STATE OF MAINE
112TH LEGISLATURE
SECOND REGULAR SESSION

JOINT STANDING COMMITTEE ON MARINE RESOURCES STUDY ON THE BLUE MUSSEL RESOURCE AND HARVESTING IN MAINE

OCTOBER 1986

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I. EXECUTIVE SUMMARY

Two bills were introduced into the second regular session of the 112th Legislature to help address conflicts in the mussel fishery. The Joint Standing Committee on Marine Resources granted a leave to withdraw to the sponsors of the two bills after requesting an interim study on the character and issues of the fishery. Background information was gathered and developed on the biology and habitat of the blue mussel, harvesting procedures, industry and market structure, aquaculture techniques, and current mussel regulation and management. A five member subcommittee held two public hearings and met throughout the fall to develop recommendations to bring to the 113th Legislature.

Five major issues emerged as a result of the study. These were:

1. Concern over the extent and status of the mussel resource.

2. Damage to mussel beds and associated species such as marine worms, herring, clams, and lobsters from dragging activities and mussel culture.

3. Conflicts between fishermen over transferring mussels from wild beds to aquaculture leases.

4. Shortcomings in the current aquaculture lease procedures.

5. Concern that the statutes for shellfish are tailored to the soft-shell clam and are not appropriate for the mussel fishery.

Resolution of some of these issues is beyond the resources of this study. There is little information available to address the status of the resource and the potential dragging damage to mussel beds. However, the subcommittee has developed the following recommendations to address management issues within the fishery:

1. A one year moratorium on the granting of all aquaculture leases.

The subcommittee recommends that a commission composed of representatives of the Legislature, DMR, fishermen, and the mussel industry develop legislation by January 1, 1988 designed to:

a. Give the Marine Resources Advisory Council the power to approve and review aquaculture leases. Testimony at the public hearings centered around the problems in having lease decisions made by only one person (the commissioner of DMR) given the controversial nature of the lease hearings and testimony.

b. Require additional criteria to be considered in granting an aquaculture lease. These include aesthetic, economic, and environmental criteria beyond those in current law. A minimum setback requirement from lobster pounds is also strongly recommended.

c. Develop regulations to discuss seed sources for mussel leases at the public hearing for aquaculture leases.

d. Investigate the intent and implementation of the 200 acre statutory leasing limit for applicants.

e. Review the time schedules under which DMR grants leases and recommend a timetable that can accommodate field visits and review during the growing season. Currently, a lease may be granted within 90 days of an application regardless of the season. An accurate survey of the proposed lease area is best done during the growing season, however this is not always possible under the current requirements.

f. Review the mechanism for public participation in lease hearings. It is frustrating for the layperson to present evidence at lease hearings. They often feel their concerns are not addressed.

2. Mussel harvesting licenses should be separated from shellfish harvesting licenses. Two categories of mussel harvesting licenses are suggested:

a. Boat licenses, similar to a scallop boat license, allowing a three person crew to harvest mussels from a vessel.

b. Hand-raker's licenses set at a lower fee than the boat license.

3. A strategy for implementing harvesting seasons for blue mussels should be developed by DMR to coincide with their spawning times. Mussel seasons are recommended to improve the quality of mussels on the market and to conserve the mussel resource. Spawning mussels have a short shelf life and are of poor quality. They also are more easily damaged during harvesting.

Legislation should be adopted to require DMR to review different mechanisms for establishing harvesting seasons and to report their findings and recommendations to the Legislature by January 1, 1988.

The subcommittee was unable to address several issues of concern to the mussel fishery because of insufficient information. The fishery is relatively new and very little scientific or inventory information is available. However, the implications of overharvesting or disturbing related fisheries are enormous. In that light, the subcommittee also recommends that DMR receive funds to study the following:

1. Implementing drag size and weight restrictions;

2. Inventorying Maine's wild mussel resource and mussel seed areas to develop management strategies to conserve the wild resource and regulate widespread seed transport and removal;

3. The effects of the "mud plume" generated during harvesting, purported silt transport, and the effects of dragging on the mussel bed itself.

4. The Department of Environmental Protection and the Department of Marine Resources regulations regarding the return of live organisms to their natural habitat.

The subcommittee recommends that legislation be adopted to require DMR to report on these studies to the Legislature by January 1, 1988 and to include an appropriation to cover the costs of the study. The Marine Resources Committee strongly supports this expenditure.

II. INTRODUCTION

The blue mussel fishery in Maine is undergoing rapid transition. Fifteen years ago, annual mussel landings averaged less than 50,000 pounds. In 1985, harvest volumes surpassed soft-shell clams to become the third largest fishery in the State. Over 6.3 million pounds of mussels were landed with an estimated dollar value of $2.1 million (see figure 1). Expanded markets and the marketing of high quality mussels have been responsible for this rapid increase.

Because of the fishery's rapid growth and changing character, conflicts are developing between traditional mussel fishermen, aquaculturists and other fisheries. Two bills were introduced into the second regular session of the 112th Legislature to help address these conflicts. The Joint Standing Committee on Marine Resources was granted a leave to withdraw the bills after requesting an interim study on the character and issues of the fishery. This report is a product of that study and includes recommendations by the subcommittee to address some of the major problems.

The report discusses the mussel resource and industry in Maine. Harvesting technology and aquacultural techniques are described. Information on the extent and stability of the resource is included as well as a brief overview of the industry. The life cycle and habitat requirements of the blue mussel are also briefly explained.

This report is a first attempt to characterize this fast-changing industry. Much of the information has come from interviews with people involved with the fishery and has not been documented.

III. EXTENT AND STABILITY OF THE RESOURCE

The annual growth rate and standing crop of commercially valuable mussels on the Maine coast is not known. It has become apparent to wild mussel harvesters and processors that the abundance of marketable wild mussel beds is diminishing. Several processors indicated that they believe the wild resource can not sustain the current harvesting pressure and will more actively encourage their fishermen to obtain aquaculture leases.

Several mussel surveys have covered portions of the coast (MARITEC, 1978; Scattergood and Taylor, 1949) but are outdated, only covered large beds, and greatly underestimated mussel volumes. However, in the absence of complete data some generalizations can be made.

MAINE MUSSEL LANDINGS

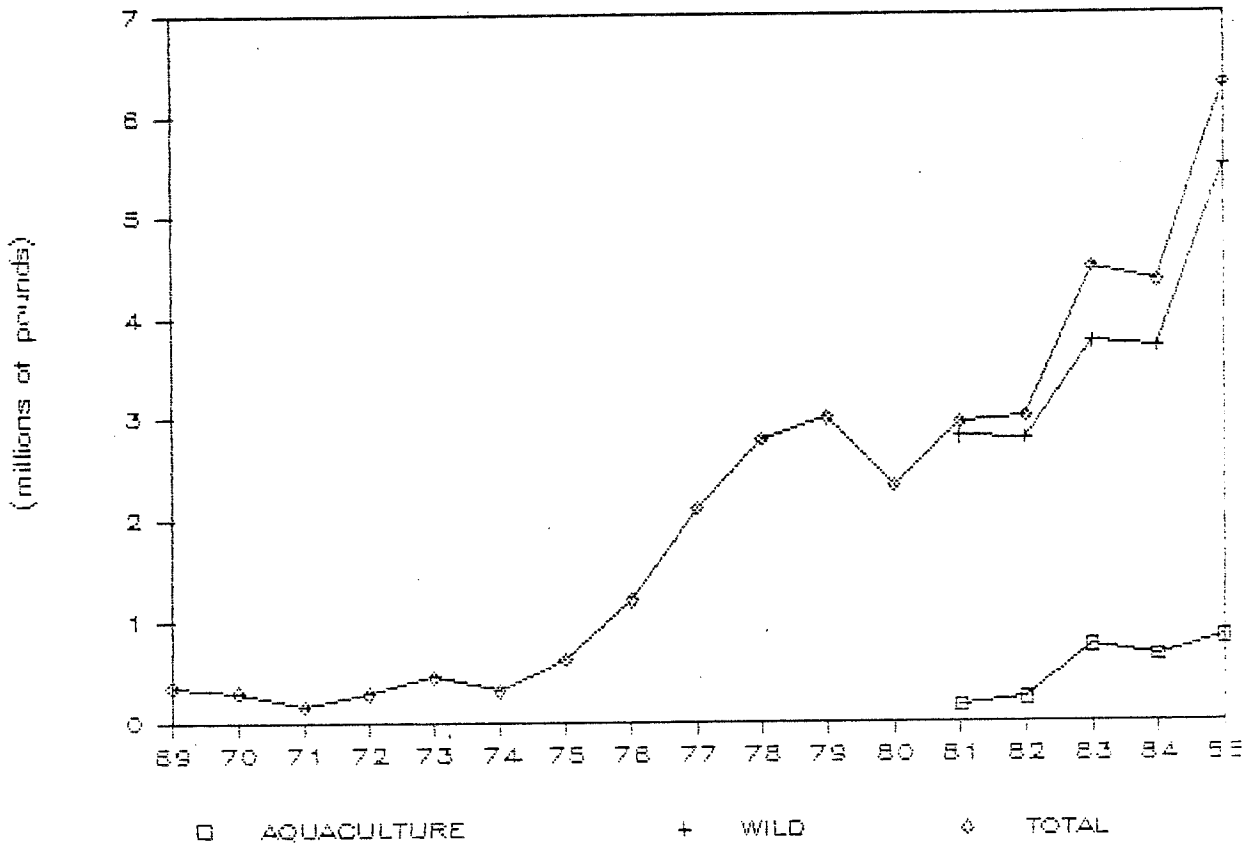


FIGURE 1

First, there are six major areas on our coast where blue mussels are commercially harvested, including Casco Bay, Tenants Harbor-Vinalhaven, Muscongus Bay, Stonington and Deer Isle, the Sorrento and Mt. Desert Narrows area, and the Jonesport area (see figure 2). These areas differ in terms of the growth pattern of mussels and mussel beds, the character of the shell, and the type of gear used to harvest them. These differences arise because of a gradient in the sediment type and geology of the coast. The descriptions below are broad generalizations and there is variation within areas.

Casco Bay: The Casco Bay estuary has a good food supply, high temperatures, and strong currents. Consequently, mussels generally reach harvestable size quickly. The best time to harvest these mussels is in the spring before they spawn, as they are of poor quality later in the summer. However, Casco Bay is prone to red tide and is usually closed to shellfish harvesting by mid May or early June through September. The sediments of Casco Bay are coarse and gravelly or soft mud and draggers often have four inch tines on their drags to keep them above the sand.

Before this past year, the mussel beds in this area were harvested by three to four fishermen in the winter and spring only. There is only one lease that includes mussels in the Bay.

Tenants Harbor-Vinalhaven: Mussel beds in this area are found in coves and are numerous although small. The mussels are generally of high quality although pearl counts are high in some areas. The bottom is somewhat ledgey with mussels found between the ledges in hummocks. Large kelp tends to set on the beds near Vinalhaven. There is a large bed in Seal Cove.

Muscongus Bay: Twenty to thirty years ago, this area supported large mussel beds however, today there are only several mussel harvesters that work this area. The western portion of the bay is quite ledgey whereas the eastern portion has ledges but large mudflats.

Stonington-Deer Isle area: Hand-rakers, draggers, and aquaculturists all work this area. There are about 15 boats working this area with 10 to 20 hand-harvesters. The mussels grow in large beds on soft mud bottoms. The beds are fairly old, deep and steep-sided. There has not been a good seed set in this area in the past 8 years creating problems for both the wild harvesters and the aquaculturists. Growth, meat yield, and the absence of red tide make this an exceptional mussel area.

Sorrento-Mt. Desert Narrows: This area has large, spread out beds that are fairly shallow. The bottom is generally a soft mud and the water is warm. One harvester worked

Figure 4

General Locations of Maine
Commercial Mussel Beds

this area for 15 to 20 years, until several years ago when 8 to 10 boats worked the area. There are now only one or two boats harvesting the beds. The Narrows still supplies good seed mussels. There are several leases proposed for this area.

Jonesport: Most of the mussels in this area are found in strong currents. The mussel beds are smaller and found on harder bottoms. Subtidal mussels are found deeper and are harvested with heavier, larger drags. The many rivers draining into this area make it a good source of seed mussels. The colder waters delay the spawn until later in the summer. Between Addison and Machias there are about a dozen boats that work full time harvesting mussels. Starfish are a problem in this area.

As shown in figure 1, it is the wild resource that is responsible for the dramatic increase in landings. It is not clear whether this harvest can be sustained as the full extent of the resource is not known.

IV. MUSSEL HARVESTING AND AQUACULTURE

1. WILD HARVESTING

Wild mussel harvesters can be classified into 3 categories: full-time and part-time draggers, and hand-rakers. Appendix A illustrates the techniques for both hand harvesting and dragging.

TABLE 1
MAINE MUSSEL HARVESTERS
1984

County	Boat Length (ft)				
	1-19*	20-29	30-39	40-49	Total
Cumberland	14	1	9	3	27
Sagadahoc	6	1	1	–	8
Kennebec	1	–	–	–	1
Lincoln	3	1	–	–	4
Waldo	1	–	–	–	–
Knox	4	1	6	1	12
Hancock	11	7	17	1	36
Washington	6	2	11	4	23
Totals	46	13	44	9	112

*Assumes smaller boats are hand rakers.

Source: DMR

As shown in table 1, DMR estimated there were 112 draggers along the coast and about 46 hand-rakers in 1984. They are concentrated in Cumberland, Hancock, and Washington Counties. DMR estimates that 40% of Maine musselers harvest full-time. Part-time mussel harvesters generally harvest lobster through the summer and harvest mussels once the lobster move offshore. A hand-raker may harvest 30 to 50 bushels per day while a mussel dragger will range from 75 to 150 bushels per day.

Although fishermen frequently modify their drags, two basic types of drags are used to harvest mussels in Maine: rock drags and chain sweep drags. The type of bottom worked determines the type of drag used. Rock drags are generally used only in Casco Bay.

Rock drags are generally 2 to 2 1/2 feet wide and 2 to 3 feet long. While in other fisheries rock drags are worked in gangs of two to eight, mussel harvesters fish them singly or in pairs. The cutting bar, a two inch metal bar at the mouth of the drag, separates the mussels from the substrate and forces them into the bag. The bag is attached to the mouth and collects the mussels scooped up by the cutting bar. their small size allows them to follow a hummocky bottom better. Several harvesters in the Casco Bay area have put 4 inch tines on the mouth of their drags so they handle better on the sandy bottom.

Chain sweep drags are generally larger than rock drags with a 4 to 8 foot mouth and 3 to 6 foot bag. Some chain sweeps use a small cutting bar, a 1/2 to 3/4 inch diameter rod to separate the mussels from the bottom. The chain sweep derives its name from the 3/4 inch chain that rides behind the mouth, attached only at the sides. This allows the chain to sweep the ocean floor and follow the contours. The bag is not attached to the mouth of the drag but rides behind the chain. In the chain sweep it is this chain that does the active fishing, rolling the mussels into the bag. It is thought to be a more efficient drag because the chain follows the contours of the bottom and more mussels are gathered per tow. Chain sweeps are used singly and are more prevalent throughout the coast.

A vacuum dredge reportedly has been used to both harvest and seed mussels. The dredge has a vacuum tube guided by a SCUBA diver along the bottom to scoop up mussels. The inventor claims a minimum of disturbance with this dredge in that very little bottom is affected.

2. AQUACULTURE

Aquaculture landings have increased by a factor of six since 1981 to over 800,000 pounds in 1985. They contribute between 10 and 15% of annual landings. The market share of cultured mussels has increased from about 4 to 15% of total landings in the past five years.

Mussel culture in Maine is based on thinning small mussels to increase their food supply and consequently their quality and growth rate. Although suspension culture, or mussels grown on ropes suspended in the water, is common in other regions, only a few firms practice suspension culture in Maine. Bottom culture is predominant.

a. Bottom Culture

Bottom culture uses seed mussels that are 1 1/4 inch to 2 inches in size as they are fast-growing and have the best chances for survival. Smaller mussels are riskier to seed on a tract because predators prefer a smaller size. Aquaculturists assert that it would be prohibitively expensive to use hatchery seed for lease tracts in that the seed would cost $.05 each. Mussels are worth only $.02 each at the wholesale level (C. Newell, pers. comm.).

The cost to seed an aquaculture tract is estimated to be $1 per bushel. Because mussels double in size by the time they are harvested, this translates into a seeding cost of $.50 per harvested bushel.

Seed mussels are usually harvested from intertidal or slow-growing areas. Seed beds often support in excess of 6000 bushels of mussels per acre or 100 to 2000 mussels per square foot. They are harvested as clumps from large and crowded beds. These are broken into smaller clumps and distributed on the lease tract.

This thinning increases the growth rate of mussels by increasing the available space and food supply. The mussels on lease tracts usually grow to marketable size within one year with the rule of thumb being that the mussels should double in size within a year. The growth rate of mussels decreases substantially after they attain a size of 2 inches and optimum conditions are needed to keep them growing rapidly.

Growth rates on aquaculture tracts are estimated to be 1mm per week for about a 30 week season, or 1 1/4 inches over the growing season. Harvest densities on mussel bottom leases are typically 1000 bushels of mussels per acre or about 25 mussels per square foot. It is estimated that two 20 acre aquaculture leases could support a mussel harvester year-round.

Because food supplies for mussels on aquaculture tracts are not limited over the growing season there isn't a particular season better for harvesting than another, except during spawning. The meats are good quality throughout most of the year. For wild mussels, April and May offer the best quality harvests.

It is not economical to gather aquaculture seed from more than a 10 mile radius of a lease tract because of time, fuel costs and boat sizes (Averill, pers. comm.). In Stonington,

where there have been poor seed sets for the past 8 years, this has been a problem. Recently a "seed barge", a converted WWII landing-craft, has been used by one firm to gather seed. The effective radius of the barge is 50 miles from a lease tract.

A "fattening up" process is sometimes used by leaseholders during the summer. Recently spawned mussels are moved to a lease for several months where food is more plentiful and their recovery time much shorter. This helps processors supply their markets while wild, spawned out mussels are of poor quality.

Because of predators, it is best to harvest aquaculture tracts within a year of seeding. Starfish can colonize an area and eat a substantial amount of mussels. In some areas, kelp invades the beds, increasing harvesting costs and decreasing the yields. Green crabs and eider ducks are also a problem especially for the smaller seed. Predators tend to feed on the edges, giving larger tracts an advantage.

b. Suspended Culture

Suspended culture, or mussels grown on ropes, has a longer history in Maine than bottom culture. It was first promoted by the University of Maine in the 1970s. Today, there are at least three firms that employ this technique.

Suspended culture relies on "catching" mussel spat when they are ready to settle for a second time. Short ropes are suspended in the water for the spat to settle on. After several months, the mussel spat is transferred to plastic mesh tubing and suspended in the water from floats or tires. This is usually done in late summer or fall. The mussels work themselves out of the mesh as they grow but remain as a clump, attached to each other through their byssal threads. The floats are left suspended from 12 to 18 months as the mussels grow to marketable size.

Suspended mussels grow much faster than mussels on wild beds or bottom culture. They have thin shells, high meat yields, sweet meat and no pearls. These mussels sell for over $30/bushel, higher than the best bottom cultured mussels. However, it is considerably labor intensive to grow suspended mussels and suspended gear is vulnerable to storm and ice damage.

c. Aquaculture Leases

There are currently 32 leases in Maine that allow harvesting of blue mussels. Some of these leases allow culturing other species. These leases are composed of 150 tracts covering 696 acres (see appendix B). Only about one half to one third of the area authorized by the lease is used at any one time as harvesters usually rotate their seeding on a tract.

Compared to other states, Maine's leased acreage is very low. Both New York and Maryland lease over 10,000 acres for oyster culture. The State of Maine receives $8229.70 in the General Fund from these leases. Figure 3 shows how current mussel culture leases are distributed along the coast.

By statute, the commissioner of the Department of Marine Resources has the authority to grant aquaculture leases for a period of up to 10 years (12 M.R.S.A. § 6072). Because an aquaculture lease grants private rights to a public resource, an adjudicatory hearing is required. The hearing procedure is subject to the Maine Administrative Procedures Act and is held in the town where the lease is proposed. DMR is required to notify the riparian landowners of the lease hearing and application.

An applicant is limited to 200 leased acres by statute. Under DMR regulations (Chap. 2, 2.12 C) the shareholders in a corporation or partners in a partnership are credited with the number of acres equal to their proportional ownership share rather than the corporation or partnership being credited the total. Thus if a person owns a 50% interest in a corporation, they are credited with 50% of the corporation's leased acreage.

Leases are granted by the commissioner if the project does not interfere with:

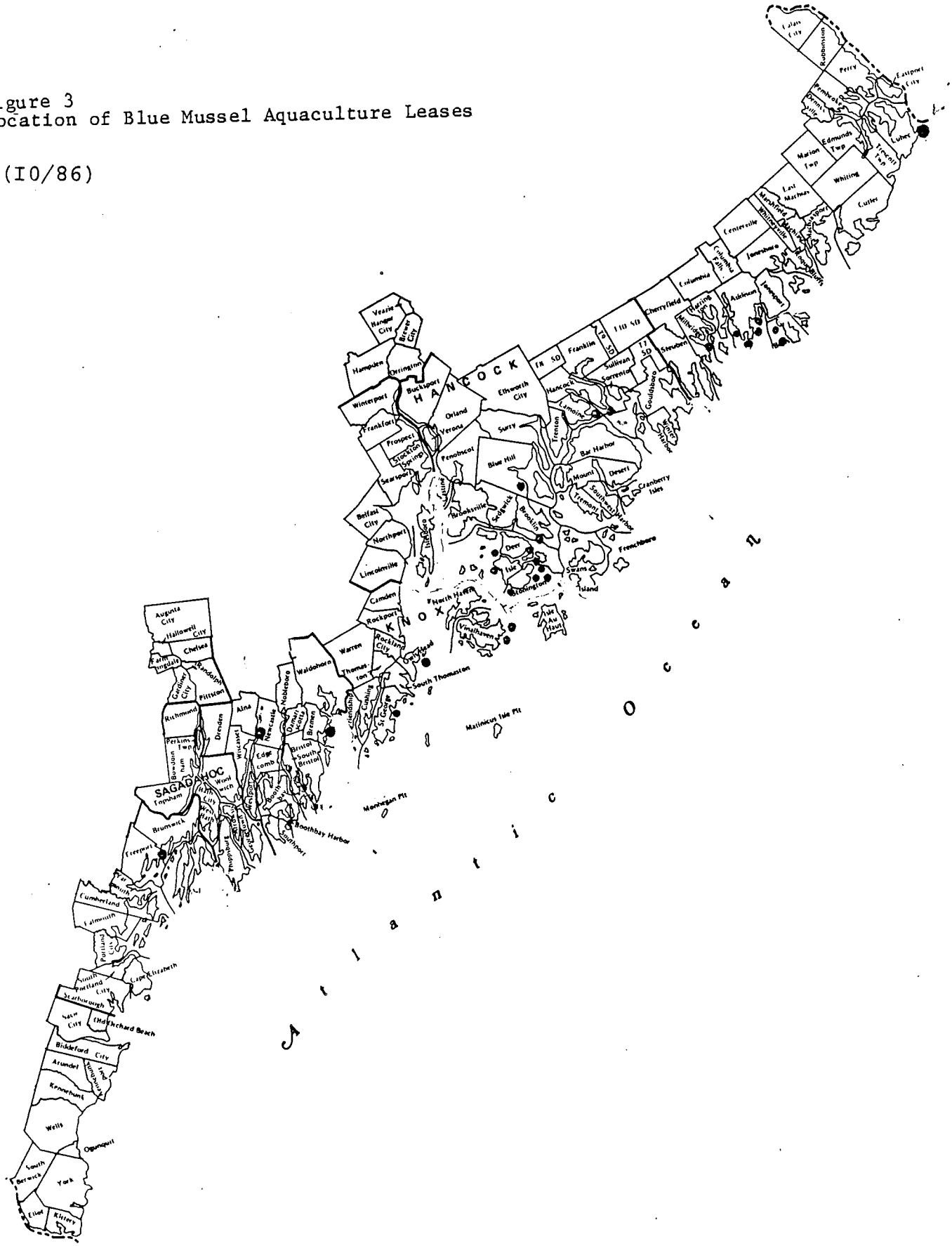
* ingress or egress of riparian owners,
* navigation,
* fishing or other uses of the area, and
* is not in conflict with applicable coastal zoning statutes or ordinances.

Prior to granting the lease DMR makes a visual check of the lease site to determine what other species and organisms are found there and whether there will be any conflicts with other fisheries. These visual checks consist of divers making spot checks of the area or DMR biologists surveying the proposed lease tract by boat. DMR has at least 30 days to check the lease site.

Frequently, conditions are attached to the lease to encourage the greatest multiple use of the leased area. These may take the form of seasonal harvesting restrictions. Leases can be transferred to another holder but the same procedure must be followed. A public hearing is not required unless requested. Leases can be revoked if no research or aquaculture was conducted within the preceeding year. Each aquaculture lease gives exclusive control only over those species listed in the lease. All other uses are allowed.

Figure 3
Location of Blue Mussel Aquaculture Leases

(I0/86)



The Legislature has directed the Bureau of Public Lands, which has jurisdiction over submerged lands, and the Department of Marine Resources to jointly study the leasing procedures and fees currently in effect. The recommendations are due January 1, 1987.

V. INDUSTRY AND MARKET STRUCTURE

Blue mussels occur from the Arctic to South Carolina but in the United States are only commercially harvested in Maine, Massachusetts, Rhode Island, and Long Island, NY. Maine ranks first nationwide in mussel landings.

1. PROCESSING

Once mussels are landed, they are often soaked by the processor to cleanse the meats. After soaking them overnight, the clumps of mussels are loaded into tumblers to break them apart. They are then sorted by size, graded, and bagged. Maine mussels are trucked throughout New England or flown air freight to more distant markets. Typical shelf life of processed mussels is 10 to 14 days depending on the health of the mussel, the season, and the amount of handling. Excessive tumbling decreases the shelf life of mussels.

2. MARKETING

The market structure of mussels is unique among Maine fisheries in that the mussels are harvested on demand. A processor usually has the mussels sold before a fisherman is asked to harvest them.

There are at least 49 dealers handling the mussel harvest in Maine. Of these, 3 each handle at least 9% or more of the annual harvest, 9 each handle more than 2% of the annual harvest and 13 handle at least 1%.

As mentioned previously, an important measure of mussel quality is the presence of pearls in the meat. Other parameters are meat yield, shelf life and the presence of mud or grit in the mussels. The majority of mussels are sold out-of-state. One processor uses roughly four grades of mussels:

Grade B: Large old mussels with silver back and a high percentage of pearls. These sell for about $3/bu. and are aimed at the chowder market.

Boat-run: Ungraded mussels, as-is off the boat. These are generally sold to out-of-state wholesalers that do not want to pay the premium for sorting the product. They sell for about $8/bu.

Premium: Graded mussels that are large- or medium-sized. They are ready to serve out of the bag and are sold to wholesalers, restaurants, and supermarkets. They sell for between $12 and $15/bu.

Select: These are the highest grade mussels and are only sold directly to restaurants and supermarkets. They sell for upwards of $18/bu.

Maine mussels serve a variety of ethnic markets. Montreal and other french markets prefer small mussels about 2 inches in length. Italian markets most notably Boston, New York, Baltimore, and Philadelphia, prefer large mussels over 2 inches in size. The West Coast also provides a strong market for Maine mussels.

Smaller mussels are harvested for shucking while mussel smokers need larger mussels. Smoked mussels must be large because of all the water lost in smoking. They also must be pearl free. While the size of mussels used may vary over the season because of spawning, they are generally 2 to 3 inches. There are few statistics available on the size of the smoked market, however there are at least 3 firms that handle smoked mussels as well as other smoked seafoods. Figure 4 is included to illustrate the range of mussel users by size.

As shown in figure 5, Mussel Landings by Month, the seasonal fluctuations of mussel markets have been declining. Summer landings are lower than the rest of the year but still strong enough to sustain employment and markets.

VI. MUSSEL REGULATION AND MANAGEMENT

A shellfish license is required by DMR to harvest, ship, or shuck mussels in Maine. The shellfish license and regulations are tailored to the soft-shell clam fishery and the fee is set at a low $13.00 in deference to the high cost of municipal nonresident shellfish licenses. Fifty three percent of these fees go to DMR's Shellfish Fund for management, enforcement, restoration, development and conservation of shellfish both in intertidal and submerged lands. This fund benefits mussels by providing personnel and supplies for monitoring red tide, a marine patrol officer, and a technician devoted to mussel research.

Aside from shellfish licenses, the only statutory authority that applies directly to mussel harvesting involves red tide (§6621(2)). It is illegal to wash, hold or keep shellfish from

Figure 4

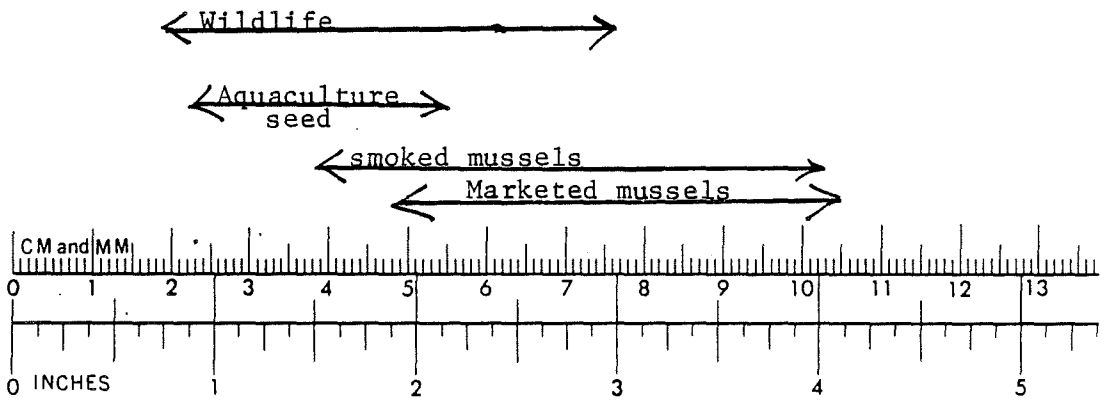
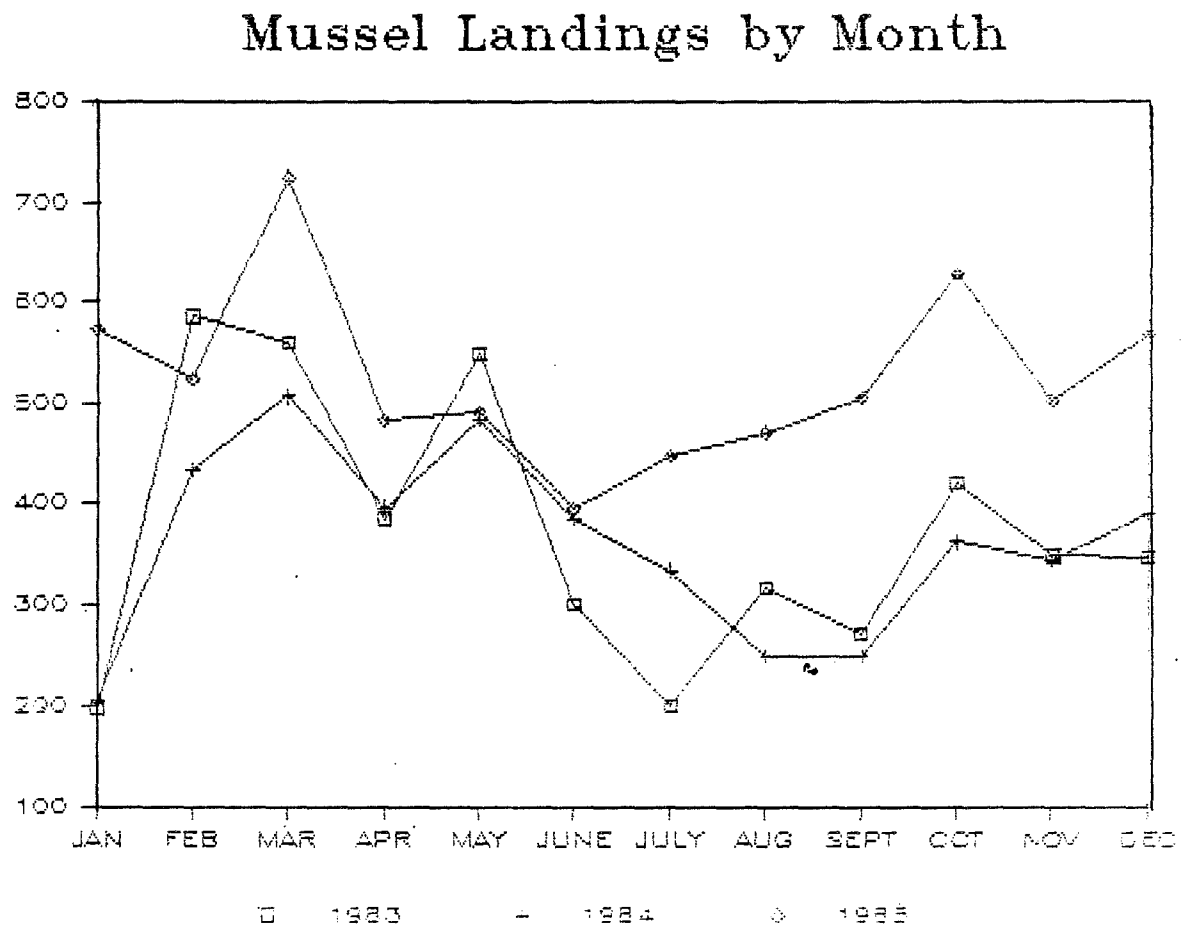

Wildlife
Aquaculture seed
smoked mussels
Marketed mussels
CM and MM
0 1 2 3 4 5 6 7 8 9 10 11 12 13
0 INCHES 1 2 3 4 5

Figure 5


Mussel Landings by Month
800
700
600
500
400
300
200
100
JAN
FEB
MAR
APR
MAY
JUNE
JULY
AUG
SEPT
OCT
NOV
DEC
1983
1984
1985

any area closed by DMR or to ship or transport them. Mussels concentrate red tide or paralytic shellfish poisoning (PSP). Significant portions of the Maine coast are closed to mussel harvesting by the DMR each year. Casco Bay has been closed to mussel harvesting for at least two to three months every summer. Scattered harbors and bays are often closed for several weeks each summer between Penobscot and Casco Bay. Cobscook Bay and Schoodic Point are often closed as well.

A municipality may regulate mussel harvesting if their jurisdiction includes intertidal or submerged lands and if their shellfish management plans include mussels. There currently are no towns that exercise this power. A municipality also is empowered to lease intertidal areas for aquaculture. Since Maine mussel culture has been practiced exclusively in submerged lands this has not yet been done.

VII. MUSSEL BIOLOGY

1. LIFE CYCLE

a. Spawning

Spawning times for mussels may vary from year to year and from habitat to habitat but generally occur during late spring and early summer. Mussel beds spawn for one to two weeks although a clump of mussels may not all spawn at the same time.

The food supply for mussels controls the duration and amount of their spawn. When mussels have a rich food supply their initial spawn may be followed by another spawn in the late summer or fall (Seed, 1976).

The timing and duration of spawning for mussels does not depend on the size of the mussel, as large and small mussels spawn at the same time (Chipperfield, 1953 as cited in Seed, 1976). However, there is a tendency for older (not necessarily larger) mussels to spawn earlier and to produce more eggs and sperm (Thorson, 1946 as cited in Seed, 1976).

Spawning is most likely controlled by water temperature, although it is not clear whether it is the temperature itself or the rate of temperature change that triggers it. Mussels from warmer waters spawn earlier than those found in northern areas. In Maine, mussels from Casco Bay might spawn in May while those from the Jonesport area may not spawn until July. Scraping or chipping the shell, or storm wave action can also stimulate mussels to spawn.

Mussels use alot of energy for spawning. Before they spawn mussels have high energy reserves and are at their best; meat weight is high and their taste is sweet. After spawning, wild

mussels have a lower meat weight, a more bitter taste, and are generally of such low quality that they are not harvested for select markets. Mussels on the market are generally of poorest quality during the summer spawn. Because mussels on lease tracts are at a lower density than those on wild mussel beds and have more food available to them, their quality returns sooner following spawning.

Processors try to avoid spawning mussels because not only are their meats of poor quality but their shelf life is poor and their mortality higher. Mussels have been known to spawn after they have been shipped, fouling the packing bags.

b. Larvae

Between 5 and 12 million eggs may be produced by a single female in a year. Fertilization occurs in the water column and the larvae remain suspended for about 19 days, although this depends on temperature, salinity, and food supplies. Larvae must eat large amounts of food to survive this stage (Bayne 1976). Predators and stress kill an estimated 99% of the larvae before they first settle and large numbers are "diluted" or washed out into the open ocean. Larvae are most abundant in May, June, and July.

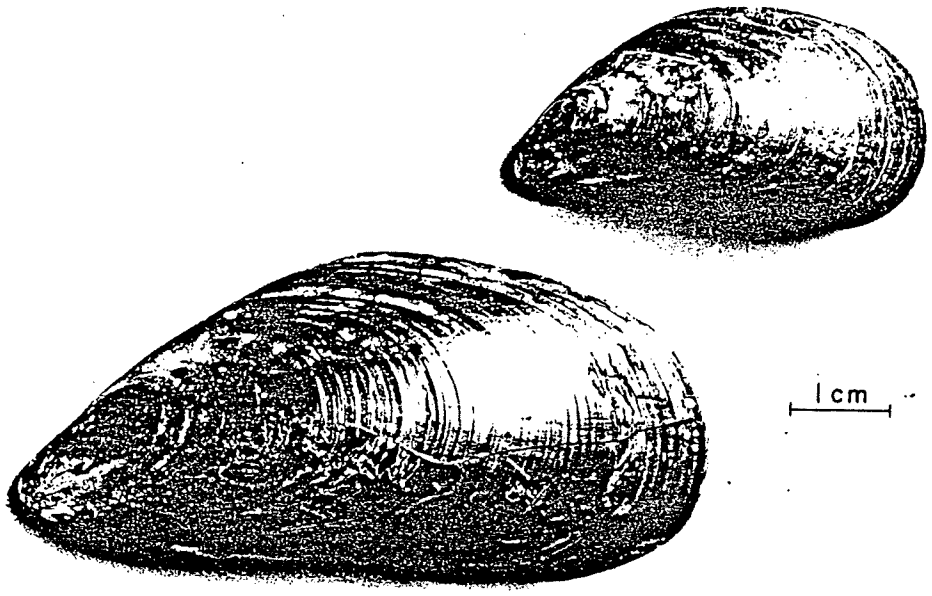
The larvae first settle on algae, eel-grass, or filamentous surfaces and become mussel spat. They move again within several weeks to a hard surface and may settle directly on older mussels. The spat attach and reattach themselves several times before finding a suitable spot as they migrate using two types of byssal threads-a drifting thread which they cast into a stream of water, and an attachment thread which they can use to hold on to a suitable substrate.

When the juveniles are about .9 to 1.5 mm, they settle a second time. For their second, more permanent settlement, they prefer rough, fibrous or hard surfaces. The rougher shells of older mussels that have been scraped or worn away are favored and larvae are attracted to a mussel bed. They find predator refuge in the spaces between the shells of the adult mussels.Mussel spat can easily smother older mussels by attaching to their shells. They also attach to gravel, shells, sand, or barnacles.

c. Growth

Growth rates of mussels vary not only between localities but also within size and age groups in the same area (see figure 6). Under ideal conditions, mussels can grow to 2 to 2 3/4 inches (50 to 70 mm) in 18 months, while under less favorable conditions, they may measure only 3/4 to 1 1/4 inches (20 to 32 mm) after 15 to 20 years (Seed 1976). Under good conditions in Maine, mussels generally grow to a one inch size within the first year Growth rates slow considerably after that time.

Figure 6



Mussels from two separate populations (cultured and natural) illustrating drastic differences in growth rate. The specimen on top was 11 years old at the time of sampling from a high intertidal population in the Damariscotta River, Lincoln County, Maine. The specimen below was sampled from an experimental culture raft 50 m offshore in the same region of the Damariscotta River and was 1½ years old at the time of sampling. Age estimates were based on interpretation of annual patterns on acetate peels prepared from polished and etched longitudinal shell sections (see Lutz, 1976a).

Mussels grow rapidly in the spring, summer, and fall but growth rates slow in the winter. In Maine, the optimum water temperature for mussel growth seems to be 41 to 60 degrees F (5 to 15 degrees C). Above 70 degrees F mussels may experience summer mortality (Carter Newell, pers. comm.). Low temperature may be only part of the reason mussel growth slows in the winter; there is very little food available at that time and the mussels are preparing to spawn.

As with spawning, the most overwhelming factor responsible for growth of mussels is the food supply. They filter their food from water and eat detritus or fragments of organic material, plankton, and bacteria. Competition and crowding slow the growth of mussels.

As mussels get larger they also grow more slowly. This is in part due to the larger amount of energy needed to sustain their size and because the larger they get the more they spawn. As shown in figure 7, as the length of the mussel grows the amount of energy available for growth, the cross-hatched area, reaches a peak at about 1 1/4 inches then declines. By the time the mussel is 2 3/4 inches in length, most of a mussel's energy is consumed by spawning and sustaining itself and there is little leftover for growth.

Mussels in the intertidal zone grow more slowly than mussels continually submerged because they cannot feed continuously throughout the day and are exposed to temperature extremes. Mussels that are exposed for 50% or more of the tide cycle expend so much energy regulating their temperature that they cannot increase their size (Seed, 1976).

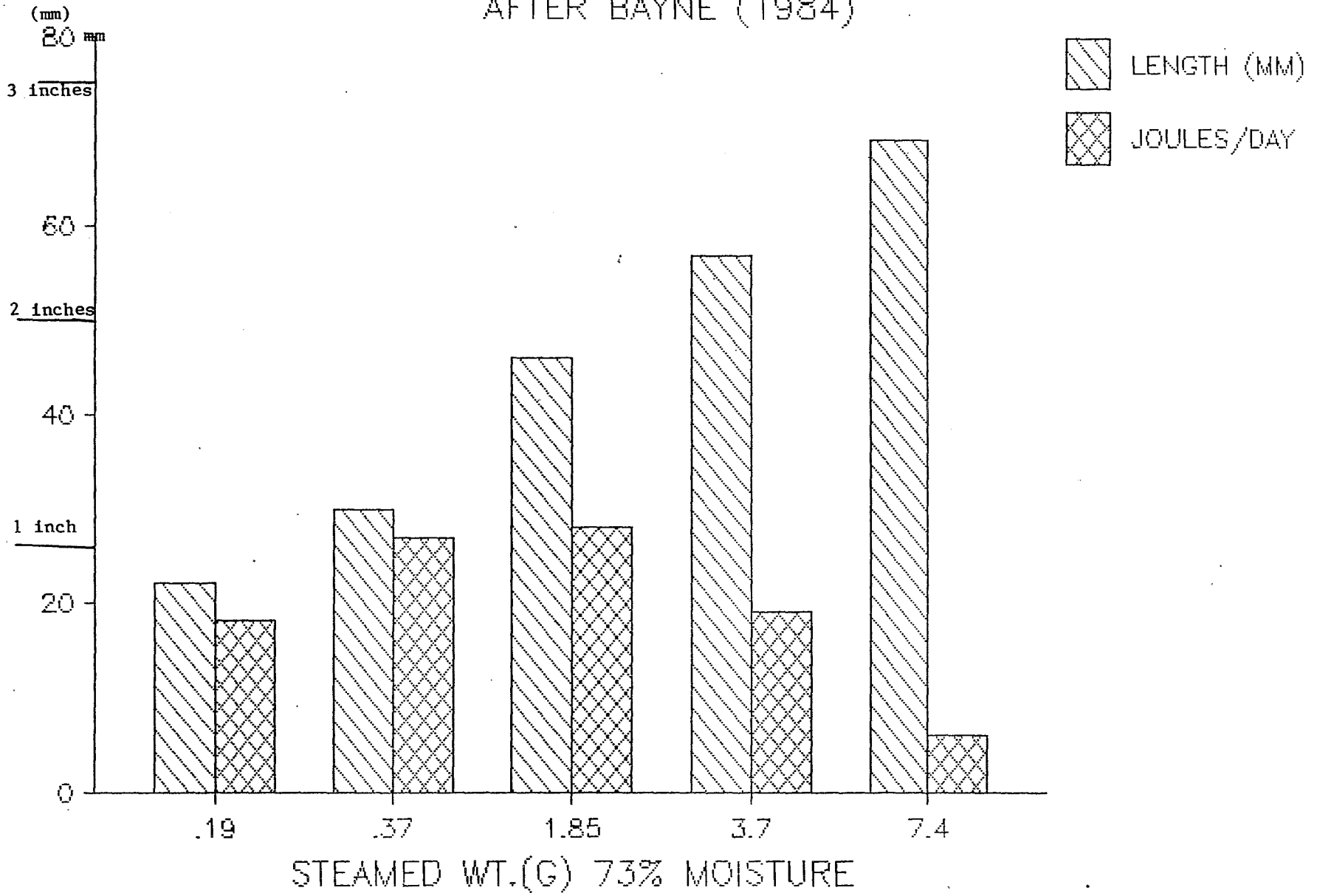
A mussel's position in a bed and the density of the bed determines how much food is available to it. In a large bed, the mussels on the edge tend to grow faster than those in the center. It is hypothesized that the edge mussels scour the food supply from water flowing over the bed, greatly reducing the available food for mussels at the center of the bed. This nutrient poor layer of water or "boundary layer" results in smaller, slower-growing mussels on the top and center of mussel beds.

A mussel's position in a bed or in the current also influences its appearance. Slow-growing mussels are generally small and thick-shelled, with "silver back" or a whitish shell where the outermost shell layers have been scraped off. Fast growing, mussels are shiny dark blue or brown and have a sharp, thin edge.

One important criteria for mussel quality is the presence of pearls in the meat. Most pearls are thought to be caused by a trematode or parasitic flatworm transmitted by the eider duck, but in flat, sandy areas can be caused by sand grains

EFFECT OF SIZE ON SCOPE FOR GROWTH

AFTER BAYNE (1984)



ingested by the mussel. Pearl incidence in mussels increases greatly after the mussel is five years old so that much of the harvesting has focused on younger mussel beds.

d. Succession

Mussels are often found in large, dense beds. It is theorized that these beds are one stage in a cycle influenced by storms and silt deposition (Thiesen 1968, as cited by Bayne 1976). The cycle begins on soft muddy bottoms inhabited by marine worms and clams. In some areas their presence hardens the surface of the bed making it more suitable for mussel seed set.

As the mussels colonize and become established in the area, mud and silt are deposited in the air spaces between their shells, raising the height of the bed. The beds resemble a carpet of shells covering a layer of mud. Their height depends on the tide levels. These are the large beds that are currently being harvested.

These wild beds continue to grow and replenish themselves until they are exposed to a major storm or hurricane. The banks may be severely damaged with the mud swept away and the mussels dissipated over the bottom or buried. The mussels on the surface gather together in patches and begin the cycle again. (Averill, pers. comm.). To some extent, harvesting mussels interrupts this succession by breaking up the structure and lowering the bed.

e. Mortality

Under normal conditions, mussels usually live about a dozen years, although mussels over 24 years old have been found (Bayne, 1976). As mussels get older and larger, they require more energy to sustain themselves and the periods during which they might require more food increase. Mussels also put out more spawn as they get older and become much weaker. They take longer to recover afterwards.

While mussels are tolerant of a wide range of environments, physical factors such as storms, salinity, ice damage, and extreme temperatures can kill a large percentage of mussels each year. Winterkill, caused by ice damage and temperature extremes is a major factor in thinning mussel beds in the intertidal zone in Maine. A cold wind at low tide can freeze 50 to 60% of the exposed mussels. Winter ice can crush or scrape mussels off a bed. While highly variable, between 20 and 50% of mussels in intertidal beds do not survive the winter. In exposed areas the percentage is higher.

Mussels are prey to sea ducks, gulls, whelks, starfish, crabs, and bottom-feeding fish. Green crabs, starfish and to some extent eider ducks are problems on aquaculture leases. Predation is most intense on the smaller mussels. Experiments

have shown that the mortality rate for 22 mm mussels was twice that for 50 mm mussels, at 67% and 34% respectively. (Thieson 1968, as cited in Seed 1976.)

For the past seven years, DMR has been conducting disease surveys of Maine mussels. Maine mussels are infected by several kinds of parasites and diseases, none of which cause mass mortalities. However, there are risks in importing mussels from areas outside of Maine. Pea crabs, Malpeque Bay disease from Canada, and Codium from southern areas are threats to Maine shellfish (S. Sherborne, pers. comm.)

2. HABITAT

a. Mussel habitat

Juvenile and adult mussels are found in every type of intertidal habitat in coastal Maine. Juveniles are extremely abundant on rocky shores, while both adults and juveniles are plentiful in low intertidal areas on gravel beaches, pilings and flats, particularly mud flats.

Mussels prefer flat shores which drain slowly or are splashed by waves but they can be found on almost any surface including pier supports and harbor walls. They are gregarious in that they like to settle densely together and frequently form mats.

Mussels are most abundant on the Maine Coast 3 feet above and below low water although further east most beds are below mean low water. Predators and competition with other organisms may limit the presence of mussels below mean low water in some areas. Subtidal beds are located almost exclusively in areas with good currents, especially around offshore islands and in the mouths of estuaries. The commercially harvested beds are principally found on intertidal mud flats and gravelly beds in shallow subtidal waters.

b. Mussel beds

Mussel beds are home to a rich community of benthic invertebrates including immature bloodworms, sandworms, amphipods, and lobsters. The larger the bed, the richer the community (Tsuchiya, 1985).

There are a number of species that are closely tied to the wild mussel beds along the Maine coast because they feed both on the mussels and other organisms found in the beds. There are major concentrations of overwintering birds that use mussels as their predominant food source, including Eiders, Goldeneyes, Scoters, and Buffleheads. These birds are tied to specific areas along the coast because of their mussels beds. The Jordan River near Mt. Desert is one of these areas.

Fish also prey on mussel beds as well as conchs, winkles, whelks, and cockles. Seals, especially younger ones, eat a lot of mussels (Field, 1916).

VIII. CURRENT RESEARCH IN THE MUSSEL FISHERY

There are several research projects currently underway to develop information for managing Maine's mussel fishery. The first is aimed at answering questions about mussel harvesting effects on the marine worm fishery. Increased mussel harvesting has raised the issue of whether the disruption of the seabed by mussel draggers destroys nursery grounds for larval and juvenile forms of commercially valuable worms. With funding from the Maine Coastal Program, DMR has begun collecting sediment samples on a monthly basis on a recently dragged mussel bed to compare with samples from a bed that has not been dragged. These samples will be analyzed to determine what species and life stages of marine worms are found there, the seasonal variation in the species, and the successional stages of harvested areas. The results of the research will be used to develop management alternatives for both the mussel and worm fisheries.

The University of Maine Fisheries and Aquaculture Research Group has until just recently funded a study of seed settlement in the Jordan River and spat settlement on eel grass. Great Eastern Mussel Farms took over funding this project in July.

The third project is funded by Sea Grant and involves developing a system for using mussel waste from shucking houses as cultch for oyster spat. It is thought that waste shells will attract oyster spat looking for a hard surface to settle on.

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APPENDIX A

Taken from: Mussel Harvest and Culture: a North American perspective, by R. A. Lutz.

Harvest Mechanization

As mentioned earlier, harvesting of mussels along the North Atlantic coast is done principally by simple non-mechanical methods (hand gathering, pitchforking, raking, etc.) or dredging (Scattergood and Taylor, 1949b; see also Chapter 2). Hand techniques not only involve considerable physical effort but also restrict the harvesting to shallow waters.

In a typical manual operation, two harvesters will work as a team. Clumps of mussels are pitchforked from shallow water into small boats (Fig. 3.3A, B), where they are partially separated by one of the harvesting crew treading over the pile (Fig. 3.3C). Very few mussels are broken by this process as their shell shape allows them to slip out from beneath the harvester's feet, with many of the byssal threads connecting individual mussels thus being broken. Separated mussels, along with remaining small

[4]The authority of the California State Department of Health Services is presently being challenged by the Pacific Legal Foundation.

A

B

Figure 3.3 A, B. See caption

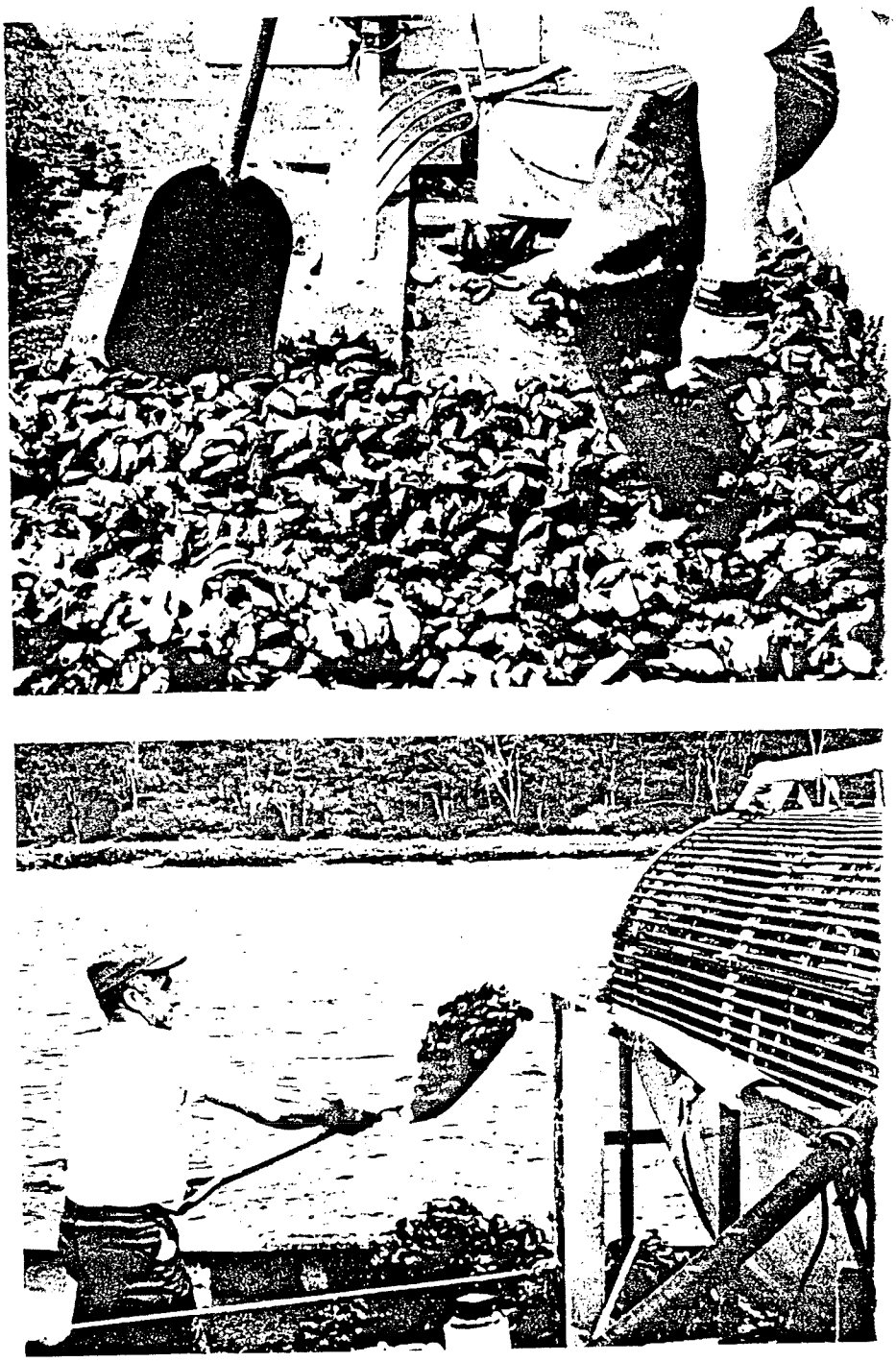
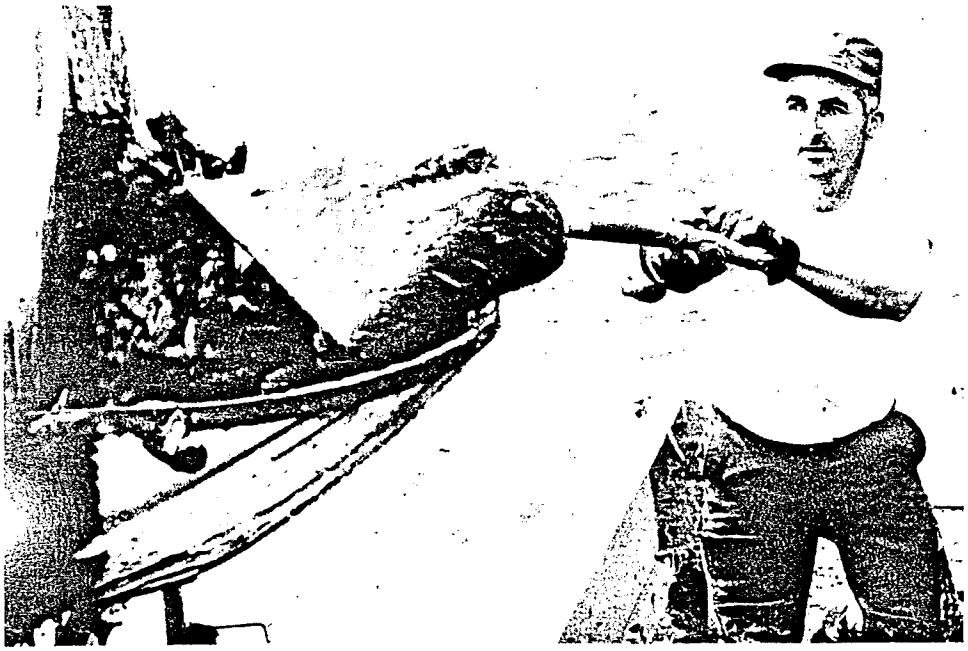
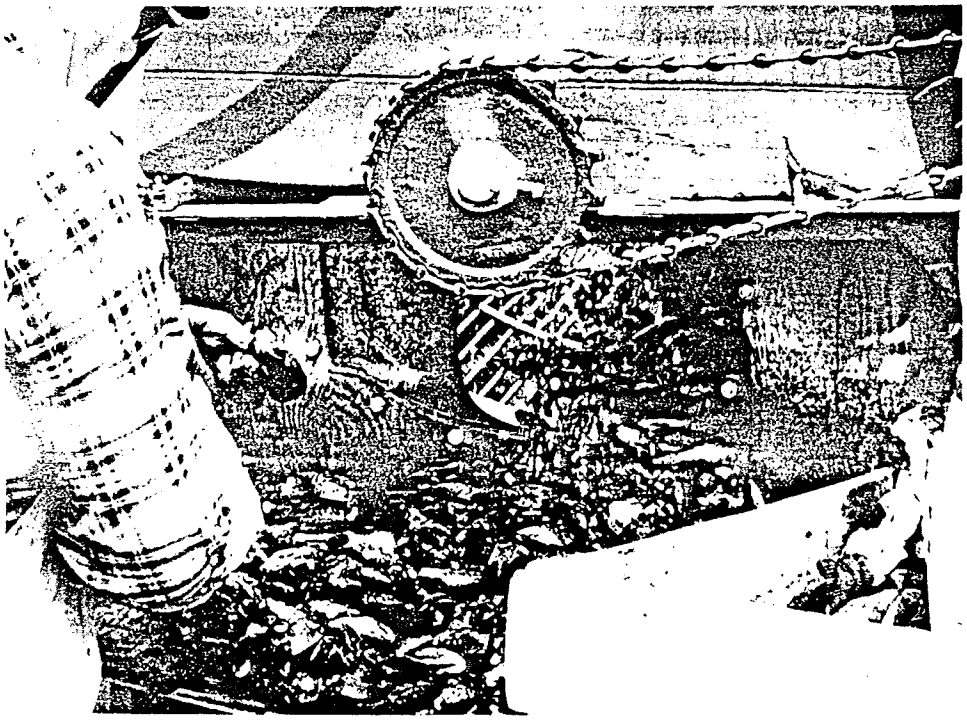


Figure 3.3 C, D. See caption



E



F

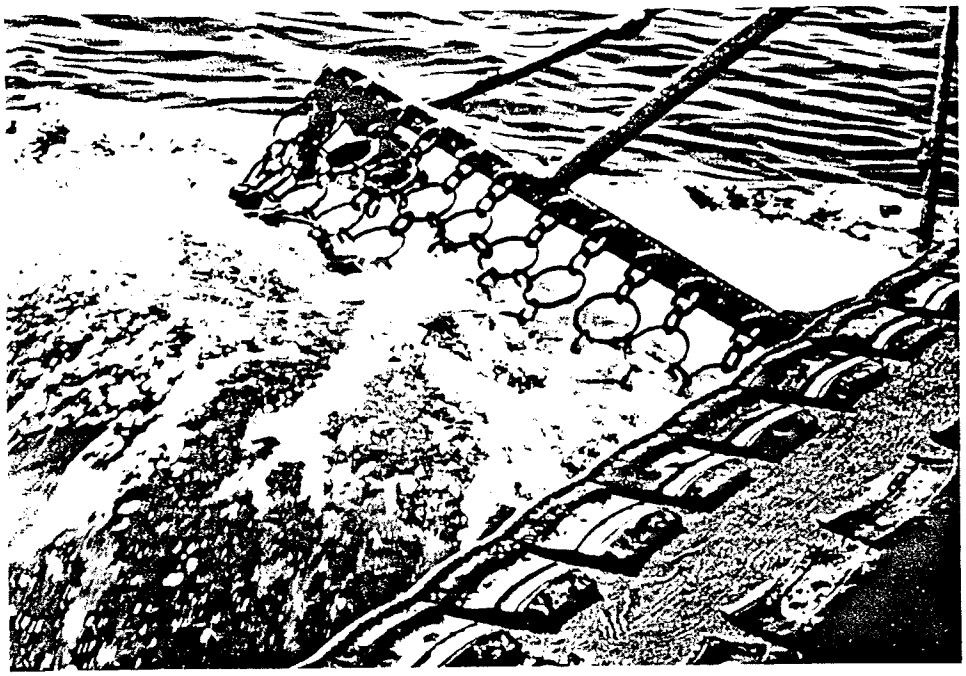
Figure 3.3 E, F. See caption

clumps, are then shoveled into a chute leading into a cylindrical drum, designed for washing and grading, which is mounted on a larger boat (Fig. 3.3D, E; see also Fig. 3.1). The washer-grader unit is operated by the second harvester. Metal teeth facing the center of the cylinder are welded onto the rods of the drum and serve to tumble the mussels and break the remaining byssal threads in the clumps as they pass through the unit. Sea water is constantly flowing from jets over the cylinder and washes the mussels as they are graded. Separated shellfish with shell lengths over 5 cm are bagged as they leave the end of the washer-grader cylinder (Fig. 3.3F).

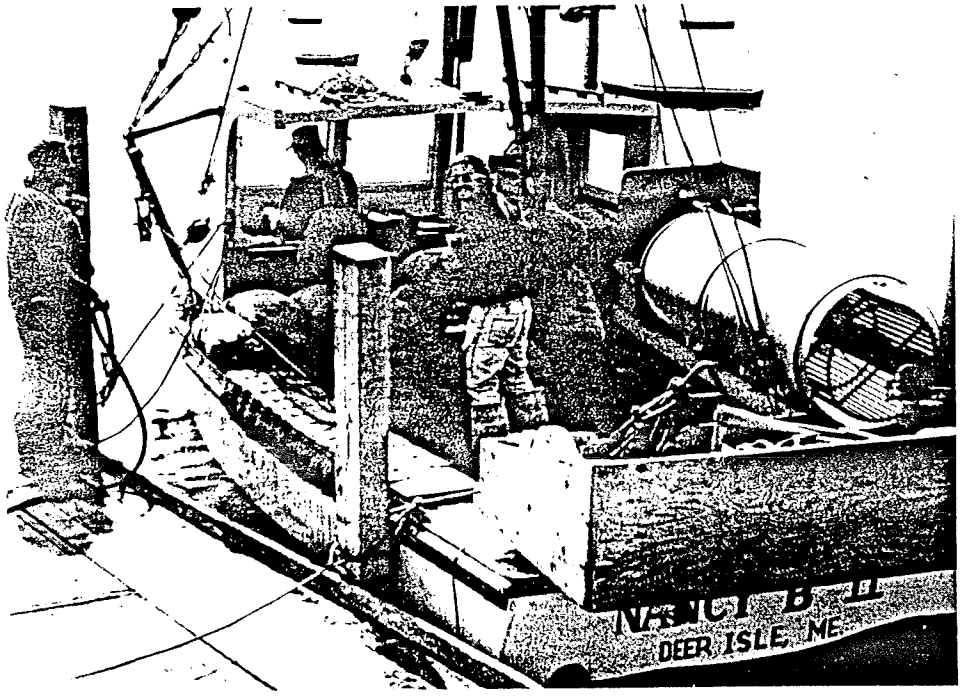
The above method of harvesting requires very little investment in gear other than a large boat with an attached washer-grader unit and two small boats. It allows the crew some choice of which mussels in an area will be harvested. However, in such an operation, all the mussels are twice moved by hand; once into the small boat and once into the washer-grader unit. In most North American environments, harvesting is limited to a few hours on either side of low tide. Approximately 60 to 100 bushels can be harvested and bagged in 3 to 4 hours by the two-man crew.

Dredging of mussels is a partial step toward mechanical harvesting. In such operations, boats (ranging in length from 9 to 12 m) similar to those employed in lobster fishing are generally used. A modified scallop drag is towed from the side of the boat over known mussel beds, in water depths of 1 to 20 m (Fig. 3.4A). Towing for 3 to 5 minutes usually fills the dredge with 7 or 8 bushels of mussels. The load of mussels is then dumped on deck, and shoveled into a cleaning drum. One type of drum which is commonly used consists of a deck-mounted unit with a hydraulically-driven rotating cage and a continuous water-wash (Fig. 3.4B-D). With this system, mussels are shoveled by hand into the unit (Fig. 3.4C). During the continuous rotation process, small mussels and single valves fall between the rods of the cage back into the water; larger mussels (shell lengths >5 cm) pass out the other end of the unit (Fig. 3.4D). Output of this system is approximately 1 to 1.5 bushels per minute. The mussels are inspected as they leave the unit and broken shells and other debris are discarded. Graded mussels are accumulated in a hopper at the stern of the boat and hand-raked into bushel bags ready for market. A second type of washer-grader unit consists of a cylindrical cage (with paddles) which is towed behind the dredging vessel (Fig. 3.4E, F). Mussels are shoveled into the cage several bushels at a time. The cage is then lowered over the stern of the boat and towed (Fig. 3.4F). The forward motion of the vessel and wash of the propeller cause the cage to rotate. Small mussels, single valves and other small debris fall between the rods of the cage into the water. After 5 to 10 minutes, the cage is hauled aboard and emptied into a hopper where broken shells and other debris are removed. As with the other washer-grader system, mussels are then hand-raked into bushel bags ready for shipment.

Fig. 3.3 A to F. A typical manual mussel harvesting operation. (A,B) Pitchforking of mussels from shallow depths (approximately 1 m) into a small flat-bottom boat. (C) Harvester treading over pitchforked mussels in order to partially separate clumps. (D,E) Shoveling of partially-separated mussels into chute leading into the cylindrical drum of a typical washer-grader unit. See Fig. 3.1 for an illustration of a similar unit. (F) Inspecting separated mussels as they leave the end of the washer-grader cylinder. Mussels are subsequently bagged ready for market.



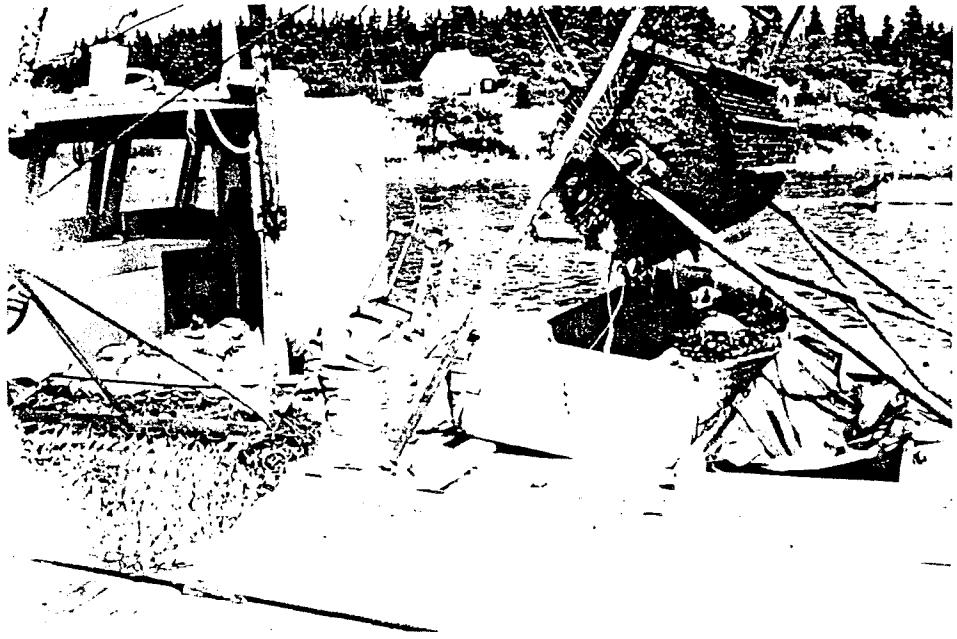
A



B

Figure 3.4 A, B. See caption

Figure 3.4 C, D. See caption



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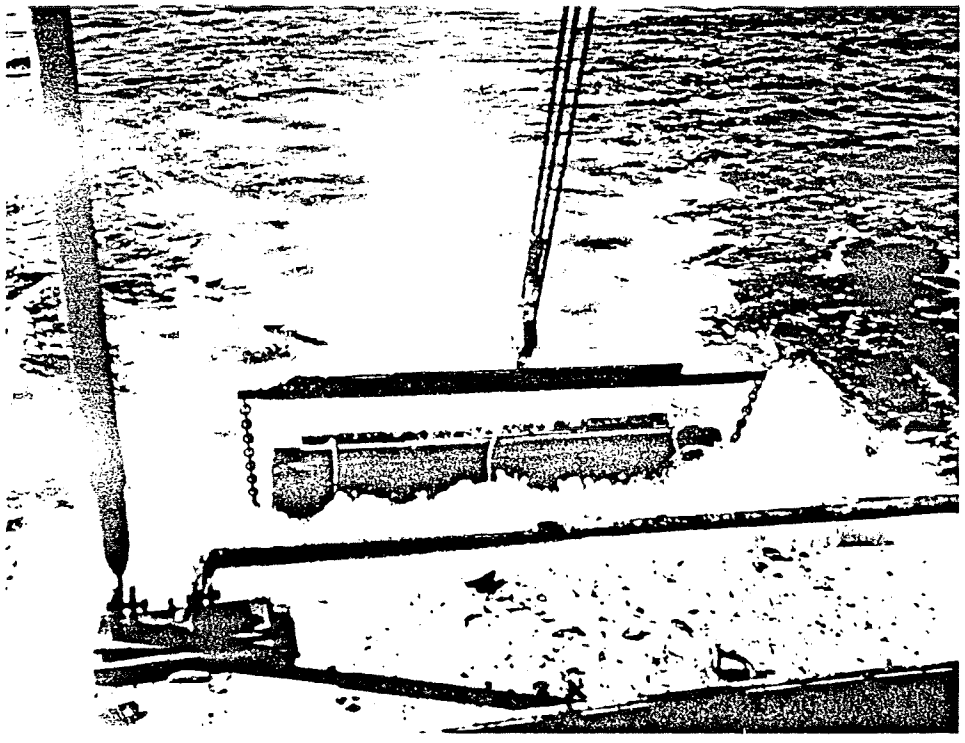

F

Figure 3.4 E, F. See caption on page 60.

APPENDIX B

Inventory of Blue Mussel Aquaculture Leaseholders
(10/86)

LEASE HOLDER	TOWN	ACREAGE	NO TRACTS	RENT
ALVIN HAWKINS	ST. GEORGE	27.30	7	$ 409.95
DAVID HUTCHINSON	STONINGTON	30.00	6	150.00
	STONINGTON	8.00	2	39.80
EDWARD A. MYERS (ABANDONED FARMS)	SO. BRISTOL	5.00	1	75.00
	SO. BRISTOL	15.00	3	75.00
EDWARD BRADLEY (CHANCE ALONG THE SEA)	FREEPORT	10.00	2	150.00
GERALD DONOVAN	DEER ISLE	36.20	9	180.90
GILBERT L. BLASTOW	STONINGTON	26.70	6	133.50
	STONINGTON	75.00	15	1,125.00
HENRY STENCE (SKYBIRD UNLTD)	LUBEC	5.00	1	25.00
ISAAC K. BEAL	BEALS	14.90	4	223.50
JAMES CHALFANT (MARITEC)	SO. BRISTOL	5.00	1	25.00
	SO. BRISTOL	15.00	3	225.00
JOHN STOTZ	BREMEN	18.70	4	93.50
MIKE & JOE SEA FARM	VINALHAVEN	15.00	3	225.00
	VINALHAVEN	35.00	7	525.00
PAUL BRAYTON	BROOKLIN	15.00	3	225.00

LEASE HOLDER	TOWN	ACREAGE	NO TRACTS	RENT
RALPH SMITH	ADDISON	5.00	1	$ 25.00
	ADDISON	8.80	3	44.00
	BEALS	4.50	1	22.50
	LAMOINE	52.70	11	791.55
RICHARD CARVER	UNORG. MRI	6.90	2	103.50
ROBERT BURGESS	STONINGTON	1.20	1	6.00
	DEER ISLE	56.90	13	284.50
	DEER ISLE	25.00	5	375.00
RONALD HUDSON	HANCOCK	20.00	4	300.00
WILLIAM GUPTILL (WOHOA BAY MUSSEL INC)	ADDISON	63.10	13	946.50
	ADDISON	20.00	4	300.00
BRUCE DAVIS	MILBRIDGE	15.00	3	225.00
CRAIG HOOPER (BLUE HILL MUSSEL FARMS)	BLUE HILL	30.00	6	450.00
KEN GRAY (MAINE MARICULTURE)	NEWCASTLE	5.00	1	75.00
	SO. BRISTOL	25.00	5	375.00
GRAND TOTAL		695.9	150	$8229.70

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APPENDIX C

OVERVIEW OF ISSUES RAISED AT PUBLIC HEARINGS

Environmental Degradation

- Dragging and its effects on the ecosystem are very complex to understand and study. Instead of looking at the whole system, study several alternative harvesting schemes including the vacuum dredge and light drags.
- The leasing regulations do not specify that environmental impacts must be addressed.
- There should be restrictions on drags. The big drags damage the beds. Beds literally furrowed by drags in Casco Bay.
- Siltation from dragging mussel beds is silting in coves, changing the character of the bottom, and disturbing marine organisms and vegetation.
- Mussel beds are much softer than other types of bottom, and kick up more silt.
- Inexperienced draggers may be taking a heavier toll on the bottom than those who have been in the fishery for several years.
- Dragging releases toxic substances to water column.

Conflicts with Other Fisheries

- Worm beds have been decimated by draggers. A dragger can wipe out an area in 2 hours that 18 people can harvest year round. Call for a closed season on dragging during the worm spawning season - March to May.
- Areas that once supported lobster are now barren. Incidence of culls is going up in Casco Bay, going down in Stonington.
- Herring schools will not enter coves immediately after they have been dragged and consequently can't be caught.
- Lobster habitat is being destroyed by aquaculture leases, siltation in coves and dragging the bottom.
- There should be a season for dragging mussels to protect other fisheries (i.e. lobsters).

Resource Depletion

- Resource depletion is more an issue of habitat degradation than availability of larvae.

- Spat is not a problem because of all the unused, unmarketable mussels left on the coast. The seed set is the issue.

Mussel Seed

- The condition of the seed and its position in the bed is more important than size in determining whether the mussels will become marketable.
- Several people asked for DMR to define a seed size.
- A regulatory seed size is difficult to adhere to because of the variation in markets and diversity of mussel sizes in a bed.
- Seed areas should be identified and discussed in aquaculture lease hearings.

Regulations

- Allow for differences in how suspension culture works when writing legislation or regulations for mussel harvesting.
- Regulating how long a mussel stays on a lease may be more important than regulating seed size.
- Examine how different nations regulate their mussel industry to understand the options.
- Dragging should be suspended in areas less than 10 fathoms deep to let the mussel resource bounce back.
- A closed mussel season would be a hardship for large dealers to work around because they need to continuously supply their markets.
- Concerned that there are no regulations for the mussel industry.
- There should be a closed mussel season during the summer spawn. It would ensure better product to the market.

Aquaculture Lease Hearings

- DMR doesn't respond to complaints brought out during the lease hearings.
- "Expert's" advice carries more weight than local people.
- Can we get a moratorium on aquaculture leases?

- The decision to grant a lease should not rest with just the Commissioner of DMR. There should be a panel or commission making the decision to appeal a lease decision, you have to work through the Commissioner. There should be another mechanism.

- DMR must do a better job of evaluating potential leases. They should be checked during the growing season and possibly at night.

- There should be an upper limit of leased acreage allowed on the coast.

- Review the stipulation that a person can only lease 200 acres. Leases are concentrated into too few hands.

- Towns should have some say in leasing procedures.