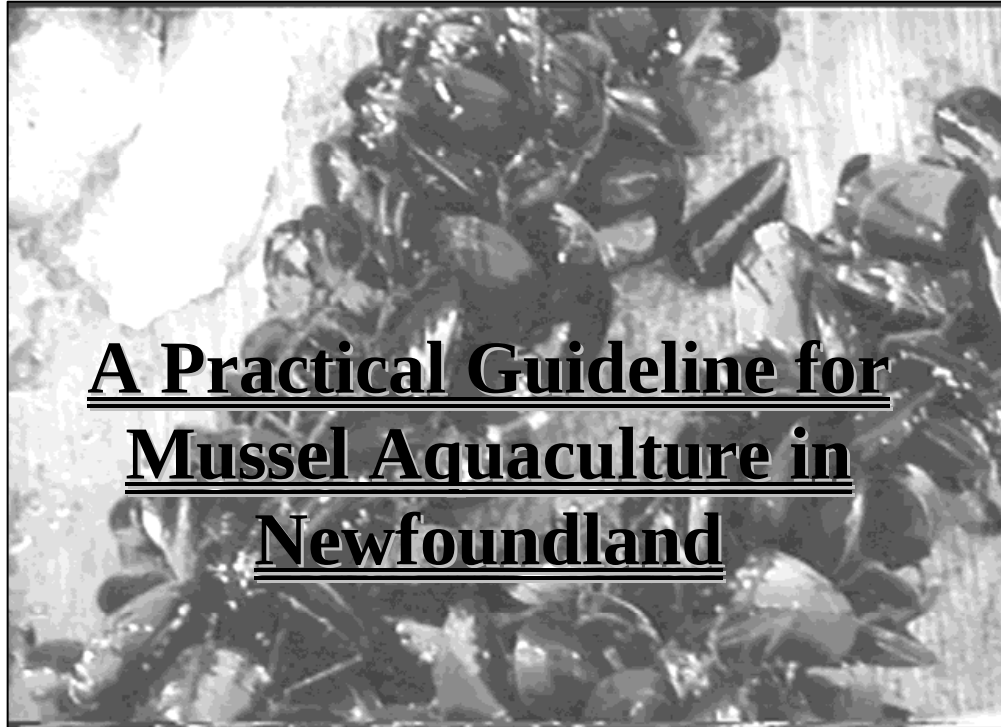




A Practical Guideline for Mussel Aquaculture in Newfoundland

Developed for the Newfoundland Aquaculture Industry Association

by

**The Marine Institute of Memorial University of Newfoundland
Centre for Aquaculture and Seafood Development
P.O. Box 4920, St. John's, NF, Canada A1C 5R3**

**Christopher Brown, Cyr Couturier, Jay Parsons, Jason Nichols, Alistair Struthers,
Sean Macneill, Miranda Pryor, Kelly Moret, and Tony Zokvic.**

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Institute of Memorial University**

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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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

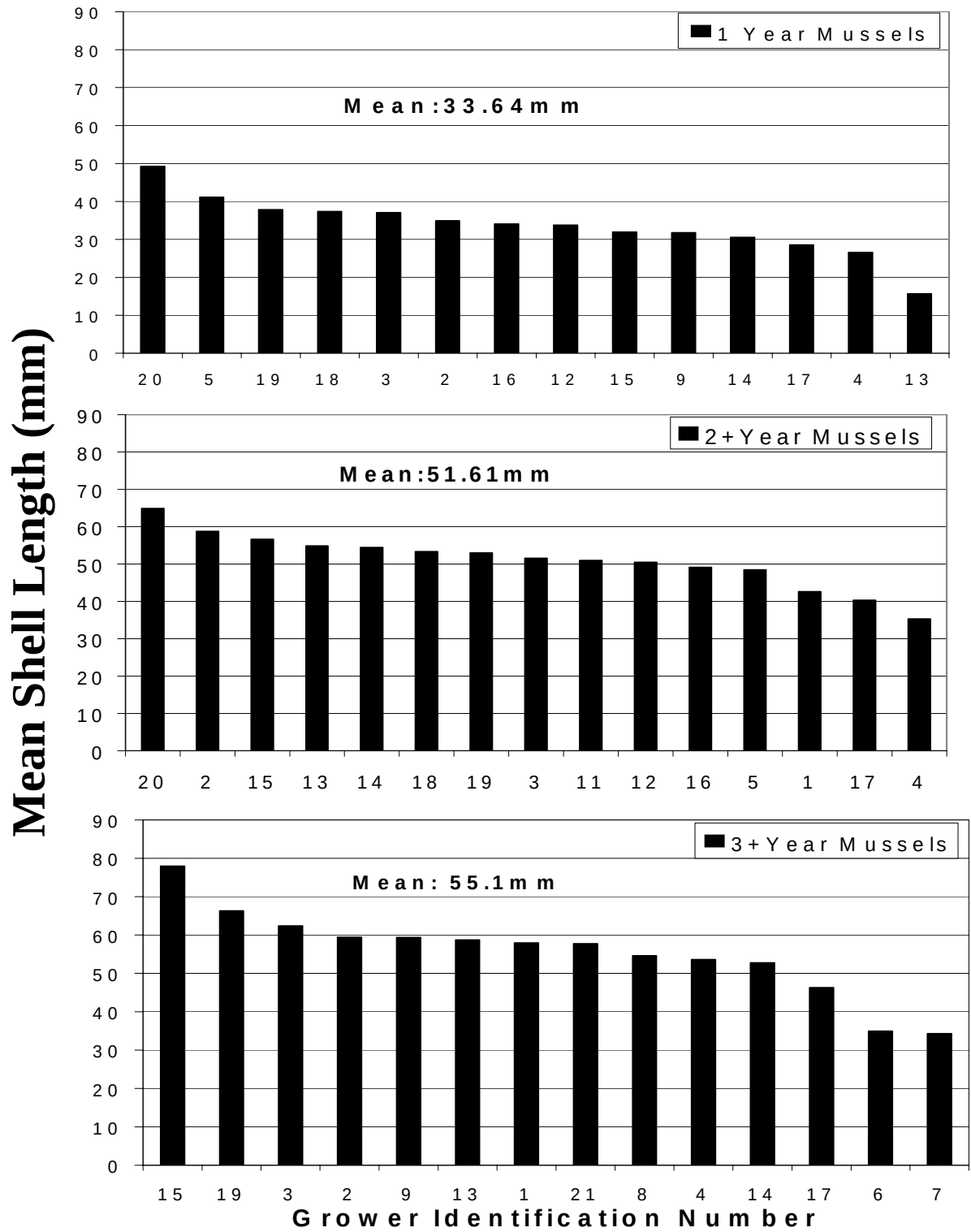


Figure 1.1: The mean shell length of 1, 2 and 3 year + mussels from 14 to 15 Newfoundland mussel sites. All shell lengths were derived from a sub-sample of 150 mussels from 3 socks located at different locations on each site. Sites were sampled from September to November in 1997 and/or 1998 by the NAIA-Marine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

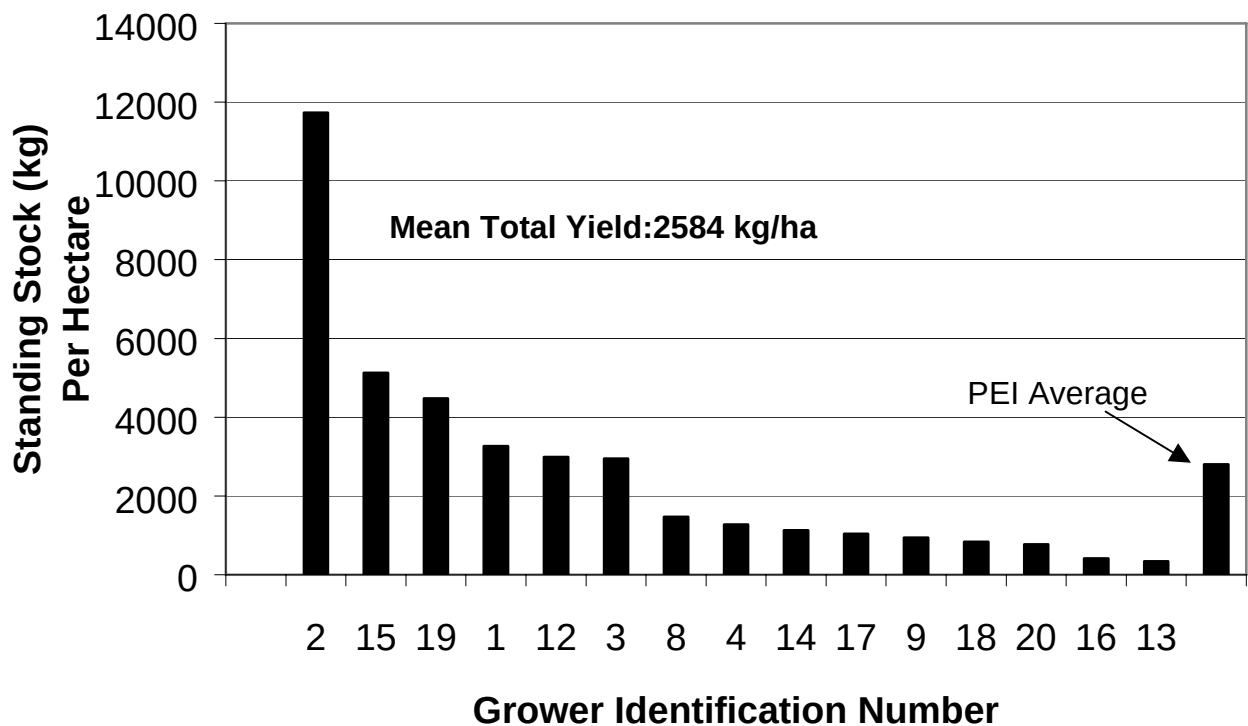


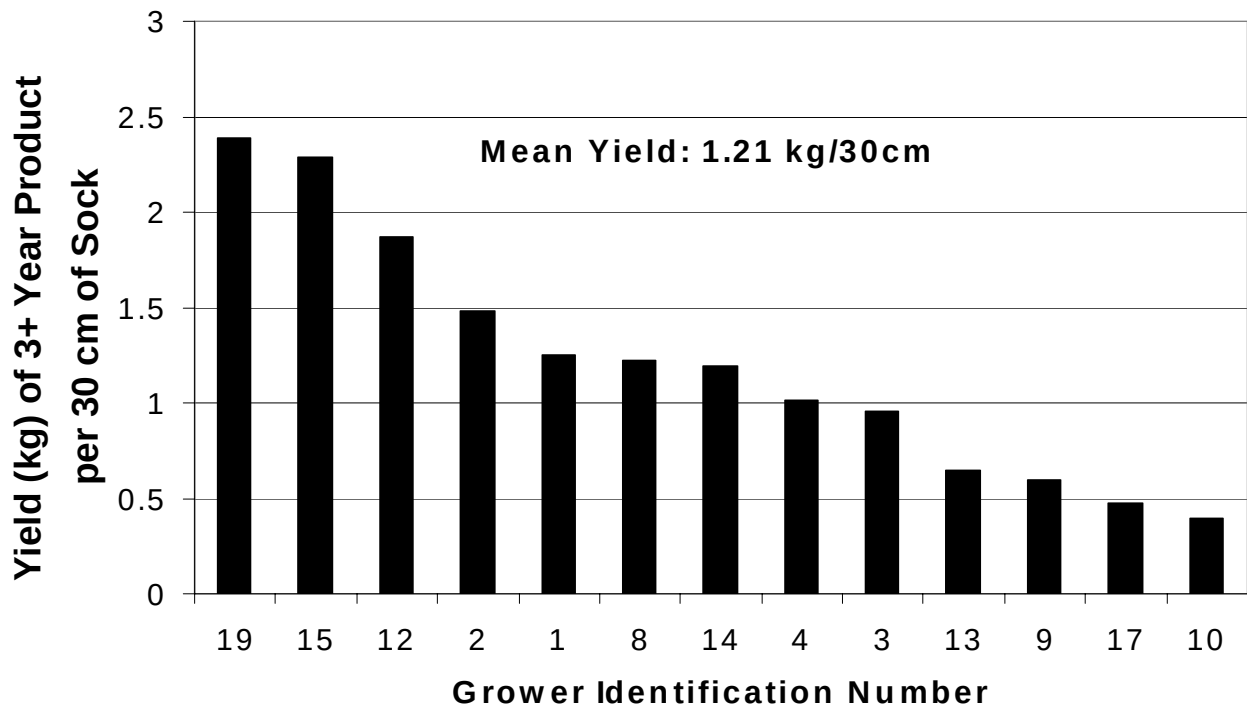
Figure 1.2: The standing stock of marketable product at 15 commercial mussel sites. Production estimates were derived from the N.A.I.A.-Marine Institute Mussel Extension Inventory Survey and were divided by total site area to determine production per hectare. Production for grower 18 and 19 was derived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

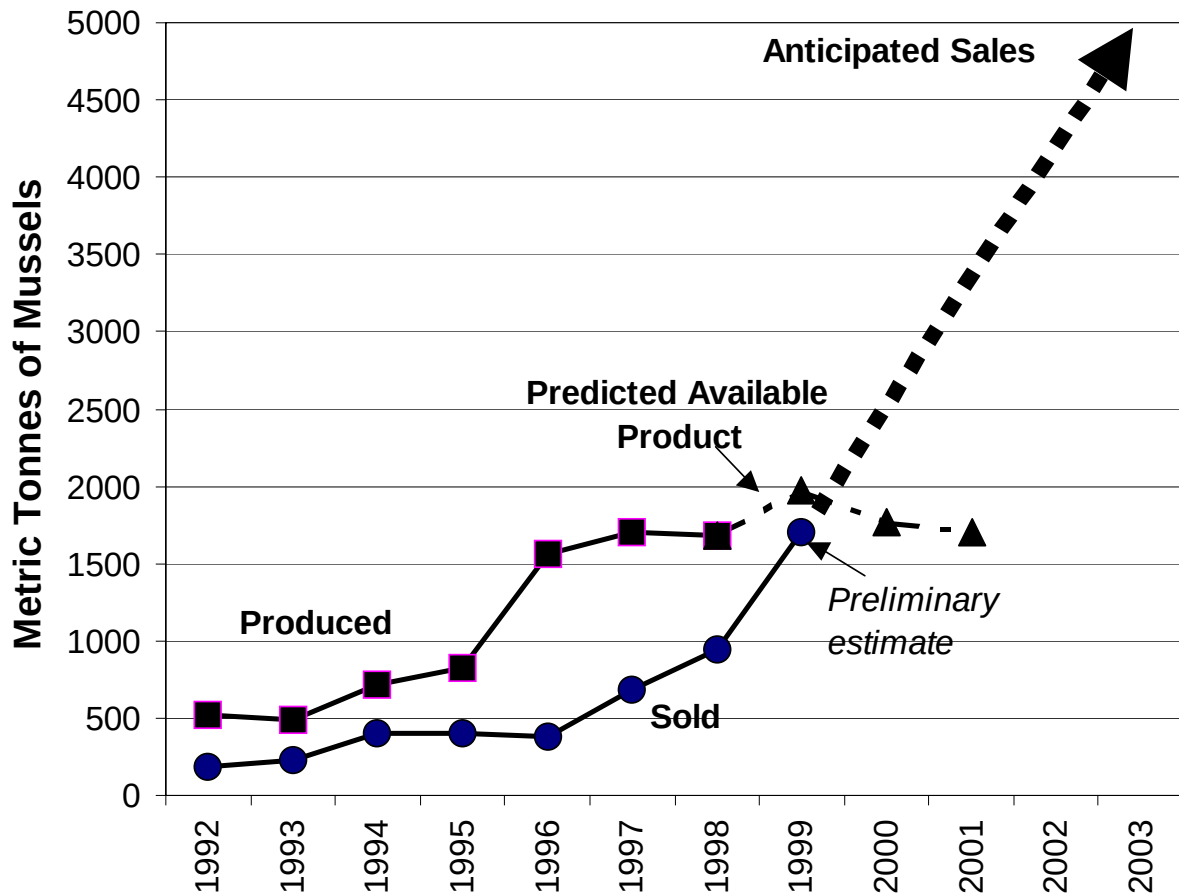


Figure 1.4: The annual mussel sales and production for Newfoundland commercial growers. Predicted production is based on the N.A.I.A.-Marine Institute Mussel Extension Service Inventory from 34 commercial mussel farms. All socks deployed prior to 1997 were not included in the predicted available product 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.

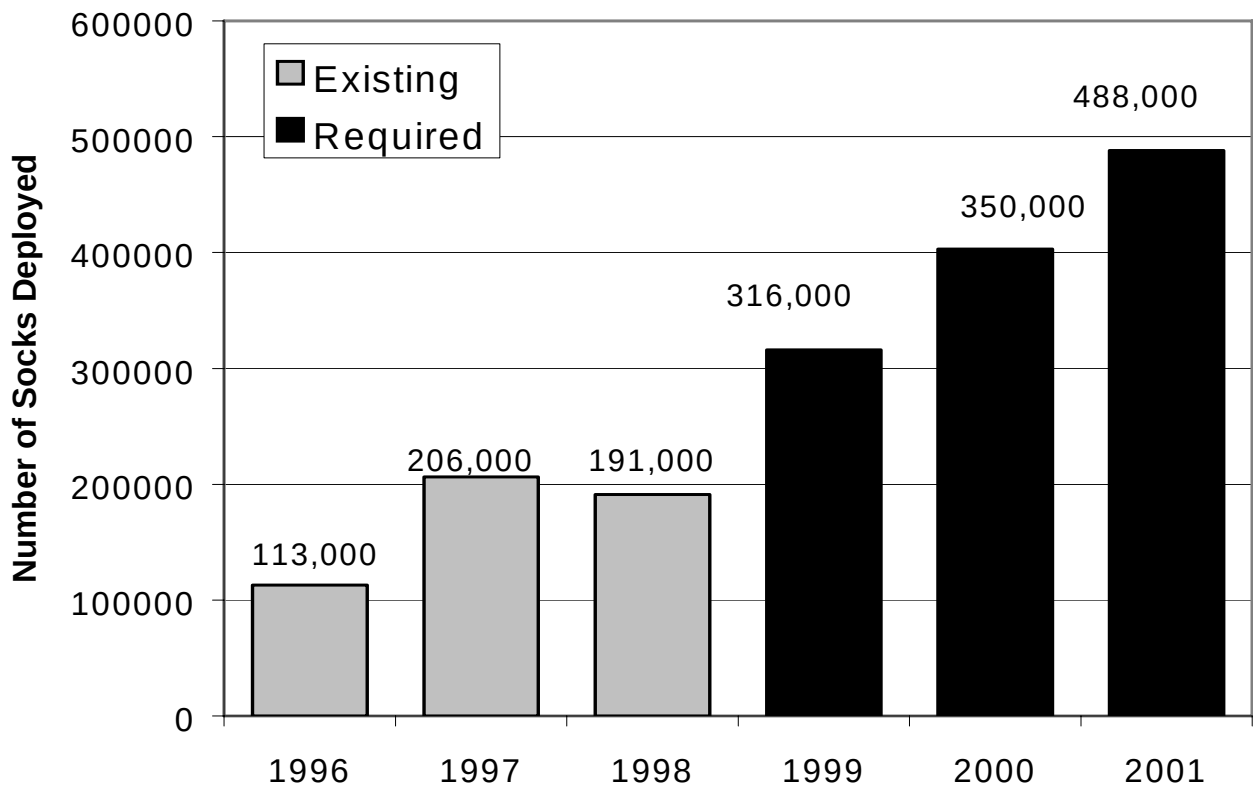


Figure 1.5: The number of socks deployed by the 34 commercial mussel grower in Newfoundland from 1996 to 1998 and the predicted deployment required to reach 5000 metric tonnes by 2003. Information is based on the Marine Institute Mussel Extension Service Survey and DFA Annual Statistics 1998.

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**

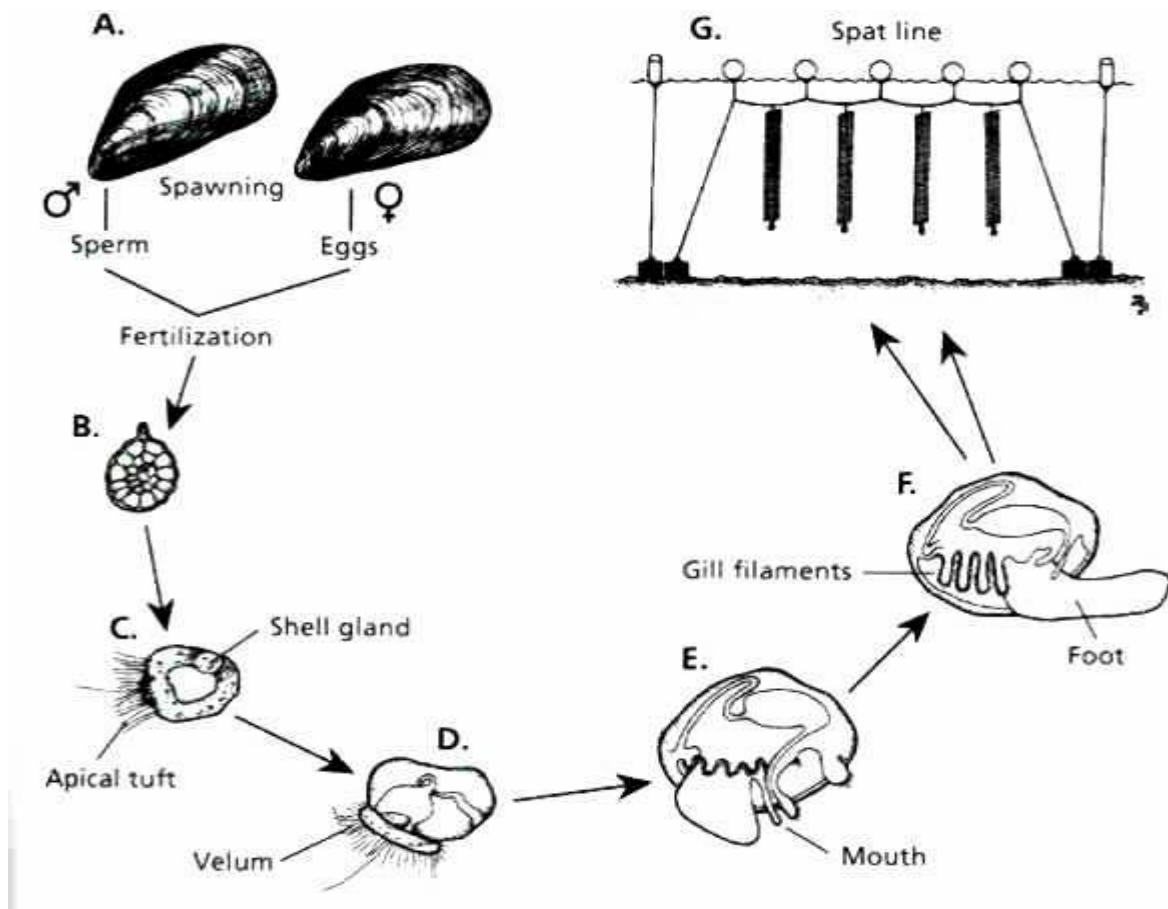


Figure 2.1: Life cycle of the blue mussel, *Mytilus edulis*, adapted from Sutterlin et al. (1981) and Mallet and Myrand (1995). A) Adult mussels, D) D-stage larva (ca. 100 μm shell length), E) pediveliger larva (ca. 250-300 μm in shell length), F) recently settled and metamorphosed spat (ca. 350 μm in 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 lower growth rates (less than 0.05 mm/day) either had overstocked 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

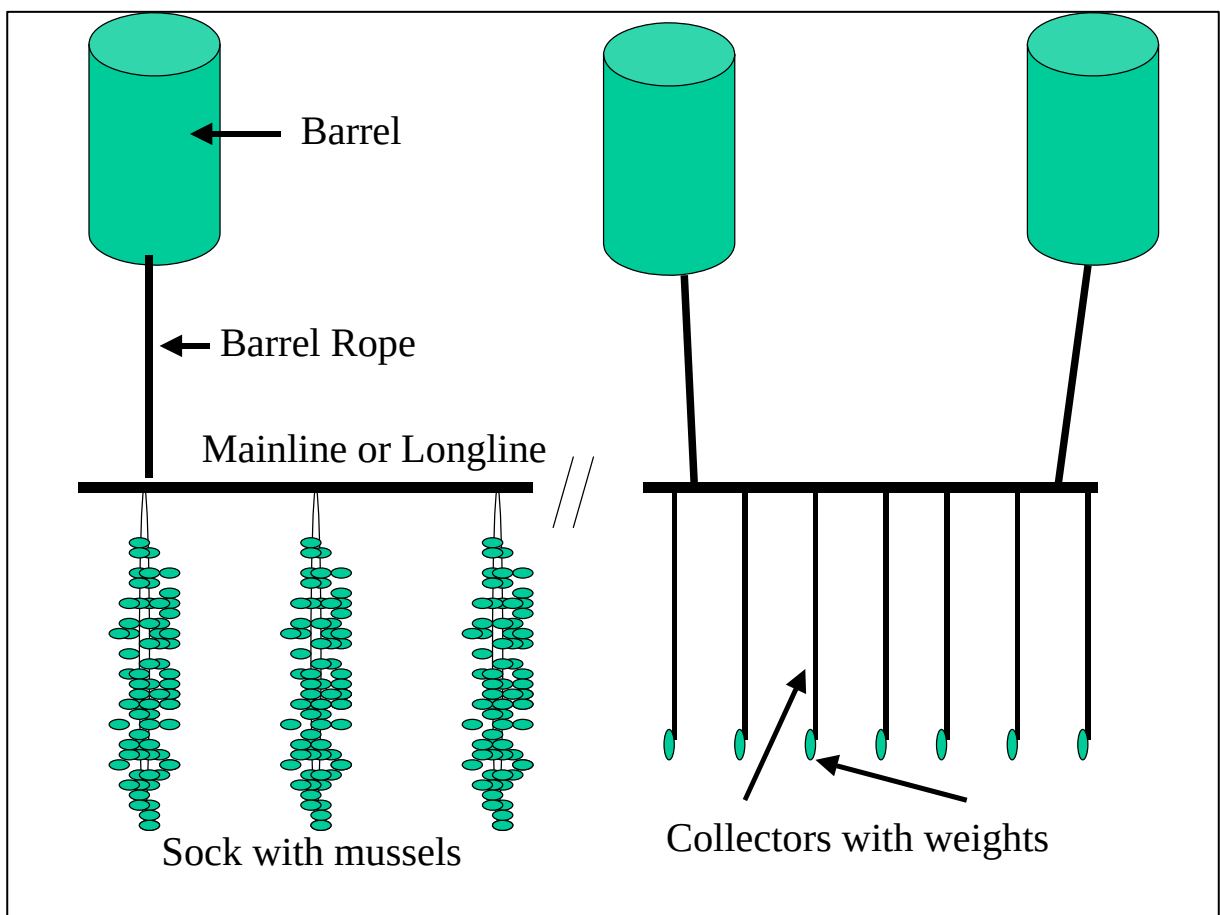


Figure 3.1: Typical mainline (longline) with mussel socks or collectors using barrel floatation.

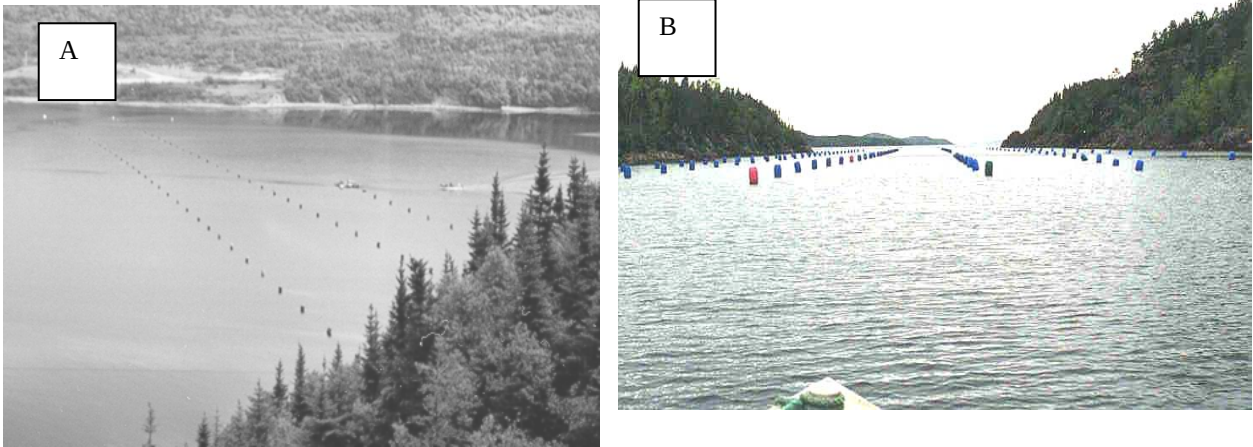


Figure 3.2: (A) Mainlines perpendicular to the shore using 45 gal barrels for flotation (photo courtesy of Sean Macneill), (B) parallel to the shore (C. Coutureier).

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.

Floataion 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

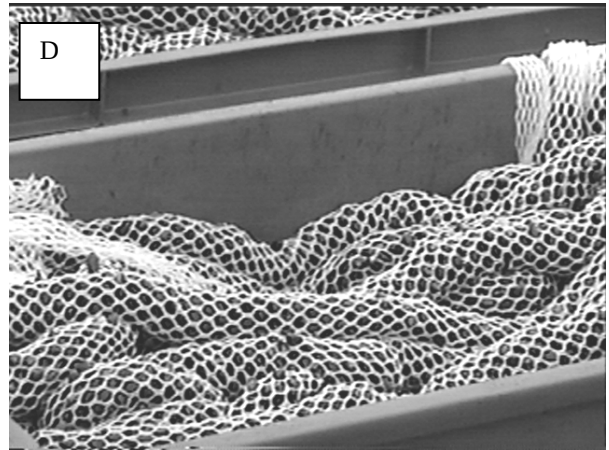
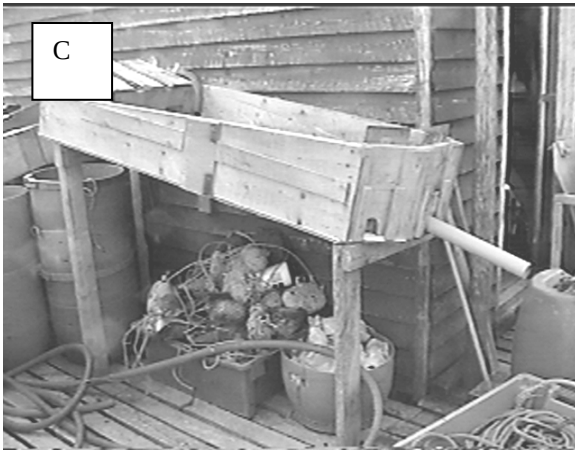


Figure 3.3: (A) Collector ropes with a variety of weights (B), collectors being stripped (C), wooden socking table (D), filled socking and (E) market size mussels on socks.

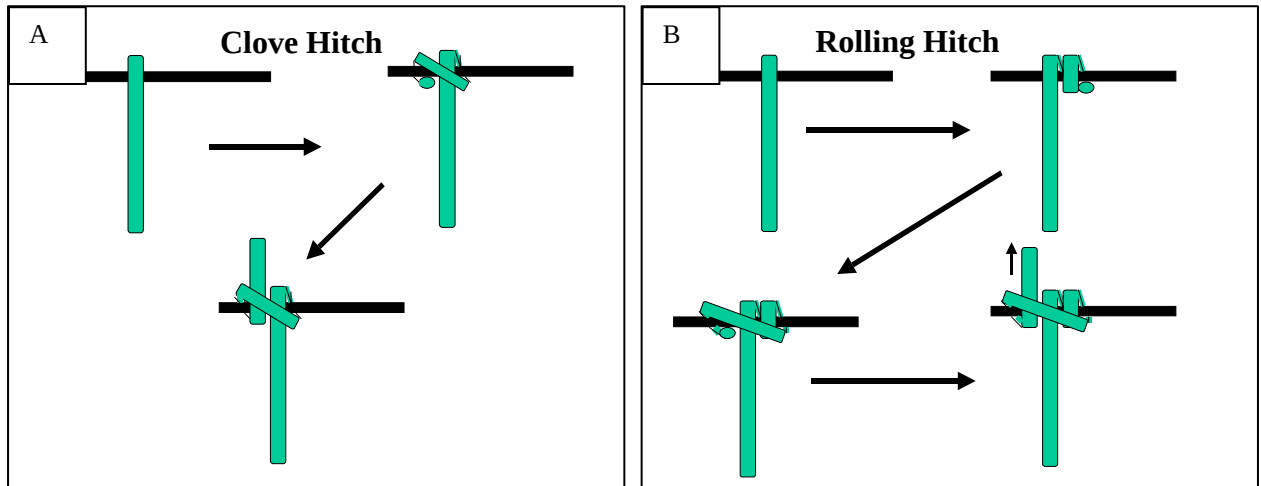


Figure 3.4: The main knots used for float and sock attachment (A), clove hitch (B), rolling hitch.

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

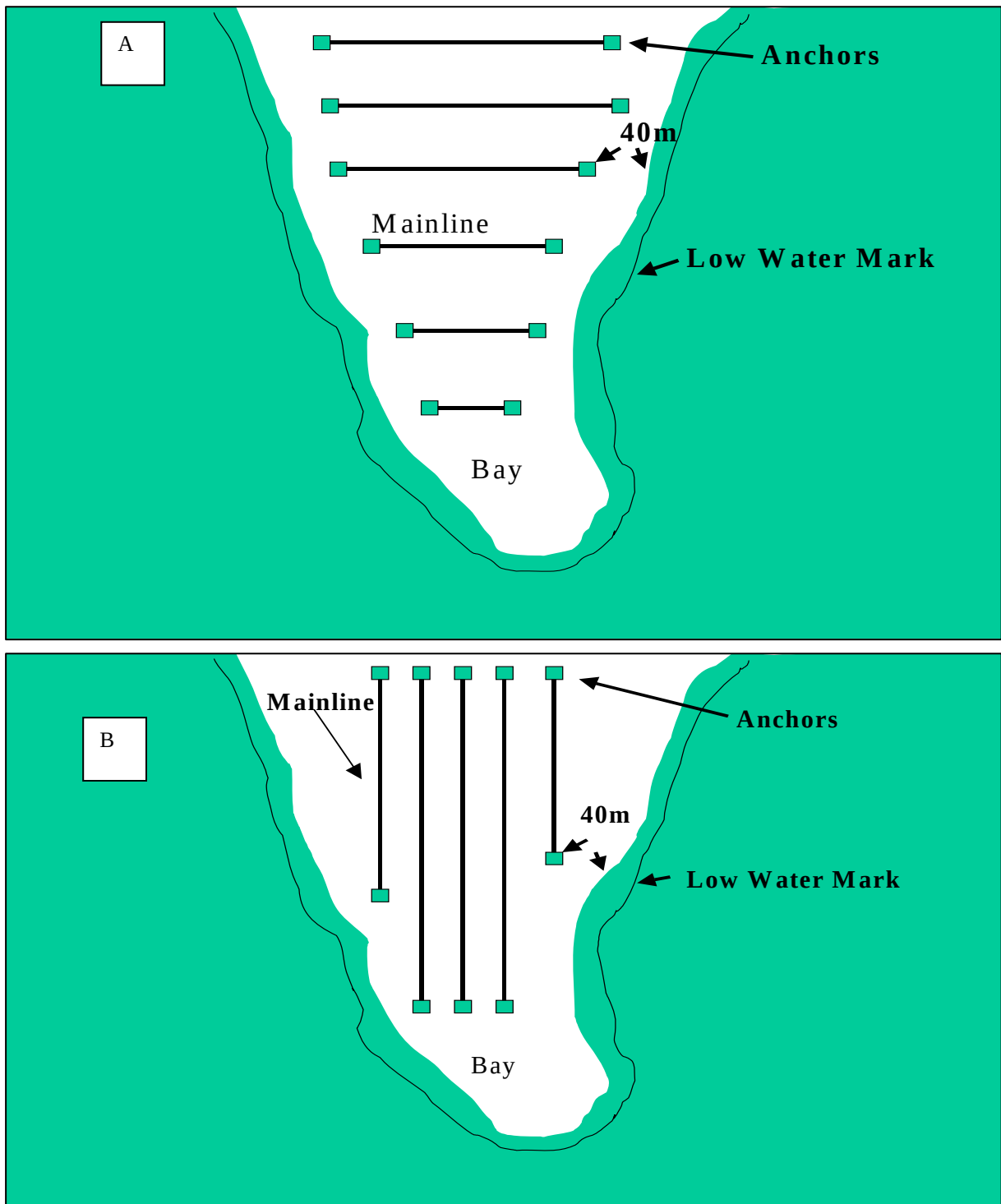


Figure 4.1: (A) shore to shore mainline system and (B) parallel mainline system. All new sites must typically leave a 40 m boundary between equipment and the low water mark (Paul Niswold, *Guidelines for Mussel Culture*, 1999).

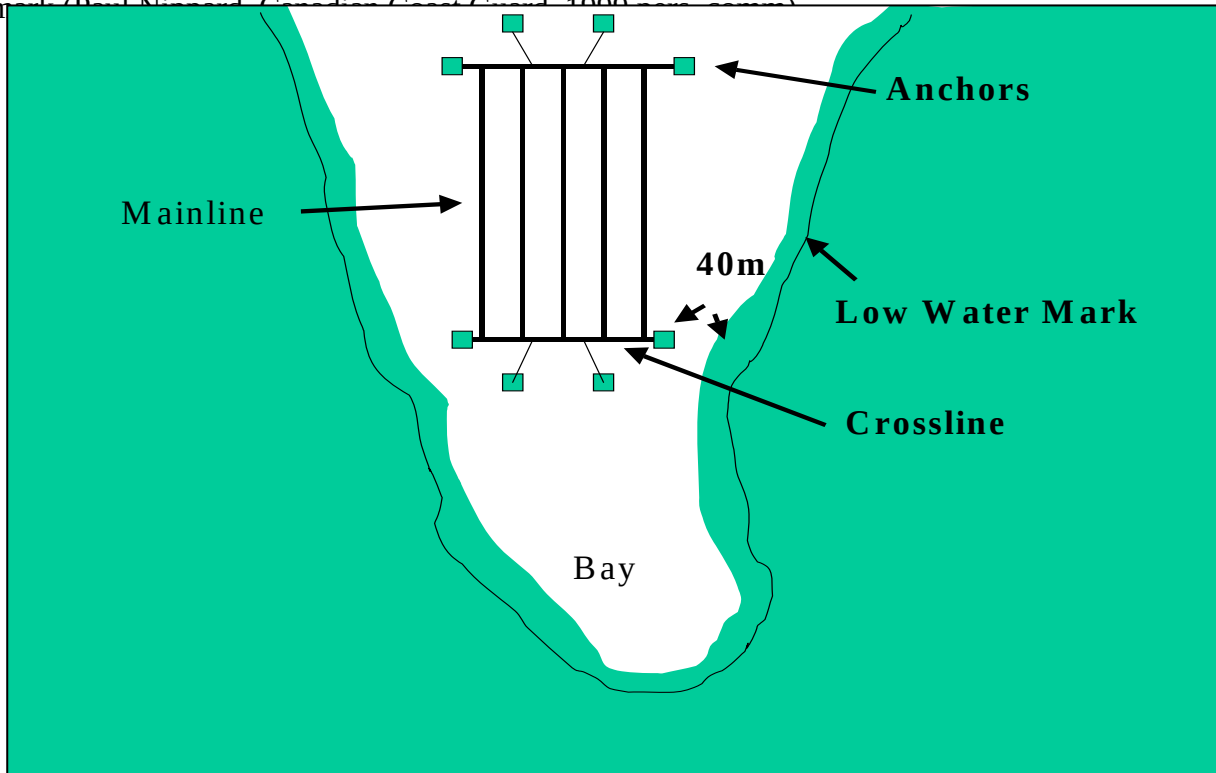


Figure 4.2: Mainline system using cross-lines.

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 into weight in water so a significant weight is required. One Newfoundland grower surveyed

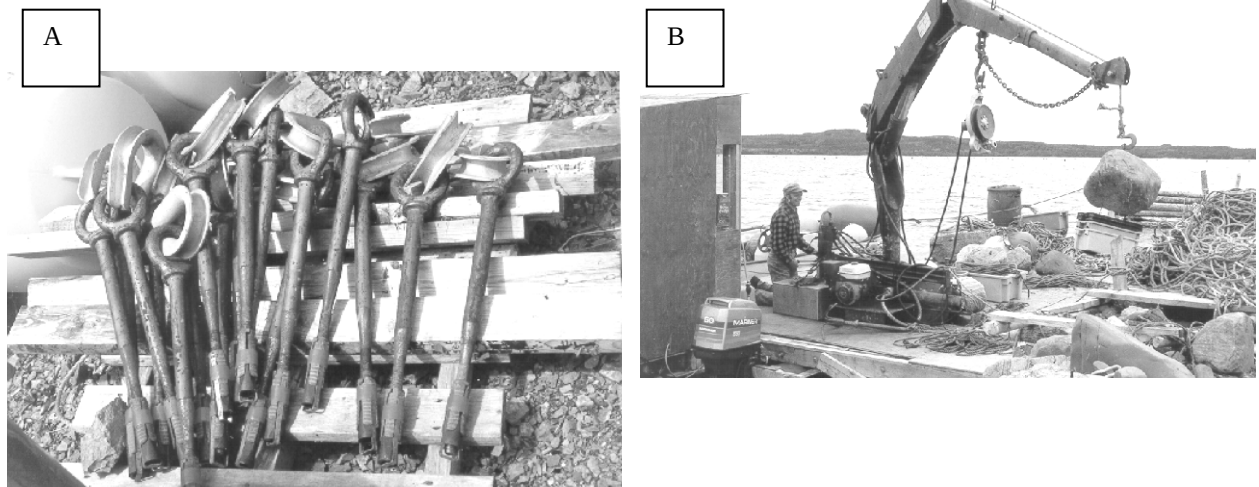


Figure 4.3: (A) Eyebolts, (B) rock anchor with an eyebolt. Photos by Sean Macneill.

together from scrap metal. These may be expensive but do not require the weight of rock or of concrete anchors (steel only loses 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").

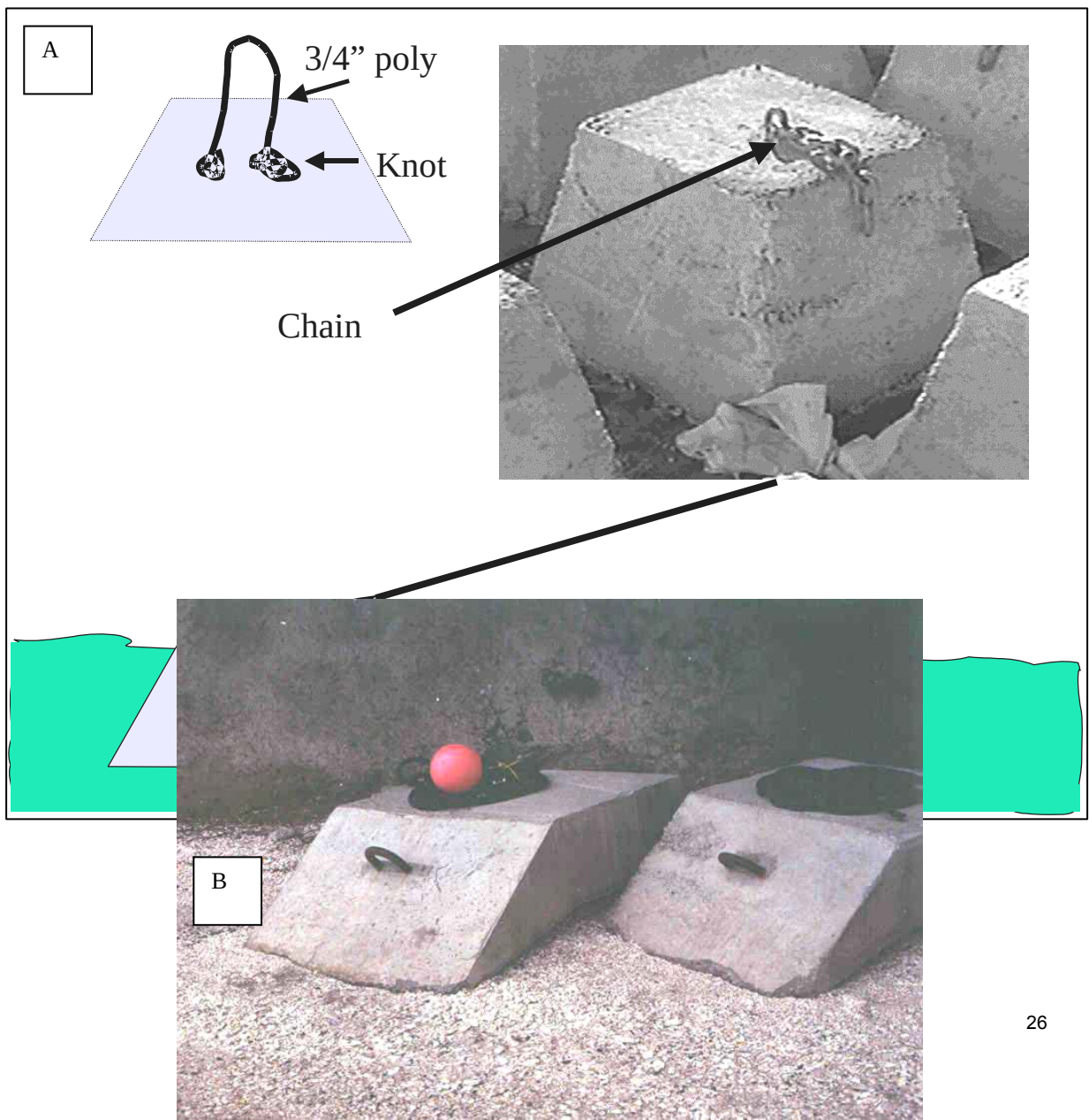


Figure 4.4: (A) Concrete mud anchor and (B) New Zealand wedge anchor system. Attachment may be in the form of chain, eyebolts or rope loops set in the concrete. Mud anchors must be given time to sink into the bottom to obtain maximum holding power.

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).

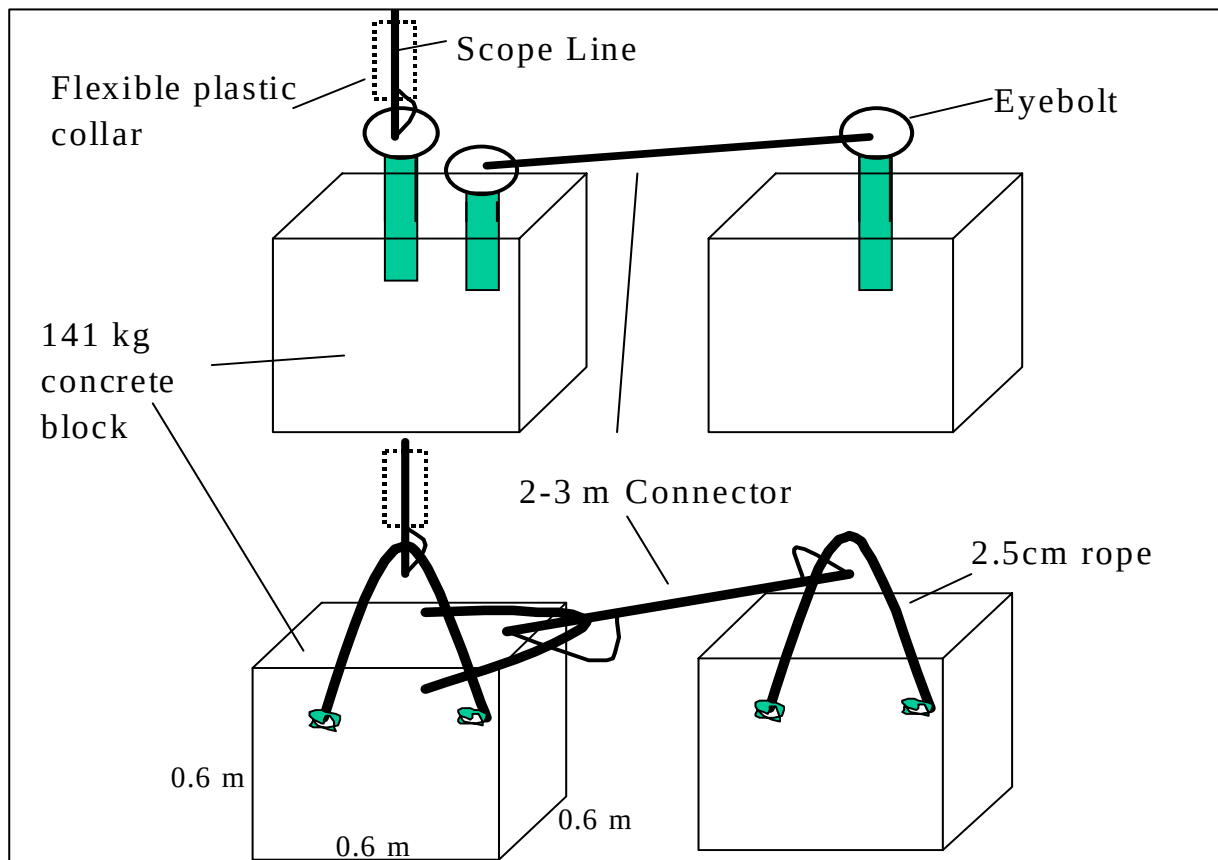


Figure 4.5: Easy to handle concrete anchor design. Total Anchor weight estimated as 272 kg.

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

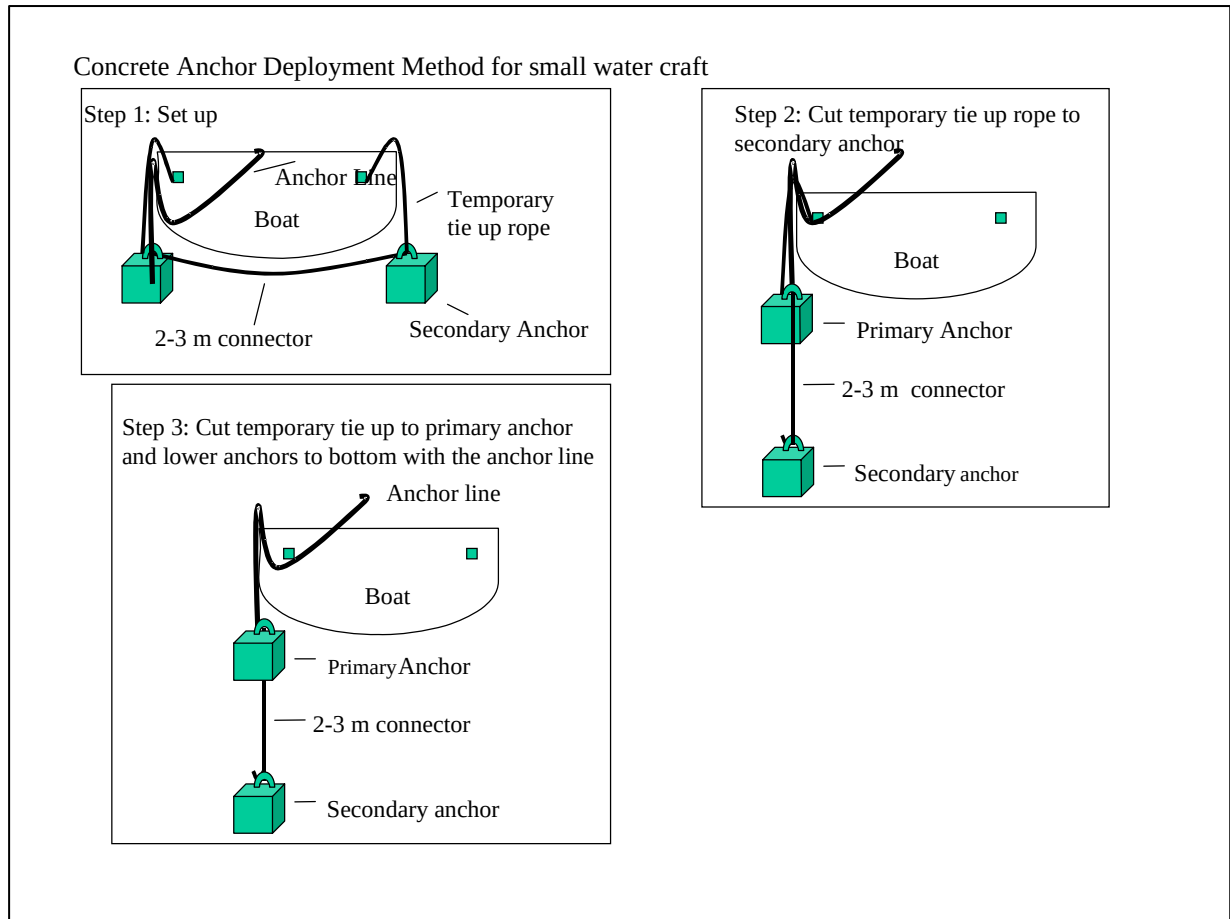


Figure 4.6: Small anchor deployment technique using a small open boat.

two boats and the anchor is suspended from the timber. Upon reaching the appropriate location the temporary line connecting 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 may 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

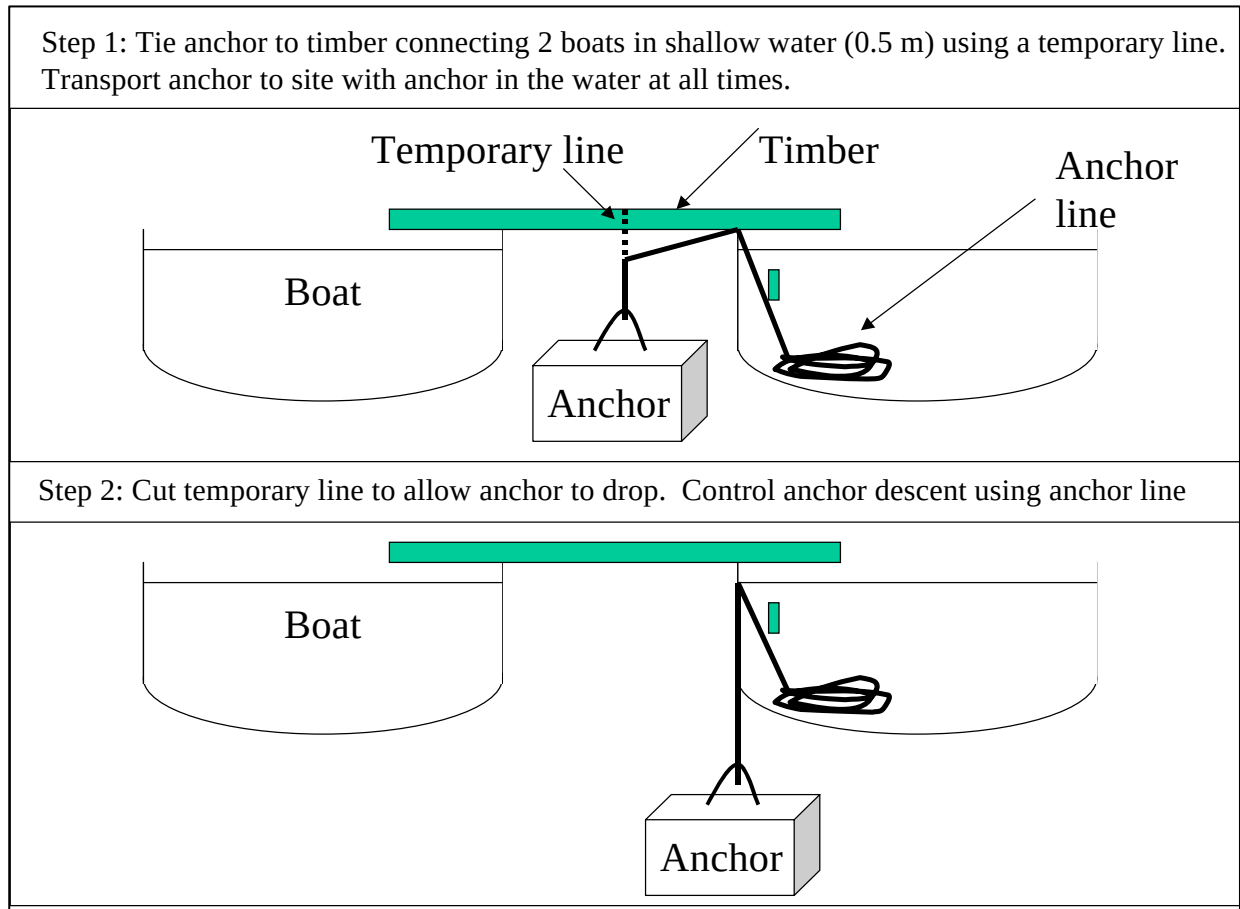


Figure 4.7: Anchor deployment technique using two small open boats (7m)

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 ($\frac{1}{2}$ ') and 14 mm ($\frac{9}{16}$ ") polypropylene rope. This is used for both anchor lines, cross-lines and mainlines. 9mm ($\frac{3}{8}$ ") 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 ($\frac{5}{8}$ ") 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.

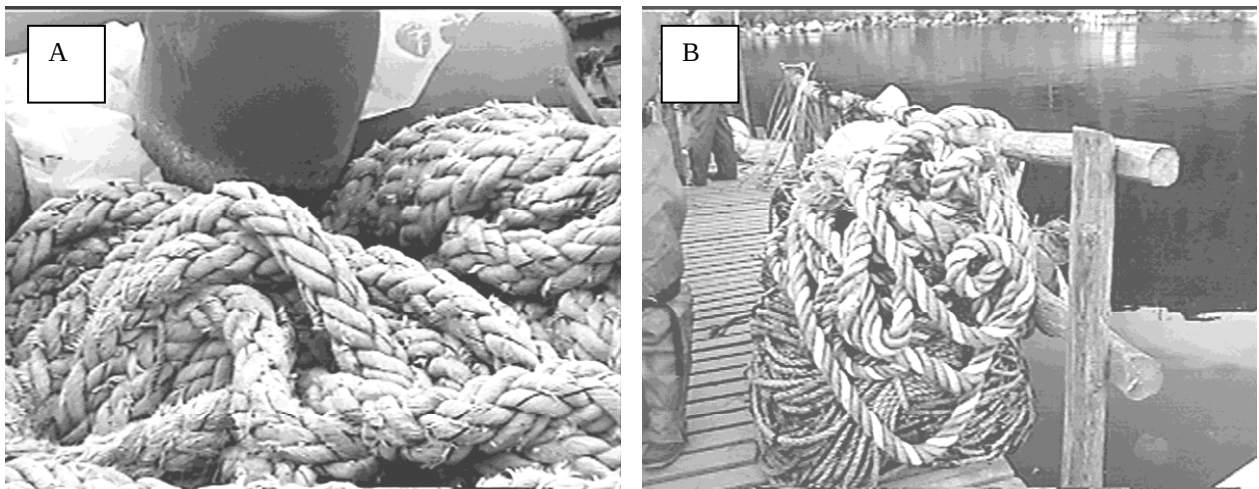


Figure 4.8: Ice boom rope, (A) manila and (B) polypropylene.

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.

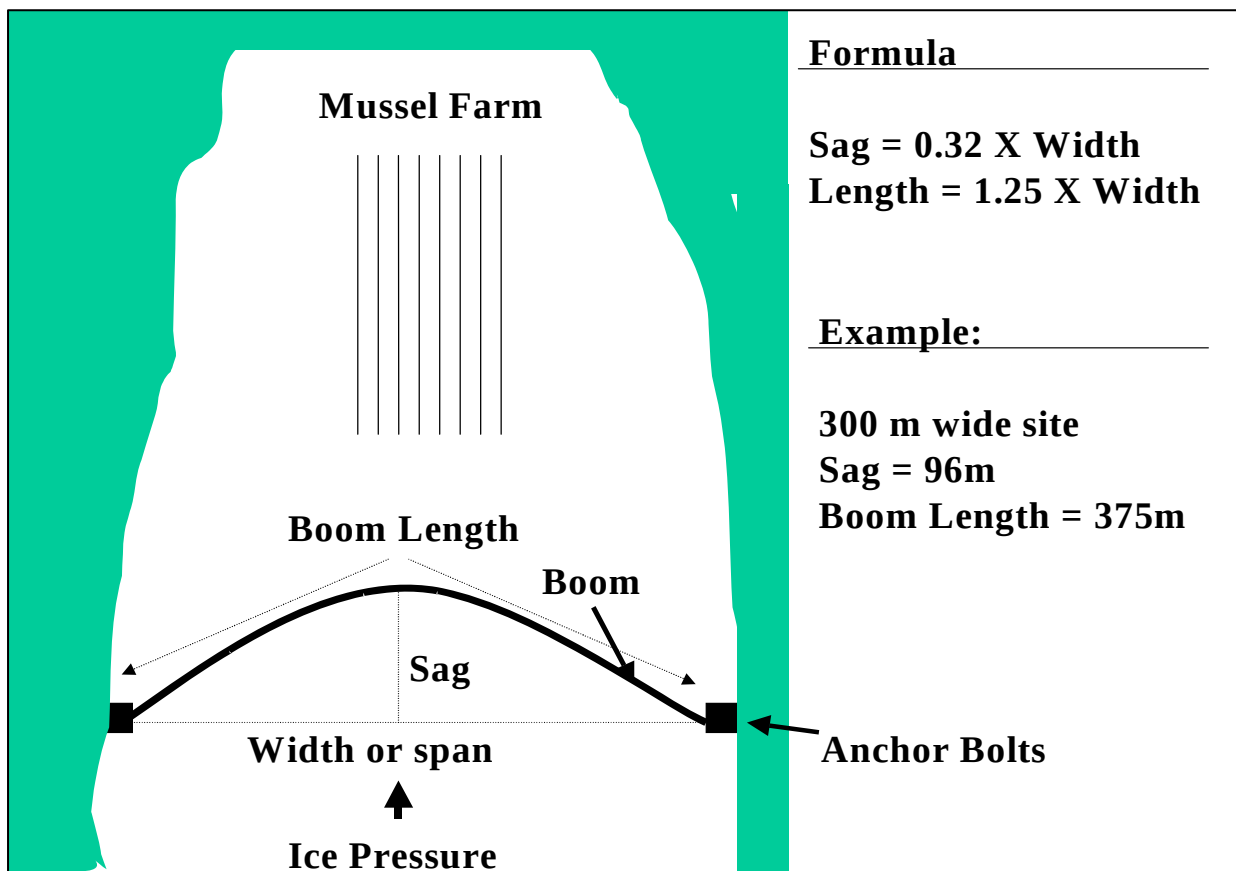


Figure 4.9: Single span Ice boom design with formulas for calculating boom length and sag. Based on Cammaert (1997).

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

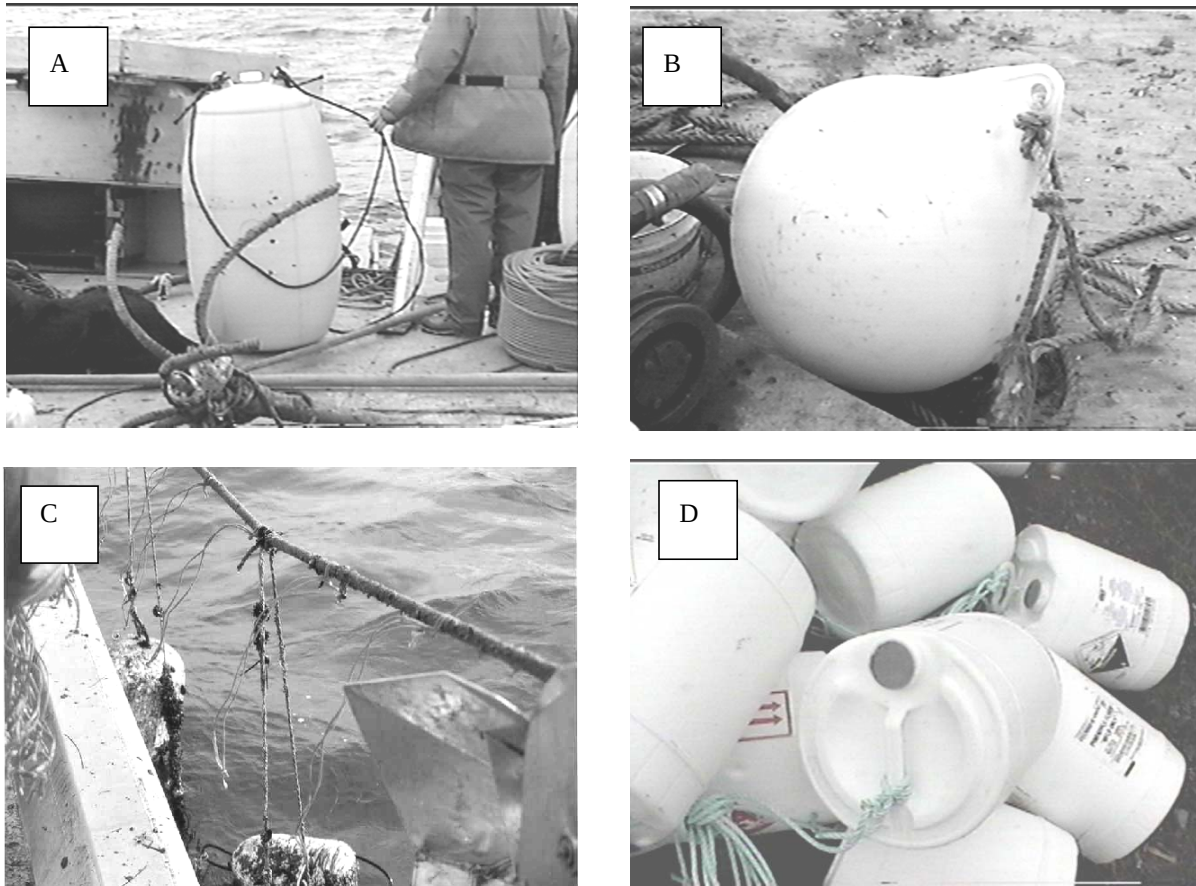


Figure 4.10: Various types of floats used in Newfoundland Mussel aquaculture. (A) barrels, (B) 0.4 m pressurized floats, (C) styrofoam floats, (D) concentrate containers.

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

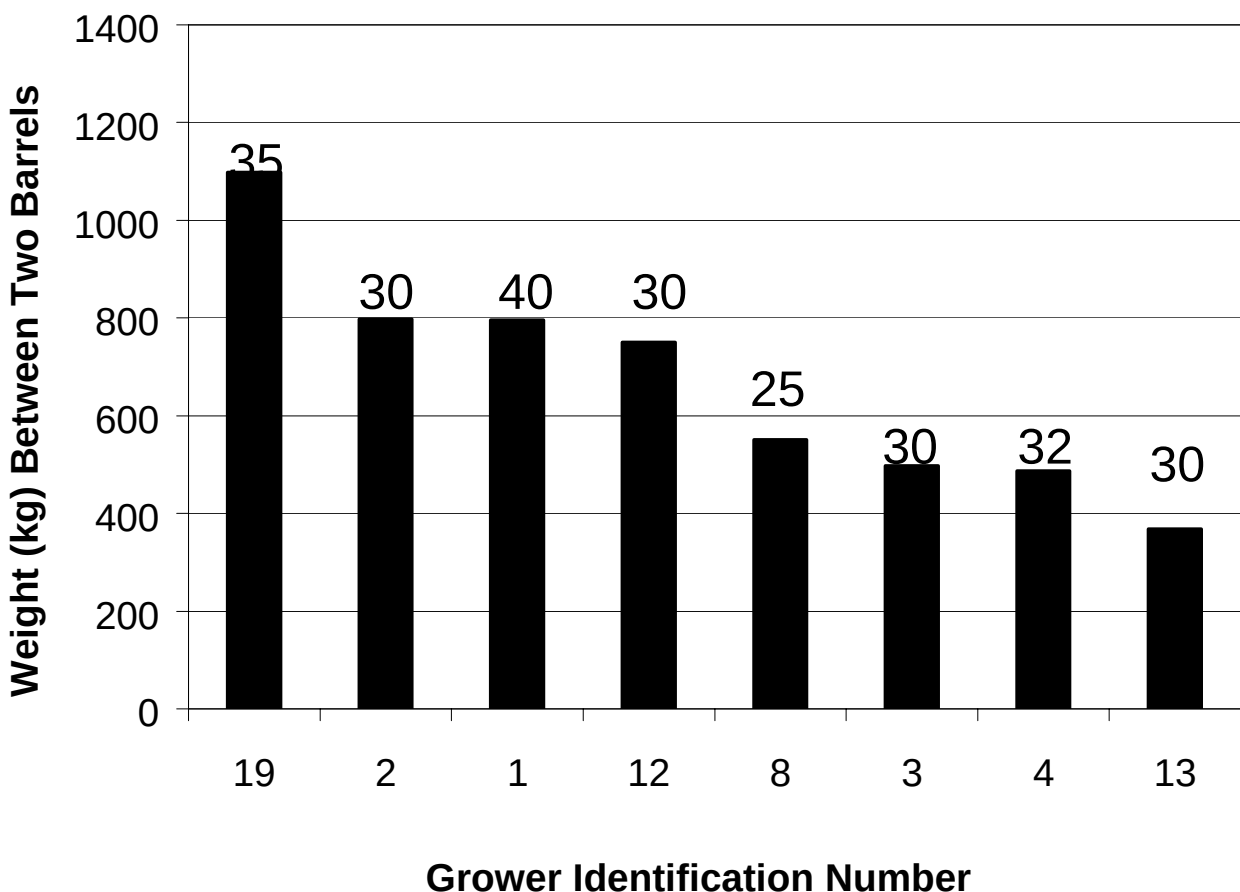


Figure 4.11: The total weight (kg) of mussel socks supported between two 200 l (45 gallon) barrels on a mainline system. Weight was based on mean total sock weight of 2

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.

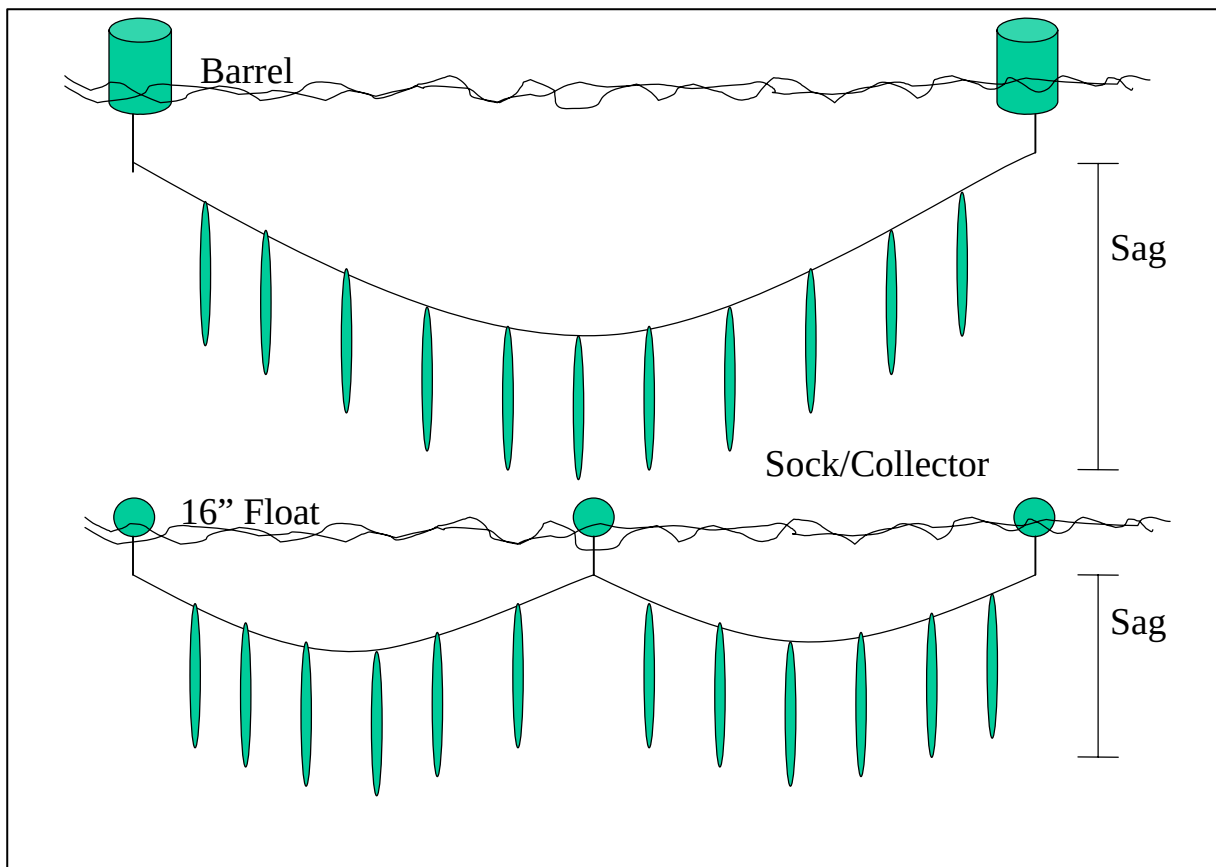


Figure 4.12: Comparative line sagging using barrels and 0.4 m floats, assuming 50 collectors between barrels and 25 between floats.

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 weight and float size.

Canadian Coast Guard requires that all sites be approved under the Navigable Waters Protection Act (NWP). All sites are assessed individually with the approved site size, location and the required markings outlined on the NWP documents issued to the grower. Perimeter 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 NWP 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

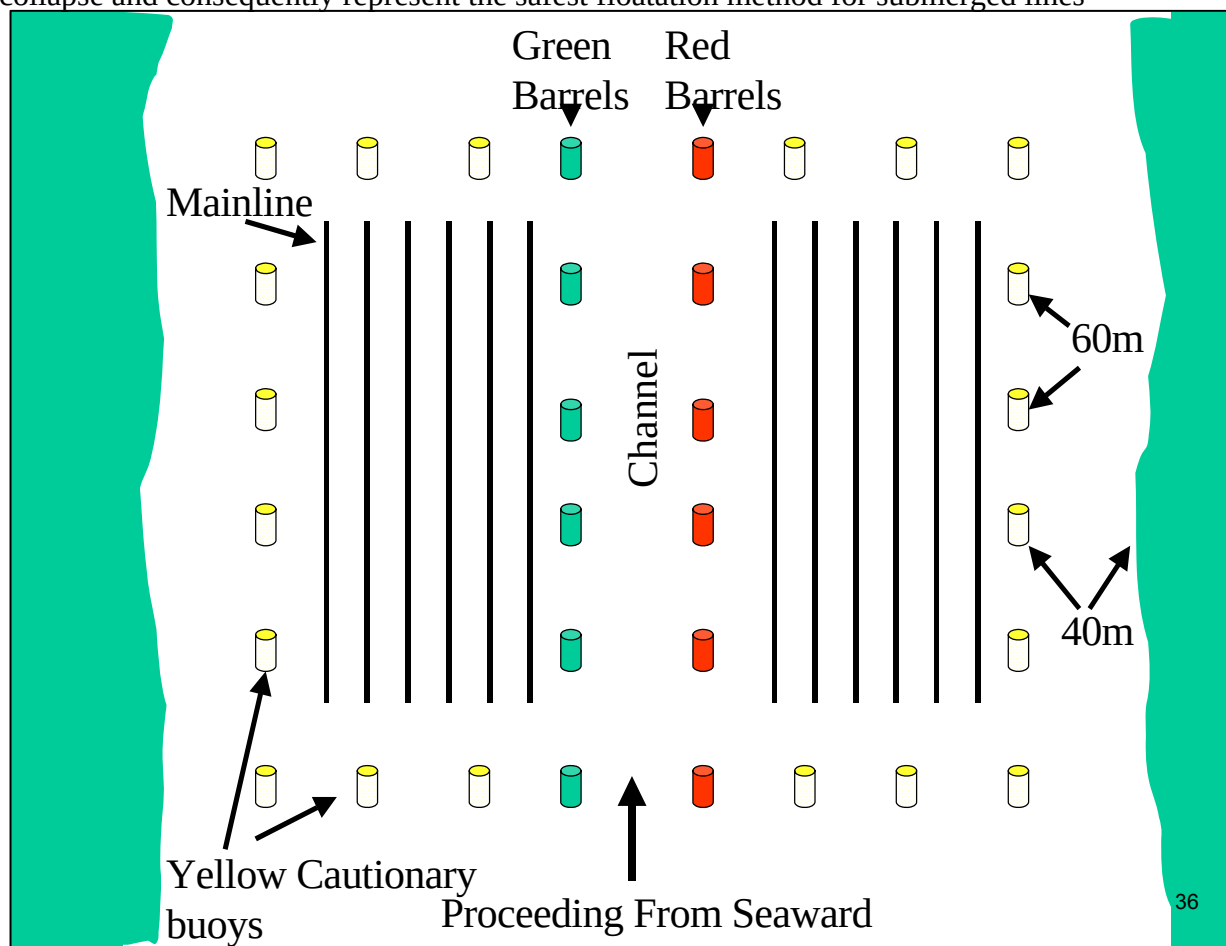
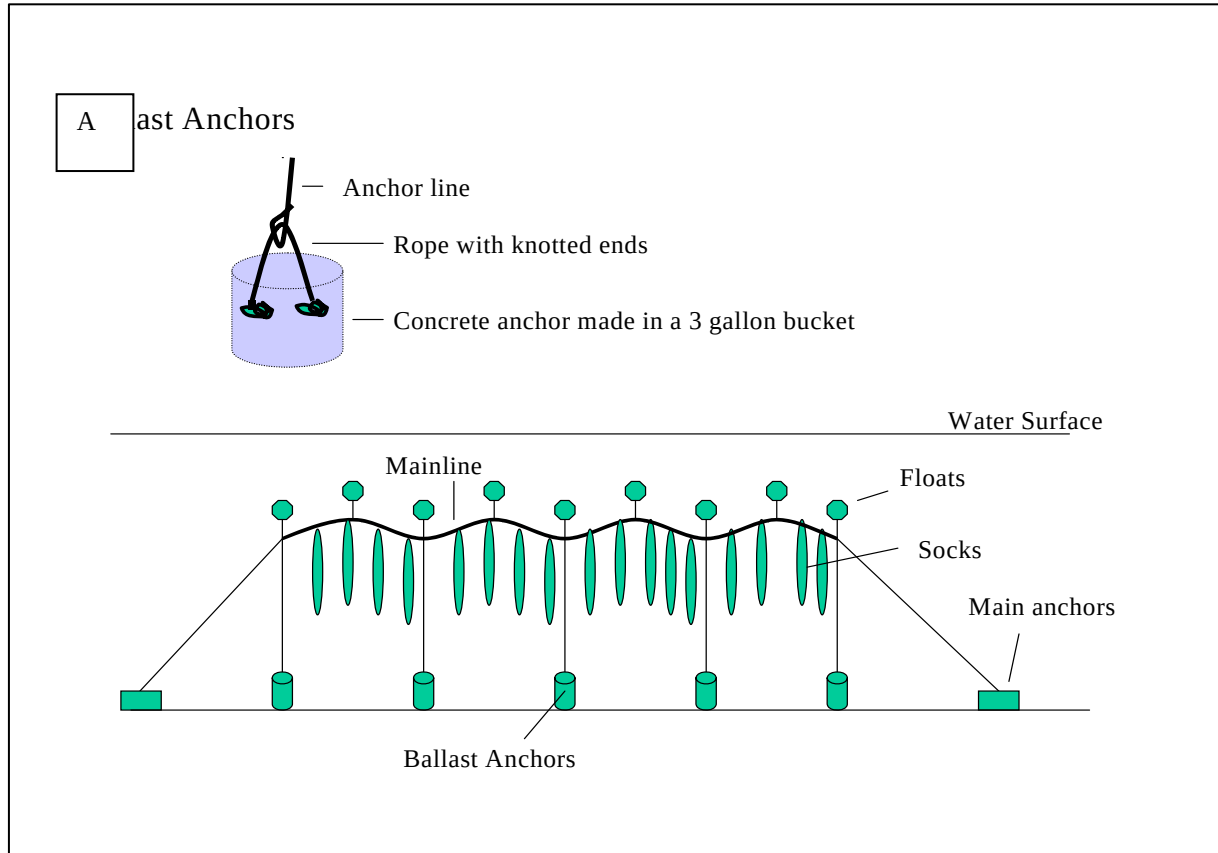


Figure 4.13: Typical site layout indicating placement of yellow cautionary buoys, and red and green channel markers.

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 mortalities.

Unfortunately, using submerged lines has an 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



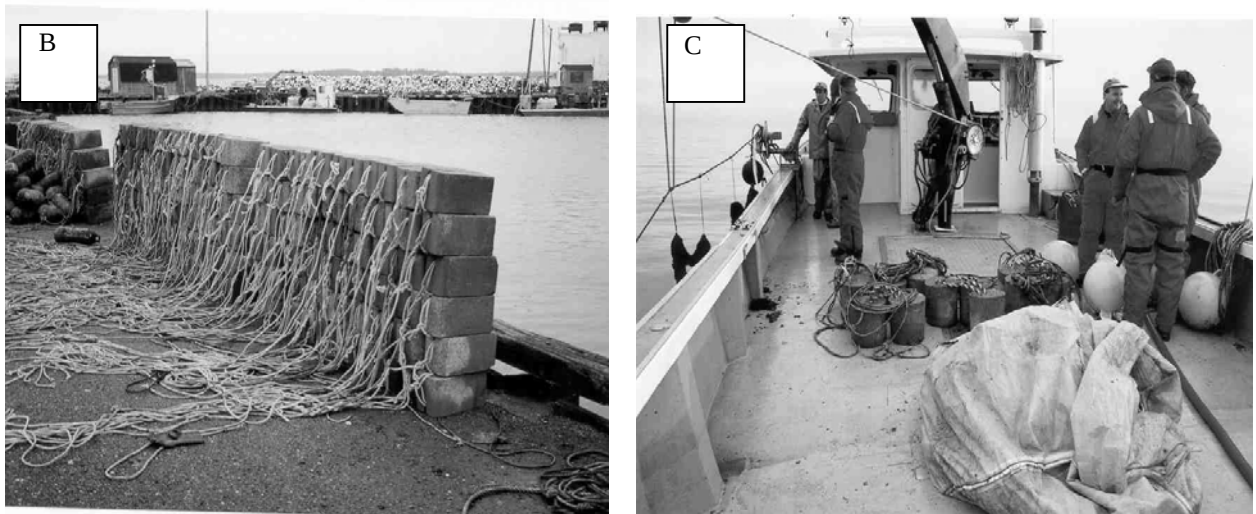


Figure 4.14: (A) Ballast anchors, and a mainline submerged using ballast anchors, (B) cinder blocks used as ballast, (C) Concrete buckets used for ballast.

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.

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