



WOODS HOLE OCEANOGRAPHIC INSTITUTION

BUSINESS PLANNING HANDBOOK FOR THE OCEAN AQUACULTURE OF BLUE MUSSELS*

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September 2003 (Rev. No. 1)

*Sponsored by the CINEMar Program at the University of New Hampshire, Agreement No. 03-671 to NOAA Grant Nos. NA06RP0454 and NA16RP1718. We acknowledge the insights and contributions of Bill Silkes and Todd Corayer of American Mussel Harvesters, Inc. in North Kingstown, Rhode Island, and the support and encouragement of Dr. Richard Langan of the University of New Hampshire.

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INTRODUCTION

For prospective growers of blue mussels (*Mytilus edulis*) in New England marine waters, this handbook is designed to be useful for assessing the structure of the market (including industrial organization and regulation), for making informed choices about organizational form, and for planning aquaculture business development. Importantly, we discuss methods for evaluating environmental and market risks. Where possible, we identify web-based and other sources of information to aid in business planning and in the design and operation of an ocean aquaculture business specializing in the production of blue mussels.

This handbook has been developed by researchers at the Woods Hole Oceanographic Institution's Marine Policy Center. The WHOI Marine Policy Center specializes in social science research, including research on the opportunities and issues associated with the development of ocean aquaculture. For further information or clarification of any of the concepts discussed or issues or facts raised in this handbook, please contact Hauke Kite-Powell (business planning: hauke@whoi.edu; 508-289-2938); Di Jin (risk modeling: djin@whoi.edu; 508-289-2874); or Porter Hoagland (market structure and regulation: phoagland@whoi.edu; 508-289-2867).

WORLD MARKET TRENDS

Worldwide, the production of mussels of all types has been increasing at an average of about 5 percent per year during 1950-2000 (Figure 1), reaching nearly 1.7 million metric tons in 1999. The United Nations Food and Agricultural Organization (FAO) estimates that the worldwide combined total landed and farmgate value of mussels in 2000 was roughly \$645 million.

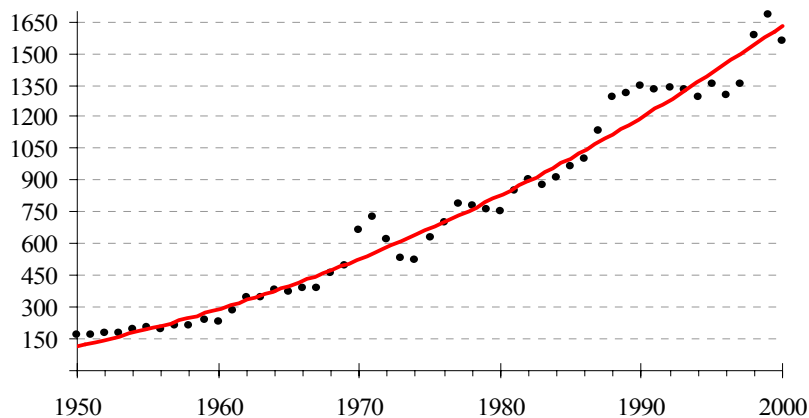


Figure 1: World production of mussels of all types during 1950-2000. Units in thousands of metric tons. Data are available at <http://www.fao.org/fi/statist/statist.asp>.

In the last several decades, the nature of the market has changed significantly, as producers have been switching away from wild harvests toward a variety of culturing techniques. Hickman (1998) refers to marine mussels as having those characteristics that make them an “ideal

candidate for aquaculture,” including their rapid rates of growth, high productivity on almost any substrate, relatively straightforward husbandry, ability to filter plankton and take up nutrients, and resilience to disease. About 85 percent of world mussel production now comes from ocean aquaculture. Denmark is the only country that still produces very large quantities of wild harvest mussels, but producers there are now investing seriously in the capacity to culture mussels.

China is the world’s largest producer of mussels today, growing more than 400,000 metric tons of a wide variety of species each year (Figure 2). Especially attractive to suppliers is a \$500 million European market for blue mussels, where Spain, Italy, the Netherlands, Denmark, and France are firmly entrenched as the region’s leading producers. New Zealand has become one of the world’s leading producers, focusing on growing the native green-lipped mussel (*Perna canaliculus*). The green-lipped mussel is processed and frozen for export to Asian, American, and European markets. An expansion of demand on the world market, particularly for blue mussels (*Mytilus spp.*), is calling forth increased production in many parts of the world, including Scandinavia (especially Norway and Sweden), Ireland, South Africa, and North America.

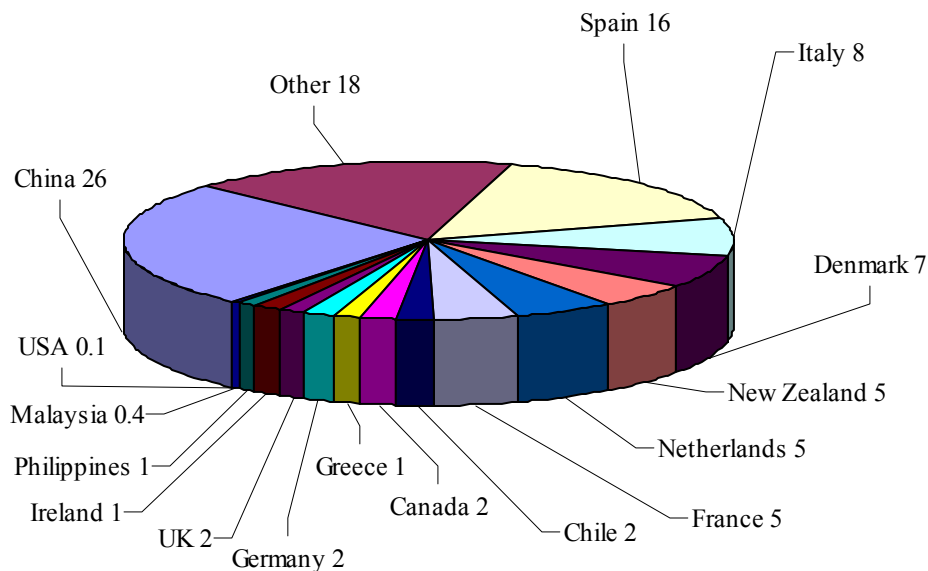


Figure 2: Share of world production of mussels of all species, including both aquaculture and wild harvest production. Shares are calculated as an average for each country during 1997-2001. Data are available through the FISHSTAT+ database at: <http://www.fao.org/fi/statist/FISOFT/FISHPLUS.asp>.

Although most of the world’s production of mussels is canned (nearly 65 percent) or frozen (nearly 35 percent), most international trade in the residual (<1 percent) is in the high-valued premium fresh or chilled product (Vannuccini 1999). Spain and Denmark lead the world in the production of canned product. Unlike the preferences for local types of some shellfish species, however, such as those for oysters in France, the international trade for mussels is very active, as sophisticated European consumers appear to enjoy mussels from both local and international sources (Holmyard 1997). European Union shellfish sanitation regulations limit imports of fresh

product from extra-EU sources, however, so much of the international trade in fresh mussels occurs among EU countries. The Netherlands leads among producers of fresh or chilled product for the European market.

NORTHEAST AMERICAN MARKET TRENDS

The Northeast American market for fresh processed blue mussels has been expanding even more rapidly than the world market, particularly during the last decade. Figure 3 depicts FAO estimates of North American farmgate production and value. Farms located in the Canadian Maritimes supply most of the market in the United States and Canada, and Canadian farm production increased more than 10 percent per year in the last decade (Couturier 2001). Mussels are produced on the west coast of both Canada and the United States, from Alaska through British Columbia and Puget Sound, and on down to San Diego. Production on the west coast tends to be restricted to *Mytilus trossulus* and *Mytilus galloprovincialis*, both of which are close relatives of *Mytilus edulis*.

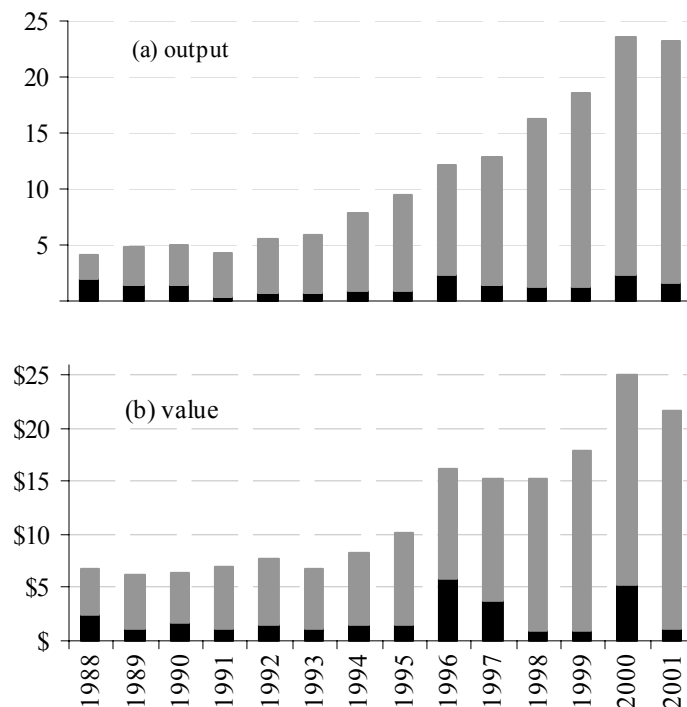


Figure 3: North American aquaculture production of mussels during 1988 to 2001 (Canada in gray and the United States in black): (a) farmgate output in thousand of metric tons; (b) farmgate value in 2003 \$US millions. Data are available through the FISHSTAT+ database at: <http://www.fao.org/fi/statist/FISOFT/FISHPLUS.asp>.

The most impressive development in the Northeast American blue mussel industry has occurred during the last two decades on Prince Edward Island (PEI). PEI mussel production grew from about 100,000 pounds per year in 1981 to nearly 40 million pounds in 2001. Although mussel

production occurs in all of the Canadian maritime provinces, PEI producers do not encounter impediments to the same degree as producers in other provinces (Muisse 1990). Among these impediments are conflicts with other nearshore uses (New Brunswick and Nova Scotia), remoteness (Newfoundland and Quebec), slowed growth due to cold temperatures (Newfoundland), and permitting delays and litigation (Nova Scotia). PEI production also occurs in waters with enough temperature diversity to allow almost a year-round supply of high-quality, pre-spawning stock to the market.

In 1987, a catastrophic harmful algal bloom, which resulted in 129 amnesiac shellfish poisonings and two deaths, stopped the PEI industry cold for a year, and rippled through producers and processors in the entire Northeastern American market. PEI producers responded to this event with an organized program of environmental monitoring and a public relations campaign to reassure consumers.

The PEI experience can be contrasted strongly with recent attempts to develop the industry in Newfoundland (KPS 2002). In response to the unemployment resulting from the severe depletion of groundfish stocks, significant levels of government support have encouraged development of capacity in blue mussel culturing, following the PEI model. This support continues to date, as about \$C20 million in federal and provincial funding has been budgeted for aquaculture development in Newfoundland during 2001-2006.

While still young, the Newfoundland industry has struggled to provide consistent quality at a competitive price. Upon careful inspection, farms were found to have low yields, to be utilizing inefficient husbandry practices, and to be operating at high costs. One critical issue is distance from the fresh market. A second problem, and one that clearly provides lessons for an industry developing in US waters, was the inability of farmers to realize economies from the geographic clustering of farms in the proximity of processing facilities. There may be at least two sources of clustering economies. First, there may be scale economies in processing and distribution because of fixed capital investments. Second, there may be transportation cost savings for farmers. These market structure characteristics are clearly recognized by the successful value-added players in the market, including processor/distributors in PEI and Great Eastern Mussels in Maine.

HISTORICAL US MARKET DEVELOPMENTS

Interest in the development of a mussel industry has a long history in the United States. Field (1921) reports on pre-World War I efforts by the US Bureau of Fisheries to create a market through publicity campaigns; the provision of free mussels to first-class hotels, restaurants, and clubs; the free distribution of mussels to members of the Boston police force; and the utilization of YMCA educational programs to increase consumer awareness. At the time, these efforts were expected to create a “permanent and growing demand” for mussels, but such was not to be the case.

Until recently, very high levels of production in New England occurred only during World War II, at which time the natural stocks were cropped off and exported (Lutz 1977), and in the late 1960s and early 1970s, during a resurgence of demand in the important New York City market (Clifton 1980).

In the mid-1970s, the US National Marine Fisheries Service (NMFS) identified a number of economic issues constraining further development of the market for mussels, including sporadic

supply, inconsistent quality, and a limited demand (Lutz 1977). A survey of 300 west coast restaurants by researchers at the University of Washington identified similar constraints (Waterstrat 1978). In particular, dealers found it difficult to cover the costs of distributing mussels other than seasonally and then only in bulk to wholesalers in large established markets, thereby bypassing local retailers.

As a complement to the 1977 NMFS study, students at the University of New Hampshire’s Whittemore School of Business analyzed the factors constraining the development of the blue mussel industry in New England (Broadhurst *et al.* 1976). This study recommended several courses of action to remedy market constraints, including: educating consumers about mussels to erase negative preconceptions; product differentiation through branding, slogans, and packaging; demonstrating quality to support a higher price; and maintaining a reliable supply. By the 1990s, several of these recommendations had been implemented.

US production exceeded supply from Canadian farms and processors until the mid-1990s (Figure 4). Since the mid-1990s, most of the eastern US market has been supplied by imports from Canada. These imports, which are a mixture of partially processed farmgate product and some wholesale product, command a premium over wild product prices, averaging more than 80 cents per pound during the last five years.

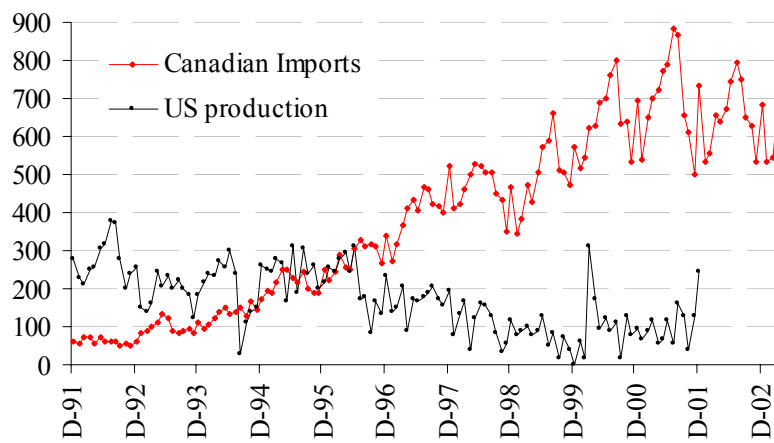


Figure 4: Monthly US production and imports from Canada into the US market during 1991-2001. US production includes both wild harvest and aquaculture. Data on US production are available at http://www.st.nmfs.gov/st1/commercial/landings/monthly_landings.html. Data on imports to the United States from Canada are available at http://www.st.nmfs.gov/st1/trade/trade_prdct_cntry_mth.html.

In March 2001, an investigation was initiated by the US International Trade Commission to consider a complaint that mussels exported from Canada to the United States had been sold at less than fair value (dumping). Although the investigation was terminated prior to any final decision on dumping, the initial determination and views of the Commission helped to define the relevant market as processed blue mussels, specifically *Mytilus edulis*. Further, the Commission distinguished between the farming and processing activities, while recognizing a “commonality of economic interest” between the industry processing mussels and the industry cultivating mussels.

This market definition might be interpreted, in retrospect, as helping to blur a distinction between alternative production technologies (bottom culture and longline culture) by redirecting the focus of the market onto the processed product. Where historically the Canadian cultured (and processed) product commanded a premium over bottom culture or wild harvest mussels, now the market is more likely to be perceived as a relatively homogeneous processed product, regardless of the culturing technology. Nowhere is this interpretation more obvious than in the value data compiled by the State of Maine for NMFS (Figure 5), which demonstrates a significant increase in the US price per pound of blue mussels, starting in January 2001.

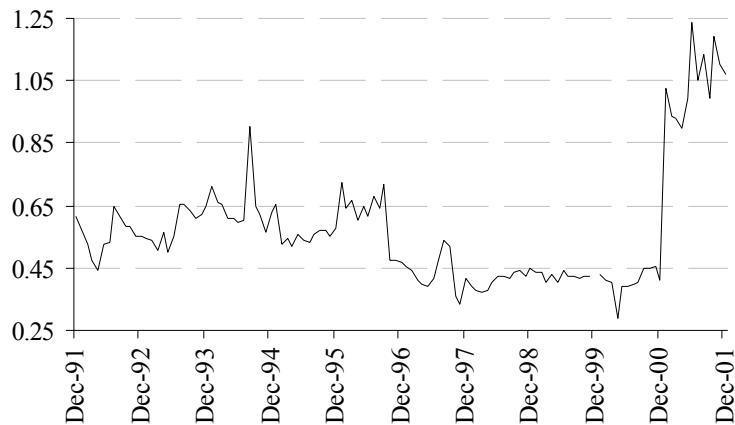


Figure 5: Monthly price of blue mussels from 1991 to 2001 in 2003 US dollars reported in NMFS data. Note that, in recent years, the NMFS landings and value data is predominantly from Maine only. Data on US landings and values are used to compute this price; these data are available at http://www.st.nmfs.gov/st1/commercial/landings/monthly_landings.html. The producer price index for unprocessed shellfish was used to express the prices in 2003 dollars.

PRODUCTION PROCESSES AND EVOLUTION OF TECHNOLOGY

Mussels for sale in the Northeastern American market are produced by three different methods. The oldest method, still practiced today, is the wild harvest of mussels by dredging from natural beds. The geographic distribution of mussel beds is patchy, and their existence in any particular location may be fleeting. Thus fishing targets may shift from time to time. Historical wild harvest production has occurred off the coasts of all of the Canadian Maritimes, the New England states, and sporadically in the mid-Atlantic states down to North Carolina.

There are as many as a dozen areas where the commercial fishery for mussels is actively prosecuted off the coast of Maine. These areas are pulse-fished, to crop down the local stock, and then left alone for two to three years in order to allow recruitment. Access to the fishery is by license only from the Maine Division of Marine Resources. There are three main markets for this fishery: (1) juveniles may be used for grow-out on nearshore leases in Maine; (2) some larger mussels are sold to processor/distributors for resale into wholesale and retail markets; and (3) others are crudely processed and sold as a product directly to retailers and restaurants.

By the mid-1980s, mussel producers had begun experimenting with transplanted bottom culturing, surface longline rope culturing, and raft culturing, and they set quality standards for a washed and graded fresh mussel product (Brooks 1994). Processors purge, declump, grade, debyss, package, and distribute mussels. Processors add value to the raw product, but a crucial role is an inventory function, to ensure a consistent and steady supply to downstream customers or distributors (“fish houses”). The fish houses purchase mussels from processors with a very small margin; they truck the mussels to retailers, restaurants, and consumers; and they typically handle a wide range of other seafood products in addition to mussels.

The raft technology has been adapted from culturing techniques in Spain and Scotland and is now being established in nearshore areas (especially in Maine and Washington State) where there are few competing uses (Newell 2000). The longline technology is related to that used for culturing the green-lipped mussel in New Zealand, and is being examined for both nearshore and open-ocean settings. In the open-ocean, the longline technology must be submerged, and the distance from shore and need to employ more durable gear may increase the costs of the operation. Nevertheless, there are even fewer potential conflicts with other ocean uses offshore than in nearshore areas (Langan 2000). Although the longline technology is more costly than either rafts or bottom culturing, the relatively warmer temperatures found in New England waters may accelerate growth (*cf.* Karayuecel and Karayuecel 1999; Mason 1976), thereby increasing productivity and revenue.

Within the last decade, interest has grown in investigating the potential for larger-scale operations in the open ocean. Two pilot projects (one organized and run by UNH scientists off the Isles of Shoals in the western Gulf of Maine and one by WHOI scientists off Martha’s Vineyard in Rhode Island Sound) have demonstrated the biological and engineering feasibilities of this new kind of technology. It has always been assumed that estuarine environments are optimal with respect to the important temperature and food availability (phytoplankton concentration) parameters. These projects have revealed that this assumption holds in the coastal ocean as well.

Researchers at the WHOI Marine Policy Center have developed a business planning model of the operations of an open-ocean aquaculture longline system for blue mussels (Kite-Powell *et al.* 2003). This model is based upon a set of assumptions about an operational open-ocean blue mussel farming operation, as summarized in the section on “Business Planning” below.

The expanding market now is leading to the research and development of new biotechnologies, including investigations into the production of triploid mussels (Brake *et al.* 1999). The production of these non-spawning varieties may reduce the pre- and post-spawning variability in meat yields. If successful, this technology could permit the culturing of a premium product with consistently high meat yields.

CURRENT MARKET STRUCTURE

The structure of the US market for blue mussels extends from the producers upstream to consumers downstream (Figure 6). The market involves a flow of mainly fresh product from growers to processors/distributors (who are commonly one entity) to retailers, restaurants, and individual consumers. The majority, sometimes as much as 95 percent, of the product is imported from Canada (Figures 3 and 4), primarily from Prince Edward Island (PEI). The market for

mussels is somewhat regionalized, because the product needs to be kept in seawater or packed in ice, and transportation costs can contribute significantly to the delivered price.

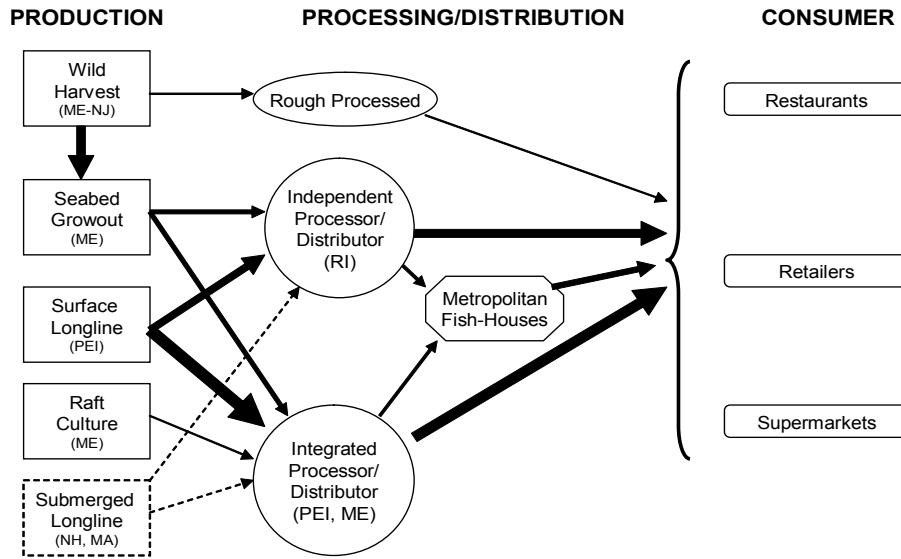


Figure 6: US market for blue mussels from production by growers with different technologies to processor/distributors (independent implies no formal contracts with growers or harvesters; dependent implies formal contracts) to consumers. A very crude estimate of product flow is represented by the size of arrows. The submerged longline technology has not yet progressed beyond the R&D stage.

Smaller markets exist for frozen (vacuum packed) and canned mussels. One US processor in the vacuum-packed market, BlueGold Ltd., operated out of New Bedford, Massachusetts, in the 1990s but now has relocated to Nova Scotia.

Other shellfish are partial substitutes for blue mussels, including soft-shell clams (*Mya arenaria*), quahogs (*Mercenaria mercenaria*), mahogany clams (*Arctica islandica*), oysters (*Crassostrea virginica* and other species), and bay scallops (*Argopecten irradians*). We provide more detail on substitutes in the description of market demand below. The green-lipped mussel (*Perna canaliculus*) from New Zealand also is a substitute, but it is typically marketed as a frozen, half-shell product, and it does not compete as a fresh product.

As the market has been expanding in the last two decades, vertically integrated processor/distributors have emerged, differentiating their product and adding value (Scarratt 2000). This vertical integration is very much in the European tradition of both fresh and canned production. On Prince Edward Island, a large number of growers (well over 200) sell to a small number (fewer than a dozen) processors. Some of these processors also are integrated back into growing. The processors truck fresh product to fish houses in eastern metropolitan markets, focusing on Montreal, Toronto, Quebec City, Boston, New York, and Philadelphia. Increasingly, fresh PEI mussels are now being trucked as far west as upstate New York, Cleveland, and Chicago, and down the east coast to Florida. There is some very limited movement of PEI mussels to the west coast of the United States and, on occasion, to Europe. Exports to Europe are costly, as they are air-freighted, and they depend crucially upon favorable exchange rates.

Mussels are produced in the other maritime provinces, including Newfoundland, Nova Scotia, and New Brunswick, but not nearly on the same scale as on PEI. Newfoundland arguably is too far from the major markets for effective delivery of fresh product, and so with government support a vacuum-packed frozen processing capacity has been under development there. The market for this product has not materialized completely, however, and Newfoundland processors currently may be sitting on as much as two years of frozen inventory, and farmers are operating at well below full capacity. There is some active culturing near Halifax, Nova Scotia, to supply that market, but local opposition to aquaculture has slowed potential development of culturing operations along the Nova Scotian coast. Minor production also occurs in New Brunswick and Quebec, and at least some of this product may be trucked to PEI processors, where it enters PEI distribution channels.

In the United States, the market is divided roughly into the eastern and western halves of the country, with the dividing line at Chicago. The western market is supplied by producers in Washington State and California, including Taylor Seafood, an integrated multiproduct firm that cultures the Mediterranean blue mussel (*Mytilus galloprovincialis*, referred to colloquially as a “gallo”). Interestingly, retail prices in the western US market have been known to be as much as a \$1.00 more per pound than those in the east. In fact, the ITC (2001) found that *Mytilus trossulus* was selling on the west coast at three times the price of *Mytilus edulis* on the east coast. Moreover, NMFS data on California production, which is compiled only annually, suggests, somewhat incredibly, a rough market price of more than \$5.00 per pound for gallos. The eastern US market is very competitive, and it is served by the PEI processors, Great Eastern Mussels (GEM) of Tenants Harbor, Maine, and American Mussel Harvesters (AMH) of North Kingstown, Rhode Island.

All of these participants tend to be vertically integrated, broadly defined, with either contracts or informal buying arrangements from suppliers, significant investment in processing capacity, and the means to distribute the product to metropolitan fish houses, supermarket chains, or restaurants. The PEI processors obtain product from surface longline culture culture (the Japanese or New Zealand method) operations. GEM contracts with independent growers who lease nearshore areas for bottom growout (the so-called Dutch method) or raft culture (the Spanish method). AMH has long standing relationships with independent harvesters who supply bottom grown mussels from the coast of Maine, and it purchases mussels from some of the PEI surface longline operators.

Product differentiation has been achieved mainly by growing a higher quality mussel in comparison with wild harvest product. In general, the differentiated cultured product commands

a higher price. The price premium is due almost solely to product quality (Clifton 1980), although there may be significant variability in price for the cultured product over a year. Price differences in processed mussels, regardless of their provenance, now tend to be fleeting, if they exist at all. Nevertheless, mussels of lower quality, such as crude-processed, wild-harvest product, will sell at a discount.

Brooks (1994) found that the mussel processors actively developed innovative marketing campaigns, employing brand names, designing creative packaging, conducting supermarket demonstrations, and developing value-added products. Brand names include Great Eastern, Restaurant Ready[®] Whitewater, Island Blues (PEI), and Scotian Pride (Nova Scotia). Both farmers and processor/distributors seem to be convinced that branding differentiates their product in the market, but it is likely that this is important only for retailers and restaurant buyers. There is as yet little evidence that consumers are able to distinguish between varieties that originate from different locations or that are produced with different technologies. The absence of a branding premium may be evidence of the immaturity of the industry, as well as the lack of a credible means for certifying brands.

CONSUMER CHARACTERISTICS AND MARKET DEMAND

The average price of processed mussels in the United States has been relatively stable over the last decade. In the eastern US market, the demand for most shellfish, and especially mussels, increases in the late summer (August) and in the early winter (December through February). Figure 7 depicts the monthly variability in a market price index for blue mussels that combines imports and domestic production during 1992-2001. The index has been created by weighting price per pound from each source by the relative share of supply from each source. The index does not vary much around the average of \$0.85 per pound. Variability in the price, shown by the thin lines that depict the range of +/- one standard deviation, appears greater in August than in the other months.

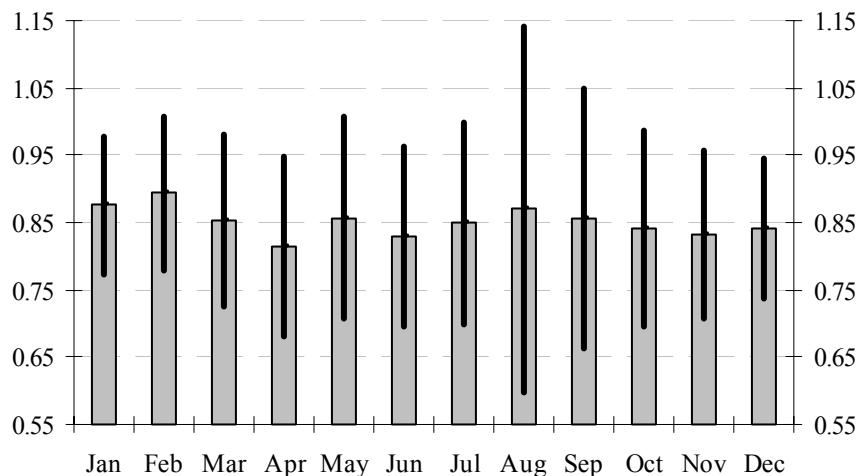


Figure 7: Supply-weighted monthly price of blue mussels during 1992-2001. Value per pound of imports and domestic production is weighted by the proportion of US sales from

each source. Units are 2003 US dollars per pound of processed blue mussels. Data are available from the sources listed in Figure 4.

Few studies exist that discuss consumer characteristics and other factors affecting the demand for shellfish, particularly mussels. What studies exist typically are dated or tailored to specific local markets. Consequently, it is difficult to generalize the results of these studies to regional or national markets or to draw lessons for the blue mussel market.

We summarize some general results here:

- Household expenditures on shellfish increase with price reductions (and vice versa) (Cheng and Capps 1988).
- Household expenditures on shellfish increase with coupon value (Cheng and Capps 1988).
- There may be significant variability in purchases of shellfish by season (Capps and Lambregts 1991).
- Household expenditures for shellfish apparently are unaffected by changes in the prices of meats and poultry (Capps and Lambregts 1991).
- In a local market, the effects of advertising on purchases of shellfish are minimal (Capps and Lambregts 1991).
- Shellfish consumption may be significantly affected by socioeconomic factors. Those more likely to consume shellfish include minorities (especially Asians), older consumers, higher income consumers, employed individuals living in small households, and urban dwellers (Nayga and Capps 1995).
- Studies of blue mussel consumption in the Netherlands show that price increases with increases in quality (Gibbs *et al.* 1994).
- Pre-spawning blue mussels, which have a relatively high meat to shell ratio, command a premium over post-spawning stock.
- The demand for mussels can be affected adversely by natural hazards, including harmful algal blooms, causing price to decline significantly (Wessells *et al.* 1995).
- The risk of eating mussels has an adverse effect on the likelihood that consumers will purchase blue mussels (Brooks and Anderson 1994).

We have developed a model of the market for processed mussels imported from Canada using monthly data from 1997 to 2001 on per capita disposable income, fish and shellfish sales, restaurant sales, and prices of substitutes, including the price of domestic mussels (historically a wild harvest or rough processed product), oysters, hard clams, softshell clams, and bay scallops. This model cannot be considered a true demand model, because we have not attempted to distinguish between demand and supply effects. Nevertheless, the model appears to describe the market well, and it could be used to help understand how changes in many of the variables might affect the US market for processed mussels.

We present the elasticities for three versions of the model in Table 1 below. These numbers represent percentage changes (positive or negative) in the quantity of processed mussels from Canada supplied to the US market that result from percentage changes in the relevant variable. A one percent change in the quantity of imported mussels averages almost 12,000 lbs during this period. Thus, according to Model A, we could predict that a one percent change in restaurant sales, for example, would lead to an increase in imports (which can be interpreted also as an opportunity for domestic supply) of about 20,000 pounds of processed mussels (1.70*12,000).

Table 1: Elasticities from a model of the market for imported processed blue mussels from Canada into the United States. Imports from Canada are used as a proxy for the market for processed blue mussels in the eastern United States. More detail on the model specifications and the model data are available upon request from the authors.

Variable	Units (1 percent change)	Model A	Model B	Model C
Price of imported mussels	\$0.008/lb	-0.47	-0.45	-0.49
US per capita disposable income	\$260	1.82	1.71	1.43
US restaurant sales	\$104 million	1.70	1.81	2.08
US mussel price	\$0.005/lb	0.08	0.09	0.07
Softshell clam price	\$0.050/lb	-0.09	-0.08	
Oyster price	\$0.028/lb	0.17	0.17	0.15
Hard clam price	\$0.065/lb	0.13		
Bay scallop price	\$0.021/lb	-0.03	-0.02	
Sea scallop price	\$0.062/lb	-0.09		

BUSINESS PLANNING

A business plan for a mussel farming operation should include the following:

- A description of the business concept
- A discussion of the market for mussels
- A description of planned production operations and biological parameters
- Plans for marketing and distribution
- Staffing and key personnel
- Financial projections

The first component in this list is a brief summary of the most important features of the plan as a whole. The second – the market for mussels – can be based on information already covered in this handbook. The remaining sections are discussed in more detail below, followed by some sample language for a hypothetical mussel farm business plan.

Production

Site and Permitting. The business plan should identify the site at which the mussel growout operation is to take place and describe the status of relevant permits or permit applications to place gear at this site (see section on Regulation below). Ideally, all permits should be in hand before approaching investors for funding. At a minimum, the process of obtaining permits must be spelled out in detail, along with a discussion of possible obstacles to obtaining permits. In federal waters, prominent issues are often the risk to threatened species from entanglement in gear and conflicts with commercial fishermen over “tenure” to a section of the seafloor.

Important features in the selection of a site include water depth (water column available for mussel growout), wave conditions, temperature and nutrients, and distance from shore base. Tools have been developed to assist in the selection of sites for aquaculture operations; for example, see <http://ortelius.who.edu/website/NMAI01/viewer.htm>.

Technology and Scale of Operations. This section should describe the proposed approach to growing mussels, e.g. longlines with grow-ropes, rafts with grow-ropes, or some other approach. It should describe the dimensions of each installation. For a longline, this includes the length of the line, size of anchors, etc. It should include a discussion of the maximum density of grow-ropes to be supported by the growout structure, and the target density of mussel product per meter of grow-rope. It is very important to know both the maximum and the degrees of loads that the gear will need to handle and what the weakest components will be. The section should also describe the overall scale of the operation, e.g. total number of longlines, overall dimensions of the operation’s “footprint” on the seafloor, and annual production targets.

Vessel Operations. In most cases, a dedicated vessel will be necessary to support the growout operations. This section should identify (if it has been selected) and describe this vessel, including its size, cargo capacity, and specialized equipment. Equipment will depend on the nature of the growout technology. For example, a vessel supporting longline operations will usually require gear to handle the longlines themselves, in addition to equipment for stripping mussels from spat collectors and grow-ropes, and possibly grading and socking equipment for mussel spat. The section should discuss where the vessel will be docked and the implications for transit time to and from the growout site. It should also include a discussion of daily vessel capacity to perform the tasks necessary to support the growout operation, taking into account transit time, cargo capacity, and reasonable limits on daily operating hours. These tasks (some of which are treated in more detail below) include:

- Deployment and retrieval of spat collectors
- Processing/socking of spat
- Deployment of grow-ropes/socked mussels
- Maintenance of growout structures (removal of fouling, addition of flotation, etc.)
- Harvest operations

Depending on the size and weight of longlines or other growout technologies, the growout support vessel may or may not be appropriate for the deployment of the gear itself. If a separate vessel is needed to deploy growout gear initially, this should also be discussed here.

Spat Collection. A reliable source of mussel spat is crucial to a sustained growout operation. This section should describe the annual spat settlement pattern and schedule in the region where spat is to be collected, and the schedule and technology for deployment and retrieval of spat collectors. Prospective mussel farmers may want to research historical spat settlements and relevant local fishing records to uncover any patterns of mussel set and area coverage. Prospective farmers should build a time frame for experimentation with various collector materials and seasonal variation in spat settlement. The extent of bio-fouling also may influence the choice of effective spat collector. This section should discuss what will be done with spat once the collectors are retrieved (grading/socking).

Production and Operations Schedule. A complete production and operations schedule should describe month-by-month operations for the first five to ten years of the proposed venture. The schedule is, in essence, a model of the planned operations of the mussel farm. Models should be developed for the nutrient levels at prospective sites and for the farm's carrying capacity. Although the longline will be located in the open-ocean, there may still be variability in the available food across seasons or across years. The suggested list of activities on the schedule includes:

- Deployment of longlines or other growout structures
- Deployment of spat collectors (meters)
- Retrieval of spat collectors (meters, mussel volume and size distribution)
- Socking and deployment of grow-ropes (meters)
- Mussel growth rates (average expected growth per month – likely dependent on water temperature and nutrient levels)
- Maintenance operations
- Harvest operations (meters, mussel volume and size distribution)
- Post-harvest processing (if any)
- Boat days at the growout site

Although this is labor-intensive, it is worthwhile in assembling this schedule to consider explicitly the use of each longline or other growout structure for the purpose of supporting spat collection or mussel growout. It may be useful in designing this schedule to work backward from desired monthly harvest targets. The production/operations schedule should also describe how operations are to be ramped up during the first years of the venture.

Processing, Marketing, and Distribution

Because the focus of this report is on the farming or growout of mussels, we do not treat the marketing and distribution component in detail. However, a business plan for mussel farming must address how the mussels are to be brought to market. This may be as straightforward as bringing mussels directly from harvest to a single buyer (a processor or distribution operation), or it may involve a range of such buyers. It can also involve a more complicated function of processing (cleaning, grading, and packaging), cold storage (warehousing), and/or distribution to a range of outlets (wholesalers, restaurants, retailers). The choice of marketing/distribution scheme has implications for staffing, facilities, and equipment requirements. It will also affect the market price range that the operation can expect to realize, the vulnerability to changes in price levels, and the ability to take advantage of short-term or seasonal fluctuations in prices.

Staffing

The business plan should identify, ideally by name, the key personnel who will be responsible for the venture. Other staff requirements should be spelled out in terms of skills and wages. The principal categories of staff required for a mussel farming operation include:

- Management (chief executive)
- Marine operations, including gear assembly/maintenance (vessel captain, crew members)
- Sales and marketing staff
- Processing and distribution (if applicable: processing facility staff, truck drivers)
- Consultants/others (biologist, quality control specialists, etc.)

Financial Projections

Financial projections are a critical component of any business plan, and are developed from the operations schedule and staffing plan. The financial projections should model the anticipated monthly cash flow, following the monthly production/operations schedule. The revenue estimate is straightforward, based on monthly harvest projections and the anticipated market price. Cost components that should be explicitly described include:

- Acquisition and deployment cost of growout structures (for a deepwater longline, components include anchors, chain, corner buoys, rope, shackles, floatation)
- Expendable supplies (spat collection substrates [may be usable for more than one season], socking material, harvest bags)
- Support vessel acquisition and maintenance
- Support vessel operating costs (fuel/lube, insurance, etc.)
- Personnel costs
 - Management
 - Marine personnel
 - Onshore personnel (processing/sales & marketing/distribution)

- Consultants
- Onshore infrastructure cost
 - Facilities for processing/distribution
 - Dock for support vessel
 - Office space

The financial projections should then be used to estimate a set of critical financial indicators, including:

- Total startup capital (investment) required
- Time until the operation has positive cash flow
- Time until startup capital (investment) is recovered
- Unit production cost (once operations have ramped up to “steady state”), for comparison to expected market price

Sample Business Plan Material

The following sections contain a hypothetical business plan discussion of a mussel farm in open waters south of Cape Cod. These sections can be used as guidance for the production/operations schedule and the financial projections section of a formal business plan. Note that for simplicity, projections are given here on an annual rather than a monthly interval.

Production and Operations

Mussels will be grown on ropes suspended vertically from longline harness sets in open water south of Cape Cod. Each harness set will consist of a 120 meter long horizontal “long line” held in place about 7 meters below the surface by submerged floatation spheres and anchored to the bottom (see Figure 8). About 200 culture ropes are suspended from each longline to a depth of 5 meters above the seafloor. At full scale, which we plan to reach in year 3, the farm will operate 120 such longlines.

Longlines are assembled on shore and deployed by a specialized vessel capable of handling the anchors (4,500 lbs each). The expected useful life of the longlines, with partial upgrades and regular maintenance, is 10 years. Deployment operations require reasonable weather and will take place primarily from March to October. Once the longlines are in place, production operations go through the following cycle:

- **Spat collectors are deployed** starting in early March. These are “fuzzy” lengths of rope or other substrate that are hung from longlines. Mussel spat (a juvenile form of the mussel) float freely in the water after spawning, and settle on solid substrates. The primary seed settlement in southern New England waters takes place in March, April, and May. Mussel settlement has been routinely observed in virtually all coastal waters of southern New England. We deploy spat collectors at several locations in addition to the primary farming site, to ensure an adequate supply of spat. The prospective farmer may need to experiment with the timing of spat collector deployment vis-à-vis the spawning cycle of mussels. Effective timing may lead to cost savings because collectors set out too far in advance of a set can foul up, thereby limiting their effectiveness.

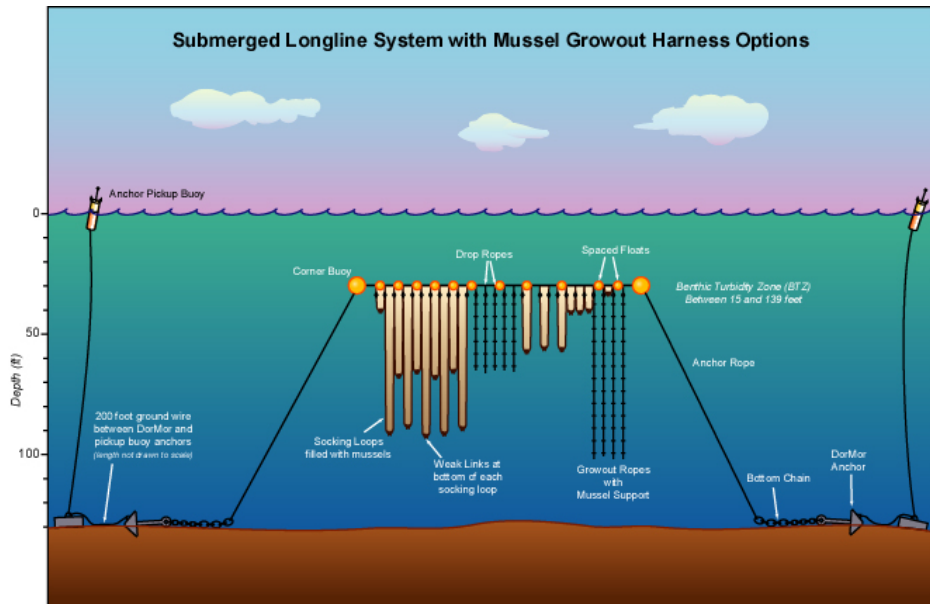


Figure 8: Drawing of an open-ocean blue mussel longline growout harness.

- **Mussel spat are socked** in June, July, September, and October. In this operation, spat collectors are retrieved and the juvenile mussels (then around 20 mm in size) are removed (stripped) from the collector, graded according to size, and “socked” in a biodegradable mesh surrounding the growout rope. This sausage-like “sock” of mussels is then suspended in loops from the longline. The mussels attach to the growout rope and the socking material disintegrates. Socking operations are not performed in August because mussels are susceptible to stress when the water is particularly warm. The entire process (stripping, grading, socking) is mechanized and performed onboard the vessel to minimize the mussels’ time out of the water.
- **Longlines are maintained** over the growout cycle until harvest. This includes the occasional removal of fouling and the addition of floatation as the mussels grow and become heavier. Some fouling organisms appear cyclically. The farmer should have an idea of what organisms to expect in order to schedule his cleaning. Properly scheduled defouling will help mussels grow better, preserve the gear, and save money on boat time.
- **Mussels are harvested** beginning in August of the following year (minimum growout time to market size is about 13 months after socking). Harvesting is staged so that a constant supply of mussels is harvested each month. The longlines remain in place after harvest for the next deployment of spat collectors or growout ropes.

Figure 9 summarizes the plan to scale up operations to 120 longlines over three years. We plan to deploy 30 longlines in year 1, and 45 each in years two and three. We will harvest 20 lines in year 2, 50 in year 3, and 60 each year after that. Production per meter of longline will continue to increase gradually after all longlines are installed, as growout ropes are lengthened and

production technique is refined. Annual harvest should reach 1,000 tons around year 6. We will use a modified second-hand fishing vessel for farm operations during the first three years, until cash flow from the farm will support the construction of a dedicated, custom-built vessel.

		year 1	year 2	year 3	year 4	year 5
lines deployed		30	75	120	120	120
lines harvested		--	20	50	60	60
mussels harvested (tons)		--	240	650	840	900
farming vessel	interim (fishing) vessel					
	build custom vessel					
	custom vessel operational					

Figure 9: Scaling up operations for a 1,000 ton/year blue mussel farming operation.

Biological Parameters

Mussels submerged continuously in off-bottom culture in southern New England have been observed to grow from 10-20 mm to over 5 cm shell length in as little as five months (summer) or seven months (fall-winter-spring), at growth rates of up to 4-5 mm/month. At harvest size, this should produce a yield of about 8.3 kg of mussels per meter of growrope. We plan to begin with a relatively low load of 12 meters of grow rope per meter of longline, with a harvest yield of about 12 tons per longline. With experience and the utilization of additional technology, such as “ladder” type growropes, we expect to increase this yield by 1 ton/year/longline.

Surface predators of juvenile mussels, such as eider ducks and other diving ducks, are unlikely to search for mussels in relatively deep water offshore. Seafloor predators, such as moon snails, starfish, oyster drills, and crabs, are not able to gain access since the grow ropes stop short of the bottom.

Pea crabs, which live inside mussel shells, reduce growth by pirating food and reduce the value of the mussel in the market. Pea crabs have two life stages at which they are planktonic, and therefore the culturing or pea crabs on a longline does not seem to affect their likelihood of invasion. Pearls, which originate as grains of sand or other foreign matter introduced into the mussel, also are undesirable. The incidence of both pea crabs and pearls is likely to be reduced by keeping mussels out of contact with the seafloor.

Red tide organisms (*Gonyaulax tamarensis*) and other toxic algae are quickly ingested by mussels, but do not injure the mussels and are quickly cleared again due to rapid filter feeding. Thus, while red tide would prevent harvesting for a time, it would not cause loss of the crop. Mussels would be tested until it is determined that the organisms have been cleared, at which point harvesting would resume.

Water temperature must be below 25°C (77°F) for mussels to thrive. The offshore location of the proposed farming operation provides insurance against high warming occasionally experienced in nearshore locations.

Boat Operations

We plan to purchase a used fishing vessel (70 to 80 ft) to perform farming operations during the startup phase of the first three years. The vessel will require minor modifications to accommodate handling of the longlines, and the installation on deck of stripping, grading, and socking machinery.

We plan to construct a new, purpose-built vessel in year 3, and begin operating with this vessel in year 4 (around the time the farm is at full scale). This vessel will be modeled on aluminum catamaran designs used on large-scale mussel farms in New Zealand, and designed for efficient longline handling in the conditions typical of open waters in southern New England. A number of builders of workboat-size vessels operate in the US, including several experienced with aluminum construction.

Marketing and Distribution

We plan to focus in this venture on mussel production, and to deliver the harvested mussels directly to the processing and distribution facilities in Rhode Island and Massachusetts.

The processing and packaging of mussels results in a wholesale price markup of about \$0.30/lb. By focusing on mussel production and relying on processors/distributors to handle marketing and sales, we are able to focus our attention on the crucial farming component of the mussel business.

Staffing

The key personnel will be a CEO who can double as chief vessel operator/boat captain or retain a captain part time. The longline gear will be assembled under contract or by the boat crew under captain's supervision. Boat crew (two part-time seamen or fishermen) are paid at rates comparable to traditional commercial fishing crew, based on time at sea. It is helpful for some of the fishing crew to be SCUBA certified.

Financial Projections

The following table shows financial projections for the first ten years of operations. Key results, assuming product sold at dock for \$0.60/lb, include:

- total up-front investment required is about \$1.2 million (\$700,000 in year 1 and \$500,000 in year 2)
- positive cash flow starting in year 4
- investment paid back in year 6
- production cost around \$0.25/lb after year 5

The operation is still profitable at dockside prices as low as \$0.50/lb, although the investment required increases to \$1.5 million, positive cash flow is pushed to year 5, and payback to year 7. A higher price of \$0.70/lb reduces the investment to \$1.1 million, produces positive cash flow in year 3, and pays back the investment in year 5.

			year 1	year 2	year 3	year 4	year 5	year 6	year 7	year 8	year 9	year 10
operations												
total lines operating			30	75	120	120	120	120	120	120	120	120
new lines installed			30	45	45	0	0	0	0	0	0	0
lines socked			30	60	60	60	60	60	60	60	60	60
lines harvested				20	50	60	60	60	60	60	60	60
tons/line				12	13	14	15	16	17	18	19	20
boat days			15	50	80	90	90	90	90	90	90	90
				240	650	840	900	960	1020	1080	1140	1200
financial (\$1,000)												
revenue	\$0.60 /lb			317	858	1109	1188	1267	1346	1426	1505	1584
cost of new longlines (installed)	\$10,000 /line		300	450	450	0	0	0	0	0	0	0
expendable supplies			51	102	102	102	102	102	102	102	102	102
used vessel acquisition & maintenance			70	10	10							
vessel upgrade & equipment			25	5	5	5						
custom boat construction & maintenance					100	700	30	30	30	30	30	30
used vessel variable cost (fuel, crew, etc)	\$1,500 /day at sea		22.5	75	120							
custom vessel variable cost	\$1,000 /day at sea					90	90	90	90	90	90	90
on shore costs			150	150	150	160	160	180	180	200	200	200
total cost			619	792	937	1,057	382	402	402	422	422	422
annualized cash flow			(619)	(475)	(79)	52	806	865	944	1,004	1,083	1,162
cumulative cash flow			(619)	(1,094)	(1,173)	(1,121)	(315)	550	1,495	2,498	3,581	4,743
production cost, \$/lb				1.03	0.41	0.30	0.28	0.27	0.25	0.25	0.24	0.22

Details behind the cost estimates include:

- longlines, \$10,000 installed
 - 2 anchors (4,500 lbs each @ \$0.20/lb) \$2,000
 - 2 corner buoys @ \$1,000 \$2,000
 - rope and chain \$2,000
 - flotation \$2,000
 - assembly and deployment \$2,000
- expendable supplies: spat collectors, growout ropes, socking material, bags, etc. \$1,700/longline/year
- used vessel, years 1 through 3
 - used vessel acquisition, \$100,000
 - vessel maintenance, \$10,000/year
 - star wheel assembly, \$3,000 installed
 - stripper/declumper/grader and continuous socking machine, \$25,000 purchase cost (Fukui), \$5,000/year maintenance
 - operating expenses incl. crew, \$1,500/day at sea
- new custom vessel
 - custom vessel, \$800,000 construction cost
 - maintenance, \$30,000/year
 - operating expenses incl. crew, \$750/day at sea

- personnel and onshore costs
 - CEO/captain salary, \$100,000/year in year 1
 - vessel dockage etc., \$20,000/year
 - miscellaneous, \$30,000/year

MANAGING RISKS

Open-ocean aquaculture operations must take into account the serious risk and uncertainty of working in an exposed, deepwater environment. Sources of uncertainties include future market demands; unexpected shifts in regulatory policies; and biological factors. In addition to uncertainty, a choice of whether to invest in open-ocean aquaculture can be characterized as irreversible (or reversible only at great cost) in the sense that equipment and materials used for aquaculture production are firm- or industry-specific and not easily retrieved and used for other purposes. The investment expenditures therefore comprise sunk costs. Importantly, in the face of such uncertainty and irreversibility, potential investors may choose to delay and consider carefully the timing and scale of their investments.

Suppose revenue and cost assessments for a mussel culturing project are accurate and there are no risks. In this special but unrealistic case, investment decisions can be made according to a basic investment rule: invest when the value of the project is at least as large as the investment costs:

$$\text{Benefits} \geq \text{Investment Costs}$$

Here, benefits are project revenues net of labor and other variable costs, and the investment costs are sunk costs that cannot be recouped (*e.g.*, a longline system purchase and installation cost).

When risk and uncertainty are present, the investment rule should be modified. Generally, a greater revenue stream will be required to justify the same level of investment. Although individuals often have different attitudes toward risk, most are either risk neutral or slightly risk averse. For risk-averse investors, the investment rule is to invest if the value of the project is at least as large as the investment cost plus a risk premium:

$$\text{Benefits} \geq \text{Investment Costs} + \text{Risk Premium}$$

A risk premium is positively related to an investor's level of risk aversion and the spread (variance) of possible benefits, which is a measure of risk. Although a risk premium may not always be straightforward to calculate, one can think of it as analogous to the insurance premium that an investor pays to prevent potential losses.

In the face of uncertainty and irreversibility, there may be value to an investor from delaying investment. This value is called an option value. Option value can exist even for risk neutral investors who would ordinarily not consider accounting for a risk premium. Risk averse investors may need to account for both a risk premium and an option value. Specifically, option value is defined as the difference in uncertain net benefits between two development strategies: invest immediately or wait until new information becomes available (Arrow and Fisher 1974).

When an investor makes an irreversible investment, he exercises ("kills") his option to invest and thereby gives up the possibility of waiting for the arrival of new information that might bear on the desirability or timing of the investment. Thus, the traditional rule of making an investment

should be modified (Pindyck 1991). With irreversibility and uncertainty, an investor should invest if the benefits of the project are at least as large as the investment costs plus the value of keeping the investment option alive:

$$\text{Benefits} \geq \text{Investment Costs} + \text{Option Value}$$

According to this new rule, investment costs are fixed, but the realization of benefits will depend upon the timing of the investment. Option Value is affected by the discount rate, any expected rate of appreciation in benefits, the spread of possible benefits, and costs.

The existence of option value depends on the nature of the relevant uncertainties and the opportunities for gaining information to reduce them (Freeman 1984). In general, information about uncertain benefits and costs can be gained by waiting. If uncertainty is due to a lack of information about the benefits of aquaculture production, then waiting (and carrying out market analyses) may resolve the uncertainty. In this case, it is the waiting strategy that creates option value.

A key feature here is that the project value may change over time. An investor can maximize a project's net present value (NPV) by choosing the optimal time at which to invest. Importantly, one needs to consider option value only if the project's benefits are appreciating, for example, due to a rising price or declining costs. Note that even if the current benefits are less than costs, implying that NPV would be negative, because benefits are growing, the option value will be positive.

Option value will be larger with larger rates of benefits growth or with greater uncertainty. For example, if benefits appreciate at 2 percent per year, the discount rate is 5 percent per year, and the investment cost is \$1.2 million, option values are as follows:

Uncertainty (% of expected NPV)	Cost	Option Value	Invest if Benefits are greater than:
0.23	\$1.2 m	\$2.39 m	\$3.59 m
0.30	\$1.2 m	\$3.26 m	\$4.46 m

On the other hand, if benefits are expected to decline over time (e.g., because costs are expected to rise due to regulation), then it is optimal to invest immediately (assuming that NPV is positive).

Irreversibility can affect not only the timing but also the scale of an investment (Viscusi 1988; Dixit 1995). Where a decision is made to proceed with an investment, the presence of irreversibility creates incentives for development at smaller scales, so long as there is the potential for revenues to decline in the future. Where the costs of development are expected to increase in the future, however, smaller scale development may not be warranted. In this case, there may be an incentive to undertake a larger scale of development now.

Finally, because of the presence of uncertainty, it is usually not possible to calculate the exact date at which to make an investment. Instead, once an option value is estimated, it is optimal to invest as soon as benefits exceed the sum of investment costs plus option value.

REGULATION

The regulation of offshore aquaculture in the United States is problematic and unsettled (Hoagland *et al.* 2003). At present, there is no federal policy pertaining specifically to the permitting of aquaculture in the area from three to 200 nautical miles offshore known as the exclusive economic zone. Public debate over the establishment of any such policy is still only in its early stages. A number of state governments have established regulatory programs for shellfish aquaculture within their territorial jurisdiction (out to three nautical miles).

A permit from the Army Corps of Engineers (ACoE) under section 10 of the Rivers and Harbors Act (RHA) is required for the installation of aquaculture gear in navigable waters. This permit relates to potential obstructions to navigation and is not an aquaculture permit, *per se*. In the course of evaluating a section 10 permit application, ACoE seeks comments from the NMFS Protected Resources Division (offices in Gloucester, Massachusetts), which determines the likelihood of any impacts from a project on endangered or threatened species or marine mammals.

Protected species concerns relate primarily to whether the proposed installation is within a transit, feeding, or nursery area. This can be a very contentious issue, one in which perceptions of problems may be as important as actual impacts. In particular, public interest groups have been concerned about the potential for the entanglement of individuals of the western North Atlantic stock of the northern right whale (*Eubalaena glacialis*), which is a highly endangered species. These concerns have the potential to halt activity on any proposed project.

In 1993, NOAA's General Counsel determined that aquaculture facilities are subject to the federal Magnuson-Stevens Act at the discretion of the New England Fisheries Management Council (NEFMC). In order to formalize its authority, NEFMC must prepare a fisheries management plan (FMP). FMP preparation is a public process requiring approval of the NEFMC membership (a group dominated by commercial wild harvest fishery interests), followed by approval from NMFS.

NEFMC has not prepared an FMP specifically for aquaculture, but in December 1996 it issued a "Draft Aquaculture Policy." This draft statement makes it clear that NEFMC intends to develop an "aquaculture management strategy" at some point in the future. The details have yet to be worked out, but it is clear that NEFMC will be concerned about any potential impacts on existing commercial fisheries, including both biological impacts and loss of access to specific areas.

Currently, there is no federal FMP for mussels. As a result, NEFMC has no specific authority to develop plans to manage mussel farming. NEFMC does have the responsibility to comment on any aquaculture activities that may affect fisheries habitat.

Mussel farming is a relatively "clean" operation. As filter feeders, mussels tend to remove suspended materials from the water column, thereby improving local water quality. Regardless of the technology employed, the culturing of mussels does not involve the application of feed or the release of pollutants in any other way. This interpretation was tested recently with respect to the release of mussel shells and other natural mussel growing byproducts from the mussel raft operations of Taylor Resources in Puget Sound. In August 2002, the 9th US Circuit Court of Appeals found that the byproducts of mussel culturing did not constitute "pollutants" subject to regulation under the federal Clean Water Act. Significantly, none of the "biological materials" released from culturing operations were considered by the Court to have been altered by a human

or industrial process. Further, Taylor's operations were found to be an exception to the EPA regulations for concentrated aquatic animal facilities.

Any federal action (such as an RHA section 10 permit) having a direct effect on the coastal zone of a state with an approved coastal zone management program (such as Massachusetts or Rhode Island) may be subject to the "federal consistency" requirements of the federal Coastal Zone Management Act. This will require a determination by the relevant coastal state that the action is consistent with their programs.

The Conservation Law Foundation (CLF) has been quoted in the media as opposed to "the privatization of public waters without a national policy debate." CLF filed suit in opposition to the proposed Norwegian American Fish Farm salmon pen operation on grounds that a federal environmental impact statement (EIS) was required. Any federal action determined to have a "significant effect on the quality of the human environment" may require the drafting of an EIS under provisions of the US National Environmental Policy Act. ACoE would be the lead agency making a determination of the need for an EIS. The costs associated with the development of an EIS should be factored into an entrepreneur's budget from the beginning, as they can be quite significant. Further, the time frame for EIS drafting and public comment may slow the permitting process.

POTENTIAL FOR COOPERATION AMONG GROWERS

Mussel growers must assess the financial and administrative benefits and costs of alternative organizational forms, including individually owned businesses, partnerships, general business corporations, limited liability companies, or cooperatives (Frederick 1997). For the prospective small-scale mussel farmer, the choice may be effectively limited to either going it alone as an individually owned business or joining with others in a cooperative. In the business planning section above, we discuss the financial aspects of an individually owned business. In this section, we present an overview of some issues relating to the cooperative choice. We also identify and describe two other forms of cooperation that could lead to future payoffs: marketing orders and trade associations.

Cooperatives

In 1995, more than 4,000 agricultural cooperatives were operating in the United States, comprising almost 4 million members and generating over \$2 billion in net earnings on more than \$100 billion in sales (Frederick 1997). One of the primary reasons for the establishment of a cooperative is to raise profits by increasing market power. One way to increase market power is through greater horizontal concentration. Recent mergers and acquisitions in agricultural cooperatives have been primarily horizontal, which suggests that cooperatives are seeking to increase their market power (Hudson and Herndon 2000).

Cooperatives must be organized according to specific rules, which typically are embodied in state law. These rules include requirements that the cooperative be operated for the mutual benefit of its members, voting rights are not tied to capital investments, and limits exist on the payment of dividends to shareholders, among others.

In 1980, over 100 commercial fishing cooperatives existed in the United States, comprising more than 10,000 fishermen (Garland and Brown 1988). Fishing cooperatives may be established under the 1934 federal Fishery Cooperative Marketing Act. Since 1934, several judicial decisions

have made clear the limits on the ability of fishing cooperatives to exert market power by anti-competitive means, such as by fixing prices or restricting production, even where such practices might lead to the beneficial conservation of fish stocks. More recent federal legislation now permits the establishment of fishing cooperatives in specific fisheries, such as those for groundfish off the west coast (Adler 2002).

In the case of aquaculture, examples of cooperative functions might include the operation of fish hatcheries, feedstock supply, value-added processing, insurance, market intelligence, and the marketing and distribution of cultured seafood. Where the industry is building up from small-scale or part-time growers who require technological expertise, processing facilities, and a market for their product, cooperatives may contribute to the reduction of risks for individual firms. Thus, small agricultural-type cooperatives have begun to be established for growing catfish, shrimp, and hybrid striped bass. Examples include the Southern Kentucky Aquaculture Cooperative and the Illinois Fish Farmers Cooperative.

Cooperatives can serve one or more of the following general functions: (1) enhance bargaining power relative to downstream consumers (who may be processor/distributors); (2) reduce the costs of inputs through volume purchasing, including the costs of purchasing insurance on various aspects of grower operations; (3) provide growers with access to a market; (4) broaden market opportunities; (5) add value through processing; (6) exploit economies of scale and reduce duplication in processing; and (7) improve the consistency of product quality.

Where market volatility increases uncertainty about the returns to investment in aquaculture, downstream processors might have opportunities to take advantage of producers. This is known as a “holdup” problem. Even the signing of contracts may not preclude holdups, because contracts may be incomplete. The possibility of opportunism may force prospective aquaculture entrepreneurs to make investments at lower levels or more slowly than they might in the absence of uncertainty. Schrader (1989) explains that this is one of the classic reasons for the establishment of processing or marketing cooperatives.

Downstream of fishermen and seafood farmers, there appears to be little concentration in the seafood processing industry, which is capable of handling a wide variety of raw products and for which there are few serious barriers to entry. The blue mussel processor/distributors, however, have made significant capital investments in grading, cleaning, and debyssing equipment and separate holding tanks for blue mussels (needed because mussels will byss-up if placed in a tank with clams). In theory, the potential geographic clustering economies referred to earlier could lead to incentives for the formation of mussel grower cooperatives to balance the market power of downstream processor/distributors or for growers to establish their own processing capability. The evidence for this is thin, however. For example, there has been some establishment of grower marketing cooperatives for blue mussels on PEI, but these tend to be unstable, in part because of competition from other growers.

Some market participants hypothesize that in the early stages of industry development, cooperatives may serve as a catalyst for the growth of the industry by reducing market risks. In New Zealand, for example, green-lipped mussel growers formed cooperatives in the early years of that industry, where mussels were first farmed to supply a market for a nutraceutical end-use. The cooperatives failed as the market for a frozen product was developed and matured, and large, fully-integrated commercial fishing companies entered the business. A competitive fringe of small producers still exists in the New Zealand industry, and small and large growers are

members of the Mussel Industry Council, a trade association that develops quality standards and codes of practice, protects intellectual property rights, conducts market promotions, and serves as the voice of the mussel industry.

Although cooperatives do exist in the aquaculture industry, the cooperative business model appears to have been utilized to a lesser extent in this industry than in agriculture generally. Although it has encountered some legal problems in its historical attempts to control the market for cultured catfish, the Delta Pride cooperative in Mississippi may be a leading example of a successful cooperative in the freshwater aquaculture business. Delta Pride is fully vertically integrated from hatcheries through distribution. The growth of the catfish aquaculture business during the last 20 years has been impressive, attracting foreign entry, such as the export of basa, masquerading as “catfish,” from Vietnam into the US market.

For small-scale, part-time freshwater growers who participate in cooperatives, a source of risk reduction comes in the form of farm product diversification, where farms produce other non-seafood agricultural or dairy products. Analogously, in the open-ocean case, aquaculture can be seen as a way for commercial wild-harvest fishermen to diversify their seafood production businesses.

Importantly, to the extent that supply can be maintained, the risks of supply disruptions to downstream consumers can be reduced through a cooperative. PEI mussel production provides an example, although it is not strictly limited to the cooperative concept. Thus, in the PEI situation, growers that are hit by harmful algal blooms may have to halt harvests for a period of time until their product detoxifies in situ. Yet there are enough growers to ensure that product continues to be supplied to the market; this geographic diversification reduces the risk of supply disruptions. One possible result is that downstream consumers may be willing to pay a premium for a consistent source of supply from a geographically diversified cooperative.

Marketing Orders

Another form of collective action is permitted under federal authority to establish “marketing orders” for agricultural commodities. Marketing orders authorize the establishment of a committee of growers and handlers (processors and distributors) to stabilize the markets for fruit, nut, or vegetable products. Successful stabilization may reduce the market risks faced by farmers. Although marketing orders are an interesting concept, we are unaware of an authority for the implementation of marketing orders in seafood commodities.

A marketing order allows the establishment of product and marketing standards that differentiate a product from substitutes. Standards may include those for minimum grade, size, quality, and maturity of product and those relating to the size, capacity, weight, and dimensions of containers. Container standards are designed to eliminate deceptive distribution practices and pricing. Other purposes of marketing orders include the compilation and publishing of market information; the establishment of volume controls (quotas) or pooled reserves to ensure production; the sponsorship of research on production and marketing; and market promotion, including advertising.

A good recent example of the application of a federal marketing order concerns the Vidalia onion, a variety of sweet, mild, hybrid yellow Granex onion grown in a specific geographic area in Georgia (Clemens 2002). Vidalia onions command a significant premium in the market for onions. The existence of this premium attracts entry into the market, including the rebagging and

mislabeling of non-Vidalia onions as Vidalias. (Mislabeling has been an issue also in the market for shellfish.) The issuance of a federal marketing order permitted growers and handlers to jointly fund market promotion, set a quality standard, and sponsor research on technology to extend the shelf life of fresh onions. The latter activity led to a capacity to lengthen the duration of the fresh market and control supply more effectively. While some market risks are controlled, the production of Vidalia onions is still subject to environmental risks, however, including weather, insects, and disease.

Trade Associations

There does not appear to be historical precedent for the use of either horizontal or vertical coordination explicitly to reduce the costs of risk in the blue mussel industry. A possible exception is the wide use of trade associations, which may reduce market risks through the supply of information. Trade associations in aquaculture also serve important roles by acting as a “voice” for the industry in legislative deliberations and commenting on proposed rules, in the adoption of best management practices or codes of conduct, in the development of product quality standards, in the establishment and protection of intellectual property, including brand names or trademarks, and in advertising and market promotions. An East Coast Shellfish Growers Association, modeled after the successful Pacific Coast Shellfish Growers Association, is now under development for a variety of cultured shellfish products grown in the eastern United States.

SUMMARY

Mussel production has been increasing worldwide. The market for mussels in eastern North America, supplied primarily by producers on Prince Edward Island and in Maine, has been among the leaders in this growth. Production is ramping up in all of the other Canadian maritime provinces, and R&D projects are well-advanced in the New England states.

The market can be defined as trade in a processed (cleaned) blue mussel in eastern North America. Processors purge, declump, grade, debyss, package, and distribute mussels. Processors add value to the raw product and ensure a consistent and steady supply to downstream customers or distributors. Some branding is present for the wholesale trade, but final consumers do not appear to distinguish mussels by source. This feature of the market could change as the market grows and consumers become more sophisticated.

There may be lessons for prospective growers to draw from experience in the development of the industry in Newfoundland. These lessons relate to the importance of husbandry and the potential for geographic clustering economies that may exist when farms are linked, formally or informally, to a processor/distributor.

Changes in the quantity of processed mussels supplied and purchased in the market are associated with general market conditions, such as restaurant sales and disposable income, and also fluctuations in the price of substitute shellfish.

We present the outline and some sample language for a business plan for the production of blue mussels. The likely customer is a processor/distributor, although the production of rough processed product or the development of a processing capacity is possible. Assuming the product sells at dockside for \$0.60/lb, the key numbers for a hypothetical 1,000 ton/year open-ocean blue mussel farming operation might include: a total up-front investment of about \$1.2 million

(\$700,000 in year 1 and \$500,000 in year 2); a positive cash flow starting in year 4; investment is paid back in year 6; and production costs are around \$0.25/lb after year 5.

Open-ocean aquaculture operations are plagued by risk and uncertainty, and some investments may be difficult to reverse if adverse events occur. Sources of uncertainties include future market demands; unexpected shifts in regulatory policies; and biological factors. In addition, equipment and materials used for aquaculture production are not easily retrieved and used for other purposes. In the face of such uncertainty and irreversibility, potential investors may choose to consider carefully the timing and scale of their investments. We discuss how investors might consider incorporating a risk premium or an option value into their decision-making to help manage risk.

Finally, we discuss some of the benefits of cooperation with other growers. Where the industry is building up from small-scale or part-time growers who require technological expertise, processing facilities, and a market for their product, cooperatives may contribute to the reduction of risks for individual firms. Unlike other agricultural products, few cooperatives exist in aquaculture.

Other forms of cooperation include marketing orders, which do not yet exist for the aquaculture industry, and trade associations. Trade associations in aquaculture serve important roles by acting as a “voice” for the industry in legislative deliberations and by commenting on proposed rules, in the adoption of best management practices or codes of conduct, in the development of product quality standards, in the establishment and protection of intellectual property, including brand names or trademarks, and in advertising and market promotions. A trade association is now emerging for the shellfish industry on the US east coast.

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