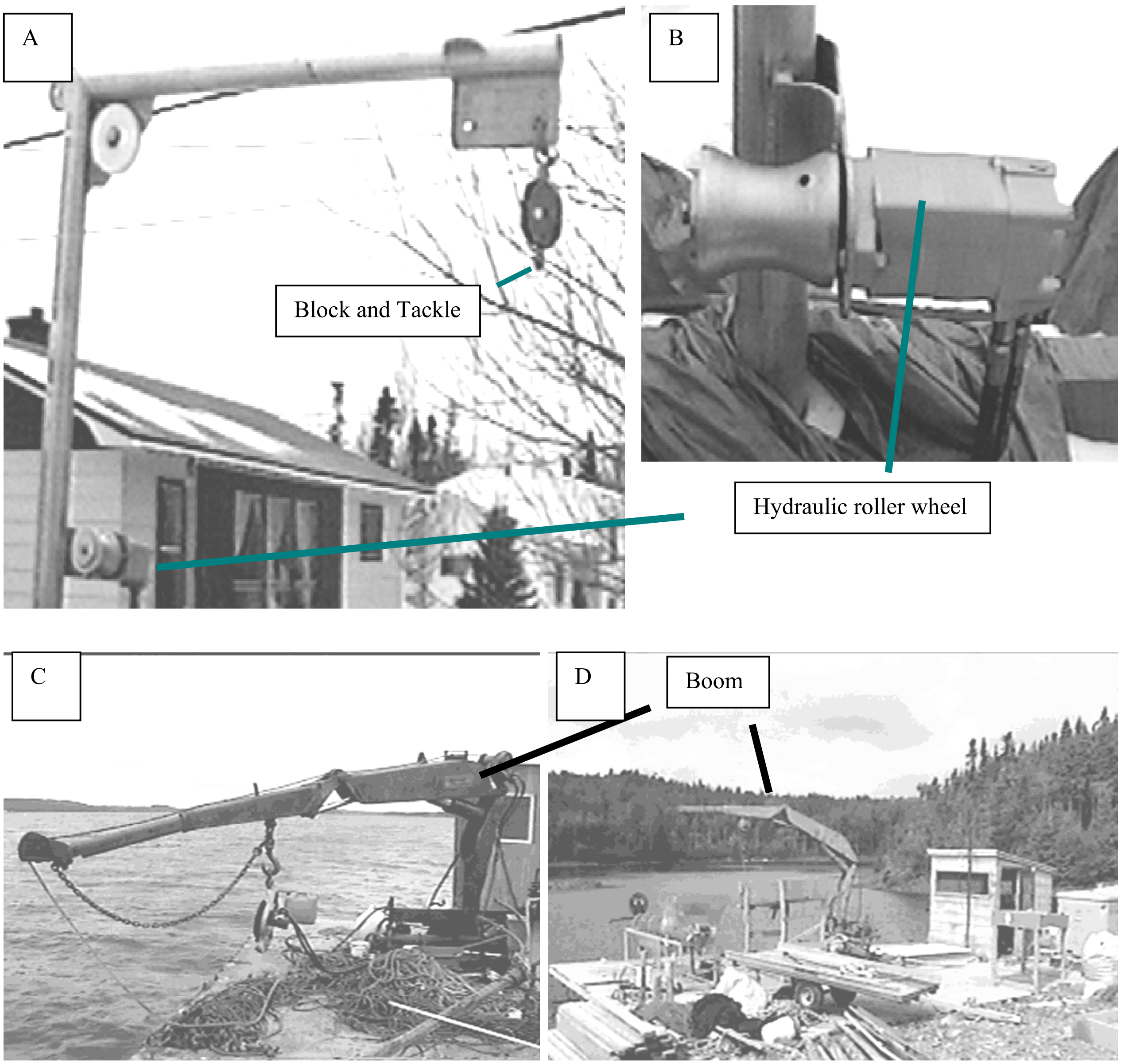



Figure 7.12: Crane Systems. (A) Crane with roller wheel, (B) hydraulic roller wheel, (C) boom with pot hauler, (D) boom mounted on a barge.

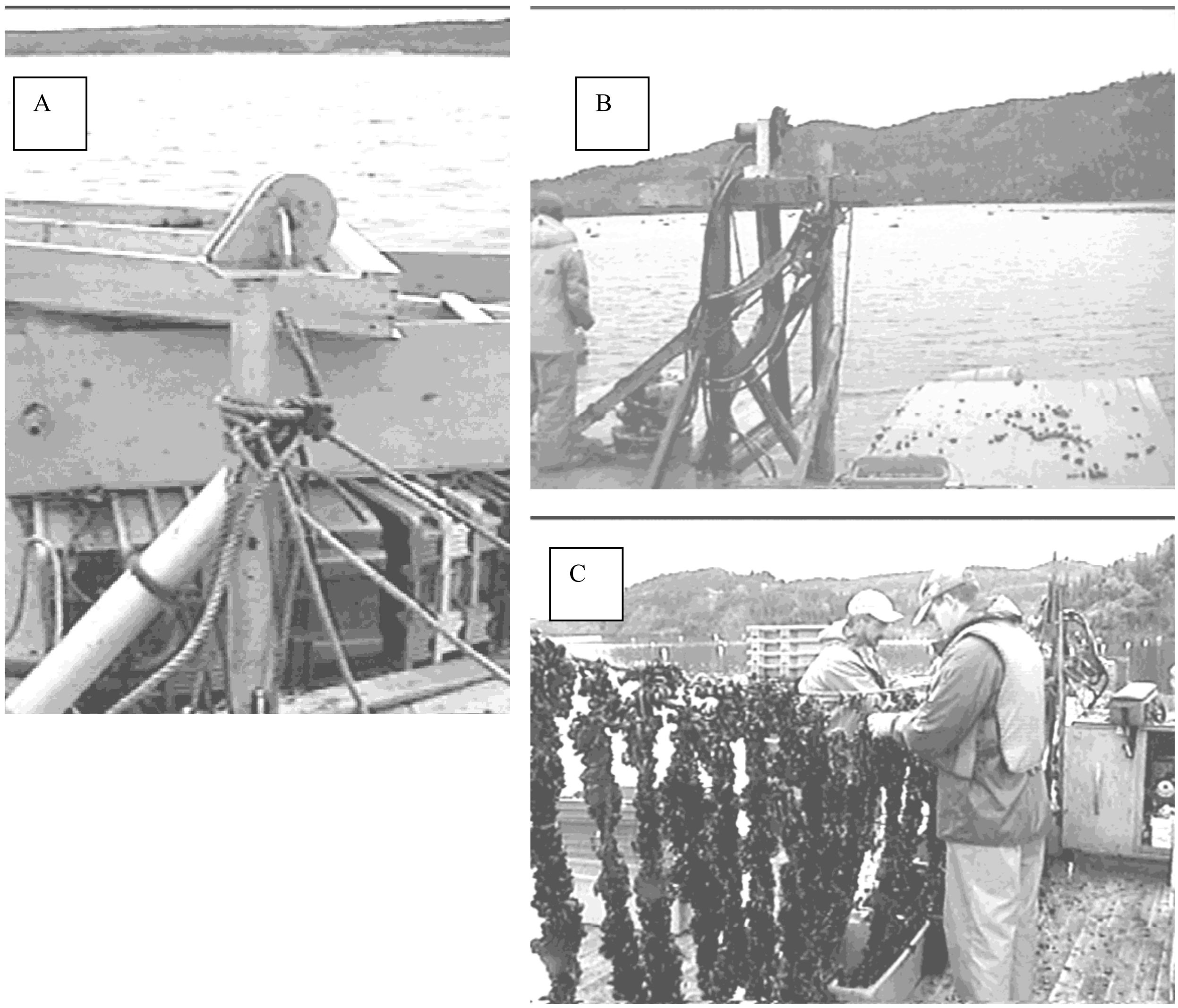



Figure 7.13: Hauler systems mounted in the center of the barge. (A) Simple aluminum post, (B) hauler mounted on the front restricting work area to the front of the barge, (C) hauler mounted at the back with star wheel at the front, work area is extended to the total area of the barge.

One system lifted the mainline only at the front of the barge and passed the mainline underneath the barge (Figure 7.15). This system prevents the barge platform from being cluttered with lines allowing deck space for stacking product and equipment but reduces the work area primarily to the front of the barge.

Figure 7.14: Barges with side mounted hauler wheels.

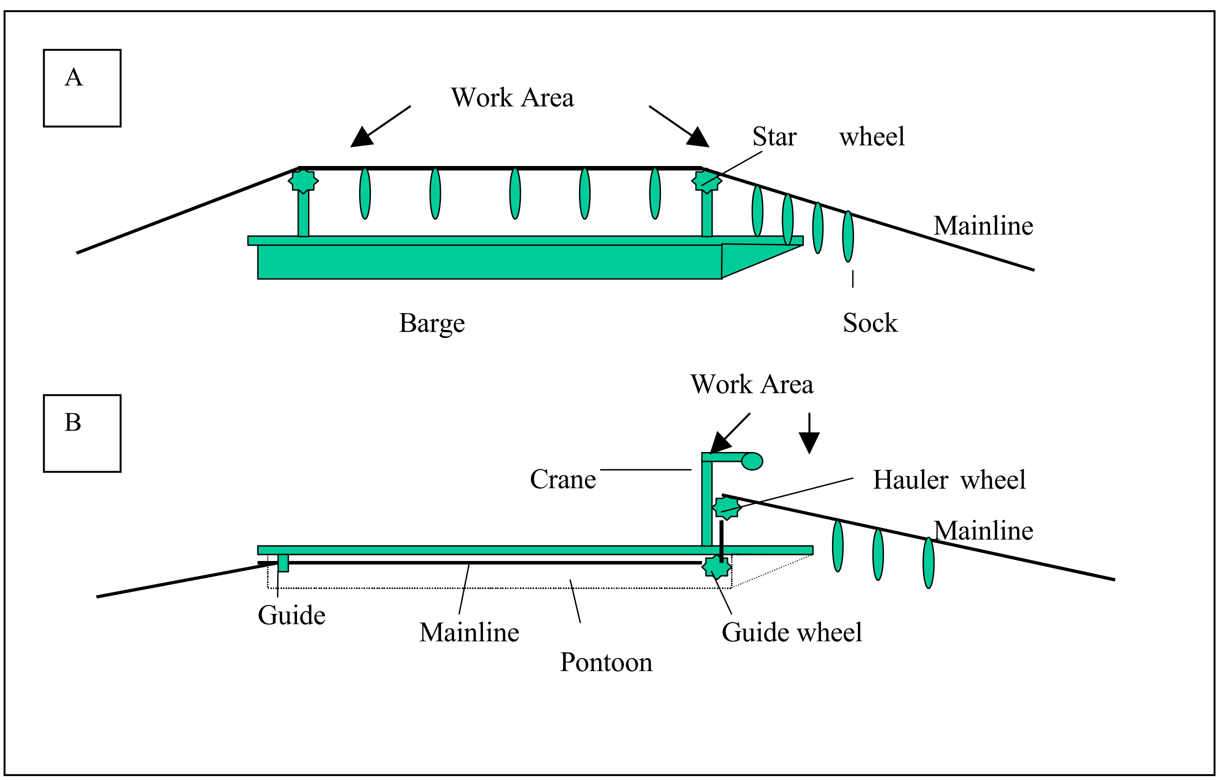



Figure 7.15: A comparison of the (A) above and (B) below barge mainline hauler designs.

Many growers do not have a work barge but simply use a variety of boats which have been modified with hauler systems for use in the mussel industry (Figure 7.16). In most cases these boats simply do not have the room or load carrying capacity to be truly effective, especially for large farms. They may be useful for line maintenance or inspection however. Large longliner type vessels are suitable but are often more costly than a barge.

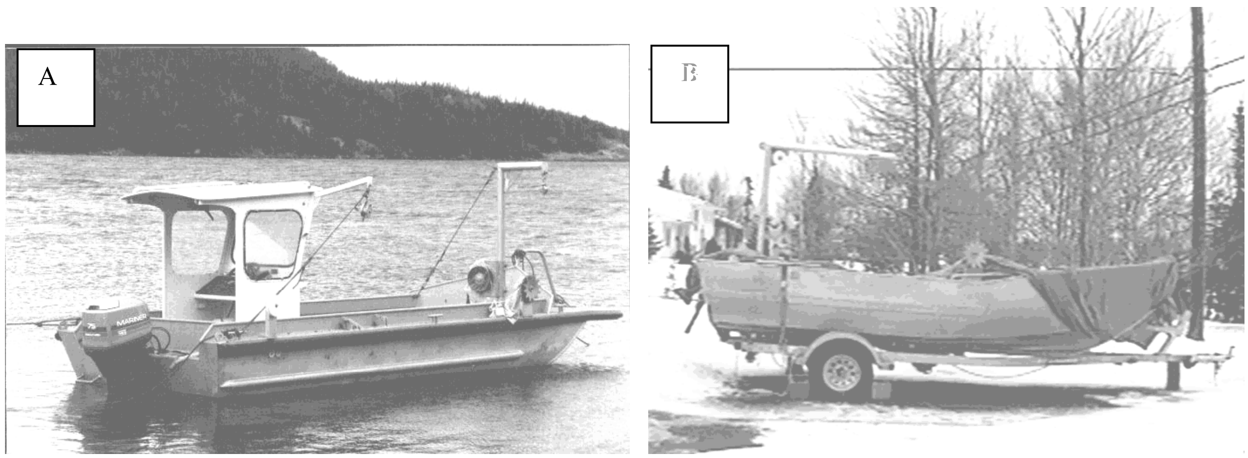



Figure 7.16: Aluminum work boats. (A) Modified boarding vessel with simple crane and side mounted star wheel, (B) 6.5 m workboat with crane and side mounted star wheel.

## Socking Tables

The typical Newfoundland socking table was composed of a plywood box that was mounted on a (5 cm X 10 cm (2 X 4) frame such that the box tilted at an angle. At the lowest end of the box a PVC pipe was inserted as a sock tube. Usually these tubes were mounted on a separate board so that different sized tubes could be easily interchanged. Typical tube sizes include (2.5, 3.75, 5, 6.75 and 7.5 cm (1”, 1.5”, 2”, 2.5” and 3”) diameter tubes which will cover the range of sock diameters which may be needed depending on sock time. Most socking tables had tubes that jutted out from the end of the box (Figure 7.17). The tubes usually had a gate across the hole to stop the flow of water and mussels thus giving control to the socking process.

Another table design placed the sock tube on the bottom of the table (Figure 7.18). This would take greater advantage of gravity flow and potentially reduce clogging. If the tube did get clogged a simple up and down motion with a pipe could free the clog. The standard end tube requires a side to side motion with the arm on an angle under water inside the sock table to free a clog.

Many tables used two tubes with two people socking and two people feeding the tubes. By cutting a notch in the side or front of the table, a simple modification, the two sock tubes could

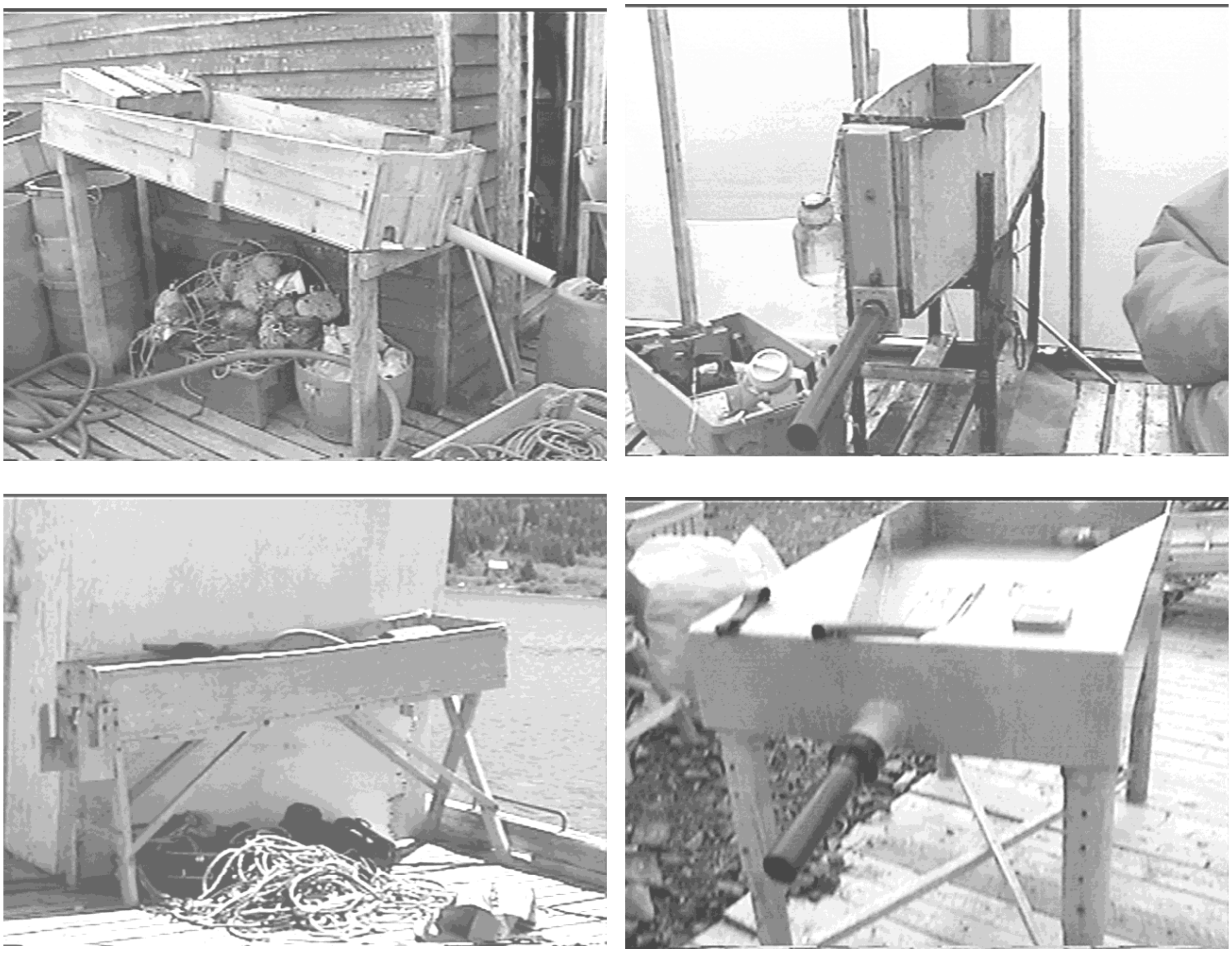


Figure 7.17: Common one tube socking tables with end tubes.

be supplied by just one feeder. This would lower the socking labour requirements and cost by up to 25%.

The table should also be elevated to try and increase gravity flow. This can be accomplished by increasing the height of the table frame and increasing the slope of the box. This usually requires a box for the feeder to stand on. With this extra height the end of the sock tube can be located at the most comfortable height for the socker. If the socker does not have to bend over to sock, socking performance should improve. The height of the sides of the table may also be increased so that more water can be held back, increasing pressure and socking speed.

Commercially manufactured tables can also be purchased (Figure 7.19). These are made of aluminum and are considerably more expensive ($2,000-$3,000) than the home made variety. Manufactured tables are very large and are usually used on land (depends on barge size). This

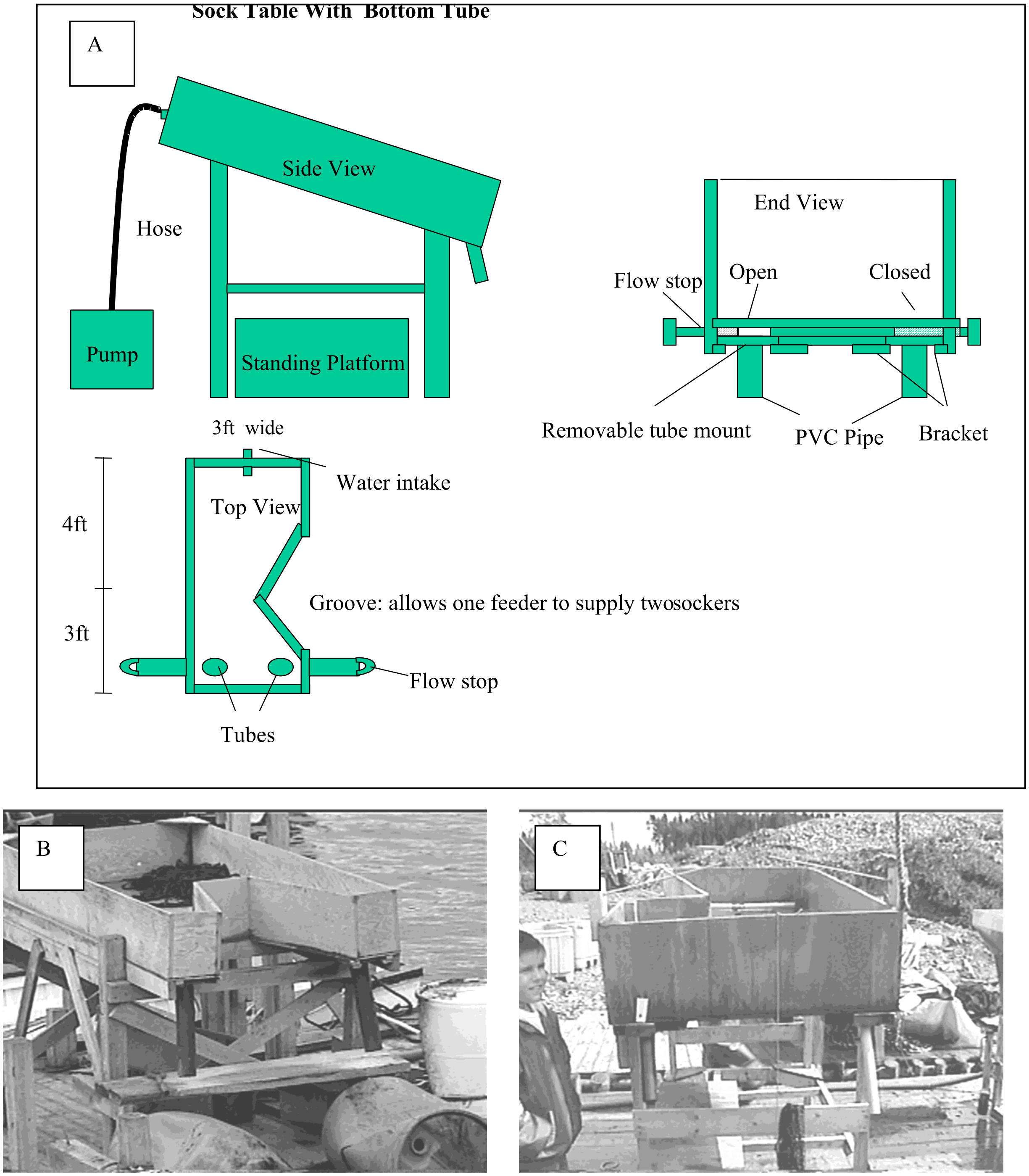


Figure 7.18: Wooden socking tables with bottom tubes that have been modified with a groove that allows one feeder to supply two sockers. (A) Diagrammatic representation, (B) front groove, and (C) side groove.

Figure 7.19: Commercially manufactured aluminum socking table.

will place a restriction on their use as many growers prefer to sock on the barge while connected to the mainline for direct deployment of socks as they are filled. The large tables will require land socking followed by the transportation of socks to mainlines for deployment. The extra sock handling may result in seed loss during deployment with some socking materials.

Water Pump

The gas powered water pump was the most popular method to supply water to socking tables in the survey. On grower used an electric water pump and socked on land and another dry socked. The gas-powered pump seemed to be more versatile and powerful than other options. The growers could take the pump on the barge and sock on site with the gas pump. Honda was the most common brand (Figure 7.20) name and purchase price was approximately $600

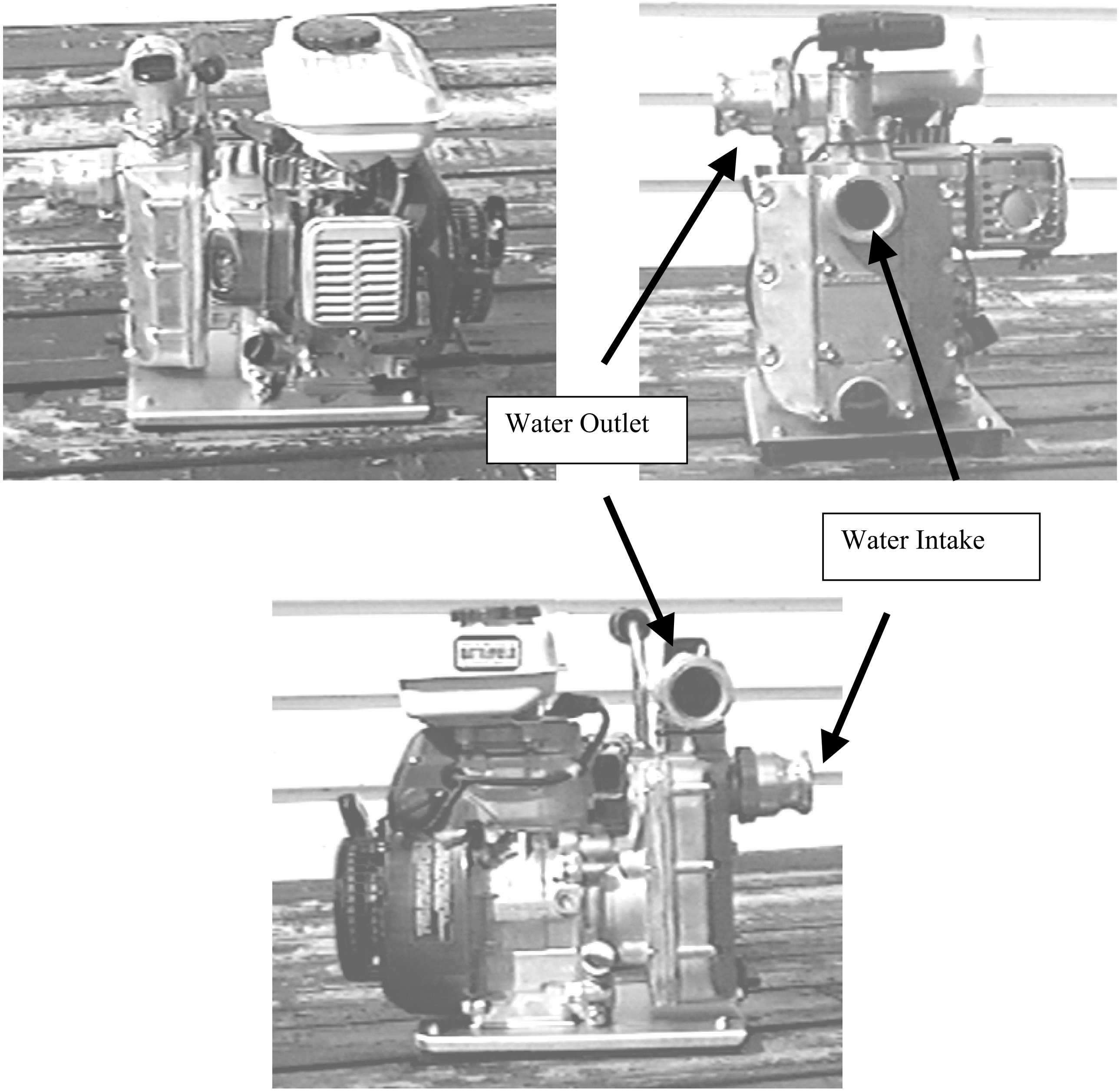



Figure 7.20: Gas powered Honda water pump.

## Seed Graders

Mussel seed graders are a relatively new technology for the Newfoundland mussel industry. The number of graders in use in Newfoundland increased dramatically in 1997. The most common type was a PEI model (Figure 7.21) which is a 3.3 m long, 180 kg aluminum and stainless steel device, which is designed to separate mussel seed into four sizes; 5 mm, 9 mm, 13 mm and greater than 13 mm shell height (3/16", 3/8", ½"and larger than ½"). It contains an aluminum hopper and drum, stainless steel shaft and declumper auger, stainless steel seed sizing bars, and hydraulic motor. A hydraulic power pack is required to power the grader. The total purchase price for the grader is approximately $5500-$6000 delivered.

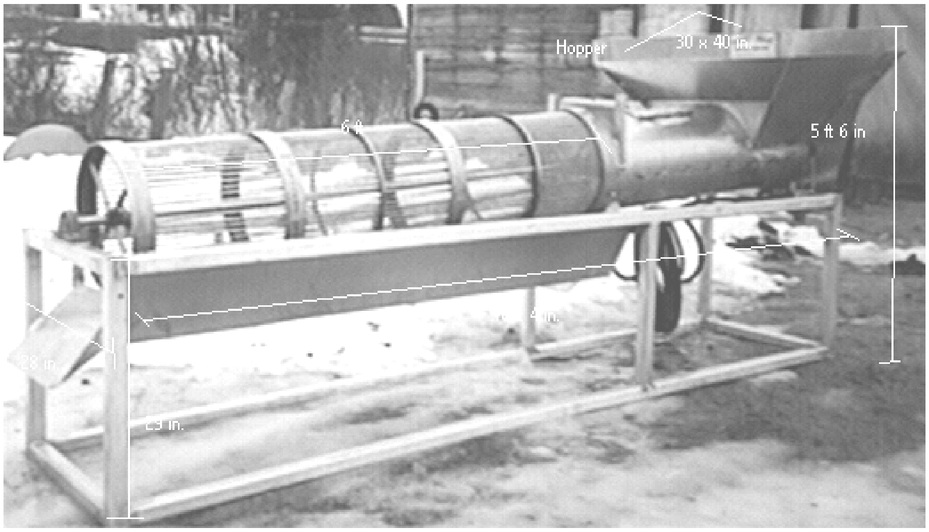
Operation of the grader is relatively simple (Figure 7.22). Mussels are dumped into the hopper and the byssal threads are torn apart by the rotating declumper bars. The separated mussels then slide over the sizing bars. The smallest mussels fall through the first set of bars and are collected in a tote plan that is placed under the grader. The second and third size groups are collected in the same manner. The seed greater than ½' will fall out of the end of the grader. These different size seed can then be placed into the appropriate size socking.

The declumped seed should also speed up the socking process. Individual mussels pass very quickly through socking tubes and rarely get clogged.

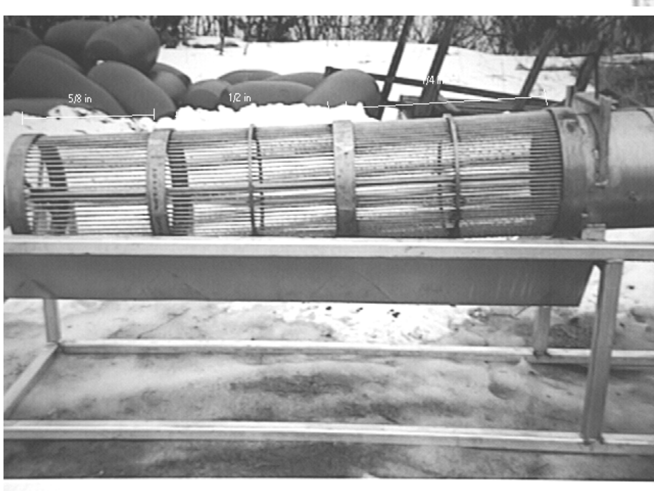
Other grader models are also in use in Newfoundland. A new model recently developed by a Newfoundland company, Fab Tech Industries, is very similar to the PEI model described previously (Figure 7.23). This model has the same size grades and is approximately the same size. It does have some improvements such as a larger grading drum and tighter joins. This increases the grading speed while at the same time reduces breakage. It is slightly more expensive, starting at approximately $6,000.

One other seed grader type was utilized in Newfoundland. This was a large grader that had only three grades and had the grading bars arranged in a circular pattern around the drum rather than straight and perpendicular to the drum as in the other models. This grader is likely too large to use on a barge (depending on barge size) and must remain on land. This makes it unsuitable for many Newfoundland sites that are remote. The grader was also considerably more expensive than the previously discussed models.

When purchasing or using a seed grader certain general practices are recommended. First seed graders should be set up at a low angle to achieve good seed separation. Secondly, graders should have high volumes of water going through them. This helps declump the mussels and reduces shell damage. Grader speed should be kept low enough to achieve a high quality grade, otherwise the grower will just declump the mussels and lose the growth benefits from size grading. If purchasing a grader, a better and faster grade can be achieved using a longer and wider grader barrel.


Hopper
30 x 40 in.
6 ft
5 ft 6 in
28 in.
29 in.


2 in hose female fittings
EAST ISLE
METAL FAB INC.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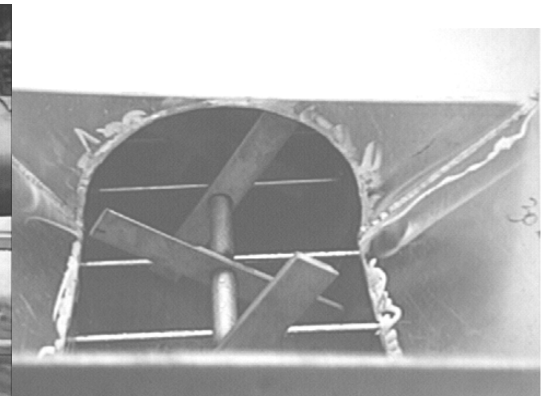


Figure 7.21: PEI model stainless steel and aluminum declumper grader purchased by the Marine Institute for the ACERA Mussel Aquaculture Project.

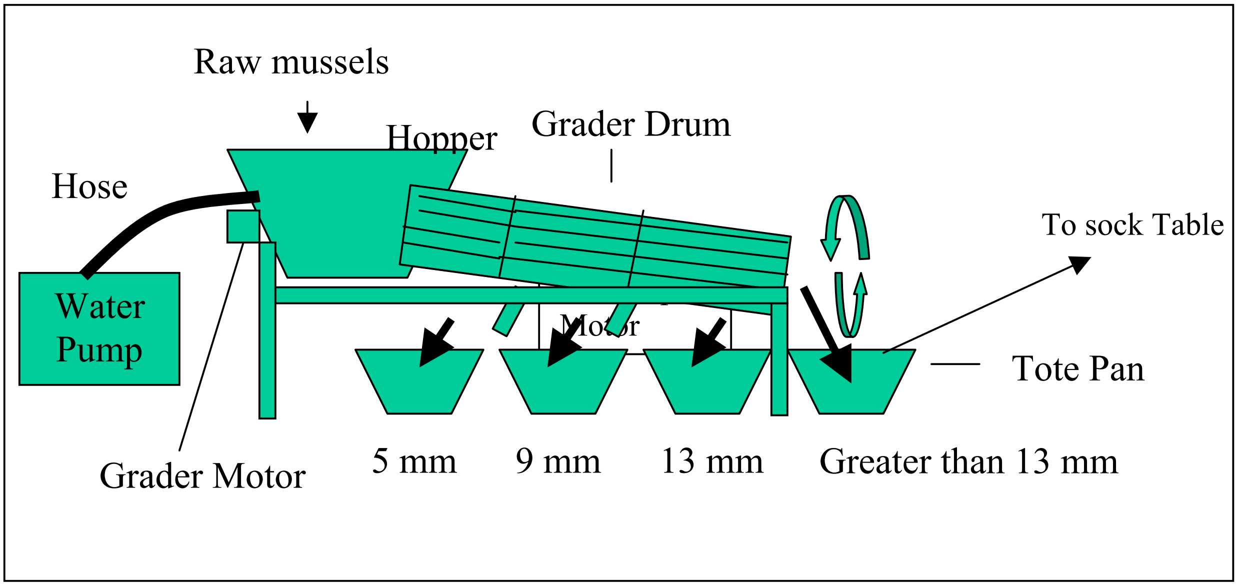



Figure 7.22: Diagrammatic view of declumper-grader operation. Sizes indicated are mussel shell height.

Sock Reel

Most of the growers surveyed stated that they measured socking material by wrapping it around two chairs or two poles that were the appropriate distance apart. This is a time consuming process which may require two people, one to hold the sock roll and one to measure it out. A sock reel can be constructed easily and inexpensively to greatly speed up the process (Figure 7.24). The sock roll is hooked on a roller and the socks simply spun on a wheel. The length of the arms of the wheel determines the length of the sock. A single person can reel off a

quantity of socking material and then cut them all off at the same place creating a large number of socks all the same length. A grower that used this system stated he could cut up a roll of socking in only five minutes. The reels can also be used to cut float ropes of the same length. When cutting ropes a heated blade was used to cut and seal the ropes at the same time (must be conducted in a ventilated area to avoid toxic fumes).

Automatic Socking Equipment

Automatic socking machines have been used around the world for many years but only two Newfoundland growers utilize this technology to date. All automatic socking machines use a biodegradable mesh that holds mussels around a rope core. Over a brief time the mussels attach to the rope core and the mesh dissolves leaving only mussels and rope. The system uses a

B

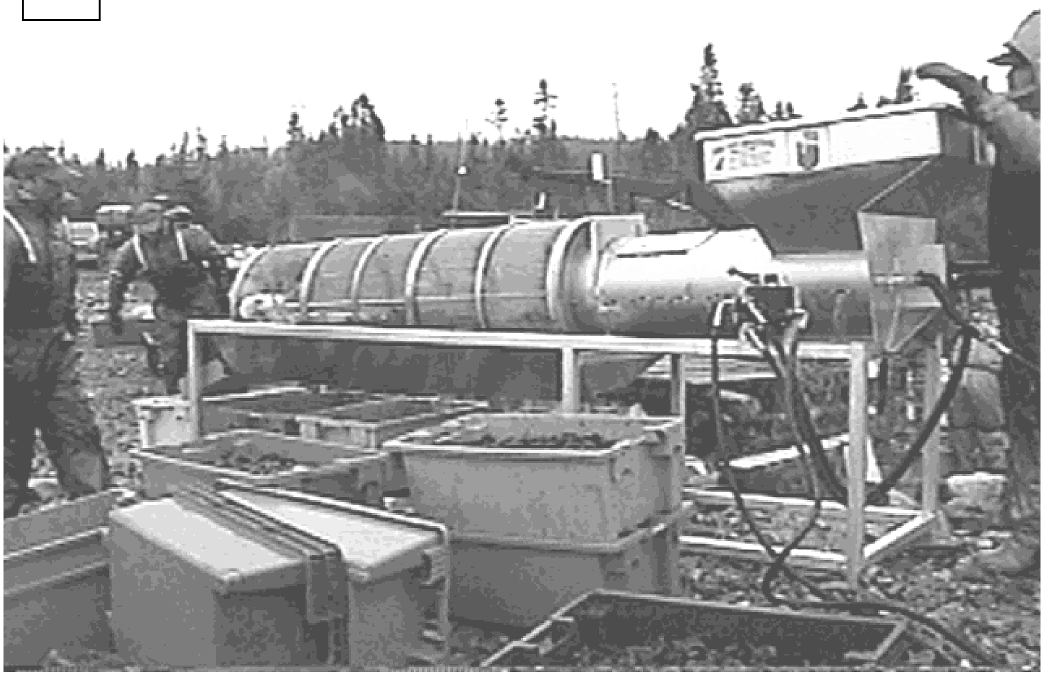


Figure 7.23: Graders; (A) Fab Tech Industries built grader with larger grading drum, and (B) large grader with circular grading bars.

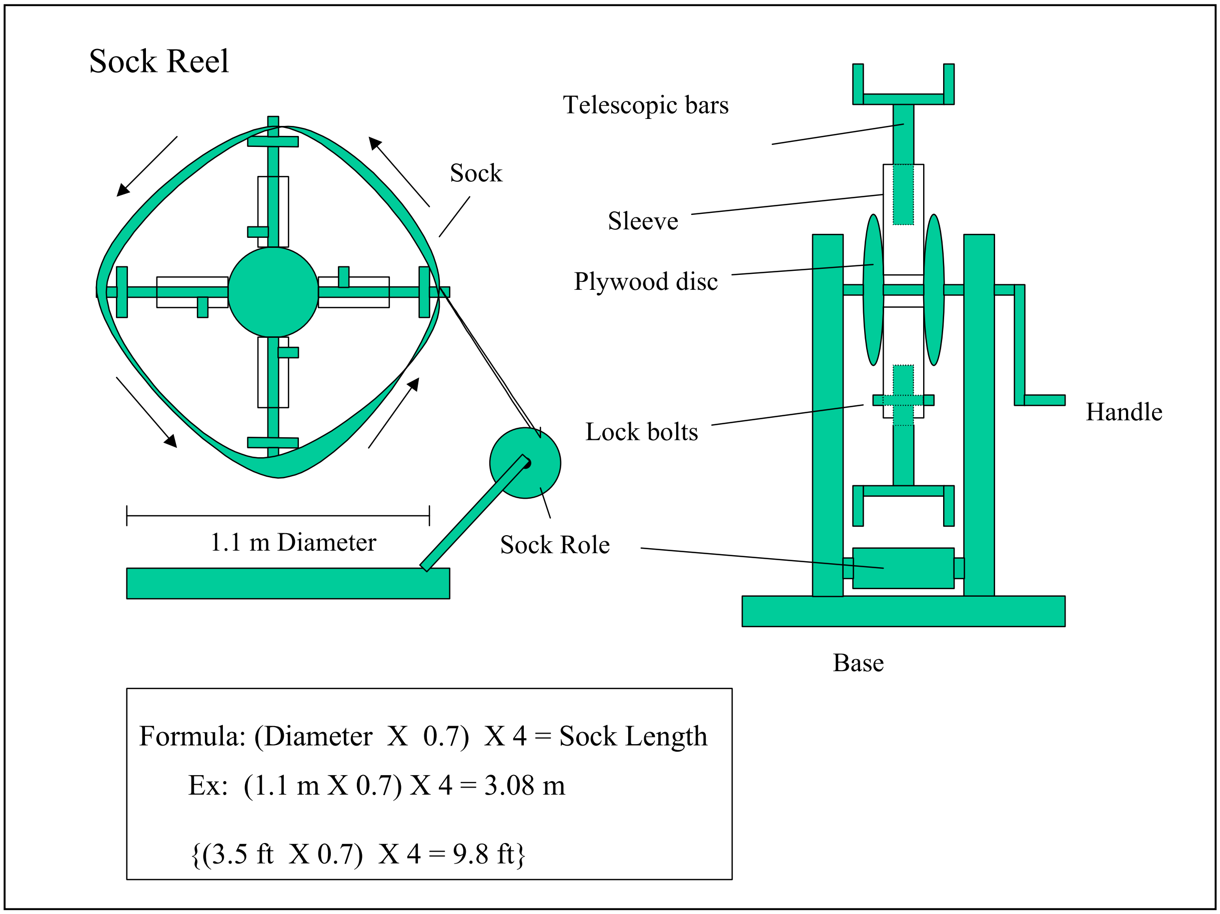


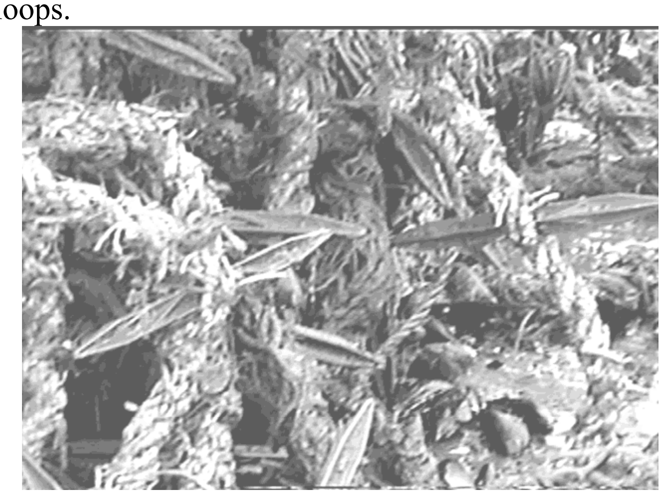

Figure 7.24: A simple sock reel with sock length formula. Based on pictures from Scarratt (1993).

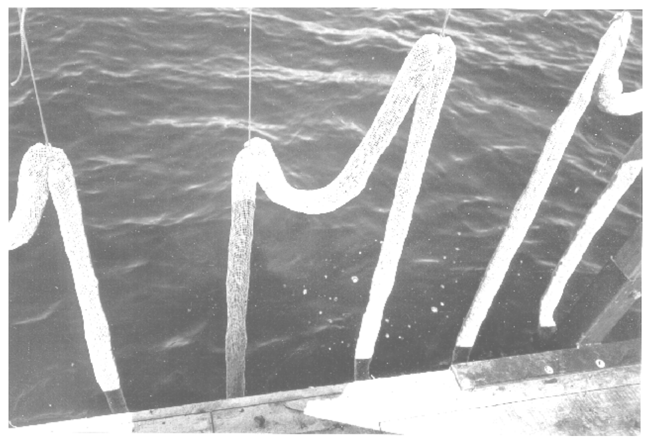
continuous socking principle. This means a long section of rope, hundreds of meters in length is socked through the machine and then tied to the mainline in loops.

There are two basic types of these continuous machines, the Spanish Wrap and the New Zealand style socker. The Spanish Wrap simply wraps a biodegradable mesh around a rope with pegs and mussels (Figure 7.25). This wrapping procedure may allow gaps where mussel seed may fall out if the operator is careless or inexperienced. The rope core usually contains pegs that help prevent the mussels from sliding off.

The New Zealand style socking machine uses a biodegradable mesh tube that is hauled over the rope core and mussels. This system eliminates the gap problem of the Spanish wrap machine.

The core is made of fuzzy rope and does not use the peg technique.  This machine has a built in computer, which will tell the grower when a specific length of rope has been socked.  This allows the grower to control the length of the loops.



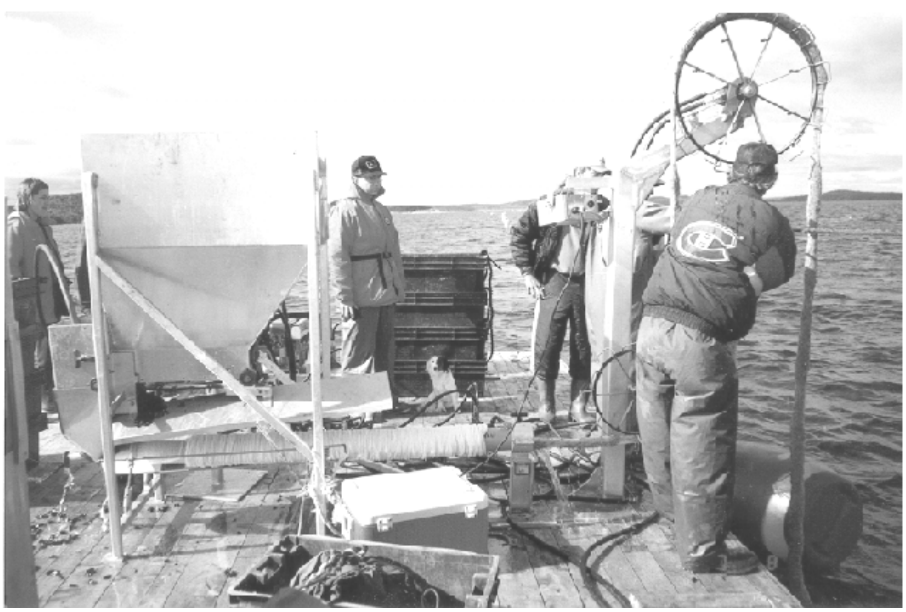


Figure 7.25: Socking Machines. (A) Spanish Style socker, (B) Rope core with pegs, (C) New Zealand style continuous socking and (D) New Zealand style continuous socking machine.

Socking speeds of these systems are suggested to be much faster than standard socking table type practices. One Newfoundland grower stated that he could sock 1500 m (5000 ft) of rope in 2 hours, the equivalent of 250 3m socks per hour. A technical mission to the Maritimes to examine this technology indicated socking rates of 17,000 m per 8 hour day with three workers. This is the equivalent of 5,000 standard socks per day (House 2000). Supplying seed to keep the systems running at capacity will likely be a problem.

# Chapter 8: Harvest Practices

The optimization of harvest practices is difficult to address for Newfoundland mussel growers. Based on poor sales or a low production volume few of the surveyed farmers were harvesting on a regular basis. Several of the surveyed growers stated that they had never harvested mussels, and many more only infrequently. Those that were harvesting regularly stated that they could easily harvest twice the volume of product that the processors were willing to take in a single day. This typically amounted to 100-115 tote pans with an estimated weight of 5,000 kg. Sales have increased dramatically in 1998 and 1999 and are forcasted to be strong in the next three to five years if production goals are achieved and a quality supply of mussels is available.

## Harvesting Techniques

Harvesting with any degree of efficiency will require the use of a barge or large boat with a hydraulic system to pull heavy mainlines from the water. The number of employees used for harvesting during our survey ranged from three to eight people with a median of 5 people. Harvesting was described as labour intensive, involving cutting the mussels socks from the mainline and stripping them by hand. Most farmers did this as each sock was pulled from the water, before it reached the hauler wheels. One farmer had starwheels on the hauler and pulled a line of socks over the barge. They then reached up and stripped each sock while it was still attached to the mainline. The starwheel appears to give an advantage as the whole length of the barge can be utilized rather than just one end. In addition floats and socks can pass over the harvesting platform without the risk of snags or ripping socks off. Other growers in Nova Scotia strip socks by attaching one end of the sock to a hauler and pulling it through a hole in a wooden block (Scarratt 1993). Recent technology in the form of an automatic stripping machine is available for use with the continuous New Zealand style socking, but can be easily adapted for use with existing Newfoundland growout gear.

Once stripped the mussels are placed in tote pans (approximately 100 lbs. or 45.4 kg per tote) on the barge. Typical barge capacity was between 50 and 100 totes although some of the larger barges could carry more mussels. The barge then transports the totes to a wharf where a truck is waiting to carry the mussels to the processor. The totes can be hoisted by the barge's crane onto the wharf or as is often the case the totes are transferred by hand (Figure 8.1). Care must be taken to avoid prolonged periods of exposure to the sun, wind and rain during harvesting to maintain product quality. Totes should be iced immediately after the mussels are taken from the water and if necessary again when they are loaded on the truck.

Other systems are available for handling mussels. These include the large half-tonne and one tonne insulated containers (Figure 8.2). Forklifts are required to handle the containers on shore and as the industry develops it is likely that these containers will become more popular. The large insulated containers not only allow more rapid handling of harvested product but also provide an insulated environment for keeping mussels in good quality during harvest and transport. Less ice is also required with these containers. One tonne bags are also available and

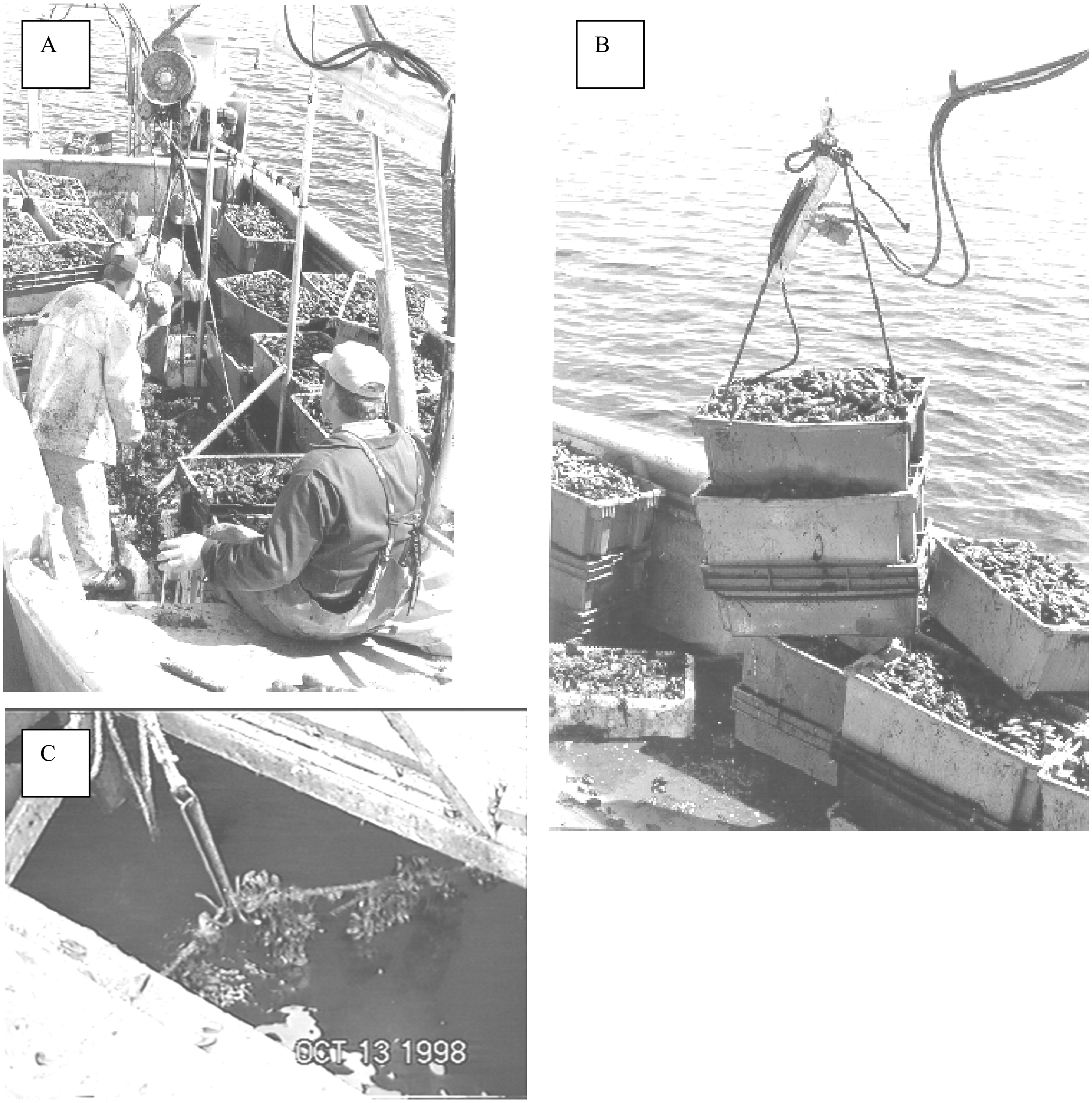



Figure 8.1: (A) Harvested product loaded on board a harvesting boat, (B) unloaded using hydraulic crane (Photos courtesy of Sean Macneill), and (C) harvest size mussels being pulled through a notch in a barge.

can be handled on the barge if the vessel is equipped with a crane or boom (Figure 8.2). These large bags can be hoisted from the barge to a waiting container on the wharf. A drawstring in the bottom of the bag allows for easy transfer of mussels from the bag to the large container.

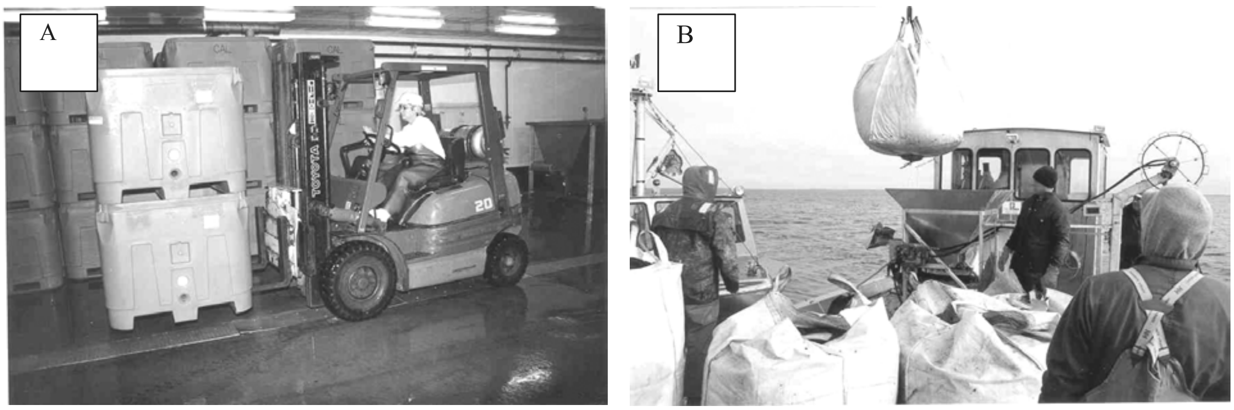



Figure 8.2: (A) Large containers and (B) bags used to transport mussels. Photos coutesy of Cyr Couturier.

Winter Harvesting

As the industry develops the need for consistent, high quality supply of product will increase. This will require year round harvesting and rapid and efficient harvesting systems of sufficient capacity (up to 10 tonnes per trip). For many growers the techniques for harvesting through the ice will be necessary.

Most growers in Newfoundland tend to leave the large floatation 200 l barrels on the surface during winter freeze up. During harvest the ice around the barrels may be cut with a chainsaw to free up the line (Figure 8.3). A long handled knife can be used to cut the line connecting the barrel to the mainline. Once the barrels are removed, the line may then be hauled up using a hauler wheel mounted on an “A” frame. Once the line is located and a hole is cut at either end, one end is hauled up through the hole using a small anchor hooked to a hauler wheel on an “A” frame. The mainline is then cut free of the anchor lines and a long rope is attached to either end of the mainline creating a continuous loop. As the hauler pulls the mainline and mussel socks through one hole in the ice the new rope is pulled down through the other hole into the water. The new rope continually replaces the harvested line. This allows the grower to simply retie the mainline when harvesting is complete. The mussels left on the line remain submerged until they are required.

Another option involves the use of submersible lines (Figure 8.4). The entire line planned for winter harvest should be sunk using ballast to a depth below the anticipated ice thickness. In winter, a large hole is cut in the ice and the end of the submerged line located. An old fisherman’s trick to locate things through the ice could be used to find the line. A narrow pole

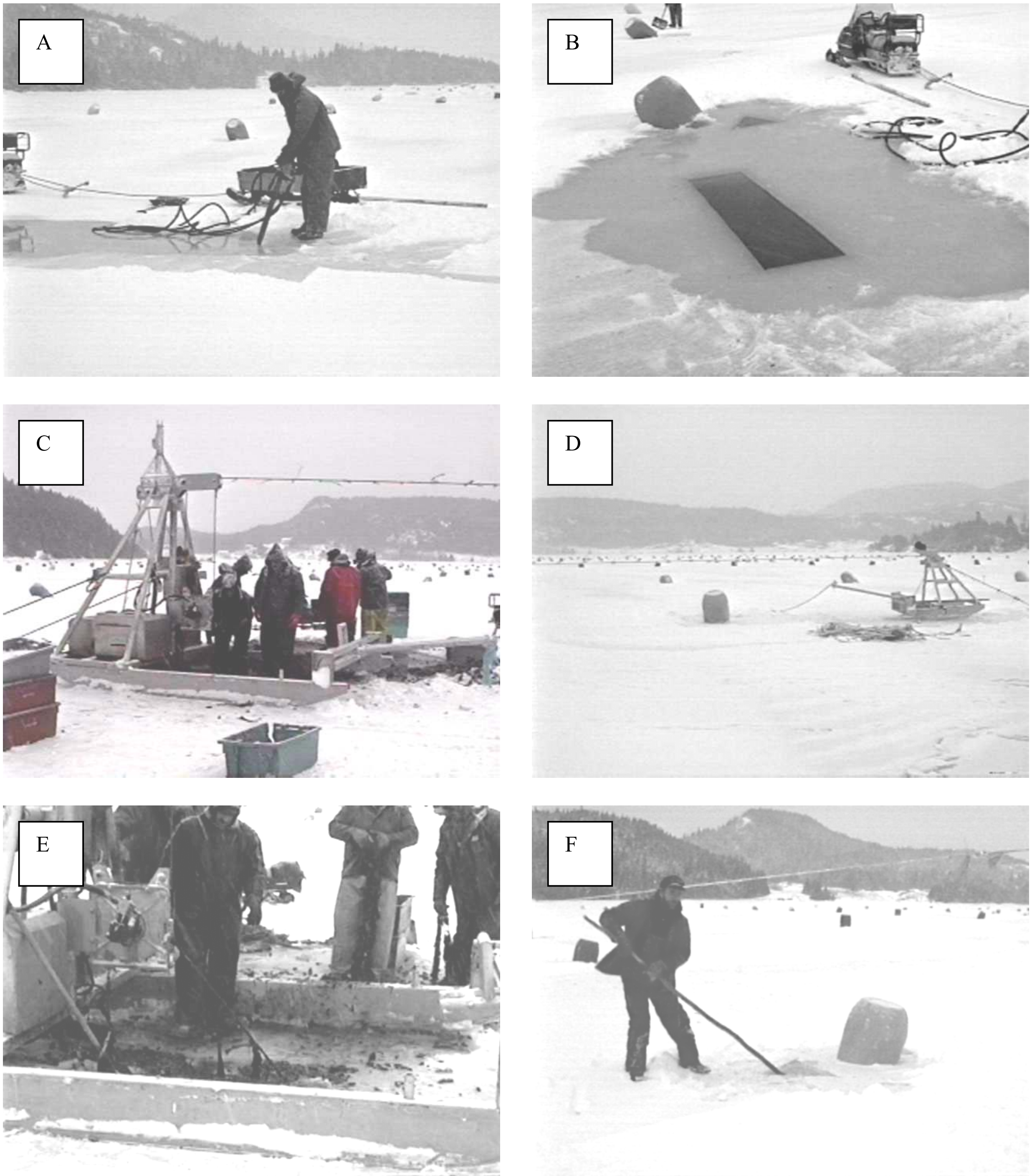



Figure 8.3: (A) Cutting holes in ice, (B) hole in ice, (C & D) winter harvesting using two “A” frame haulers, (E) hauling socks though hole in the ice and (F) cutting barrels from mainline. (Photos courtesy of Cyr Couturier).

could be tied to the mainline so that it hangs vertically in the water. The movement of the tide will cause the pole to move up and down preventing it from freezing in the ice. The grower then, only has to find the piece of the pole sticking out of the ice to find the mainline. The technique is similar to the previous method except the floats do not have to be cut to allow the line to be harvested. An "A" frame is used to haul the mussels, floats and ballast anchors form the water and new rope is connected to create the loop indicated above. Mussels not harvested will remain suspended by the submerged floats until they are required.

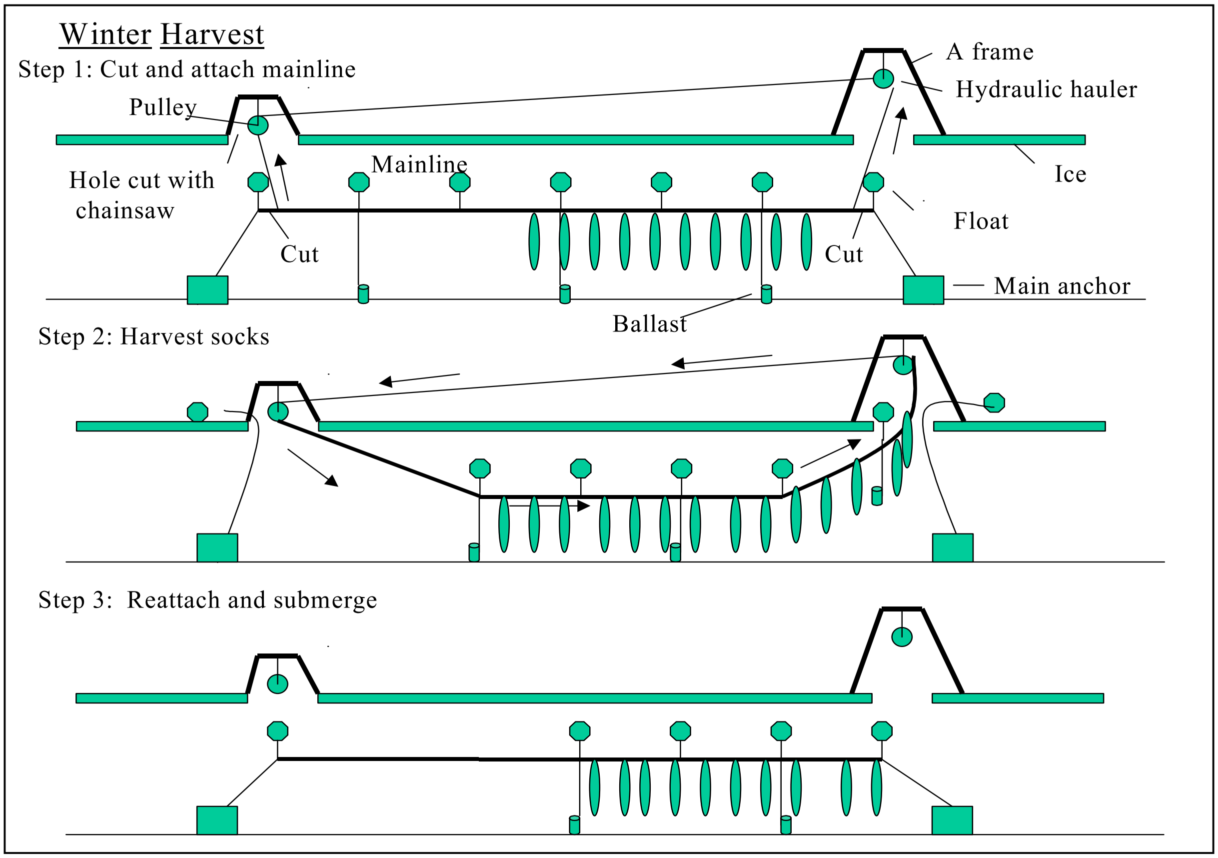



Figure 8.4: Step by step technique for the harvesting of mussels through the ice using submerged lines.

# Chapter 9: Quality Assurance

Food safety is a major area concern for shellfish consumers around the world. As such, protocols for ensuring food safety standards and quality control procedures have been developed to provide a high measure of assurance that shellfish products are safe to consume. In Canada, this is accomplished primarily through the Canadian Shellfish Sanitation Program or CSSP. This program is regarded as one providing the highest of standards for product safety around the globe. An overview of the program and its importance to the mussel producer was prepared and distributed to all shellfish growers/processors in Newfoundland in the fall of 1999. The CSSP overview is included in the present Guide for reference and can be found in Appendix 3.

Quality assurance (QA) simply refers to the level of security provided by food safety standards to the end-user i.e., consumer (Kingzett and Pirquet 1995). A workshop detailing the Canadian and New Zealand QA protocols was provided to Newfoundland shellfish growers in April 1999. A manual entitled "Towards Quality Assurance - An Information Manual for Shellfish Growers in British Columbia" was circulated to all participants. Extra copies may be obtained from the NAIA.

Rather than revisiting the fundamentals of QA in the current section, we will point out a few of the more pertinent concepts and refer the reader to the CSSP overview appended herein and the QA manual mentioned above (listed in reference section of the Guide).

Ultimately, the grower is responsible for the safety of a product from his or her site. Recent liability cases in Canada and the US have brought a focus on this, and some farmers have been found liable for shellfish product safety even though the product has gone through a processing plant. It is critical therefore that each mussel producer understand clearly what his or her responsibilities are regarding product safety.

Shellfish product QA involves <u>every stage</u> of the farming operation, from the time collectors are placed into the water until the mussels are served up on a plate. What a farmer does on his site can and will affect not only the quality but perhaps the safety of the product. In addition, what happens to the product once off the site may also affect quality and/or safety of the product. Some of the more relevant areas regarding QA that growers should be familiar with are:

CSSP program and types of food safety issues covered
Growing conditions and how this affects QA
Harvesting dos, don'ts
Wet storage and QA (if required)
Product labelling
Shipping/transportation of shellfish from farms
Harvesting from closed areas (not applicable yet to NFLD)
Understanding of shipping and processing procedures

Finally, shellfish product safety is <u>every producers'</u> business. If one person provides an unsafe cultured mussel product to the market place, the entire industry will pay the price. The following publications are also recommended as additional reading for interested growers: Guide to Mussel Quality Control (Newell 1990) and Code of Practice for Mussel Processing (Warwick 1983).

# Chapter 10: Monitoring

Many Newfoundland mussel farmers have only rudimentary information about their site and the product they are growing. The more experienced producers maintain extensive records of site and line performance. As a business it is imperative that as much information as possible is collected about a specific site. There are general criteria that predicts the approximate time when a product should be ready to harvest or when collectors and socks should be deployed but these do not apply to all locations. If a grower does not keep track of the specific conditions at a site, then unexplained losses in seed collection and harvest yields may occur making production forecasting impossible. Monitoring will allow the grower to optimize seed collection and maximize the quantity of market size mussels and meat yields at harvest. Monitoring will also enable mussel farmers to accurately predict future yields allowing the creation of solid business plans and easier access to financing.

Basic site monitoring is relatively cheap and easy. This involves basic inventory, mussel growth, meat yields and larval monitoring. Environmental monitoring, other than basic water temperatures and salinity may be too expensive for an individual grower but there are relatively inexpensive ways of monitoring mussel stock health and performance which provide good indicators of environmental conditions at a site.

## Basic Inventory

Basic inventory is simply keeping track of the volume, size and location of product on a mussel farm. A grower will need to know the quantity of product on his/her farm that is ready for market and where it is located. The information is also necessary for insurance coverage and lending agencies. Many growers claim to know their site by memory but even the best memories cannot keep track of the specific details within the site. Effective record keeping is the key to keeping track of inventory. One suggestion is to have a general logbook or folder for each site. These can be done on paper or on computer or both. The first section of the log should contain a site plan indicating the location of collector and sock lines on the site. Each line should be numbered on the plan and identified on a float on the site itself. Next, a page should be set aside for each line. Modifications to each line should be recorded on that page. These would include socks harvested, collectors deployed and socks deployed and the timing of these operations. Other information such as poor collection, slow growth, secondary set, mussel size and growth should also be recorded. As this information accumulates the specific characteristics of the site will be available for decision making. For example, a sock line in one location may have poor growth. The records will allow the grower to identify this problem and correct it or relocate the sock line.

A logbook may also contain information on license numbers, important contacts, general observations etc (see Macneill et al 1998 in Appendix 4).

Growth is one of the easiest characteristics of mussel farming to monitor. At least every two months (every month would be preferred) the grower should measure the length of mussels from each year class of sock. Measurements can be taken using plastic calipers, which can be purchased, at many hardware stores for less than $5. This mussel shell length information can be used as an inventory predictor (Figure 10.1). Using this prediction, mussel lines that have the greatest predicted harvest yield can be targeted, reducing losses from the harvest of undersized mussels. This should improve grower yields as the best mussels are always harvested.

Inventory and growth information will become even more important in the future as government funding organizations and banks will require detailed inventory and growth history to facilitate financing of mussel operations. The initiation of these requirements are evident even now. In addition, insurance agencies will require the same information to provide coverage for the mussel grower. Even more important, the grower will require detailed inventory information in the event that he/she must file a claim to the insurance agency. Without this type of information it will be very difficult to prove a loss of product in the unfortunate event such a loss occurs.

## Meat Yields

Maintaining a high quality product is essential to a prosperous mussel industry. Mussel quality is characterized primarily by shell size and appearance and by the quality of the meat. Meat quality is defined by meat yield (Steamed Meat Yield for North America and European Meat Yield for Europe), the weight of the meat relative to that of the whole animal (Figure 10.2 and Appendix 4). Generally, the higher the yield the higher the quality. A good quality meat would typically have a Steamed Meat Yield of 35 % or greater.

Meat yields can provide additional information to mussel growers beyond simply knowing if yields are great enough to allow harvest. If meat yields are preformed regularly (every two weeks or so) then a general trend can be established. This will allow the grower to predict at what time of the year he/she is likely to be able to harvest. As sites get developed and more mussels are grown, reductions in meat yields may indicate an over capacity problem. A large drop in meat yield in the spring or summer may indicate mussel spawning and allow the grower time to get collection material ready for deployment. Finally, meat yield determination at a variety of locations on a site is recommended to allow growers to evaluate the performance of their mussels at these locations

## Larval Monitoring

It is very important for a grower to time collector deployment correctly to maximize collection and to minimize fouling of collector ropes. If collectors are deployed too early heavy fouling by algae, clams or other organisms (Figure 10.3) may prevent or dramatically reduce mussel attachment; if deployed to late the major settlement period may be missed. Meat yield and larval monitoring are used to determine the correct time to deploy collectors. A sudden drop in

Weigh and measure at least three socks from a potential harvest area (3 year old mussels, or other being considered for harvest) from different locations on the site and calculate average weight and length of the socks. The greater the number of socks sampled the greater the accuracy of the estimate.

2. Take a sample of mussels from each sock and mix together in a container, including any fowling organisms present.

3. Randomly measure 50-100 mussels, placing those greater than 50 mm shell length in a separate container.

Weigh the mussels greater than 50 mm and record weight, then add the mussels under 50 mm mussels and weigh the total weight.

5. Divide the weight of mussels greater than 50 mm by the total weight and multiply by 100, this is the Percent of Harvest Size Product in the sample (see equation (A) below).

6. Subtract 30% from the percent of harvest size product to account for over-pack at the processor, this value is termed Total Market Percentage (see equation (B) below.

7. Multiply the Total Market Percentage by the sock weight to give Marketable Yield per Sock (see equation (C) below).

Divide the Yield per Sock by the sock length at harvest to give an estimate of Marketable Yield per foot or per 30 cm of sock.

9. Predicted harvest can be estimated by multiplying the Marketable Yield per Sock by the number of socks of the year class being examined

(A) $\text{Weight of } \frac{\text{mussels Greater Than 50mm}}{\text{Total Weight}} \times 100 = \text{\% of Harvest Size Product}$

% of Harvest Size Product – 30% = Total Market Percentage

Total Market Percentage X Average Sock Weight (kg)= Marketable Yield per Sock (kg/sock)

(C) $\frac{\text{Marketable Yield Per Sock(kg)}}{\text{Average Sock Length (30 cm or ft)}} = \text{Marketable Yield per 30 cm (foot) of Sock}$

Predicted Harvest = Marketable Yield per Sock X Number of Socks Harvested

Figure 10.1: A simple method used to estimate the marketable weight per Sock and the predicted harvest yield on a mussel site.

Steamed Meat Yield

$$\frac{\text{Shucked Steamed Meat Weight (g) X 100}}{\text{Empty Shell Weight (g) + Shucked Steamed Meat Weight (g)}} = \text{\% Meat Yield}$$

European Meat Yield

$$\frac{\text{Shucked steamed Meat Weight (g) X 100}}{\text{Total Live Weight of Uncooked Sample (g)}} = \text{\% Meat Weight}$$

**Procedure:**

Obtain 1 kg of mussels (approximately 55 mm in length) randomly from the site and clean of diet and slub. Rinse in fresh water and drip dry for 5 minutes.

2. Weigh and record the sample of whole live mussels (g).

3. Preheat a pot with a small amount of water, just enough to cover the bottom. When the pot begins to boil and steam, place the mussels in the pot and cover. The pot should be large enough such that the mussel take up only one third of the space.

4. Begin timing the process and cook the mussels for 10 minutes.

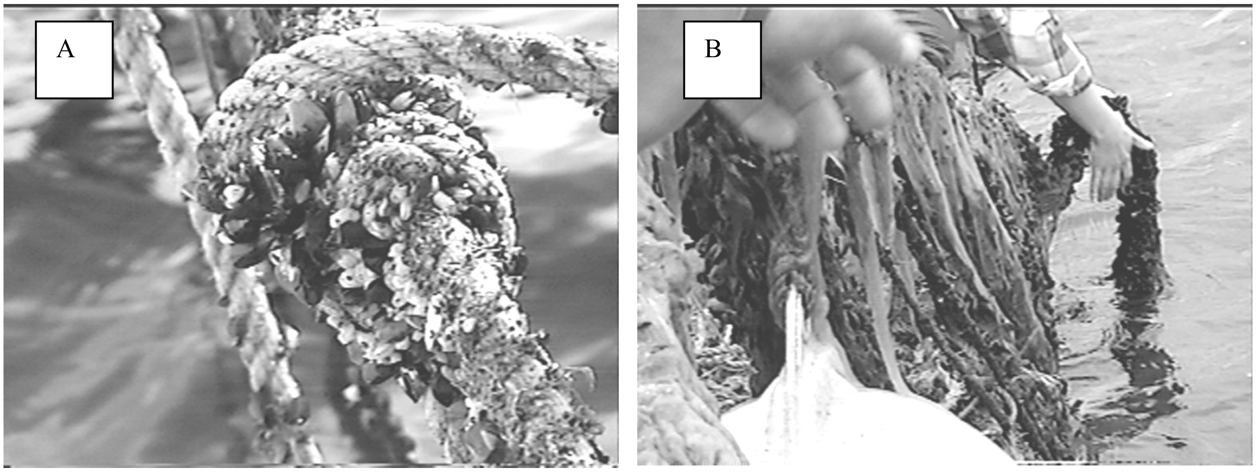
5. Shuck the meats and weigh the total meats and shells separately.

6. Record these values and calculate yields based on the above formulas.

Figure 10.2: Meat yield formulas and procedure (Based on Macneill et al 1998 A, Appendix 4).

steamed meat yield typically indicates mussel spawning and suggests preparation for collecting should begin. Once spawning has occurred, the second technique, larval monitoring becomes most valuable. Larval monitoring should also be used before local mussels spawn to see if mussel larvae may be present from sources other than the growers mussels. (see Appendix 4 for larval monitoring procedures)0

Mussel larvae exist as free swimming zooplankton usually in the upper levels of the water column. By sampling these larvae and determining first their presence, then abundance and size the optimum time for collector deployment can be determined. Larval sampling in Newfoundland typically requires the use of a plankton net that is hauled either vertically or horizontally through the water (Figure 10.4). The Newfoundland Mussel larval/Spatfall




Monitoring program uses a vertical tow from about 2 m off the bottom or 20 m depth, which eve

Figure 10.3: Fouling organisms on collectors. (A) Clams (*Hiatella arctica)*, and (B) algae.

Figure 10.4: Larval Monitoring using a plankton net. (A) Collecting the sample, (B) emptying sample in a bucket, (C) sieving the sample to remove larger particles, leaving the mussel larvae.

is less. (Macneill 1998 A). These vertical tows should be repeated at three to four different areas throughout the site.

Once samples have been collected they must be examined under a microscope so that larvae can be counted and sized. Larval numbers tend to vary widely among sites and consequently a level of abundance, which is considered good, must be determined for a particular site. For some sites 5-10 larvae per ml of sample may be a high number, for others 200-300 per ml of sample may be considered a high abundance (Macneill 1998 B). Generally collector deployment times are recommended when 50% of the larvae sampled are greater than 200 um in length (0.2 mm). After this percentage has been achieved growers are advised to deploy collectors, as settlement will soon occur (Macneill 1998 A).

## Spat Fall Monitoring

Spatfall monitoring involves observing the success of the mussel collection. This includes determining if mussels were collected and in suitable numbers and checking for the presence of predators.

Mussel abundance on collectors varied considerably throughout Newfoundland. Initial mussel density may be as low as several thousand per collector to greater than 200,000 per collector in the autumn of the year collected. Because of food and space limitations mussels self-thin and densities drop from up to hundreds of thousands mussels per collector to approximately 10,000-15,000 mussels per collector by the following spring. Further reductions in density will occur as the mussels grow. (Macneill 1998B pp42-47)

The most common predator of mussel seed is the starfish. There are several species present at Newfoundland mussel sites, the northern sea star or common sea star (*Asterias vulgaris)* and the daisey brittle star (*Opheopholis aculeata)* are the most common (Figure 10.5). Of these only the common starfish is predatory on blue mussels. These starfish are so voracious that only several maybe necessary per collector to kill most of the mussels on that collector, depending on mussel numbers (Macneill 1998B pp36). Other predators include eider ducks, sea urchins, rock crabs and conners (*Tautogolabrus adspersus*) (Sutterlin et al 1981).

Starfish also have planktonic larval stages and as such settle on top of the mussel collectors. Unfortunately these larvae typically settle after the mussels settle out, making it impossible to avoid starfish by altering collector deployment time. Consequently, starfish must be removed from collector and/or sock lines post settlement. If starfish densities are high, removal can be accomplished in two ways. The first is labour intensive and requires the handpicking of individual starfish from collectors. The second method is termed liming (Figure 10.6). In this technique the collectors are dipped in a container containing 2% hydrated lime solution (20 g/l)

(M. Prior, NAIA. 1999, pers.comm.). The lime burns the tube feet of the starfish causing them to drop off. The mussels are unaffected.

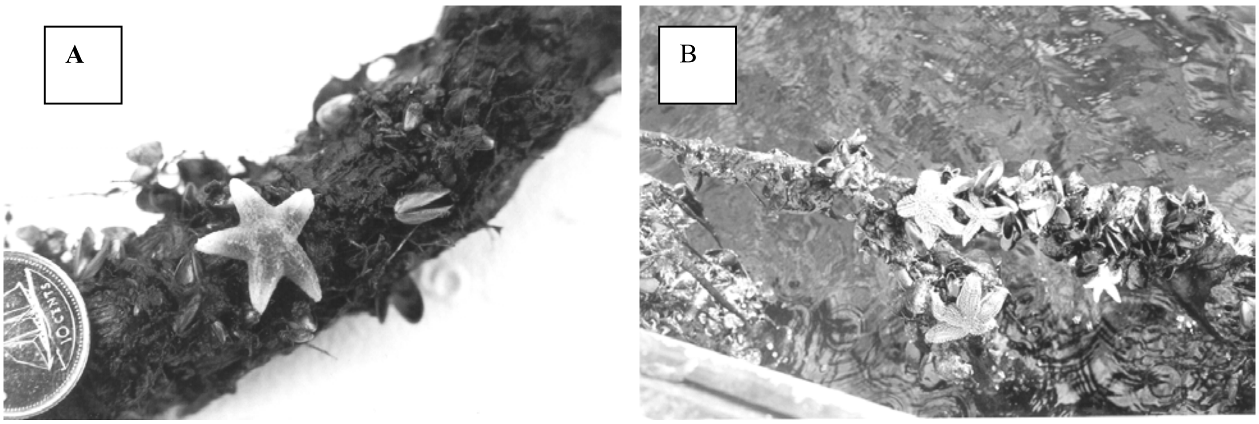



Figure 10.5: Starfish predation. (A) newly settled starfish on a collector and (B) starfish damage on socks. Photos courtesy of Sean Macneill.

Starfish also have planktonic larval stages and as such settle on top of the mussel collectors. Unfortunately these larvae typically settle after the mussels settle out, making it impossible to avoid starfish by altering collector deployment time. Consequently, starfish must be removed from collector and/or sock lines post settlement. If starfish densities are high, removal can be accomplished in two ways. The first is labour intensive and requires the handpicking of individual starfish from collectors. The second method is termed liming (Figure 10.6). In this technique the collectors are dipped in a container containing 2% hydrated lime solution (20 g/l) (M. Prior, NAIA. 1999, pers.comm.). The lime burns the tube feet of the starfish causing them to drop off. The mussels are unaffected.

For more information on the methods used in meat yields, and larval and spatfall monitoring please refer to the Handbook of Mussel Larval/Spatfall & Environmental Monitoring of Mussel Farm Sites by Macneill et al 1998, for the Newfoundland Aquaculture Industry Association and the Marine Institute of Memorial University (Appendix 4).

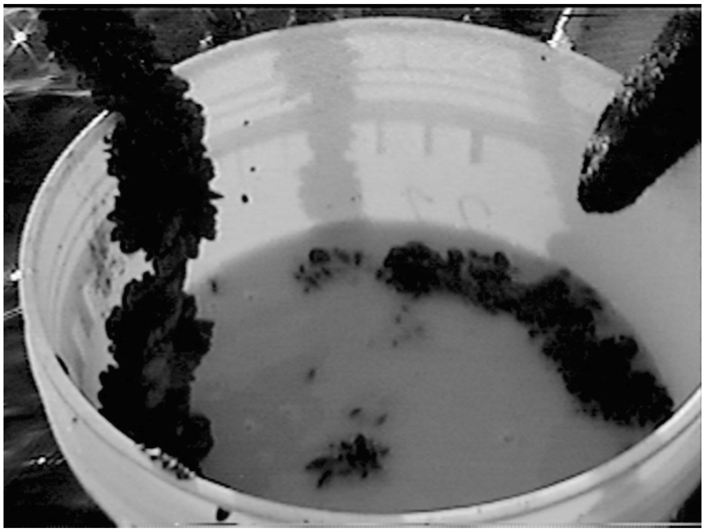


Figure 10.6: Collector being limed to remove starfish.

# Chapter 11: Funding Sources

## Summary

Analysis of Newfoundland mussel aquaculture revealed an expanding industry, yet low production output for a large number of mussel farms still exists. This low output appears to be the result of inefficient husbandry practices at the farm site plus a lack of resources and desire to expand production. The ever improving marketing and sales conditions will likely improve resources and mindset, resulting in an expansionist attitude. It is imperative that expansion occur using efficient husbandry techniques. The review of current farm practices suggests the need to improve both the techniques and the technology used by the grower to take full advantage of any expansion activity. Some growers are already very efficient but the majority are not. This is especially true for new entrants in the industry who can learn efficient husbandry techniques without many of the trial and error methods of their predecessors. The potential result of improving practices and technology is both a shorter production cycle and substantial increases in profitability for the mussel farmer.

This guideline was designed to supply the mussel growers with the best information available to allow informed decisions in their aquaculture business. The techniques and technologies presented are not an absolute as the mussel farmer must evolve with the industry as it develops. The guideline is only an aid, with a series of suggestions that will hopefully contribute to the success of the Newfoundland mussel aquaculture industry into the next millenium.

Updates on many of the topics presented here, including socking experiments, mussel health, production capacity and larval monitoring should be available in the year 2000.

## Summary Suggestions

### Anchorage

1. Switch from shorefast to underwater anchors (now a requirement).

If possible, consider arranging mainlines parallel to the shoreline for improved production.

### Flotation

Determine if floats are being used unnecessarily.

Use 0.4 m (16 inch) floats instead of barrels to support collector lines.

### Layout

Separate collector lines and sock year classes.

Place mussel seed of different sizes on separate lines when socking.

Consider submerging lines to avoid ice damage in high risk areas

Consider parallel lines if possible, to maximize site production.

Collection
Make collectors permanently attached to the mainline.
Do not remove collectors from mainline to clean, simply remove entire line with collectors attached.
Use nails, concrete cups or rock weights on collectors.

Socking
Redesign socking table and improve seed harvesting practices.
Determine optimum socking density for specific sites.
Grade seed.
Test spring socking to take advantage of the main growout period and a higher seed density on collectors.

Harvest
Use starwheels to maximize barge usage during harvest

Monitoring
Check meat yields on a biweekly basis.
Record the number of socks and collectors that are set and the number harvested per line and the location of musssels on the site.
Measure mussel growth to determine percent harvest on a monthly basis
Check general health and feeding status of mussels regularly.
Maintain accurate and complete records of farm sites

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Appendix 1: Additional Information and Assumptions

A. Criteria Used to Estimate Collector Construction Costs

Equipment (Based on IMP and Home Hardware purchase prices 1998)

3/8 rope: 1200 ft for $ 62.90
Twine: 600 ft for $9
Lead Rope:1200 ft for $148
Concrete: $0.0067/collector

Sock: 3300 ft for $75
Lead Sinkers: 12 for $2.50
7 inch Nails: 12 for $1.35
Styrofoam Cups: 50 for $1.07

Assumptions:

Collector is 6 ft long
Combined length of two collectors woven through the mainline is 13 ft
Assume 1.5 ft of sock is used to hold the rock weight (Type 1A and B)
2 ft of twine is used to tie rock to collector and 2 ft is used to tie collector to mainline for type 1A
Usefull life of rock weights is 3 years (Gardner and Coombs 1997)

Table 1A: A comparison of the labour and material costs to make and set 10,000 collectors of various types (1A) rock weight, (1B) rock weight permanent, (2) concrete cup, (3) nail weight, (4) lead weight and (5) socking maetrial. Costs do not include mainline or float requirements. Assume labour costs are $8/hour (Gardner and Coombs 1997). See above for individual item costs.

| Collector Type | 1.A. | 1.B. | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| **Material Cost** | | | | | | | |
| 3/8 rope | 3144.00 | 3406.00 | 3406.00 | 3406.00 | 3406.00 | 0.00 | 3144.00 |
| 1/8 twine | 600.00 | 300.00 | 0.00 | 0.00 | 300.00 | 0 | 600.00 |
| Socking | 340.50 | 340.50 | 0.00 | 0.00 | 0.00 | 1362.00 | 0.00 |
| Nails | 0.00 | 0.00 | 0.00 | 1125.00 | 0.00 | 0.00 | 0.00 |
| Styrofoam cup | 0.00 | 0.00 | 200.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cement | 0.00 | 0.00 | 67.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Lead Sinkers | 0.00 | 0.00 | 0.00 | 0.00 | 2080.00 | 0.00 | 0.00 |
| Lead Rope | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1233.33 |
| **Total Materials** | **4084.5** | **4046.5** | **3673** | **4531** | **5786** | **1362** | **4977.33** |
| | | | | | | | |
| **Labour Cost** | | | | | | | |
| Construction | 1918.47 | 1324.14 | 2402.40 | 1280.00 | 1300.00 | 768.27 | NA |
| Deployment | 1213.96 | 408.51 | 640.00 | 512.00 | 640.00 | 768.31 | NA |
| **Total Labour** | **3132.43** | **1732.65** | **3042.40** | **1792.00** | **1940.00** | **1536.58** | |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Total Cost(Year 1)** | **$7216.93** | **$5779.15** | **$6715.40** | **$6323.00** | **$7726.00** | **$2898.58** |

**Table 2A: The costs to maintain the six collector designs at 10 000 collectors per year.**

| **Collector Type** | 1A | 1B | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| Materials | | | | | | |
| Twine | 300 | 0 | 0 | 0 | 0 | 0 |
| Socking | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1362.00 |
| Maintenance (5%) | 360.85 | 288.96 | 335.77 | 316.15 | 386.30 | 0.00 |
| Total Materials | $660.85 | $288.96 | $335.77 | $316.15 | $386.30 | $1362.00 |
| Labour | | | | | | |
| Deployment | 1213.96 | 160.00 | 160.00 | 160.00 | 160.00 | 1536.58 |
| Total Cost | $1874.81 | $448.96 | $495.77 | $476.15 | $546.30 | $2898.58 |
| Additional costs | | | | | | |
| Year 4: Rock weights must be replaced on Rock weight | | | Collectors | | | |
| Twine | 150.00 | 150.00 | 0 | 0 | 0 | 0 |
| Socking | 340.50 | 340.50 | 0 | 0 | 0 | 0 |
| Labour | 633.09 | 436.97 | | | | |
| Total Cost | $1123.59 | $927.47 | 0 | 0 | 0 | 0 |

B. Assumptions used to compare purchasing seed to growing one's own.

**Table 1B: The comparative costs of purchasing seed vs collecting one's own.**

Seed : Purchase Vs Grow

Seed cost to deploy 10,000 socks — Assume harvest after 24 months in sock

| Assumptions | | | |
|---|---|---|---|
| Socks | 10000 | Floats | 400 |
| Socks/tote | 15 | Cost/coll | 0.6 |
| No. Totes | 667 | Float Cost/coll | 0.48 |
| sock:collector | 1 | Mainline Cost/Coll | 0.26 |
| No. Collectors | 10,000 | Anchor cost/coll | 0.048 |
| Cost/tote | 20 | Harvest labour/coll | 0.56 |
| % of lease used for collectors | 15% | harvest/sock (kg) | 11 |
| Revenue ($)/kg | 0.88 | | |

| Item<br>Year 1 | Collect own | Purchase seed |
|---|---|---|
| Collectors (build: materials+labour) | 6,000 | 13,333 |
| Floats | 4,800 | |
| Mainline (4300m) | 2,600 | |
| Anchors (24) | 480 | |
| harvest Labour (70 days@ $80/day) | 5,600 | |
| Total | 19,480 | 13,333 |

| Year 2 | | |
|---|---|---|
| 10,000 collectors | 6,000 | 13,333 |
| 400 0.4m floats | 4,800 | |
| Mainline (4300m) | 2,600 | |
| Anchors (24) | 480 | |

| | | |
|---|---|---|
| harvest Labour (70 days@ $80/day) | 5,600 | |
| | 19,480 | 13,333 |

| | | |
|---|---|---|
| Year 3 | | |
| 10,000 collectors<br>400 0.4m floats<br>Mainline (4300m)<br>Anchors (24)<br>harvest Labour (70 days@ $80/day) | 0<br>0<br>0<br>0<br>5,600 | 13,333 |
| | 5,600 | 13,333 |

| | | |
|---|---|---|
| Year 4 | 5,600 | 13,333 |
| Year 5 | 5,600 | 13,333 |
| Year 6 | 5,600 | 13,333 |

| | | |
|---|---|---|
| 6 year cost | 61,360 | 80,000 |

**Appendix 2: Mussel Equipment Suppliers and Funding Agencies**

Mussel Equipment

Newfoundland

| | |
|---|---|
| IMP<br>St. John's: 722-4221 | Type: Irish Square Mesh, Dupont and Italian.<br>socking, floats rope, etc |
| AIMS<br>Bill Spurrell<br>17 Kyle Avenue<br>Donovans Industrial Park<br>Mount Pearl, NF<br>A1N 4R4<br>Phone: 709-368-2467 | Type: Irish Square Mesh, floats, rope |

Other Provinces

| | |
|---|---|
| SFT Venture<br>RR1 Hubbards, NS<br>B0J 1T0<br>Phone: 902-228-2579<br>Fax: 902-228-2297 | Type: Spanish Socking |
| FUKUI North Ameriaca<br>Don Bishop, Operations Manager<br>Box 119, Island View Drive,<br>Golden Lake, Ont.<br>K0J 1X0<br>Phone: 613-625-2544<br>Fax: 613-625-2688 | Type: FUKUI-Octagonal Mesh socking, floats,.<br>cages, etc |
| Bridge Port Industries | Type: Irish Square Mesh socking |

Phone: 902-835-2888
Fax: 902-835-2352

Go Deep International — Type: square mesh socking, floats, rope, lights, etc.
Kent Ferguson
Box 493, Station A.
Fredricton, NB
E3B 4Z9
Phone: 506-454-5341

Cold-Water Sea Products
Box 915 RR#1
Tantallon, NS
B0J 3J0

Alluminium Equipment: Grader and Boats etc

Newfoundland

C& W Welding — Boats, tables etc.

Fab-Tech Industries Inc. — New grader similar to the East Isle Metal Fab Inc
Doug Holloway
Box 168
Glovertown, NF
A0G 2L0
Phone: 709-533-375

Other provinces

Atkinson & Bower Ltd. — New Zealand Style Continuous Socking Machine, hydraulics, etc.
Box 879
135 Hariott St.
Shelburne, N.S.
B0T 1W0
Phone: 1-800-565-4867

East Isle Metal Fab Inc — This is the grader pourchased by the Marine Institute
P.O. RR#3
Grandview, Belfast
C0A 1A0
Phone:902- 651-3000

Fabco Weldiing
RR#1, Kensington
PEI  C0B 1M0

Phone: 902-836-3792

Vince's Welding & Fabrication
Mt. Stewart RR#1
Bedfprd, PEI
C0A 1T0
Phone: 902-629-1409

Charlottetown Metal Products
Box 323, Charlottetown, PEI
C1A 7K7
Phone: 902-566-3044
Fax: 902-566-1856

Brothers' Machine & Welding ltd.
Box 40, Cardigan, PEI
C0A 1G0
Phone: 902-838-3500

F.B. Welding & Maintenance
Rollo Bay. PEI
C0A 2B0
Phone: 902-687-4709

Funding Agencies

Atlantic Canada Opportunities Agency (ACOA)
Contact: Paul Strickland
Phone: 1-800-668-1010

Farm Credit Corporation
Phone: 772-4635

Business Development Bank of Canada
Phone: 772-5505
No Charge Dial: 1-888-463-6232

The Department of Human Resources and Development
Contact your local office

The Department of Development and Rural Renewal
Contact you local office

## Appendix 3: Overview of The Canadian Shellfish Sanitation Program and Shellfish Safety

**An Overview of The Canadian Shelfish Sanitation Program and Shellfish Safety**

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Cyr Couturier

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## Introduction

The Canadian Shellfish Sanitation Program (CSSP) sets standards for shellfish meats and growing waters to reduce the risk of illness associated with the consumption of contaminated shellfish products. Its standards are among the highest in the world and are equivalent with the National Shellfish Sanitation Program (NSSP) under the bilateral agreement between Canada and the United States of America. Thus, it is very important that the Newfoundland aquaculture industry growers know and understand the regulations and operations of the CSSP.

This paper was prepared for the shellfish growers in Newfoundland to provide valuable information about the operations and regulations of the CSSP in a concise, easy to read review. In addition, the paper allows feedback from the Newfoundland growers regarding the CSSP.

## CSSP Rationale

On April 30, 1948, a formal shellfish agreement between Canada and the United States was reached regarding standards for bivalve growing waters and products, resulting in the National Shellfish Sanitation Program (NSSP). The bilateral agreement was formed to improve the sanitary practices in shellfish industries and to guarantee the quality of the products prior to export to reduce risk of illness due to shellfish contamination. This agreement arose due to a typhoid fever outbreak in the United States in 1924 -25 that was caused by contaminated oyster consumption and resulted in 1500 cases and 150 deaths. The Canadian Shellfish Sanitation Program (CSSP) was also developed as a result of the typhoid fever outbreak, setting the standards for shellfish meats and growing waters in Canada..

The CSSP is governed by three federal agencies: Department of the Environment, the Canadian Food Inspection Agency (CFIA), and the Department of Fisheries and Oceans (DFO). The Environmental Protection (EP) Branch of Environment Canada (EC) classifies shellfish growing waters based on shoreline sanitary surveys and bacteriological water quality conditions in the area. CFIA regulates the handling, processing, import and export of shellfish, and the marine biotoxin monitoring program. DFO manages the harvesting of shellfish from closed growing areas and enforces shellfish closures in accordance with the Fisheries Act. These standards of the CSSP that are enforced and governed by EC, CFIA, and DFO are among the highest standards in the world for production of shellfish.

## Importance of Water Quality

Bivalve molluscs, including mussels, scallops, clams, and oysters, feed by filtering the water from their environment. The animals can select the particles they prefer for food by taking in particles of appropriate size, whether good or bad, and rejecting only a small amount of the particles. When bivalves feed they can accumulate algal, bacterial, and chemical contaminants from the water, even when the source is very far away. The contaminants may become concentrated in the meat of the shellfish and when humans consume it may result in illness or even death. Thus, it is essential that aquaculture sites be tested for food safety reasons before harvesting to reduce or eliminate illnesses due to shellfish consumption.

Sources of Contamination

A large number of sources may result in shellfish contamination and make them unsafe for human consumption. Some of these sources include:

Raw sewage
Land-wash runoff containing organic wastes, pesticides, fertilizers, and other pollutants
Industrial discharges
Wastes from wildlife and marine life
Toxin producing phytoplankton species

The contaminants that affect shellfish quality may be divided into three categories: microbes (bacteria and viruses), pollutants, and phycotoxins (discussed in section 5.2.5).

Bacteria and Viruses

Many human diseases may be spread by the ingestion of water and shellfish containing bacteria or viruses. Shellfish growing in water contaminated by fecal material from humans and warm-blooded animals that might carry human pathogens spread diseases such as cholera, typhoid fever, hepatitis, polio, and gastroenteritis. It is thought that most shellfish-related gastroenteritis may be due to viruses and most bacterial infections due to different *Vibrio* species. In addition, shellfish-borne *Aeromonas* bacteria are known to cause fatal disease in people with immature or distressed immune systems, such as infants, the elderly, persons with AIDS, etc.

Many people assume that when shellfish are cooked any disease-causing organism in the meats will be destroyed. Actually, most bacteria and viruses that cause disease are destroyed when shellfish are ***thoroughly*** cooked. However, shellfish are usually eaten raw or only lightly cooked by steaming since long periods of cooking leaves the meats tough and unappealing to the consumer. Thus, the bacteria and viruses in the meat are most often still alive when consumed and they can induce disease.

Pollutants

If chemical pollutants from sources such as industries, surface runoff, mining or other operations reach shellfish growing areas, the chemicals can be ingested or absorbed into the bivalve tissues. These pollutants are serious health hazards to people who consume the contaminated shellfish. Some of the pollutants that are of major concern are:

| Pollutant | Examples |
|---|---|
| Metals | mercury, copper, lead, cadmium |
| Chlorinated organics | pesticides, herbicides, wood preservatives |
| Petroleum products | oils, diesel, gasoline, tars |
| Other organic compounds | dyes, antibiotic residues |

Once shellfish become contaminated with these pollutants, they may never be safe for human consumption. Thus, it is very important that growers are aware of all human activities that may impact the growing waters, both at the time of site selection and later. In addition, shellfish growers must be cautious to avoid unintentional contamination during normal farm activities.

## CSSP Administration

### The Department of the Environment

Environment Canada has two major responsibilities directed by the Canadian Shellfish Sanitation Program. First, Environment Canada has to identify all sources of pollution to shellfish growing waters through shoreline sanitary surveys. Second, the growing waters are tested for fecal coliform bacteria, which is a positive indicator of sewage pollution. The purpose of these studies is to identify and assess any sources that may affect the water quality of the growing area that would affect the shellfish in the area. When all the information is obtained, Environment Canada recommends a classification for the aquaculture site with regards to harvesting shellfish from the area.

### Shoreline Sanitary Surveys

Sanitary surveys are conducted in shellfish growing areas where no previous data exist or where pollution conditions have changed since the preceding survey. For instance, the addition of homes, cabins, industrial buildings, and other possible pollution sources in the vicinity of an aquaculture site would require a sanitary survey of the area. When conducting a sanitary survey, point and non-point pollution sources are determined that may affect the quality of shellfish harvested from the area. A point source of pollution is a source entering at a distinct, measurable location whereas a non-point source is when pollution does not enter the water at identifiable locations. Examples of point and non-point sources are:

| Point Sources | Non-Point Sources |
| --- | --- |
| Sewage inputs | Runoff |
| Industrial plants | Animal fecal pollution |
| | Sewage discharge from boats |
| | Mining - Leaching |

Point sources of pollution are recorded on a site map during a sanitary survey. Non-point sources are determined by observing the site during bacteriological surveys (Section 5.1.2) and may also be included on the map. These observations are recorded in the field log book and are included in the classification report. In addition, the presence of raw sewage and industrial wastes are noted for the classification procedures.

Bacteriological Surveys

The second major responsibility of Environment Canada is a total fecal and bacteriological examination of the shellfish growing waters. The waters are tested for *Escherischia coli* (*E. coli*), which is a fecal coliform bacterium that is present in the intestinal tracts of all warm-blooded animals. This bacterium is used as an indicator of sewage pollution, which may suggest the presence of other disease causing organisms. However, *E. coli* is not usually pathogenic.

Before sampling begins at a site, shoreline sanitary surveys are conducted to determine the locations of the sampling stations based on the proposed area for the aquaculture gear, freshwater inputs, such as streams or rivers, location of cabins, and the presence of coves or inlets. The stations are clearly marked on a map of the site to show the sampling stations. In addition, the water has to be sampled in the same spot to obtain consistent results.

Aquaculture sites that have not been previously tested by Environment Canada are required to be tested at least 15 times during the initial classification, which in Newfoundland normally takes place between May and September. After the initial sampling and classification, the stations at a site have to be sampled again for re-classification, according to the Risk Management approach adopted by Environment Canada. The Risk Management approach determines how often the site has to be re-tested and how many samples are needed depending on the level of risk at the site. Thus, the higher the level of risk the more often it is tested. In Newfoundland, the stations at a site are usually tested 5 times every 3 years
While sampling at a site, relevant hydrological, meteorological and geographical conditions in the area are recorded by the sampler, including:

Weather conditions
Wind strength and direction
Tidal period and range (observation)
Water temperature at each station
Freshwater flows
Levels of human and animal activity in the area of the sampling locations

This information may help explain the occurrence of positive samples for fecals at the site during the final classification procedures. Also, a temperature control is taken that is kept with the other samples and is used to determine how the temperature of the samples changed during transport to the laboratory.

The CSSP manual has set specific guidelines and regulations for sampling on site and testing the water at the mobile laboratory. The procedures are designed so the samples do not become contaminated from another source, which would result in inaccurate results. The sampling procedure is as follows:

Samples from overlying waters are taken in sterile bottles using aseptic techniques
The inside of the bottle cap has to remain untouched
The bottle is put 20-cm under the water to take the sample
Water samples should be kept chilled during shipment to prevent changes in bacterial growth (1°C to 10°C)
Samples must be tested within six hours of collection

At the laboratory the samples are tested for fecal coliforms using the Most Probable Number (MPN) method. This method estimates the number of bacteria in a sample based on a series of dilutions of the sample, and the sample must contain gas formation to be positive for fecal coliforms.

The MPN procedure is as follows:

Sample is mixed by shaking
Five tube serial dilution incubated for 2 hours at 35.0°C and then 22 hours at 44.5°C
Control tubes are inoculated with the samples to ensure the testing equipment and supplies were not contaminated
After 24 hours, tubes are observed for positive growth-cloudy with gas production
Positives are recorded and compared with a standard MPN table to obtain a quantitative estimation of bacterial numbers
Positives are further tested to identify the bacteria

## Classification

The classification of shellfish growing waters is based on the results from the shoreline sanitary survey and bacteriological analysis, including the effects of wind, rain, freshwater inputs, and other factors on the bacterial concentration at the sampling stations. These factors and observations from the shoreline sanitary may explain high numbers of bacteria in a particular area.

During the final stage of classifying a site, Environment Canada presents their findings to a Newfoundland committee, which includes CFIA, the Department of Fisheries and Aquaculture (DFA), DFO, and industry representatives. A report is composed recommending the site classification and is then presented to the Regional Shellfish Growing Area Survey and Classification Committee, which determines the final classification. The site will receive one of three classifications: approved, conditionally approved, or closed.

| | Approved | Conditionally Approved | Closed |
|---|---|---|---|
| Water Quality | Not contaminated with fecal material, poisonous or deleterious substances or marine biotoxins | Under some conditions, water quality exceed criteria | Contaminated with fecal material, poisonous or deleterious substances or marine biotoxins |
| Mean Fecal Coliform MPN of Water | Does not exceed 14mpn/100mL & less than 10% exceed 43mpn/100mL | Must meet **approved** conditions during times of harvest | Exceeds 14mpn/100mL and/or 10% exceeds 43mpn/100mL |
| *Direct* Harvesting for Consumption | Yes | Controlled | No |

In the Atlantic Provinces, all three site classifications occur. In many areas in PEI, New Brunswick, and Nova Scotia, some sites have both approved and closed areas. The closed areas are usually close to land and further inland whereas the approved areas are in more exposed areas. For instance, this is observed in Malpeque Bay, PEI, and Lunenburg Harbour, Nova Scotia. Also, some areas are conditionally approved in Colville Bay, PEI and Burnt Church River and Neguac River, New Brunswick. The conditionally approved classification is not very common and the classification is not observed in Newfoundland yet.

The Canadian Food Inspection Agency

The Canadian Food Inspection Agency has three main responsibilities in the CSSP. First, it ensures that processing plants meet the federal regulatory requirements for processing, holding, and import and export of shellfish. Second, it sets standards for the handling of shellfish from the growers to the processing plants, including wet storage, labeling and shipping. Third, the CFIA administers the marine biotoxin program, which tests for toxins in shellfish meats causing Paralytic, Diarrhetic, and Amnesic Shellfish Poisoning. In addition, the CFIA tests shellfish meats at the processing plants for fecal coliforms.

Plant Requirements

Processing plants must meet specific requirements to be able to process shellfish. They must be registered in accordance with specific requirements for construction and equipment, and operating requirements for establishments of the Fish Inspection Regulations (FIR). Plants that export to the U.S must meet the National Shellfish Sanitation Program (NSSP) protocols. In addition, all federally registered fish processing plants must participate in the Quality Management Program (QMP), a program based on Hazard Analysis Critical Control Point (HACCP) principles. This requires all plants to develop and execute an in-plant quality management program to add extra guarantee that the fish products meet the regulatory requirements of the FIR.

Wet Storage

Shellfish are sometimes stored by a method know as wet storage until the stock is prepared to be shipped for final processing. The animals may be stored in baskets or sacks nearshore or they may be kept in holding tanks on land. If animals are stored temporarily after harvesting, the storage facilities have to meet the requirements outlined by the FIR. However, shellfish should not be held for extended periods since the quality of the meat deteriorates and the mortality numbers increase, resulting in loss of product. In addition, shellfish to be kept in wet storage must be harvested from approved or conditionally approved sites.

Before shellfish can be kept in nearshore areas, the area must meet approved levels of fecal coliforms and biotoxins as outline by Environment Canada and CFIA, respectively. Also, onshore storage facilities must meet the following criteria:

Labeling

It is very important that harvested shellfish be labeled properly. For instance, if contaminated products reach consumers and cause illness, it is easy to track the source of the product and recall the shellfish if labeled properly. This reduces the number of illnesses caused by contaminated shellfish.

Shellfish being shipped to market should have two different tags. The first tag is a harvest tag, which each grower fills out for transport from harvest site to the receiving plant. The label must be attached to each container of shellstock. The harvest tags must include the following information:

Harvester’s name
Date of harvest
Harvest location
Type and quantity of shellfish

The processor attaches a shipping tag after the product has passed through the processing facility. If the processor is also the harvester, the shipping tag may be used as the harvester's tag. The shipping tags must have the following information:

Name, address, registration number assigned by CFIA
The original shipper's certificate number
Date of harvest
Harvest location
Name and address of processor
Type and quantity of shellfish

Shipping

During shipping, it is critical that the shellfish product is kept at a low temperature in a clean container constructed from safe materials that are non-absorbent and non-corrodible, such as onion sacks, vexar, and containers made of plastic and metal that can be easily cleaned. An increase in temperature supports bacterial growth, and thus, shellfish that contained safe levels of bacteria when harvested may exceed the standards of the CSSP after shipment. Thus, the shellfish may become contaminated during the shipment, resulting in loss of product and revenue. In addition, product quality and shelf life will deteriorate faster when subjected to warm temperatures. The CSSP regulations state that shellstock should be iced or the storage area shall be maintained at or below 7.2°C until final sale to customer or until processing. Shellfish should be iced from an approved source immediately after harvest and it must remained iced or chilled during transport.

Another important point to remember when shipping shellfish, either by boats used for harvesting and transport or trucks, is that it cannot be shipped with any materials that may cause contamination of the product. The boats should be designed as follows to comply with the CSSP regulations:

Decks and storage bins are built and located to prevent bilge water from coming in contact with the shellfish
Bilge pumps are located so that it will not contaminate shellfish
Boats & storage bins are kept clean with water from an approved source and are provided with effective draining
Coverings are used when necessary to protect shellfish from the hot sun, birds, etc.
Animals are not permitted on vessel

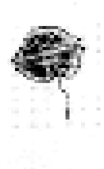
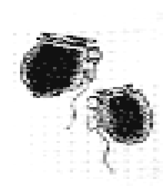
When trucks are used for shipping the same guidelines apply with the addition of:

*If mechanical refrigeration is used, they must be equipped with automatic temperature controls and prechilling the trucks is recommended*

Marine Biotoxin Monitoring Program

Algae, some of which produce toxic compounds known as phycotoxins, impact many areas in the world. Bivalve shellfish feed on algae, and they may accumulate the toxins in their meat if they are in the vicinity of the toxic species. The international scientific community uses the term harmful algal bloom (HAB) to refer to problems caused by algal species since some algae are harmful in other respects.
Shellfish containing concentrated toxins from algae in their meats will induce illness and even death in humans that consume the contaminated shellfish. Thus, as part of the CSSP, the Canadian Food Inspection Agency is required to test the meats of cultured shellfish to ensure that a safe product is shipped to market. Some areas are tested more often if biotoxins have been detected at the site in previous years. The agency tests for three types of shellfish poisoning: Paralytic (PSP), Diarrhetic (DSP) and Amnesic Shellfish Poisoning (ASP). The PSP and ASP toxins are monitored in shellfish meats on a regular basis, whereas DSP is usually only tested when consumers complain of symptoms of DSP poisoning or if the area has a history of DSP occurrences it will be tested regularly. Also, only the digestive tissue of the meats is tested for DSP, while the entire shellfish meat is tested for PSP and ASP.

PSP toxins is tested using a procedure known as the mouse bioassay (Ken Malone, CFIA. Personal communication. 1999). DSP and ASP are tested by chemical analysis and is a much more difficult procedure than the mouse bioassay. The following table outlines important information about these three illnesses.

| **Facts** | **PSP** | **DSP** | **ASP** |
|---|---|---|---|
| Responsible organisms | *Alexandrium* species (dinoflagellate) | *Prorocentrum lima* (dinoflagellate) | *Pseudo-nitzschia* species (diatom) |
| Diagram of responsible organism |  |  |  |
| Phycotoxin produced | Saxitoxin derivatives | Okadaic acid and derivatives | Domoic acid |
| Symptoms in humans after consumption | Tingling, numbness, giddiness, drowsiness, fever, rash & staggering | Diarrhea, nausea, vomiting, cramps & chills | Disorientation, digestive upset, short term & permanent memory loss, seizures |
| Seriousness | Life threatening | Non-lethal | Can be life threatening |
| CSSP limit | 80µg/100g of meats | 1µg/g of digestive tissue | 20µg/100g of meats |

Many documented cases of shellfish poisoning have occurred in Atlantic Canada where shellfish sites had to be temporarily closed. For instance, in 1982 the first incident of PSP toxicity causing human illness in Newfoundland occurred in Conception Bay. Since then several harvesting sites have been temporarily closed and 4 permanently closed.

In 1990, DSP became a major problem when 13 people became ill after consuming cultured mussels from Mahone Bay, Nova Scotia. Bonavista Bay was the first place that DSP was detected in Newfoundland when people became ill from consuming mussels. As a result, harvesting was closed for 10 months due to the DSP toxin.

Amnesic shellfish poisoning was first detected in Canada in 1987. It was detected in mussels in PEI and caused 107 illnesses and three deaths. In addition to being hazardous to the public health, it resulted in severe economic loss. A trace of domoic acid was first seen in Newfoundland in 1994 in mussels and scallops but no harvesting areas were closed because of the low levels.

The costs associated with testing the shellfish meats are as follows:

| | 1 to 5 samples | 6 to 10 samples |
|---|---|---|
| Fecal coliform | $122.00 | $ 244.00 |
| PSP & ASP | $ 191.00 | $ 382.00 |

Department of Fisheries and Oceans

The Department of Fisheries and Oceans (DFO) major role in the CSSP is the enforcement of closures. This is accomplished by posting signs in the closed areas warning of the dangers of consuming shellfish from the area. In addition, DFO is responsible for controlling harvesting from closed areas. However, the product harvested from closed areas is not direct harvesting since the shellfish are not sent directly to market for consumption. Instead, the animals are moved from closed areas to a purification facility or relay location. These locations contain seawater from an approved source, and since the water is clean and unpolluted, the shellfish can cleanse themselves of fecal coliforms. A purification facility involves holding the shellfish in a land-based wet storage facility in a specific quantity of water for a specific time. Controlled relaying involves cleansing the animals under natural conditions by moving the stock to an approved area. ***Permits for harvesting shellfish from areas contaminated by PSP, ASP, and chemical pollutants cannot be obtained.***

Controlled Harvesting

Shellfish cannot be harvested from closed area without a special permit from DFO. To obtain a permit, a proposal must be submitted to the DFO Conservation and Protection office containing the following information:

Description of proposed harvest location
Harvest method
Purification facility or relay location
Timetable of operations
Controls to ensure proper requirements are fulfilled

After the proposal is reviewed, three conditions must be satisfied before a permit can be issued:

Acceptability of the harvest site
Approval of the purification facility or relay location
Acceptance of responsibility by the operator for the process and quality control of the shellfish from harvest to final release

When the application is approved, a special license for harvesting in closed areas is issued and an agreement is signed that specifies all procedures that must be followed during the entire operation.

## CSSP and Shellfish Growers

The CSSP is very important to shellfish growers since it sets the standards for safe growing waters and the harvest, shipping, and processing of shellfish to protect the public health. The standards set forth by the CSSP manual of compliance protects the farmers from economic loss, liability risk, and poor quality standards.

One of the main objectives of the CSSP is to set the standards for safe growing waters and processing of the product. When an aquaculturist wants to upgrade a developmental license to a commercial license, the site must be tested and approved by the CSSP standards before a commercial license can be issued. This reduces the loss of revenue by the grower since sites high in bacteria, pollutants and toxins are closed before the farmer contributes large sums of money to the site. In addition, the CSSP decreases revenue loss due to handling by setting guidelines to follow. For instance, low levels of bacteria can quickly multiply if the product is mishandled. This will result in a contaminated product and when the meats are tested at the plants, the stock may be rejected and not sent to market. Growers will lose money from the harvesting and shipping costs and lose profit since the product will not be sold for consumption.

The liability risk affiliated with the consumption of contaminated shellfish will affect growers. If growers sell their product to market without following CSSP standards, people may get very ill from the product. This will reflect on the grower, the result may be money loss from damages.

Finally, seafood markets want a reliable product that is free from disease organisms, toxins, and pollutants and that is high in quality (taste, freshness, texture, colour, etc.). This is a very important marketing issue and reported incidences of illness from a specific farm may damage buyer confidence in the supplier and potentially the industry as a whole. Buyers must be assured the product has been professionally tested and is safe and wholesome for human consumption.

## Future Problems

From 1996-1999 NAIA has supplied Environment Canada with two employees to help re-classify and classify potential aquaculture sites. This joint venture was necessary since the funding available for Environment Canada for the Shellfish Water Quality Program under CSSP protocols has decreased greatly in recent years. Overall, this has been a win-win arrangement between Environment Canada and NAIA for several reasons. First, by working through the association, Environment Canada was able to classify over 30 new potential aquaculture sites in addition to the re-classification of many more sites. Without help from NAIA, the program would not be able to classify new aquaculture sites, which would hinder the rapidly expanding aquaculture industry in Newfoundland. Second, this joint venture provided valuable work experience for Marine Institute aquaculture graduates. In addition, the Department of Fisheries and Aquaculture supported the venture because it helped the department achieve its mandate to help the Newfoundland aquaculture industry grow.

After 1999, NAIA will not be contributing any funds or workers to Environment Canada for the water quality program. This will pose serious problems to the aquaculture industry in Newfoundland if Environment Canada is not able to maintain its program funding for the re-classification and classification of shellfish growing waters. Presently, growers contribute their boat and time to NAIA employees for the classification of new aquaculture sites. However, decreased funding may result in more involvement from the shellfish growers, including the growers sampling and being responsible for the testing of the waters.

Recognizing the issues as national concern, the Canadian Aquaculture Industry Alliance (CAIA) is currently looking at a pilot project to evaluate alternative methods for CSSP delivery. This will include the growers performing their own sampling and on site, which will hopefully result in improved product safety, reduction in costs to government and industry, and provide a competitive advantage in the market for shellfish. If this pilot project works, it would be optional for growers.

The CSSP implements protocols for shellfish products that are among the highest standards in the world. This program reduces the risk of illness in consumers and ensures that the highest quality shellfish products reach market. In the future, it is very important that these standards are upheld or surpassed by EC, CFIA, DFO, and the shellfish growers in Newfoundland and Canada to protect the public health and to guarantee a high quality product.

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www.ns.ec.gc.ca - EC website

www.redtide.whoi.edu/hab/illness/illness.html – Source of photographs

## Appendix 4: Hanbook of Mussel Farm Site Monitoring and Enhancing Seed Production

Handbook of Mussel Farm Site Monitoring
Enhancing Seed Production

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## Introduction

An important part of operating any mussel farm is careful site monitoring. Each site is unique with ever changing oceanographic and environmental conditions. Regular monitoring of site conditions and their impact on the mussel lifecycle can aid the grower significantly in running farm activities. This handbook is a guide to site monitoring methods related to mussel seed collection, a critical step in the mussel production cycle. Without a reliable seed source, annual farm production may fluctuate and/or make it difficult for expansion. Through regular meat yield and larval/spatfall analysis, a grower can better predict mussel spawning, larval growth and timing of settlement, optimum collector locations and deployment times, plus many other benefits, such as those shown below.

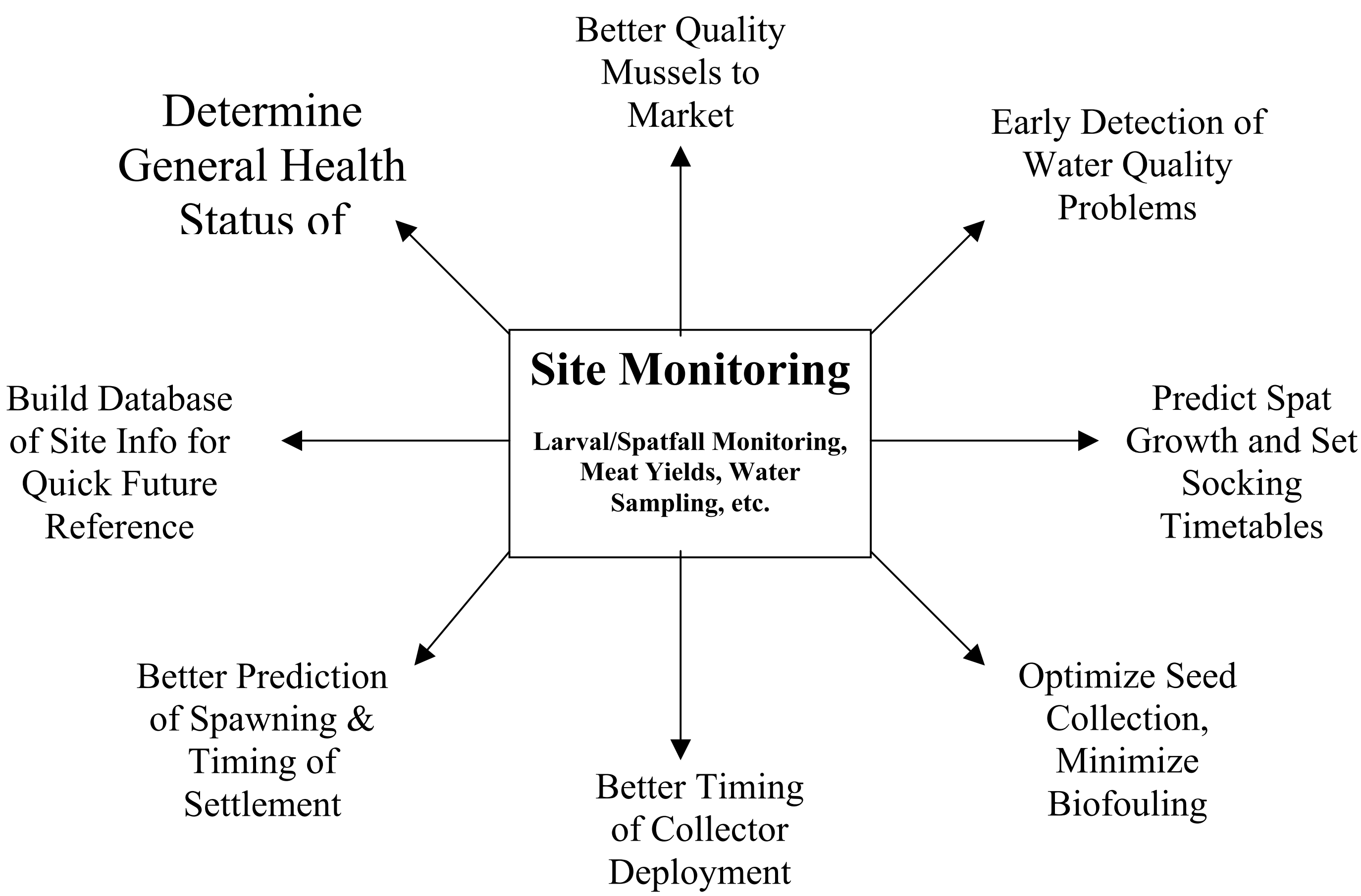



Figure 1. Some advantages of site monitoring.

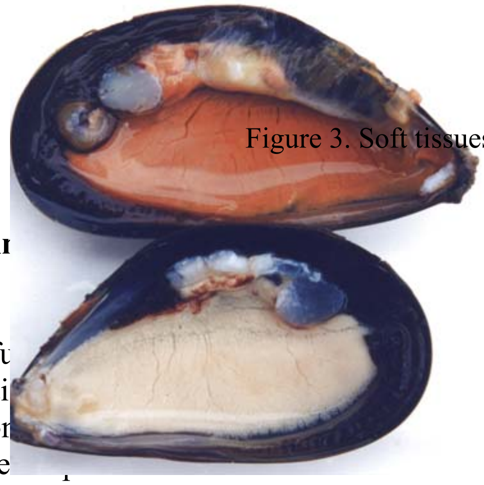


Figure 3. Soft tissues (meats) of

**Organizing and Record Keepi**

An organized farm is a successfu … el spawning and larval settlement that site conditi … , to write things down in a well organized fashion … collector locations, periods of algal blooms and othe … n scraps of paper **simply will NOT do**. By writing things in a well organized daily log book, a grower can look back at data from previous seasons as a comparison to current site conditions. This may help significantly in site operation decision making.

A log book may be as simple as an exercise book or binder for each season. Have sections for site names and physical layout, weekly meat yield calculations, results of weekly larval monitoring, collector deployment information, fall and spring spat collection summaries, water quality, plus a section for daily entries of site observations. Sometimes, even the subtle observations may prove useful.  Also include a section on phone numbers, contacts for equipment, etc.  With everything at your fingertips, running the farm will be more efficient.

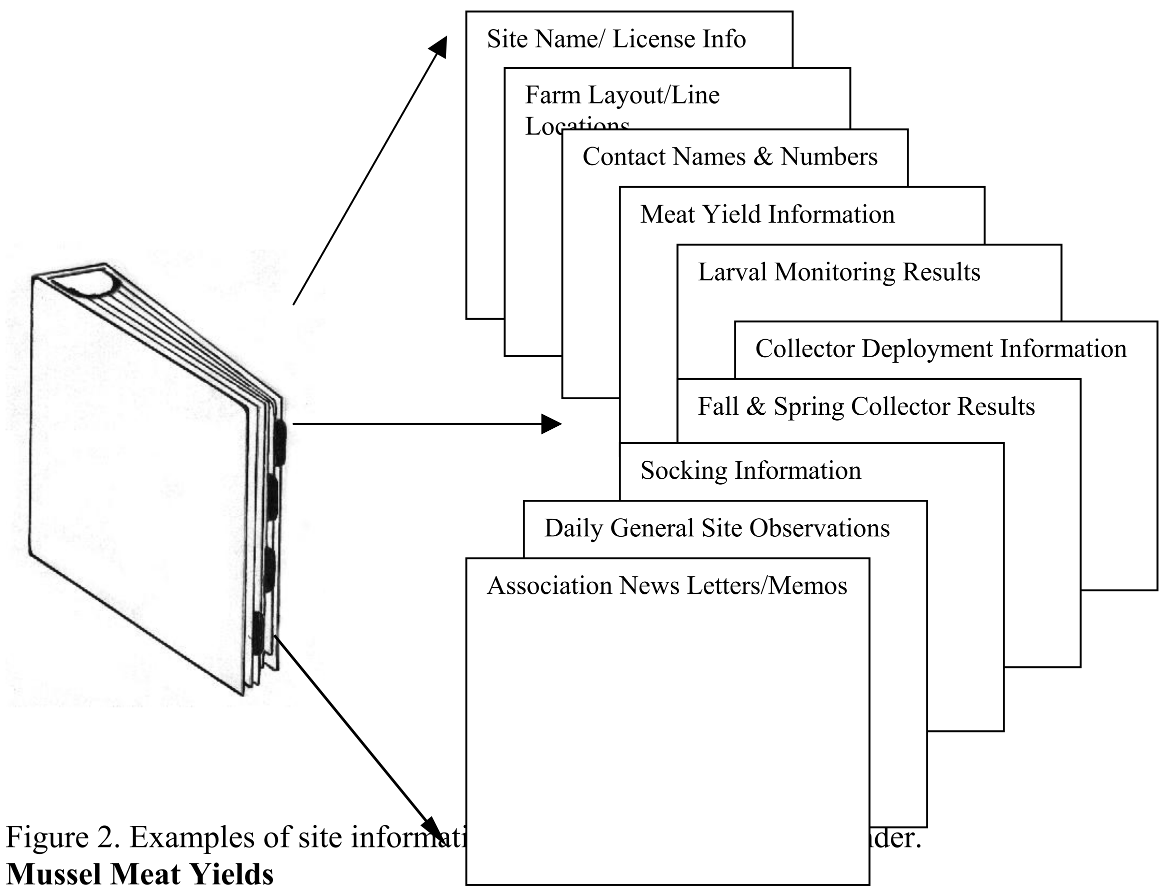



Figure 2. Examples of site informati … der.

**Mussel Meat Yields**

It is essential to maintain a healthy supply of high quality product year round in order for the mussel industry to prosper.  Because poor quality products will only lead to future losses in sales and farm production, it is important that they not be sold to market. Methods have been developed to analyze the condition of existing shellfish populations, the most frequently of which is the mussel steamed meat yield. This meat yield is also an indicator of quality, since it gives the relationship of meat to shell, with higher values generally indicating better quality. There are other indicators of mussel quality, including mussel size, shell shape and appearance, and growers should be aware of these.

Mussel meat yields are also used to provide an indication of the general condition of the soft tissues (Figure 3). They can be used to examine the overall health status of the animals, as well as provide an indication of poor growth conditions due to such things as over-stocking, low food levels, etc. There may even be differences in mussel meat yields from different places on the farm.

**Consistent monitoring** of meat yields can also give an estimate of the seasonal variation in mussel weights in relation to reproductive events such as spawning in a population of mussels on a site: a rapid loss in meat yield following high levels usually indicates spawning has occurred. It is **important** that meat yields be recorded on about a weekly basis, if possible, after the winter ice is gone to ensure that an accurate pattern of mussel development is being determined.

## Methods of Determining Meat Yields

Need for Consistency in Sampling Techniques

It is very important to ensure that the correct meat yield procedure is followed each time a sample is taken. Otherwise, yields can vary greatly, which misrepresents the true condition of the mussel and a leads to poor understanding of the mussel spawning/recovery cycle at the farm site. Any farmer, whether on land or in the sea, should want to know how well his or her animals are doing, not only for themselves, but for their customers as well.

Steamed Meat Yield vs. European Meat Yield

There are two common methods of determining meat yields. In Canada, the most common of these is the **Steamed Mussel Meat Yield**, which is calculated using mussel meats that have been steamed. In Europe and Asia, the meat yield most often used is the **European Meat Yield**, which is the ratio of the weight of cooked meats to the live weight of the mussel before cooking. Both methods of meat yield can be very easily determined from the same sample of mussels, and it is probably a good practice to calculate both each time. This will allow the grower or processor to compare their values among themselves, and with other mussel producing regions of Atlantic Canada and Europe.

**Wild vs. Cultured Mussels**

Some growers believe that the mussel seed they collect each year originated from 'wild' mussel beds near, but not on, their sites. This indeed may be the case, as mussel larvae can drift long distances. If you can identify a bed of mussels close by, then perform occasional meat yields on them as well. Although not documented, these 'wild' mussels may spawn before cultured mussels because those in the intertidal zone are exposed to warmer water or air for part of the day, which may play a role in triggering spawning. Growers often find meat yields from wild mussels consistently lower than those of cultured mussels, even though the meats look full. A thicker shell on a wild mussel is heavier and will affect the meat yield calculation. However, the trends of meat build-up and spawning can still be determined, the value of the wild mussels will just be lower than the cultured mussels

**Procedures**

The procedure below has been adapted from recent reports (Bernard, T. 1997. PEI Mussel Monitoring Program, PEI Dept. of Fisheries Technical Report #218, Charlottetown, PEI. 29p. and Ibarra, D. 1998. Factors Influencing Cultured Mussel Meat Yield and Recommendations for a Standard Method. Independent Research Option Final Report, Marine Institute, St. John's, NF. 68p.). A sample meat yield data sheet follows the procedures. Record all weights, lengths and calculated meat yields in the spaces provided on the data sheet.

Obtain approximately 1 kg of adult mussels, sized approximately 55 mm or greater in length, randomly from the site (at least 2 or 3 socks). Clean mussels of any dirt or slub. Rinse in fresh water.

Weigh and record the sample of whole, live mussels (g) using a balance or any other scale capable of reading 1 g increments. The weight should be about 1 kg.

Using the calipers, measure and record the lengths of 20 adult mussels from your sample (mm) on the data sheet.

**(4) Steaming:**

Preheat a pot on the high setting (electric Wok with a vent is ideal) with just a small amount of water, enough only to cover the bottom. Pot should be big enough so that the mussels do not take up more than about one third of the space (about 5 liters).
When the water boils and emits steam, put all the mussels in the pot and cover. Allow the water begin boiling again on high heat. Begin timing the cooking process. Loosen lid a little to allow steam to escape and prevent boiling over.
**Steam** mussels for **10 minutes**.

After steaming, shuck the meats from the shells and obtain separate weights of the total shucked steamed meats and the total empty shells using a balance or any other scale capable of reading 1 gram increments.

Calculate both steamed meat and European meat yields using the formulas shown on the sample data sheet.

Keep data sheets in a safe place (e.g., binder) that you can easily access. Over time, you'll have a database of information on meat yields at your fingertips. You may wish to plot your values for each sampling on graph paper to quickly identify trends in meat yield levels throughout the year, such as the sample one below.

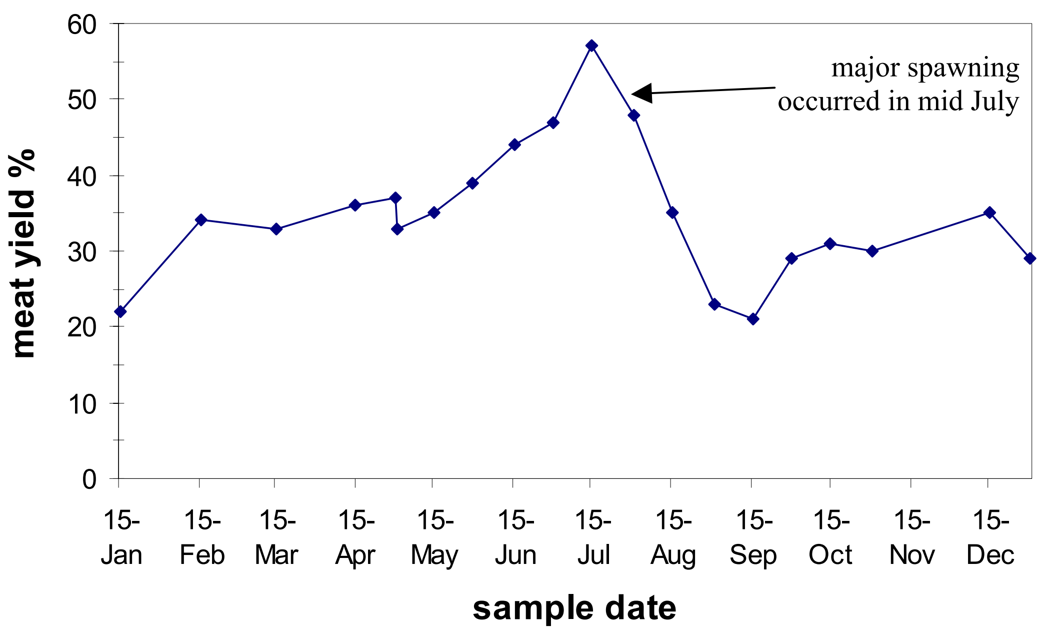



Figure 4. Example plot of meat yields.

**Meat Yield Data Sheet**

Grower: ________________________
Site:___________________________
Date/Time: _____________________
Water Temperature: _____________ ($^oC$)
Salinity (if possible): _____________ (ppt)

**Mussel Lengths (mm):**

| | | | |
|---|---|---|---|
| 1. | 6. | 11. | 16. |
| 2. | 7. | 12. | 17. |
| 3. | 8. | 13. | 18. |
| 4. | 9. | 14. | 19. |
| 5. | 10. | 15. | 20. |

**Mussel Weights (g)**

| | |
|---|---|
| Total Un-Cooked Mussel Weight | g |
| Steamed Meat (Shucked) Weight | g |
| Steamed Shell (Empty) Weight | g |

**Steamed Meat Yield (%)**:

Shucked Steamed Meat Weight (g) X 100 = _____________
%
Empty Shell Weight (g) + Shucked Steamed Meat Weight (g)

**European Meat Yield (%)**:

Shucked Steamed Meat Weight (g) X 100 = ______________
%
Total Live Weight of Uncooked Sample (g)
*Other Notes and Observations:*

## Larval Monitoring

Through regular meat yield analysis, a grower can determine when mussel spawning has occurred by a large drop in the percentage yield over several weeks (Figure 4). Mussels will lose weight as eggs and sperm are released from the gonadal tissue. Visual evidence of a major spawning event is a rise in flotation along the main lines (Figure 5). Growers are urged to begin larval monitoring as soon as they see evidence of spawning (drop in meat yields or rise in flotation), or by mid May in many regions of the island.

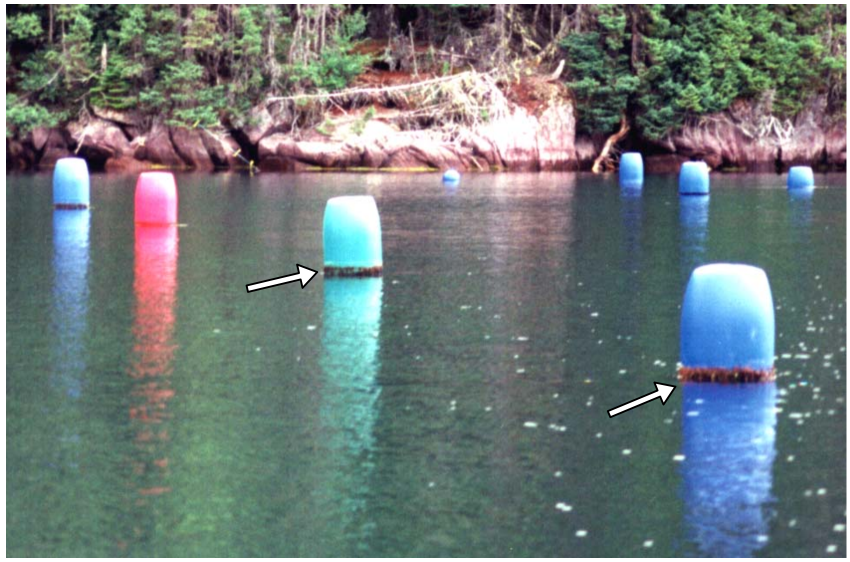
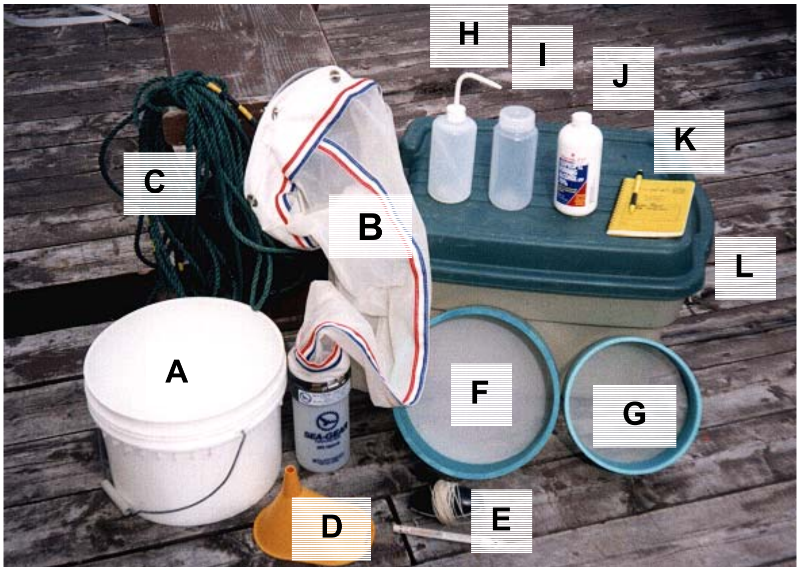


Figure 5. Rise in floatation (arrows) is often an indication that spawning has occurred (*Sean Macneill – photo*).

The timing of collector deployment is important to maximize seed collection while minimizing fouling of ropes. Through larval monitoring, a grower can determine the optimum time to deploy collectors. That is, when mussel larvae are most abundant and the majority are of settling size. Collectors deployed too early will result in slubbing of collectors; too late and the major settlement period will be missed.

Larval monitoring has become routine for many mussel farmers each year through a mussel larval & spatfall monitoring program. The program, offered to members of the Newfoundland Aquaculture Industry Association (NAIA), has been very successful in helping growers secure an annual seed supply. Participants are trained in the techniques of plankton tow sampling, microscopy and larval invertebrate identification as well as being assisted with site specific seed collection issues. Larval monitoring kits, such as the one shown in Figure 6, were developed and purchased by many mussel farmers. Below lists the components of the kit followed by procedures for plankton tow sampling – the first step in larval monitoring. There are two types of plankton tow techniques that will be discussed – 1) Vertical Tow and 2) Horizontal Tow.

Components of the Larval Monitoring Kit




K. Rubbing Alcohol (70% isopropyl)
L. Plastic rough tote carry container

Figure 6. Larval monitoring kit. An inexpensive necessity to secure a reliable seed supply *(Miranda Pryor – photo*).

Procedures for Plankton Tow Sampling

Vertical Tow

1. Place the plankton net over the side of the boat and remove the air from the net and bottle. A small rock inside the jar will help the net sink better.

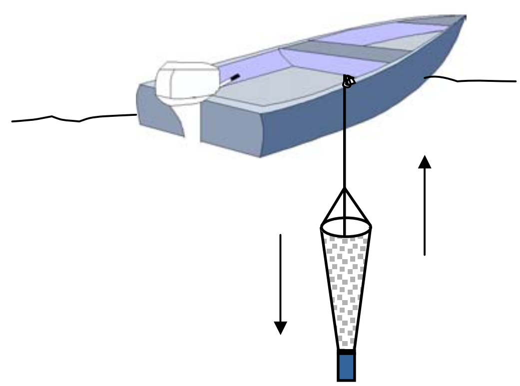


Figure 7. Vertical plankton tow.

2. Lower the net to about 2 meters from the bottom, or 20 meters, which ever is less. Whatever depth you choose, make a note of it and continue to use that depth for each sampling.

***Tip* Don't forget to tie the end of the rope attached to the net to the boat!**

3. Slowly pull net back up (about 0.5 m/sec). Try to keep boat from drifting.

4. Hold the net up outside the boat and rinse the net with a scoop or wash bottle (Figure 8A).
5. Unscrew bottle on net and pour contents into 20 L bucket (Figure 8B). Rinse bottle and
inside net using wash bottle (Figure 8C).
6. Repeat steps 2 - 5 at two more chosen sampling areas of the site. Combine the contents of **all three samples** in the 20 L bucket upon completion. Your chosen sites for sampling should be sampled each week.

Hold the screens on top of one another so that the **larger mesh (500 µm)** screen is on top. Pour the contents of the bucket slowly through the screens (Figure 8D). Rinse the bucket and pour onto screens to make sure all material is screened (Figure 8E).

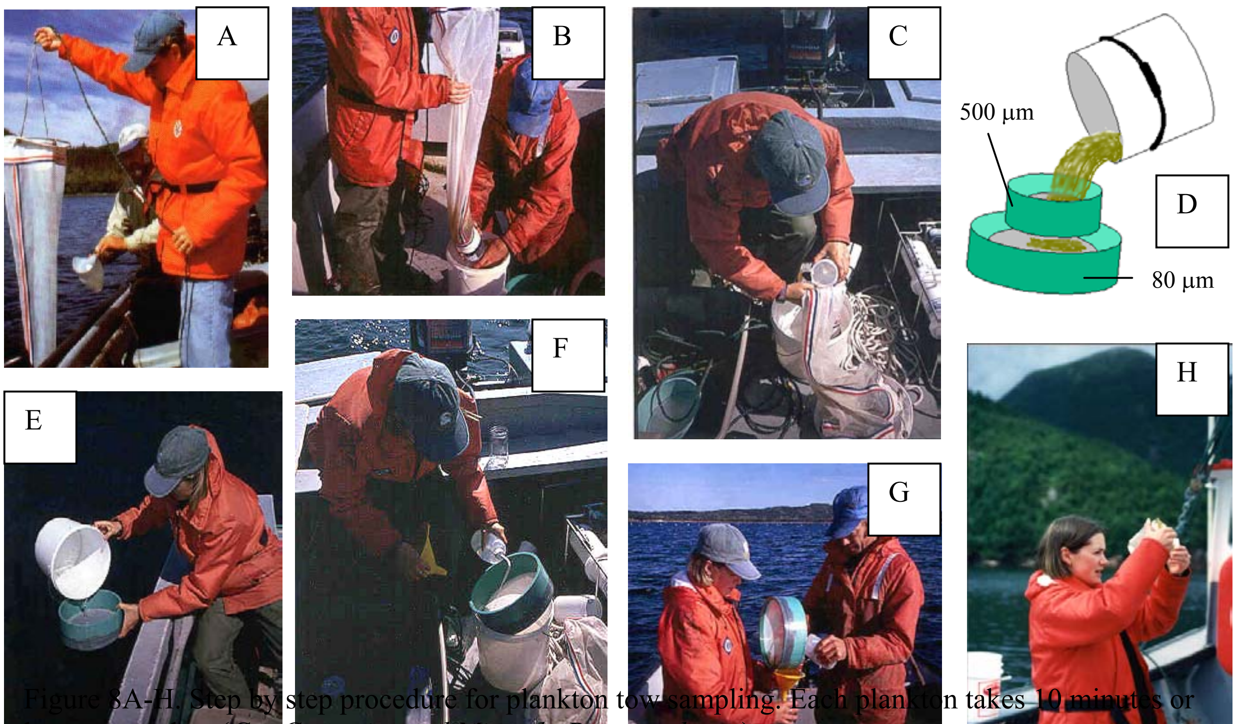



Figure 8A-H. Step by step procedure for plankton tow sampling. Each plankton takes 10 minutes or less to complete (*Cyr Couturier and Miranda Pryor – photos*).

Using a wash bottle, gather plankton to one section of the 80 µm screen. Make sure any grooves in the screen are rinsed thoroughly (Figure 8F).

Using a funnel and wash bottle, carefully direct the plankton into a sample jar. Rinse the funnel with seawater and ensure sample jar is 2/3 full (Figure 8G).

To check for starfish larvae, repeat steps 7-8, washing the contents of the **500 µm mesh screen** into another sample jar and fill to an appropriate level.

Top off sample jar with rubbing alcohol (Figure 8H). For the **STARFISH** sample, **DO NOT**

**ADD ALCOHOL**. Alcohol will dissolve the starfish larvae. Keep sample cool and examine promptly!

To label the samples, use a strip of masking tape and a pen/waterproof marker, label the cover of sample jar, or write the information in your field notebook. Include the information listed below. For the sample with starfish larvae, label the same but indicate 'starfish'. Ensure cover is on tightly and put in a safe place.

| | | |
|---|---|---|
| Site Name: | Grower: | |
| Sample Date: | | |
| Horizontal or Vertical Tow: | Tow Depth (m): | Length of Tow (m): |
| Tide Conditions: | | Time of Tow (min): |
| Water Temperature: | | |
| Wind Direction and Strength: | | |

Figure 9. Plankton tow information to record on sample jar and/or field notebook.

Samples are now ready for microscopic analysis. See next sections for use of microscope, sample preparation and analysis. After use, screens and plankton net should be rinsed with **fresh** water and put somewhere to dry for until the next tow.

Horizontal Tow

**Equipment Required**

Larval monitoring kit
Watch or timepiece to keep time
1 meter of rope with heavy weight attached (~8 kg)

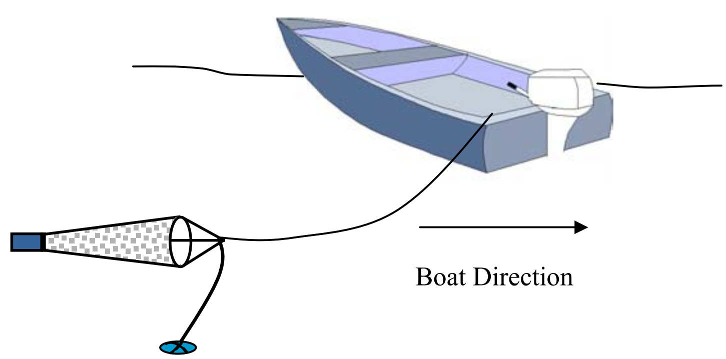



Figure 10. Horizontal plankton tow.

**Procedure**

Fix approximately 8 kg weight to the bridle of the net with about 1 meter of rope. Ensure collector bottle is properly attached. Attach one end of the 20 m rope to the bridle and the other to the boat.

2. Place net over the side of the boat and remove air from the net and sample jar.

3. Slowly pay out the rope and increase speed of the boat so that the net is approx. 1 meter under the surface. Many growers find it easier to idle the motor in reverse while towing net.

4. Using a time piece, tow at a steady slow speed until 3 minutes or 100 meters is up.

*Note: From Step 5 onward, the procedure is the same as the vertical tow. Refer to Figure 8A-H.*

5. Pull net up to boat and hold outside to rinse with scoop. Rinse contents of the net **from the outside** starting at the top and moving toward the bottom.

6. Empty the collector bottle into the 20 L bucket and rinse off the bottom of the net using the wash bottle.

7. Stack the filter screens on top of one another so that the **larger mesh (500 μm)** screen is on top. Pour the contents of the bucket slowly though the screens. Rinse the bucket and pour on screens.

8. Using a wash bottle, gather plankton to one section of a screen and using the funnel, direct the plankton into a sample jar. Rinse the funnel with seawater and ensure sample jar is 2/3 full. To check for starfish larvae, wash the contents of the **500 μm mesh screen** into another sample jar and fill to an appropriate level.

9. Top off bottle with rubbing alcohol. For the **STARFISH** sample, **DO NOT ADD ALCOHOL**. Alcohol will dissolve the starfish larvae. Keep sample cool and examine promptly!

10. To label the samples, use a strip of masking tape and a pen/waterproof marker, label the cover of sample jar or write the information in your field notebook. Include the information listed in Figure 9. For the sample with starfish larvae, label the same but indicate 'starfish'. Ensure cover is on tightly and put in a safe place.

11. Samples are now ready for microscopic analysis. Make sure net and screens are washed with
**fresh** water, dried and stored properly until next use.

Comments on the Horizontal Tow vs. Vertical Tow

In a practical sense, the horizontal tow is no more difficult to perform than a vertical tow, and both tow types are easier to carry out when more than one person is available. However, through experience, a horizontal tow performed at, say, 1 meter depth for 100 meters is rarely accurately carried out at those conditions. Often, the 100 meters or 3 minutes are estimated, and the depth varies considerably throughout the tow (e.g., the boat motor shuts off & net sinks to bottom or boat goes too fast and net comes to surface, etc). When the tow ***is*** carried out close to one depth, the majority of larvae ***may*** be missed due to uneven larval distribution in the water column. Mussel larvae of different size classes (e.g., d-stage <200 μm & eyed larvae >250 μm) have been found at different depths, so a vertical tow is the best way to find out the true size distribution of larvae, as it samples the entire water column. In addition, from a vertical tow, the depth is known and the amount of water filtered through the plankton net can be more accurately calculated. This gives a clearer estimate of the number of mussel larvae ***per liter*** of original seawater, rather than the number of larvae in a 500 mL sample jar. The best approach to take when deciding on a tow type is to do the vertical tow always, and carry out the horizontal tow second, as a comparison. Too much information is better than not enough.

**Mussel Larval Sample Preparation and Analysis**

Plankton tow samples must be examined using a microscope to determine size and abundance of mussel larvae present in the water. Below is a brief overview of the compound light microscope and its use, followed by procedures for analyzing larval samples.

Use of the Compound Light Microscope

Below is a compound light microscope similar to that used in the analysis of the larval samples.

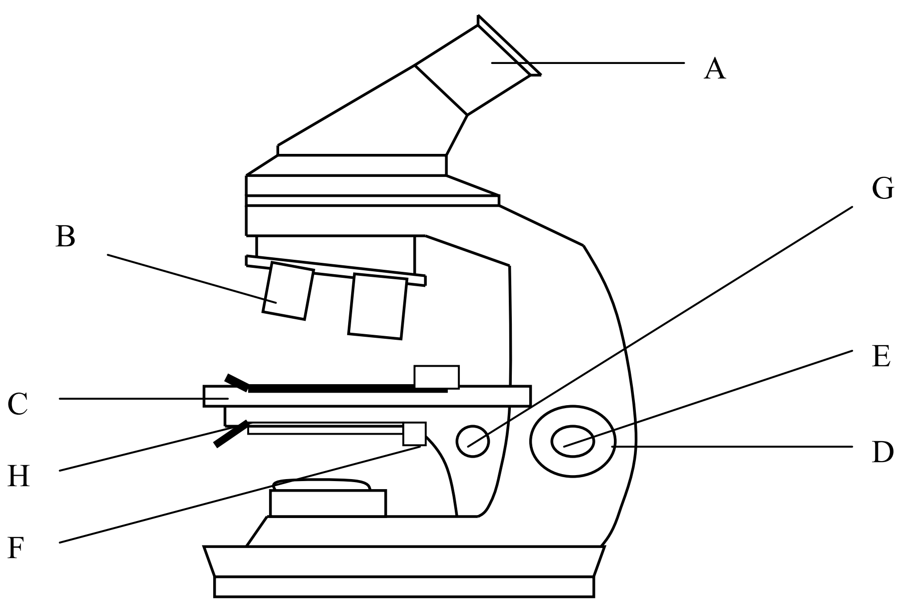


Figure 11.The compound light microscope.

Table 1. Major parts of the microscope and their functions.

| Major Part | Function |
|---|---|
| | |
| A. Ocular (eyepiece) | Magnifies image 10X |
| B. Objective lens | Revolving magnifying lens low power (4X) medium (10X) high.(40X) |
| C. Stage | Holds slides |
| D. Coarse adjustment | Rapidly brings sample into focus |
| E. Fine adjustment | Slowly brings sample into focus |
| F. Substage adjustment knob | Raises and lowers condenser |
| G. Mechanical stage control | Moves slide about on stage |
| H. Diaphragm lever | Controls amount of light reaching specimen |

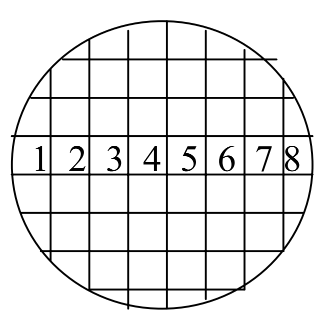
***Tip*** ***Growers should contact grade schools and local colleges to borrow/rent microscopes for a few months during the monitoring period. A few growers already do this and in return, they provided mussels for use in biology labs/science classes.***

**Calibration for Size Measurement**

Microscopes allow for precise measurement of microorganisms. Some microscopes have an ocular micrometer, a circular disk of glass which has graduations engraved on one surface. You can see the ocular micrometer by looking though the microscope. It appears as a tiny ruler. If you don't see it, try closing one eye. If that doesn't work, there may not be one. You can add an ocular micrometer by replacing the ocular lens with a lens equipped with one. At different magnifications, each unit of the ocular micrometer represents a different length, thus it is necessary to calibrate the ocular micrometer. This is done by using a stage micrometer. If the microscope doesn't have an ocular micrometer and one isn't available, sizes of the mussel larvae under each power of magnification can be done using the field of view method. Both procedures are described below.

Field of View Method to Size Mussel Larvae

Under the desired power, place a piece of graph paper ($mm^2$) on the stage of the microscope. Focus the grid on the paper and count the number of squares that fit across your viewing area, or field of view. Below is an example.

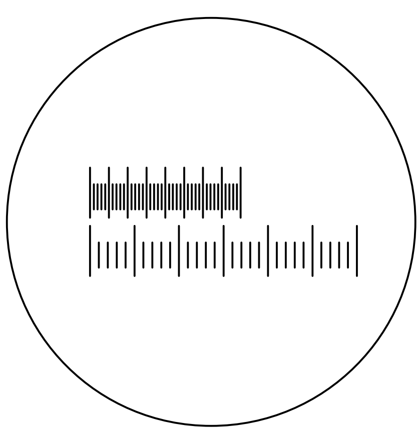


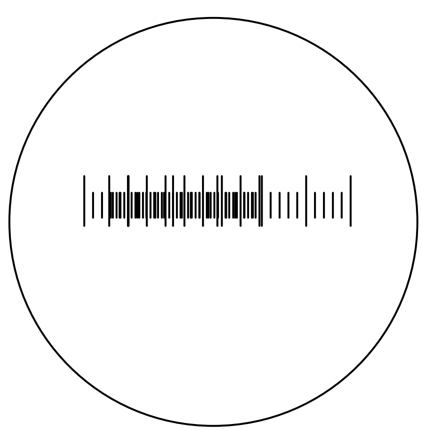
In this example, 8 squares fit across the field of view, so the diameter is 8 mm or 8000 μm. To determine the size of individual larvae, estimate how many of these will fit across the
field of view if they were lined up end to end. If approximately 32 could fit across, then each larvae is 8000÷32 = 250 μm. Note that each time you change to a different power of magnification, you must determine the field of view.

Using the Ocular Micrometer to Size Mussel Larvae

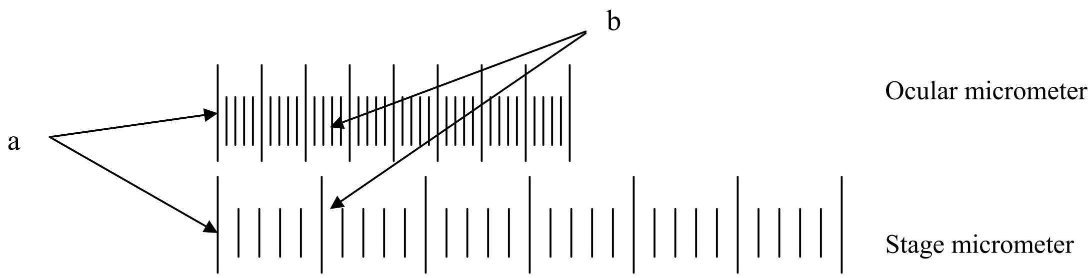
People often find this method most confusing and frustrating, but it is simple and more accurate than the field of view method. The confusion arises in that to determine larval size under each power of magnification, you must first determine the distance between each unit (bar or line) of the ocular micrometer. To do this, the ocular micrometer is calibrated using a special slide called a stage micrometer. The stage micrometer also has a tiny ruler on it, but its units are exactly 0.01 mm or 10 μm apart. Below is the step by step procedure with an example, at **low power (4X objective lens)**.

1. Place the stage micrometer on the stage of the microscope and focus. You will see either
separate 'rulers' or they will overlap into a mass of lines as below.

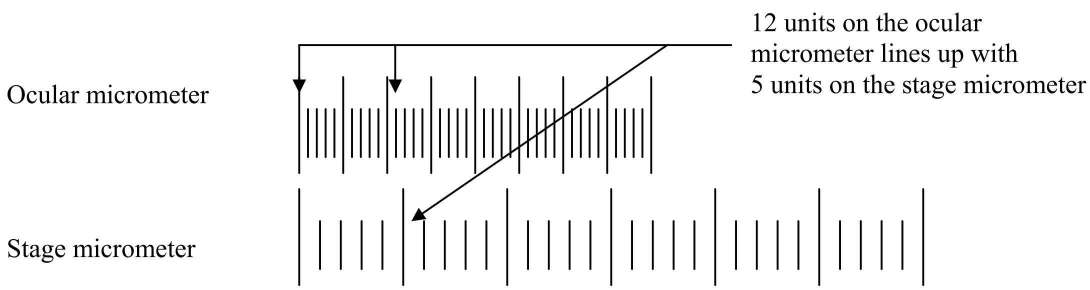




Move the stage micrometer until one line of the stage micrometer coincides with a line of the ocular micrometer (a). Then look for another line along the stage micrometer that coincides with a line on the ocular micrometer (b).




3. Count the number of units (lines) between each of the coinciding lines.




4. Divide the number of ocular micrometer lines by the number of stage micrometer lines (a).
Multiply the resulting value by 0.01 mm to get the distance of each ocular division (b). Finally,
multiply by 1000 to get measurement in micrometers (1 mm = 1000 μm) (c).

a) $\dfrac{\text{12 units ocular}}{\text{5 units stage}} = 2.4$

b) 2.4 X 0.01 mm = 0.024 mm

c) 0.024 mm X 1000 μm/mm = 24 μm /ocular unit

Note that the procedure must be repeated when you change magnification and some microscopes have calibrations written on the side of the microscope.

Preparation of Sample and Analysis

*Equipment Required:*

microscope with total magnification of 100X and preferably with an ocular micrometer (ruler in eyepiece)

small plastic petri dish or glass depression slide

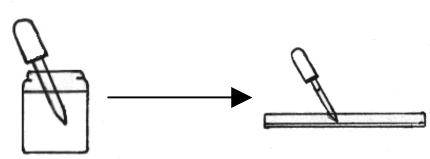
water dropper that can measure 1 mL

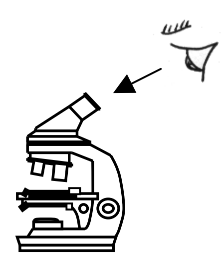
notebook or data sheet/pencil to record measurements

Procedure

1. Take sample jar from plankton tow, shake to create homogeneous (larvae scattered throughout) solution. Do not swirl jar as this causes large larvae to concentrate at the bottom center of the bottle.

2. Remove 1 mL with water dropper or pipette and place in petri dish or slide.





3. Place slide or petri dish on microscope stage and scan for mussel larvae

4. Count the larvae and measure the lengths of a representative sample. Record data and comments on data sheets or in notebook*.

5. Repeat steps 1 - 4 so that 3 - 1mL samples are analyzed.

6. Grower should deploy collectors if results indicate that >50% of larvae sampled were >200 μm in length.* +

*To assist growers in how to distinguish mussel larvae from other bivalve larvae and plant material, a colour key is being created from plankton tow samples of last season. Work completed thus far is included in this handbook at the end as well as a sample larval data sheet.

**Collector Deployment Decisions**

Based on meat yields and larval monitoring a grower can better predict the timing of mussel spawning and settlement. **Its best to wait until larval monitoring shows a majority of mussel larvae of settling size before deploying collectors**, but here are some other considerations:

Number of collectors to be deployed and how long it will take

Manpower available to do the job

Bad weather

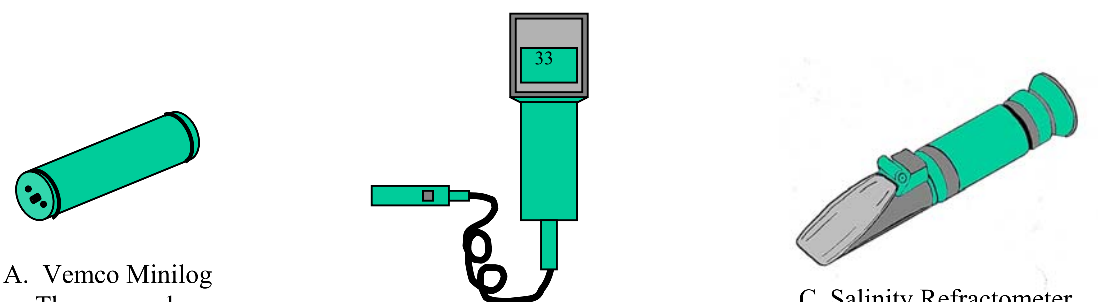
Is the site prepared?

Growers must have equipment prepared beforehand and not be making collectors when the optimum time to deploy collectors is upon them. Use common sense and good judgement. Through meat yield checks and larval monitoring a well organized plan of farm activities can be drawn up and followed.

**Water Monitoring (Temperature and Salinity)**

Fluctuating temperature and salinity can each directly affect the animal being cultured, most notably newly settled mussel spat and scallops. For example, heavy rains that lower the salinity near the surface can cause a loss of newly settled spat, as freshwater tends to weaken their byssal attachment. High water temperatures have a similar effect. Sudden lowering of salinity can be fatal to scallops. High water temperature can also lead to healthy blooms of phytoplankton, providing food and quick growth opportunity for newly settled mussel spat.

There are a number of instruments used to monitor temperature and salinity. In the larval monitoring kit, a thermometer is used to measure surface temperatures. Over time, one can see the trends in temperature. Another simpler way to keep track of temperature is to deploy a thermograph, such as the one shown below (Figure 12A). A thermograph (brand name examples – Vemco Minilog or Onset StowAway™ ) is programmable to take temperature readings at a specified time interval for up to a year or more at a time. Information is downloaded through computer software and the device is reset and deployed again.




A. Vemco Minilog Thermograph

B. YSI temperature/Salinity Meter

C. Salinity Refractometer

Figure 12. Examples of the many simple water monitoring devices available to growers.

A YSI meter (Figure 12B) measures both salinity and temperature through a sensitive probe on the end of a long cord. The unit is battery operated and different length cords can be purchased. Finally, a device that requires no computers or batteries is the salinity refractometer (Figure 12C). A few drops of water on its glass slide and you get an instant reading of salinity.

**Spatfall Monitoring**

As part of the larval & spatfall monitoring program, during the fall and spring of each season, a random sample of 3 collectors from each site is retrieved and analyzed for spat numbers, density, weight, average spat size and biofouling. This gives an indication of how timely collectors were deployed, spat growth over the winter period etc., and can help in setting time tables for collector stripping and socking.

At each site, 1 collector is retrieved from the front, middle and back of the spat collection area for a total of 3 sample collectors. Spat on each collector are removed and stored frozen, until analysis is carried out by monitoring staff.

An on-site approach to spat monitoring can easily be done by the growers themselves. By monitoring the progress of spat growth, one can get a better understanding of how site conditions influences the life cycle of the mussel and better planning of farm activities such as socking schedules can take place.

**Equipment Required**

Set of measuring calipers
A weigh scale (digital or analog – accurate as possible)
A good field notebook

**Procedure**

After settlement has occurred and spat are visible on collectors, ***carefully**** obtain a small sample and measure lengths of a few dozen. Record information in your notebook.

***If water is particularly warm, or if there was a sudden rainstorm, DON'T lift up collector lines. Newly settled spat are very poorly attached and disturbing the lines may cause a heavy loss in seed. It's best to wait a few weeks (months) until you are sure the collection period is over and conditions are more favorable.**

By sampling every few weeks, one can get an idea of their growth. If you want to get more involved, you can choose different locations on your farm site and sample as a comparison (e.g., inside site and outside site ).

You can also measure the increase in weight of your collectors over time using the weigh scale. Record the weights in your notebook.

**Summary/Conclusion**

Site monitoring is very important to ensure farm success. It is especially important for seed collection, a critical step in the mussel production cycle. By carrying out meat yields and larval monitoring, a grower can more accurately determine the timing of mussel spawning and settlement. Collectors can be deployed at the optimum time of settlement to maximize seed collection while minimizing biofouling of equipment. Spatfall monitoring in the fall and spring can help determine how timely collectors were deployed, amount and types of fouling, spat growth over the first season and can help set timetables for collector stripping and socking. Monitoring water conditions can be very important for the health of your animals and gain a better understanding of how environmental conditions affects production on the farm. Regular monitoring and record keeping will result in smoother, more efficient farm activities and allow growers to prepare for events in advance.

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