A Comprehensive Review of the Commercial Mussel Industries in the United States

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A Comprehensive Review of the Commercial Mussel Industries in the United States

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The views and recommendations contained in this report are not
necessarily those of The National Marine Fisheries Service

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A STATEMENT CONCERNING THE STATUS OF THE MUSSEL
INDUSTRY IN THE UNITED STATES WITH AN
ASSESSMENT OF RESEARCH NEEDS AND OPTIONS

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1.0 TABLE OF CONTENTS

Section		Page
2.0	MATRIX INDEX TO MUSSEL REPORT.....	5
3.0	INTRODUCTION.....	6
4.0	BRIEF NATIONAL HISTORY.....	7
5.0	CURRENT RESEARCH.....	7
6.0	SUSTAINABILITY OF THE RESOURCE.....	9
6.1	Patterns of Exploitation and Biological Limitations to the Sustainability of Natural Populations.....	9
6.2	Limits to the Sustainability of the Resource: A Maine View.....	10
6.3a	Feasibility of Mussel Culture.....	11
6.3b	The Advantages of the Cultured Mussel.....	13
6.4	Biological Constraints to Mussel Culture Using Rafting Techniques.....	14
6.5	Feasibility of Alternate Culture Techniques.....	14
6.6	Prospectus for the Culture of Other Species of Mussels.....	14
7.0	PRESENT STATUS OF THE INDUSTRY.....	16
7.1	East Coast.....	16
7.2	West Coast.....	20
7.3	Economic Profile.....	22
7.31	Introduction.....	22
7.32	Current Economic Status of the Industry: Subjective...	26
7.33	Current Economic Status of the Industry: Objective...	29
7.4	Processing.....	38
8.0	STATE GOVERNMENTS AND REGULATION OF THE INDUSTRY.....	42
8.1	East Coast.....	42
8.2	West Coast.....	43
9.0	INDUSTRY PROBLEMS AND RESEARCH NEEDS.....	47
9.1	Economic Problems of the Industry.....	47
9.11	Resource Availability, Harvesting, and Distribution...	47
9.12	Policy and Research Options.....	48
9.2	Marketing--A Situation Analysis.....	49
9.3	The Occurrence of Pearls in Mussel Meats.....	60
9.4	Handling of Mussels and the Extension of Shelf Life...	62

9.5	Closure of Shellfish Harvest Areas Due to Paralytic Shellfish Poisoning and Other Causes.....	64
9.5a	East Coast.....	64
9.5b	West Coast.....	69
9.6	Institutional Disincentives to the Expansion of the Mussel Industry.....	70
9.7	Harvest Technology.....	72
10.0	SUMMARY.....	74
11.0	SUMMARY OF RESEARCH OPTIONS AND NEEDS.....	75
12.0	PERSONAL COMMUNICATION REFERENCES.....	77
13.0	LITERATURE CITED.....	79
14.0	APPENDIX.....	88

2.0 MATRIX INDEX TO MUSSEL REPORT

Growing Waters/Environment	3.0
Technical Problems	9.5
Economic Problems	9.11, 9.12
Social Problems	-
Political Problems	8.0
Institutional Problems	9.6
Public Health	9.3, 9.4, 9.5
Resource Availability	6.0-6.6, 9.11, 9.5
Technical Problems	6.0, 7.1, 7.2, 9.3, 9.7
Economic Problems	9.11
Social Problems	9.6
Political Problems	8.0, 9.6
Institutional Problems	9.6
Public Health	9.4, 9.5
Harvesting	6.1, 6.2a
Technical Problems	9.7
Economic Problems	9.11
Social Problems	8.0
Political Problems	8.0
Institutional Problems	9.6
Public Health	9.3, 9.5
Processing	7.4
Technical Problems	7.4, 9.4
Economic Problems	7.4, 9.4
Social Problems	7.4
Political Problems	7.4
Institutional Problems	7.4
Public Health	7.4, 9.4
Marketing and Consumption	3.0, 4.0, 9.1, 9.2
Technical Problems	9.2
Economic Problems	9.11
Social Problems	9.2
Political Problems	8.0
Institutional Problems	9.12, 9.6
Public Health	9.3, 9.4, 9.5

3.0 INTRODUCTION

The blue mussel, Mytilus edulis, is extremely abundant along the east coast of North America from Cape Hatteras to Labrador, and many large beds contain high-quality mussels (Field, 1908). Mytilus is also abundant on the west coast. Except during World War II, there has been little interest in harvesting this species for food (Dow and Wallace, 1954; Field, 1922).

However, a renewed interest in the harvest of Mytilus has resulted from pressures on present fishery products, especially clams. Increased population, rising fuel costs, changes in weather patterns, and present economic conditions have combined to deplete the supply of certain fishery products and drive the price of food consistently higher. The availability and price of several seafood species has been affected by lack of supply and increased demand. One method of providing a sustainable yield of seafood products is to encourage the use of currently under-utilized species, such as the blue mussel.

For a number of reasons, the blue mussel industry has been slow to materialize in the United States. When clams and oysters were abundant and inexpensive, there was little impetus to try something new. More importantly, the American public has never been adequately introduced to fresh or prepared mussels of high quality, and consequently is unaware that mussels are a good seafood product. The incidence of pearls, muddy flavor, labor involved in cleaning, improper handling of some mussels, and misconceptions about the product safety (particularly with reference to shellfish poisoning) are some problems that have discouraged many potential users. The supply of quality mussels from the natural beds has been limited and unreliable, which makes them difficult to obtain anywhere but in the most specialized markets and restaurants. These factors have discouraged market development.

In April of 1973, the consumer boycott of beef products in protest of rapidly escalating meat costs set a national mood which proved receptive to new sources of protein. The Maine Department of Marine Resources and the University of New Hampshire capitalized on this situation by undertaking a pilot project to test the consumer acceptance of blue mussels. In-store demonstrations throughout New England and at seafood shows across the country have resulted in increased demand for mussels, both regionally and in the traditional New York and Boston markets (Bouchard, 1976). During the spring of 1975, Maine mussel productivity was estimated as high as 2,500 bushels per week (Bouchard estimates). Yearly production at this rate would result in an annual yield of about 2,000,000 pounds wet weight, nearly equal to the peak wartime production of 2,594,000 pounds (1944).

The use of the west coast populations of mussels is relatively unexplored. Although Alaska has vast resources, little is known of the demand there. Mussels are reportedly in demand in Washington, Oregon, and California, although few are being taken at present.

However, several immediate and long range problems confront the developing mussel industry. Outlined, these are:

- (1) Consumer acceptability and market demand
- (2) The occurrence of pearls in the meats
- (3) A short shelf-life of the fresh product
- (4) The periodic closure of shellfish harvest areas due to blooms of the dinoflagellate Gonyaulax tamarensis in the East and G. catanella in the West.
- (5) A lack of conservation regulations governing wild harvest.

The following report outlines these problems while providing a detailed assessment of the present status and research needs of the mussel industry in the United States.

4.0 BRIEF NATIONAL HISTORY

Despite the availability of large standing crops of mussels, the consumption of this shellfish in the U.S. has historically been low, with a consistent, albeit small, demand only in a few metropolitan areas (Bouchard, 1976). From 1929-1941, fewer than three processing plants handled mussels in the U.S. (Fisheries of the U.S., 1975). It was not until World War II that mussels were processed extensively as a substitute protein source. Most of these were canned for export.

The number of processing plants which processed mussels increased in 1942-1943 to 15, and 12 or more continued to operate through 1946. Peak production (1945) reached 823,000 pounds of canned product. After 1946, production rapidly decreased. Today, only a few plants are known to process mussels in this country.

Mussels have recently received renewed attention as a valuable seafood resource as reflected by increased commercial landings (see Section 7.3). Various institutions and businesses have become interested in the potential of the mussel industry. This has led to both increased research and investment on both coasts of the United States. Recent surveys indicate a large market potential for mussels (see Section 9.1). The nation's first commercial mussel cultivation effort was begun in Maine in 1973.

5.0 CURRENT RESEARCH

Research on the biological and economic problems associated with stimulating and sustaining the use of blue mussels by American consumers is currently underway at a number of institutions in the United States. Research at the University of Maine has contributed significantly to the knowledge of pearl formation, age determination, and growth in mussels.

Research programs operated jointly by the University of Maine (U.M.O.) and University of New Hampshire (U.N.H.) are exploring the economic and market development aspects of the mussel industry as well as the experimental culture of M. edulis (Lutz, 1976b; Myers, 1976), and studies at U.N.H. and Harvard (Hurlburt, 1977) have resulted in new mussel recipes designed for large-scale restaurant preparation and home consumption. Problems of shelf-life and handling practices are being resolved (Slabyj and Hinckle, 1976). Paralytic shellfish poisoning (PSP) and other conditions of public health concern are monitored on a regular basis, and the biology of the PSP organism is being studied by scientists at the Bigelow Laboratory for Ocean Sciences and U.N.H. (Yentsch et al., 1975; Sasner and Ikawa, 1975; Buckley et al., 1976; Sasner et al., 1974). Studies currently in progress at the Darling Center, University of Maine, and at a nearby commercial mussel operation are providing information needed to develop new procedures for commercial raft cultivation in this country. Growth studies of mussels along the New England coast are being conducted with the assistance of a number of private cooperators (Lutz, 1976b).

Measurements of the uptake, accumulation and loss of radionuclides by Mytilus edulis experimentally cultured in the heated effluent of a nuclear power reactor was begun in May 1976 by Hess and others at U.M.O. employing methods used in similar studies on the American oyster, Crassostrea virginica (Hess et al., 1975; Price et al., 1976). The research effort is aimed at (1) establishing biological accumulation rates to encourage a decision from the FDA on wild harvest and shellfish aquaculture in areas affected by thermal effluents from nuclear power plants, (2) suggesting environmentally optimal effluent discharge schedules, and (3) determining the extent to which heated effluents can benefit aquaculture. The Environmental Protection Agency laboratory at Narragansett, Rhode Island is investigating possible causes of observed large-scale fluctuations in distribution, vitality, and extent of natural mussel populations in Narragansett Bay.

Current research on M. edulis on the west coast of the United States has been centered at the University of Washington during the last several years. The biological and economic feasibility of establishing a mussel industry in Puget Sound is being investigated. Results of the last several years indicate that conditions in Puget Sound are conducive to successful raft culture (Chew and Chaves, 1976; Chaves, 1976). Mussels have been found to grow to market size (50 mm or more) in a period of one year. Research is also being conducted on the possibilities of obtaining mussel seed from a hatchery and comparing its growth with natural seed growth. Marketing studies are being developed for the mussel industry in the northwest to find out how to present a new and different product on the market and establish where the greatest consumer demand will be.

Paralytic shellfish poisoning (PSP) has been known in the northwest since the 18th century (Orth, 1975). PSP research is being conducted at the University of Washington (Norris and Chew, 1975), at the University of Alaska (Chew, pers. comm.), and at the University of Wisconsin (Roberts, pers. comm.). Growth parameters are still being defined and rapid, inexpensive chemical and bioassay methods are being sought.

6.1 Patterns of Exploitation and Biological Limitations to the Sustainability of Natural Populations

Most commercially harvested blue mussels in the United States are taken from Maine, Massachusetts, Rhode Island, and Long Island, but the harvest fluctuates greatly among these and a few other areas. The behavior of blue mussel populations is unpredictable because they are susceptible to many changing environmental conditions. The human factor also exerts great influence, depending on fishing pressure and market demand and upon the whims of the fishermen.

Maine affords a favorable environment for the production of M. edulis (such as an abundance of appropriate substrate, productive coastal waters, and suitable temperatures), and supports the most extensive populations. However, evidence indicates that the extensive harvests of the World War II years depleted the commercial exploitable stocks (Dow and Wallace, 1954); production in 1947 was only 2 percent of the previous year's catch. The Long Island and Virginia resources were also greatly taxed during the war years (Fisheries Statistics of the U.S., 1975), and production declined with the post-war decrease in demand.

New Jersey mussel resources are extensive, but are now largely condemned due to high levels of pollution. After seven years of having no reported commercial catch, New Jersey produced 7,050 and 15,000 pounds in 1974 and 1975, respectively. The harvest dropped off to an insignificant amount again in 1976, apparently because most shellfishermen devoted their efforts to clamming in order to take advantage of inflated clam prices (LoVerde, pers. comm.).

Narragansett Bay yielded some of the nation's largest catches in the 1950's, and again in 1974-76. However, exploitable populations were not found in the bay from 1963-73 (Wilcox, pers. comm.).

A productive blue mussel dredge fishery in the Oyster Bay area of Long Island ceased to function in 1974 when a principal bed of 30 acres disappeared. The cause of this disappearance is unknown.

Many fishermen report that large-scale mussel mortalities occur as a result of severe environmental conditions. Extensive mussel grounds from southwestern Rhode Island to Stonington, Connecticut, were destroyed by the 1938 hurricane. High mortality rates are frequently a common phenomenon. Estimates of annual late-summer mortalities of blue mussels are as high as 95 percent on the eastern shore of the Delmarva Peninsula.

A once-flourishing West Coast mussel industry has declined steadily since the turn of the century. Hydraulic mining, which smothers mussel beds by depositing thick layers of silt on the sea floor, was partly responsible for this decline. Pollution from human populations has closed many additional areas (Smith, pers. comm.). Most of the present harvest, which is very limited, is used for bait.

It is known that M. edulis occurring in natural beds require at least two to three years to grow to market size. They do not always spawn and set in the same places year after year and may not spawn at all if conditions are poor. With this in mind, it seems that natural mussel populations would have difficulty renewing themselves year after year.

These fluctuations in the availability of mussels indicate problems with trying to maintain the resource and develop an industry based on a sustainable and dependable supply. A better understanding of the environmental parameters which affect Mytilus populations is needed, and successful fishery management techniques need to be devised accordingly.

6.2 Limits to the Sustainability of the Resource: A Maine View

Conditions favor the growth and survival of mussels along the Maine coast, as they are abundant there. Scattergood and Taylor (1949) estimated that 20 million pounds of mussels existed in commercially exploitable beds in Maine at the time of their survey. The first large-scale exploitation of the blue mussel in Maine occurred during World War II, when they were canned as a substitute protein source. The 1944 commercial landings were 2,594,000 pounds of wet meat (N.O.A.A.).

Despite the apparent abundance of these animals, however, Dow and Wallace (1954) have indicated that the post-war decline in mussel production was due not only to a shift back to more traditional protein sources, but also because readily available natural stocks were nearly depleted. Concerning the second factor, they state that the "canning operations during the preceding war years had cropped almost completely the readily available supply."

In addition to that provided by Dow and Wallace (1954), other evidence indicates that the renewability of natural mussel populations may be limited, despite their great fecundity (Field, 1922; Mossop, 1921; Storrow, 1940; Scattergood and Taylor, 1949). Growth of recently settled spat in populations of mixed age is greatly reduced (Seed, 1969). Recruitment of mussels on bare rocks does not seem to be successful either. Myers (pers. comm.) has found that mussels fail to re-establish themselves on areas of offshore rocks scraped of adults in April, before the spring spawn. The smaller mussels which had been left in numerous crevices had completely disappeared by August and October, and no mussels were found on the scraped surfaces. Eider ducks (Somateria mollissima) had been observed feeding on and about the scraped ledges (Myers, pers. comm.). Adult eiders have been known to consume up to a pint (approximately 425 g) of mussels per day (Field, 1922), and the stomach content of these ducks in the summer has been found to consist of up to 80 percent young mussels (Graham, 1975). Eiders prey heavily upon the mussel beds of the Dutch Waddensee (Thiesen, 1968).

Whatever the precise explanation, natural populations do not appear to be capable of a large, sustainable yield, and earlier findings (Dow and Wallace, 1954) indicate that we may now be approaching that threshold level.

Conversations with commercial mussel harvesters in Maine indicate that several mussel beds are being less carefully picked--that some harvesters are clearing some areas of apparently stunted mussels with a known pearl incidence. Faced with increasing consumer demand (Miller, 1964) and the need for market quality control (Dow and Wallace, 1954; Lutz, 1974a), a scrupulous examination of natural stock management and an assessment of the total resource is needed.

Aquaculturing of mussels is a means of expanding the resource base. Preliminary experiments in culturing mussels have been successful in Washington and Maine and indicate a potential for expansion of the industry.

6.3a Feasibility of Mussel Culture

The blue mussel is a good candidate for successful shellfish culture. It is a more efficient filter-feeder, exhibits more rapid growth, yields a higher meat : total weight ratio, and is nutritionally superior to more traditional shellfish species (Lutz, 1974a; Myers, 1974; Scattergood and Taylor, 1949; Joyner and Spinelli, 1969; McLeod, 1975; Field, 1908; McLean, 1972; Loosanoff, 1943; Mason, 1971).

Shellfish culture in the United States has already met with some production and economic success. In particular, at least one Long Island, New York, oyster operator has made a success of spawning oysters (Crassostrea virginica), rearing the larvae to metamorphosis, and planting leased bottom with the resulting seed. Adults are harvested 2-3 years later by conventional dredging operations (Relyea and Zahtila, pers. comm.). Several other shellfish companies are trying similar culturing approaches to the production of oysters (C. virginica) and quahogs (Mercenaria mercenaria) (Chanley, Czyzyk, Campbell, and Hart; pers. comm.). Pilot mussel culture operations are presently underway in Maine (Myers, 1974) and Washington State (Chew and Chaves, 1975), and in Canada (McLeod, 1975).

The methods for raising mussels are simple because natural set is plentiful. Mussel larvae attach themselves to any suitable substrate suspended in the water column at the time of natural spawn (May-June) (Lutz, 1974a; Bayne, 1976; Davies, 1974). Collection of spat on ropes, then, is a relatively easy and inexpensive operation (Lutz, 1974a). However, because the time of spatfall varies from year to year and because the extent of spatfall in any one locale varies from year to year, this collection method is not dependable or efficient from a production standpoint. Experiments in hatchery spawning and setting on ropes are being conducted at Abandoned Farm, Inc. on the Damariscotta River (Porter, pers. comm.). Present culture methods depend on the collection of seed mussels from natural populations for attachment on the culture substrate (Hurlburt and Hurlburt, 1974). This dependence on wild parent stocks further necessitates the management of natural populations.

Mussel culture by various methods is widely practiced in Spain, France, and the Netherlands, and has been described there and in other localities by numerous workers (Andreu, 1968; Mason, 1971; Bardach et al., 1972;

Hurlburt and Hurlburt, 1974). There are two distinct advantages which the Spanish raft system has over the other two culture methods mentioned. The first is the utilization of three-dimensional space. The resulting production per surface area far surpasses that possible on the land or sea bottom (Andreu, 1968). The annual yield of an average raft (5,500 square feet) is 5060 tons of mussels (Mason, 1971). Adler (1966) reports that one European mussel farm averages 108,000 pounds of mussels per acre per year using this method. This production is over 20,000 pounds of high-grade protein per acre per year. The second advantage is that the mussels are suspended above the bottom, and so are effectively free from bottom predators such as the starfish (Asterias spp.), snails (Thais), and crabs (Carcinus meanas) (McLeod, 1975). Spanish rafts yield higher productivity than any other current method of mussel husbandry (Mason, 1971; Lutz, 1974a; Hurlburt and Hurlburt, 1974).

Furthermore, this technique is most suited to the geography of the Maine coast. Maine does not possess the extensive tidal flats or extensive tidal range of northern France, where the bouchot system is employed, nor can it offer extensive offshore beds for bottom culture, as in the Netherlands; but the drowned coastline does afford numerous, deep, protected bays and inlets characterized by high summer productivity and good tidal energies. The five Spanish rias of the northwest coast are deep, drowned river valleys with steep, granite sides and a (maximum) four meter tidal range producing a maximum tidal current of 50 cm/sec (Andreu, 1968). They are deeper, longer, and wider, but also less protected than the inlets characteristic of the Maine coast. Although the surface areas of these rias are very large (the largest, Ria de Arosa, is 33 km long and covers 230 square km), the rafts are located only along the coastline in a maximum depth of 35 feet (McLeod, 1975). Work by Fraga and Vives as reported by Andreu (1968) measured primary productivity from 1.1 - 61.6 mg carbon per liter per hour (mg C l⁻¹ hr⁻¹) with an average production of 10.5 mg C l⁻¹ hr⁻¹.

Two rivers along the central coast of Maine, where experimental mussel culture is presently underway, are 14.96 km and 18.70 km in area at mean low water (MLW) (Damariscotta and Sheepscot Rivers, respectively). The mean depths of these MLW areas are 8.69 and 9.43 meters respectively (McAlicie, unpubl. data). Tidal ranges in these rivers approach 4 meters, and tidal velocities exceed 50 cm sec⁻¹.

Primary productivity was measured in a deep harbor of similar geological features (Boothbay Harbor) located between the mouths of these two rivers. August values are up to 39.8 mg C l⁻¹ hr⁻¹. The lowest productivity values appear in January and February and are about 1/10 of the July and August values (Yentsch, unpubl. data).

Environmental conditions, then, indicate a good prospectus for Mytilus culture in Maine. This has been substantiated by recent mussel-farming efforts on the Damariscotta River (Lutz, 1974a). If these efforts prove successful in developing an economic industry, methods for extending culture procedures to waters south of the Gulf of Maine could be developed.

6.3b The Advantages of the Cultured Mussel

The advantages of rafting over natural harvest have been discussed above. The rafting system, by making use of three dimensional space, achieves the greatest exposure to food supplies in the water and is hence capable of supporting extremely high animal densities. Use of natural energy flows is maximized, animal biomass is concentrated (Nixon et al., 1971), and so management and harvest energy is minimized. Utilization of this presently under-utilized species can thus be done quite efficiently.

Rafted mussels grow more rapidly than those in natural populations (Andreu, 1968; Lutz, 1974b, 1974d; Hurlburt, 1975; McLeod, 1975). One reason is that their constant submergence enables them to pump water and to feed at any time (McLean, 1972). The thinned population experiences less growth retardation by crowding (McLeod, 1975) and fewer mortalities due to smothering (Thiesen, 1968). Growth is enhanced by the shaded conditions afforded by constant submergence (Coulthard, 1929; Bardach et al., 1972), and the animal is not traumatized by severe wave action at low tide or extremes in daily temperature regimes with the tidal cycle (Mason, 1971; McLeod, 1975).

In addition, the cultured mussel presents a superior product. At market size of 50 mm, the cultured mussel represents a meat yield of nearly 50 percent (Loosanoff, 1943; Andreu, 1968). This compares favorably with a 10 percent yield for the American oyster, C. virginica (Loosanoff, 1943). This is also higher than for natural populations of mussels which have relatively heavier shells (Loosanoff, 1943). The shells of the rafted mussels are clean (unfouled) and the byssus is easily removed (McLeod, 1975). This has the advantage of reducing any trauma when pulled from the substrate and leaving a smaller byssal gape through which shell liquor may be lost in shipment (Bardach et al., 1972). There is seldom any byssal thread or "beard" left on the mussel meats inside the shell. This beard would otherwise have to be removed in processing after the shell is opened. The valves are more easily shucked. Furthermore, mud, which is often trapped in the wild mussels during harvest, seldom, if ever, presents a problem to the processor of cultured mussels.

6.4 Biological Constraints to Mussel Culture Using Rafting Techniques

The accelerated growth and superior condition of rafted mussels is due to their maintenance under optimal available conditions in the environment. Simply stated, this involves maximizing exposure to food while minimizing physical trauma and predation. The success of this technique is directly dependent upon the production of food and oxygen in the growing waters and upon adequate circulation.

A dense population of mussels is an extremely heterotrophic community requiring an environment which can provide abundant supplies of food and oxygen and assimilate or otherwise remove and process metabolic wastes (Nixon et al., 1971). The rapid growth of this sessile organism is subsidized by physical energy flows in nature--mussels require considerable volumes of

water to meet their metabolic needs, and these volumes are provided primarily by tidal circulation. While these free energy flows help to make mussel aquaculture an extremely efficient means of protein production, limits to the productivities of natural waters necessarily limit the amount of shellfish biomass which can be supported before competition for available nutrients limits over-all growth.

A consideration of possible constraints to mussel production in an estuary or bay would involve an extension of the ecological concept of "carrying capacity" to the culture or husbandry of mussels. By evaluating the ability of a body of water to support dense aggregations of shellfish, the optimal production density can be determined. This evaluation would involve an assessment of primary productivity, levels of suspended particulate matter, tidal velocities and exchange, and the effects of temperature, salinity, and particle size on rates of filtration. The importance of these findings to the efficiency of aquaculture production is obvious.

Aspects of this problem have been investigated in Europe (Jørgensen, 1949, 1952, 1959, 1960, 1966; Fraga and Vives, 1960; Davids, 1964; Dral, 1968), and some studies of ecological energy flows of natural populations of mussels and other shellfish have been conducted in this country (Odum and Smalley, 1959; Kuenzler, 1961; Dame, 1972).

6.5 Suitability of Alternate Culture Techniques

Although raft culture is the method apparently most suited to the Maine coast, other production methods have proven successful in Europe (Hurlburt and Hurlburt, 1974) and may be applicable to other areas of the United States. For example, the extensive, sandy bottoms of shallow bays on the East Coast south of Maine may prove to be more suited to bottom culture methods. Extensive natural populations on the bottoms of many of these bays (see Section 7.1) indicate conditions favorable for growth and a potential for increasing production with proper management and re-seeding. A pilot re-seeding project has been initiated in Ipswich, Massachusetts. The applicability of alternate methods of mussel cultivation to various sections of the country should be explored.

6.6 Prospectus for the Culture and Harvest of Other Species of Mussels

While the blue mussel, Mytilus edulis, is the mussel species normally harvested and cultivated within the United States, several other indigenous species of mussels offer attractive commercial potentials.

Northern horse mussels, Modiolus modiolus, have recently been harvested in limited quantities along the Atlantic coast and were enthusiastically received at an international European food exhibition (Bouchard, pers. comm.). The life history and aquacultural potential of this species have been studied in some detail at the University of Maine (Lutz and Porter, 1975; deSchweinitz and Lutz, 1976; Lutz, 1976b). The growth and mortality of experimentally cultured M. modiolus in two Maine environments, including the heated effluent

waters of a nuclear power plant, is currently under investigation, and the uptake of gamma-emitting radionuclides by these mussels is closely monitored (Lutz, 1976b).

The Atlantic ribbed mussel, Geukensia (=Modiolus) demissa, is abundant in brackish waters along the Atlantic coast from the Gulf of St. Lawrence to the northeast coast of Florida. With the exception of small quantities taken during World War II, this species has received little commercial attention (Castagna, pers. comm.). The aquacultural potential of this mussel in various estuarine environments is unknown.

The Californian mussel, Mytilus californianus, is currently harvested (primarily for bait) in both California and Oregon (Price, pers. comm.) (see Section 7.2). Although the growth rate of this species has been studied by several workers (Coe and Fox, 1942, 1944; Fox and Coe, 1943; Dehnel, 1956), little or no research has been directed toward assessment of the cultivation potential of this mussel.

In order to adequately assess the sustainability and aquacultural potential of the above species of mussels, relatively accurate methods for determining the age and growth rate of individual specimens should be developed. The techniques described by Lutz (1976a) for Mytilus edulis and Dodd (1964) for Mytilus californianus offer attractive potentials and should be applied in future research efforts to all three of these species. Experimental culture of these bivalves in various marine and estuarine environments should also be encouraged. The market potential of these under-utilized mussel species requires assessment.

7.0 PRESENT STATUS OF THE INDUSTRY

7.1 East Coast - Willard Brownell

This section is a state-by-state analysis of blue mussel fisheries, based on extensive interviews with fishermen, dealers, government officials and biologists. The information included represents facts and opinions that are generally agreed upon by several people interviewed in a particular area.

Maine. Mussels are abundant along most of the Maine coast. Although mussel beds exist in some areas, the coast as a whole is characterized by prominent rock ledges and outcroppings, and it is on this rocky substrate that most mussels are found. The southern coast of Maine, west of Cape Elizabeth, is largely closed to shellfish harvest due to fecal contamination. Dense mussel populations are found east of this cape, and these are harvested commercially and recreationally. Most commercial harvest is concentrated in the mid-coast section, Muscongus and Penobscot Bays. More than 3,000 bushels per week are harvested, primarily by rake from small, flat-bottomed skiffs, and exported to Boston and New York for further distribution. Recreational mussel harvest is minimal. Attempts to develop the market for mussels have resulted in increased landings and exports, and have stimulated the development of the nation's first commercial mussel aquaculture operation.

New Hampshire. The Hampton and Piscataqua Estuaries of New Hampshire produce extensive and healthy populations of blue mussels, especially on pilings, mud bars, and the sides of the outer marsh channels. There is no record of commercial harvest of this area. Some recreational digging for mussels occurs, primarily on weekends. There are no significant numbers of blue mussels in the coastal subtidal zone.

Mussels are generally considered to be a plague, and are successful competitors of the important soft shell clam (Mya arenaria) stocks. Occasionally, the state will hire a fisherman to dredge mussels off the clam flats.

Massachusetts. The most plentiful harvests of M. edulis in Massachusetts have been made by pitchforking and raking in the harbors and outer estuarine channels of Buzzard's and Cape Cod Bays. Traditionally productive grounds that have yielded very few mussels in 1976 are Plymouth, Kingston, and the North River at Marshfield. Some mussels were taken at Eastham, Duxbury, and Sandwich in 1976, but catches were relatively low.

Most Massachusetts mussel fishermen are principally clam diggers who collect mussels by hand when requested by local dealers. Dredging, although seldom employed, is practiced in the North River, Vineyard Sound, and in the mouth of Narragansett Bay by one Cape Cod boat. The shellfishermen receive from \$2.50 to \$4.50 per bushel of mussels collected in sacks. They gather 40-60 bushels of mussels in a day's labor of 4-5 hours.

Small numbers of blue mussels are gathered commercially at Gay Head, Plum Island Sound, Ipswich, Scituate, and in the Cape Cod Canal. A team of divers in Gloucester collects mussels for commercial sale from underwater beds.

Most Massachusetts shellfish dealers feel that there is much room for expansion of mussel markets, primarily in New York City, where most of the state's production goes. However, sometimes the market becomes unexpectedly flooded, a shipment may be rejected, and dealers and fishermen get discouraged. Demand is very slowly increasing in Massachusetts. More and more people go out to gather mussels at low tide for home consumption.

Dealers sell blue mussels for \$5.00-\$9.00/bushel locally and \$6.50-11.00 delivered in New York.

Rhode Island. One of the principal U.S. mussel fishermen uses a standard shellfish dredge to work the beds of Narragansett Bay in 20 to 100 feet of water. He can average 100 bushels/hour if the fishing is good, and sometimes harvests 5,000 bushels/week. These mussels sell for \$5.00/bushel wholesale, delivered in New York. This fishery fluctuates greatly, due to massive mortalities which occur very unexpectedly. One such die-off started in late October 1976. When the Rhode Island supply decreases, New York distributors request more mussels from Massachusetts and Maine dealers.

There is also a small sport fishery for blue mussels along the banks of Narragansett Bay, the Providence River, and the Point Judith area. The principal mussel spawning in Rhode Island occurs in September and October.

Connecticut. Stonington fishermen used to harvest mussels with scallop dredges in Fisher's Island Sound and along the shore of Rhode Island. Sometimes these were sold to New Jersey dealers, but the majority were used for cod bait on the hooks of "tub trawls." This practice has not been employed in recent years, and the only mussel collecting activity is restricted to "weekenders" who work the outer breakwater and the rocky, protected shores at low tide.

There are many dense mussel beds in depths of 40-60 feet throughout a wide area from Niantic, through Fisher's Island Sound, out to (and around) the Moraine Islands to the east. Biologists feel that dredging for these mussels would be very harmful to the very productive bottom communities that have developed within and around the mussel beds. The beds also serve as an ideal habitat and food supply for lobsters, which are abundant in the area throughout the year. Few mussels are found along the Connecticut coast southwest of these areas.

Divers have observed major mussel mortalities in the open water beds due to silting-over (smothering) and predation (Asterias starfish and Pagurus hermit crabs). Most individuals in these beds are less than 5 cm in length.

New York. Blue mussel fishing on Long Island is now limited to digging, tonging, and raking in the estuaries for home and some commercial use. Long Island mussels are believed to be of lower quality than the ones that come from Maine, and often bring lower prices in the city markets. The baymen receive \$4.00/bushel, but generally only collect mussels commercially when they cannot get clams or oysters, or when a dealer makes a special request.

Mussel fishermen are also frequently hampered by having their prime gathering areas closed by the state due to high coliform counts in the growing waters. The most frequently fished areas currently are Cold Spring Harbor, Mt. Sinai, Smithtown, Port Jefferson, Mattituck, Huntington, and the mouth of the Nissequogue River.

There is a good mussel set nearly every year all around Long Island. A major spawning occurs in July. Very dense sets are common and extreme overcrowding occurs. In most areas, the overcrowding causes stunted growth, and major mortalities of 2-4 cm individuals occur in intertidal areas in late summer due to exposure to high air temperatures, starfish predation, and competition for food (especially in the eastern half of the Island, where productivity is lower). Long Island oyster farmers generally agree that the mussel beds should be thinned out in their first year and that the culls could be re-seeded or raised on rafts. However, no one seems interested in doing this, at least as long as oysters and clams continue to bring much higher prices than the mussels.

Blue mussels are normally available in Long Island fresh fish stores, and these are supplied locally. When the local demand is low, fishermen sell to Fulton Fish Market and other dealers. A good fisherman can get 60 bushels/day at low tide or by tonging in shallow water. Some Long Island fish markets will buy mussels from dealers from Massachusetts or Maine when the local supply is low.

Mussels also grow successfully at some sites close to New York City, such as Rye Beach and Powell's Cove (near the Whitestone Bridge). Mussel beds in this area often disappear completely, while others become established at new locations. However, because the waters of western Long Island sound are presently condemned, these mussels have no immediate commercial value.

New Jersey. Large catches of mussels were made in New Jersey at the beginning of this century, but very little commercial musseling has been done since then. The consumer demand for mussels in New Jersey is relatively high, but most of the supply comes from points north. Most of the small commercial catches of blue mussels in New Jersey are made by Tuckerton-area shellfishermen in the waters around Beach Haven Inlet. They use Shinnecock rakes, clam forks, and oyster tongs to collect the clumps of mussels from shallow bars and the sides of channels in the outer estuary.

Shellfish gathering is a popular recreational activity in the Great Bay-Oyster Creek-Little Egg Harbor area, and the blue mussel is one of

the species taken. Most people go along the shores on foot or in small boats, but some go in party boats and use oyster tongs or Shinnecock rakes in shallow water (up to 25 feet) to get mussels.

The mussel populations are basically limited to the outer channels. They are very seldom found offshore, except on occasional "mussel reefs" which are temporary, due to the highly unstable nature of the bottoms. Heavy sets have grown on towers and floats three miles offshore at a proposed power plant site. They do not grow well in the outer, exposed bays because wave action there is heavy. In the inner reaches of the estuaries they are limited by high temperature, low salinity, and poor circulation.

There are thick sets of mussels in late winter and early spring in lower Delaware Bay, which give rise to mussel beds in the Cape May area, extending as far out as three miles and to depths of 40 feet. The entrances to Raritan Bay and Old Orchard Bay also harbor extensive M. edulis populations, but most of these are in condemned waters. These stocks are not being commercially exploited.

Delaware. Delaware Bay is the southernmost area on the East Coast where there is substantial spawning, growth and survival of blue mussels, but major die-offs also occur from time to time. The bay is usually closed to all shellfisheries due to pollution. During the times when localized areas are opened up to fishermen, they concentrate on gathering the available oysters and hard clams. The rest of the time, shellfishermen poach (despite the efforts of the state marine police), but they usually don't bother with mussels because of their low commercial value. No fish stores in the state carry mussels and apparently no one eats them except for the occasional shellfisherman or beachcomber.

Ralph Williams, a Delaware Marine Extension Agent, has made efforts to get Lewes area fishermen to gear up to harvest mussels, but little interest has been demonstrated. The breakwaters at the mouth of Delaware Bay serve as a preferred habitat for blue mussels, and give rise to dense, fast-growing colonies. Apparently, no one takes advantage of this resource.

The population suffered an almost total mortality in September 1976, but the reason for this has not been determined. Another problem is the lack of landing centers in Delaware. The closest collection and distribution points for Delaware fishery products are Ocean City, and Secretary, Maryland.

Maryland - Virginia - North Carolina. Blue mussels live in this region, but are very unsuccessful, primarily due to high temperatures in August and September. Massive die-offs of mussels which are less than one year old occur yearly when the water temperature remains at 25-28°C for several weeks and the air temperature approaches 35°C. Mytilus edulis is found in the estuaries of Chincoteague, Wachapreague, Albemarle, and Pamlico. A good set of year-classes occasionally develop in these areas, but most of the juveniles die off by the end of their first summer, with very few reaching a length of more than 3 cm. They are even less successful in the estuaries of the Chesapeake, where high temperatures are frequently combined with pollutants and low salinities to decrease the chances of mussel survival.

In the Maryland-Virginia-North Carolina region mussels are seldom found in fresh seafood stores. Specialty seafood shops and restaurants, primarily in Washington, D.C., occasionally purchase blue mussels from New York dealers. Most of the baymen and other people who live by the ocean in these states are familiar with mussels, but rare is the person who has ever eaten them. The very few coast dwellers who would be inclined to gather a pail-full of mussels from time to time are usually deterred from this activity by their trepidations about pollution. Marine biologists gather blue mussels for home consumption from the Chesapeake Light, 14 miles offshore from Norfolk, where they grow abundantly. However, most people in this region regard mussels as a nuisance, an animal which they would do away with if possible, due to its fouling tendencies.

Some blue mussels (perhaps 10 percent) survive the high summer temperatures in deeper water, or by air-gaping while attached to structures just below the mean high water (MHW) mark. However, populations residing in those parts of the estuaries where water circulation is less than optimum usually experience close to 100 percent die-offs in summer. The few occasions in which mussels are gathered in this region usually take place in June-July.

Mussels are abundant in the Chincoteague estuary, mainly along the inlet channels and the flats that rim the bays where there is good circulation of ocean water. There has never been any reported commercial harvest due to both the traditionally productive and profitable oyster and clam fishery of that area and the total lack of market value for mussels locally. Mussels were gathered in this region during World War II and tested as a possible source of vitamins.

7.2 West Coast - Linda Chaves-Michael

Alaska. At the present time there are no commercial landings of mussels in Alaska (Torgerson, pers. comm.). An interest has been shown recently by several individuals who would like to harvest natural stocks in Alaska. Bay mussels occur throughout southeastern and southcentral Alaska and the southern Bering Sea (Paul and Feder, 1976).

Several problems must be overcome before mussels can be harvested on any commercial scale. Very little capital is presently available in Alaska for investment. Transportation and labor costs are high. This is in part due to the high inflationary rate brought about by the Alaskan pipeline. Under present laws, mussels cannot be harvested in Alaska because no areas have been certified for them (Torgerson, pers. comm.). Only three areas have been certified for any kind of shellfish harvest and these are designated specifically for razor clams (Orth et al., 1975). If one were to set up rafts in those areas, it might be possible to gain approval from the FDA within a one year period. This would necessitate an expansion of their existing program. However, harvesting of mussels in any other areas of Alaska would require sanitary surveys and PSP monitoring for a period of up to one and one-half years prior to commencement of an industry. The cost of this would have to be borne by the state, which would be reluctant to embark on this type of program unless it were guaranteed that the resultant industry would bring in a proportionate number of jobs and profits. It is felt by some

Alaskans that the price of the product would be prohibitively high and would not be marketable on a national scale.

Washington. The State of Washington has been involved with the culture and harvest of mussels just during the last few years. During the 1960's several hundred pounds of mussels were harvested from natural stocks and sold to restaurants at about \$.70/pound shellstock (Lindsay and Yamashita, pers. comm.). This was done by an oyster grower who decided not to continue this endeavour as the market was not ready at that time for mussels and a steady supply was not available. Today, oyster growers are still harvesting a few mussels (by hand) and selling them for \$.80 to \$2.50 per pound. The casual harvester can be of great help while this industry is being developed in Washington. Markets are not yet large enough to sustain several mussel farms, but the demand is growing day by day. Thus, if the casual farmer can continue to supply the market (usually one specific restaurant), mussels may become more popular and the demand will increase.

Only one mussel farmer is presently operating in Washington State. The first year of business was poor because of weather conditions, but during the second year he has been selling about 300 pounds per month and could be selling much more if it was available. If his present raft potential were fully realized he could expect to produce 123 metric tons of mussels per year, representing a value of \$27,000 if sold at \$1.00/pound (pers. comm.).

The major biological obstacle in Puget Sound is the collection of natural seed. As stated earlier, mussels do not spawn and set consistently year after year. This problem is being circumvented by the development of an experimental hatchery which would supplement natural stocks. Seed from this hatchery would be used for research purposes and for distribution to interested mussel farmers.

Oregon. The mussels which have been harvested in Oregon during the last several years are M. californianus which occur in large numbers on the ocean beaches. Very few M. edulis are known to grow in the state. They occur naturally only at the mouth of estuaries. Shellfish harvesters occasionally harvest mussels for human consumption, but this is usually done only upon special request. The obstacle to harvesting mussels for human consumption (even M. californianus) is generally not PSP, however, problem levels of PSP occurred in 1957 and 1973. However, shellfish can be harvested only from certified waters if they are meant for human consumption. The areas of greatest populations, along the ocean beaches, have not been legally certified. The entire coastal area is open except for sewage outfall areas. A harvester must only request certification from the Oregon Health Division. In the past, the few such requests have been approved.

Recreational shellfishermen are limited to 72 mussels, which may be harvested only by hand or by hand-powered tools.

California. Currently, mussels may not be taken commercially in California for human consumption at any time of the year (Alton, pers. comm.). A quarantine exists from May 1 to October 31 during which time they may not

be taken recreationally either. This is due to the high recorded levels of PSP. Thus, to satisfy the demand for mussels at the retail level, mussels are imported from the east coast. During the non-quarantine period, mussels are being harvested by one individual who produces mussel broth for use in his restaurant. Provisions are being made to allow the harvest of mussels from San Francisco Bay, but they must go through a depuration process if they are to be used for human consumption (Sharpe, pers. comm.). The small quantities of mussels which have been harvested during the past several years have been the California mussel, M. californianus; these have been used solely for bait (Price, pers. comm.).

Several people in California are now interested either in harvesting natural mussel stocks or growing them on rafts. All of these people are located near San Francisco. There is also a small group of people at the University of California at Davis which is advocating more practical regulations governing the mussel industry. At least one shellfish hatchery has expressed interest in providing mussel seed for mussel farmers. This could be necessary if seed cannot consistently be obtained under natural conditions.

The greatest obstacle to increased harvest of mussels in California is the Department of Health, which has neither the money nor the manpower to monitor all the bays and beaches along the California coastline for PSP. Nor would it be practical for them to inspect mussels immediately after harvest if they are meant for human consumption. In addition, a number of people feel that the present total coliform standards are inadequate. Coliform counts are used to indicate the potential presence of pathogens found in fecal wastes. High coliform counts can also be of non-fecal origin (e.g., runoff which occurs from agricultural fields when heavy rains follow hot, dry summers). Sanitary shoreline surveys should therefore be combined with fecal counts to properly classify shellfish growing waters.

7.3 Economic Profile of the Mussel Industry

7.31 Introduction

In order to understand the current and prospective economic problems of the U.S. mussel industry, an economic profile of the industry was developed. This research was based upon the collection and analysis of data on the mussel industry and also upon the results of twenty interviews with firms and individuals engaged in different facets of the industry.

The subjective profile focuses on the industry at the present time, as perceived by harvesters, growers, dealers and local wholesalers. Nine personal interviews were conducted in Maine.¹ A similar interview format was used as a mailed questionnaire for a sample of firms and individuals outside of Maine. A copy of this appears as Appendix A. Due to time and

¹The interview format was developed with the assistance of the Social Science Research Institute at the University of Maine-Orono. The Institute also trained the interviewer to ensure as complete and accurate results as possible.

resource constraints, the sample is not a large one, nor can it be said to be "scientifically" representative. Nonetheless, the high consistency of answers among the twenty respondents suggests an accurate subjective profile of the industry as a whole. The regional distribution and breakdown by business category of the interviews and questionnaires is presented below in Table One. As indicated from Table One the majority of Survey responses are from Maine and New York, the two states comprising the greater part of total U.S. commercial production in recent years.

Table I: Mussel Industry Survey by Regional Distribution and Business Category

	Harvester	Grower	Dealer-Wholesaler
Maine	3	1	5
Massachusetts	1	1	
Connecticut	1		1
New York	1	1	2
Oregon			1
Washington	1		1

The objective profile consists of a presentation and analysis of data on the mussel industry from the period 1941-1976.² Data was obtained from three primary sources: U.S. Department of Commerce, N.O.A.A. Fishery Statistics of the United States; United National, F.A.O., Yearbook of Fishery Statistics; U.S. Department of Commerce, N.M.F.S., Fishery Market News Report; and from unpublished data supplied by the National Marine Fisheries Service. The analysis is divided into five parts:

1. A long-run profile of the U.S. industry, by major producing state and by volume and value of production;
2. A long-run comparison of the U.S. mussel industry with the world industry by major producing nation;
3. A long-run profile of wholesale prices in the U.S. by major producing state, nominal and deflated values;
4. A short-run profile of wholesale prices in the U.S., mussels in comparison with soft and hard shell clams;

²In some cases the period covered is shorter due to limitations of the particular data available or, insofar as 1976 is concerned, due to its not having been compiled at the date of publication of this report.

5. A long-run comparative profile of the mussel and clam industries. Since it is only the recent historical period that is analyzed in detail below, some background information is necessary to complete the picture.

The commercial mussel industry in the United States has always been, and continues to be, a small part of the shellfish industry. It is misleading, in fact, to denote it as a separate industry. Typically, those individuals and firms engaged in any facet of the business, from harvester to metropolitan wholesaler, are simultaneously engaged in the harvesting and distribution of other shellfish as well.³ Accordingly, the actual size of the industry cannot be measured accurately by data such as that appearing in Appendix E: Operating Unit Data of the Sea Mussel Fishery, 1966-1975 for the fisherman and craft listed do not devote all their time to mussel harvesting.

Until World War II and the post war period, statistics on quantity and value of commercial mussel landings in the U.S. indicate the industry was marginal and sporadic.⁴ (See Appendix C). Until the Great Depression of the 1930's the only recorded years of significant mussel production for the East are from the Middle Atlantic states: 1887, 1888, 1897, 1904, 1908 and 1921. For the West Coast the only recorded years of significant activity are 1888 and 1892. These latter have been explained elsewhere in the report. No information is available on the harvests for the early years in the Mid-Atlantic states. However, unemployment in the area was high in 1908 following the panic of 1907. Unemployment in the third quarter of 1921 was the highest since the depression that followed World War I, and widespread wage cuts also contributed to a low standard of living. As an inexpensive source of protein, mussels were substituted for more costly foods as the standard of living declined.

From the period 1929 on, commercial mussel production has been on a sustained basis. The industry has shown secular through highly uneven growth both in quantity and value of product between 1929 and 1975. The sustained level of activity leading up to World War II may again be explained by the low standard of living during the Depression years. Economic studies generally indicate that inexpensive foods tend to be substituted for relatively expensive items at low income levels.⁵ Without further evidence, however, this must remain as a speculative conclusion at the present time.

³The major exception to this general portrait is the local dealer-wholesaler who hauls his own mussels through dredging or raking.

⁴Statistical sources prior to the 1930's are quite poor, however, so that the size of the commercial industry before that period is not necessarily accurate. In addition harvests for self consumption rather than sale are excluded from the statistics.

⁵Even during prosperous periods, mussel consumption has been largely limited to ethnic populations which typically are on the lower end of the income scale. Wild mussels, in the economist's vocabulary, may therefore be labelled as an inferior good, one which only tends to be consumed at low income levels and for which substitutes are consumed as incomes rise. In the case of cultured mussels in Europe, however, the food is perceived as a superior good.

INDUSTRY STRUCTURE

Figure 1.

7.32 Current Economic Status of the Industry: Subjective

Three aspects of the U.S. mussel industry were investigated in the mussel Survey referred to in the Introduction: technique of production; industry structure; and market relationships. These elements are summarized in Figure 1: Industry Structure. Each box is an independent firm or individual except harvesters employed by a dealer as part of his own operation. Lines between the boxes refer to market relationships among independent economic agents. Only markets of types 1, 1', and 2 were investigated due to time, logistical, and resource constraints. The three major types of markets are: retailers buying from metropolitan wholesalers; metropolitan wholesalers buying from local wholesalers; local dealers/wholesalers buying from harvesters, or producing directly on demand for metropolitan wholesalers. Variants of these basic market types are denoted by a superscript prime, (e.g. 1'). Vertical dashed lines refer to basic divisions within the industry by type of function, production or supply, distribution, and retailing for final demand or consumption. The local dealer/wholesaler box encompassing producers indicates relations of production internal to a firm, employer to employee, as distinguished from market relations. At the level of production, three techniques may be distinguished and are noted in the left hand margin and bottom of Figure 1: labor intensive, capital intensive, and highly capital intensive. Finally, the separation of the industry as between wild mussels and mussels produced through aquaculture indicates that there are really two sectors of the industry since the respective products have very different characteristics.⁶ The smaller size of the farmed mussel sector is indicated by a smaller box.

The technique of production for wild mussels is labor intensive (individuals using hoes) or capital intensive (a boat up to 60' with a crew up to four dredging or raking mussel beds) depending upon the location of the resource. (Appendix F lists landings by type of gear and state 1971-1975.) Entry into the industry is relatively easy for individuals harvesting by hand or with hoes. Traditionally, however, dealers are supplied by regular harvesters of long-standing acquaintance. With limited demand for mussels, therefore, net additional entrants into harvesting have been few in number, despite the ease of entry due to low initial capital requirements. Productivity per man-day varies depending upon the individual concerned and the availability of the resource. Ten bushels per man-day using labor using labor intensive techniques was the average from the survey responses.

Capital intensive techniques of production typically require a crew of between 1 and 4 men operating a dredge or rake over mussel beds from boats 32' to 60' in length. Productivity per man-day varied from 40 to 80 bushels for firms employing rakes and 20-30 bushels for firms employing

⁶The cultured mussel is currently being marketed as a gourmet specialty in fine restaurants. The cultured product is therefore not an inferior good, but, rather, a food item which may prove in time to have a high income elasticity of demand. This appears to be a matter of consumer education.

dredges. The total capital requirements for these techniques was considered proprietary information and is not included in this report.

The technique of production for cultured mussels is not well-established since it is a very new method of producing mussels. Of the three growers surveyed, only one is approaching a commercially feasible level of production. The other two are experimenting with aquaculture as a means of supplementing the supply of wild mussels or improving quality. Although aquaculture ventures are all highly labor intensive at this early stage of the art, initial capital requirements for the firm are substantially higher than either of the two previous techniques and will probably increase over time as mechanization proceeds. Higher capital requirements reflect the greater complexity of an aquaculture business compared to the harvesting of wild mussels and the fact that a considerable scale of operations will be necessary to minimize costs of production. Figures for productivity per man day are not yet available and in any event would not be comparable with those for other techniques since the product produced is very different.

Industry structure is dominated by firms comprising the metropolitan wholesale market. Four city markets and two regional markets were identified from the survey results. Other markets undoubtedly exist but will require further research for identification. Metropolitan wholesalers buy the greater proportion of mussels sold by local wholesalers, although the exact proportion could not be determined. In turn, they sell to other metropolitan wholesalers and directly to retailers. Markets of type 2' were identified between east coast metropolitan wholesalers and Montreal and west coast wholesalers. Retail sales from the metropolitan market are distributed among foodstores and restaurants and as bait. Orders for mussels are placed with metropolitan wholesalers who then transmit the demand through the distribution channels to local wholesalers and finally to the harvesters. Supply forthcoming to the market prior to demand is minimal.

Local wholesalers also tend to be dealers and supply retail markets directly. A much greater proportion of total sales is to metropolitan wholesalers, however. In the case of dealers purchasing mussel stocks from independent harvesters, any risk from holding inventories is absorbed by the dealer/wholesaler. Moreover, dealer/wholesalers are a source of credit for independent harvesters when business conditions are poor. With one or two exceptions, local dealer/wholesalers did not have severe credit problems, possibly because they are engaged in the shellfish industry generally, and not only in mussels.⁸ Individual dealers surveyed had not been in the mussel business for a long time, with one exception on Long Island. They tend to move in and out of the "industry" depending upon demand. Dealers recognize they are too small individually to increase the demand for mussels

⁷The latter figure does not necessarily indicate lower productivity for dredges, since 3/4 of an 8 hour day is for cleaning done on the boat. Moreover, the average productivity for dredges is closer to 40 than to 80 bushels.

⁸This is not true for aquaculture operations, however, which require considerably more capital for a product of uncertain demand.

through advertising but did not appear to favor a cooperative advertising venture. Transportation by local wholesalers to metropolitan wholesalers is either by common carrier or by trucks owned by the local wholesalers.

For the industry as a whole, metropolitan wholesalers appear to dominate price determination. Local dealers and wholesalers, who supply most of their stocks to metropolitan wholesalers, receive \$4 - \$8 per bushel depending primarily upon size and quality of stock. Fluctuations in demand do not cause substantial price changes; rather they are met by changes in quantity supplied to the market at a fairly constant price. The stability of prices also extends backward to the market between harvesters and local dealers/wholesalers. In New England harvesters receive \$3 - \$4 bushel; in Washington state \$3 per hour; on Long Island, where the cost of living is higher, \$6 per bushel. In short, for markets of types 1 and 2, prices are stable and demand determines volume. Typically, orders are placed by metropolitan wholesalers to their regional or local counterparts. Demand is then transmitted to the harvesters who either work directly for local dealers or have longstanding market relationships with them.

Responses by dealers and harvesters to the Survey indicate that greater supply would be forthcoming in the short run at existing prices if demand increased. On the east coast this would require increasing the number of harvesters and possibly the number of boats since the utilization of existing capacity appears quite high at the present time, especially for those dealers/harvesters focusing most of their fishing effort on mussels. The distribution network could handle a much larger volume of mussel production if demand were forthcoming without an increase in the number of firms. The long-run picture is very different, however. Almost all respondents indicated that doubling the supply of mussels to the market for a period of 5 years would deplete or exhaust the wild resource. In sum, demand factors are a limitation to the growth of the industry in the short run and the long run. Supply factors due to limitation of the wild resource are a limitation to the growth of the industry in the long run but not the short run.

The price stability of mussels, also analyzed in section 7.33 below, is due to two factors. First, there is some risk to handling mussels for firms in the distribution channel since demand for the product has not been great compared with other shellfish species in the past. Second, since the product is not in great demand and does not promise a very high rate of return, bargaining power over prices from firms supplying mussels to metropolitan wholesalers is not as strong in comparison with species such as clams. In effect, metropolitan wholesalers may exhibit a degree of monopsony power over local dealers/wholesalers, which is transmitted through to the harvester.

Responses from the survey attribute price changes more to changes in quality and size of product than to variations in demand conditions in the short run. Local dealers/wholesalers set quality standards for harvesters depending upon demand conditions, however, so the latter do have some influence on price.

Finally, mussels grown by aquaculture have not as yet entered the well-established distribution network for wild mussels depicted in Figure 1. Sales have been directly to retailers for the most part.

7.33 Current Economic Status of the Industry: Objective

Between 1942 and 1975, three distinct periods in the history of the mussel industry can be distinguished: 1942-1947; 1948-1964; 1965-1975. These phases are evident from Figures 2 and 3, quantity and value of mussel landings by year and state.

The first was the period of greatest U.S. mussel production in recorded history. Yields exceeding 2.7 million pounds were maintained steadily for 4 years. These were canned for export for U.S. troops overseas during the war and possibly for consumption by European countries such as France as well. Maine supplied the greater part of this yield with New York a distant second. The rapid drop in yields soon after the conclusion of the war reflects a return to more traditional sources of protein and a depletion of wild stocks according to Dow and Wallace (1954).

Between 1948 and 1964 the industry as a whole exhibited highly uneven harvest levels with no secular trend observable. The distribution of the harvest between states changed noticeably from the first period as well. Although Maine regained prominence from New York in 1950 after the drastic decline in landings in 1947, from 1953 to 1965 Maine accounted for a small percentage of total U.S. landings. Rhode Island was prominent between 1955 and 1959 with no reported landings of significance after 1961. Massachusetts landings remained uneven between 1948 and 1958, showing no secular trend. However, between 1959 and 1963 Massachusetts landings increased markedly and accounted for almost all U.S. production. The trend in production since 1959 has been downward for Massachusetts in the face of a secular increase in total U.S. landings. Finally, New York landings in the second period are low relative to other states except in the years 1953 and 1954.

The third period, 1965-1975, is the most significant. The trend, albeit highly uneven during this period, is distinctly positive. The average rate of growth per year for the period is 16 percent. From 1965-1967 Maine and Massachusetts comprise the bulk of U.S. landings. From 1968-1973 New York and Maine account for most of U.S. production. In 1974 and 1975, however, New York landings have dropped rapidly but have been more than offset by a rapid rise in Maine landings insofar as total industry growth is concerned. Whether the decline in New York landings is due to resource depletion, as indicated by the survey results, is not a conclusion which has been firmly established at the present time. Landings for 1976, when available, may help to further clarify this issue. Since the U.S. market as a whole has been increasing the past few years quite rapidly, however, it is difficult to reconcile the New York performance with any other explanation than resource depletion.

Fig. 2 QUANTITY (By Live Weight) OF UNITED STATES MUSSEL LANDINGS BY YEAR AND STATE
A Long-Run Profile

Source: (United States Department of Commerce, N.O.A.A., Fisheries Statistics of the United States,
Washington, D.C., Annual)

Fig. 3 VALUE OF UNITED STATES MUSSEL LANDINGS BY YEAR AND STATE - A Long - Run Profile

Source: (United States Department of Commerce, N.O.A.A., Fisheries Statistics of the United States, Washington, D.C., Annual)

The top two lines in Figure 3 represent value of total U.S. landings per year in current dollars and real dollars as deflated by the appropriate price index. Using 1967=100 as the base date of the index, the higher value of the constant dollar series before 1967 indicated dollars were worth more in real purchasing power before 1967 than since 1967. In fact there is continuous inflation throughout the post-war period although it was very low from 1952 through 1968.

Inflation has hurt the mussel industry seriously since 1972. The gap between sales in current and real dollars has widened considerably. Indeed, comparing the quantitative performance of the industry with value of landings for 1974, we find that real value of landings fell sharply while volume increased. Inflation is certainly a more severe problem for fledgling industries like the mussel industry than for well established industries which can administer prices. The purchasing power from sales by the industry is declining. As the survey results indicate, this sector faces an increase in labor and fuel costs in the near future.

Figures 4 and 5 enable an historical comparison of the U.S. industry with the world mussel industry for a twenty year period. Unfortunately, data for 1974 and 1975 are not yet available. Nonetheless, several important economic observations can be made.

Although the U.S. industry has exhibited marked growth in recent years, it is still an insignificant proportion of the world industry, which is centered in Europe and based largely upon aquaculture rather than the harvesting of wild supplies. However, between 1962 and 1973 the average rate of growth for the world industry was 5 percent, considerably lower than the 16 percent rate of growth for U.S. harvest during the period 1965-1975. Until very recently the Netherlands was the largest producer of mussels. Since the mid-1960's however, the growth in world production has come mainly from Spain, with other major producing countries exhibiting no secular trend of positive growth. Indeed, the leveling-off of world production in 1973 was due to a decline in harvests in the Netherlands, France, and Denmark. Spain is now the world's largest producer.

It is not clear from the small amount of information on the European industry now available whether demand has leveled-off recently in Europe or whether all available growing waters for mussels are being utilized to capacity.⁹ A 1975 NMFS report prepared by Fisheries Development Limited in London indicates production is now sufficient to meet European demand. However, there is also evidence indicating long-term supply constraints due to the lack of additional growing waters.

One possible implication of this for the U.S. industry might appear to be to emphasize export markets as a way of stimulating demand for the industry. In 1974, for example, wholesale prices in the United Kingdom were

⁹Figures 4 and 5 show that the growth in value of landings in France is considerably outstripping growth in volume, thus indicating a supply constraint and rising prices as demand outgrows supply.

Fig.4 WORLD MUSSEL PRODUCTION BY COUNTRY AND YEAR, 1953-1973*

Source: (United Nations, Food and Agriculture Organization, Yearbook of Fishery Statistics, New York, Annual)

*BLUE MUSSEL, COMMON MUSSEL, by Country and World Total.

"OTHER MUSSELS" by World Total only.

(Series Exclude Aquaculture for Spain through 1960, but
Include Aquaculture for Spain 1961 -)

Fig. 5 VALUE OF WORLD MUSSEL PRODUCTION BY YEAR, 1952-1972

Source: (United Nations, Food and Agriculture Organization, Yearbook of Fishery Statistics, New York, Annual)

38 cents per pound wholesale f.o.b. from the continent, somewhat above the comparable U.S. price for recent years. (See Appendix C.2). Transportation charges would be considerably greater for U.S. produced mussels, however. Moreover, the UK price is for the markedly superior cultured mussel and not the wild mussel, which dominates U.S. production. Thus, export markets are not a feasible path of industry growth currently, or in the foreseeable future. On the contrary, if U.S. demand for the cultured mussel develops sufficiently in the future, European exports to this country may well pose a severe constraint to the growth and survival of the U.S. industry. Since the technique of production for aquaculture is better developed in Europe than the U.S., average costs of production are without question considerably lower. Even with the costs of transportation, therefore, foreign competition may be a reality to which policy makers and firms must address themselves while U.S. mussel aquaculture is still an infant industry. At present there are no tariffs or other special import restrictions on mussel products in this country.

Figures 6 and 7 illustrate the long term behavior of wholesale prices for mussels in the New York market. Prices in Figure 6 are computed on a bi-monthly basis so that it is possible to compare short-term price behavior with the long-term trend. In Figure 7 yearly averages are used since the major focus is on long term price behavior at current and real prices.

Between 1950 and 1965, wholesale prices in the New York market varied considerably among the three states at any point in time. Prices for each state also varied considerably over time within the period. Finally, there is no secular trend in prices during this period. The average price for the period was constant, about \$2.50 per bushel. This price behavior reflects the marginal size of the industry in the post-war period leading up to 1965 as noted in the analysis of Figure 2.

With the growth of the industry in the period following 1965, however, prices have moved steadily upwards. The variability in prices among states has also narrowed considerably. This probably reflects the growing rationalization of price determination towards a cost-plus basis and away from the pure market forces of supply and demand concomitant with the growth of the industry. This is similar to the history of price determination for most produced commodities.

Nonetheless, price variation in the later period is by no means minimal. Results from the survey indicate, however, that differences in quality and size are mainly responsible for price variation, demand fluctuations being of secondary importance.¹⁰ This does not mean, however, that prices are

¹⁰Since cultured mussels exhibit greater uniformity in size and quality, the stability of prices should increase if this product comes to dominate the market. Price stability is desirable from a business standpoint as it reduces one element of risk. Variations in market conditions are then limited to changes in inventories rather than changes in both prices and inventories.

Fig.6 MUSSEL WHOLESALE PRICES, NEW YORK MARKET, BI-MONTHLY AVERAGE - 1950-1976

Source: (United States Department of Commerce, N.O.A.A., National Marine Fisheries Service, Unpublished Data)

Fig. 7 MUSSEL WHOLESALE PRICES, NOMINAL AND DEFLATED VALUES, YEARLY AVERAGES - 1950-1975

Source: (United States Department of Commerce, N.O.A.A., National Marine Fisheries Service, Unpublished Data)

determined by harvesters or local wholesalers. Metropolitan wholesalers appear to exhibit some monopsony power in price determination, though, obviously, prices must in the long run cover average costs at each point in the production-distribution channel.

From Figure 7, it is evident that current and real wholesale prices for the industry did not vary widely until the 1970's. In the 1970's, however, the mussel industry has suffered falling prices in real terms. Although this is by no means unique, an emerging industry is much more vulnerable to inflation than well established industries, as noted earlier. The fall in prices in real terms is a serious setback to an industry which cannot administer prices and thereby protect itself from inflation. In effect, a fall in real prices makes it harder for the mussel industry to maintain profit margins and purchase additional inputs necessary to sustain a given volume of production, let alone a growth in production. If current prices were keeping pace with inflation the real dollar price series would be horizontal for the 1970's.

Figure 8 is a short-run profile of wholesale prices in the New York market for mussels and its closest substitutes. For the period analyzed, July 11, 1975 - October 1, 1976, the stability of mussel prices compared to soft clams and two varieties of hard clams is remarkable. Although time and resource constraints prevented an econometric analysis of cross-price elasticities, the periods of greatest vulnerability in mussel prices appear to be correlated with the periods of greatest variability of soft clam prices, December 26 - March 5 and June 25 - August 6.

Data presented in Figure 9 tend to support the view that soft clams and mussels are substitutes. The substantial decline in soft clam production during World War II is matched by a substantial rise in mussel production during the same period. A less dramatic rise in mussel production between 1971 and 1973 is associated with another large drop in U.S. clam production.

7.4 Processing

Mussels are in greatest demand as fresh shellfish. The shelf-life of fresh mussels is limited under existing practices, and a method of safely extending safe holding-time while maintaining product quality is needed. These needs are discussed in Section 9.4 of this report.

Mussel processing is reviewed by Scattergood and Taylor (1949a). Prolonged shelf life and increased range of distribution are the principal advantages. However, other benefits exist. Mussels can be canned with conventional machinery used to process fish and other shellfish species, thus minimizing capital investment. Furthermore, this can be done during the winter, when fish processing is at its minimum and mussel harvest is not limited by the occurrence of red tides. This would have the added social value of stabilizing employment in an established industry--namely fish processing. Also, mussels are conditionally more fit for canning during the winter, when meats are firm and the animal has recovered from the summer spawn (Scattergood and Taylor, 1949a).

Fig. 8 MUSSEL, SOFT CLAM AND HARD CLAM WHOLESALE PRICES, NEW YORK MARKET

A Short - Run Profile

Source: (United States Department of Commerce, N.O.A.A., National Marine Fisheries Service, Statistics and Marketing News Division, Fishery Market News Report, (weekly), July 1975 - October 1976).

Fig. 9 QUANTITY (By Live Weight) OF MUSSEL AND SOFT CLAM PRODUCTION, UNITED STATES AND MAINE, 1942-1973
 Source: (United States Department of Commerce, N.O.A.A., Fishery Statistics of the United States, Washington, D.C., Annual)

The commercial market in the U.S. today consists primarily of fresh product. Mussels of 2 to 3 inches in length are brought from the harvest area, usually in small boats, to a mussel dealer. They are then washed and sorted in a washer-grader (this is the same piece of machinery used in sorting other shellfish species). Mussels are usually held in seawater on rafts for several days before shipping. While this procedure enables the dealer to ship in bulk and assures him of an adequate supply for his customers, it also improves the survival of mussels in transport. This is presumably due to a reacquisition of shell liquor and recovery of the animal from harvest trauma (picking, transporting, cleaning and sorting) (Slabyj and Hinckle, 1976).

To date, no machinery has been specifically designed to shuck mussels; this process must still be done by hand and constitutes a large expense in mussel processing. The byssal threads must be removed from the meats after shucking, and this increases considerably the time and care required to prepare mussels (pers. comm.). Cooked mussel meat can be easily removed from the shell after steaming or boiling.

Although the meat yield of wild mussels varies both seasonally and specifically for each animal, a bushel of 3-inch mussels yields about one gallon of wet meats. Smaller mussels have a slightly higher yield (Stewart, pers. comm.).

8.0 STATE GOVERNMENTS AND THE REGULATION OF THE INDUSTRY

8.1 East Coast - Willard Brownell

Public health aspects of mussel harvesting and commercial sales have been under the control of either PHS or the FDA administration of the National Shellfish Sanitation Program (NSSP) since 1925 (Roberts, pers. comm.), but each state and several major cities have further controls, which are carried out by local sanitation departments. Fishing licenses and management of stocks are controlled by the states and/or towns. The leasing of bottoms for harvest and/or culture of shellfish is controlled at various levels. Most coastal states have marine police, or wardens, who work for a state department of marine resources (or equivalent) to enforce these controls and regulations. The following is a summary of some of the legal matters that affect mussel fisheries in the principal producing states (as described in Section 5.1).

Maine. The opening and closing of shellfish harvest areas, including Mytilus, is regulated on a species basis by the Maine Department of Marine Resources (DMR). Regulation is required to safeguard against contamination by fecal pollution, industrial pollution, and paralytic shellfish poisoning. These sanitation regulations are in compliance with the NSSP administered by the FDA. The state is responsible for licensing of in-state dealers as well as interstate shellfish transporters.

Licenses for commercial harvest are issued by this department for \$10 per year, and no restrictions are placed on size of mussels, size of total catch, method of harvest, or season. However, numerous towns impose ordinances restricting shellfish harvest to town residents. Many of these towns will issue non-resident licenses.

Regulations requiring shore access and lease of bottom areas for aquacultural operations are also under the jurisdiction of the DMR. These vary with locations.

Massachusetts. State law requires all coastal towns to assume responsibility for management of their inshore shellfisheries. Commercial licenses are generally \$25 or \$50 per year. Some towns issue daily sportfishing permits (cost: \$1.00 to \$2.50) for small quantities of shellfish. The towns with the largest resources and the most fishermen usually employ extensive management practices. For instance, Duxbury has closed seasons on clams, but mussels are only restricted by the number of licenses given out (10). Currently, there are four fishermen working the mussel beds there. They complain because they are not permitted to have helpers at any stage of the operation. A local large-volume dealer complains because the stocks are so extensive that they could be exploited at a much higher level and could satisfy a demand which usually exceeds the supply. Mussel stocks are consumed each year by migrating eider ducks.

Ipswich has initiated programs to harvest all mussels in dense beds, market all individuals that are over 5 cm in length, and relocate the smaller ones in deeper water (4-5 feet at low tide) where there is better water circulation and more space. It is believed that the relocated mussels, which are never exposed by the tide, have better taste, grow faster, have a whiter color, and more meat per volume of animal. A local dealer in Ipswich gave away some free samples of mussels prepared in different ways in order to stimulate the local industry.

Connecticut. The State Department of Health publishes a yearly report describing the restricted shellfish harvest areas. Norwalk has opened a conditional area to shellfishing for permit holders; this is closed for 5 to 9 days immediately following a rainfall of 0.5 inches or more. There is no government control on mussel fisheries at any level.

Rhode Island. There are no state regulations governing either the commercial or recreational harvest of mussels in Rhode Island waters.

New York. Leasing of bottom-rights is the principal question concerning Long Island mussel fishermen. All available bay bottoms have been either commercially leased or reserved specifically for use by town residents. There exists great controversy over the distribution of these special rights, which often set aside areas for extensive shellfish culture that are considered to be good natural production areas for other species. Often, leased areas are closed due to pollution, especially in the western part of the island. There are no management policies for mussels.

New Jersey. The regular clamming license is required of mussel fishermen. The State Department of Environmental Protection, Shellfish Control Section publishes condemned area charts for fishermen. The fine for taking mussels from condemned waters is \$100. Mussels are not considered to be a resource that requires management in New Jersey, since so few are taken.

8.2 West Coast - Linda Chaves-Michael

Alaska. There are presently no specific regulations pertaining to mussels in Alaska, whether M. edulis or M. californianus.

The Alaska departments of Fish and Game, Public Safety, and Health and Social Services are jointly functioning as the shellfish control agencies for the State of Alaska as outlined below.

Department of Health and Social Services

1. Coordinating agency for State shellfish program
2. Classifies growing areas
3. Conducts sanitary surveys
4. Establishes sanitary standards

5. Conducts PSP testing
6. Issues numbered certificates to approved clam processors

Department of Fish and Game

1. Collects clam samples for PSP testing
2. Issues licenses to commercial clam diggers
3. Assists in sanitary surveys

Department of Public Safety

1. Active patrolling of beach areas
2. Enforcement of clam fishery laws

(from Orth et al., 1975).

Shellfish growing areas are closed to commercial harvesting for human consumption unless the areas have been certified by the commissioner for the designated shellfish species. In Alaska, only three areas, Cordova, Swikshak, and Polly Creek, have been certified for shellfish harvest (Orth et al., 1975). Since these areas are approved for razor clams only, mussels cannot be harvested there. Prior to harvesting mussels, one would have to convince the Departments of Health and Social Services and Fish and Game that the investment of time and money in approving these or other areas would be rewarding to the state (Torgerson, pers. comm.).

The requirements for leasing tidelands are still being developed and have not specified any regulations which would pertain to rafting. The Coastal Zone Management Program is also in the developmental stages. Due to the vast resources of shellfish which are available for fishing, little effort has been devoted to aquaculture planning. The state is tremendous in size, lacks a historical fishery for mussels, and is still a number of years behind the rest of the country as far as management and organization of that fishery are concerned.

Before attempting an aquaculture venture in Alaska, it would be wise to contact the Army Corps of Engineers, Department of Natural Resources, Department of Environmental Conservation, Department of Health and Social Services, Department of Fish and Game, and local coastal zone management agencies. The regulations are at a stage where they are still being developed and are thus likely to change during the next few years.

Washington. The sportfishing daily bag limit for mussels in Washington is 10 pounds in the shell. Neither a license nor a permit is required for recreational harvest.

Gear limitations for the commercial harvesting of mussels specify that one may harvest only with a pick, mattock, fork, or shovel operated by hand. A mechanical device may be used, but only if it has a special permit. Mussels may be taken only from the tidelands of licensed farms. Within Puget Sound harvesting may only take place from November 1 through

March 31 on the tidelands lying west of Dungeness Spit. Elsewhere on Puget Sound there is no closed season. Harvesting of mussels may take place throughout the year from licensed clam farms in Grays Harbor and Willapa Harbor.

The Department of Fisheries issues a clam farm license (\$15) if mussels are to be commercially harvested from beds or an aquaculture license (\$100) if mussels are to be cultured. No specific mussel aquaculture regulations have been established yet; however, they would probably be similar to the existing regulations governing salmon aquaculture. The Department of Fisheries encourages private and commercial aquaculture in Washington. The Department of Natural Resources is responsible for leasing waters for the purpose of aquaculture. Leases last for five year periods with options to renew up to a twenty year period.

The Department of Health and Social Services oversees water quality in the State of Washington. It implements the regulations of the National Shellfish Sanitation Program of the FDA. Waters are subject to a sanitary survey before they are certified for shellfish harvesting. Commercial shellfish harvesting is not permitted from any other beaches or bays. A PSP monitoring program is also in effect; in the event that toxic levels are found, commercial shellfish growers and the media are informed to prevent harvesting or marketing of affected shellfish.

Within the State of Washington, each county has developed its own shoreline management plan. Thus, county authorities must be contacted prior to setting up a mussel farm as regulations vary considerably among the different counties.

To give an example of how one obtains all necessary permits, a mussel farmer in Washington contacted three agencies to obtain the permits for setting up his culture business. These were: the U.S. Army Corps of Engineers, State Department of Fisheries, and the County Government. The Army Corps of Engineers coordinated with all other agencies necessary, such as the Department of Ecology, Natural Resources, EPA, U.S. Fish and Wildlife, and the National Marine Fisheries Service. Without any objections from anyone, all permits were granted within a ten-month period. Had there been any objections to the proposed plans for putting rafts in the water, the mussel farmer would have had to resolve these personally with the offended parties prior to being issued the permit (Jefferds, pers. comm.).

Oregon. The Department of Fish and Wildlife in Oregon is responsible for all sportfishing regulations. Seventy-two mussels are allowed per harvester per day. The season is open the entire year. Mussels may not be taken from the marine gardens at Otter Rock unless they are taken singly for use as bait. They may only be taken by hand or hand-powered tool.

No species requirements for mussel raft culture have been established. No precedents have been set for the leasing of waters for raft culture and this idea is apparently not favored. Harvesting of natural stocks is possible and has been done by at least one harvester. Twice monthly PSP

samples by the Health Division are a type of survey and harvest has been permitted under these conditions. The state does not wish to incur the cost of establishing and maintaining sanitary surveys of the ocean beaches just for the mussel industry.

The State Lands Division is responsible for the leasing of land and water; it has delegated to the Department of Fish and Wildlife the responsibility for leasing lands for aquaculture. This department may lease intertidal and other areas for oyster culture, but no regulations have yet been established for mussel culture (Snow, pers. comm.).

California. A 25-pound daily limit is placed on the harvesting of M. edulis and/or M. californianus from California waters. These must be collected by hand. Due to the presence of PSP in the waters a quarantine on both sport and commercial harvesting of mussels normally extends from May 1 through October 31. In 1976, however, the shellfishery had to be closed on March 22.

At the present time, mussels may not be harvested from California waters if they are to be sold fresh for human consumption. Some harvesting may soon be permitted from San Francisco Bay, providing the mussels are relayed or depurated. Mussels may be harvested from waters which are certified for other shellfish species (such as oysters) while a Health Department inspector is present. These may be used only to make broth. This obviously creates an unmanageably costly program for the Health Department (Sharpe, pers. comm.). The health agencies cannot be expected to favor a mussel industry under these conditions.

Mariculture regulations are in existence, but are not outlined for individual species. A \$25 license must be obtained for the privilege of cultivating marine life, "whether planting, promoting their growth, or harvesting them in, on, or from waters of this state." This license is administered by the California Fish and Game Department. Bottom-rights are also leased through this department. Leases are granted only if they are in the public interest--if no public clam digging is taking place on the bottom area in question, and if recreational purposes are not hampered. Leases are awarded to the highest bidder for a period of not more than 25 years, with renewal options after a period of 20 years.

Other agencies which must be consulted before establishing a mussel farm are the Army Corps of Engineers, the Coastal Commission, the Department of Public Works (county), and the Department of Public Health.

9.0 INDUSTRY PROBLEMS AND RESEARCH NEEDS

9.1 Economic Problems of the Industry

9.11 Resource Availability, Harvesting, and Distribution

The economic problems identified with the U.S. mussel industry from the subjective and objective profile may be grouped under three headings: resource availability, harvesting, and distribution. The first two categories conform to the NMFS matrix guideline; the last one is not included in the matrix format, as necessitated by findings from the research.

Resource availability does not appear to be a short-run problem but is without question a long-run problem if demand continues to grow at the same rate as the past ten years. Both the subjective and objective economic profiles indicate depletion of the wild mussel resource. Mussels are competing with other species for growing waters in a biological and economic sense. Survey responses from the west coast indicated mussels were harvested primarily to clear waters for species promising higher rates of return such as oysters. The quality of the resource is reduced in the summer months, thus dampening demand. Accordingly, the season is largely between October and May. In the winter months, however, ice can damage mussel beds and equipment so as to restrict resource availability. Finally, over half the respondents indicated knowledge of mussel beds being closed because of pollution.

Harvesting problems as perceived by dealers and harvesters include the following. Cutting and cleaning mussels is very time consuming and quite inefficient from an engineering and economic point of view. This is as true for capital intensive techniques of harvesting as it is for labor intensive techniques. More efficient gear both for the harvesting, sorting and cleaning of mussels could improve efficiency in the industry for the wild resource. Aquaculture has the great advantage of allowing more effective and efficient harvesting independently of improved gear since mussels are grown under controlled conditions.

In contrast with dealers/wholesalers, harvesters face problems in obtaining working capital. Dealers indicated a willingness and need to pay harvesters more but the wholesale price in metropolitan markets does not permit this. At the same time dealers emphasized the need to educate harvesters better as to an acceptable level of quality for the market. Finally, costs of harvesting are expected to increase from increasing fuel expenses and cost of maintaining equipment.

Distribution channels for wild mussels are well developed and pose few economic problems for the industry. One, however, is clearly evident from the survey results. Respondents from Maine did not indicate any serious losses due to problems with mussel freshness, storage, and shelf life in the summer. Most respondents from mailed questionnaires to the west coast and the east coast exclusive of Maine indicated such problems were severe constraints. Research in solving these problems has been conducted at the University of Maine - Orono during the past few years,

funded through the National Office of Sea Grant, N.O.A.A. Results from this research appear to have been disseminated effectively in Maine but not effectively throughout other mussel producing states.

9.12 Policy and Research Options

The Short Run:

1. Completed research from the National Sea Grant Blue Mussel Project should be systematically distributed to mussel harvesters, growers, and dealers outside of Maine. The survey results show that businesses in Maine have far fewer problems with respect to handling and storage that maximize freshness and shelf life than businesses in New York and Washington.

2. Assuming continued growth in the demand for mussels as projected from the period 1965-1975 into the future, efforts should be undertaken in the immediate future to prevent overfishing of the wild resource. Overfishing has in the past and could well again result in a short term glut in the market which would depress prices even lower than they are now and discourage suppliers. Moreover, by depleting the resource for a period of time it would undoubtedly compromise and perhaps even reverse the upward trend in demand that has been sustained for the past ten years.

3. Research efforts might be undertaken to increase productivity at the harvesting level in order to facilitate supplying a growing market. This would include, for example, improvements in the mechanization of very time consuming processes such as sorting, cleaning and shucking. Although the Survey results indicate that a larger supply of mussels would be forthcoming at the current price to harvesters if demand expanded, this would come from increased numbers, not increased effort by individuals currently in the business. By making returns more attractive in this industry for those now employed through increased productivity, a relative change in harvesting effort could be brought about which would economize on other species and exploit this underutilized resource.¹

The Long Run:

4. In the long run research along a broad spectrum aiding the development of mussel aquaculture must be undertaken if demand continues to grow at the same rate as the past 10 years. The unanimous conclusion of harvesters and dealers from the Survey is that the wild mussel supply is not sufficient in quantity or quality to enable a large scale industry to develop in this country such as exists in Europe.

5. Such an industry, based on aquaculture, would have to be designated an infant industry by the federal government and protected from European competition until it matures.

¹This should not be done at the expense of overfishing the mussel resource, however. More research is needed to see just how large the available supplies of wild mussels are.

9.2 Marketing - A Situation Analysis

Expansion of the blue mussel industry in the United States has been restricted by a historically limited market (Scattergood and Taylor, 1949a). In May 1973 the country's first major blue mussel promotional campaign was initiated by the University of Maine (U.M.O.), the University of New Hampshire (U.N.H.), and the Maine Department of Marine Resources (D.M.R.) through a tri-institutional Sea Grant Program. Consumer enthusiasm for the product was documented during the campaign at numerous national food exhibits and in-store demonstrations (Bouchard, 1976). From a marketing standpoint, the following general conclusion can be drawn. Given a steady and reliable source of high-quality supply, and adequate consumer education as to the benefits to be derived from the eating of mussels, the major impediments to the establishment of a successful mussel fishery would be removed.

Toward achievement of that goal, the NOAA Office of Sea Grant has commissioned U.N.H. and U.M.O. to continue the investigation into the problems associated with the marketing of blue mussels.

The eventual goal of the marketing project is to determine:

1. The reasons for negative attitudes concerning mussels on the part of certain suppliers and consumers.
2. The methods for altering these attitudes.
3. The principal economic impediments to the development of a natural mussel fishery.
4. The methods for removing these impediments.
5. The market potential for commercial raised mussels.

Termination of this phase of the project will follow formulation of specific marketing strategy plans.

The development of effective marketing proposals is dependent upon the collection of "the facts" surrounding the product or industry referred to as a "situation analysis." It is the purpose of this report, or situation analysis, to present the background data on the mussel industry needed by the marketing strategist. This was accomplished by:

1. Summarizing the available mussel data of relevance to the marketing function.
2. Presenting the results of additional primary research involving mussel fishermen, dealers, wholesalers, retailers and consumers.
3. Presenting options for future research in specific areas in order to facilitate future strategy plans.

The research methods employed were fairly simple and routine in keeping with the basic purpose of the report. The initial phase involved the preparation of a research outline indicating specific types of data needed, together with suggested sources of secondary data. With one or two exceptions, these efforts went unrewarded due to the limited amount of relevant published data. In an attempt to correct this deficiency, a detailed questionnaire was designed to collect primary data directly from businessmen involved with the collection, selling, and reselling of blue mussels. The results of this phase of the research were more encouraging. Businessmen in general were quite willing to discuss their operations and the problems they encountered. Unfortunately, due to time and manpower constraints, the number of interviews conducted was rather small, and limited to a narrow geographical area, (the Portland and Brunswick-Rockland areas of Maine, and the greater Portsmouth area in New Hampshire). Therefore, although the interviewers were able to identify issues of primary importance, these were too few to provide all the data desired on the industry and the impediments to its growth.

The positive results of the study were substantial, however, and should not be ignored:

1. Identified principal problem areas and impediments to industry growth.
2. Confirmed and/or clarified secondary source material.
3. Elicited detailed commentary from those closest to the issues and problems.
4. Indicated attitudes at different levels of the distribution channel.
5. Assisted in the identification of areas needing future research.

Product and Production System. Despite a comparatively low level of consumption in the U.S., blue mussels are not necessarily considered an undesirable commodity. The low consumption level seems to be attributable, rather, to a low level of consumer awareness and supplier interest.

Current consumption is generally limited to European ethnic populations in large cities (the mussel enjoys widespread popularity in Europe), metropolitan epicures, and pockets of innovators in the New England seacoast area. Current detractors are also in a distinct minority, limited to: (1) those who have seen the relatively unattractive clusters of mussels among rocks and pilings and assume them to be worthless; (2) native New Englanders who have traditionally seen them used as fish bait; and (3) those few who have tasted the product and, for reasons explained in detail below, have been dissatisfied.

Recent promotional brochures have, almost without exception, made reference to the positive attitude with which the Plymouth Pilgrims received mussels: "This bay is a most hopeful place..an abundance of muscels (sic), the greatest and the best we ever saw..." (Hurlburt and Hurlburt, 1974). It is difficult therefore, to explain why a product which was received so enthusiastically by our ancestors is now high on the list of under-utilized species. Except for a brief period of intensive fishing during the lean World War II years, mussels have been largely ignored (Dow and Wallace, 1954). This would seem to indicate that in the U.S., mussels (at least until the war years) had been considered a valuable food only in times of extreme shortage of preferred foods. The possibility that such a shortage may be imminent is helping proponents of mussels to attract attention to the potential of that shellfish. Several other factors contribute to the market potential for the blue mussel: the consistent increase in the per capita consumption of seafood (10.6 pounds in 1967 to 12.9 pounds in 1973) (Cobb, 1973), the gradual decline of available domestic resources, and the steadily increasing costs and decreasing supplies of preferred shellfish and other foods.

Regardless of whether mention of these facts is considered alarmism or foresight, mussels are an abundantly available under-utilized species. They have the additional proven advantages of being well-suited to commercial cultivation. Their potential as a partial solution to a number of problems is, therefore, readily apparent.

On the sand, amongst rocks, or on pilings, the harvesting method is a time-consuming manual process involving hoes, pitchforks, or clam rakes. The principal advantage of this method is that it permits greater attention to the size and quality of the mussel to be harvested.

After harvesting, the mussels are washed in a machine which separates the clusters and cleans the shells. The machine (which costs approximately \$1700) does not, however, remove the mud and silt trapped within the shell. This is one of the primary causes of consumer dissatisfaction with the product. Proper post-harvest preparation calls for the immersion of the mussel in seawater, usually in rafts, or in depuration tanks for 1-3 days. This permits the mussel to cleanse itself of foreign particles and to restore body liquids depleted in washing and handling. Oftentimes, however, the mussel is immediately packed and shipped after washing. During the winter months this does not seem to present as serious a problem as it does during the summer when post-harvest immersion of mussels is almost mandatory due to the generally weaker condition of the mussel after spawning and harvesting in warmer temperatures. Most fishermen claim that immersion overnight is sufficient for restored vitality. However, the problem of low quality associated with foreign particles trapped in the mantle remains.

Mussels are then packed in bushel quantities in well ventilated burlap or polypropylene bags. In the summer, quantities of crushed ice are added to the bags to aid in the preservation of the product. However, actual freezing of the product results in a significantly increased mortality

rate (Slabyj and Hincle, 1976). Although shelf life of the mussel is considered to be 3-4 days, recent experiments have shown that, packed with the correct quantity of ice under ideal temperatures, the mussel will live up to 30 days in the winter, and from 17-20 days in the summer months (Slabyj and Hincle, 1976). These results were obtained in a laboratory environment, but indicate the increased market potential of the product when shipped and stored under proper conditions. At present, the use of refrigerated trucks is not considered necessary by many dealers.

As stated previously, the benefits of mussels are substantial.

1. They contain a high degree of protein. In fact, one pound of mussel meat contains 65.3 grams of protein while a similar quantity of choice beef contains only 59.1 grams of protein (Cobb, 1973).

2. They contain more total nutrient content than other popular shellfish (Hurlburg and Hurlburt, 1976).

<u>Species</u>	<u>Total Nutrients Per Pound</u>	<u>Calories of Fuel Value Per Pound</u>
Sea mussels	8.4	150
Lobster	7.6	141
Long clams	8.2	136
Round clams	4.5	68
Oysters	2.5	41

3. They are highly efficient in terms of food conversion (protein consumed to create protein). While a steer consumes approximately 21 pounds of protein (in the form of grains, etc.) to produce one pound of protein, the mussel simply filters plankton, which is not considered protein otherwise available to humans (Hurlburt, 1976).

4. They are generally considered to be very tasty: "Better than clams", "rich", "robust", "somewhere between an oyster and a clam" in taste, are a few of the taste descriptions found in consumer surveys.

5. They are adaptable to a great number of recipes as protein substitutes in recipes calling for other high-priced meats, or recipes developed exclusively for mussels.

6. They are abundant and available for harvesting year round.

7. The price is generally low, usually about 1/3 that of clams. Retail prices range from a low of 25 cents/pound in Maine during the fall to 79 cents/pound or more in Boston.

8. The successful marketing of blue mussels could:

- a. Pave the way toward acceptance of other underutilized species.
- b. Postpone or prevent the depletion of traditionally preferred shellfish resources.

c. Provide an "economic boost" to the New England fisheries.

Conversely, the following disadvantages characterize the blue mussel:

1. Because they are not a well-established product, their availability at the retail level is sporadic.
2. Their physical appearance, as clusters along the tidal flats or among rocks "...piled high into a black mass on a table..." is quite unattractive to some consumers (Nathan, 1975).
3. The occasional presence of pearls and particulate matter in the mantle tissue or within the shell cavity of the mussel lends an unattractive "grittiness" to the product and could result in a broken tooth (in extreme cases).
4. Some mussels, especially those which remain exposed for long periods intertidally, are characterized by low meat yields.
5. Traditional eating habits and customs militate against the trial of a new product among certain consumers.
6. The traditional use of mussels as fish bait in New England promotes a negative attitude when suggested as a food source.
7. Mussels are highly susceptible to red tide and to other toxic substances due to their location near the surface of the water and their filter feeding method.

In summarizing the marketing implications of the product and production system, it seems quite clear that two general factors act to impede the growth of the mussel industry. First, consumers are not sufficiently familiar with the product, and the consequent lack of demand results in sporadic supply. A more efficient supply channel could develop in the wake of an increased and sustained demand for mussels. Second, because of limited demand and low prices, few incentives exist to insure a quality control at the retail or dealer level. Poor quality mussels discourage expansion of the market.

Industry Profile

Due to the lack of consumer demand and lack of established concepts of quality, an efficient supply system has failed to develop. This failure superimposes some of the following characteristics which further limit the expansion of the industry.

1. Poorly developed distribution channels.
2. Frequent low-quality harvest.
3. Destructive competition among dealers for a limited number of wholesalers during the peak winter months and sporadic supply during the summer.

4. An attitude of discouragement among conscientious fishermen concerned with quality and among proponents of mussels in general.

In an attempt to clarify these observations and to identify the primary impediments to the industry, the following profile is offered, based upon interviews with industry spokesmen from fishermen to retailers.

The Fisherman. The need for appropriate incentives to promote the successful expansion of the industry is especially apparent at this level of the industry. The quality of mussels at the retail level is almost solely dependent upon the fisherman's care in harvesting.

During the summer, spawning activities combined with the warmer waters results in a generally weaker product.

Over-fishing the most convenient mussel beds is another direct result of insufficient education and incentives. The most accessible beds can soon become exhausted. Immature mussels are harvested along with those of marketable size, and none are left to reseed the area. Although carelessness and irresponsibility are partially to blame, the economic motive is clear. The ratio of cost to payoff does not warrant increased care in the short run. Most commercial fishermen will concentrate on the more profitable shellfish with a ready market. Mussels, then, are only harvested sporadically in order to fill the boat. The effects on supply consistency are obvious.

To combat the various problems and impediments at the fisherman level, interview respondents suggested implementation of the following measures:

1. Prohibition of summer harvesting in certain areas (much like the closed season on scallop fishing). This would permit the mussel to spawn unhindered in depleted, heavily-harvested areas and would aid in upgrading quality.

2. Enactment of regulations prohibiting the harvesting of mussels less than two inches long.

3. Agreement among fishermen to reseed depleted beds.

4. Agreement among fishermen to refrain from pilfering beds transplanted by other fishermen. (This of course implies establishment of defined "territories.").

5. Increased quality checks, possibly regulated by the Department of Marine Resources (or equivalent). The expected effect would be to facilitate consumer acceptance by insuring a higher-quality product. These checks would be for characteristics such as lack of mud, pearls, etc., and would be in addition to required sanitary inspections.

6. An increase in the price paid to fishermen in order to stimulate consistent and quality supply. (Currently the fishermen are paid between \$3-\$4 per bushel compared to \$16-\$20 per bushel for clams.)

Dealers and Distributors. Dealers form the first link in the supply and distribution channel, which operates from fisherman to dealer to metropolitan wholesaler to retail marketer or restaurateurs.. (The amount of mussels which go from dealers directly to local retailers or restaurateurs is small by comparison.) Demand is generated at the retail level and cascades down this series of links. Because mussels do not store well (see Section 9.4), a dealer cannot gamble in futures without assuming risks which are not warranted by the low prices paid for mussels. Sporadic supply at the dealer level is perpetuated by uncertain and discontinuous demand. These factors effectively limit the number of dealers who can profitably enter the business.

This situation further prompts many dealers to handle the product only seasonally (usually October through April) when increased local quality promotes increased demand and supply. While this is a long season, it cannot take advantage of locally increased demands for shellfish during the summer tourist season. An additional effect is the inability of most dealers to depend upon mussels as their sole source of business. Most are clam or lobster dealers handling mussels as a side activity.

Despite established dealer-wholesaler relationships, demand from the wholesaler is rarely consistent or guaranteed in any way. Dealers prefer to deal in bulk quantities to more established markets such as Boston, New York, Philadelphia, or Montreal. As a result, the smaller retailer or restaurateur outside these areas is often neglected, contributing to insufficient exposure and spotty supply.

Dealers surveyed generally shipped between 100-300 bushels per week during the summer and approximately 500-600 bushels during the winter. They paid between \$3-\$4 per bushel to the fisherman, and resold the bushel for \$5-\$6 to the wholesaler. Transportation costs to Boston were \$1.50 per bushel. All sales terms were indicated to be f.o.b.

As indicated previously, shipment is by truck. The mussels are packed in ventilated bushel bags with a limited amount of fresh water ice to reduce mortality. It is important to note that, in most cases, the distribution costs of mussels are largely covered by the shipment of "money-earners", such as lobsters, in the same load. The increased market area possible through air freight shipment is not presently feasible due to the bulkiness of the item in relation to its price.

There is very little advertising at this level. Promotion is limited to selling stock to the next level in the channel.

Retailer. The principal problems at the retail level are inconsistent quality of supply and a limited demand. Restaurateurs are particularly concerned with quality and often carry mussels only during

winter months. Presently, the mussel is used as either an appetizer or menu variation in restaurants. Very few restaurants list it as standard fare, reflecting the concern for both consistent quality and supply.

An obvious solution to the supply problem seems to be direct supply by the fisherman or dealer. Unfortunately very few dealers are willing to negotiate anything but bulk orders. Similarly, most fishermen find small, fragmented supply impractical and unattractive.

The advertising and promotion of mussels even at the retail level (fish markets, supermarkets) is extremely minimal. First, it is often difficult to induce a supermarket to carry a product like the mussel which is not a "guaranteed mover." Also, there is little packaging or branding done, with the very limited exception of canned mussels. The principal reason for this seems to be uncertainty as to "proper" packaging procedures. One supermarket, for instance, placed the mussels in a plastic tube with a film seal, affixing the store's name to the outside. This particular procedure seems to be an exception rather than the rule, however.

At present, packaging and branding decisions must be made at the retail level. In the supermarket, this would seem to be a relatively simple proposition. One pound quantities of mussels could be easily packaged by the same method used for other seafoods and meats. Similarly, if branding is considered to be desirable, the most logical solution would be to use the store name. The fact that little branding is used for other fresh-packaged meats and seafoods may indicate this is unnecessary. Packaging and branding may do much to increase product appeal to the consumer, however.

Supply and Demand. As previously indicated, the dynamics of supply and demand at various levels of the distribution channel are at the mercy of a rather complicated and cyclical interaction of economic forces. The following is a superficial description of these interacting problems which should serve to acquaint the reader with their basic scope and effects.

1. Dealers are never certain of the wholesaler demand for mussels.
2. This results in inconsistent dealer demand for mussels from the fisherman.
3. This limits the number of dealers who can profitably enter the market.
4. The dealer generally prefers to deal in bulk quantities to a wholesaler, avoiding the problems of meeting small, scattered, and sporadic retailer demand. Available mussels are funneled into a limited number of wholesalers. The majority of small retailers outside ethnic markets are consequently neglected and lose interest in the product.
5. The dealer could break this funnel effect by dealing directly with retailers, but he is usually small and ill-equipped to do so, and limited demands do not warrant his efforts to establish such a trade route.

6. Lower quality at the wholesale level during the summer results in decreased demand. This imposes a seasonality of the product.

7. During the winter months, quality is more consistent and demand increases. The limited number of wholesalers may cause a high degree of competition among dealers at this time of year, however, perpetuating competitively low costs.

This completes the cycle. Because demand at the consumer, and hence retail, level is uncertain, dealers and fishermen cannot depend on a steady mussel business. Low prices paid for mussels limit dealer profit-making to bulk quantities, which are sold to metropolitan wholesalers. Local exposure and expansion of the mussel market is consequently forfeited. Continued low demand and low prices fail to encourage much consciousness of product quality at any stage of the distribution network. Frequent poor quality discourages both traditional consumers as well as newcomers.

Market Profile

From 1964 to 1975 the quantity and value of New England landings of mussels has exhibited a fluctuating, but generally upward trend:

New England Landings of Mussels (figures expressed in thousands)

<u>Year</u>	<u>Maine</u> <u>Quant/Val</u>	<u>Mass.</u> <u>Quant/Val</u>	<u>Rhode Is.</u> <u>Quant/Val</u>	<u>Conn.</u> <u>Quant/Val</u>	<u>Totals</u> <u>Quant/Val</u>
1964	15/1	179/16	-/-	-/-	194/17
1965	32/3	150/11	2/1	-/-	184/15
1966	240/20	186/25	4/1	-/-	430/46
1967	371/31	404/62	-/-	-/-	775/93
1968	389/31	103/16	-/-	-/-	492/47
1969	353/29	86/17	-/-	-/-	439/46
1970	301/64	166/34	-/-	-/-	467/98
1971	150/35	209/50	-/-	(1)/(1)	359/85
1972	281/71	42/11	-/-	-/-	323/82
1973	440/116	35/10	-/-	-/-	475/126
1974	308*/33	53/11	43/13	1/C	410/107
1975	612/198	50/15	224/63	-/-	886/276

(Dollar amounts refer to prices paid to fisherman)

(1) Less than 500 pounds or 500 dollars.

*The decrease from 440,000 lbs to 308,000 lbs. in Maine during 1974 reflects the affects of widespread red tides in the Gulf of Maine. Indications are, however, that 1975 witnessed a return to more or less normal levels. These figures look rather optimistic, but comparison with similar figures during the World War II years indicates the enormous potential currently unrealized.

(Source: Fishery Statistics of the United States.)

New England Landings of Mussels, 1942-1947

(Thousands of Pounds)

	<u>Maine</u>	<u>Mass.</u>	<u>Conn.</u>	<u>Totals</u>
<u>Year</u>	Quantity	Quantity	Quantity	Quantity
1942	46	-	.5	46.5
1943	2,612	-	-	2,612
1944	2,594	36	-	2,630
1945	2,733	50	-	2,783
1946	2,314	32	5	2,351
1947	40	-	5	45

(Source: Fishery Statistics of the United States)

For additional perspective on the relative position of mussels in the market, the following New England landing statistics for traditionally preferred shellfish are offered:

(Note: Figures are 1973 statistics in thousands of pounds and thousands of dollars. Dollar amounts are prices paid to the fisherman.)

New England Shellfish Landings, 1973

	<u>Pounds</u>	<u>Dollars</u>
Clams	11,738*	9,060
Shrimp	20,734	5,657
Lobster	26,500	37,600
Scallops	3,900*	7,100
Mussels	475*	126

* Wet meat weight.

(Source: Fishery Statistics of the United States, 1973)

As previously indicated, mussels are priced considerably lower than other shellfish at all levels of the distribution channel:

	<u>Price Paid</u>		
	<u>Fisherman</u>	<u>Dealer</u>	<u>Retailer</u>
Mussels	Approx. \$.08/lb. \$3-4/bushel	\$3-4/bushel	Approx. \$.25-.79/lb. depending on location
Clams	Approx. \$16-20/bushel	\$23-30/bushel	Approx. \$.60-.90/lb. depending on location

Several fishermen expressed dissatisfaction with this situation. In their judgment, only the retail level was "turning a decent profit." The implication was clearly that increased prices paid to fishermen and dealers would stimulate increased quality of supply at all levels. In addition, the potential for industry expansion through price incentives is further enhanced by the fact that most mussel fishermen are also clam fishermen. They consider the harvesting of clams to be tedious and time consuming in comparison with that of mussels.

In closing, some brief mention should be made concerning the commercial cultivation of mussels. This report has been concerned solely with the current situation within the New England mussel industry, and the impediments to its expansion. The potential of cultivation, given solutions to the current problems surrounding demand, is enormous. In fact, it is reasonable to assume that with sufficient demand, capital, cultivation areas, and expertise, cultivation could furnish the market with a higher quality mussel in far greater quantity than would be possible on a sustained basis with wild mussels. The success of commercial cultivation in Europe is adequate testimony to this statement.

From a marketing perspective, however, the following are the more important problems which must be overcome before duplication of European mussel cultivation success can occur:

1. The same product preconceptions and misconceptions must be overcome as with wild mussels, though the higher quality of cultivated mussels can be expected to alleviate this situation somewhat.
2. Marketing solutions must accompany economic feasibility studies to justify increased expenditures for material and equipment.
3. Adequate demand must be in evidence to attract venture capital.
4. The effect of increased price would have to be accurately predicted.

Research Needs and Options

The following is a list of areas which, based on the above discussion, warrant additional research.

1. During the primary research phase of this investigation, it became apparent that a number of consumers thought of mussels in terms of "steamers." This indicates a generally preferred form of preparation. It may be of interest to determine the effects of "generic branding" of mussels as steamers. In other words, if the mussel is thought to be some form of "steamer variant", initial acceptance of the product may be facilitated through the promotion of these similarities.

2. Additional research must be conducted into the entire area of retail package and display variations. What would the consumer prefer? What would the supermarket expect of the wholesaler? Does the retailer know of the ideal conditions under which the product should be kept? How would this affect his display?, the packaging?, and so forth.

3. A more exhaustive study needs to be undertaken to determine the actual extent and effects of the various supply and demand constraints within the distribution channel.

4. In conjunction with recommendation #3, the economic feasibility of incentives to the fisherman in the form of an increased price per bushel should be determined. As a means for spurring consistency of quality and supply at all levels, wholesale price increases warrant considerable study.

5. Similarly, the effects of increased price at the consumer level need to be explored during the test market phase. It must be remembered that mussels are currently priced at approximately 113 the level of clams. The current interest in mussels by a large restaurant chain is a prime example. A price increase should not be considered a deterrent to acceptance.

6. The current number and location of mussel dealers, wholesalers, and canneries should be determined for more accurate assessment of industry conformation and potential.

7. The size and value of U.S. exports and imports of mussels need to be known together with an assessment of the potential for increased exports.

9.3 The Occurrence of Pearls in Mussel Meats

Among the principal objections and limiting factors to the commercial use of a large quantity of natural mussels is the presence of large (greater than 1 mm) and numerous pearls embedded directly in the mantle epithelium of the mussel. These have been encountered by Herrington and Scattergood (1942) and Scattergood and Taylor (1949b) in a survey of mussels along the Maine coast. Their results indicated considerable variations in both the number and size of pearls with geographical location. Because pearls affect consumer acceptance of the product (Herrington and Scattergood 1942), they recommended the closing of six areas in Maine where pearl incidence was high. This represented about 1/5 of the total estimated (commercially-exploitable) Maine mussels at the time. Before examining the effect of rafting upon the presence of pearls, a brief review of the existing knowledge concerning the subject of pearls in mussels might be instructive.

The presence of pearls in mussels has been known for at least 300 years (Giard, 1907). Garner (1872) recognized that such pearls were formed as a reaction by the mussel to a small parasite (harmless to man), later found to be a digenetic trematode in the genus Gymnophallus (Lutz, 1974a).

Thus far, the suggested life cycle involves a sea duck (either an eider, Somateria mollissima, or a scoter, Oedemia nigra) as the adult host, and the blue mussel as an intermediate host (Stunkard and Uzmann, 1958). Whether a second intermediate host is required remains uncertain. In general, therefore, the life cycle of the trematode is not well-established.

Research in progress at the University of Maine suggests that the presence of pearls in mussels from Maine waters is also the result of infection by the trematode Gymnophallus. In support of this idea are three pieces of evidence: (1) when the pearls are treated with dilute hydrochloric acid, the resulting residue consists of an amorphous mass, which is probably organic in nature. It is reasonable to conclude that this may be the remains of a trematode although, conceivably, it may represent the remnants of the organic matrix within the structure; (2) the diameters of the smallest pearls found correlate quite nicely with the lower limit of the size range reported for the larval trematode (approximately 120 microns), and (3) larval trematodes which are morphologically very similar to those described by Jameson (1902) have been isolated from the mantle tissue of mussels from Maine waters (Lutz, 1974a). Alternate natural mechanisms (if existent) of pearl formation, other than trematode initiation, are not well understood.

Whatever the factors involved in pearl formation, research to date suggests that rafting techniques eliminate pearl production as a limiting factor to the commercial use of cultivated mussels in both U.S. and Europe (Lutz, 1974a, 1974c). However, the presence of pearls continues to be a deterrent to the commercial exploitation of natural populations throughout the northeast.

Further research at the University of Maine suggests that differences reported by Scattergood and Taylor (1949b) in the size and number of pearls in various populations through the state may be largely a reflection of differences in the ages of the studied populations, i.e., older populations might naturally be expected to contain larger and more numerous pearls. If so, the locations of pearl-producing areas might be expected to fluctuate with time depending on the age structure of the various mussel populations. The exact relationship between age and the incidence of pearls in numerous areas along the Atlantic coast must be investigated before adequate management guidelines can be established for east coast beds.

To date, pearls have not been a problem in mussels collected from the west coast.

Summary

1. The presence of pearls within the mantle epithelium of M. edulis represents one of the chief limiting factors to the commercial utilization of large quantities of mussels along the Atlantic coast.

2. Research at the University of Maine has demonstrated that, when raft cultivation techniques are employed, pearl production is no longer a commercial deterrent.

3. The relationship between mussel age and pearl incidence has been quantified for two populations of M. edulis.

4. Factors responsible for the presence or absence of pearls in natural populations of M. edulis are not well understood.

Research Needs

1. Basic life history studies on the trematode(s) reportedly responsible for pearl formation in M. edulis should be conducted.

2. Alternate natural mechanisms (if existent) of pearl formation, other than trematode initiation, should be understood.

3. Environmental and biological factors responsible for the presence or absence of large and numerous pearls in geographically isolated populations of M. edulis should be further researched.

4. The exact relationship between age and the incidence of pearls in numerous areas along the Atlantic coast must be investigated before adequate guidelines can be established for east coast beds.

9.4 Handling of Mussels and the Extension of Shelf Life

Mussels are packed by the dealer into one-bushel burlap or polypropylene mesh bags and transported by truck to metropolitan wholesalers. The trucks are usually cooled, but the mussels are generally not shipped in ice. Packaging display, and handling practices vary in the retail store.

Under existing practices, the shelf life of the blue mussel, Mytilus edulis is approximately 3-4 days, though the shelf life of this mollusk has been increased significantly by storage in ice. However, standard practical and economical methods designed to increase mussel shelf life are needed to expand both the geographical range and the local volume of the mussel market (Slabyj and Hinckle, 1976). An increase in possible safe holding time would reduce risk of loss by the wholesaler, who should then be able to provide a high quality product at a reasonable price. This, in turn, should encourage retail sales. Both consumer protection and market business could benefit from an extension of shelf life.

Food quality standards for mussels are presently the same as those established for other shellfish by the NSSP administered by the Federal Food and Drug Administration (Hurst, personal communication; Apollonio, 1975). Recent research, however, indicates several problems associated with those regulatory standards (Miskimin et al., 1976; Corlett, 1976). Processing

(primarily freezing and canning) is known to extend shelf life by extending the time period during which shellfish samples comply with present food quality standards. However, both processes may have economic and food quality limitations (Corlett, 1976).

The level of fecal coliform organisms is presently used as the standard for evaluating the market acceptability of shellfish (Andrews et al., 1976)*. Since there are regulations governing the allowable total coliform counts in the growing waters (70/100 mls) (Andrews et al., 1976), high coliform counts in meats at the retail level indicate poor post-harvest handling procedures and possible buildup of microorganisms of public health significance. However, regulations based on fecal coliform levels may be inadequate. While Salmonella and Streptococci counts frequently correlate well with those of E. coli (Andrews et al., 1976), high counts of other pathogenic microorganisms may occur irrespective of E. coli levels due to the competitive elimination of enter-obacteria in seawater (Jannasch, 1968) and the environmental incompatibility of marine waters with E. coli (Faust et al., 1975).

The environmental interrelationships of these organisms and their behavior with respect to E. coli under storage conditions are poorly understood (Miskimin et al., 1976). Since E. coli eventually dies out in seawater (Jannasch, 1968; Faust et al., 1976), it may be a poor indicator of other pathogens, not likewise affected, from the same pollution source. These pathogens may grow rapidly after processing methods eliminate the normal spoilage microflora. In one instance, Staphylococcus aureus was found in processed seafood (crabmeat) which was acceptable by E. coli standards (Slabyj et al., 1965). Furthermore, pathogens which are not of fecal pollution origin would not necessarily be suspected when tests for fecal coliforms yield negative results. Clearly, microbial standards for mussel meats need to be re-evaluated.

Post-harvest multiplication of fecal coliforms in initially acceptable mussels presents a problem to the food handler. Qualitative changes in bacterial populations occur during storage, and these changes may be responsible for decreases in product quality (Slabyj and Hinckle, 1976). Research is needed to evaluate the public health significance of these qualitative and quantitative changes. This investigation should be directed specifically to each species of commercial shellfish because each has its own peculiar microbial flora which presents different competitive situations with respect to microbes of human health concern (Slabyj, personal communication).

While bacterial multiplication is itself apparently not related to the mortality of mussels being held, cold storage decreases both bacterial multiplication and shellfish mortality. Determination of optimal cold storage

* The total fecal coliform count in meats at the market is 230/100 g meat, and the total bacterial count can be no greater than 500,000/100 g meat.

temperatures is needed in order to provide increased shelf life of the fresh product while minimizing bacterial growth (Slabyj and Hinckle, 1976). The inadequacies associated with equating product quality to present microbial standards have already been discussed (Miskimin et al., 1966; Andrews et al., 1976; Corlett, 1976). Recent work by Corlett (1976) extends the need for evaluation of microbial standards to refrigerated and frozen food items; Slabyj and Hinckle, (1976) and Chichester and Graham (1973) stress the importance of such investigation to improvements in the handling of blue mussels and other seafood commodities. This optimal temperature, then, will have to reflect new findings regarding microorganism growth in mussels in cold storage, fluctuations in temperatures normally encountered in transport and sales, and the costs of refrigeration at various temperatures.

Processing by freezing or canning may provide the key to a major part of the mussel market. Although not as desirable as the fresh product, processed mussels are less risky to transport. While frozen handling certainly extends the shelf life of the food product, it is expensive and is not immune to the microbial changes described above by Corlett (1976). Canning provides perhaps the greatest benefit in safe, prolonged shelf life, but results in a loss to the packer due to meat shrinkage. Specific investigation of the long term taste-quality and microbial activity of frozen and canned mussel products is needed (Slabyj, personal communication).

RESEARCH RECOMMENDATIONS

The specific and major research needs described above can be recapitulated as follows:

1. Investigate the pre-harvest and post-harvest interrelationships of pathogenic microorganisms (with respect to counts of fecal coliform organisms in mussels) in order to evaluate present shellfish quality standards as they pertain to mussel products. The significance of this investigation to the economics of the food industry is discussed in a paper by Miskimin et al., (1976).
2. Determine the optimal temperature and other relevant conditions for storage of live mussels, taking into account such factors as mortality, product acceptability, and loss of shell liquor.
3. Determine long-term taste quality and sanitary quality of various processing methods.
4. Establish new microbial standards for the evaluation of mussels.

9.5a Closure of Shellfish Harvest Areas Due to Paralytic Shellfish Poisoning and Other Causes - East Coast

A problem associated with the harvest of bivalves in general, and Mytilus edulis in particular, is the repeated but unpredictable occurrence of Paralytic Shellfish Poisoning (PSP) caused by blooms of the dinoflagel-

late Gonyaulax tamarensis in the Gulf of Maine (Sasner, 1974; Yentsch, unpublished manuscript). Gonyaulax blooms, or "red tides", can and do occur at any time during the summer, but the most extensive blooms occur in the spring (May) and fall (late September - early October). These blooms are presumably due to the breakdown of thermal strata which results in increased nutrient availability, although a number of other environmental parameters are probably involved (Sasner et al., 1974; Yentsch et al., 1975). The density of the spring bloom is commonly limited by marginally acceptable water temperatures (about 7°C); fall blooms are usually the most severe (when surface water temperatures average 15°C) (Yentsch, pers. comm.). However, this simple generality is complicated by marked geographical and annual variations (Sasner et al., 1974). Mussels are the most efficient of commercially valuable bivalve filter-feeders (McLeod, 1975) and are themselves unaffected by the presence of blooms of G. tamarensis. As a result, they accumulate tremendous amounts of toxin, presenting a problem to consumers of mussel meats (Sasner et al., 1974; Sasner and Ikawa, 1975). Information on the chemical and physiological characteristics of toxins elaborated by marine algae has been reviewed by numerous authors (Medcof et al., 1947; Prakash et al., 1971; Norris et al., 1973; Sasner et al., 1974; Sasner and Ikawa, 1975; Schantz et al., 1975; Evans, 1975; Yentsch et al., 1975; Yentsch, 1976; Buckley et al., 1976).

Consequently, all areas of the Maine coast must be monitored throughout the summer primary productivity season (April through October) for the accumulation of this toxin in shellfish. Laboratory testing of mussel meats is conducted using a modification of the mouse bioassay first employed by Sommer and Meyer in 1937 (see Buckley et al., 1976). A dose-response formulation converts the resultant death-time data to micrograms (μg) saxitoxin equivalents per 100 g of fresh mussel meats. A level of 80 μg toxin per 100 g fresh mussel meats (80 $\mu\text{g}/100\text{ g}$) is sufficient to warrant closure of a shellfishery in geographical locations where these levels are found. This bioassay is faster and more reliable than serological or chemical tests developed to date (Buckley et al., 1976).

Because of the unpredictability of spreading, the observed patchiness of blooms, and the problems associated with continuous monitoring of a 2,500-mile coastline, a generous "buffer zone*", also closed to shellfish harvest, must be established. The technology of our present monitoring system and the sometimes sudden and extensive blooming tendency of G. tamarensis as well as its varying toxicity to different individuals makes this rather conservative approach necessary. Although there is wide variation among human beings, an average individual would become sick after consuming about 1000 μg of the toxin (Sasner et al., 1974). The LD₅₀ for cats and mice is between 5-10 $\mu\text{g kg}^{-1}$ (Evans, 1975). This suggests that the LD₅₀ for a human is between 500-1000 μg . A single mussel had accumulated

*A "buffer zone" is an area which is not yet affected by toxic levels of PSP, but which a) is quite likely to be affected in the very near future and/or b) is convenient to establish because of prominent geographic (cartographic) features, such as a river or headland.

upwards of a thousand μg of toxin after a prolonged and particularly intense bloom along the southern coast of Maine (Hurst, pers. comm.), and PSP scores of up to 9,500 were recorded in some Massachusetts samples after the 1972 red tide (Sasner et al., 1974). Mussels from Monhegan Island, Maine (a permanently closed area) reached levels of 24,000 $\mu\text{g}/100\text{ g}$ after the 1974 red tide (Gilfillen et al., 1976)..

The illness associated with PSP first manifests itself as a tingling sensation at the extremities, followed by a loss of equilibrium, and vomiting. Extreme cases have led to respiratory arrest and death. The avoidance of mussel meats as "poisonous" by the Indians and by people of our coast (Field, 1908)--people whose ancestors came largely from mussel-consuming European countries--is probably the result of such illnesses prior to our awareness of PSP. Mussels will gradually purge themselves once the red tide has subsided. The rate of this depuration is a function of the total accumulation of toxins and other parameters affecting the pumping rate of the mussel (Hurst, pers. comm.).

PSP Monitoring Program

The Maine Department of Marine Resources (DMR) is responsible for the regular monitoring of 2,500 miles of rugged, irregular coastline. Due to cost-effective restraints, direct and regular monitoring is possible only at a limited number of locations. There are 18 of these primary monitoring sites, located largely on exposed shores and peninsulas. Based on current experience, PSP can be detected here first, before it moves into the bays where most of the shellfish harvest occurs (Hurst, pers. comm.). Samples of shellfish are collected by DMR staff members and returned to the laboratory at Boothbay Harbor, where they are tested via mouse-assays (see above) for toxin levels (expressed in $\mu\text{g}/100\text{ g}$ meat). There are 100 secondary stations where the progress of dinoflagellate blooms and the accumulation of toxins by mussels can be monitored.

Checks at the primary stations are performed about every other week beginning in early April (April 30 is the earliest occurrence on record), and every 7-10 days starting June 1. If levels at any one site, or a number of sites, are sufficiently high (80 $\mu\text{g}/100\text{ g}$) the shellfishery in the area is closed. The geographical extent of the closure depends on the level of toxin found at the monitoring site and the history of spreading in that particular coastal section (DMR has records of closures and toxin levels beginning with 1958). Monitoring of secondary stations is immediately begun to closely watch the extent of the bloom. Levels of toxins in the meats are periodically checked throughout the bloom period and through natural depuration until the fishery is again opened, after which time the shellfish in the affected area are checked once weekly. Two full-time staff members are responsible for this field work, and 50-100 samples can be assayed in one day at the Boothbay laboratory. Since the monitoring is staggered, this pace rarely becomes necessary, but may occur during "crisis" blooms when large areas are affected (Hurst, pers. comm.).

The shellfish monitoring program's foremost concern is consumer protection against periodic health hazards. To this end the present program is effective and reliable. Through its numerous monitoring sites, DMR also tries to accommodate the shellfish industry by: 1) its practice of only partial closings, and 2) reopening of beds once they are again safe.

As the mussel industry increases in importance, it will be desirable to better understand the environmental biology of Gonyaulax, to improve specific monitoring technology, and to understand the time-exposure relation between Mytilus edulis and Gonyaulax tamarensis. Improvements in this field should enable better prediction of the timing, location, and potential severity of red tides and enable more discriminatory judgments on the opening and closing of mussel harvest areas. Optimal location of cultivated mussel operations could also result from a better understanding of the environmental parameters affecting Gonyaulax blooms. For instance, current research on the effects of available trace metals on Gonyaulax could prove instrumental in these regards. The extreme sensitivity of this organism to trace metal concentrations above ambient oceanic levels correlates well with the apparent "immunity" of several areas of the Maine coast to red tide (Yentsch, unpublished manuscript). Also of importance to the location of shellfish harvest and culture areas is the observed (from DMR's data) density gradient of Gonyaulax from the heads of tidal bays, to the outer peninsulas, and to the offshore islands (approximately IX to 10X to 100X, respectively) (Yentsch, pers. comm.).

Research on the effects of PSP on mussels themselves (as well as other shellfish), rates of intoxication, and rates of detoxification are being investigated. These studies should indicate the feasibility of artificial depuration and allow for estimates of natural depuration times.

Gonyaulax tamarensis is not the same organism responsible for the red tide of the southern Atlantic seaboard (Gymnodinium breve), and its toxins are more complex than those of the west coast species Gonyaulax catanella (Sasner and Ikawa, 1975). Its environmental biology, then, is unique to the Gulf of Maine and requires individual attention. The environmental biology and toxicity of G. tamarensis is presently the chief focus of the Bigelow Laboratory for Ocean Sciences in West Boothbay Harbor, Maine. Current research at U.N.H. is focused on isolation of the toxins produced by G. tamarensis and determination of fluorescence spectra for use as an assay tool. Research in these areas would be of immense value to a developing mussel industry and to the shellfish industry in general. Some needed research and development ideas follow.

Research and Development Needs

(1) Research the possibility of monitoring the presence of dinoflagellates by assaying for peridinium pigment, a water-soluble pigment characteristic of dinoflagellates. Gonyaulax is large (35-50 μ) and could easily be identified microscopically from water samples testing positively for dinoflagellates.

(2) Research and develop an assay for dinoflagellates (and Gonyaulax in particular) using floral spectrophotometry. Dinoflagellate toxins produce distinctive spectral peaks; these need to be studied more carefully and a system adapted to field assay.

(3) Develop a reliable and cost-efficient chemical test for levels of toxin in shellfish meats to replace the inconvenient mouse bioassay.

(4) Study the encystment and over-wintering biology of Gonyaulax. This may be of value in helping to predict the cause, location, timing, and severity of the spring bloom.

(5) Study the behavior of red tide spreading and its action at boundary conditions.

(6) Try to determine the environmental parameters responsible for unialgal blooms of Gonyaulax. What factors lead to its periodic dominance? Do man's activities affect the outbreak of blooms?

(7) Try to determine time-exposure factors relating mussel toxin accumulation and Gonyaulax concentrations in the water. This relation should provide a better understanding of acceptable levels of Gonyaulax in the water column.

(8) Determine intoxication and detoxification times for mussels to establish the possibility of artificial depuration and the length of time required for natural depuration.

Other Public Health Problems

Many productive mussel beds along the Maine coast have been permanently closed due to pollution. The presence of fecal coliforms is used as the standard median; counts greater than 14 per 100 mls water with not more than 10 percent in excess of 46 per 100 ml will result in the closure of an area to all shellfish harvest. Total coliform counts cannot exceed median 70 per 100 mls water with not more than 10 percent exceeding 230. This standard is set in conjunction with the National Shellfish Sanitation Program administered by the Federal Food and Drug Administration. Approximately 25 percent of the areas closed to shellfish harvest on the Maine coast are only seasonal used for summer cottages. Sewage abatement laws may affect these figures in time. Some areas are closed because of potential pollution threats--meaning that conditions in an area may unpredictably vary from acceptable to unacceptable (Hurst, pers. comm.).

Due to the already-established shellfish industry in Gulf of Maine waters, there exists a good data history, good regulatory agencies, and established research facilities for dealing with red tide and other public health problems. Advancements in research and development in these areas could be of great value to a potentially flourishing blue mussel industry.

9.5b West Coast

Incidents of paralytic shellfish poisoning have been recorded as far back as 1799 when over 100 Aleut hunters in Alaska died from the consumption of mussels. Meyer et al. (1928) reported six deaths from 102 known cases in July 1927 near San Francisco. Since then, there have been sporadic outbreaks of PSP along the west coast in spite of warnings that shellfish may be harmful. Certain areas are known to regularly have toxic levels of PSP; these are the California coastline and the Straits of Juan de Fuca in Washington.

Paralytic shellfish toxicity has been the object of a variety of studies as far back as 1888 when Schmidtman demonstrated that levels of toxicity in M. edulis occur rapidly in nature (Sribhibhadh, 1963), but it was not until 1957 that attempts were made to show that outbreaks of paralytic shellfish poisoning could be correlated with environmental factors (Dupuy, 1968). This was a direct result of serious outbreaks in British Columbia and Washington. Research has since been done on the season of shellfish toxicity, rates of uptake of Gonyaulax by various bivalves, artificial growth of Gonyaulax, identification and taxonomy of the species of Gonyaulax, and bioassay methods, to name a few.

Excellent descriptions of the causative organism of PSP in Washington are made by Dupuy in his thesis. These are too lengthy for present discussion, but it is important to note that several strains of Gonyaulax catenella occur in Washington waters alone. The optimum growth requirements of these strains vary (Norris, 1975). Toxin production also differs according to the species of Gonyaulax.

Comparison of Maximum Amount of Toxin Produced by Four Species of Gonyaulax

Organism	Cells per ug of Toxin
<u>Gonyaulax tamarensis</u> (Bay of Fundy; Prakash, 1963)	16,665
<u>Gonyaulax</u> sp. (Sequim Bay, Washington, 1965)	154,355
<u>Gonyaulax polyedra</u> (California; Schradie and Bliss, 1962)	850,000
<u>Gonyaulax catenella</u> (California; Burke et al., 1960)	1,405,000

(Source: Dupuy, 1968)

The results of research on Gonyaulax species of the west coast of the United States indicate that blooms may occur from late spring through early fall (Dupuy, 1968; MacDonald, 1970; Neal, 1966; Norris, 1975). Typically, the water temperature increased from 10°C to 19°C during this time of the year. Toxic conditions occur during generally lower nutrient levels (Norris, 1975), in salinities between 29-32 o/oo, during periods of increased insolation, and when the populations of diatoms is reduced (Dupuy, 1968). The growth requirements have not been sufficiently defined yet; G. catenella is not restricted by physical parameters and thus can create a widespread, serious hazard.

The effect of paralytic shellfish poison on the shellfish industry on the west coast of the United States is far reaching. The most prominent effect is the closure of harvesting seasons in different states. This is based on the occurrence of illnesses in the past, and findings of current monitoring programs.

In California, no mussels may be harvested from May 1 through October 31 from any beaches or bays. The industry in Alaska has not yet begun, but the possibility of PSP would require a vast monitoring service to be conducted at the state's expense. Prior to embarking on this monitoring program, the state would like the assurance that a developed mussel industry would be financially rewarding to the state in jobs and revenues. In Washington, a monitoring program is in existence and is conducted by the Department of Health, which contacts shellfish growers in the event of PSP outbreaks. A closure exists west of Dungeness Spit from April 1 through October 31. Oregon is the only state which does not have a problem with PSP. A monitoring program exists, but toxic levels are not reached.

The major problems with PSP is that monitoring is expensive and time-consuming. Ideally, a method of detecting toxic levels which would be simple and inexpensive and could be conducted at a harvesting site should be developed. Until new methods are developed for detection, blanket closures will have to continue.

The present state of knowledge of Gonyaulax catenella is inadequate. Some parameters affecting growth are known, but factors affecting survival and toxin production are poorly understood.

9.6 Institutional Disincentives to Fishery Development

Significant progress has been made towards identifying quality control problems which have earlier discouraged development of the mussel fishery. As discussed above, both the relationship of meat quality with growing conditions and a relationship of mussel longevity with pearl development have been observed. Management of wild stocks; proper quality control screening after separation, cleaning, and resubmergence in salt water; and transportation under proper refrigerated conditions can do much to ensure a good quality product at the retail market. Sea Grant supported research both by university scientists and private industry has demonstrated that consistent

crops of excellent quality can be cultured. Also, as discussed in other sections of this report, the current world demand for mussels and the strengthening of the U.S. market over the past 10 years points to a positive economic climate for emergence of this new industry.

Institutional Arrangements Hindering vs. Helping an Emerging Industry

There are a number of institutional arrangements, however, which, instead of encouraging the development of mollusk fishery, act as disincentives to its growth. Although many of these institutional problems are shared by the entire shellfish industry, their effect on an emerging industry such as the mussel fishery (both wild harvest and aquaculture) is especially damaging. From state to state, shellfish management and control is practiced at different levels, e.g. state, county/region, municipal. Regardless of the primary management level which has evolved, significant institutional problems have arisen. These are manifested in different ways from area to area.

Conflicting jurisdiction. Whether a management agency seeks development of the fishery or whether an individual or firm is considering investment into aquaculture of mussels, conflicting jurisdictional authorities are a disincentive. If management authority is maintained at the state level, manipulation of the resource may be possible without significant conflict. Other institutional controls over related resources may well conflict with a sound management plan. Coastal zone management planning in a particular area may not include shellfish management, nor may water quality control regulations be consistent with shellfish production. Even if plans within a particular coastal zone or water quality management area are consistent with fishery development, activity in adjacent zones or areas may result in poor water quality. When management of the shellfish resource is at the county/regional or local level, the likelihood of jurisdictional dispute increases.

Limited management priority. Fisheries management, coastal zone management, and water quality regulation decisions are all made within the reality of limited financial resources. Because the mussel industry is an emerging one, and therefore not easily recognized as a significant financial resource, it faces special institutional barriers. In several states there is a reluctance to allow the harvesting of mussels because the investment by the fishery management agencies into health controls, such as PSP and fecal pollution, may not be offset by revenues from the harvest of the mussels. A more mature industry could more easily demonstrate an appropriate cost-benefit relationship. Similarly, the lack of recognition of mussels, whether wild or cultured, as a valuable resource places the industry at a disadvantage when water quality control regulations or coastal zone management plans are being developed.

Uncertainty concerning institutional direction. The dynamic nature of several institutional decision-making processes, which may ultimately affect an investment in the fishery, is a subtle but significant disincentive to fishery development. This disincentive is particularly important

when management of the fishery is at the local/municipal level or when individuals or small firms are considering investment. For instance, without a reasonably well-defined route for the application for an aquacultural permit, few outside the bureaucratic or legal establishment would find the necessary involvements interesting or even tolerable. In several states, the review process is not clearly defined, and various state and federal agencies are ambivalent about the requirement for a permit. Similarly, without clear guidance concerning the proper management of the species, and without reasonable expectation of profitable harvest not adversely affected by other institutional decisions, few will want to initiate the process of good fishery management. Here, institutions seem to be providing neither the positive incentive of effective guidance, nor the assurance against the negative aspects, by providing long term leases or authority in some way initiating "grandfather" protection for the industry. The issue may be further complicated by the lack of clear property rights over submerged and intertidal lands. Much of the uncertainty in all of these institutional and legal considerations is caused by the basic conflict of private use and restricted exploitation of a resource which is common property.

Research needs. Little research has been sponsored to review the effect of various institutional arrangements on shellfish management and on development of the fishery. A broad spectrum of arrangements have emerged, and a number of patterns are already available for investigation. Research in this area might well produce positive results if it proceeded in sequence with the biological research and the more specific economic research. Effective guidance now might spur on an industry already developing, despite certain institutional disincentives.

9.7 Harvest Technology

Measures to increase harvest efficiency must be taken in order to reduce the labor intensiveness of the industry. However, this does not necessarily mean mechanization at all levels. Many areas are not suited to mass-harvest methods, though they may be very suited to the growth of mussels. Hand-picking or raking is the method used in such places. This forced situation enables selective harvest while minimizing damage to the mussel beds.

There are, however, many productive areas which are not only amenable to mass-harvest methods, but may also be unavailable to hand harvest--such as subtidal beds. Many of these areas have been dredged in the past (see Section 7.1). However, the demise of many of these same beds may be due to failure to recover from dredge damage. Research is needed to assess the effect of dredging on mussel beds and to improve dredging or other mass-harvest techniques to maximize natural recovery of the beds. If re-seeding of such beds is ultimately necessary, then proper management practices should be developed accordingly.

Mussels are cleaned and sorted with a mechanical washer-grader developed for other shellfish species. This system seems quite satisfactory at present (Hemingway, Myers, Stewart; pers. comm.). However, no machinery has been developed to shuck mussels. This must be done by hand if fresh (uncooked) meats are desired. Mussel meat can be easily removed from the shell after steaming or boiling. (See Section 7.4 for an overview of processing.)

Mussel culturing is presently a very labor intensive process. A review of this subject is provided by Hurlburt and Hurlburt (1974). Seed mussels must be attached to the culture substrate, the market-sized mussels selected at harvest, and the smaller ones returned for further growth. While bottom culture may be less intensive than raft culture in many of these respects, losses to predation and smothering are greater and growth is not as rapid. All of the commercial culture systems used in the world today require great care and time.

Regardless of the culture method employed, more efficient operating procedures need to be engineered. In many cases, this would involve mechanization. This would allow for an expansion of production levels without increasing human labor. This should, in turn, enable production at a competitive cost.

10.0 SUMMARY

Blue mussels are abundant on the east and west coasts of North America and are a potentially valuable seafood product. They grow more rapidly, yield a greater meat:total weight ratio, and are nutritionally superior to more traditional shellfish species. Increased mussel landings in recent years reflect a renewed interest in this currently underutilized species and a potential for market development.

Various problems, which are not insurmountable, have contributed to the slow materialization of the mussel industry in this country. A major impediment involves the present lack of market demand. Promotion of consumer awareness and acceptability would seemingly eliminate this problem--promotional campaigns have encountered favorable customer reaction.

Objective biological problems which affect the quality of the mussel are being researched at a number of institutions. These problems include the occurrence of pearls in mussel meats, the short shelf life of the fresh product, and the seasonal occurrence of biotoxins in the growing waters. An improved understanding of all of these problems should enable better harvest management and control of product quality.

Although mussels are abundant, possess good reproductive capacities, and grow rapidly, limits to the sustainability of the mussel resource should be investigated to avoid the dramatic supply dynamics characteristic of over-exploited species. A proper understanding of recruitment and a carefully executed management plan could greatly increase the level of production on a sustained yield basis. There exists a good background of basic biological information concerning mussels. Practical application of this knowledge to various conditions found along our coastlines is needed.

Aquaculture of mussels presents an effective means of expanding the resource base, and the accelerated growth and superior quality of cultured mussels make this product an attractive addition to the industry. Experimental mussel culture has been successful in Maine and Washington waters and offers the potential for a dependable commercial supply of high quality. Biological and physical parameters affecting growth and production efficiency need to be studied.

Finally, there exists a potential for the aquaculture of mussels other than M. edulis. The level of basic biological information about these mussels needs to be increased, and the feasibility for cultivation of these species studied.

11.0 SUMMARY OF RESEARCH OPTIONS AND NEEDS

The following is a summary of research options and needs which have been discussed in detail throughout this report. Specific research needs concerning major impediments to the development of the industry have been discussed and outlined in Section 9. These are also summarized below. For detailed needs, the appropriate sections should be consulted.

(1) Continued economic growth in the demand for mussels necessitates transforming conditions of supply based on wild harvest, to conditions based on aquaculture. Long-range research should, therefore, focus on the problems and needs of aquaculture operations. In the short run, however, research and government policy should focus on improving the productivity of harvesting natural stocks. In addition, government policy should try to ensure stability in the volume of production so as not to damage the market. As this infant industry develops along aquacultural lines, measures should be taken at the federal level to ensure that it is not faced with unfair competition from abroad.

(2) The effect of various institutional arrangements on blue mussel management and on the development of the industry should be researched.

(3) An assessment of the available stocks and a scrupulous evaluation of natural stock management should be made. Populations of mussels in the more southerly parts of their east coast range suffer sporadic high mortalities. Causes of these die-offs should be investigated and possible management plans developed. The sustainability of West Coast mussels has not been tested because demand for them has been historically low. Sustained production yields for West Coast conditions should be evaluated as interest in the harvest of mussels continues to increase.

(4) Wherever commercial mussel culture is practiced in the world today, natural seed is collected for attachment of the culture substrate. This requires the development of management policies concerning the continued mass collection of seed mussels. This will become increasingly important as the production of cultured mussels increases. The feasibility of rearing mussel larvae in a hatchery should be investigated, although this may prove to be industrially less efficient than the collection of seed from the environment.

(5) While shellfish aquaculture is an extremely efficient means of protein production, the total biomass of shellfish in a culture system is limited by the capacity of the growing waters to provide food and oxygen and to remove and process metabolic wastes. This limitation is a function of the natural productivity of the water and the total volume of water to which the shellfish are exposed. Given limits to natural productivity and tidal exchange, there exists an optimal shellfish production level specific to each culture location. If this level is exceeded, over-all growth is retarded and production efficiency is reduced. To maximize the efficiency of aquacultural production on an individual and regional basis and to determine, in advance, the suitability of an individual site for

for aquacultural operations, a system for evaluating the carrying capacity of growing areas should be developed.

(6) In order to accurately assess the sustainability and aquacultural potential of indigenous mussel species other than Mytilus edulis (such as the California mussel--Mytilus californianus, the Northern horse mussel--Modiolus modiolus, and the Atlantic ribbed mussel--Geukensia demissa), relatively accurate methods for determining the age and growth rate of individual specimens of these species should be developed. To this end, more basic studies of both shell structure and calcium carbonate deposition are required. Experimental culture of these species in various marine and estuarine environments should also be encouraged. The market potential of these underutilized species requires assessment.

(7) The seasonal and sporadic occurrence of dinoflagellates of the genus Gonyaulax which led to a condition commonly referred to as the "red tide" is a phenomenon with which the mussel industry must deal. The geographic extent and history of blooms of the causative organism is well-documented on the East Coast. Similar data does not exist for the west coast, and an assessment of the "normal" conditions of paralytic shellfish poisoning (PSP) must be made for those waters. The encystment and overwintering biology as well as the environmental parameters affecting the timing, location, and severity of blooms of the various Gonyaulax species responsible for PSP must be investigated. Attempts to develop improved field bioassay methods need further research. Finally, an assessment of intoxication and detoxification rates for various mussel species should be determined to evaluate the required time for natural depuration and/or the feasibility of artificial depuration.

(8) An extension of shelf life of the fresh product would increase the geographical range of distribution and would encourage retail sales by reducing risks of poor product quality. Microbial standards for shellfish need to be re-evaluated to minimize undue waste of product while continuing to ensure product safety. The long-term taste quality and sanitary quality of various processing methods need to be evaluated.

(9) More basic research is needed concerning factors responsible for the presence or absence of pearls in certain populations of mussels along the Atlantic coast.

(10) Research is needed to assess the effects of dredging on mussel beds and to improve dredging or other mass-harvest methods to maximize natural recovery of the beds. If re-seeding of such beds is ultimately necessary, then proper management practices should be developed accordingly. In order to relieve mussel culture techniques of some their labor intensiveness, more efficient operating procedures need to be engineered. This would, in many cases, involve mechanization.

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A P P E N D I C E S

- A. Mussel Survey Interview Guide
- B. Historical Fishery Statistics 1887-1975
- C.1. Nominal and Real Value of Industry Landings, 1942-1975
- C.2. Average Price Per Pound by Year and Major Producing State 1942-1975
- D. Five Year Average Landings and Value of Mussels, 1966-1975 by State, Region, and U.S. Total
- E. Operating Unit Data, 1966-1975
- F. Landings by Type of Gear and State, 1971-1975
- G. Public and Private Acres Leased, by State, 1975

BLUE MUSSEL INDUSTRY STATUS PROJECT

University of Maine & University of New Hampshire

Institutional Sea Grant Program

Mail Questionnaire

Explanation of Questionnaire:

We are part of a team under contract with the National Marine Fisheries Service to fulfill compliance with a Congressional Law requiring information on the commercial status of the U.S. shellfish industry. Our particular assignment is to report on the status of the mussel industry.

We would appreciate very much your cooperation in helping us to fulfill our contract. In order for this valuable food to become a full-fledged industry in the U.S., work such as we are doing is needed. We will be sampling through this questionnaire individuals and firms engaged in many different aspects of the business. The results of our survey will be mailed to you upon completion. We hope they will be of use to you in your own planning.

Compliance with the contract requires the questionnaire to be completed and returned as soon as possible, and no later than the last week of November.

Please complete and return in the enclosed envelope to:

Dr. James A. Clifton
235 Stevens Hall
Economics Department
University of Maine
Orono, Maine 04473

Thank you for your cooperation.

General Questions

A1. How many bushels of mussels do you handle in

1. a week _____ 2. a month _____ 3. a year _____ (1976 to date)

4. a week _____ (1975) 5. a month _____ (1975) 6. a year _____ (1975)

A2. Do different seasons influence your business? 1. Yes 2. No
(go to A3) (go to A4)

*Prepared with the assistance of the Social Science Research Institute, University of Maine - Orono.

A3. (If yes) How do they influence your business?

- 1.
- 2.
- 3.
- 4.
- 5.
- 6.

A4. What part(s) of the mussel business are you involved in?

1. Grower
2. Harvester
3. Dealer
4. Processer
5. Wholesaler
6. Retailer

A5. If mussels were as valuable as clams or oysters and demand were to increase greatly, could you supply some of the increased demand?

1. Yes (See A-6)
2. No (See A-7)

A6. (If yes to A5) How would you increase your supply?

- 1.
- 2.
- 3.
- 4.

A7. (If no to A5) What factors would inhibit an increase in your supply?

1. Labor (time, costs, availability)
2. Capital
3. Mussel beds becoming depleted
4. Equipment
5. Other (specify) _____

B. Resource Availability

(This section for growers, harvesters, dealers. Processers see Section D. All others Section E.)

B1. When you are devoting your time to mussels, how much of that time is spent in searching for supplies?

Over 50%	10-50%	Less than 10%
1. A great deal	2. Some	3. Very little

B2. Is this time

1. Greater than

2. Less than

3. The same

as it was when you started in business?

B3. Has your volume of production changed since you have been in business?
Has it

1. Increased

2. Remained the same

3. Decreased

B4. Is the wild mussel supply such that the harvest could be doubled for a
period of ten years?

Yes

No

Could it be increased to ten times the current level?

yes

No

B5. Is there competition from other parts of the fishing industry for mussel
growing areas?

Yes

No

B6. (If yes to B6) If so, what other industries compete for the areas?

1. _____ 2. _____ 3. _____

C. Mussel Harvesting

(For growers, harvesters)

C1. About how much do mussel harvesters get per bushel for their work? _____

C2. If there are plenty of mussels, how many bushels can one person harvest
per day? _____

C3. Do you expect your costs within the next year to increase, decrease, or
stay the same?

Increase
(Go to C4)

Decrease
(Go to C5)

Stay the same
(Go to C6)

C4. What items will have the greatest effect on the increased costs?

Labor _____
Machinery _____
Fuel _____
Other _____
Specify _____

C5. What items will have the greatest effect on the decreased costs?

Labor _____
Machinery _____
Fuel _____
Other _____
Specify _____

C6. Are there parts of the business you're not in now that may be attractive for expansion in the future?

List _____

C7. Do you feel that lack of money prevents you from expanding your business?

Yes Sometimes No

C8. What agencies provide financial help by way of loans, etc. to the mussel business?

List _____

C9. Do you have any problems with the following?

	Yes	Sometimes	No
1. Keeping mussels fresh	_____	_____	_____
2. Storing mussels	_____	_____	_____
3. Transporting mussels	_____	_____	_____

D. Mussel Processing

(For processors)

D1. When mussels are in season how many harvesters supply mussels to you?

On a regular basis? Number _____
Irregularly? _____

D2. What per cent of your mussels come from harvesters who supply mussels to you on a regular basis? _____%

D3. After you receive the mussels do you clean them in any way?

If yes, how? How much time do you spend on this? Does this limit your willingness to handle mussels? _____

D4. What percentage of all the mussels you handle are unsalable due to

Spoilage? _____

Poor quality? _____

D5. Are there fish processing plants in this area?

Yes

No

D6. (If yes to D5) Could they also handle mussels?

Yes

No

D7. Who do you sell mussels to?
(Wholesaler, retailer, restaurants)

	<u>Wholesale</u>	<u>Retail</u>	<u>Restaurant</u>
List Names	_____	_____	_____
	_____	_____	_____
	_____	_____	_____
	_____	_____	_____

D8. Are you: Satisfied with prices?

Somewhat satisfied?

Dissatisfied with prices?

D9. How do you determine what price you charge for your mussels? _____

D10. Does the price of mussels change a lot during the year?

Yes

Sometimes

What is the range in the last few years? Low _____ High _____

D11. What are the reasons for the price changes?

	Yes	No
Season	_____	_____
Fluctuating size	_____	_____
Quality	_____	_____
Demand	_____	_____
Supply	_____	_____
Any other reasons	_____	_____
(Specify)	_____	_____

D12. What price per bushel would you have to charge to cover all your expenses and give you a reasonable profit? _____

D13. Do you have any credit problems?

Yes No Sometimes

D14. (If yes to D13) What kind of credit problems? _____

D15. Would you be willing to share advertising costs with others if it would expand the mussel industry

Yes Depends No

E. General Questions

(For growers, harvesters, dealers, processors, wholesalers, and retailers.)

E1. Are there any advantages to being a small industry such as the mussel industry (If so, what are they?)

E2. What are the disadvantages of being a small industry?

E3. How do you perceive the longer term advantages and disadvantages?

E4. What kind of business problems do you have that could be helped by public spending for research?

E5. Is there any future in growing mussels instead of just harvesting existing supplies?

E6. Do you have any problems with:

1. Yes 2. Sometimes 3. No

1. Bad weather	_____	_____	_____
2. Red Tide	_____	_____	_____
3. Labor supply	_____	_____	_____
4. Other, specify	_____		

E7. Are there any mussel areas you know of that are closed quite often due to pollution?

1. Yes 2. No

E8. (If yes) Where are they? 1. _____ 2. _____

E9. Do you know of any federal, state or local regulations that cover the blue mussel industry?

Yes No

If yes, what are they?

1. _____
2. _____
3. _____

E10. How do these regulations affect prices?

E11. Assuming your total expenses were \$100, how would that be allocated among the following items, based on current allocation of your actual expenses?

\$	\$	\$	\$	\$	\$
Labor Expense	Equipment Expense	Storage Expense	Processing Expense	Transport Expense	Financial Expense & Profit

E12. How long have you been in the mussel business?

E13. What business were you in before you became interested in mussels?

Thank you for your help!

Appendix B.1 HISTORICAL FISHERY STATISTICS 1887-1975*

Summary of Sea Mussel Landings, 1887-1975

Year	New England		Middle Atlantic		Chesapeake		Total Atlantic Coast	
	<u>Pounds</u>	<u>Dollar</u>	<u>Pounds</u>	<u>(in thousands) Dollar</u>	<u>Pounds</u>	<u>Dollar</u>	<u>Pounds</u>	<u>Dollar</u>
1887	6	(¹)	845	10	-	-	851	10
1888	7	(¹)	892	11	-	-	899	³ 11
1889	-	-	1	(¹)	(2)	(2)	(2)	(2)
1890	(2)	(2)	49	2	-	-	(2)	(2)
1891	(2)	(2)	27	1	-	-	(2)	(2)
1892	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1895	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1897	(2)	(2)	2,550	3	-	-	(2)	(2)
1898	23	1	(2)	(2)	(2)	(2)	(2)	(2)
1899	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1901	(2)	(2)	637	3	-	-	(2)	(2)
1902	-	-	(2)	(2)	(2)	(2)	(2)	(2)
1904	(2)	(2)	1,552	7	-	-	(2)	(2)
1905	-	-	(2)	(2)	(2)	(2)	(2)	(2)
1908	12	(¹)	8,462	9	-	-	8,474	9
1915	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1918	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1919	27	1	(2)	(2)	(2)	(2)	(2)	(2)

See Footnotes at end of table.

*Data supplied by National Marine Fisheries Service.

Year	New England		Middle Atlantic		Chesapeake		Total Atlantic Coast	
	<u>Pounds</u>	<u>Dollar</u>	<u>Pounds</u>	<u>Dollar</u>	<u>Pounds</u>	<u>Dollar</u>	<u>Pounds</u>	<u>Dollar</u>
1920	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1921	(2)	(2)	841	8	(2)	(2)	(2)	(2)
1922	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1923	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1924	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1925	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1926	(2)	(2)	257	11	(2)	(2)	(2)	(2)
1927	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1928	130	1	(2)	(2)	(2)	(2)	(2)	(2)
1929	10	1	185	10	-	-	195	11
1930	11	2	295	14	-	-	306	16
1931	117	7	174	8	-	-	291	15
1932	63	4	113	8	-	-	176	12
1933	141	6	53	3	-	-	194	9
1934	(2)	(2)	(2)	(2)	23	1	(2)	(2)
1935	117	3	98	6	23	1	238	10
1936	(2)	(2)	(2)	(2)	77	2	(2)	(2)
1937	16	1	93	5	28	1	137	7
1938	24	1	243	18	30	1	297	20
1939	23	3	184	7	-	-	207	10
1940	18	1	263	14	2,212	88	2,493	103
1941	(2)	(2)	(2)	(2)	915	46	(2)	(2)

Year	New England		Middle Atlantic		Chesapeake		Total Atlantic Coast	
	<u>Pounds</u>	<u>Dollar</u>	<u>Pounds</u>	<u>Dollar</u>	<u>Pounds</u>	<u>Dollar</u>	<u>Pounds</u>	<u>Dollar</u>
1942	46	3	326	23	164	23	536	49
1943	2,612	111	1,028	81	(²)	(²)	(²)	(²)
1944	2,630	78	572	72	175	25	3,377	175
1945	2,783	82	433	87	49	7	3,265	176
1946	2,351	63	(²)	(²)	304	46	(²)	(²)
1947	45	2	730	176	-	-	775	178
1948	157	18	267	63	-	-	424	81
1949	788	52	127	25	-	-	915	77
1950	692	57	68	14	-	-	760	71
1951	684	46	38	8	-	-	722	54
1952	356	20	14	3	-	-	370	23
1953	200	15	259	65	-	-	459	80
1954	219	13	291	62	-	-	510	75
1955	508	40	119	25	-	-	627	65
1956	459	22	29	6	-	-	488	28
1957	471	27	10	2	-	-	481	29
1958	415	43	36	6	-	-	451	49
1959	483	57	29	5	-	-	512	62
1960	494	45	14	2	-	-	508	47
1961	615	48	18	2	-	-	633	50
1962	565	43	27	3	-	-	592	46
1963	727	55	74	11	-	-	801	66

Year	New England		Middle Atlantic		Chesapeake		Total Atlantic Coast	
	<u>Pounds</u>	<u>Dollar</u>	<u>Pounds</u>	<u>Dollar</u>	<u>Pounds</u>	<u>Dollar</u>	<u>Pounds</u>	<u>Dollar</u>
1964	194	17	126	17	-	-	320	34
1965	184	15	296	45	-	-	480	60
1966	430	46	133	23	-	-	563	69
1967	775	93	28	8	-	-	803	101
1968	492	47	207	63	-	-	699	110
1969	439	46	674	63	-	-	1113	109
1970	467	98	200	60	-	-	667	158
1971	359	85	318	96	-	-	677	181
1972	323	82	496	161	-	-	819	243
1973	475	126	685	195	-	-	1160	321
1974	410	107	490	209	-	-	900	316
1975	886	276	123	55	-	-	1009	331

Year	Pacific Coast		Grand Total U.S.	
	<u>Pounds</u>	<u>Dollar</u>	<u>Pounds</u>	<u>Dollar</u>
1887	(²)	(²)	(²)	(²)
1888	32,396	378	33,295	89
1889	(²)	(²)	(²)	(²)
1890	(²)	(²)	(²)	(²)
1891	(²)	(²)	(²)	(²)
1892	2,880	12	(²)	(²)

Year	Pacific Coast		Grand Total U.S.	
	<u>Pounds</u>	<u>Dollar</u>	<u>Pounds</u>	<u>Dollar</u>
1895	512	5	(²)	(²)
1897	(²)	(²)	(²)	(²)
1898	(²)	(²)	(²)	(²)
1899	383	4	(²)	(²)
1901	(²)	(²)	(²)	(²)
1902	(²)	(²)	(²)	(²)
1904	28	2	(²)	(²)
1905	(²)	(²)	(²)	(²)
1908	68	2	8,542	11
1915	20	2	(²)	(²)
1918	8	(²)	(²)	(²)
1919	6	(²)	(²)	(²)
1920	6	(²)	(²)	(²)
1921	2	(²)	(²)	(²)
1922	7	1	(²)	(²)
1923	10	3	(²)	(²)
1924	8	1	(²)	(²)
1925	4	1	(²)	(²)
1926	1	(¹)	(²)	(²)
1927	3	(¹)	(²)	(²)
1928	(¹)	(¹)	(²)	(²)
1929	(¹)	(¹)	195	11

Year	Pacific Coast		Grand Total U.S.	
	<u>Pounds</u>	<u>Dollar</u>	<u>Pounds</u>	<u>Dollar</u>
1930	(1)	(1)	306	16
1931	(1)	(1)	291	15
1932	(1)	(1)	176	12
1933	(1)	(1)	194	9
1934	-	-	(2)	(2)
1935	-	-	238	10
1936	-	-	(2)	(2)
1937	(1)	(1)	137	7
1938	-	-	297	20
1939	-	-	207	10
1940	-	-	2,493	103
1941	-	-	(2)	(2)
1942	-	-	536	49
1943	-	-	(2)	(2)
1944	-	-	3,377	175
1945	-	-	3,265	176
1946	(1)	(1)	(2)	(2)
1947	(1)	(1)	775	178
1948	1	(1)	425	81
1949	-	-	915	77
1950	(1)	(1)	760	71

Year	Pacific Coast		Grand Total U.S.	
	<u>Pounds</u>	<u>Dollar</u>	<u>Pounds</u>	<u>Dollar</u>
1951	-	-	722	54
1952	(1)	(1)	370	23
1953	(1)	(1)	459	80
1954	(1)	(1)	510	75
1955	-	-	627	65
1956	-	-	488	28
1957	-	-	481	29
1958	-	-	451	49
1959	-	-	512	62
1960	-	-	508	47
1961	-	-	633	50
1962	4	(1)	596	46
1963	-	-	801	66
1964	-	-	320	34
1965	-	-	480	60
1966	-	-	563	69
1967	-	-	803	301
1968	-	-	699	110
1969	-	-	1113	109
1970	-	-	667	158
1971	-	-	677	181

Year	Pacific Coast		Grand Total U.S.	
	<u>Pounds</u>	<u>Dollar</u>	<u>Pounds</u>	<u>Dollar</u>
1972	58	19	877	262
1973	48	19	1208	340
1974	41	18	941	334
1975	1	1	1010	332

¹Less than 500 pounds or \$500.

²Data not available.

³Includes a small production of clams.

Note: --Data are shown in pounds of meats.

Appendix B.2 SUMMARY OF SEA MUSSEL LANDINGS BY STATE 1887-1975:

Year	Maine		Massachusetts		Rhode Island	
	<u>Pounds</u>	<u>Dollar</u>	(in thousands)		<u>Pounds</u>	<u>Dollar</u>
			<u>Pounds</u>	<u>Dollar</u>		
1887	6	(1)	-	-	-	-
1888	7	(1)	-	-	-	-
1898	-	-	7	(1)	16	1
1908	-	-	1	(1)	4	(1)
1919	17	(1)	-	-	10	1
1928	-	-	-	-	130	1
1929	-	-	10	1	-	-
1930	-	-	11	2	-	-
1931	90	2	27	5	-	-
1932	33	1	30	3	-	-
1933	110	3	30	3	1	(1)
1935	117	3	-	-	-	-
1937	11	(1)	-	-	5	1
1938	7	(1)	16	1	1	(1)
1939	-	-	20	3	3	(1)
1940	-	-	14	(1)	1	(1)
1942	46	3	-	-	-	-
1943	2,612	111	-	-	-	-
1944	2,594	75	36	3	-	-
1945	2,733	72	50	10	-	-
1946	2,314	61	32	1	-	-
1947	40	1	-	-	-	-

Year	Maine		Massachusetts		Rhode Island	
	<u>Pounds</u>	<u>Dollar</u>	<u>Pounds</u>	<u>Dollar</u>	<u>Pounds</u>	<u>Dollar</u>
1948	124	13	-	-	30	4
1949	386	15	120	8	186	23
1950	325	11	164	16	200	30
1951	447	13	72	12	165	21
1952	288	9	68	11	(¹)	(¹)
1953	51	1	29	2	120	12
1954	81	2	119	9	18	2
1955	105	3	193	16	210	21
1956	122	2	85	7	251	13
1957	39	5	32	3	400	19
1958	120	9	69	6	226	28
1959	24	2	189	15	270	40
1960	50	3	360	29	84	13
1961	2	(¹)	543	41	70	7
1962	7	1	556	42	2	(¹)
1963	20	2	706	53	1	(¹)
1964	15	1	179	16	(¹)	(¹)
1965	32	3	150	11	2	1
1966	240	20	186	25	4	1
1967	371	31	404	62	-	-
1968	389	31	103	16	-	-
1969	353	29	86	17	-	-

Year	Maine		Massachusetts		Rhode Island	
	<u>Pounds</u>	<u>Dollar</u>	<u>Pounds</u>	<u>Dollar</u>	<u>Pounds</u>	<u>Dollar</u>
1970	301	64	166	34	-	-
1971	150	35	209	50	-	-
1972	281	71	42	11	-	-
1973	440	116	35	10	-	-
1974	308	83	53	11	48	13
1975	612	198	50	15	224	63

¹Less than 500 pounds or \$500.

Note:-- Surveys made for 1889, 1902, 1905, and 1924 in all New England States and for 1925 and 1926 in Connecticut, indicate that no sea mussels were landed during these years. Data for 1925 and 1926 are not available for the other states.

Year	Connecticut		Total New England	
	<u>Pounds</u>	<u>Dollar</u>	<u>Pounds</u>	<u>Dollar</u>
1887	-	-	6	(¹)
1888	-	-	7	(¹)
1898	-	-	23	1
1908	7	(¹)	12	(¹)
1919	-	-	27	1
1928	-	-	130	1
1929	-	-	10	1
1930	-	-	11	2
1931	-	-	117	7
1932	-	-	63	4
1933	-	-	141	6
1935	-	-	117	3
1937	-	-	16	1
1938	-	-	24	1
1939	-	-	23	3
1940	3	1	18	1
1942	(¹)	(¹)	46	3
1943	-	-	2612	111
1944	-	-	2630	78
1945	-	-	2783	82
1946	5	1	2351	63
1947	5	1	45	2

Year	Connecticut		Total New England	
	<u>Pounds</u>	<u>Dollar</u>	<u>Pounds</u>	<u>Dollar</u>
1948	3	1	157	18
1949	96	6	788	52
1950	3	(1)	692	57
1951	-	-	684	46
1952	-	-	356	20
1953	(1)	(1)	200	15
1954	1	(1)	219	13
1955	(1)	(1)	508	40
1956	1	(1)	459	22
1957	(1)	(1)	471	27
1958	(1)	(1)	415	43
1959	-	-	483	57
1960	-	-	494	45
1961	-	-	615	48
1962	-	-	565	43
1963	-	-	727	55
1964	-	-	194	17
1965	-	-	184	15
1966	-	-	430	46
1967	-	-	775	93
1968	-	-	492	47
1969	-	-	439	46

Year	Connecticut		Total New England	
	Pounds	Dollar	Pounds	Dollar
1970	-	-	467	98
1971	(¹)	(¹)	359	85
1972	-	-	323	82
1973	-	-	475	126
1974	1	(¹)	410	107
1975	-	-	886	276

¹Less than 500 pounds or \$500.

Note:-- Surveys made for 1889, 1902, 1905, and 1924 in all New England States and for 1925 and 1926 in Connecticut, indicate that no sea mussels were landed during these years. Data for 1925 and 1926 are not available for the other states.

Year	New York		New Jersey		Delaware		Total Middle Atlantic	
	<u>Pounds</u>	<u>Dollar</u>	<u>Pounds</u>	<u>Dollar</u>	<u>Pounds</u>	<u>Dollar</u>	<u>Pounds</u>	<u>Dollar</u>
1887	845	10	-	-	-	-	845	10
1888	892	11	-	-	-	-	892	11
1889	1	(¹)	-	-	-	-	1	(¹)
1890	49	2	-	-	-	-	49	2
1891	21	1	6	(¹)	-	-	27	1
1892	(²)	(²)	-	-	-	-	(²)	(²)
1897	30	1	2,520	2	-	-	2,550	3
1901	262	2	375	1	-	-	637	3
1904	159	5	1,393	2	-	-	1,552	7
1908	8,175	8	287	1	-	-	8,462	9
1921	50	2	791	6	-	-	841	8
1926	210	10	47	1	-	-	257	11
1929	165	8	19	2	1	(¹)	185	10
1930	271	12	4	(¹)	20	2	295	14
1931	170	8	4	(¹)	-	-	174	8
1932	86	6	4	(¹)	23	2	113	8
1933	48	3	5	(¹)	-	-	53	3
1935	82	5	3	(¹)	13	1	98	6
1937	90	5	-	-	3	(¹)	93	5
1938	241	18	-	-	2	(¹)	243	18
1939	172	7	-	-	12	(¹)	184	7

Year	New York		New Jersey		Delaware		Total Middle Atlantic	
	<u>Pounds</u>	<u>Dollar</u>	<u>Pounds</u>	<u>Dollar</u>	<u>Pounds</u>	<u>Dollar</u>	<u>Pounds</u>	<u>Dollar</u>
1940	215	14	-	-	12	(¹)	263	14
1942	326	23	-	-	-	-	326	23
1943	1,028	81	-	-	-	-	1,028	81
1944	572	72	-	-	-	-	572	72
1945	429	87	4	(¹)	-	-	433	87
1946	447	104	(²)	(²)	(²)	(²)	(²)	(²)
1947	686	171	44	5	-	-	730	176
1948	267	63	-	-	-	-	267	63
1949	127	25	-	-	-	-	127	25
1950	68	14	-	-	-	-	68	14
1951	38	8	-	-	-	-	38	8
1952	14	3	-	-	-	-	14	3
1953	259	65	-	-	-	-	259	65
1954	291	62	-	-	-	-	291	62
1955	119	25	-	-	-	-	119	25
1956	29	6	-	-	-	-	29	6
1957	10	2	-	-	-	-	10	2
1958	36	6	-	-	-	-	36	6
1959	29	5	-	-	-	-	29	5
1960	14	2	-	-	-	-	14	2
1961	18	2	-	-	-	-	18	2
1962	27	3	-	-	-	-	27	3
1963	74	11	-	-	-	-	74	11

Year	New York		New Jersey		Delaware		Total Middle Atlantic	
	<u>Pounds</u>	<u>Dollar</u>	<u>Pounds</u>	<u>Dollar</u>	<u>Pounds</u>	<u>Dollar</u>	<u>Pounds</u>	<u>Dollar</u>
1964	125	17	1	(¹)	-	-	126	17
1965	295	44	1	1	-	-	296	45
1966	115	18	18	5	-	-	133	23
1967	28	8	-	-	-	-	28	8
1968	207	63	-	-	-	-	207	63
1969	674	63	-	-	-	-	674	63
1970	200	60	-	-	-	-	200	60
1971	318	96	-	-	-	-	318	96
1972	496	161	-	-	-	-	496	161
1973	685	195	-	-	-	-	685	195
1974	483	205	7	4	-	-	490	209
1975	106	45	15	8	2	2	123	55

¹Less than \$500.

²Data not available.

Year	Maryland		Virginia		Total Chesapeake	
	<u>Pounds</u>	<u>Dollar</u>	<u>Pounds</u>	<u>Dollar</u>	<u>Pounds</u>	<u>Dollar</u>
1887	-	-	-	-	-	-
1888	-	-	-	-	-	-
1890	-	-	-	-	-	-
1891	-	-	-	-	-	-
1897	-	-	-	-	-	-
1901	-	-	-	-	-	-
1904	-	-	-	-	-	-
1908	-	-	-	-	-	-
1920	-	-	-	-	-	-
1925	-	-	-	-	-	-
1929	-	-	-	-	-	-
1930	-	-	-	-	-	-
1931	-	-	-	-	-	-
1932	-	-	-	-	-	-
1933	-	-	-	-	-	-
1934	-	-	23	1	23	1
1935	-	-	23	1	23	1
1936	-	-	77	2	77	2
1937	-	-	28	1	28	1
1938	-	-	30	1	30	1
1939	-	-	-	-	-	-
1940	-	-	2212	88	2212	88
1941	-	-	915	46	915	46
1942	-	-	164	23	164	23

Year	Maryland		Virginia		Total Chesapeake	
	<u>Pounds</u>	<u>Dollar</u>	<u>Pounds</u>	<u>Dollar</u>	<u>Pounds</u>	<u>Dollar</u>
1944	-	-	175	25	175	25
1945	-	-	49	7	49	7
1946	-	-	304	46	304	46
1947	-	-	-	-	-	-
1948	-	-	-	-	-	-
1949	-	-	-	-	-	-
1950	-	-	-	-	-	-
1951	-	-	-	-	-	-
1952	-	-	-	-	-	-
1953	-	-	-	-	-	-
1954	-	-	-	-	-	-
1955	-	-	-	-	-	-
1956	-	-	-	-	-	-
1957	-	-	-	-	-	-
1958	-	-	-	-	-	-
1959	-	-	-	-	-	-
1960	-	-	-	-	-	-
1961	-	-	-	-	-	-
1962	-	-	-	-	-	-
1963	-	-	-	-	-	-
1964	-	-	-	-	-	-
1965	-	-	-	-	-	-

Year	Maryland		Virginia		Total Chesapeake	
	<u>Pounds</u>	<u>Dollar</u>	<u>Pounds</u>	<u>Dollar</u>	<u>Pounds</u>	<u>Dollar</u>
1966	-	-	-	-	-	-
1967	-	-	-	-	-	-

Note: Landings of sea mussels in the Chesapeake States were confined to Virginia. Sea mussels were taken only during the years from 1934 to 1946.

1968-73--No catch, see note.

Year	Washington		California		Total Pacific Coast	
	<u>Pounds</u>	<u>Dollar</u>	<u>Pounds</u>	<u>Dollar</u>	<u>Pounds</u>	<u>Dollar</u>
1888	-	-	12,396	178	12,396	178
1889	(2)	(2)	2,100	9	(2)	(2)
1890	(2)	(2)	2,700	11	(2)	(2)
1891	(2)	(2)	2,998	13	(2)	(2)
1892	-	-	2,880	12	2,880	12
1895	24	(3)	488	5	512	5
1899	19	(3)	364	4	383	4
1904	-	-	28	2	28	2
1908	-	-	68	2	68	2
1915	1	(3)	19	2	20	2
1918	(2)	(2)	8	(2)	8	(2)
1919	(2)	(2)	6	(2)	6	(2)
1920	(2)	(2)	6	(2)	6	(2)
1921	(2)	(2)	2	(2)	2	(2)
1922	-	-	7	1	7	1
1923	-	-	10	3	10	3
1924	-	-	8	1	8	1
1925	-	-	4	1	4	1
1926	-	-	1	(3)	1	(3)
1927	-	-	3	(3)	3	(3)
1928	-	-	(3)	(3)	(3)	(3)
1929	-	-	(3)	(3)	(3)	(3)
1930	-	-	(3)	(3)	(3)	(3)

Year	Washington		California		Total Pacific Coast	
	<u>Pounds</u>	<u>Dollar</u>	<u>Pounds</u>	<u>Dollar</u>	<u>Pounds</u>	<u>Dollar</u>
1931	-	-	(3)	(3)	(3)	(3)
1932	-	-	(3)	(3)	(3)	(3)
1933	-	-	(3)	(3)	(3)	(3)
1937	-	-	(3)	(3)	(3)	(3)
1946	-	-	(3)	(3)	(3)	(3)
1947	-	-	(3)	(3)	(3)	(3)
1948	-	-	1	(3)	1	(3)
1950	-	-	(3)	(3)	(3)	(3)
1952	-	-	(3)	(3)	(3)	(3)
1953	-	-	(3)	(3)	(3)	(3)
1954	-	-	(3)	(3)	(3)	(3)
1962	-	-	4	(3)	4	(4)
1972	-	-	58	19	58	19
1973	-	-	48	19	48	19
1974	-	-	41	18	41	18
1975	-	-	-	-	1	1

¹Includes a small production of clams.

²Data not available.

³Less than 500 pounds or \$500.

Note: Surveys made for 1934-1936, 1938-1945, 1949, 1951, 1955-1961, and 1963-1971 indicate that no sea mussels were landed during these years. Data for 1974 and 75 include a small catch in Oregon. Less than 500 lbs and \$500 in 1974 and 1,000 lbs valued at \$1,000 in 1975.

Appendix C.1 NOMINAL AND REAL VALUES OF INDUSTRY LANDINGS, 1942-1975*

Total Aggregate Value

Year	East and West Coast		(1967 \$)
	Lbs.	Dollars	Deflated Value
1942	536,000	49,000	
1943	3,640,000 ¹	192,000	
1944	3,377,000	175,000	
1945	3,265,000	176,000	322,344
1946	3,102,000 ²	213,000	341,894
1947	775,000	178,000	232,679
1948	424,000	81,000	97,826
1949	915,000	77,000	
1950	760,000	71,000	86,797
1951	722,000	54,000	59,276
1952	320,000	23,000	25,959
1953	459,000	80,000	91,520
1954	510,000	75,000	85,650
1955	627,000	65,000	74,035
1956	488,000	28,000	30,884
1957	481,000	29,000	31,088
1958	451,000	49,000	51,793
1959	512,000	62,000	65,410
1960	508,000	47,000	49,538

*Source: U.S. Department of Commerce, N.O.A.A., Fisheries Statistics of the United States, Washington, D.C., Annual.

¹ Does not include data for the Chesapeake.

² Does not include data for Middle Atlantic.

Total Aggregate Value

East and West Coast			
Year	Lbs.	Dollars	(1967 \$) Deflated Value
1961	633,000	50,000	52,900
1962	596,000	46,000	48,530
1963	801,000	66,000	69,828
1964	320,000	34,000	35,904
1965	480,000	60,000	62,100
1966	563,000	69,000	69,138
1967	803,000	101,000	101,000
1968	699,000	110,000	107,360
1969	1,113,000	109,000	102,351
1970	667,000	158,000	143,148
1971	677,000	181,000	158,918
1972	877,000	262,000	220,080
1973	1,208,000	340,000	252,280
1974	941,000	334,000	208,750
1975	1,010,000	332,000	191,564

Appendix C. 2: AVERAGE PRICE PER POUND BY YEAR AND MAJOR PRODUCING
STATE 1942-1975.

Total Value/lbs.

Year	U.S.	West Coast	Me.	Mass.	N.Y.
		cents/lb.			
1942	0.070		0.065		0.071
1943	.053		.042		.079
1944	.047		.029	0.083	.126
1945	.054		.026	.200	.202
1946	.069		.026	.03	.233
1947	.246		.025		.249
1948	.191		.105		.236
1949	.084		.039	.067	.197
1950	.093		.034	.098	.206
1951	.075		.029	.167	.211
1952	.062		.031	.162	.214
1953	.174		.019	.059	.251
1954	.147		.025	.076	.213
1955	.104		.029	.083	.210
1956	.057		.016	.082	.207
1957	.060		.13	.094	.200
1958	.109		.075	.087	.167
1959	.121		.083	.079	.172
1960	.092		.060	.081	.143

Total Value/lbs.

Year	U.S.	West Coast	Me.	Mass.	N.Y.
		cents/lb.			
1961	0.080			0.076	0.111
1962	.077		0.143	.076	.111
1963	.082		.100	.075	.149
1964	.106		.067	.089	.136
1965	.125		.094	.073	.149
1966	.123		.083	.134	.156
1967	.126		.084	.153	.286
1968	.157		.080	.155	.304
1969	.098		.082	.198	.093
1970	.237		.213	.205	.300
1971	.267		.233	.239	.302
1972	.299	.328	.253	.262	.324
1973	.281	.396	.264	.286	.285
1974	.355	.439	.269	.208	.424
1975	.329	1.000	.324	.300	.425

Note: Data for U.S. price/lb. from Appendix C.1 - Data for other areas Appendix B Landings by states.

FIVE YEAR AVERAGE LANDINGS and VALUE of MUSSELS
1966-75
MAINE

* Data Supplied by National Marine Fisheries Service.

Five Year Average of Landings and Value of Mussels
1966-75
United States

Five Year Average of Landings and Value of Mussels
1966-75
Middle Atlantic Region

FIVE YEAR AVERAGE of LANDINGS and VALUE of MUSSELS
1966-75
NEW JERSEY

FIVE YEAR AVERAGE of LANDINGS and VALUE of MUSSELS
1966-75
NEW YORK

FIVE YEAR AVERAGE LANDINGS and VALUE of MUSSELS 1971-75 CONNECTICUT

FIVE YEAR AVERAGE of LANDINGS and VALUE of MUSSELS
1966-75
NEW ENGLAND REGION

FIVE YEAR AVERAGE of LANDINGS and VALUE of MUSSELS
1966-75
RHODE ISLAND

FIVE YEAR AVERAGE of LANDINGS and VALUE of MUSSELS
1966-75
MASSACHUSETTS

Appendix E: Operating Unit Data 1966-1975*

FISHERMEN AND CRAFT EMPLOYED IN THE SEA MUSSEL FISHERY, 1966-75

YEAR	NEW ENGLAND															
	MASSACHUSETTS															
	HOES		DREDGES, MUSSEL		RAKES		FORKS		DIP NETS		POTS AND TRAPS, CONCH		CONNECTICUT		RHODE ISLAND	
	FISHERMEN	CRAFT	FISHERMEN	CRAFT	FISHERMEN	CRAFT	FISHERMEN	CRAFT	FISHERMEN	CRAFT	FISHERMEN	CRAFT	FISHERMEN	CRAFT	FISHERMEN	CRAFT
1966.	2,290	-	11	8	1,074	754	21	-	-	-	-	-	-	-	2	1
1967.	2,265	-	12	9	1,091	682	-	-	-	-	-	-	-	-	-	-
1968.	2,696	-	10	8	956	567	34	2	-	-	-	-	-	-	-	-
1969.	3,388	-	8	4	1,127	350	45	2	-	-	-	-	-	-	-	-
1970.	3,934	-	19	11	1,068	582	-	-	-	-	-	-	-	-	-	-
1971.	4,529	-	17	13	908	516	-	-	-	-	11	11	-	4	-	-
1972.	5,541	-	8	4	1,076	695	-	-	-	97	86	-	-	-	-	-
1973.	7,369	-	8	4	784	593	-	-	-	79	68	-	-	-	-	-
1974.	6,255	-	5	5	1,112	696	-	-	-	-	-	-	-	-	9	3
1975.	6,490	-	5	5	-	-	-	-	-	-	-	-	-	-	16	5

YEAR	MIDDLE ATLANTIC													
	NEW YORK													
	RAKES		DREDGES		CLAM		TONGS		TONGS		NEW JERSEY		DELAWARE	
	F	C	F	C	F	C	F	C	F	C	F	C	F	C
1966.	1,365	1,190	-	-	-	-	-	-	-	-	-	-	-	-
1967.	1,660	1,550	-	-	-	-	-	-	-	-	-	-	-	-
1968.	2,085	1,779	-	-	-	-	-	-	-	-	-	-	-	-
1969.	2,100	1,760	-	-	-	-	-	-	-	-	-	-	-	-
1970.	2,390	1,000	-	-	-	-	-	-	-	-	-	-	-	-
1971.	2,590	2,260	-	-	-	-	-	-	-	-	-	-	-	-
1972.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1973.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1974.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1975.	-	-	-	-	-	-	-	-	-	-	-	-	-	-

YEAR	PACIFIC											
	CALIFORNIA				OREGON, COASTAL							
	SAN FRANCISCO		SAN PEDRO		SAN DIEGO		SHOVELS					
	BY HAND	C	BY HAND	C	BY HAND	C	BY HAND	C				
1966.	-	-	-	-	-	-	-	-	-	-	-	-
1967.	-	-	-	-	-	-	-	-	-	-	-	-
1968.	-	-	-	-	-	-	-	-	-	-	-	-
1969.	-	-	-	-	-	-	-	-	-	-	-	-
1970.	-	-	-	-	-	-	-	-	-	-	-	-
1971.	-	-	-	-	-	-	-	-	-	-	-	-
1972.	-	-	-	-	-	-	-	-	-	-	-	-
1973.	-	-	-	-	-	-	-	-	-	-	-	-
1974.	-	-	-	-	-	-	-	-	-	-	-	-
1975.	-	-	-	-	-	-	-	-	-	-	-	-

*Data supplied by National Marine Fisheries Service

*Data supplied by National Marine Fisheries Service

Appendix G: Public and Rivate Acres Leased, by State 1975*

	<u>Mussels</u>		
	Public	Private	Total
Maine	100,000	45	100,045
New York	26,100	--	26,100
Oregon	1/	--	1/
Washington	1/	--	1/
California	1/	--	1/

1/ Not available

Note: There are some States not listed that have small quantities of commercial landings of one or more of these shellfish.

*Data supplied by National Marine Fisheries Service.

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