Economic Analysis to Inform the Alaska Mariculture Initiative:

Phase 1 Case Studies

Prepared for

Alaska Fisheries Development Foundation

March 2015

Northern Economics

In association with

Pacific Shellfish Institute

Maine Shellfish Research and Development

This publication was prepared with funds from Award #NA14NMF4270058 from the National Oceanic and Atmospheric Administration, U.S. Department of Commerce. The statements, findings, conclusions and recommendations are those of the authors and do not necessarily reflect the views of NOAA or the Department of Commerce.

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Abbreviations

AAC	Aquaculture Association of Canada
ADF&G	Alaska Department of Fish and Game
AFDF	Alaska Fisheries Development Foundation
AKCRRAB	Alaska King Crab Research Rehabilitation and Biology
AIMAP	Aquaculture Innovation and Market Access Program
AMA	Aquaculture management area
B.C.	British Columbia
BIM	Bord Iascaigh Mhara (Irish Sea Fisheries Board
CLAMS	Coordinated Local Aquaculture Management Systems
CSEP	Comprehensive salmon enhancement plan
CZM	Coastal zone management
DA	Domoic acid
DACS	Florida Department of Agriculture and Consumer Services
DAFM	Department of Agriculture, Food and the Marine (Ireland)
DFO	Department of Fisheries and Oceans Canada
DO	Dissolved oxygen
DOC	Department of Conservation
EU	European Union
FCMP	Florida Coastal Management Program
FDA	Food and Drug Administration
FLAG	Fishery Local Action Group
FRED	Division of Fisheries Rehabilitation, Enhancement and Development
IFAS	University of Florida Institute of Food and Agricultural Sciences
kg	Kilogram
lb	Pound(s)
m^2	Square meter
mm	Millimeter
MPI	Ministry of Primary Industries
MRI	Mariculture Initiative
mt	Metric tons
NDP	National Development Plan 2000–2006
NIWA	National Institute of Water and Atmospheric Research Limited

NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
PEI	Prince Edward Island
ppt	Parts per thousand
RMA	Resource Management Act 1991
RPT	regional planning team
PSI	Pacific Shellfish Institute
PNP	Private Nonprofit
R&D	Research and development
RTDI	Research, technology, development and innovation
SFPA	Sea-Fisheries Protection Authority
SGP	General Secretariat of Fisheries
SGPM	General Secretariat for Maritime Fisheries
SHA	Shellfish Harvest Area
WDFW	Washington Department of Fish and Wildlife
WDNR	Washington Department of Natural Resources
WDOE	Washington Department of Ecology
WDOH	Washington Department of Health
USDA	United States Department of Agriculture

Executive Summary

The potential economic impact of a fully developed mariculture industry in Alaska is not well understood by industry or policymakers. It is also not entirely clear what is needed to move from Alaska's current micro industry to a fully developed industry. The Alaska Fisheries Development Foundation (AFDF) has been awarded a grant from NOAA in order to spearhead the Alaska Mariculture Initiative (AMI) with the following goals: (1) expand the stakeholder base, create partnerships, and increase capacity to be effective; and (2) develop a clear and comprehensive strategic plan, including a written commitment to implement the plan by the various stakeholders and agencies. Northern Economics, Inc. was contracted by AFDF to conduct an economic analysis to help inform decisions to be made in the creation of the AMI strategic plan. The economic analysis will contain three phases:

- Phase I: Comparative case studies which outline examples of successful mariculture industries in different regions of the world
- Phase II: Preliminary economic analysis to support the development of a statewide strategic plan
- Phase III: Analysis of the costs, benefits, and economic impact of the statewide strategic plan developed as part of the AMI

This report represents the work completed for Phase 1. Funding for Phases II and III is pending.

In this report we describe nine case studies. Drawing on existing literature, each case study includes (1) a description of the industry; (2) the current economic impact of the industry, (3) the history and reasons for the industry's growth, as well as past and current obstacles to growth; (4) best available estimates of private and public investments in order to reach current levels of development; (5) estimates of costs and benefits of the return on investment in these regions; and similarities and contrasts to Alaska (e.g., workforce, transportation, government support programs) and relevance and applicability of the industry's experiences to Alaska. Case studies completed include:

- Alaska salmon enhancement
- Alaska king crab enhancement
- Washington geoduck
- Florida hard cams
- Ireland Seaweed
- Spanish mussels
- Prince Edward Island mussels
- New Zealand mussels
- British Columbia First Nations aquaculture

These case studies provide insights into best practices in development of strategic mariculture initiatives, and attributes and characteristics (such as access to markets, employment base, government and public support, etc.) that have led to the success of mariculture development in other parts of the world. These factors can be compared to the current social, economic, regulatory, investment and political climate in Alaska to allow for efficient and effective development planning and implementation. The following subsections provide brief descriptions of each case study.

Alaska salmon enhancement

In response to precipitous declines in salmon harvests in the 1950s and 1960s, the State of Alaska initiated its salmon fisheries enhancement program in 1971. In that year, the state legislature created the Division of Fisheries Rehabilitation, Enhancement and Development within the Alaska Department of Fish and Game and tasked the division with planning the rehabilitation, enhancement and development of all aspects of the state's fisheries to insure perpetual and increasing production and use, and encourage investment by private enterprise. Perhaps the most distinctive feature of Alaska's salmon fisheries enhancement program is that most hatcheries in the program are owned and operated by private, nonprofit "regional associations" comprised of commercial, recreational and subsistence fishermen, seafood processors, conservationists, and local civic interests. A 2008 economic impact analysis estimated that hatchery operations and the commercial harvesting and processing of salmon produced by three regional associations in southeast Alaska produced $233 million in total (direct, indirect, and induced) economic output and generated a total of 1,192 jobs and $59 million in labor income.

Alaska king crab enhancement

The Alaska King Crab Research Rehabilitation and Biology program was established in 2006 with the mission of understanding the large-scale culturing needs of red and blue king crab, and perfecting strategies for hatching and rearing these species to a stage where they can be released into the wild and contribute to reversing low wild stock abundance in Alaska. Acquiring this knowledge base will aid policymakers in making informed decisions about whether to pursue active rehabilitation of Alaska's long-depressed wild king crab stocks through hatchery enhancement. Several more years of developmental research are probably required before a full-scale hatchery-enhancement operation is feasible. Once initial cultivation and releases have occurred, at least another seven years will be required before released crabs grow to sizes that could be recaptured, and the success of a rehabilitation and enhancement program can be determined. Therefore, any potential economic benefit from a king crab enhancement program is at least 10 to 15 years off in the future.

Washington Geoduck

The commercial dive harvest of geoduck began in the early 1970s as a managed fishery producing a relatively low value product (< $1 per pound [lb]). However, by the early 1990s a developing market in Asia transformed geoduck into a much higher valued product. These initial steps led to successful development of commercial geoduck aquaculture in the State of Washington and a significant expansion of production volumes and values for both cultured and dive harvested geoduck. Challenges remain, however, with continual demand for hatchery-produced geoduck seed, slow growth, and an ongoing presence of Paralytic Shellfish Poisoning contamination. Nevertheless, the future growth of the industry looks promising, especially for growers interested in the long-term production of a high-value product. Aquaculture production has increased significantly over the last 20 years from zero pounds in 1995 to over a million pounds since 2008. The average yearly value of production (2003–2012) is over $10 million, with 2012 recording a record value of $16,432,111.

Florida hard clam

Hard clam aquaculture began in Cedar Key following the ban on the use of gill nets in Florida state waters. As a result many commercial fishermen were out of work. Clam culture training was begun to offer new employment opportunities and train fishermen to become aquatic farmers. In addition, shellfish aquaculture leases were identified, permitted, and marked, allowing for placement of trainees onto farm sites in Cedar Key and other coastal areas of Florida. These measures resulted in a rapid expansion of clam aquaculture. Statewide production in 1987 was about 100,000 lb. By 1999, 351 growers produced over 4.5 million pounds of farm production. Corresponding farm gate sales have also increased, with the value in 2012 reported at $38.7 million. Although the hard clam industry endured challenging events, such as the 2004 and 2005 hurricane seasons, the 2007–2012 recession, and the 2010 Deepwater Horizon oil spill, the industry exhibits a resiliency that allows for recovery and continued future market expansion. Associated with the increased shellfish farming activity was the development of spin-off businesses in support of the industry. Farm expansions also led to an increased level of public and private sector research on a broad range of issues, including market expansion, genetics, diseases and the possible culture of other shellfish species. Currently, clam farming is a mature industry in Florida, and an excellent example of a successful and community driven transition from an at-risk fishery dependent culture.

Ireland Seaweed

As part of the Sea Change strategy (and with the support of the Marine Institute and the Marine Research Sub-program of the *National Development Plan, 2007–2013*) a project was carried out to develop and demonstrate the viability of cultivation methodologies for seaweed species with known commercial potential. This project was led by the Bord Iascaigh Mhara (Irish Sea Fisheries Board or BIM) and involved two universities and six enterprises. The project operated from 2008–2011 and aimed to farm three commercially important species, *Palmaria palmata*, *Laminaria digitata,* and *Porphyra sp*. This project has proved to be pivotal in development of the industry, as it identified crucial data that ensures strategic investment. It clearly demonstrated that brown seaweeds (kelp) can be farmed, and provided business plans and economic analyses for hatchery and grow-out businesses. The project concluded that the price for brown seaweed (off the farm) needs to be about $1,275/wet metric ton to be profitable. The project also highlighted the limitations for farming *Palmaria*, and concluded that currently farming *Porphyria* is not viable. The funding required to make this project possible is not publicly available information. Through coordinated and focused industry development led by BIM, seaweed aquaculture in Ireland is now a viable but fledgling industry. Going forward, the main obstacle will be labor costs. Development of mechanized seaweed cultivation will be required to achieve cost objectives.

Spanish mussels

Mussel raft culture originated in the Mediterranean region of Spain (Barcelona) in the early twentieth century. The number of floating raft farms established in the Galician rıas experienced growth from 10 rafts in 1946 to over 3,300 in 1997. During this 30-year period, there were a large number of lease areas granted, mostly to family entities which owned one or two rafts each. The number of rafts has stayed the same for nearly 40 years, with raft size increasing from about 2,691 to 5,382 square feet, and culture ropes from 33 to 39 feet long through the 1990s. Since production has reached its maximum levels in Spain, some of the original companies have established operations in Chile, where they grow 8,000–10,000 tons of mussels per year (with a production capacity of 30,000 tons) and export frozen mussel meat and mussels on the half shell. The mussel raft aquaculture industry in northwest Spain grows an annual crop of over 200,000 metric tons, and is the second largest mussel farming area in the world behind China. The industry is composed of approximately 3,300 rafts with a production as high as 75 tons per raft. Production has maximized since the early 1990s, and there have been no additional rafts or lease sites since 1976. The economic impact of mussel aquaculture, in the growing, services, and processing sectors in terms of jobs and value makes it a very valuable component of the sustainable economic activity in Galicia.

New Zealand mussels

The New Zealand aquaculture industry began in the mid-1960s with marine farming of oysters and then mussels, typically by small, innovative operations. It quickly established a domestic market and began making inroads into export markets in the 1970s. As aquaculture techniques and value chains became more sophisticated in the 1980s, small owner-operator farms became less common and aquaculture/seafood-related companies expanded and consolidated. There are now approximately 645 mussel farms in New Zealand over seven major regions. Production efficiency, control of stock, and cost reduction dominated industry thinking as export markets expanded. During the 1990s global competition in seafood products intensified, driving further consolidation of the industry in an attempt to achieve increased production and marketing efficiencies. With the introduction of the Resource Management Act in 1991, the expanding industry began to focus on sustainable production, acknowledging its associated environmental and social issues. In 2011, New Zealand produced 101,000 tons of mussels, worth $197 million, providing three-quarters of the country's seafood export value. The New Zealand mussel industry has developed over 30 years to become the world's leader in efficiency of mussel farming technologies, value added processing, and mussel research and development.

Prince Edward Island mussels

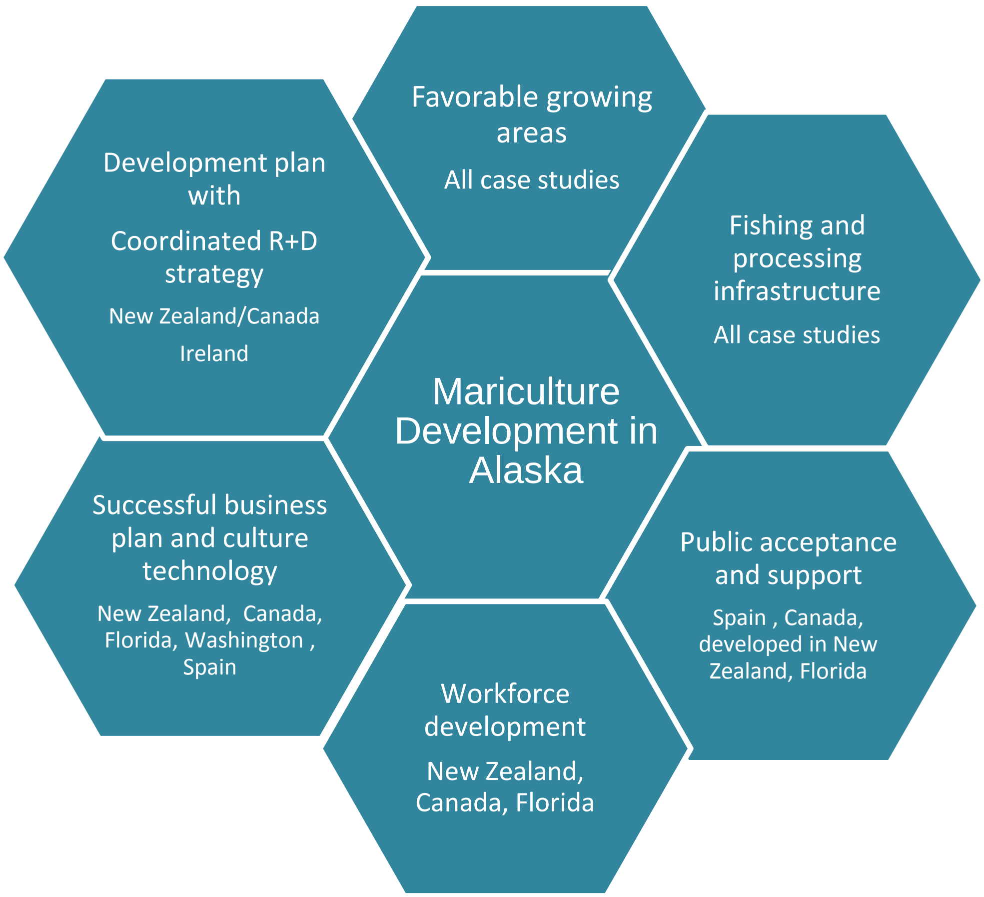
Prince Edward Island (PEI) mussel production has not grown much since 2000, when landings were nearly 18 million lb. Most of the growth of the industry took place between 1986 and 2001 due to skilled entrepreneurs. During the last decade, there has been consolidation of numerous smaller operations resulting in five large companies with an economy of scale. The utilization of long-line technology allowed for efficient seeding and harvesting, and adaptation to the relatively shallow waters in the enclosed PEI bays. Canada (and the maritime provinces) benefit from a strong federal aquaculture development policy, regional development centers, and financial support for outcome-based research and development. Mussel leases account for a total of 10,932 acres. In 2013, PEI produced 22.9 million pounds of mussels with a farm gate value of $29.43 million. Prince Edward Island's aquaculture industry contributes significantly to the PEI tax base, contributing $24 million in gross value added to local economies annually. The industry is also a vital component of the Island economy providing approximately 2,500 direct and indirect jobs. Many of these jobs provide year-round employment in local rural communities.

British Columbia First Nations aquaculture

Canada's First Nations communities are uniquely positioned to benefit from aquaculture due to hunting, fishing and gathering rights, and access to aquaculture development sites. In many cases, the necessary skills and infrastructure for aquaculture development already exist because of past involvement in traditional fisheries. There are currently 50 Aboriginal groups across Canada that have developed aquaculture business ventures and partnerships, with many more expressing interest and a desire to get involved in new aquaculture sector opportunities. In British Columbia, 21 First Nations are engaged in shellfish aquaculture activities and 14 First Nations are engaged in finfish aquaculture. There are currently 56 different species of finfish, shellfish and aquatic plants commercially cultivated, generating about $1.81 billion in total economic activity, much of which takes place in rural and coastal communities. Immediate opportunities exist for further development of finfish, shellfish and freshwater aquaculture endeavors, with additional longer-term opportunities for species such as geoduck, scallop, sablefish, sea cucumber and rockfish, where culture technology is under development.

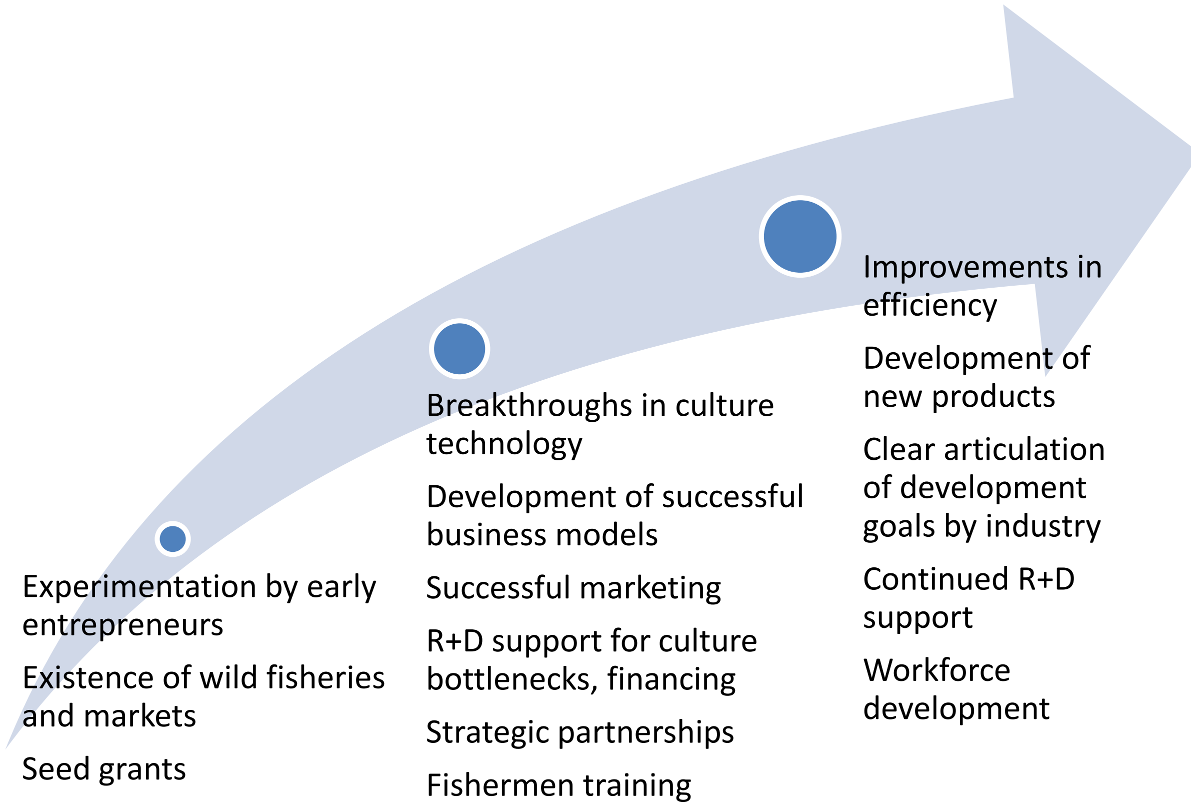
During the process of this investigation we have identified key elements for sustainable mariculture development—necessary factors in the success of mariculture development around the world. Figure ES-1 illustrates these elements and which case studies contain them. Figure ES-2 further illustrates the elements observed in the successful growth over time of the mariculture industries in the case studies reviewed.

Figure ES-1. Key Elements for Sustainable Mariculture Development



Source: Maine Shellfish Research and Development, 2015

Figure ES-2. Elements of Successful Mariculture Industry Growth



Source: Maine Shellfish Research and Development, 2015

1 Introduction

The Alaska Fisheries Development Foundation (AFDF) is in the process of developing an Alaska Mariculture Initiative (AMI) with the goals of (1) expanding the stakeholder base, creating partnerships and increasing capacity in the mariculture sector and (2) developing a clear and comprehensive strategic plan for mariculture development in Alaska. This report provides a set of comparative case studies, each of which provides an example of a successful mariculture industry in a different part of the world with similar or relevant environmental and/or economic conditions to Alaska, including native species and potential stakeholders. Drawing on existing literature, each case study includes a description of the industry; the current economic impact of the industry; the history and reasons for the industry growth; the best available estimates of private and public investment in order to reach current levels of development; cost/benefit analyses, if available; and a list of references[1]. The case studies in this analysis include:

- **Section 2: Alaska salmon enhancement**
- **Section 3: Alaska king crab enhancement**
- **Section 4: Washington State geoduck**
- **Section 5: Cedar Key Florida Northern hard clam**
- **Section 6 Irish seaweed**
- **Section 7: Spanish mussels**
- **Section 8: Prince Edward Island mussels**
- **Section 9: New Zealand mussels**
- **Section 10: British Columbia First Nations' aquaculture**

Each of the case studies completed have characteristics that led to the success of aquaculture development in that region. The relevancy of each case study to AMI is outlined below.

The long history and success of **salmon hatcheries** for enhancement, and interest in **king crab stock restoration** provides a positive environment for mariculture development in Alaska, where there has been a demonstrated benefit from hatchery produced marine species, and stakeholders supportive of the working waterfront.

In **Washington** State**,** because geoducks are native to and farmed in both Washington and Alaska, a considerable amount of crossover can be applied from this case study to Alaska. The intertidal farming technique is already being applied in a few areas in Alaska. In addition, as Washington struggles to add additional land, Alaska is a prime location for expansion. It is important, however, to recognize the factors that may make it difficult to apply Washington techniques and achieve similar success. These factors include:

[1] Because information in some of the case studies are reported in local dollars and metrics, we have done the best that we can to convert values into U.S. dollars and provide metrics in terms of pounds (lb). We were confounded in that it is not always clear in what year data were reported, and thus it was not always possible to use the correct exchange rate due to volatility in the market place over time. Both New Zealand and Canada have relatively stable currencies, so this is less of a problem in these two countries. Note that because many of the tables included in the case studies were copied directly from other sources, we were not able to convert these values. In those instances we note the exchange rate for the reader's reference.

- Increased predation in Alaska, specifically by sea otters, large sea stars and Dungeness crabs
- Transportation limitations in Alaska that increase time and costs for all aspects of production from seed to harvest
- A cooler climate in Alaska that contributes to a shorter growing season
- Lack of a Coastal Zone Management (CZM) Program (This limits Alaska's ability to apply for national grant funding that targets projects aiming to protect coastal waters from pollution, restore coastal habitats and enhance state run coastal zone programs).

In **Florida,** the hatchery, nursery, and grow-out methods employed by the Cedar Key producers are highly applicable to any Alaska shellfish production, provided fundamental differences in water temperatures, phytoplankton culture conditions, transport and construction/operating costs are considered. Alaska growers may experience many of the same water quality issues affecting Cedar Key, including red tides (Paralytic Shellfish Poisoning [PSP], ASP [Amnesic shellfish poisoning]), oil spills, and occasional Vibrio outbreaks. This case study is most relevant in the approaches taken to offset major losses to employment in the fisheries sector with the use of comprehensive retraining projects. The success of those programs was not dependent on big government spending on major programs. Rather it was a comprehensive local community and stakeholder driven approach, which integrated existing fisheries skill sets and resources with a flexible and nuanced regulatory policy and intelligent technical and scientific support. Financial support was provided to jump-start the novice aquatic farmer. Long-term extension and technical assistance was (and is) maintained onsite long after completion of the training programs. Of particular note to AMI is that rapid expansion of hard clam farming in Cedar Key would not have been possible without the existing infrastructure (roads, power and communication), the nearby availability of government offices, research and laboratory facilities, a large pool of researchers and extension personnel familiar with hard clam biology and culture, and the presence in the state of existing hard clam farms. Hatchery and nursery facilities and local extension support at Cedar Key were also important early factors in the success of the industry.

In **Ireland** the high level of strategic planning and coordination that has ensured a sustained focus on industry development for more than a decade may be relevant to the AMI. The National Seaweed Forum identified activities that appear to have been pivotal in successful industry development. Those with the greatest impact include: the appointment of a regionally based Seaweed Development Officer, to bring projects to commercialization; and pilot trials involving the economic feasibility of seaweed aquaculture. Development of a seaweed cooperative may serve as a model for small Alaskan communities, where members are willing to engage in additional activities to increase their income or are interested in aquaculture but are not capable of taking on the financial risk to set up a business on their own.

In **Spain**, Galician mussel mariculture offers a valuable case study to the AMI because it represents a world leader in mussel production. Due to their exceptional growing areas, mussel raft polygons, or parks were established decades ago and developed into over 2,000 family-run production systems in the sheltered rias. The technology of raft cultivation is relevant to Alaska where predation of sea ducks and sea otters would require a protected (i.e. predator nets) culture system, and the system is in institutional equilibrium. It is also relevant because Spain, like Alaska, has huge wild fisheries and an extensive seafood processing industry and therefore has the advantage of private infrastructure which could be using in aquaculture production, processing, marketing and distribution. The persistence of small, family owned businesses is also an interesting business model. This is facilitated by industries supporting seed gathering, mussel processing, freezing and canning.

The **Prince Edward Island** case study is relevant to Alaska as it demonstrates a very effective shellfish aquaculture development strategy, an efficient and improving production and processing sector for mussels, the key involvement of local growers, government support and development based research, and how an aquaculture research and development policy can pay off in jobs and economic development. Mussel farming has great potential for aquaculture development in Alaska, and developing a cost-effective growing technology, processing industry, and workforce is essential to achieving that potential. PEI aquaculture was supported by a streamlined aquaculture leasing program and loan program (technology transfer fund, and aquaculture and fisheries research initiative. Businesses also had good margins and were able to fund growth using a successful business model. There were regular meetings of the Great Atlantic Shellfish Exchange to compare notes and build on successes. In addition, the island was home to innovative fishermen and farmers, the growers received technical support (federal, provincial universities), and there were rapid response solutions to ongoing problems. Adequate harbors, wharves and distribution networks also aided in industry development.

Similar to Alaska, **New Zealand** has a large wild fishery industry with both transportation and seafood infrastructure which could provide the backbone over which the aquaculture industry can be developed. In New Zealand, many of the major fishing companies process, distribute, and market both aquaculture and fisheries products. New Zealand also offers a successful system for preparing the workforce for mussel farming and aquaculture trades. Of particular relevance to AMI is the concise, industry-driven New Zealand aquaculture research and development plan with the goal of $1 billion (New Zealand dollars) sales by 2025. Aquaculture New Zealand, developed as a single voice for the entire aquaculture industry, and funded by a small production tax, rallied the industry and government to implement the Aquaculture New Zealand Research Strategy. This is a key document which provides a framework for public investment in research and development. The main elements are growth, diversification and efficiency, maintenance, sustainability and security, capability, expertise, and infrastructure. Lastly, a history of the regulatory climate demonstrated that an interactive process (which is still continuing) resulted in the development of an expansion of the industry while simultaneously resulting in an improvement in public attitudes about aquaculture. A marine spatial plan occurring in the Hauraki Gulf region, including aquaculture, is part of a comprehensive management exercise involving all stakeholders including the native Maori. Using the GIS platform SeaSketch, AMAs (aquaculture management areas) were created for socially and ecologically sustainable industry expansion.

The **British Columbia** case study illustrates the impact of significant public investments in aquaculture planning and development, and its impacts on small rural coastal economies that are such an integral part of Alaska. The physical environment of coastal British Columbia is very similar to that of Alaska, especially southeast Alaska, due to proximity. As such, many species successfully reared for mariculture in B.C. could likely be reared successfully in Alaska. In many instances, this is already the case and future efforts could focus identification of suitable production sites and expanded culture of these species.

Of particular interest to Alaska is how each case study's regional conditions compares to the biological, social, economic, and governance systems in Alaska. Table 1 provides a summary of critical attributes to the success of mariculture development and illustrates a comparison of the case study areas to Alaska. These attributes include (1) industry growth capacity (are there areas that would allow for industry growth and expansion?), (2) rapid growth rates (do species grow fast enough so allow profitable production cycles?), (3) workforce development (are there training programs, business incubators, colleges and technology schools that train people to engage in aquaculture and run successful businesses?), (4) government support (has the sector a development plan supported by local, state or federal government?), (5) large capture fisheries (is there a history of large wild capture fisheries that potentially jumpstarted the aquaculture sector?) (6) advanced culture technology (is the technology employed state of the art or obsolete, older technologies?), (7) public and private investment (does the government invest in industry development and is the industry making investments in companies?), (8) coordinated research and development (does the industry, government and universities have an active focused research and development plan for industry?), and market access (is there a transportation infrastructure that allows for efficient distribution of product?).

Table 1. Critical Attributes, Case Study Areas Comparison with Alaska

Area	Industry growth capacity	Rapid growth rates	Workforce development	Stakeholder supported development	Large Capture Fisheries	Advanced culture technology	Public and private investment	Coordinated research and development	Market access
Alaska	**x**			**Not yet**	**Finfish and crab**		**minimal**		**limited**
WA	new acreage limited			in progress	x	x	mostly private investment	x	export
FL	x	x	re-training program	x	x	x	x	new species development	x
Ireland	x	x	state agency support	x	x		x	new species development	
Spain	at capacity	x	small family enterprises	x	x	x	subsidies		x
PEI	at capacity	x	x	x	x	x	x	x	export
New Zealand	x	x	x	x	x	x	x	x	export
British Columbia	x	x		x	x		x	x	

2 Case study: Alaska Salmon

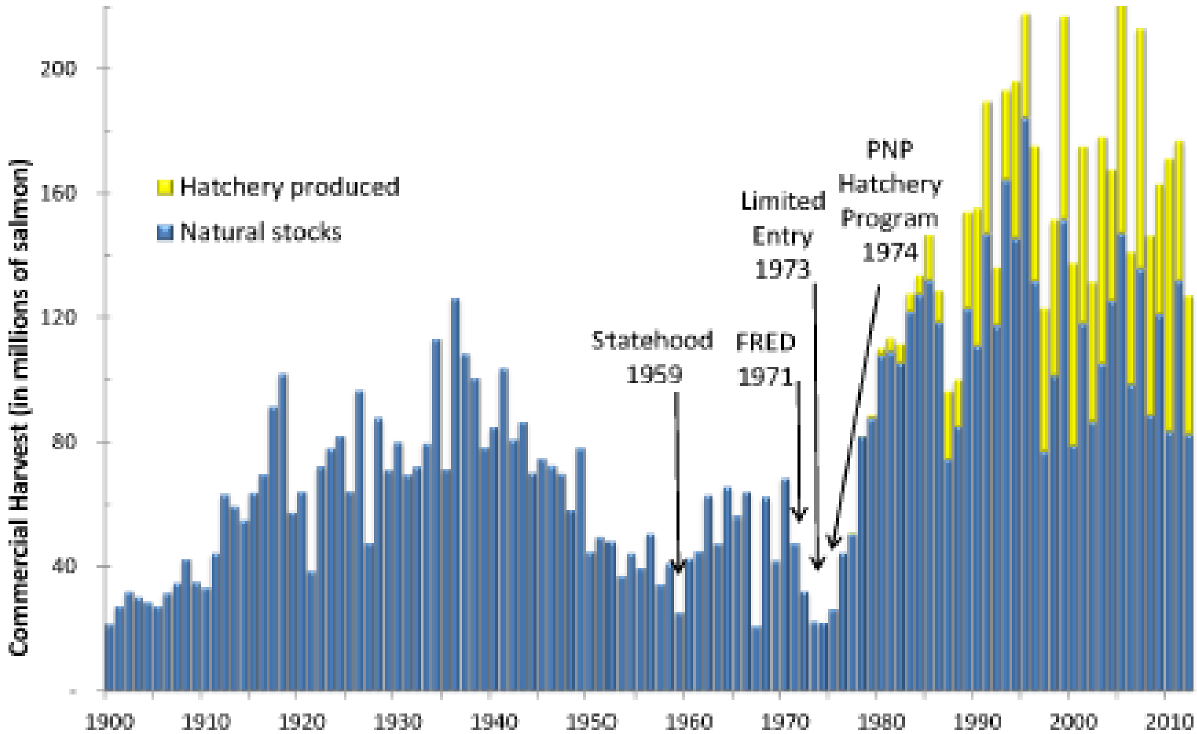
2.1 Overview of the current status of the industry and its current economic impact

The enhancement of Pacific salmon populations in Alaska with hatchery-reared fish plays an important role in smoothing out population fluctuations induced by ocean-climate variability in the North Pacific. The numbers of hatchery-reared juveniles released in some areas are greater than the numbers of juveniles from wild populations.

2.2 History and growth of the industry

In response to precipitous declines in salmon harvests in the 1950s and 1960s (Figure 1), the State of Alaska initiated its salmon fisheries enhancement program in 1971 (Heard 2003). In that year, the state legislature created the Division of Fisheries Rehabilitation, Enhancement and Development (FRED) within the Alaska Department of Fish and Game (ADF&G) and tasked the division with planning the rehabilitation, enhancement and development of all aspects of the state's fisheries to insure perpetual and increasing production and use, and encourage investment by private enterprise (AS 16.05.092). The Private Nonprofit (PNP) Hatchery Act of 1974 authorized the private ownership of salmon hatcheries by qualified nonprofit corporations, with the goal of meeting the public need in fisheries by conserving wild stock salmon while contributing to the harvest by increasing salmon abundance through enhancement efforts (Vercessi 2013a). Hatcheries were used to cultivate large numbers of salmon in an enclosed environment, and the hatchery-produced fish were released into the wild to augment commercial or recreational fishing. In 1975, the state established the Alaska Fisheries Enhancement Revolving Loan Fund through the Alaska Department of Commerce and Economic Development (now the Department of Commerce, Community and Economic Development) specifically for providing grants and loans for hatchery planning, construction, operation, and implementation of fisheries enhancement and rehabilitation activities. In 1988, the state legislature authorized operation of state hatcheries to be contracted to qualified private, nonprofit corporations. In 1993, the Division of Fisheries Rehabilitation, Enhancement and Development merged with the ADF&G Division of Commercial Fisheries, which continues to oversee and regulate all state and private sector fisheries enhancement and rehabilitation projects (Vercessi 2013a).

Figure 1. Commercial Salmon Harvest in Alaska, 1900-2012

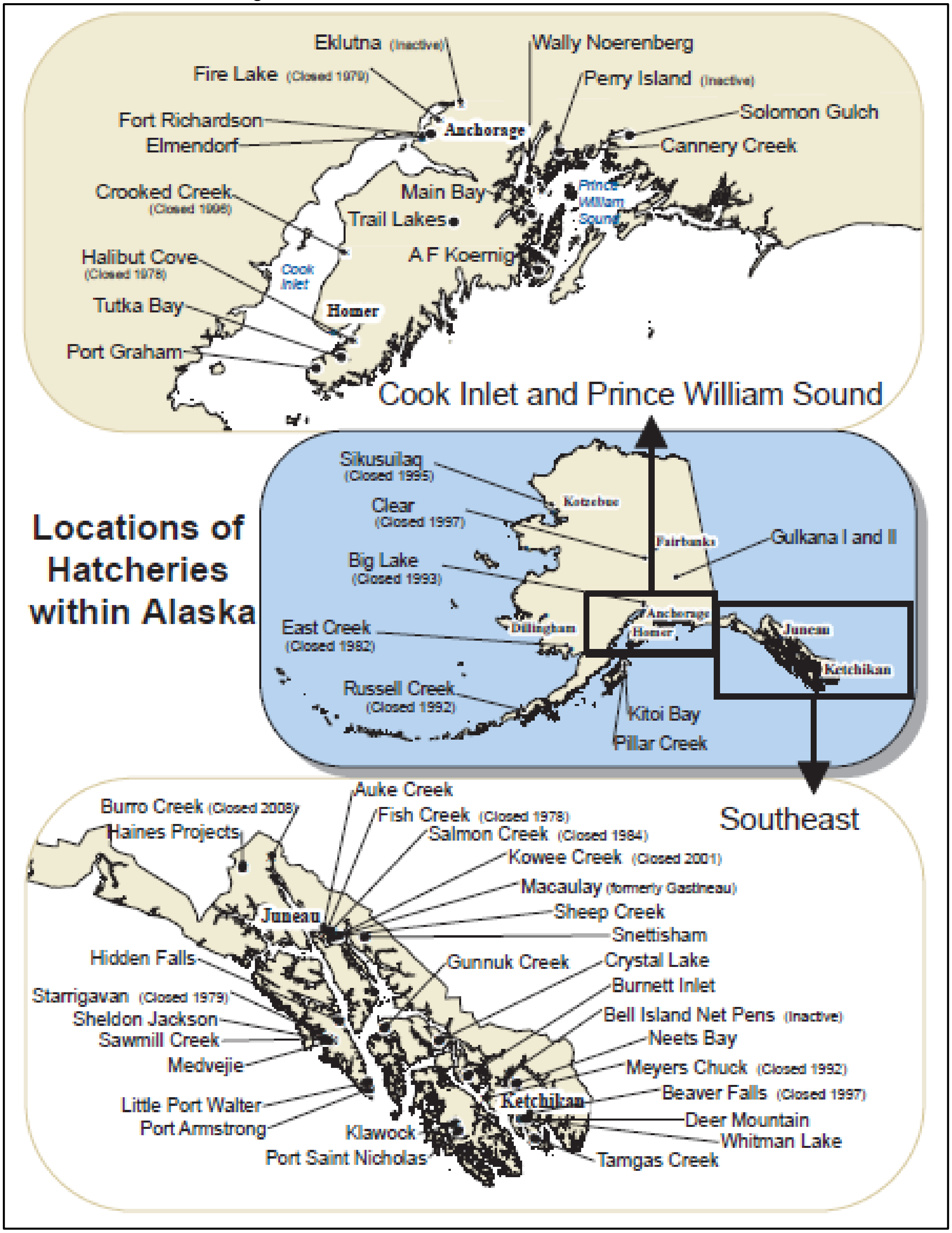


Source: Vercessi (2013b)

During the late 1980s, more than 40 salmon hatcheries were operating in Alaska (see Figure 2 below). However, as Alaskan salmon enhancement has matured, many hatcheries have been closed or rendered inactive for various reasons, including disease or genetic concerns for protecting wild stocks, avoiding major disease consequences in hatcheries, other biological concerns in the hatchery, management concerns over mixed stock fisheries, and cost efficiencies or other economic issues (Heard 2003).

Perhaps the most distinctive feature of Alaska's salmon fisheries enhancement program is that most hatcheries in the program are owned and operated by private, nonprofit "regional associations" comprised of commercial, recreational and subsistence fishermen, seafood processors, conservationists, and local civic interests (Heard 2003). Five such regional associations were incorporated in the 1970s to produce salmon via the program. Currently, Alaska has 35 production hatcheries: 18 private, nonprofit corporation-owned and operated hatcheries; 11 state-owned hatcheries contracted to private, nonprofit corporations; 3 federal/tribal hatcheries; and 3 state-owned and operated hatcheries. The private, nonprofit corporation hatcheries produce fish primarily for commercial harvest, as well as for harvest by the hatchery to pay for operations (called "cost-recovery fisheries"). The ADF&G Division of Sport Fish operates three hatcheries that produce juvenile fish, including salmon, trout char, and grayling, intended for both salt and fresh water recreational fisheries at many locations along the coast and in numerous interior lakes. Two federal hatcheries that are lower-production facilities focus on research. One federally-recognized tribe, the Metlakatla Indian Community, operates a hatchery within the federal Annette Island Reserve in southeast Alaska (Vercessi 2013a).

Figure 2. Current and Past Salmon Hatcheries in Alaska



Source: Alaska Department of Fish and Game (2015a)

In 2012, the most recent year for which data on the Alaska salmon enhancement program are available, hatchery operators collected an estimated 1.8 billion eggs and released nearly 1.7 billion juvenile fish. Over 47 million hatchery-propagated salmon returned, with the majority (24 million) being pink salmon produced by hatcheries in Prince William Sound (Vercessi 2013a).

2.2.1 Private and public investment and capitalization

As discussed above, the majority of Alaska's salmon hatcheries are operated by regional associations of user groups. Alaska statutes provide that these regional associations may only be nonprofit. However, by design, the associations are allowed to recover operating and capital expenses, costs for research and development, and expansion of the production system, including wild stock rehabilitation work.

Most regional associations received initial funding from state grants and capital and operating loans from the Alaska Fisheries Enhancement Revolving Loan Fund, to be repaid from hatchery revenues. Hatcheries may earn revenues to cover operating expenses and repay state loans in two ways. First, hatcheries are authorized to catch a percentage of the adult salmon returning to terminal "special harvest areas" for sale (these are the aforementioned cost-recovery fisheries). Typically, cost-recovery fish are caught by a few boats, catching very large volumes, working under contract to the hatcheries in the special harvest areas. All other returning hatchery salmon are caught in "common-property fisheries" by commercial, sport, and subsistence fishermen. Second, in management areas with regional associations, fishermen may vote to assess an "enhancement tax" on the ex-vessel value of their salmon landings. These enhancement tax funds also support hatchery operations. Enhancement tax rates are presently three percent in southeast Alaska and two percent in Prince William Sound, Cook Inlet, and Kodiak. No enhancement taxes are assessed in other areas (Knapp et al. 2007).

2.2.2 Investment climate

One problem for the Alaska salmon enhancement program is that real (inflation-adjusted) prices have declined significantly since the start of the program, in particular for chum and pink salmon. As ex-vessel prices fell, enhancement tax collections dropped, so that the hatcheries have had to rely on cost-recovery catches for a greater share of their revenues. As a result, an increasing share of the hatchery returns were caught in cost-recovery fisheries rather than by commercial fishermen in the common property fisheries. Over time, this may create both a political and economic problem for the hatcheries, which depend upon enhancement taxes paid by fishermen on all catches—not just catches of hatchery fish (Knapp et al. 2007). More recently, however, the price of Alaska salmon has increased, especially for pink and chum salmon, and the financial dependence of hatcheries on cost-recovery fisheries has diminished.

In addition to covering their operating costs, hatcheries also need to make payments on state loans. As ex-vessel prices declined, many hatcheries requested and received permission to reschedule loan repayments. However, with the decrease in Alaska's oil revenues, the state may be less likely to extend this kind of assistance should hatcheries face financial difficulties in the future (Knapp et al. 2007).

2.2.3 Lead state agency support

The ADF&G oversees and regulates all state and private sector salmon fisheries enhancement and rehabilitation projects.

2.2.4 Level of coordinated research and development

In 1976, a law was enacted that directed the commissioner of ADF&G to designate regions around the state for the purpose of fisheries enhancement planning (AS 16.1 0.375). Within each designated region, a regional planning team (RPT) assembled, consisting of ADF&G personnel and representatives of the qualified regional association comprised of commercial, sport, and subsistence fishermen, processors, and members of the local communities. The primary purpose of a RPT is to develop a regional comprehensive salmon enhancement plan (CSEP) for their respective region (5 AAC 40.300). Each regional CSEP is designed to guide the enhancement efforts regarding development and protection of salmon resources by providing production goals, objectives, and strategies. Plans are developed with consideration of the needs of fishery user groups and communities of the region. The RPTs also review hatchery permits and ongoing and proposed fisheries enhancement projects, and provide recommendations on such subjects. RPTs continue to be responsible for ensuring that the public has the opportunity to review and provide comment on fisheries enhancement projects (Vercessi 2013a).

ADF&G maintains pathology, genetic, coded wire tag, and otolith processing laboratories that provide in-season information to ADF&G fishery managers and technical expertise to the private sector (Vercessi 2013a). In the 1980s, salmon hatchery programs in Alaska pioneered use of otolith thermal marks for mass-marking hatchery production. Now almost all hatchery salmon in most of the state are marked. Marking programs have made possible accurate detection of hatchery-bred salmon on the spawning grounds of wild salmon (Alaska Department of Fish and Game 2015b).

2.2.5 Regulatory process

Before permitting the construction or operation of a private nonprofit salmon hatchery in Alaska, an extensive review of the proposed hatchery, including the suitability of the proposed site, hatchery design, contribution to Alaska's fisheries, and the potential effects on natural salmon stocks, is conducted. ADF&G provides fisheries management considerations, among other information, to accompany applications for RPTs to review. The RPT must determine if the proposed hatchery is compatible with the regional comprehensive salmon enhancement plan. A public hearing and comment period provides time for local community members and fisheries stakeholders to ask questions and provide comments on all aspects of the proposed facility. ADF&G renders a final decision for the hatchery permit based on the completed review, as described in regulations for PNP salmon hatchery permit application procedures (Vercessi 2013a).

Prior to a hatchery conducting fish culture operations, additional review and permitting is required for the take or transfer of eggs or fish, or release of any fish into Alaska waters, as required by regulation. Geneticists, pathologists, and biologists review all portions of each specific hatchery project prior to the issuance of a permit. Reviews are based on established ADF&G policies that provide guidelines and criteria for their respective areas of expertise for the purpose of developing a rigorous and healthy fisheries enhancement program while minimizing potentially negative effects on wild stocks.

ADF&G exercises authority over the hatchery production of regional associations by regulating the harvest of hatchery-released fish in the common property fisheries, hatchery brood stock and cost-recovery harvests, and by amending those portions of hatchery permits relating to the source and number of salmon eggs, hatchery harvests, and the designation of special harvest areas by the adoption of appropriate regulations. ADF&G may suspend or revoke a permit after determination of a failure to comply with conditions and terms of the permit.

While hatcheries play an important role in Alaska's salmon production, the practice of finfish farming, defined as raising fish to maturity in captivity for commercial purposes, is prohibited in Alaska.

2.2.6 Development strategies and key stakeholders involved

As discussed above, Alaska's salmon fishery enhancement program is stakeholder driven, with provisions for planning and oversight by representatives of regional user groups.

2.2.7 Coastal zone management plans

Alaska withdrew from the National CZM Program on July 1, 2011.

2.2.8 Species present

The five Pacific salmon species produced in hatcheries are the same species that spawn in Alaska inland waters: *Oncorhynchus nerka* commonly known as sockeye or red salmon; *O. gorbuscha*, commonly known as pink salmon; *O. keta*, known as chum or dog salmon; *O. tshawytscha* commonly called Chinook or king salmon; and *O. kisutch* commonly known as coho or silver salmon.

2.2.9 Biophysical characteristics

A number of scientists have raised concerns about the potential impact of Alaska's salmon hatcheries on wild salmon populations (Brenner et al. 2012; Grant 2012; Jasper et al. 2013). From the beginnings of Alaska's salmon fishery enhancement program, it was recognized that salmon stray and that hatchery stocks would stray; consequently, policies and regulations were adopted to mitigate concerns associated with straying. For the protection of wild salmon stocks, hatchery programs are required to use local stocks as the brood source and locate hatcheries away from important wild stocks. Requiring the use of only local salmon stocks means that straying hatchery fish are less likely to reduce fitness of local populations. Marking programs have made possible accurate detection of hatchery-bred salmon on the spawning grounds of wild salmon (Alaska Department of Fish and Game 2015b).

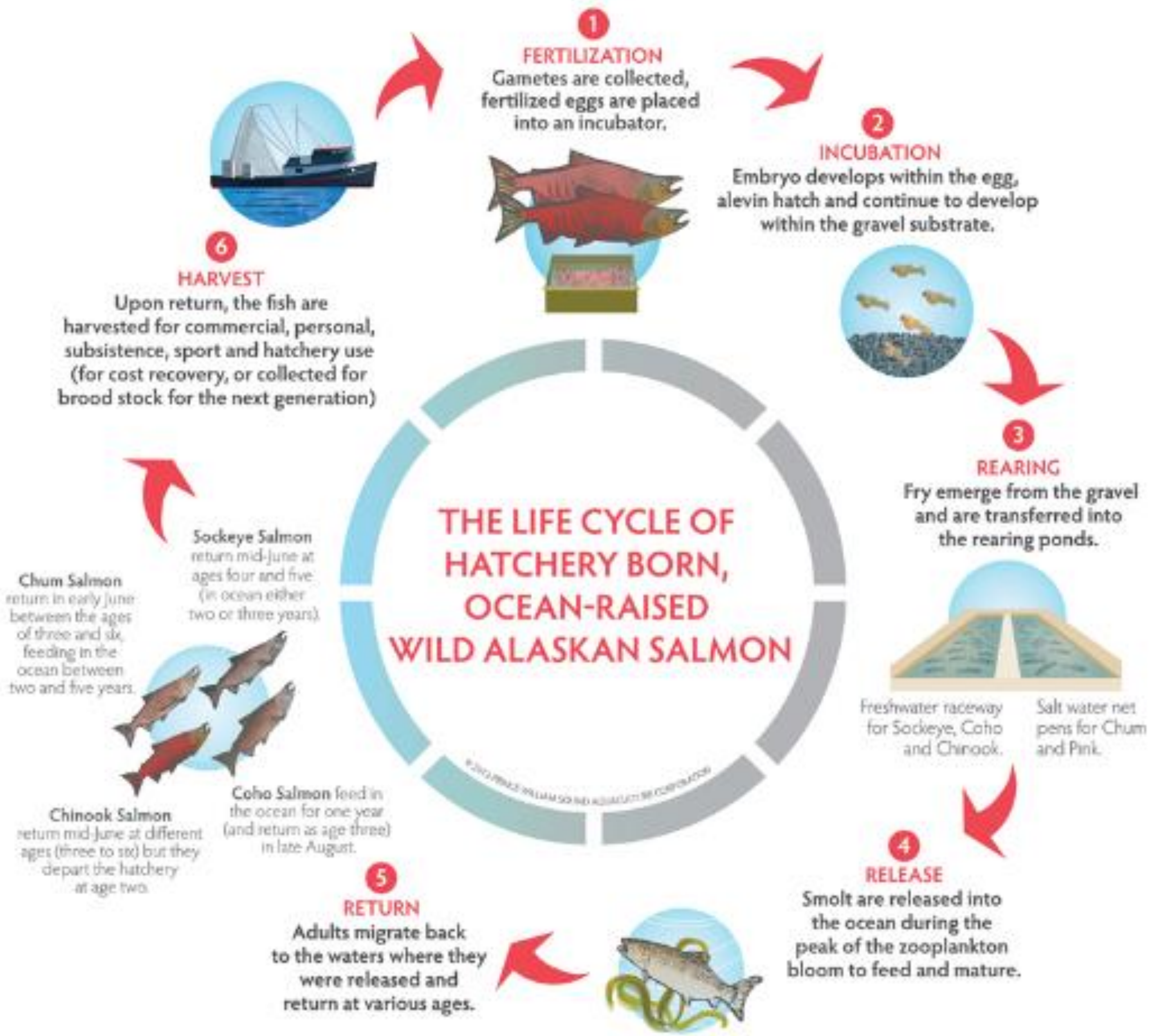
However, hatchery pink salmon are showing up in rivers at levels that are much higher than previously thought. The levels of hatchery salmon in spawning populations in many areas of Prince William Sound exceed commonly used risk thresholds (2–10 percent hatchery-origin salmon in the spawning population) (Brenner et al. 2012; Grant 2012). Straying on a sub-regional level appears to be on the order of 5 to 10 percent for pink and chum salmon; and less for other species. However, in a few select streams it can be over 50 percent (Alaska Department of Fish and Game 2015b).

In response to those concerns, ADF&G is expanding its own studies of wild and hatchery interactions to better understand those relationships as they occur in Alaska. ADF&G organized a science panel composed of current and retired scientists from ADF&G, the University of Alaska, aquaculture associations, and National Marine Fisheries Service. The science panel designed a long-term research project to potentially answer some of the questions. A study plan was prepared and ADF&G solicited proposals from entities interested in conducting a research program to address interaction of wild and hatchery pink and chum salmon in Prince William Sound and southeast Alaska. As these studies provide results, the agency will evaluate and decide if any modifications to Alaska's salmon fishery enhancement program may be warranted.

2.2.10 Culture and processing technology

Hatcheries in Alaska collect gametes, incubate fertilized eggs, and release juveniles to the ocean. Unlike fish farming, Alaska hatcheries neither raise fish to market size nor selectively breed salmon for market demands or hatchery conditions. Hatcheries use local stocks as the original broodstock for production, and improve egg to juvenile survival by protecting developing eggs from predators and natural elements such as freezing. These juveniles are then released into the ocean to exist with their naturally-produced counterparts, returning as adults and harvested with other Alaskan salmon (Stopha 2013). Figure 3 depicts the life cycle of hatchery-raised salmon.

Figure 3. Life Cycle of Hatchery-raised Salmon in Alaska



Source: Prince William Sound Aquaculture Corporation (2015a)

Scientists and professionals from ADF&G and other agencies have developed special policies for genetics, fish health, pathology, limnology and fish culture procedures for Alaska's salmon hatcheries. Some of these policies were codified into state law. The genetics policy prohibits both interstate transport of live salmonids (including gametes) into Alaska and interregional transport of salmonids within the state (Heard 2003).

Engineering requirements and especially the siting of hatcheries are also considered. Most Alaska hatcheries are located at or near tidewater and are often built on non-anadromous water sources below barrier waterfalls so that freshwater interactions between wild and hatchery salmon are eliminated. Hatcheries in Alaska also make ready use of new fish culture practices and technologies, such as high-density substrate incubation systems, marine net-pens for short-term rearing of pink and chum salmon fry, floating raceways, and barriered lake systems for natural rearing of anadromous juveniles (Heard 2003).

Figure 4 shows the Wally Noerenberg Hatchery, which is owned and operated by the Prince William Sound Aquaculture Corporation, a private nonprofit corporation created in 1974. The salmon hatchery was built in 1985 with monies borrowed from the Alaska Fisheries Enhancement Revolving Loan Fund. It is currently permitted for 148 million pink, 165 million chum, 4 million coho, and 4 million Chinook salmon eggs annually (Prince William Sound Aquaculture Corporation 2015b).

Figure 4. Prince William Sound Aquaculture Corporation's Wally Noerenberg Salmon Hatchery

Source: Prince William Sound Aquaculture Corporation (2015b)

2.2.11 Cost/benefit analysis

The majority of hatchery production is harvested commercially, benefiting the economy of communities across much of the state. The contribution of hatchery-produced salmon to the commercial harvest enhances fisheries and can decrease fishing pressure on naturally spawned salmon stocks.

During the past several years hatcheries have accounted for 14 to 45 percent of the statewide commercial salmon harvest. The annual ex-vessel value of hatchery harvests averaged over $100 million from 2003 to 2012. Although the hatchery harvest volume fluctuated widely, the value of the hatchery harvest showed an increasing trend, exceeding $100 million for the first time in 2008. and exceeding $200 million in 2010 (Stopha 2013).

In 2012, ADF&G estimated that approximately 37 million fish, or 31 percent of the 120 million salmon harvested in the commercial common-property fishery, were produced by the Alaska salmon hatcheries (Vercessi 2013a). The return of hatchery salmon provided an estimated $149 million, or 28 percent of the ex-vessel value of the statewide commercial common-property harvest. By species, the fisheries enhancement program accounted for 61 percent of the chum, 38 percent of the pink, 20 percent of the coho, 18 percent of the Chinook, and 9 percent of sockeye salmon ex-vessel value. In addition, an estimated 300,000 hatchery-produced salmon were harvested among personal use, sport, and subsistence fisheries in 2012 (Vercessi 2013a). ADF&G did not estimate the costs of Alaska salmon hatchery operations.

In 1991, a cost-benefit analysis of the Alaska's enhancement program for salmon was performed with cooperation from ADF&G (Boyce et al. 1993). The main results were that the additional producer's surplus generated by the pink and sockeye hatchery programs were estimated to be less than the costs of running those programs. However, these results should be treated with caution, as the data used for the analysis no longer reflect the current economic conditions of the programs.

Economic impact analyses for various Alaska salmon hatcheries have been prepared by McDowell Group. The consulting firm estimated that in 2008, hatchery operations and the commercial harvesting and processing of salmon produced by three regional associations in southeast Alaska produced $233 million in total (direct, indirect, and induced) economic output and generated a total of 1,192 jobs and $59 million in labor income (McDowell Group 2010). McDowell Group (2012) estimated that from 2007 to 2011, hatchery operations and the commercial harvesting and processing of salmon produced by operations managed by Prince William Sound Aquaculture Corporation, a regional association in southcentral Alaska, created an annual average of $51 million in total labor income for an average of 2,495 workers, including fishermen, processing workers, regional association employees, and workers in the support sector. According to McDowell Group (2013), from 2008 to 2012, hatchery operations and the commercial harvesting and processing of salmon produced by operations owned by Valdez Fisheries Development Association created an annual average of $21 million in total labor income for an average of 824 workers, and generated an average of $80.1 million in total output per year. McDowell Group (2004) reported that the Port Armstrong Salmon Hatchery operated by Armstrong Keta, Inc. made a significant economic contribution to the regional economy, but the total economic impact was not estimated.

2.3 Relevancy to Alaska Mariculture Initiative

Alaska's salmon enhancement program demonstrates the ability to mobilize stakeholders and agencies in the state (including coastal communities, industry, the State of Alaska, the National Marine Fisheries Service [NMFS], and tribal and conservation groups) to promote, support, and develop mariculture activities in Alaska. The program has utilized this successful partnership of interested parties to address the challenges of mariculture in the state, including high capital and operating costs and regulatory hurdles.

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3 Case study: Alaska King Crab

3.1 Overview of the current status of the industry and its current economic impact

The Alaska King Crab Research Rehabilitation and Biology (AKCRRAB) program was established in 2006 with the mission of understanding the large-scale culturing needs of red and blue king crab, and perfecting strategies for hatching and rearing these species to a stage where they can be released into the wild and contribute to reversing low wild stock abundance in Alaska. Acquiring this knowledge base will aid policymakers in making informed decisions about whether to one day pursue active rehabilitation of Alaska's long-depressed wild king crab stocks through hatchery enhancement (Alaska Sea Grant 2012).

Large-scale larval culture has been conducted at the Alutiiq Pride Shellfish Hatchery since 2007 using red and blue king crab. Much of the research has focused on whether larval and early juvenile stage crab can be successfully mass cultivated in the laboratory and, once cultivated, whether they can survive in the wild and augment natural populations (Adkison and Kruse 2014). At the termination of its research, the AKCRRAB program is expected to have reliable insight into the economic and biological feasibility of king crab enhancement (Alaska State Legislature 2014).

3.2 History and growth of the industry

King crab are Alaska's most valuable crab per pound and are generally sold at the highest prices of any crabs in U.S. fisheries. The state's king crab fishery was concentrated at first in the eastern Bering Sea, but largely shifted to the Kodiak area in 1954. During the 1960s, the Kodiak fishery was a major producer of king crab with a peak in 1965 of 43,180 metric tons (mt), which was close to 70 percent of the total domestic Alaska king crab harvest. This record high harvest was followed by a precipitous decline in the late 1960s due to stock depletion. The Kodiak fishery continued at low levels until 1982, when the fishery was closed. It has remained closed ever since, but king crab stocks in the Kodiak area show no signs of recovering (National Marine Fisheries Service and North Pacific Fishery Management Council 2004). King crab fishing grounds in the Pribilof Islands area of the Bering Sea are also now closed due to conservation concerns. The red king crab population in the waters around the Pribilof Islands has shown signs of recovery during the past couple of decades, but no directed fishing has occurred since 1998 in order to prevent the bycatch of blue king crab, the population of which remains in a depleted condition.

At the request of Kodiak and Pribilof Islands fishermen, Alaska Sea Grant convened a workshop in 2006 that brought fishermen together with scientists and managers to discuss hatchery enhancement as a way to rebuild red and blue king crab stocks. During the workshop, fishermen endorsed enhancement to revitalize the fisheries (Alaska Sea Grant 2014). The AKCRRAB program was formed that same year with the goal of investigating the feasibility of hatchery rearing of king crab species for the purpose of population rehabilitation. Large-scale larval culture has been conducted at the Alutiiq Pride Shellfish Hatchery in Seward, Alaska since 2007 using both red and blue king crab.

The AKCRRAB program has made considerable progress toward advancing the science and technology necessary to support hatchery production of juvenile king crab (Daly et al. 2011). By 2010, the program was able to produce about 100,000 juveniles per year (Hawks 2014). Production biologists have achieved high survival rates for both red and blue king crab. In 2007, the survival rate was one percent to the juvenile stage; by 2013, survival rates had climbed to 31 percent (Alaska Sea Grant 2014).

In 2013, the AKCRRAB program conducted its first out-stocking experiments. About 6,000 juvenile red king crab were transferred from the Alutiiq Pride Shellfish Hatchery to the Kodiak Laboratory in the NMFS Kodiak Fisheries Research Center and then to Cozy Cove near the village of Old Harbor, where they were released by scuba divers. In 2014, 11,000 hatchery-grown juvenile red king crabs were released into Trident Basin near Kodiak (Hawks 2014). NMFS biologists conducted observational dives recording behavior of the released crabs in 2014 and will continue to do so in 2015 (Alaska State Legislature 2014; Beder and Eckert 2014a). In 2014, the AKCRRAB program also expanded to St. Paul Island in the Pribilof Islands. Preliminary field work has been conducted, and an out-stocking location for blue king crab identified. The Aleut Community of St. Paul Island, a federally-recognized tribal government, is investing in a facility to support the blue king crab enhancement work (Alaska State Legislature 2014).

3.2.1 Private and public investment and capitalization

The AKCRRAB program was created as a public-private partnership. Participants and contributors include the Alaska Sea Grant, University of Alaska, Alutiiq Pride Shellfish Hatchery, NMFS, State of Alaska, Chugach Regional Resources Commission, Alaska Bering Sea Crabbers, Bering Sea Fisheries Research Foundation, United Fishermen's Marketing Association, Central Bering Sea Fishermen's Association, Aleutian Pribilof Island Community Development Association, Kodiak Crab Alliance Cooperative, Santa Monica Seafoods, Groundfish Forum, and Aleut Community of St. Paul Island (Alaska Sea Grant 2014). In addition to cash donations, industry groups have also offered local crab knowledge and assistance with collection, storage, and transport of broodstock and other program needs (Beder and Eckert 2014b; Beder and Eckert 2014c).

3.2.2 Investment climate

Stable funding is required for the continued use of production facilities at the Alutiiq Pride Shellfish Hatchery. Funding is also necessary for habitat and environmental studies, and the monitoring that is required before, during, and after the release of juvenile crabs during the pilot restoration phase (Alaska Sea Grant 2014). While the AKCRRAB program has been able to continue for several years by utilizing a wide array of public and private funding sources, obtaining the necessary budget to meet the program's goals is an ongoing problem (Hawks 2014).

Over the long-term, public institutions cannot be expected to take responsibility for crab enhancement because it is too expensive and will benefit only a minority of users. Construction and operation of an enhancement facility will occur only with industry investment, as has been done for Alaska's salmon fisheries enhancement program (Stevens et al. 2014).

3.2.3 Lead state agency support

ADF&G's involvement in the AKCRRAB program has primarily been in the permitting process (Section 3.2.5).

3.2.4 Level of coordinated research and development

A steering committee of stakeholder representatives oversees strategic planning and implementation of the AKCRRAB program, while a science team develops annual research plans and conducts research (Alaska Sea Grant 2014). Over the last several years, AKCRRAB program research has produced 26 publications in peer-reviewed journals and revealed key factors that lead to a greater understanding of the lack of recovery of king crab in Alaska, including juvenile king crab growth, habitat, juvenile behavior, interaction with predators, population genetic structure, and responses to increased temperature and ocean acidification (Eckert 2014).

3.2.5 Regulatory process

During broodstock collection and out-stocking experiments, AKCRRAB program scientists work with ADF&G in securing broodstock acquisition permits and stock transport permits (Beder and Eckert 2014a). Permit applications must be approved by the ADF&G pathology section, the genetics section, and director of the department. All permit applications must be signed by the Commissioner of Fish and Game.

3.2.6 Development strategies and key stakeholders involved

As discussed in Section 3.2.1, the AKCRRAB program was created as a public private partnership.

3.2.7 Coastal zone management plans

Alaska withdrew from the National CZM Program on July 1, 2011.

3.2.8 Species present

The two king crab species raised in hatcheries are the same species that occur in Alaska offshore waters: red king crab (*Paralithodes camtschaticus*) and blue king crab (*Paralithodes platypus*).

3.2.9 Biophysical characteristics

According to Adkison and Kruse (2014), the AKCRRAB program has not yet fully addressed important questions such as whether adding more juvenile crab would increase catches, or what effects release of large numbers of hatchery juveniles might have on wild abundance, stock structure, or local adaptation. The authors point to the concerns that have been raised about the potential impact of Alaska's salmon hatcheries on wild salmon populations. The authors also note that features of crab biology—they don't home and are difficult to permanently mark—may make them less suitable to a well-monitored enhancement program capable of measuring success or failure. To date, monitoring of released hatchery-grown juvenile crabs has been done by scuba divers and to some extent by using underwater video cameras (Hawks 2014).

However, AKCRRAB program representatives note that the crabs it is raising are hatched from broodstock captured in the wild. This technique means that much of the genetic selection of released crabs remains in the wild (Hawks 2014). Moreover, University of Alaska geneticists have developed genetic markers and described king crab genetic stock structure, which will help fishery managers identify where stock boundaries should be placed, and thus maximize the benefits of harvest and enhancement activities while minimizing negative impacts on long-term stock sustainability (Alaska Sea Grant 2014).

In addition, program representatives argue that while raising hatchery crabs and releasing them into the wild may or may not eventually lead to a reversal of the low wild stock abundance in Alaska, it will contribute to an understanding of why the state's king crab stocks haven't recovered. What's more, scientists can use the hatchery crabs for spinoff projects such as developing a method to accurately determine the age of a crab. Knowing the age range of stocks can improve fishery management success (Hawks 2014).

3.2.10 Culture and processing technology

Over the last couple of decades, considerable progress has been made in the development of king crab larval culture techniques. Advancements in the cultivation of several species of king crab have been made in Japan, Norway, Argentina, and Russia, as well as in Alaska. A plethora of techniques and approaches have been narrowed down to a series of almost "cookbook" steps (Stevens et al. 2014). A description of hatchery operations at the Alutiiq Pride Shellfish Hatchery is provided in a conference presentation by Hetrick (2011). A selection of photographs included in the presentation are shown in Figure 5.

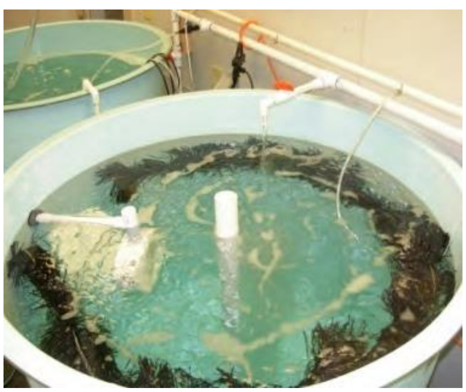
Figure 5. Overview of Steps in the Cultivation of King Crabs

Commercial fleet captures broodstock

Biologists ship broodstock to hatchery

3000-liter broodstock holding tanks with chillers

Adult female king crab in broodstock holding tank



1200-liter production tanks with artificial seaweed

Newly-settled glaucothoe-stage king crab

Juvenile-stage king crab ready for release (approx. 2 millimeter [mm] carapace length)

Source: Hetrick (2011)

3.2.11 Cost/benefit analysis

Several more years of developmental research will probably be required before a full-scale hatchery-enhancement operation would be feasible. Once initial cultivation and releases have occurred, at least another seven years will be required before released crabs would grow to sizes that could be recaptured, and the success of a rehabilitation and enhancement program could be determined. Therefore, any potential economic benefit from such an undertaking is at least 10 to 15 years off in the future (Stevens et al. 2014).

The director of the Alutiiq Pride Shellfish Hatchery roughly calculated the costs of hatchery operations and the potential benefits of the commercial harvesting of king crab produced by the hatchery (Table 2).

Table 2 Cost-Benefit Analysis of Hatchery for King Crab

Production Costs		Assumptions	Benefits
3 employees, facility, supplies, fuel and electricity	$250,000	1 million larvae to C1 (50% survival)	$30/crab ($6/lb-5 lb average)
1200-liter tanks produce 1 million (C1's or C2's)	$.025 per crab	Y1 to harvest (10% survival = 45,000 adults)	$200,000 to fishery
		15% exploitation = 6,750 crabs	Added value = localized fishery, increased breeding biomass, increased opportunity on other fisheries.

Source: Hetrick (2011)

3.3 Relevancy to Alaska Mariculture Initiative

The AKCRRAB program demonstrates the ability to mobilize stakeholders and agencies in the state (including coastal communities, industry, the State of Alaska, NMFS, and tribal groups) to promote, support, and develop mariculture activities in Alaska. The program has utilized this successful partnership of interested parties to address the challenges of mariculture in the state, including high capital and operating costs and regulatory hurdles.

3.4 References

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4 Case study: Washington State Geoduck Aquaculture

4.1 Overview of the current status of the industry and its current economic impact

Geoduck (*Panope generosa*) are native to the west coast of North America, with the highest abundances in Washington, British Columbia, and Alaska. These are the largest burrowing clams in the world, weighing an average of 1.5 lb for cultured clams. Specimens weighing over 15 lb have been taken from wild populations.

The geoduck industry in Washington State is currently in a strong position after a brief slowdown in production due to a 2014 Chinese ban on all U.S. West Coast raised and harvested bivalves. The ban was based on concerns over elevated levels of arsenic and Paralytic Shellfish Poisoning (PSP) and lasted over five months. During that time, other markets for geoduck harvested in Washington State eventually opened to relieve the economic loss caused by closure of the Chinese market, which is where the majority of geoduck have historically been sold.

The Pacific Shellfish Institute (PSI) frequently compiles production data from the Washington Department of Fish and Wildlife (WDFW) commercial shellfish harvest database. Based on the most current data, the Washington wild geoduck fishery harvested on average (2003-2012) 4,624,853 lb of geoduck per year at an annual value of $28,978,151. Aquaculture production has increased significantly over the last 20 years from zero lb in 1995 to over a million lb harvested every year since 2008. The average yearly value (2003–2012) is over $10 million, with 2012 recording a record value of $16,432,111.

4.2 History and growth of the industry

The commercial dive harvest of geoduck began in the early 1970s as a managed fishery producing a relatively low value product (< $1 per lb). However, by the early 1990s a developing market in Asia transformed geoduck into a much higher valued product. According to the online commerce company Alibaba (www.alibaba.com), current aquaculture prices range from $12 (wholesale bulk) to $80 (retail delivered) per lb for 1.5 to 2-lb animals.

WDFW research on general ecology (Goodwin and Pease 1987), larval development (Goodwin et al. 1979), and culture and enhancement efforts (Beattie 1992; Beattie et al. 1995) resulted in the establishment of basic methods for the aquaculture production of geoduck. Private companies, seeing the high value of geoduck in the Asian market, started planting significant numbers of geoduck seed in intertidal areas in the 1990s. WDFW encouraged new geoduck farms by saying they could supply millions of seed (Unknown). Early experiments were conducted by Dahman's Shellfish Co. and Taylor Shellfish farms. Dahman Shellfish saw raising geoduck as a way to utilize intertidal beds not suitable for manila clams or oysters. The company perfected its hatchery operations and found that seeding was inefficient. Taylor Shellfish evaluated two predator control techniques, car cover netting and PVC tubes with netting. Results showed that while time consuming initially, the use of PVC tubes with netting was more advantageous, as tubes required less maintenance and yielded greater survival rates (Phipps). By 2000, Taylor Shellfish Farms was planting 2 million seed a year (King).

These initial steps led to successful development of commercial geoduck aquaculture in Washington State and a significant expansion of production volumes and values for both cultured and dive harvested geoduck. Challenges remain, however, with continual demand for hatchery-produced geoduck seed, slow growth, and an ongoing presence of PSP contamination. Nevertheless, the future growth of the industry looks promising, especially for growers interested in the long-term production of a high value product.

4.2.1 Investment climate

As the geoduck aquaculture industry expanded in the 1990s and early 2000s, it was difficult to find banks that would loan money to raise a product that required at least four years of grow-out. Instead, prospective geoduck farmers would find private investors and rely on credit cards to pay startup bills. The geoduck aquaculture industry has become more attractive to investors as its profitability has grown.

Current investment in Washington State geoduck aquaculture is limited by land availability. According to a local newspaper, *The Kitsap Sun*, local shoreline organizations have repeatedly opposed new farms and legal battles have been commonplace (Stang 2011), thus slowing down new farm development. Developing county and city shoreline rules have also slowed down new farm creation. These hurdles require additional funds to pay for permits, ecological baseline studies and lawyers for court hearings and out-of-court settlements.

4.2.2 Private and public investment and capitalization

Major state investment in geoduck enhancement started in the 1970s as WDFW began culturing geoduck with the goal of enhancing wild populations and restocking public beaches for recreational harvest. Early larval and juvenile culture techniques where developed by the WDFW Point Whitney Laboratory. The number of available 10 mm seed surpassed a million in the 1980s and grew to 18 million from 1987 to 1990 (Beattie). A report by Goodwin and Pease (Goodwin, Pease) stated that as by 1989, WDFW and Washington Department of Natural Resources (WDNR) expected to annually seed 30 million geoduck over 160 to 200 hectares. However, years of grow-out and survivorship studies later revealed survival of less than one percent (Beattie, Blake et al).

An intermediate step between the hatchery and grow-out site was established by WDFW to combat high grow-out mortalities. This nursery phase enabled the seed to increase in size before outplanting, which, in turn, increased post-outplanting survival (Leitman). In WDFW trials, survivorship inside the nursery tubs covered with netting reached up to 100 percent (Shuman, Roberts). Although many important cultivation techniques were developed during the WDFW and WDNR geoduck enhancement program, it was deemed too cost ineffective and was shut down in the early 1990s.

After the shuttering of the state program, public investment became limited to literature and field research studies on possible impacts and feasibility of geoduck aquaculture. In 2003, the WDNR was directed by the state legislature to develop a pilot project assessing the suitability of geoduck aquaculture on state land. This resulted in an extensive literature review on geoduck ecology and aquaculture and summary of research needs.

In 2007, the state legislature allocated $750,000 to the Washington Sea Grant program to study geoduck aquaculture and its interaction with the environment. An additional $300,827 was provided to the University of Washington from the WDNR via interagency agreement (Washington Sea Grant 2013). The National Marine Aquaculture Initiative and National Sea Grant Program have funded studies looking into predator-prey interactions and best farm practices.

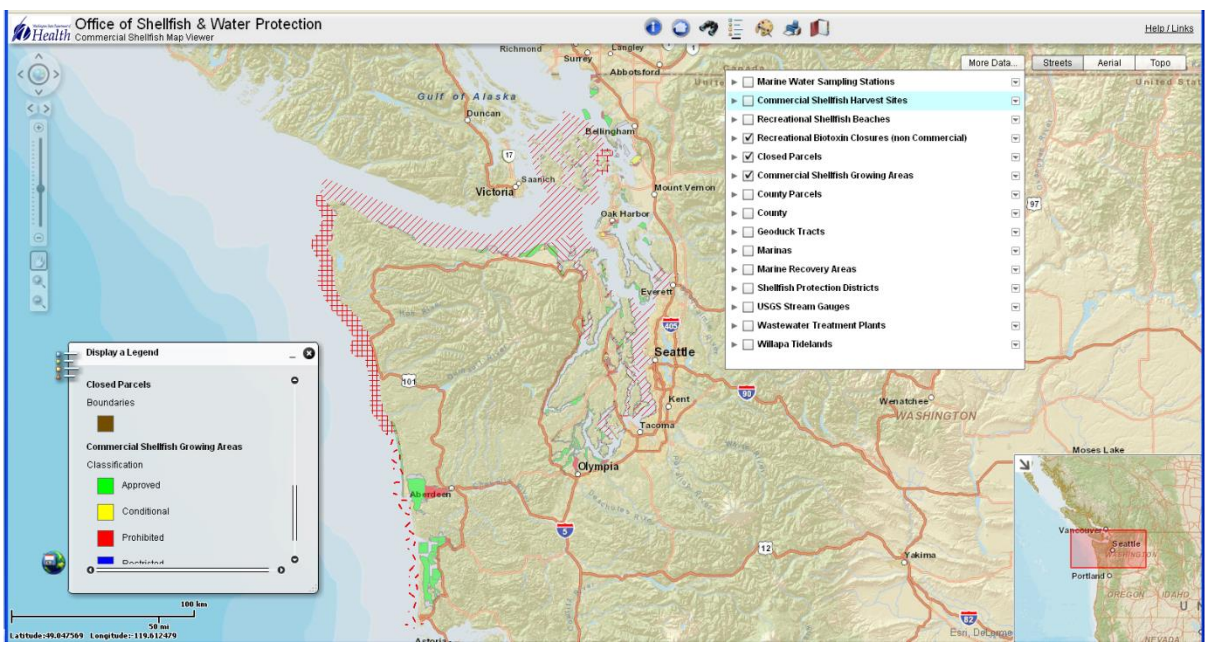
The three largest growers funded a study in 2004 researching potential interactions with endangered species and essential fish habitat. Studies like these have been limited due to conflict of interest concerns. National programs such as the United States Department of Agriculture (USDA) Small Business Innovative Research Program have funded two grower-led studies exploring better predator protection methodologies. National Oceanic and Atmospheric Administration (NOAA) Saltonstall-Kennedy program grants have also funded research surrounding genetic consideration for geoduck clams in Washington State.

4.2.3 Lead state agency support

The Washington Department of Health (WDOH) takes the lead in certifying harvest waters and shellfish products. WDOH, in collaboration with tribes, shellfish growers and county health departments, has successfully increased harvestable shellfish grounds in recent years. This agency collaborates with federal agencies, including the Food and Drug Administration (FDA), USDA, and NOAA as well as state agencies such as the Washington Department of Ecology (WDOE), WDFW and WDNR. WDOE also belongs to the regional Pacific Rim Sanitation Association that includes all West Coast states and the national Interstate Shellfish Sanitation Conference, which is where national rule making takes place.

During the ban on exports to China, WDOH worked closely with FDA, USDA and NOAA to resolve the issue expediently. WDOH collaborates closely with shellfish growers in new rule making and guidelines. It recently launched a web-based commercial shellfish WebMap viewer to allow real time access to closure areas along with recreational beaches, geoduck tracts and approved areas (Figure 6). Closures resulting from biotoxins, rainfall, or wastewater intrusions are reported promptly to impacted shellfish growers via phone and to a wider audience via email listserve.

Figure 6. Screenshot of Washington Department of Health's Commercial Shellfish Viewer.



Source: Washington Department of Health (2015)

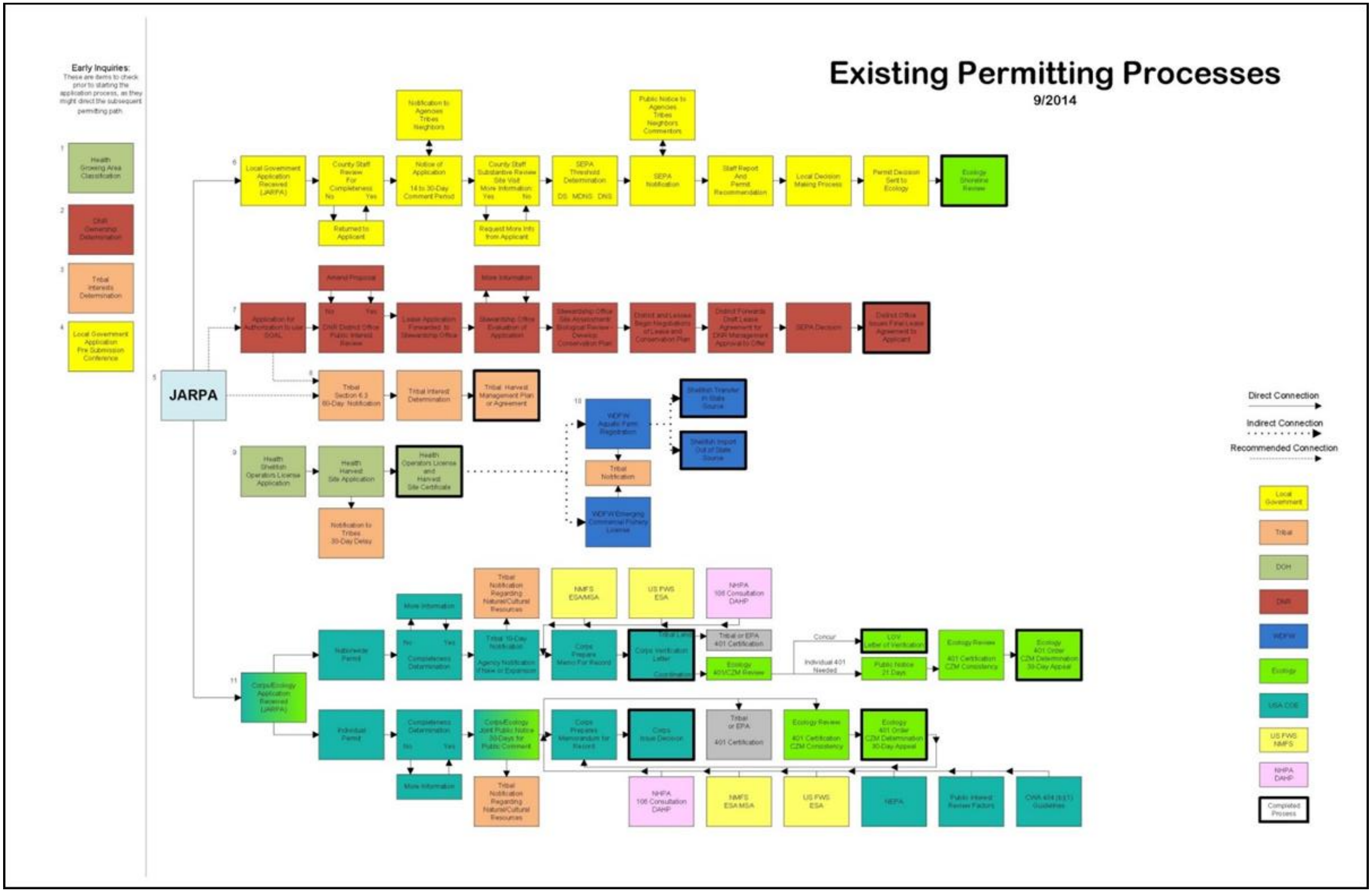
4.2.4 Level of coordinated research and development

Geoduck growers have successfully applied for Small Business Innovative Research grants working with non-profits such as the PSI in search of better predator protection. Overall, the industry is very collaborative, and many formal and informal partnerships exist, specifically involving seed production and discussion of best farming practices. During the Chinese ban on shellfish imports, geoduck growers participated in increased health screening sampling and weekly meetings with WDOH, NOAA and FDA via the Pacific Coast Shellfish Growers Association, the regional shellfish commodity trade association that covers members from California to Alaska. The association also conducts yearly conferences where a specific geoduck session is common.

4.2.5 Regulatory process

Washington State has been attempting to streamline an arduous geoduck aquaculture permitting process via the Washington State Shellfish Initiative. The Joint Aquatic Resource Permit Application formed by the Shellfish Interagency Permitting Team allows growers to fill out one application to cover permits from the U.S. Army Corps of Engineers, U.S. Coast Guard, WDFW, WDNR, WDOE, and county agencies (Figure 7). Prior to submitting this application, growers must determine that a prospective growing area is classified to harvest shellfish (approved, conditionally approved or restricted) by WDOH, determine that the land is not owned by WDNR, determine tribal interests via the Northwest Indian Fisheries Commission, and conduct a pre-submission conference with local government (county/city). The local government process has been the most arduous, as local resistance to geoduck aquaculture has increased. Out-of-court settlements and drawn out hearings are now commonplace. The overall process is likely to take years for new farms to complete, especially farms that were not included in the 2007 tribal settlement with commercial shellfish growers. Tribes have the right to 50 percent of the naturally occurring shellfish at farms that were not included in the settlement and at new farms that have no history of aquaculture. The permitting process is listed as averaging $3,500 in fees, with an additional $7,500 needed for baseline ecological surveys (Kraley 2011).

Figure 7. The existing permitting process for aquaculture in Washington State.



Source: Washington Department of Ecology (2014)

4.2.6 Development strategies and key stakeholders involved

Geoduck aquaculture is an offshoot of WDNR and WDFW efforts in wild stock enhancement. When hatchery and outplanting techniques were adequately advanced by WDNR, private interests adjusted the techniques for intertidal aquaculture. Key stakeholders in this advancement include Taylor Shellfish, Seattle Shellfish and Chelsea Farms. Hatcheries include Lummi, Lego Bay, Whiskey Creek, Point Whitney (now privately owned by Troutlodge Inc.), and Jones Farms.

Individual development strategies include searching out suitable land to buy or lease, procuring seed or adding geoduck production to already existing hatcheries, and advancing predator protection methodologies. The development of new markets/buyers is a function of distributors and in some cases the growers themselves.

4.2.7 Coastal zone management plans

Washington State has participated in the national CZM program via WDOE since 1976. The state's program includes all counties that border or contain saltwater bodies, such as the Pacific Ocean, the Puget Sound and the saltwater intrusion at the mouth of the Columbia River. It mainly serves as a grant program to protect coastal waters from pollution, restore coastal habitats and enhance state run coastal zone programs. It also serves as a way to detail Washington coasts and priority areas.

In addition to this program, counties and cities in Washington State have shoreline master programs that serve as networks of WDOE's own shoreline program. These city and county programs serve as the local permitting agency for aquaculture projects. Permitting on the city and county level was historically effortless, but currently is one of the most arduous steps in permitting and in some cases rules are still in flux. For example, the City of Bainbridge Island recently issued a moratorium on new aquaculture projects until they are able to amend their local aquaculture regulations.

4.2.8 Species present

Geoduck (*Panope generosa*) are a native species to Alaska and Washington. They interact with other native species primarily as prey for sea stars, diving ducks, Dungeness crabs and other species. Geoduck may compete for space with other species, although bivalve populations (i.e. cockles, *Clinocardium nuttallii*) usually increase in areas of geoduck cultivation due to predator protection devices (PSI, unpublished).

4.2.9 Biophysical characteristics

As a native species, Puget Sound is an ideal place to grow geoduck, although growth and survival can be limited by geography and subsequent substrate, flow, and water quality characteristics. Table 3, taken from a 2004 study conducted for WDNR by PSI, describes the priority siting criteria for Puget Sound geoduck aquaculture (PSI 2004). It has been established since then that water quality conditions such as dissolved oxygen (DO) and pH should be given a higher priority.

Table 3. Summary of siting criteria with priority scale: 1 (low priority) to 5 (high priority) and related key components.

Criteria	Priority	Key Components
Substrate	5	High Percentage of Sand, Depth (3 ft)
Temperature	3	Low Surface Water Temperature, Low Ambient Water Temperatures
Salinity/Riverine Influence	4	Salinity above 26 parts per thousand (ppt), Freshwater Avoidance
pH/DO	1	None noted
Phytoplankton/Nutrients	5	Abundance
Elevation	4	Intertidally: -2ft to -4ft MLLW, Subtidally: -4ft to -25ft MLLW
Biotoxins	4	No PSP History
Human Influence	4	Limited Access Points, Proper Husbandry Practices:
Currents	4	Moderate Current
Wind/Wave Action	3	Small Fetch
Geoduck Populations	3	Presence
Ulva/Enteromorpha	3	Avoidance
Geographic Region	5	Proximity to Current Operations, South Puget Sound preference

Source: PSI, 2004

A report by the Washington Department of Fisheries (1987) reached the following conclusions:

- Geoduck were largest in sand and sand/mud > pea gravel > mud.
- South Sound had the largest geoduck, Central Sound and the Strait were intermediate, and Hood Canal had the smallest, maybe due to warmer water and sustained food supply.
- Densities were as follows: South Sound (2 per square meter [m^2]) > Hood Canal/Central Sound (1.8 per m^2) > Strait (.6 per m^2) > North Sound (.2 per m^2). .
- Densities were highest in sand (2.1m^2) then mud/sand (2.0m^2), pea gravel/gravel (1.8m^2) and mud (1.2m^2).

A 2006 WDNR/WDFW report (Sizemore 2006) to the state legislature on the impacts of low DO in Hood Canal found that geoduck populations in Southern Hood canal were much younger than those north of Seabeck. This suggests that low DO levels can cause slower growth and in extreme cases, mortality. Geoduck appear to only recruit and grow in between pulses of extremely low DO.

In short, suitable areas for aquaculture contain sand or sandy mud substrates down to 1 m; avoid low salinities, DO, and pH; and have moderate currents and high food availability. Areas that contain or have contained a healthy higher age class of geoduck are ideal, while areas with a large predator population (i.e., Dungeness crab) should be avoided or protected for much of the grow-out.

4.2.10 Culture and processing technology

As noted above, the culturing of geoduck started via WDFW and WDNR experiments on wild stock and recreational enhancement. Commercial hatcheries produce seed from post set size (500um) to large seed (15mm), with prices proportional to the size. The smaller seed is placed in sand-filled nurseries allowing them to grow to a larger size or overwinter until seeding occurs. Care of geoduck nurseries requires dedicated year-round staff to manage fouling, transfers and maintain substrate, containers and predator protection screens. Larger seed is either held in nursery systems until outplanting or planted as soon as possible to avoid mortalities due to over-handling.

Seeding geoduck involves either a beach crew working a low tide or divers. Dive seeding is becoming more common as it increases the time when seed can be planted (year-round) and limits the effect/interaction of extreme air and water temperatures on geoduck. Since seed costs are substantial, seeding is done by sprinkling, finger poking or dropping specific numbers into areas enclosed by predator protection devices.

Protection from predators is a critical component of increasing geoduck survival. Significant time and money has been spent on protecting geoduck for various commercial, enhancement and research efforts (Gibbons 2014). The industry standard for predator protection is the utilization of PVC tubes and either blanket or individual netting. Some growers prefer to use mesh tubes, biodegradable tubes or just blanket netting. These materials stay in place for one to two years and are then either replaced with large diameter blanket netting or removed. The large diameter blanket netting is used in areas with high predation and may be used until harvest. A large workforce (maintenance/installation crew) is required for the preparation of beds, installation and removal of predator protection, and planting of juvenile geoduck.

Prior to harvesting, the beds are maintained as needed. Some locations require increased maintenance due to macroalgae fouling, sedimentation burial of nets/tubes, and wave activity that dislodges devices. When product is ready to harvest, companies employ or contract dive or low tide harvesters. Large and midsize companies can employ a dive harvest crew year-round and utilize them to plant seed. Smaller companies that don't have enough product for year-round harvest will utilize all staff members and harvest during low tide. All harvest is conducted by liquefying the sediment with a high flow of ambient seawater via a pvc "stinger". The harvester then reaches down to grab the geoduck, preferably by its shell to prevent damage to the neck.

Since the majority of geoduck are exported to Asia, transportation is a critical issue. Most geoduck growers sell their product to wholesalers who pick up the product from a central location at the farm via refrigerated truck. Increasingly, geoduck are housed in flow through tanks, sink floats or refrigerated tanks while awaiting shipment. This allows for a higher quality product, increased price, and lower rate of rejected product. The product is then repackaged the same day for refrigerated shipment via air cargo directly to Asia. One large shellfish company has essentially become wholesalers themselves; they coordinate air shipment internally, cutting out the middlemen while adding other growers' product as needed.

4.2.11 Cost/benefit analysis

Costs associated with geoduck aquaculture include seed, predator protection, boats, vehicles, labor, permitting, and leasing/purchasing land. Permitting and land acquirement or leasing costs should be the initial consideration of any aquaculture project. Washington State geoduck aquaculture is limited by geographically and regulatory suitable intertidal land availability. Land leases include a yearly fee, which averages $1,000 per acre. An additional harvest time payday is based on a percentage, usually 7 to 10 percent, of harvest revenue. The cost of the permitting process averages $3,500, with an additional $7,500 needed for baseline ecological surveys (Kraley 2011).

Seed costs are driven by supply and demand, leading to wild fluctuations in market prices. Over the past 10 years prices have ranged from $0.25 to $1.50 per seed in Washington State. Predator protection devices range from $0.47 to $1.60 a piece, depending on quantity, and most can be used for multiple crops.

Boats and vehicles are necessary to transfer protection devices, crew members, and ultimately the product. These costs will vary greatly based on company size, and in rare cases boats are not necessary because upland access is provided for small operations. Significant other costs include labor to install, maintain, and remove the predator protection and to seed and harvest the geoduck.

The return on investment for any geoduck farm hinges greatly on geoduck survival. Predator protection and bed maintenance is critical and prolonged as time to harvest averages five to seven years. As described earlier the potential economic impact of geoduck farming is significant. At a price of $12 per lb, return on investment is attainable with good survival and can grow significantly as survival increases.

A report by Canadian Aquaculture Systems (2012) assessed the feasibility of geoduck aquaculture in British Columbia based on previous studies and Washington State grower interviews (Canadian Aquaculture Systems Inc. 2012). Based on a two hectare farm and survival rate under 50 percent, it was estimated that annual losses averaging $124,000 would be incurred for eight years ($1,055,520 total) until product is harvest size. Factoring in lower food availability and temperatures in British Columbia vs. Washington, it was assumed geoduck would be harvest size by year nine. By year 11, enough profit would be attained to pay off all previous debts (Figure 8). Every year thereafter would be profitable.

Figure 8. Summary of modeled profit and loss for intertidal geoduck aquaculture in British Columbia.

Table 10: Pro forma Income Statement for a 2-hectare inter-tidal geoduck aquaculture venture.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Revenue															
Aquaculture Sales															
#1 Grade Product	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 520,000	$ 520,000	$ 520,000	$ 520,000	$ 520,000	$ 520,000	$ 520,000
#2 Grade Product	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total Aquaculture Sales	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 520,000	$ 520,000	$ 520,000	$ 520,000	$ 520,000	$ 520,000	$ 520,000
Cost of Production															
Direct Costs															
Seed	$ 26,250	$ 26,250	$ 26,250	$ 26,250	$ 26,250	$ 26,250	$ 26,250	$ 26,250	$ 26,250	$ 26,250	$ 26,250	$ 26,250	$ 26,250	$ 26,250	$ 26,250
Tube Planting	$ 11,250	$ 11,250	$ 11,250	$ 11,250	$ 11,250	$ 11,250	$ 11,250	$ 11,250	$ 11,250	$ 11,250	$ 11,250	$ 11,250	$ 11,250	$ 11,250	$ 11,250
Seed Planting	$ 5,750	$ 5,750	$ 5,750	$ 5,750	$ 5,750	$ 5,750	$ 5,750	$ 5,750	$ 5,750	$ 5,750	$ 5,750	$ 5,750	$ 5,750	$ 5,750	$ 5,750
Predator Netting	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000
Site Maintenance	$ 1,560	$ 3,120	$ 4,680	$ 6,240	$ 7,800	$ 9,360	$ 10,920	$ 12,480	$ 12,480	$ 12,480	$ 12,480	$ 12,480	$ 12,480	$ 12,480	$ 12,480
Site Management	$ 2,600	$ 5,200	$ 7,800	$ 10,400	$ 13,000	$ 15,600	$ 18,200	$ 20,800	$ 20,800	$ 20,800	$ 20,800	$ 20,800	$ 20,800	$ 20,800	$ 20,800
Tube Cleaning	$ -	$ -	$ 4,500	$ 4,500	$ 4,500	$ 4,500	$ 4,500	$ 4,500	$ 4,500	$ 4,500	$ 4,500	$ 4,500	$ 4,500	$ 4,500	$ 4,500
Miscellaneous	$ 625	$ 1,250	$ 1,875	$ 2,500	$ 3,125	$ 3,750	$ 4,375	$ 5,000	$ 5,000	$ 5,000	$ 5,000	$ 5,000	$ 5,000	$ 5,000	$ 5,000
Harvest Cost	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 35,000	$ 35,000	$ 35,000	$ 35,000	$ 35,000	$ 35,000	$ 35,000
Harvest Monitoring	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000
Total Direct Costs	$ 50,035	$ 54,820	$ 64,105	$ 68,890	$ 73,675	$ 78,460	$ 83,245	$ 88,030	$ 124,030	$ 124,030	$ 124,030	$ 124,030	$ 124,030	$ 124,030	$ 124,030
Gross Margin	**($50,035)**	**($54,820)**	**($64,105)**	**($68,890)**	**($73,675)**	**($78,460)**	**($83,245)**	**($88,030)**	**$395,970**	**$395,970**	**$395,970**	**$395,970**	**$395,970**	**$395,970**	**$395,970**
Indirect Costs															
Aquaculture Licence	$ 418	$ 418	$ 418	$ 418	$ 418	$ 418	$ 418	$ 418	$ 418	$ 418	$ 418	$ 418	$ 418	$ 418	$ 418
Aquaculture Tenure	$ 1,433	$ 233	$ 233	$ 233	$ 233	$ 233	$ 233	$ 233	$ 233	$ 233	$ 233	$ 233	$ 233	$ 233	$ 233
Depreciation	$ 126,005	$ 90,404	$ 65,229	$ 47,387	$ 34,703	$ 25,654	$ 19,170	$ 14,499	$ 11,113	$ 8,640	$ 6,816	$ 5,459	$ 4,436	$ 3,656	$ 3,053
Interest	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total Indirect Costs	$ 127,856	$ 91,055	$ 65,881	$ 48,038	$ 35,354	$ 26,305	$ 19,821	$ 15,151	$ 11,764	$ 9,291	$ 7,468	$ 6,110	$ 5,088	$ 4,308	$ 3,704
Net Income Before Tax	**($177,891)**	**($145,875)**	**($129,986)**	**($116,928)**	**($109,029)**	**($104,765)**	**($103,066)**	**($103,181)**	**$384,206**	**$386,679**	**$388,502**	**$389,860**	**$390,882**	**$391,662**	**$392,266**
Taxes	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$52,448	$52,631	$52,769	$52,874	$52,956
Profit (Loss) After Tax	**($177,891)**	**($145,875)**	**($129,986)**	**($116,928)**	**($109,029)**	**($104,765)**	**($103,066)**	**($103,181)**	**$384,206**	**$386,679**	**$336,055**	**$337,229**	**$338,113**	**$338,788**	**$339,310**

Source: Canadian Aquaculture Systems Inc. (2012)

4.3 Relevancy to Alaska Mariculture Initiative

Because geoduck are native to and farmed in both Washington and Alaska, a considerable amount of crossover can be applied from this case study to Alaska. The intertidal farming technique is already being applied to a few areas in Alaska. It is important to keep in mind that many factors make it harder to apply Washington techniques to Alaska and come out with a similar success. These factors include:

- Increased predation in Alaska, specifically by sea otters, large sea stars and Dungeness crabs.
- Transportation limitations in Alaska that increase time and costs for all aspects of production from seed to harvest.
- A cooler climate in Alaska that contributes to a shorter growing season; geoduck will need 9 to 12 years to become harvest size.
- Alaska is not part of the CZM Program. This limits its ability to apply for national grant funding that targets projects aiming to protect coastal waters from pollution, restore coastal habitats and enhance state run coastal zone programs.

With that in mind, the following aspects can be applied to Alaska geoduck aquaculture:

- *Industry Growth*: The market for geoduck remains strong. As Washington struggles to add additional land, Alaska is a prime location for expansion.
- *Cooperation*: Frequent formal and informal meetings between farmers have expanded industry innovation. The use of meetings that Alaska growers already attend to share and grow the industry is vital.
- *Hatchery*: Hatchery competition in Washington has recently brought the price down for geoduck seed. Expansion beyond just a single source of seed would provide for better quality and quantities.
- *Culture and Processing*: Notwithstanding transportation limitations, similar culture and processing techniques can (and are) being employed in Alaska. Predator protection would be needed throughout the whole grow-out cycle given the number and veracity of predators in Alaska.
- *Biophysical characteristics*: The same water quality, flow, exposure and sediment characteristics would apply to Alaska.
- *Regulatory process*: In most states the regulatory process is becoming harder rather than easier. Alaska can learn from Washington’s efforts to streamline the process.
- *Lead Agency*: The Washington Department of Health has a substantial shellfish division that works closely with shellfish growers. This allows for increased collaboration, a higher definition of growing areas and expedient closure notifications.

Note that the Alaska wild geoduck dive harvest industry has seen fluctuations in harvest quotas (125,000 to 868,700 lb) and price per lb ($0.21 to $10.31 per lb). For the last 10 years the dive fishery averaged over 600,000 lb of geoduck per year, with an average price of $6.00 per lb for a yearly total value of $3,638,375 (ADF&G 2015). In comparison, clam aquaculture (native littleneck and geoduck clams) has produced a yearly average (2010–2013) of only 6,787 lb of product at a value of $31,961 (ADF&G 2015). Clearly, geoduck aquaculture has yet to take off significantly in Alaska.

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5 Case Study: Northern Hard Clam Culture in Cedar Key, Florida

5.1 Overview of the status of the industry and its current economic impact

Hard clam aquaculture began in Cedar Key following the ban on the use of gill nets in Florida state waters. As a result, many commercial fishermen were out of work. Clam culture training was begun to offer new employment opportunities and train fishermen to become aquatic farmers. In addition, shellfish aquaculture leases were identified, permitted, and marked, allowing for placement of trainees onto farm sites in Cedar Key and other coastal areas of Florida. These measures resulted in a rapid expansion of clam aquaculture. Statewide production in 1987 was about 100,000 lb. By 1999, 351 growers produced over 4.5 million lb of farm production. Corresponding farmgate, or dockside sales have also increased, with the value in 2012 reported at $38.7 million. Although the hard clam industry endured challenging events, such as the 2004 and 2005 hurricane seasons, the 2007–2012 recession, and the 2010 Deepwater Horizon oil spill, the industry exhibits a resiliency that allows for recovery and continued future market expansion. Associated with the increased shellfish farming activity was the development of spin-off businesses in support of the industry. Farm expansions also led to an increased level of public and private sector research on a broad range of issues, including market expansion, genetics, diseases and the possible culture of other shellfish species. Currently, clam farming is a mature industry in Florida, and an excellent example of a successful and community-driven transition from an at-risk, fishery-dependent culture.

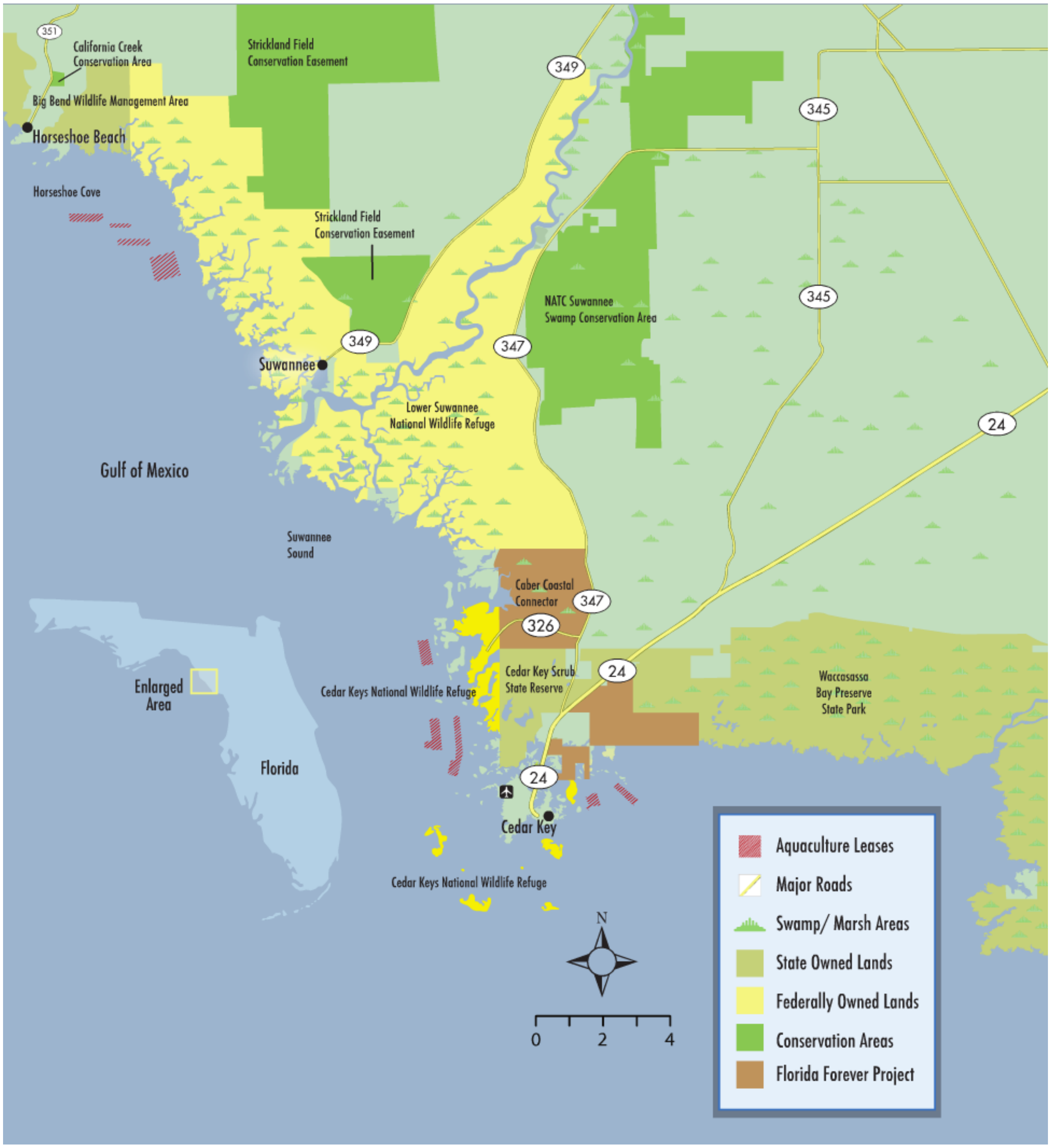
5.2 History and growth of the industry

Cedar Key has long been an important fishing community on Florida's Gulf Coast (Figure 9 and Figure 10) with fish and oysters historically making up the bulk of the harvest (IFAS 2015a). However, the hard clam culture industry has a short history extending back just 25 years. The development of the industry on the Gulf Coast of Florida began in the early 1990s, primarily through job retraining program efforts designed for displaced workers in the commercial fishing industry. Over 200 underemployed oyster harvesters and net fishermen were trained and placed into small-scale business enterprises. These technology transfer programs launched a new industry for Florida's Gulf coast (Sturmer 2015).

The commercial hard clam culture industry in Florida is now an aquaculture success story, also known as "Clamelot", for the effect on the aquatic farmers and community (Colson and Sturmer 2000). Statewide, there are currently more than 400 shellfish growers who farm high-density, submerged leases totaling over 1,700 acres (DACS 2014). More than 189 million clams were produced in Florida during 2007 (Sturmer 2015). There are also 14 hatcheries and 90 land-based nurseries and other businesses that provide input to the grow-out sector of the industry. As a result, the industry represents an important source of economic activity, jobs, and tax revenue to Cedar Key and several other coastal communities in Florida (Ruth et al. 2005).

Figure 9 shows Cedar Key and its surrounding area. Over 1,300 acres of state owned submerged lands are available for shellfish aquaculture. These lands are surrounded by a mix of federal and state owned uplands, and conservation areas and easements, protecting shellfish from adverse land-use practices.

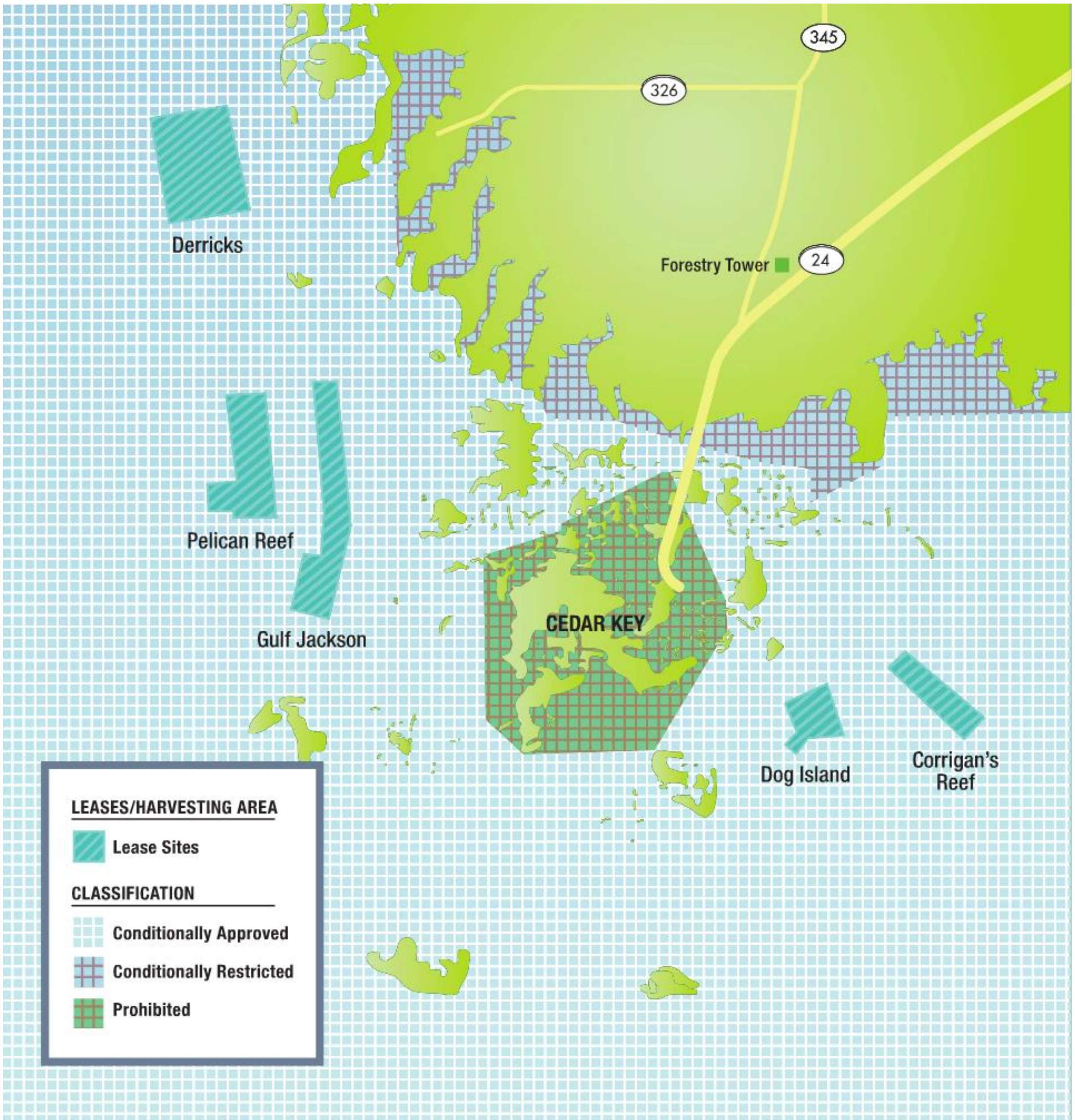
Figure 9. Cedar Key and Surrounding Area



Source: IFAS 2015a

Figure 10 shows the locations of aquaculture leases that are located in conditionally approved waters within 191,000 acres of the Cedar Key Shellfish Harvesting Area. When rainfall over a four-day period exceeds five inches, the area will temporarily close. This has resulted in an annual average of five closure days.

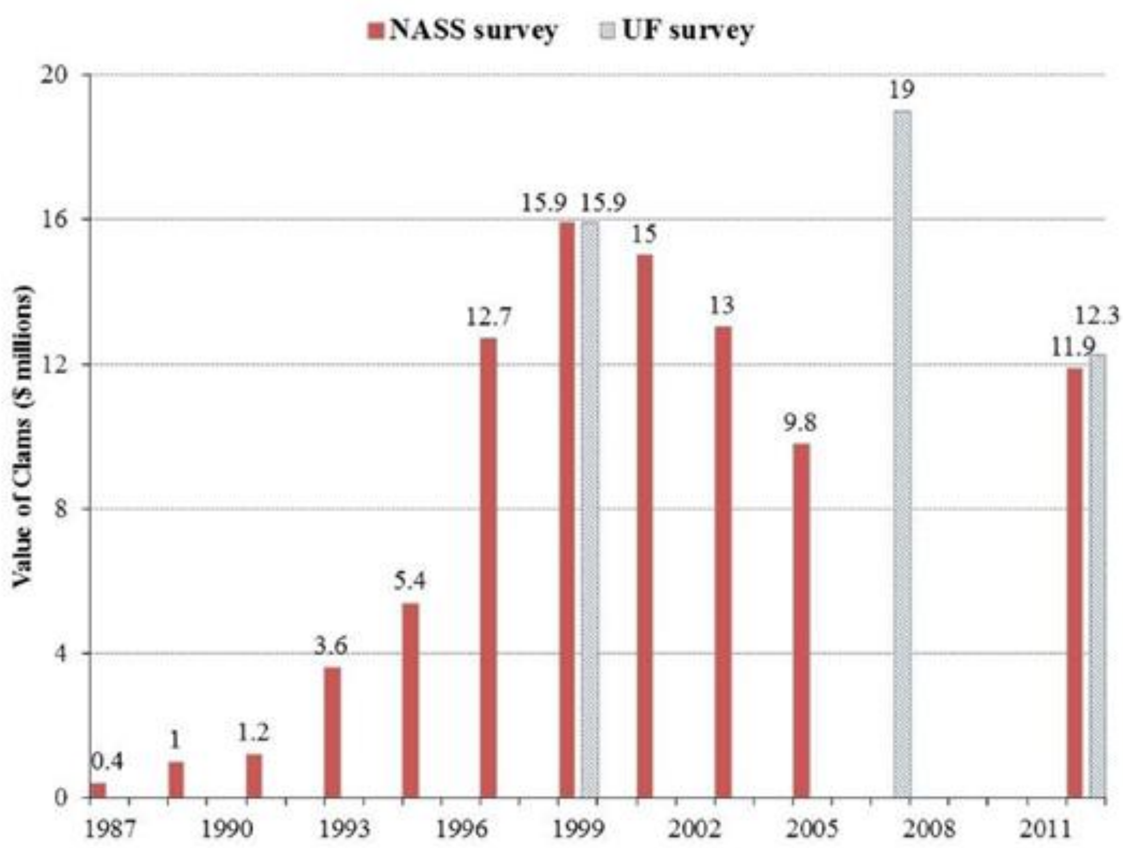
Figure 10. Aquaculture Lease Areas



Source: IFAS 2015a

The latest assessment of the economic impacts associated with the commercial hard clam culture industry in Florida was completed in 2012, with previous studies being conducted for the calendar years 1999 and 2007 (Philippakos et al. 2001; Adams et al. 2004, 2009 and 2014). These were statewide surveys, and Cedar Key production was estimated to contribute 85 percent of the total (Sturmer 2015). The industry was characterized by a strong upward trend in production during the 1987 to 1999 period, with 1999 being a peak production year (Figure 11). Production exhibited a declining trend after 1999, leading into 2004 and 2005, when major hurricanes hit the Gulf region. Although hard clam production was impacted by these storm events, the industry recovered and exhibited record numbers of harvested clams by 2007. As a result, economic output increased by 59 percent from 1999 to 2007. However, the economic recession that began in 2007 and continued through 2012 generated weaknesses in markets for seafood products, resulting in depressed prices and declining sales. In addition, the 2010 Deepwater Horizon oil spill further weakened consumer demand for Gulf of Mexico seafood in general, as unfounded concerns regarding contamination influenced consumer perceptions. As a result, the output impact estimates for 2012 ($38.7 million) indicated a 28 percent decline during this period (Adams et al. 2014). Overall in 2012, the clam culture industry supported 543 jobs and generated $14.7 million in labor income. Hard clam sales generated $1.4 million in state/local tax revenues and $2.7 million in federal taxes (IFAS 2015b).

Figure 11. Farmgate value of cultured hard clam sales in Florida, 1987–2011



Note: NASS = National Agricultural Statistics Service; UF = University of Florida

5.2.1 Investment climate

The development of the hard clam aquaculture industry in Cedar Key was due to successful job retraining programs for fishermen, an excellent leasing program and regulatory framework, and year-round growing conditions allowing for continuous production. The required investment for new growers was relatively modest with most of the initial costs being borne by the Florida shellfish aquaculture retraining programs and other public resources (Adams and Sturmer 2004).

While training funds are no longer available, investment opportunities for growers, seed suppliers, and equipment providers obviously still exist. The investment climate is enhanced by the application of low-level technology adaptable to local conditions, inexpensive start-up and operating costs encouraging small business development, no natural or wild clam fishery on Florida's west coast, and ready market channels. However, current operations demand access to sources of hatchery-reared seed and/or nursery systems, neither of which are inexpensive for prospective investors. Adams and Pomeroy (1992) offer a good, although dated, analysis of these cost items.

An underlying assumption in the above analysis is that market prices are not sensitive to industry output. Clam prices tend to fluctuate, particularly based on production levels, the availability of locally harvested or farmed East Coast clams, and general economic conditions. The current price is $0.10 a piece, up about a penny from last year. Therefore, potential investors must assess the impact to local market prices resulting from large production levels and other variables. An analysis assuming a constant market price may not be valid as the production volumes from large scale competing operations are released onto the market.

To maintain growth and protect investments in the industry, local, statewide, and regional organizations have recently been formed to assist in regards to regional and national marketing and promotion, research and education on industry-wide problems, and more comprehensive political visibility and lobbying efforts (Ruth et al. 2005). These include: Cedar Key Aquaculture Association (CKAA 2015), Florida Aquaculture Association (FAA 2015), and the East Coast Shellfish Growers Association (ECSGA 2015).

5.2.2 Private and public investment and capitalization

The development of shellfish aquaculture in Cedar Key required a significant level of local community, state, and federal involvement to correct and respond to changing economic, regulatory and environmental conditions. In 1990 shellfish production was set back by closure of the area's commercial wild oyster operations by the FDA due to high and persistent levels of sewage-borne bacteria escaping from septic tanks. Overnight, more than a hundred oyster harvesters and workers were out of work.

Beginning in 1991, the Florida Department of Labor and Employment Security introduced federally funded programs in shellfish aquaculture to train unemployed or underemployed oyster harvesters and other seafood workers. Named "Project Ocean" and continuing through 1993, this was directed at a "bottom up" approach to assist prospective shellfish farmers in all aspects the farming business. A Sea Grant aquaculture extension agent (Leslie Sturmer) was based at Cedar Key as the on-site project manager, with a land-based office, a water-based field site, and a working hatchery/nursery operated by Florida's Harbor Branch Oceanographic Institute. Trainees were provided with hands-on farming and business instruction, free seed, grow-out bags, and available free lease sites. By 1993, over 130 program graduates had received shellfish aquaculture leases and the knowledge to put the submerged lands into production.

A farm site lease program, previously established for Apalachicola Bay oyster harvesters, was approved by local county and state agencies, with the cooperation of federal agencies. The government also worked on a process to serve as a "conceptual applicant" to offer fully permitted farm sites to prospective farmers. This was much like the "aquaculture park" now in place in Hawaii (Hawaii Ocean Science & Technology Park).

The success of Project Ocean largely hinged on the adoption of clam farming. In the early 1990s, oyster culture was viewed as a less-than-profitable venture requiring too much labor, with poor demand, and ongoing bacteria and biotoxin issues. With the help of scientists at Harbor Branch, the northern hard clam *Mercenaria mercenaria* was brought to Cedar Key from Florida's east coast, where the clam was native. With the area's combination of excellent water and bottom or soil conditions, and an available trained work force, the northern hard clam thrived in Cedar Key.

When the retraining effort ended in 1993, few sensed that it would essentially be a demonstration project for an even bigger effort, because in 1994 the Cedar Key community was forced to deal with another equally serious event. Florida voters passed a constitutional amendment intended to prevent overfishing and banning the use of gill nets in state waters. Many commercial fishermen in Cedar Key and elsewhere in Florida faced a tough decision, retire or find another way to make a living. That action greatly affected Cedar Key's fishing industry, putting hundreds of fishermen and seafood handlers out of work.

"Project Wave" was launched in 1995, also with state and federal support, to cope with the cataclysmic outfall of the net ban. Unlike its predecessor, Project Wave was designed exclusively for displaced net fishermen and focused entirely on growing clams. The Sea Grant extension and training program put in place for Project Ocean was maintained intact. Harbor Branch continued to sell seed until commercially available clam seed became available by 1998–99, and still maintains a research presence in Cedar Key. A total of about 70 participants ultimately took part in the training program, which continued to 1998. Today, the key extension and service elements of the program remain, with investigations for new species development and other research and development activities.

During the same period, significant progress was made in resolving the water quality issues that led to the closure of the oyster beds in 1990. Citizens of Cedar Key formed the Cedar Key Water Alliance to encourage citizen participation in finding solutions to some of the town's most pressing water resource concerns. The committee's advisory groups worked closely with elected officials and agency representatives in planning and implementing a wide range of water quality activities, including improved stormwater and wastewater treatment systems and environmental education. The community received substantial funding from the state's Surface Water Improvement and Management Program to conduct a master stormwater system study and to develop a master stormwater plan. Additional funds were appropriated for implementation of stormwater projects, with funds provided through the Florida Department of Transportation's wetlands mitigation program. One of Cedar Key's top priorities was to replace all existing septic tanks with connections to the town's centralized sewer system. The city and its water and sewerage district, with support from their local legislative delegation, received funds to eliminate every septic tank in the community by the year 2000. As a result, the leading cause of the harvest closure, failing septic tanks, was resolved by connecting all homes in Cedar Key to a sewage treatment system. This removed the non-point sources of pollution and allowed the affected areas to be reopened (Colson and Sturmer 2000; Florida Natural Resources Leadership Institute 2010).

Installation and operation of water quality monitoring stations at nine shellfish aquaculture lease areas in Florida began in 2002 as part of the Clam Lease Assessment, Management, and Modeling using Remote Sensing project, funded by the USDA. Continuous monitoring over a four-year period documented conditions that could negatively impact clam survival and growth and identified relevant water quality differences among leases (Bergquist et al. 2000). From 2006 through 2012, a partnership agreement with the USDA National Institute of Food and Agriculture and USDA Risk Management Agency (the funding agency) allowed for continued operation of stations. A lack of federal funding later resulted in all but one of the stations being dismantled (a live feed from the remaining station is at http://shellfish.ifas.ufl.edu/water-quality-monitoring/) (IFAS 2015c).

Large areas of publically owned and or managed lands surround Cedar Key (Figure 9). The Suwannee River Water Management District currently owns and manages nearly 100,000 acres of riverfront and wetlands to provide natural storage areas for flood waters, protect ground and surface water resources, and protect natural systems associated with floodplain ecosystems. The U.S. Fish and Wildlife Service manages the Lower Suwannee and Cedar Key National Wildlife Refuges. In additional to several upland reserves,, the state manages the Big Bend Seagrasses Aquatic Preserve, which covers almost a million acres of submerged land and hosts the second largest seagrass community in the Gulf of Mexico (FDEP 2015).

5.2.3 Lead state agency support

The Florida Department of Agriculture and Consumer Services (DACS) is the state's lead aquaculture agency and is responsible for coordinating and assisting in the development of aquaculture statewide. In 1999 the Florida Legislature created the Division of Aquaculture within the Department of Agriculture and Consumer Services, and aquaculture is defined as an agricultural practice (Florida Senate 2015). The Division of Aquaculture conducts numerous activities to promote the development of aquaculture in Florida. These activities include regulatory, administrative, advisory, and technical assistance functions directed toward ensuring that aquaculture operations are compatible with the Florida Aquaculture Plan, Aquaculture Certification Program, best management practices, resource management goals, and public health protection. Florida's marine waters encompass 4,460 square miles of estuaries and 6,758 square miles of coastal waters that total approximately 7,179,520 acres. Currently DACS manages 1,454,180 acres, or 20 percent of the total, for the harvest of shellfish (clams, oysters and mussels) for human consumption. Within that managed acreage, the State of Florida has leased 2,208 acres (or 0.03 percent) of the total to shellfish farmers (DACS 2015).

5.2.4 Level of coordinated research and development

The State of Florida has, by employing a variety of local, state and federal resources, put a considerable level of effort into both the development of commercial hard clam farming, and in supporting ongoing research on issues affecting the growth and health of the industry. Much of the information regarding the status of current and past research can be found at the Florida Shellfish Aquaculture website, http://shellfish.ifas.ufl.edu (IFAS 2015b). This site provides, through the University of Florida Institute of Food and Agricultural Sciences (IFAS) Shellfish Aquaculture Extension Program, information about shellfish farming and related activities, a "news blog", updates on research and extension projects, presentations from industry workshops, suppliers' lists, and pertinent publications. Figure 12 shows examples of research and development projects from several recent Clam Culture Industry Workshops sponsored by IFAS.

Figure 12. 2014 Workshop Project Updates (examples)

Source: IFAS, 2015b

Project examples from IFAS-sponsored 2012 Workshops include:

- Selection for heat tolerance in cultured clams using biomarkers -- Shirley Baker, UF SFRC Fisheries and Aquatic Sciences and John Scarpa, Harbor Branch Oceanographic Institute at FAU.

- Clam stock improvement projects: results of grow-out field trials -- Leslie Sturmer, UF IFAS Cooperative Extension Service and John Scarpa, Harbor Branch Oceanographic Institute at FAU.
- Examination of wholesale market attributes for sunray Venus clams -- Chuck Adams, UF IF AS Food and Resource Economics.
- Developing product standards or guidelines for sunray Venus clams -- Steve Otwell, UF Aquatic Food Products Lab.

5.2.5 Regulatory process

Hard clams are only grown on estuarine or coastal submerged lands leased from the State of Florida. The Florida Department of Agriculture and Consumer Services, Division of Aquaculture administers the lease program and monitors coastal waters for shellfish harvesting classifications. The lease is for a 10-year term and is renewable and transferable. The lessee pays an initial application fee and an annual rental fee thereafter. In addition, the leaseholder must plant a minimum of 100,000 clam seed per acre per year to fulfill their agreement. In addition, potential sites must undergo a resource survey, be located on nonproductive “bare” bottom areas and in waters approved for shellfish harvesting, cannot impede navigation or conflict with recreational or commercial uses of area, and are usually grouped in block areas, i.e. high-density lease areas or aquaculture use areas (IFAS 2015b). When the lease application is complete, a copy is sent to various entities for review; including the U.S. Army Corps of Engineers, the Florida Department of Environmental Protection, and the Florida Fish and Wildlife Conservation Commission.

A lease application processing fee in the amount of $200 is required to be submitted along with the completed lease application. Upon approval of the lease, an annual rental fee is required. The current (2012) rates charged annually for aquaculture leases are $16.73 per acre (adjusted based on the five-year change in the Consumer Price Index), and a surcharge in the amount of $10 per acre. All aquaculture leaseholders, subleasers, or “sharecroppers” are required to obtain an aquaculture certificate. The certificate identifies the aquaculturist, his/her lease, product, and facility. The annual fee is $100.00. Other permits and certifications are similar to those required in Alaska and other states with commercial shellfish aquaculture.

In this process aquaculturists, their farms, and products are recognized as agricultural commodities through the aquaculture certificate. This exempts cultured species from resource management rules, replaces a number of environmental permitting requirements, applies best management practices developed for aquatic facilities and a means of assuring aquafarms do not negatively impact the environment, eliminates duplicative and confusing environmental permitting/licensing, and supports site visits/inspections of certified facilities to ensure compliance (DACS 2014; DACS 2015).

The Florida Division of Aquaculture monitors the quality of the water that shellfish live in by establishing management plans for Shellfish Harvest Areas (SHAs). These plans prescribe environmental sampling of 1,490,000 acres of state waters within 37 SHAs on a routine basis to insure that the shellfish sold by Florida producers is free of marine toxins and disease-causing bacteria and viruses. This requires continuous data collection and analysis, and every 12 years the Shellfish Environmental Assessment Section completes a comprehensive survey.

Growing areas in Cedar Key are still conditionally approved, but areas prohibited for harvest are now very limited (Figure 10). This was due to a strong community response to the original 1990 closures, and continued involvement by shellfish farmers and regional leaders in oversight of coastal development.

5.2.6 Development strategies and key stakeholders involved

The development of shellfish aquaculture in Cedar Key is an excellent example of a broad community effort by strong negative economic pressures, personal commitment, targeted training and aquatic farming assistance and an effective government and regulatory response. Oyster harvesters and gillnet fisherman provided a base of field-savvy capable growers with an installed capacity of work vessels and support facilities. The two retraining programs were carefully crafted to match their needs with technical, physical and personnel resources provided by the University of Florida and Harbor Branch. The key stakeholders and still both active and locally involved with the industry. Leslie Sturmer, the state shellfish aquaculture extension agent involved with the retraining projects, is an active member of the Cedar Key community, and University of Florida researchers are involved in many research projects addressing water quality, new species, production, and marketing of Cedar Key shellfish.

5.2.7 Coastal zone management plans

The Florida Coastal Management Program (FCMP) is based on a network of agencies implementing 24 statutes that protect and enhance the state's natural, cultural and economic coastal resources. The goal of the program is to coordinate local, state and federal agency activities using existing laws and regulations. The state does not have a CZM Program similar to the top-down program in Oregon. Florida's Department of Environmental Protection is responsible for directing the implementation of the statewide coastal management program. It also conducts Section 309 assessments for FCMP partners. The DACS implemented the Improved Coordination & Monitoring strategy in FY 06. This strategy involved establishing a steering group of agency and aquaculture industry representatives that identified priority issues to be addressed through ongoing coordination, seminars, bulletins and technical reviews (Florida Coastal Office 2014).

5.2.8 Species present

Currently, clam farmers in Cedar Key grow only the non-native northern hard-shell clam (Mercenaria mercenaria). Also known as quahogs, these clams get marketed as midneck, littlenecks, and topnecks—names all based on size. While Cedar Key is home to a close relative, Mercenaria campechianus, this species does not match the shelf-life of the northern hard-shell clam. The two species are currently being evaluated in breeding efforts to improve productivity and reduce high water temperature mortalities, while maintaining product quality, and to assess how Mercenaria mercenaria culture can influence naturally occurring congeneric populations in the vicinity of the culture operation (Arnold et al. 2004; Sturmer et al. 2006; Sturmer et al. 2012a).

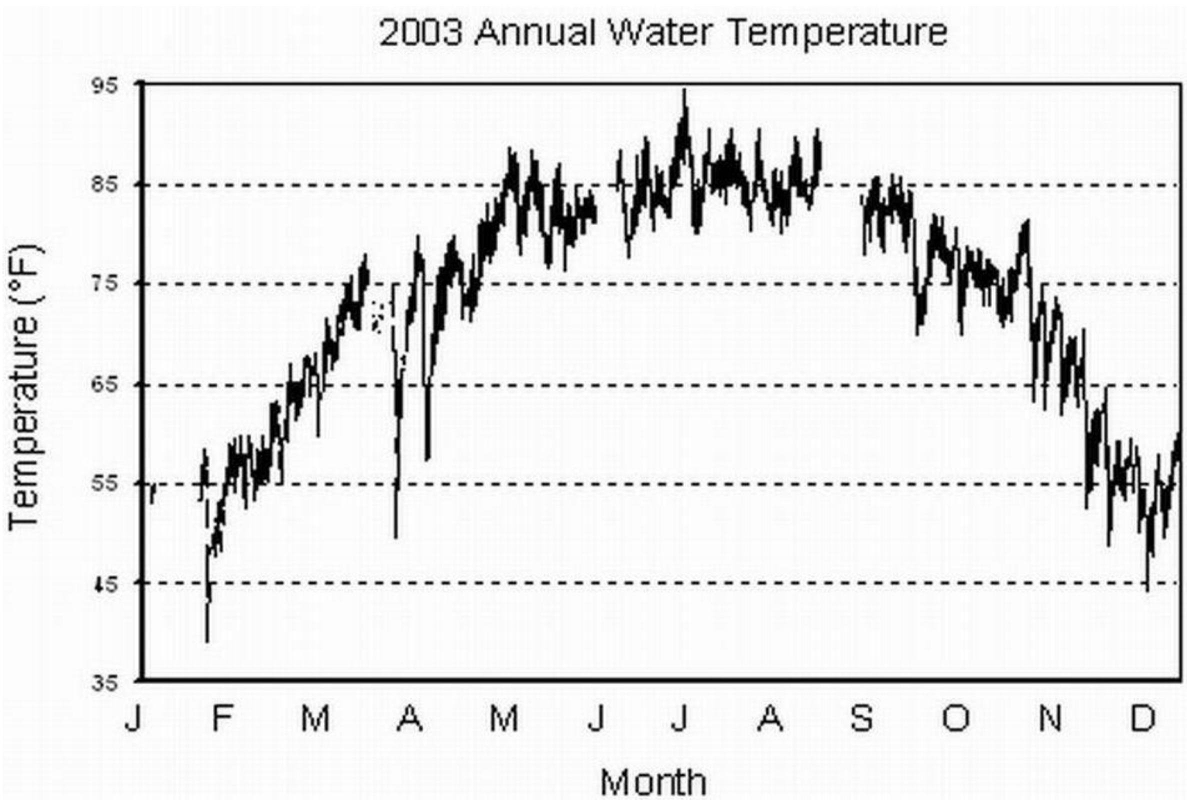
The sunray Venus clam, Macrocallista nimbosa, is being evaluated as a new aquaculture species to diversify the industry. It is a native species that was commercially fished in the Gulf of Mexico during the 1960s and 1970s (Scarpa et al. 2009; Sturmer et al. 2010; Sturmer et al. 2012b).

There is also a resurgence in interest in culture of the eastern oyster (Crassostrea virginica) primarily directed at changes in grow-out methods from the traditional bottom culture or wild harvest in the Cedar Key area (Sturmer et al. 1995; Sturmer 2015).

5.2.9 Biophysical characteristics

The environmental conditions at Cedar Key are exceptional versus other locations on the Florida coast. Growing conditions including water temperatures (Figure 13), salinity, water flow or currents, and bottom sediments have generally proved to be optimal for hard clam culture. Many natural areas in the surrounding uplands coupled with a relatively low population density, elimination of on-site septic systems, and improvements to the waste treatment system greatly reduce the risk of water quality-caused closures. The area is still subject to conditional approval for shellfish harvests, but conditional closures are infrequent (Figure 10).

Figure 13. Water temperature fluctuation at the Gulf Jackson lease area, Levy County, Florida, in 2003



Source: Weber et al. 2010.

However, Florida represents the southernmost limit of the northern hard clam, *Mercenaria mercenaria*, and water temperature stress is an emerging problem. Growers across the state have experienced increasing losses of market-size clams when summer water temperatures exceed 90º F (see above). This indicated a need for a heat-tolerant clam strain if the Florida industry to reduce current summer mortalities and adapt to future climate change. Recently completed studies using two basic breeding techniques, triploidy and hybridization, indicated that thermal tolerance in clams may be under genetic control and could be applied for increasing survival and production in Florida waters (Sturmer et al. 2006; Baker and Scarpa 2012).

Red tides are another cause for closure of Cedar Key clam grounds. The dinoflagellate phytoplankton, *Karenia brevis*, is the principal Florida red tide organism, associated with Neurotoxic Shellfish Poisoning (NSP, versus PSP in Alaska). While most bivalve shellfish appear to be unaffected during *K. brevis* blooms, to protect public health, the DACS closes oyster, clam and mussel harvesting areas during blooms of this and other toxic phytoplankton. An extended closure occurred in fall 2014. Other natural and human events, such as hurricanes, oil spills (the BP spill missed Cedar Key), and naturally occurring *Vibrio* bacteria, also remain risk factors.

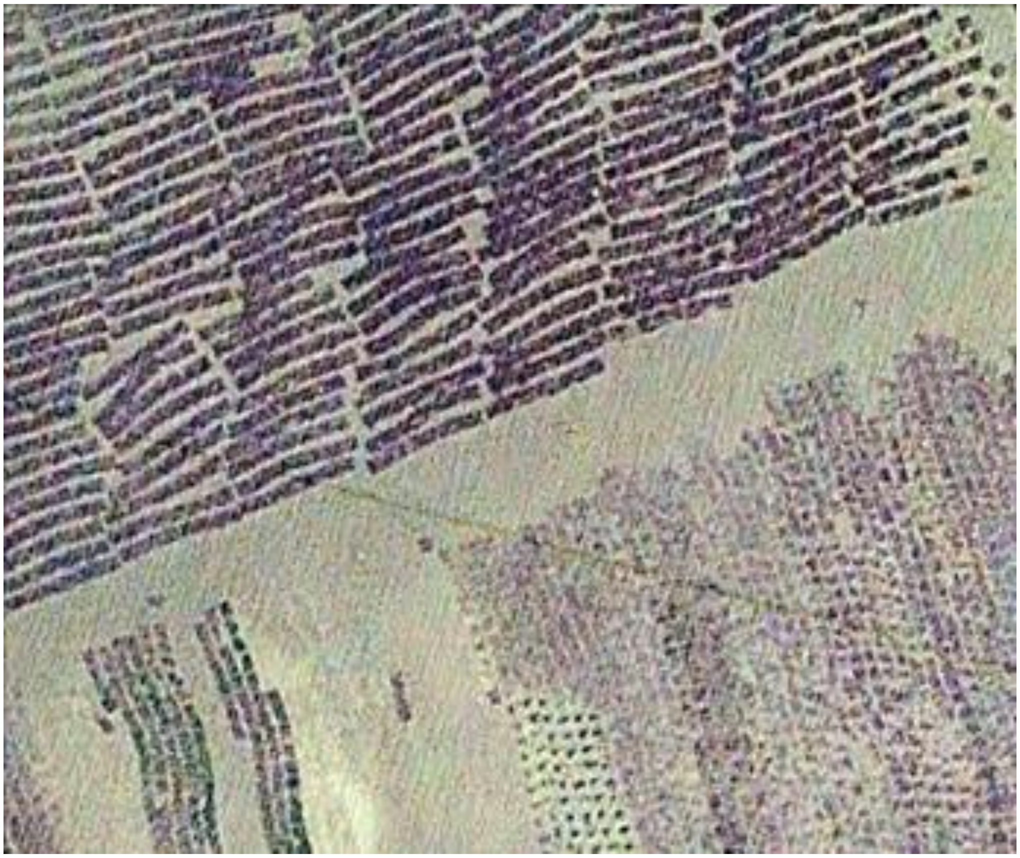
5.2.10 Culture and processing technology

The following is excerpted from a summary of the hard clam culture and production methods on the IFAS website (IFAS 2015b).The extent of shellfish grow-out at one site in Cedar Key is shown in Figure 14. Selected photographs of these operations in Cedar Key are shown in Figure 16 and Figure 17, below.

> **Hatchery:** Clam culture begins in the hatchery with the production of seed. While hatchery techniques are well defined, they are fairly complex. In addition, a hatchery operation requires a capital investment in property, facilities, equipment, and skilled labor. For these reasons, most growers prefer to purchase seed from a hatchery. There are 8-10 hatcheries in the state, ranging from small backyard operations to commercial-sized facilities, which provide almost a half billion seed annually. In the hatchery, adult clams, or broodstock, are induced to spawn by manipulation of water temperatures. Fertilized eggs and resulting free-swimming larval stages are reared under controlled conditions in large tanks filled with filtered, sterilized seawater. Cultured marine phytoplankton, or microalgae, are fed at increasing densities during the 10 to 14-day larval culture phase. After which, pediveliger larvae begin to settle out of the water column, or metamorphose. Even though a true shell is formed at this time, post-set seed are microscopic and vulnerable to fluctuating environmental conditions. They are maintained in the hatchery for another 30 to 45 days in downwellers until they reach about 1 mm in size.
>
> **Nursery:** This component serves as an intermediate stage and provides the small clam seed produced in a hatchery with an adequate food supply and protection from predators until they are ready to be planted for growout. Nursery systems built on land usually consist of wellers or raceways. A weller system consists of open-ended cylinders placed in a water reservoir. Seawater circulates through the seed mass, which is suspended on a screen at the bottom of the cylinder. The direction of the water flow defines whether the system is referred to as a downweller or upweller. Raceways consist of shallow tanks or trays with salt water pumped from an adjacent source providing a horizontal flow as opposed to a vertical flow in the wellers. The water flow provides food (naturally occurring phytoplankton) and oxygen to the seed. Many growers are attracted to the nursery option as seed costs are lower and, at times, smaller seed are more available. Further, the systems can be constructed inexpensively and maintained on a part-time basis. Depending on water temperatures, 1-2 mm seed require from 6-12 weeks to reach 5-6 mm in shell length, the minimum size planted in the field. Currently, about 40 land-based nursery facilities are located statewide. These systems can be novel, such as floating upwellers or FLUPYS, which are employed at specific sites, usually marinas.
>
> **Growout:** Since clams are bottom-dwelling animals, growout systems are designed to place the seed in a bottom substrate and provide protection from predators. The system must allow substantial water flow to provide both oxygen and natural food, or phytoplankton, for growth. Most growers in the state use the soft bag, which is made of a polyester mesh material. The bag is staked to the bottom using a variety of materials, such as PVC pipe. Bags are typically "belted" together in units of 5 to 10 and planted in rows on the lease *(Figure 14)*. Naturally occurring sediments provided by tidal action and currents, as well as the digging activity of the clams, allow the bag to become buried in the bottom sediments. When harvested, only the product and

mesh bag are removed from the bottom. A winch or roller rig operated from the boat assists in harvesting the bags.

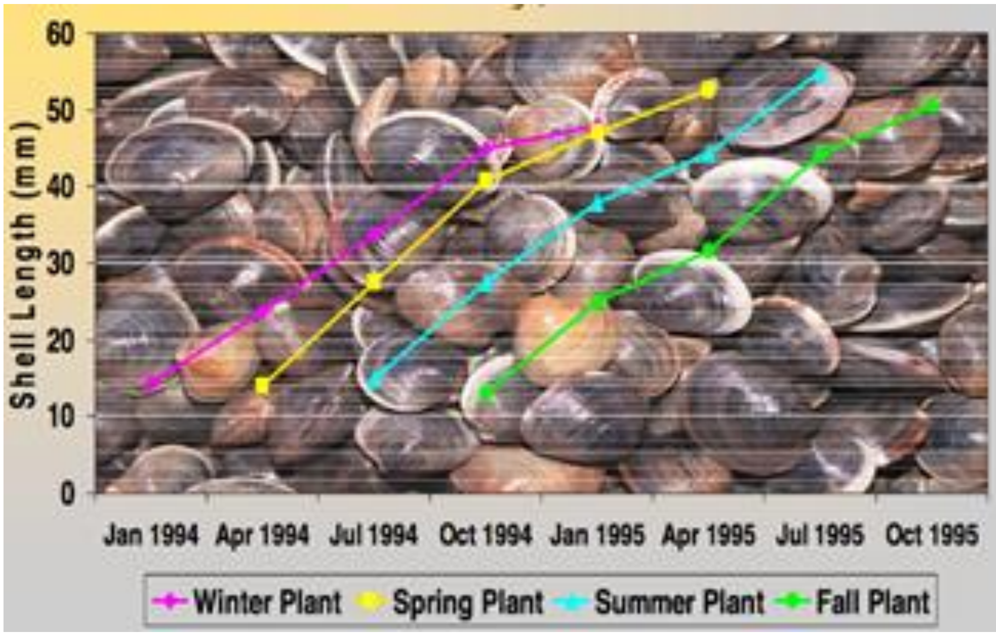
Figure 14. Clam Grow-out Bags, Cedar Key



Source: Cheney, 2009

The bag culture method usually involves a two-step process. The first step involves field nursing seed, minimum size of 5-6 mm (1/4 inch) in shell length, in a small mesh bag. Typically, about 10-15,000 seed are planted in a 3 to 4 mm mesh bag with the dimensions of 4 feet by 4 feet, or 16 ft2. When the seed reach a size of 12-15 mm (1/2 inch), usually after 3 to 6 months, they are transferred to the final bag size, which may range from 9 to 12 mm in mesh size. The larger seed are stocked at a lower density at rates from 800 to 1,400 per bag (50-85/ft2). A crop of littleneck-sized clams, which are one inch in shell width, can be grown within 12-18 months depending on water temperatures and food availability *(Figure 15)*. Survival rates are specific not only to planting methods and experience, but also predator abundance. Additional cover netting, such as galvanized wire or plastic netting, placed over the bags is required in some growing areas. Crabs, snails, rays, fish, and humans are among the many predators that contribute to mortalities. Another culture method, traditionally used in the Northeast, is now being used by growers on the east and southwest Florida coasts. The bottom plant method places a single layer of cover netting over the broadcasted seed.

Figure 15. Seasonal hard clam growth, Cedar Key



Source: Cheney, 2009

> Once clams are harvested, they are delivered by the grower to a certified shellfish wholesaler. At the wholesaler's processing plant, clams are prepared for market by washing, sorting, grading by size, counting, packaging, and tagging. Clams are generally sold live, or as shellstock, and refrigerated trucks are used in transporting product to marketplaces throughout the state and nation."

Marketing is typically not an issue, and most clams are purchased by East Coast buyers who pick up the Cedar Key product using their own trucking services (Sturmer 2015). About 55 certified shellfish wholesalers in the state purchase clams from growers, add value, and distribute product to markets throughout the nation. Some growers/processors sell their clams under trademark names, for example, Cedar Key Sweets ™ and PastaNeck™. Also, locally in Cedar Key, businesses spun-off from the clam production include clam bag production, boat builders specializing in clam work skiffs, and manufacturers producing harvesting and processing equipment.

Additional information regarding Cedar Key shellfish aquaculture can be obtained from the University of Florida and DACS Division of Aquaculture websites (IFAS 2015b; DACS 2015). These contain a wide range of technical reports, conference proceedings and other documents. Sturmer (2005) summarizes most of the key aspects of hard clam production. Specific information on environmental and production conditions affecting clam growth and survival is reported for effects of varying salinity (Baker et al. 2005); influence of culture on water conditions (Philips et al. 2008); biofouling (Cassiano et al. 2012; Fitridge, et al. 2012); remote setting (Sturmer et al. 2003); planting density and predator exclusion (Fernandez et al. 1997); and taste or sensory aspects (Otwell et al. 2012).

5.2.11 Cost/benefit analysis

The following information was prepared for presentation at workshops held in Collier County, southwest Florida for new growers (Adams and Sturmer 2004). With several exceptions, the production and financial assumptions are also applicable to Cedar Key.

Production Assumptions

- Two-acre shellfish aquaculture lease in southwest Florida area
- Maximum 2-year grow-out period, which combines both nursery and grow-out phases
- Nursery phase is ~ 3 months
- Grow-out phase is ~ 10-14 months
- Harvest period is extended over several months as dictated by demand, environmental conditions, growth, etc.
- Production on total lease area is staggered: one acre is planted in Year 1 and one acre is planted in Year 2
- Nursery bags are stocked at a density of 10,000 clams per bag
- Grow-out bags are stocked at about 60 clams per square foot, or ~ 1,000 per bag
- Planting 1,070,000 seed clams per acre
- Survival rates are: Nursery: 70 percent; Grow-out: 80 percent; and Overall: 56 percent
- Size distribution of clams harvested per grow-out bag is assumed to be: 1″ littlenecks: 80 percent; and 7/8″ pastas: 20 percent

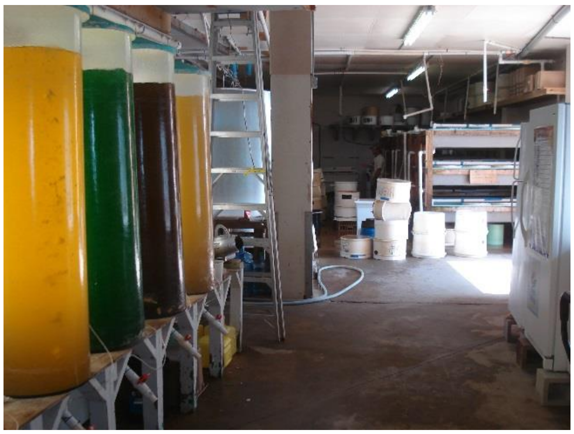
Financial Assumptions

- Seed clams are purchased at 4-8 mm at a price of $0.008 each, or $8 per thousand (currently some growers purchase 1-2 mm seed at a lower cost, and raise them in their own nursery systems)
- Market price of clams: 1″ clams: $0.09 each and 7/8″ clams: $0.07 each (currently growers are paid about $0.10 per clam)
- All initial capital costs, asset replacement costs, and operating costs are owner financed. No borrowed capital.
- Capital assets depreciation is computed using straight-line method with zero salvage value
- Annual cost for repair and maintenance on boat, motor, trailer, and truck is assessed at 10 percent of initial investment
- Hired labor is required each year during the harvest period
- Laborers are self-employed and paid a daily rate of ~ $100 per day ($12/hr) -- 10 days planting and 66 days harvesting
- Most variable costs, overhead expenses, and capital asset purchases are inflated at a 3 percent annual rate
- Income and self-employment taxes are ***not*** included
- Withdrawals from the business income for owner “salary” or family living expenses are NOT included
- Owner / family labor cost is ***not*** included
- All net returns are pre-tax to the owner/operator’s capital, management labor, and risk

Figure 16. Hard clam culture in Cedar Key, Part 1

Market sized northern hard clams

Venus clams



Small-scale algae culture system

Nursery system

Clam brood-stock

FLUPSY

Source: Cheney, 2009

Figure 17. Hard clam culture in Cedar Key, Part 2

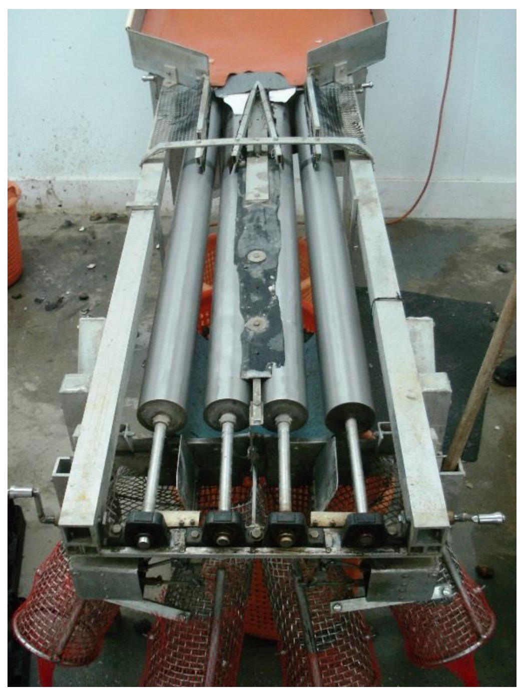
Clam harvest boat (note bow mounted outboard)

bagged and tagged clams

clam sorting and cleaning machine

UF extension center

harvest from grow-out bags



clam bagging machine

Source: Cheney, 2009

The authors created detailed tables for initial investment and capital costs, annual production costs, annual cash flows (for a 5 year duration), and the average per-acre annual budget. Table 4 illustrates their sensitivity analysis on key production and management variables.

Adams and Pomeroy (1992) presented an expanded but somewhat dated analysis for all three phases of production: hatchery, nursery, and grow-out. A summary of their sensitivity analysis is shown in Figure 18. Their assessment indicated that at moderate output levels for stand-alone operations, the nursery and grow-out phases were profitable, but the hatchery was not. However, economies of size existed for larger levels of hatchery output and significant benefits to integration were achieved when the hatchery was vertically linked with the nursery.

Based on their analyses using year 1992 costs and market prices, the stand-alone hatchery operation became profitable at some long-run output level of between 24 and 72 million clams. The stand-alone nursery was characterized by long-run average costs that were below market prices at all facility sizes. Significant cost reductions were achieved through vertical integration of the hatchery and nursery facilities at output levels of 72 and 36 million clams and beyond, respectively. The authors suggested benefits to vertical integration may provide incentives for local investors to become less dependent on non-local supplies of seed clams.

Table 4. Small scale hard clam production, cost and income sensitivity

Variable	# Clams Harvested	Total Costs	Net Returns	Cost per Clam	Break-even Survival (%)
			($)		
Seed Price (ea.)					
$0.007	600,000	30,181	21,419	0.050	33
$0.008	600,000	32,732	18,868	0.055	36
$0.010	600,000	34,872	16,728	0.058	38
Market Price (1” / 7/8”)					
$0.07/0.05	600,000	32,732	6,868	0.055	46
$0.08/0.06	600,000	32,732	12,868	0.055	40
$0.09/0.07	600,000	32,732	18,868	0.055	36
$0.10/0.08	600,000	32,732	24,868	0.055	32
$0.12/0.10	600,000	32,732	36,868	0.055	26
Survival Rate					
42%	449,000	32,732	5,882	0.073	36
49%	524,300	32,732	12,358	0.062	36
56%	600,000	32,732	18,868	0.055	36
63%	674,100	32,732	25,241	0.049	36
Size Distribution (1” / 7/8”)					
90/10	540,000/60,000	32,732	20,068	0.055	35
80/20	480,000/120,000	32,732	18,868	0.055	36
70/30	420,000/180,000	32,732	17,668	0.055	37

Source: Adams and Sturmer, 2004

Figure 18. Nursery and hatchery production, cost and income sensitivity

Costs[1] associated with a stand-alone upflow hard clam nursery system of various sizes.

Cost Category	Facility Size (× One Million Clams)					
	12	36	60	90	120	240
Initial capital investment:						
Support lab	$ 77.5	$ 77.5	$ 77.5	$ 77.5	$ 81.5	$ 81.5
Nursery equipment	93.4	93.4	115.0	115.0	137.2	137.2
Annual cash costs:						
Interest on capital[2]	10.3	10.3	11.6	11.6	13.1	13.1
Variable costs	83.6	227.9	375.6	556.1	740.3	1,460.8
Salaries/Benefits	15.9	15.9	32.0	32.0	42.3	59.4
Overhead	4.0	4.0	6.5	6.5	9.0	9.0
Interest on operating loan[2]	12.4	29.7	46.7	71.4	94.9	183.5
Annual non-cash costs:						
Depreciation[3]	21.2	21.2	23.4	23.4	26.1	26.1
Opportunity cost of owner equity[2]	8.0	8.0	8.9	8.9	10.0	10.0
Total annual costs[4]	155.5	317.1	504.7	709.9	935.8	1,761.9

Costs[1] associated with a stand-alone Milford hard clam hatchery system of various sizes.

Cost Category	Facility Size (× One Million Seed Clams)					
	24	72	120	180	240	480
Initial capital investment:						
Support lab	$198.6	$198.6	$244.3	$244.3	$307.9	$307.9
Hatchery equipment	44.5	44.5	65.0	65.0	88.6	88.6
Annual cash costs:						
Interest on capital[2]	14.6	14.6	18.6	18.6	23.8	23.8
Variable costs	30.5	32.8	37.5	40.1	44.3	58.2
Salaries/Benefits	36.3	36.3	58.1	58.1	80.0	80.0
Overhead	3.0	3.0	5.5	5.5	8.0	8.0
Interest on operating loan[2]	8.4	8.7	12.1	12.5	15.9	17.5
Annual non-cash costs:						
Depreciation[3]	24.1	24.1	34.5	34.5	42.0	42.0
Opportunity cost of owner equity[2]	11.0	11.0	13.8	13.8	17.5	17.5
Total annual costs[4]	127.9	130.5	180.2	183.1	231.3	247.0

[1] Units of $1,000.
[2] Computed on interest rate of 12 percent.
[3] Straight-line method.
[4] May not add due to a rounding error.

Source: Adams and Pomeroy, 1992

5.3 Relevancy to Alaska Mariculture Initiative

None of the shellfish species occurring in Florida are native in Alaska or are suitable for cultivation in the cool temperate waters of the region. The littleneck clam (Leukoma staminea), native in Alaskan waters, is the most comparable species both on terms of morphology and market. However, it is slow growing relative to the high rate of growth of Mercenaria mercenaria (2 to 4 years versus 12 to 16 months).

The hatchery, nursery, and grow-out methods employed by the Cedar Key producers are highly applicable to any Alaska shellfish production, provided fundamental differences in water temperatures, phytoplankton culture conditions, transport and construction/operating costs are considered. Alaska growers may experience many of the same water quality issues affecting Cedar Key, including red tides (PSP, ASP [Amnesic shellfish poisoning]), oil spills, and occasional Vibrio outbreaks.

This case study is most relevant in the approaches taken to offset major losses to employment in the fisheries sector with the use of comprehensive retraining projects. The success of those programs was not dependent on big government spending on major programs. Rather it was a comprehensive local community and stakeholder driven approach, which integrated existing fisheries skill sets and resources with a flexible and nuanced regulatory policy and intelligent technical and scientific support. Financial support was provided to jump-start the novice aquatic farmer. Long-term extension and technical assistance was (and is) maintained onsite long after completion of the training programs.

The rapid expansion of hard clam farming in Cedar Key would not have been possible without the existing infrastructure (roads, power and communication), the nearby availability of government offices, research and laboratory facilities, a large pool of researchers and extension personnel familiar with hard clam biology and culture, and the presence in the state of existing hard clam farms. Hatchery and nursery facilities, and local extension support at Cedar Key were also important early factors in the success of the industry.

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6 Seaweed Aquaculture in Ireland

6.1 Current Status and Economic Impact of the Industry

The vast majority of Ireland's marine (including aquaculture) businesses have common characteristics such as small size and workforce, which leads to a reduced diversity of in-company skills to draw on. In addition, these businesses have limited access to capital and capacity for research and innovation.

In 2007, the government of Ireland launched *Sea Change–A Marine Knowledge, Research and Innovation Strategy 2007-2013* to address the 2020 vision developed in the National Marine Foresight Exercise undertaken by the Marine Institute. *Sea Change* aimed to transform the entire marine economy from one primarily associated with low value-added food harvesting activities to one embracing cultural traditions but focused on high value, intensive, commercial opportunities developed in a sustainable manner (Marine Institute undated(b)). One of the marine sectors targeted in the *Sea Change* strategy has been aquaculture. The challenge addressed by *Sea Change* is to accelerate the development of the aquaculture sector by exploiting market-led opportunities and increasing the use of technological innovations.

In 2014, the Irish seaweed industry was still primarily producing high volume, low value products (such as animal feeds, plant supplements, specialist fertilizers and agricultural products). This accounted for nearly 100 percent of the market return, and 86 percent of the sector value of €15.5 million ($20.6 million) per year (Watson 2014). High value products (such as functional foods, cosmetics and therapies) only accounted for 1 percent of the market return but were worth 14 percent of the value of the sector (€2.5million [$3.3 million] per year) (Watson 2014). Irish seaweed is exported to 30 countries, in bulk to South America, Europe, Middle East and Asia (Watson 2014). Only 3 to 6 mt of edible seaweed is consumed in Ireland per year, but there is increasing demand from Spain and France for some species (e.g. *Palmaria palmata* €16-€19 [$21-25]/kilogram [kg]) bulk dry quantities) (Watson 2014). There is a market for seaweed in some cosmetic products such as therapy centers and seaweed baths. For both human food and cosmetics, the domestic market is largely saturated, so for industry growth the focus needs to be on the export market.

As part of the *Sea Change* strategy (and with the support of the Marine Institute and the Marine Research Sub-program of the *National Development Plan, 2007–2013*) a project was carried out to develop and demonstrate the viability of cultivation methodologies for seaweed species with known commercial potential (Project PBA/SW/07/001–The Seaweed Hatchery Project). This project was led by the Bord Iascaigh Mhara (Irish Sea Fisheries Board or BIM) and involved two universities (National University of Ireland and Queen’s University Belfast) and six Small Medium Enterprises. The project operated from 2008–2011 and aimed to farm three commercially important species, *Palmaria palmata*, *Laminaria digitata* and *Porphyra sp.*

This project has proved to be pivotal in development of the industry, as it identified crucial data that ensures strategic investment. It clearly demonstrated that brown seaweeds (kelp) can be farmed, and provided business plans and economic analyses for hatchery and grow-out businesses. The project concluded that the price for brown seaweed (off the farm) needs to be about €1,000 ($1,275)/wet mt to be profitable. The project also highlighted the limitations for farming *Palmaria*, and concluded that currently farming *Porphyria* is not viable. The funding required to make this project possible is not publicly available information.

Through coordinated and focused industry development led by BIM, seaweed aquaculture in Ireland is now a viable but fledgling industry. Going forward, the main obstacle will be labor costs.

Development of mechanized seaweed cultivation will be required to achieve cost objectives (Marine Institute 2008).

Marine Institute (2008) provides a case study of a seaweed farming initiative in a parish (community) called Roaring Water Bay that may be of particular relevance to Alaska. Roaring Water Bay is a parish of about 300 people. Shareholders, 95 percent of whom were from the parish, were recruited for the seaweed farming initiative. Cooperative management structures were established, including a committee of 15 members. Crucially, before the seaweed farming initiative was launched, the parish had already been active in seaweed wild harvesting for several end uses, and market connections were already established. While the cooperative did not survive, the case study highlights the importance of market connectivity to the success of local seaweed farming initiatives.

6.2 History and growth of the industry

Detailed data for the seaweed aquaculture sector in Ireland are not available, but Table 5 provides an overview of the growth of the industry in terms of production volume and value and number of jobs. In 2004, Irish seaweed aquaculture was in its infancy, but showed huge potential. At that time, a number of species (e.g., *Alaria esculenta, Palmaria palmata, Asparagopsis armata, Chondrus crispus* and *Laminaria saccharina*) were identified as suitable for cultivation in Ireland. A market demand already existed for many of these species for human consumption, nutraceuticals, and cosmetics due to a long established seaweed wild harvest. In 2007, four licenses were issued for counties Cork and Galway, and cultivation trials and pilot projects were undertaken with a number of species. By 2014, there were seven commercial licenses and 23 license applications were pending with the issuing authority, the Department of Agriculture, Food and the Marine (DAFM) (Watson 2014).

Following the National Seaweed Forum in 2000, a national seaweed aquaculture strategy was developed that outlined a 10-year industry development plan. The target for 2020 was to increase the combined wild harvest and aquaculture sector value to €30 million (Marine Institute undated [b]). As of November 2014, BIM believes this target will be achieved (Watson 2014). The combined Irish seaweed industry was valued at €18 million ($25 million) per year in 2011 (Morrissey et al. 2011). Farmed seaweed production had increased to 41.5 mt per year by 2013 (Bord Iascaigh Mhara 2015d), but this was still a small percentage of the overall Irish seaweed industry production of 20,000 mt per year. The challenge yet to be met is to expand seaweed production, with a focus on high value products.

Table 5. Growth of the Irish Seaweed Aquaculture Industry

Year	Sector Value (Euros/Dollars)	Sector Volume (Metric Tonnes)	Jobs (Total Staff)
2004	-	0.0	4
2007	-	0.0	2
2008	-	2.8	4
2009	-	0.0	3
2010	€1,050/$1,394	2.1	3
2011	€3,000/$4,178	3.0	Unknown
2012	€8,500/$10,928	8.5	Unknown
2013	€41,500/$55,131	41.5	Unknown

Source: Bord Iascaigh Mhara (2005, 2006, 2007, 2008, 2012, 2013, 2014, 2015a, 2015b, 2015c, 2015d)

6.2.1 Investment climate

Anecdotally, it appears that the data generated by the Seaweed Hatchery Project, and other work carried out by BIM under the *Sea Change* strategy, have increased investor confidence in seaweed aquaculture. These data have been published in reports such as *A Market Analysis towards the Further Development of Seaweed Aquaculture in Ireland* (Bord Iascaigh Mhara 2011b) and *Model Business Plans for the Establishment of a Seaweed Hatchery and Grow-out Farm* (Bord Iascaigh Mhara 2011d). Seaweed aquaculture has particularly attracted interest from triple bottom line investors (looking for economic, social, and environmental sustainability).

6.2.2 Private and public investment and capitalization

There are multiple public investment and capitalization schemes in Ireland's aquaculture industry, most of which are supported via BIM (Morris 2014). Of particular impact are investments via a European Union regional development policy. The European Union (EU) co-funded investment into the Irish economy under the National Development Plan 2000–2006 (NDP). In 2007, the combined investment in aquaculture projects under the NDP EU co-funded measures and BIM's Pilot and Resource Development Grant Scheme was €13.062 million ($17.9 million). The Aquaculture Development Measures of the two Regional Operational Programs of the NDP have provided the overall framework for the commercial development of aquaculture. Thirty-eight BIM-sponsored aquaculture projects, with an aggregate eligible investment cost of €19.291 million ($24.2 million), were approved for combined Financial Instrument for Fisheries Guidance and Exchequer grant assistance of €8.908 million ($11.2 million) in 2006. The private sector contributing the balance of funding of €10.38 million ($13.0 million) (Marine Institute undated(a)).

Complementing the NDP Aquaculture Development Measures, BIM administers an Aquaculture Grant Scheme under which small-scale aquaculture projects are promoted in a pilot development phase prior to full-scale commercial development under the NDP. The Aquaculture Grant Scheme also promotes the introduction of new technology, new species and the establishment of new site locations for aquaculture. During 2007, 94 projects were approved for grant assistance under this scheme of €1,886,395 ($2.4 million) on aggregate investment costs of €4,639,534 ($5.8 million) (Marine Institute undated (a); Morris 2014).

BIM also supports development under the Pilot and Resource Development Grant Scheme. During 2007, grant payments of €0.863 million ($1.1 million) were paid to 63 aquaculture projects under this scheme. Of this amount, 33.1 percent was paid towards the development of finfish species, 59.3 percent was paid towards investment in shellfish, and 7.6 percent was paid towards the development of seaweed aquaculture (Marine Institute undated(a); Morris 2014).

The Applied Industry Program was another measure under the NDP intended to facilitate small and micro companies who, because of size, were generally unable to participate in other research and development (R&D) grant aid programs. Companies who do not have in-house R&D staff were encouraged to link up with third level institutes to carry out research. The maximum grant-aid payable under this scheme was €100,000 ($133,000) (Marine Institute undated (a); Morris 2014).

Much of the support outlined above has provided investment into aquaculture over the past decade or more, including development work for seaweed aquaculture. Current support available from BIM for seaweed aquaculture includes (Morris 2014):

- **Pilot Aquaculture Development Scheme:** This scheme funds pilot projects for small-scale aquaculture. It is targeted at investment projects costing less than €100,000 ($133,000) with grant aid only comprising up to a maximum of 40 percent of eligible expenditure.

- **Aquaculture Innovation and Technology Scheme:** This scheme provides investment into innovative technology, new species and sites, and enhancing the skills and knowledge base of the industry. The grant aid can only comprise up to a maximum of 40 percent of eligible expenditure.
- **Fishery Local Action Group (FLAG) Funds:** These funds support projects in local areas to maintain and support jobs, add value to fisheries and aquaculture products, support industry diversification, support economic and social restructuring of areas facing difficulties as a result of changes in the fisheries sector, enhance economic and social prosperity, and promote the quality of the coastal environment. Grants are capped at €20,000 ($26,600). BIM vets proposed projects for eligibility and legality, but the local FLAG has the final decision regarding granting the go-ahead to a project.

In addition, a new program is being developed for 2014–2020 under the European Maritime and Fisheries Fund. Proposed Aquaculture Measures within this program include (Morris 2014):

- **Capacity Building Scheme:** This scheme is aimed at productive investments in aquaculture through promoting economic, social and environmental sustainability.
- **Knowledge, Innovation and Technology Scheme:** This scheme is aimed at supporting R&D and science-based innovation including research and development into novel species.
- **Organic and Environmental Management Scheme:** This scheme will support projects that explore aquaculture for providing environmental services.
- **Stock Insurance Scheme**
- **Processing Measures:** These measures will support development of food and non-food seaweed products within the new program. Processing measures will encourage companies to work together to take advantage of economies of scale and develop new markets and support capital investment in the seafood processing industry.

This new program is currently under public consultation.

6.2.3 Lead state agency support

The lead state agency for industry development is BIM. BIM's role in seaweed aquaculture development is three tiered, with support being given by the Aquaculture Development Division, the Market Development Division and the Marine Services Division.

The Aquaculture Development Division is charged with promoting the sustainable development of the Irish aquaculture industry in terms of volume and value of output. It has three sections. The Technical Section provides a specialist technical support service to the aquaculture industry. The Project Development Section evaluates and prioritizes investment proposals for grant assistance and assesses payment claims for draw-down of approved grants. The Environment and Quality Section promotes quality and environmental best practices in the aquaculture industry by providing specialist advice and guidelines and developing codes of practice and quality assurance schemes for the sectors.

The role of the Market Development Division is to promote Irish seafood at home and abroad and provide a range of market supports to help clients capitalize on market opportunities. The Division provides a range of services to the sector. The Market Research and Intelligence Section provides market intelligence and targeted market research on products. BIM Overseas Officers located in Paris, Madrid and Dusseldorf provide support in business development including facilitating buyer and customer contact, providing market information, and undertaking promotional activities. The Product

Quality and Process Development Section provides a technical advisory service to clients through the Seafood Development Centre including the Laboratory facility. The Trade and Market Development Section operates two support programs which help develop marketing expertise and skills in seafood companies and support market development efforts, namely the Irish Seafood Business Program and the Market Investment Program. The Consumer Support Section focuses on encouraging consumer demand for Irish seafood. It manages a number of promotional initiatives at the retail and food service level including consumer educational programs to enhance the status of Irish seafood products.

The Marine Services Division is charged with developing the industry's human resources through the provision of training and educational programs and to raise the quality of fish supplies through increased use of ice and improved fish handling practices. Training for the seafood industry is provided through a coastal service that includes the National Fisheries College, the Regional Fisheries Centre, and two mobile coastal training units. Courses for the aquaculture sector have been developed in consultation with industry and are accredited by statutory bodies. The Engineering Services Section manages BIM's ice plant network, which provides a supply of ice to fish farms and fish processors.

The DAFM is the lead regulatory authority for aquaculture. The DAFM Aquaculture & Foreshore Management Division ensures the efficient and effective management of aquaculture licensing and foreshore licensing.

6.2.4 Level of coordinated research and development

There is a high level of coordinated R&D for seaweed aquaculture in Ireland. In preparation for *Sea Change*, the Marine Institute carried out the first detailed identification of marine research capacity in the third-level sector in Ireland. The study identified around 500 researchers in 56 research groups/teams in 16 higher education institutions either active, or recently involved in, marine-related research. This includes groups that are entirely focused on marine research and teams that are involved in marine research projects but whose research interests are wider.

A number of public sector agencies are also involved in some aspect of marine-related research in Ireland. The Marine Institute engages in a wide range of marine research and development activities and, through the NDP, provides funds to stimulate research in the higher education and private sectors. BIM participates in research that is linked closely to industry needs in the fishing, seaweed and aquaculture sectors. The Agri-Food and Biosciences Institute in Northern Ireland has a network of scientists active in identifying bioactive compounds in macroalgae that have a growth stimulating effect on agricultural crops and farm animals.

6.2.5 Regulatory process

Seaweed farming requires an Aquaculture License and Foreshore License, which are issued by DAFM.

6.2.6 Development strategies and key stakeholders involved

In addition to the development strategies outlined in Section 2.2.2, several key development strategies were implemented in the early 2000's (Marine Institute undated(a)). These included:

- The establishment of an Irish Seaweed Centre in 2001 as a center of excellence for seaweed research.
- The appointment of a Seaweed Research Coordinator at the Marine Institute. The main objectives of the coordinator post were to select and realize R&D-based key ideas in the areas

of seaweed aquaculture production and seaweed harvesting, and to facilitate technology transfer and innovation.

- The appointment of a regionally based Seaweed Development Officer by BIM to promote and assist in the development of seaweed aquaculture (and wild harvesting) and to bring projects to commercialization.
- Pilot trials involving national agencies and regulatory bodies and assessment of the economic feasibility of seaweed aquaculture.

Key stakeholders involved in the development of the Irish seaweed aquaculture industry include:

- **BIM and DAFM** (Section 6.2.3).
- **The Sea-Fisheries Protection Authority (SFPA**): An independent statutory agency established in 2007 under the provisions of the Sea-Fisheries and Maritime Jurisdiction Act of 2006. A principle role for SFPA is securing compliance with sea-fisheries conservation and seafood safety legislation. The bulk of this function involves verification of the compliance by food business operators with the relevant safety requirements, through a program of official controls, including inspections, audits, monitoring, sampling and analysis. The official controls also entail direct involvement in specific monitoring programs in shellfish production areas. SFPA conservation controls include the rational management of mussel seed harvesting and ensuring compliance with minimum size requirements for certain species. In addition to protection of consumer health, SFPA ensures consumers' interests through verification of accurate labeling of seafood produced and marketed in Ireland.
- **The Marine Institute:** As Ireland's national marine R&D agency, the Marine Institute carries out a number of specific roles in relation to aquaculture. Personnel provide statutory advice to DAFM in relation to the granting of aquaculture licenses and provide keys inputs to SFPA. The Institute carries out research and supports RTDI (research, technology, development and innovation) activity in the aquaculture sector under the Marine Research Measure of the NDP. It collaborates with BIM and Taighde Mara in many areas of aquaculture, including the planning of research programs, quality schemes and the work of the Coordinated Local Aquaculture Management Systems (CLAMS) process in selected bays nationwide.
- **Údarás na Gaeltachta:** This regional development agency brings an integrated approach to the development of aquaculture within each Gaeltacht area. The agency provides support to new entrants and to expanding or diversifying aquaculturists. A broad range of support measures are available depending on the client's needs. Financial support is usually by way of grant aid for capital, training and research and development and may also include investment by means of preference or redeemable shares depending on a project's financing requirements.
- **Universities and institutes of technology** have played a major role in the development of seaweed aquaculture. Scientific expertise on seaweed research and application of novel developments with respect to seaweed aquaculture are mainly centered at universities, whereas engineering and management knowledge derives predominantly from institutes of technology. Among the universities, the major center of expertise for seaweed research is the Martin Ryan Institute of the National University of Ireland, Galway, including the Irish Seaweed Centre. Basic and applied research includes genetic studies, seaweed physiology and ecology, and aquaculture studies.

- **Enterprise Ireland:** This government agency administers and promotes a number of industry support measures that are grant aided under the industry RTDI Measure and the NDP Productive Sector Operational Program.

In addition, integration of the expertise of other industries and sectors has been important during the development of the seaweed aquaculture industry. Valuable practical expertise is available from fishermen and aquaculturists, including knowledge of installing and maintaining moorings and aquaculture structures, rope work, boat handling, and local conditions of bays (e.g., site exposure, tidal currents, substratum, benthic flora and fauna). In addition, there are many service companies in Ireland that offer services relevant to seaweed aquaculture, including physical, chemical and biological surveys, environmental impact assessments, project planning and management, financial projection, and licenses preparation and submission. Moreover, the Irish seaweed wild harvest industry has accumulated extensive expertise in product development in different sectors (e.g. agriculture/horticulture, cosmetics).

6.2.7 Coastal Zone management plans

The CLAMS process is a nationwide initiative to manage the development of aquaculture operations in bays and inshore waters at a local level. The process evolved from the Single Bay Management, which was initially introduced as an initiative for coordinated salmon farm management to efficiently introduce lice control on farmed fish. CLAMS incorporates and builds upon the Single Bay Management concept of embracing the interest of other groups using bays and inshore waters and integrates CZM Policy and County Development Plans. CLAMS provides a comprehensive compilation of relevant data of a bay (hydrophysical characteristics, aquaculture operation data, infrastructure, socio–demographic data, etc.), which allows a holistic approach to coastal management. CLAMS has proved to be successful in bringing together different interest groups and exchanging information, thereby increasing mutual acceptance and coordinating activities.

6.2.8 Species present

All of the candidate seaweed species for aquaculture in Ireland are native species.

6.2.9 Biophysical characteristics

For the selection of the most appropriate seaweed aquaculture sites, two key areas of consideration must be balanced: suitability of a site with respect to requirements of the target seaweed species; and feasibility of aquaculture development with respect to availability of space and competition with other interest groups and coastal resource uses (e.g., shellfish and finfish farming, fishing, shipping, yachting, tourism, conservation). Several other criteria have to be met for selection of an aquaculture site with respect to logistical operation of a farm. These criteria include exposure of a site, pier access, access to the hinterland and other activities in the potential area.

As discussed in Section 6.1, a project led by BIM aimed to farm three commercially important species, *Palmaria palmata*, *Laminaria digitata* and *Porphyra sp*. The project included a desk-based assessment of potential sites for seaweed aquaculture that showed that the highest potential for development is on the west coast of Ireland, followed by the north, southwest and south coasts. In contrast to the coast of the Irish Sea, these coasts provide:

- A large number of sheltered to semi–sheltered sea Loughs, bays, inlets and estuaries
- Good water exchange and different strength of tidal currents

- Generally unpolluted water
- Different degrees of nutrient enrichment
- On average, lower water turbidity than at the east coast due to different bottom substrata

6.2.10 Culture and processing technology

Globally, approaches to seaweed farming are varied. In Ireland there is a combination of land-based, tank-based aquaculture techniques during the seeding and nursery stage, and extensive techniques for grow-out. The grow-out approaches use low technology techniques in open water situations. Seaweed cultivation tends to operate on a batch basis. Seedlings are planted, grown for a set period and then harvested. Selected plants are then chosen to provide the next seedlings or reproductive material to continue the cultivation. The cultivation periods and duration vary, as there is a need to establish the optimal conditions at each site. The practice is well established and in need of innovations and possibly some form of mechanization.

The Seaweed Hatchery Project (BIM 2015b) identified that kelp (*Laminaria digitata*) can be farmed commercially in Ireland, but dulse (*Palmaria palmata*) and nori (*Porphyria* spp) cannot at this time. The project resulted in several publications including a manual outlining cultivation techniques for kelp (BIM 2011a) and techniques for cultivating dulse (BIM 2011c, e, f).

Kelp is currently farmed on a batch basis (Figure 19), and BIM has published a manual clearly outlining the farming process (BIM 2011a). DAFM must license all land and sea aquaculture facilities. This includes seaweed hatcheries, which also must hold an effluent discharge license obtained from the Local Authority.

Figure 19. Overview of the kelp cultivation process

Source: BIM (2011a)

Kelp seedlings must be cultured in a hatchery, which has to be located on flat, low-lying land adjacent to the sea with a low pumping head. It must have electrical power, road access and sufficient space for adequate tankage, a laboratory, an office and facilities. The kelp is seeded onto string and when grown to sufficient size is transferred to a sea-based grow-out site. Parameters for good site selection can be divided into those required for the organism to grow well, and those that make the site easy to access and work in (BIM 2011a). Economic and business factors that require consideration to ensure a seaweed aquaculture operation is viable are outlined in BIM (2011a) and BIM (2011d).

Initial seaweed aquaculture is unlikely to be at a scale sufficient to support a stand-alone processing facilities, and most companies will not have sufficient size or capacity to be vertically integrated. The early experience of the industry is that tapping into existing processing infrastructure is crucial to early success of the industry.

6.2.11 Cost/benefit analysis

It appears that seaweed can fall under a variety of registration categories, and wild harvest and cultured products are often combined, making it difficult to determine how much is produced from the aquaculture industry and its value. Also, the fresh weight of seaweed is generally 75–90 percent water and some statistics are given in wet weight. Industry statistics are expressed in dry weight, but percentage water content in dry biomass can vary considerably.

As discussed in Section 6.1, the Irish seaweed industry still primarily produces high volume, low value products. A smaller proportion does go into higher value products such as foods, cosmetics and therapies. BIM (2011b) recommends that processors move down the value chain in order to achieve higher returns from their product. To achieve this, increased automation and efficiency is required for harvesting and processing, and more sophisticated processing and packaging techniques. Reducing labor costs is considered a key driver of increased competitiveness in this sector, as well as creating a sustainable year-round supply through farming.

BIM (2011a) and BIM (2011d) outline an economic analysis and business plan for a kelp hatchery and grow-out farm. For a site that will yield 100 wet mt of kelp (equivalent to 15 mt of dried product), a hatchery and grow-out site are required totaling €306,778 ($427,251) (Table 6). Assuming a high quality end product, the estimated market value for wet product (for human consumption only) is €1/kg, and the value of bulk dried and bagged product is €10-16/($14-22)/kg. Drying costs (i.e., primary processing) have to be incurred to achieve the value of dried product. As a contracted out process, it would cost approximately €150 ($209)/dry mt of seaweed for industrial scale drying. The potential value of sales from a 100 mt seaweed facility for a high quality dried and bagged product is €150,000 ($208,906) to €240,000 ($334,249). The first year sales (conservatively) are half of the cost of the first year set-up and labor costs.

Table 6. Year One Costs of a Kelp Hatchery and Grow-Out Farm

Cultivation Phase	Category	Costs
Hatchery	Equipment	€137,650 ($191,706)
	Staff	€60,000 ($83,562)
Grow-Out	Equipment	€84,128 ($117,165)
	Staff	€25,000 ($34,818)
Total		**€306,778 ($427,251)**

Source: BIM (2011a; 2011d)

BIM has carried out several case studies and analyses show that a price of over €1 ($1.39)/kg or additional income (e.g. shellfish spat collection) is required to be profitable. The profit is realized in a short time window (spring–summer) and is not year-round.

Table 7. Sensitivity Analysis: 3-Year Break-even Point for *Laminaria digitata* (Fresh Weight) under Case Studies 1-4

Case Study	Description	Break-even price €/$
1	Seaweed hatchery and grow-out farm	€2.15/$2.99
2	Seaweed hatchery and existing mussel site	€1.65/$2.30
3	Seaweed and scallop hatchery and grow-out farm	€1.63/$2.27
4	Seaweed and scallop hatchery and existing mussel site	€1.12/$1.56

Source: BIM (2011a)

6.3 Relevancy to Alaska Mariculture Initiative

Strategic planning

Following the National Seaweed Forum in 2000, a national seaweed aquaculture strategy was developed that outlined a 10-year industry development plan. This strategy was consistently implemented within the NDP and SeaChange. This high level of strategic planning and coordination has ensured sustained focus on industry development for more than a decade.

The National Seaweed Forum also identified some other activities that appear to have been pivotal in successful industry development and those with the greatest impact include: the appointment of a regionally based Seaweed Development Officer by BIM to promote and assist in the development of seaweed aquaculture (and wild harvesting) and to bring projects to commercialization; and pilot trials involving state agencies and regulatory bodies and assessment of the economic feasibility of seaweed aquaculture.

Cooperative farming

The Roaring Water Bay cooperative was not enduring. However, the co–op approach is advantageous in several aspects:

- Capital investment for business development (and consequently risk) is distributed among the shareholders.
- Expertise of different areas is brought in by the diversity of professions of the members and can cover a range of essential functions, such as research, marketing and sales, and administration.
- Labor input for the individual on average is minor, because it is divided between several members (part-time activity and "giving up the day job" is not necessary during the infancy of the business)
- During labor-intensive periods (bringing out seed stock, harvesting, processing) additional labor can be recruited more easily.

This example of a cooperative may serve as a model for small Alaskan communities, where members are willing to engage in additional activities to increase their income or are interested in aquaculture but are not capable of taking on a financial risk to set up a business on their own.

It is also noteworthy that Ocean Approved, a seaweed cultivation enterprise based in Maine, has developed a seaweed cultivation manual which may be helpful to Alaska as it develops its industry.

The manual is entitled "Kelp Farming Manual: A Guide to the Processes, Techniques, and Equipment for Farming Kelp in New England Waters" (Ocean Approved 2013).

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7 Case study: Spanish Mussels

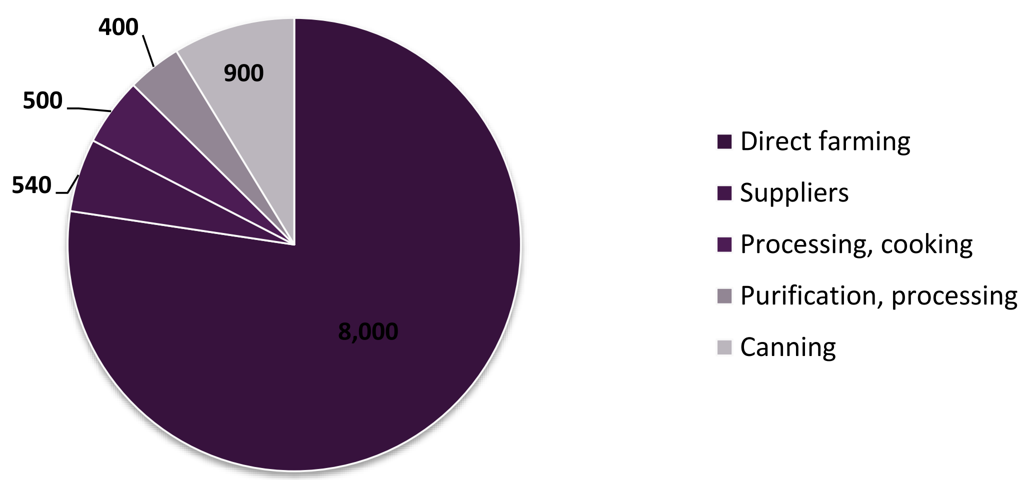
7.1 Overview of the current status of the industry and its current economic impact

Figure 20. Mussel rafts and Google Earth image of mussel rafts in Ria Arousa

Source: Regulatory Council of the Galician Mussel 2012; Google Earth 2015

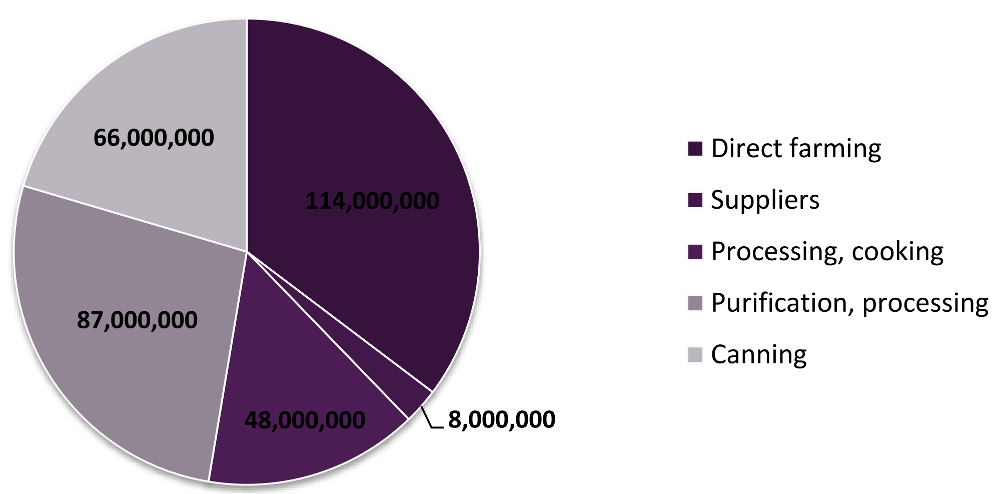
The European country of Spain, which is composed of 17 autonomous regions like U.S. States, produces most of its mussels from the autonomous region called Galicia in northwest Spain (Figure 23). Galician mussels (*Mytilus galloprovincialis*) are some of the first and still most important shellfish aquaculture crops in the world, occurring in very productive waters in the protected coastal inlets, or rias. The mussel raft aquaculture industry in northwest Spain grows an annual crop of over 200,000 mt, and is the second largest mussel farming area in the world behind China. The industry is composed of approximately 3,300 rafts (Figure 20) with a production as high as 75 tons per raft. Production has maximized since the early 1990s, and there have been no additional rafts or lease sites since 1976. The economic impact of mussel aquaculture, in the growing, services, and processing sectors, in terms of jobs (Figure 21) and value (Figure 22) makes it a very valuable component of the sustainable economic activity in the Galician region (Franco Leis 2006) According to 2013 records, Galicia hosts more than 2,000 small and middle size companies in the sector, which employs 11,500 people or 17.5 percent of the region's working age population. Their output reached 227,228 mt in 2012, equivalent to 40 percent of the entire mussel production in the European Union and 15 percent of the world's mussel production (Jimenz 2014). Spain had a high per capita consumption of seafood, about 95 lb per year, and while three-quarters of the mussels are consumed in Spain, there are still imports from other countries, notably Chilean frozen mussels. The large scale production of mussels from rafts in an organized and efficient system involving designated growing areas (polygons); an organized mussel producing sector with regional management, a long history of profitable raft cultivation success involving efficient vessels, machinery, processing, and marketing; and an extensive public health and red tide monitoring system make mussel mariculture in Galicia a good model for Alaska.

Figure 21. Jobs in the mussel farming, supplying, processing, and canning sectors in Spain, 2006



Source: Franco Leis, 2006

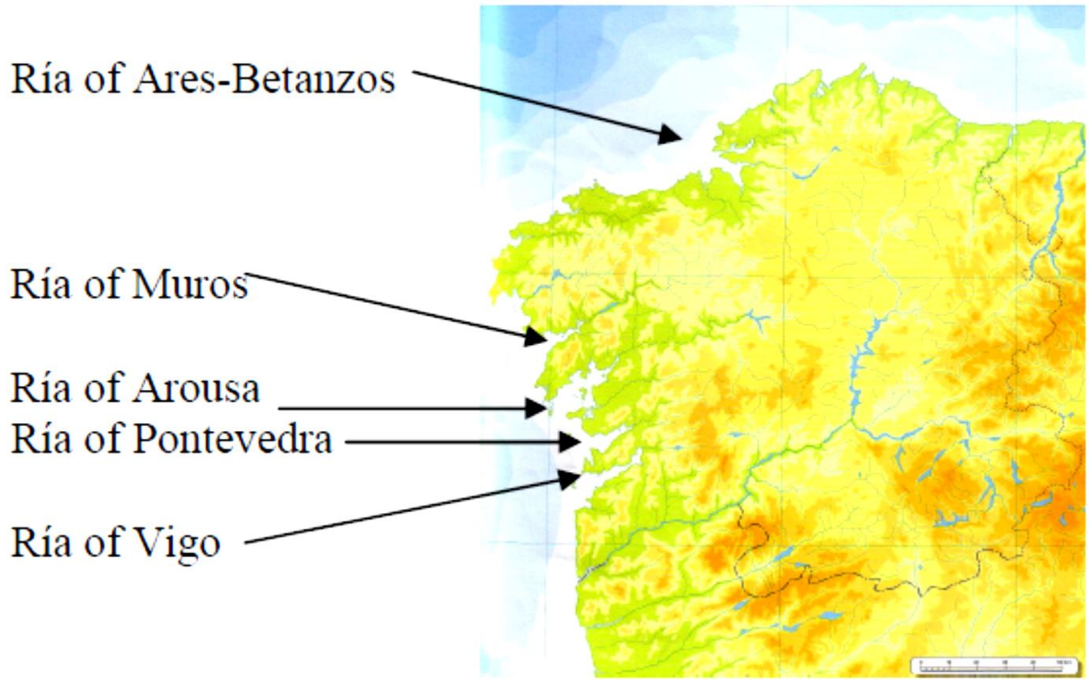
Figure 22. Value of mussel aquaculture in the farming and processing sectors (Euros, 2006)



Source: Franco Leis, 2006
2006 euro exchange 1.256316+1 USD

Mussel processing in Spain can be seen in the context of the Europe's largest fish processing industry (2012 turnover of $5 billion), of which 350,000 mt, worth $2.6 billion is the canning of fish such as tuna, sardines, anchovies and shellfish (Eurofish 2015).

Figure 23. Location of mussel rafts in the Spanish Rias



Source: Miguez et al, 2009

Native species: in Spain, natural spatfall of *Mytulis galloprovincialis* on the rocks in Galicia provides most of the mussel seed used in the grow-out. The use of this natural spatfall, like in New Zealand and Prince Edward Island (PEI), saves on the cost of obtaining seed from hatcheries and provides a locally adapted, vigorous strain to be cultivated.

Preparation of the workforce: A Ph.D. in aquaculture is offered at the University of Barcelona in Spain. An M.S. in Aquaculture and Fisheries, Marine Resources and Sustainability is offered at the University of Cadiz in Spain. An M.S. in Mariculture is offered at the University of las Palmas de Gran Canaria in the Canary Islands. Marine sciences and oceanography degrees are also offered at those institutions. Fees are about $664 a year. Vocational training in all trades in Spain occurs as part of the Vocational Education and Training program, which occurs throughout Europe. Several Professional Training career programs include aquaculture studies, included in the "Professional Maritime-Fishing Family" and two training cycles are taught, each lasting two years: Operations Technician in Aquatic Cultivation, and Aquatic Production Technician (FAO 2014).

Regulatory climate: Mussel raft aquaculture is at an institutional equilibrium in Spain, as a result of over four decades of production in the Galician rias, and benefiting from the establishment of aquaculture parks and a uniform regulatory structure resulting in a maximum raft size, rope length and management by the autonomous regions (i.e. Xunata Galicia). Challenges of maintaining the industry in light of urbanization and climate change are being addressed in the context of integrated CZM.

7.2 History and growth of the industry

Mussel consumption was recorded back to the fifth century by the Galicia Celtic tribes and interior to the Roman Galicia (Regulatory Council of the Galician Mussel 2012). Mussel raft culture originated in the Mediterranean region of Spain (Barcelona) in the early twentieth century. The number of floating raft farms established in the Galician rıas experienced growth from 10 rafts in 1946 to over 3,300 in 1997 (Table 8).

Table 8. Number of mussel rafts from 1946-1997 in NW Spain

Year	Number of Rafts
1946	10
1956	410
1960	1,099
1975	3,134
1997	3,337

Source: Miguez et al., 2009

During this 50-year period, there were a large number of lease areas granted, mostly to family entities which owned one or two rafts each. In 1973, two key companies, Finistere Mar and Tinomenor, SL, and other pioneering companies soon to follow, developed the successful production model which continues to today (FAO 2014). The number of rafts has stayed the same for nearly 40 years, with raft size increasing from about 2,691 to 5,382 square feet, and culture ropes from 33 to 39 feet long through the 1990s. Permits only allow one mussel raft on a 328x328 ft. plot, and ropes no longer than 39 feet. Since production has reached its maximum levels in Spain, some of the original companies like Paquito SL have established operations in Chile, where they grow 8,000–10,000 tons of mussels per year (with a production capacity of 30,000 tons) and export frozen mussel meat and mussels on the half shell.

7.2.1 Investment climate

The vessels cost about $797,500 (Figure 24). Each vessel can tend six or seven rafts, which cost about $1.33 million each (including moorings and ropes), with a total capital investment of about $1.6 million, of which 50 percent is subsidized by the government.

Figure 24. A mussel harvest vessel next to a 20 x 27 m mussel raft in Ria Muros

Source: Carter Newell photo, 2013

Many of the farming and processing companies which found maximum production in Galicia and saw a rising cost in raw materials (mussels) for processing have moved their investments overseas to Chile where frozen mussel exports now exceed those of Spain. In 2014, Chile exported $154 million in just the first 8 months. As of 2012, the Chilean industry, in which many Spanish mussel companies are participating, is now modernizing to utilize state of the art New Zealand mussel cultivation techniques (see New Zealand Mussel case study, Section 9). Investment in the processing sector goes hand in hand with other seafood such as tuna, mackerel, squid, clams, and other seafood products harvested in Spain and imported.

7.2.2 Private and public investment and capitalization

Due to the lack of expansion of the mussel industry in the autonomous region of Galicia, there has been little public and private investment and capitalization. However, if there is need for a new raft or a new vessel, companies are eligible for a 50 percent subsidy on capital equipment (Chicolino 2014). Much of the investment and capitalization has occurred in Chile where the industry is currently expanding. There is rapid and steady growth of inland aquaculture, however, (trout, etc.) as well as new species (such as abalone) and finfish aquaculture where investment is occurring, however.

7.2.3 Lead state agency support

The role of the Ministry of Agriculture, Food and Environment is the coordination and representation of international organizations, and the General Secretariat of Fisheries (SGP) cooperates with the Autonomous Communities (i.e. Galicia) in aquaculture.

The Spanish Fisheries Observatory Foundation developed an aquaculture strategic plan in cooperation with industry experts, the autonomous communities, and major produce organizations (Towers 2015). The main goals, proposed for 8 strategic lines, 35 national activities, and 335 actions, had the following goals:

Within each of the autonomous regions, a number of mussel sector associations provide the lead in mussel R&D issues, related not only to product quality, marketing, and food safety, but also to sustainability. The current structure of the producers of mussels in Galicia consists mainly of three associations representing 97 percent of producers:

- Mussel Producers Organisation of Galicia. Opp-18, part of the European Association of Producers Organizations
- the Galician Mussel Association
- Federation of Associations of North Arosa Mussel

Representing the whole region is the Mussel Regulating Council of Galicia, composed of representatives of producers and marketers of mussels. The main role of the council is to promote the Galician mussel.

In the Catalonia area, there are four additional producer associations: Producers Association Bay Alfacs; Producers Association Bay of Fangar; Producers Association Mollusks Gulf of Sant Jordi; and Union of Producers of molluscs of the Delta del Ebro.

In Valencia there is an additional association of producers of mussels, the Mejillonera Union of Puerto de Valencia.

7.2.4 Level of coordinated research and development

In 2002 the Spanish Aquaculture Observatory was created with the overall aim of providing a platform for the development of aquaculture in Spain, both in relation to scientific research, technological development and innovation including public and private entities.

In Spain the funding of scientific research and development related to aquaculture is provided by state, regional, community, and business entities. Different funders of scientific research and development include:

- Interministerial Commission on Science and Technology
- Centre for the Development of Industrial Technology
- Departments of the Autonomous Communities
- General Secretariat for Maritime Fisheries (SGPM)

The SGPM, through the National Advisory Board for Mariculture, has funded research projects within the framework of National Plans for Mariculture. The National Plans provided support in the areas of research, development and innovation, and are considered important for the harmonious development of Spanish aquaculture. Since 1988 a total of 112 plans have been developed, involving all the autonomous communities, 56 research centers and more than 40 companies. Public Research Centers that operate fully or partially in the field of marine aquaculture are distributed throughout the Spanish territory. Some of these centers are:

- Central Veterinary Laboratory, which is the National Reference Laboratory for Fish Diseases.
- Institute of Marine Research, which is the National Reference Laboratory for Mollusc Diseases.
- Centre for Marine Research
- Aquaculture Institute of Torre de la Sal
- Institute for Agricultural and Fisheries Research and Training
- Institute of Food Research and Technology
- Canarian Institute of Marine Sciences
- Spanish Institute of Oceanography
- Murciano Research Institute and Agricultural Development and Food
- Research Laboratory of Marine and Aquaculture
- Instituto Investigaciones Marina de Vigo

7.2.5 Regulatory process

At the national level, the Law on Marine Aquaculture (Law 23/84) and the Law of the Sea (Law 22/88) apply to Spanish mussel farming. Starting with the Royal Order of 1930 allowing for lease areas and ending with a ban on more lease sites in 1976, and regulations in 1986 specifying limits to raft specifications, Spain has a long period of legislative history (Miguez at al. 2009). The Orders from the Ministry of Commerce of 1963 set in place a group of designated cultivation areas that organized a total of 4,750 anchoring points particularly for the establishment of raft cultivation. In the 1990s, most of the regulatory authority was granted to the autonomous regions. In general, most of the regulation, permitting and enforcement occurs at the autonomous level, through the Xunta de Galicia. Mussel raft size, numbers of rafts per concession, and rope length are strictly regulated in Spain.

7.2.6 Development strategies and key stakeholders involved

The SGPM has prepared the "National Strategic Plan for Fisheries" (*Plan Estratégico Nacional en materia pesquera*), in agreement with the mandate of the new European Fund for Fisheries 2007–2013 and the Common Fisheries Policy. Spain established the following strategic priorities for the development of aquaculture throughout from 2007–2013:

- Species diversification
- Supply of the market (increase in the production of species with good market potential)
- Establishment of methods or means of aquaculture exploitation that reduce adverse consequences or improve positive effects on the environment
- Support to traditional aquaculture activities
- Public health measures
- Promotion of specific actions on the market
- Promotion of quality measures
- Socioeconomic measures
- Animal health measures

Mussel industry groups are also currently engaged in region of origin labeling, public health quality control, sustainability and marketing.

Stakeholders are being engaged in integrated CZM plans (see section 7.2.7) but since most of the development of the existing mussel raft aquaculture parks, or polygons, occurred in the 1960s, development strategies have not been the focus. In response to stagnant growth of the sector, the Multiannual Strategic Plan for Spanish Aquaculture has recently been prepared (Towers 2014).

Multiannual Strategic Plan for Spanish Aquaculture

In order to try and help the further development of Spain's aquaculture sector, the National Marine Advisory Board, the National Advisory Board of Continental Growers, and the Inland Marine Crops recently approved the Multiannual Strategic Plan for Spanish Aquaculture 2014–2020, which was produced as part of the requirement Member States have to the EU, through the Ministry of Agriculture, Food and Environment.

The General Secretariat of Fisheries commissioned the Spanish Aquaculture Observatory Foundation to help develop the Strategic Plan along with the integrated contributions of all the Autonomous Communities (coastal and inland), as well as experts in different areas of aquaculture. It also contained collaborated efforts and views of major producer organizations and scientific/technical aquaculture experts.The plan aims to set the strategic directions for the continuation and support of the industry whilst also analyzing the current and future growth prospects of the aquaculture sector. The plan outlines 4 strategic directions:

- The simplification and standardization of the legal and administrative framework and the strengthening of the representativeness of the sector in order to provide greater legal certainty for producers and to *reduce the current wait for the granting of new authorizations*.

- The increase of aquaculture production and its economic value from improving sectorial planning through the use of *integrated CZM* and the selection of new areas of interest.
- Strengthening the competitiveness of the sector, which can be achieved through *innovation, research and development*, better *health management* and closer relations between the *scientific community* and the industry.
- Reinforcing aspects related to the *processing and marketing* of aquaculture products through innovation, advocacy and support for producer organizations.

In order to develop these four objectives, eight strategic lines, which include 37 strategic national activities and up to 335 actions, have been set up by the autonomous communities *through regional strategic planning*. According to the vision of the plan, the Spanish aquaculture sector could continue to lead aquaculture production in the EU until 2030, strengthening its weight economically and creating employment in coastal areas. At the same time, the sector will also guarantee consumers the highest quality products through sustainable methods. The plan will now be submitted to the European Commission in the coming months for analysis.

Javier Ojeda, Business Association of Marine Aquaculture Producers of Spain commented that despite the government's belief in the plan, Spanish aquaculture producers are skeptical on the willingness of the public administrations to properly implement it (Towers 2015):

> Firstly, some of the main public offices that help to shape and control aquaculture, such as environmental, harbor authorities and social security, amongst others, have not been involved in the plan and many probably do not even know of its existence and therefore will not feel obliged to implement it. Secondly, many regional aquaculture competent authorities seem to have lost faith in the industry and have given in with respect to other public departments and industries.

7.2.7 Coastal zone management plans

Spain's Integrated CZM Strategy sets out the following strategic objectives:

1. To improve the environmental, economic and social conditions of the coastal zone and ensure use of its resources in accordance with the principles of sustainable development.
2. To review and adapt the management and decision-making model in order to incorporate the principles of Integrated CZM.

The Spanish Strategy for Coastal Sustainability (SCS) was an initiative aimed at implementing coastal interventions under the principles of Integrated Coastal Zone Management (ICZM) and improving the state of the coast at the Spanish national level. The SCS, promoted by the Spanish Ministry of the Environment, started as a broad national strategy in 2005 and was finally delivered as a coastal planning instrument at the regional level in late 2007, designed to address coastal policies within the Spanish maritime–terrestrial public domain (MTPD). The initiative was triggered by the increasing pressure on the coastal zone and its preparation was supported by different European initiatives, first of all the European Recommendation on ICZM (413/2002/EC), while taking into consideration the future requirements of the Mediterranean Protocol on ICZM of the Barcelona Convention, signed in February 2008. Technically, the preparation of the SCS included four steps: (i) a Stakeholder Identification and Engagement process, including a stocktaking of the laws and regulations, (ii) the design of a broad Strategic Framework for the Spanish coastal zone, including a set of specific objectives and the instruments for its implementation, (iii) the signature of cooperation agreements for ICZM between the central government and the regions, and (iv) a detailed Technical Diagnosis at the local scale, designed to address future coastal interventions in the maritime–terrestrial public domain and its areas of influence (Sano et al. 2010). Responses dealing with the major threats of urbanization, water quality degradation, climate change, increased tourism were hampered by a lack of a clear legal and administrative framework for overlapping jurisdictions. A first step was the prioritization of areas that needed interventions.

Aquaculture "polygons", a long historical feature of the Galician Coast, have long been accepted by the public. According to Miguez et al. 2009, "the institutional foundations for the production of mussels in the Galician rias since the last quarter of the 20th century has set up a scenario of institutional equilibrium, in which there has not been any new licenses granted for floating raft culture and in which a winning coalition has been organized that maintains the status quo".

The Pyrenees Climate Change Observatory (OPCC) maintains a website devoted to gathering and disseminating information regarding climate change. One recent study discussed on the site is the Atlantic Network for Coastal Risks Management (ANCORIM) project (OPCC 2015). The ANCORIM Project includes four EU countries (Ireland, Spain, Portugal and France), and is designed to help coastal regions in the Atlantic Arch development management and action plans in response to climate change. OPCC has funded five case studies, one of which is in the Ria de Vigo. In this case study, the mussel rafts in Vigo were examined relative to coastal risks due to other uses in the ria, including sewage plants, port activities, tourism, shipping, fish and shellfish harvesting and processing, recreational fishing and boating, and locations of urban areas. In a GIS context, a suitability index was developed for the mussel rafts using a hierarchical weighted model (ANCORIM, 2012).

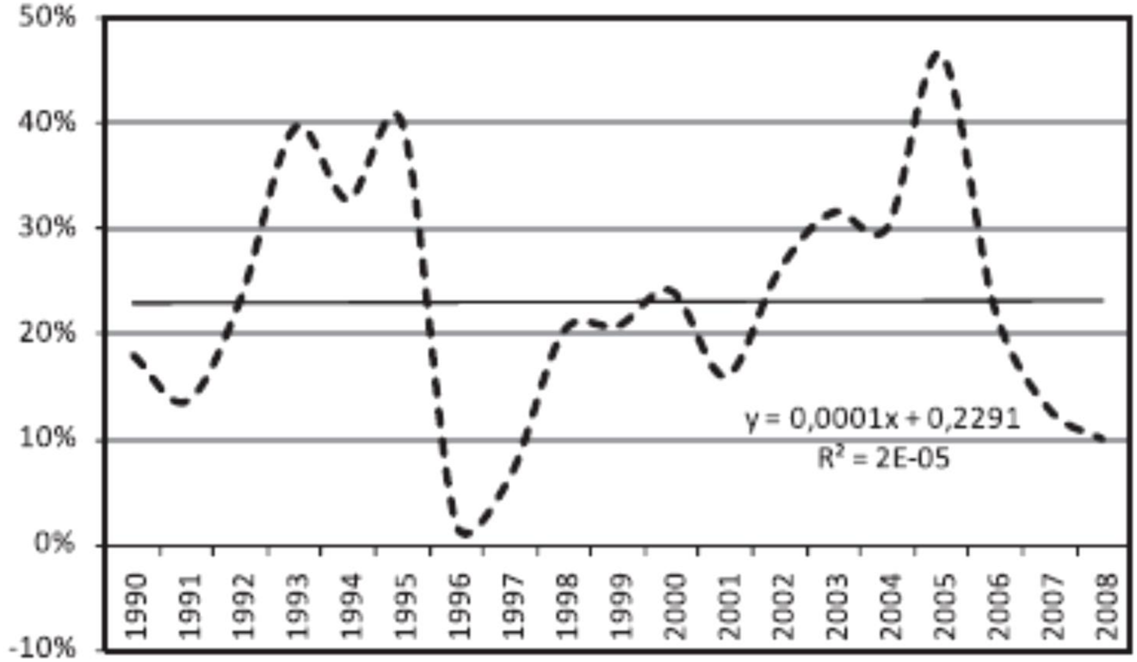
7.2.8 Species present

The native Mediterranean mussel, *Mytilus galloprovincialis* is cultured in Spain.

7.2.9 Biophysical characteristics

The Galician Rias Ponteverda, Arosa, Vigo and Muros have a surface area of 46-88 mi^2, a volume of about 720-960 mi^3 a water temperature range of 12-18 °C, high chlorophyll levels and a salinity range of 30-36 ppt (Martinez-Urtaza et al. 2008) which is ideal for mussel growth. The shallow (131-213 ft depth) rias experience wind driven upwelling of inorganic nutrients from deeper shelf waters from March to October, as well as nutrients from fresh water runoff, resulting in phytoplankton blooms, and making the rias ideal locations for shellfish aquaculture. The geomorphology of the rias also provides relatively protected locations for mussel farming in comparison to the open ocean. However, the rich nutrients and upwelling may also result in blooms of toxic algae, especially *Dinophysis*, causing DSP (and occasionally PSP) ,closing the harvest for extended periods, although the industry has had some flexibility in marketing the mussels after the closure ends (Rodriguez et al. 2011). In the past two years, DSP closures have affected over 1/3 of the growing areas in Spain. In 2013, Galician producers were concerned that shutting down more than 80 percent of mussel platforms because of the presence of red tide produced less availability of the products for the Italian and French markets. Following that, when the platforms reopened, an oversupply resulted in a drop in prices. In 2014, an August closure of 2/3 the mussel parks, or polygons led the Xunta Galicia to give $2 million to the mussel producers to soften their losses. Historical levels of incidence of toxic algae bloom closures in Galicia are presented in Figure 25.

Figure 25. Percentage of time that mussel closures, due mostly to DSP, occurred in the mussel growing areas of Galicia from 1990-2008



Source: Rodriguez et al. 2011

7.2.10 Culture and processing technology

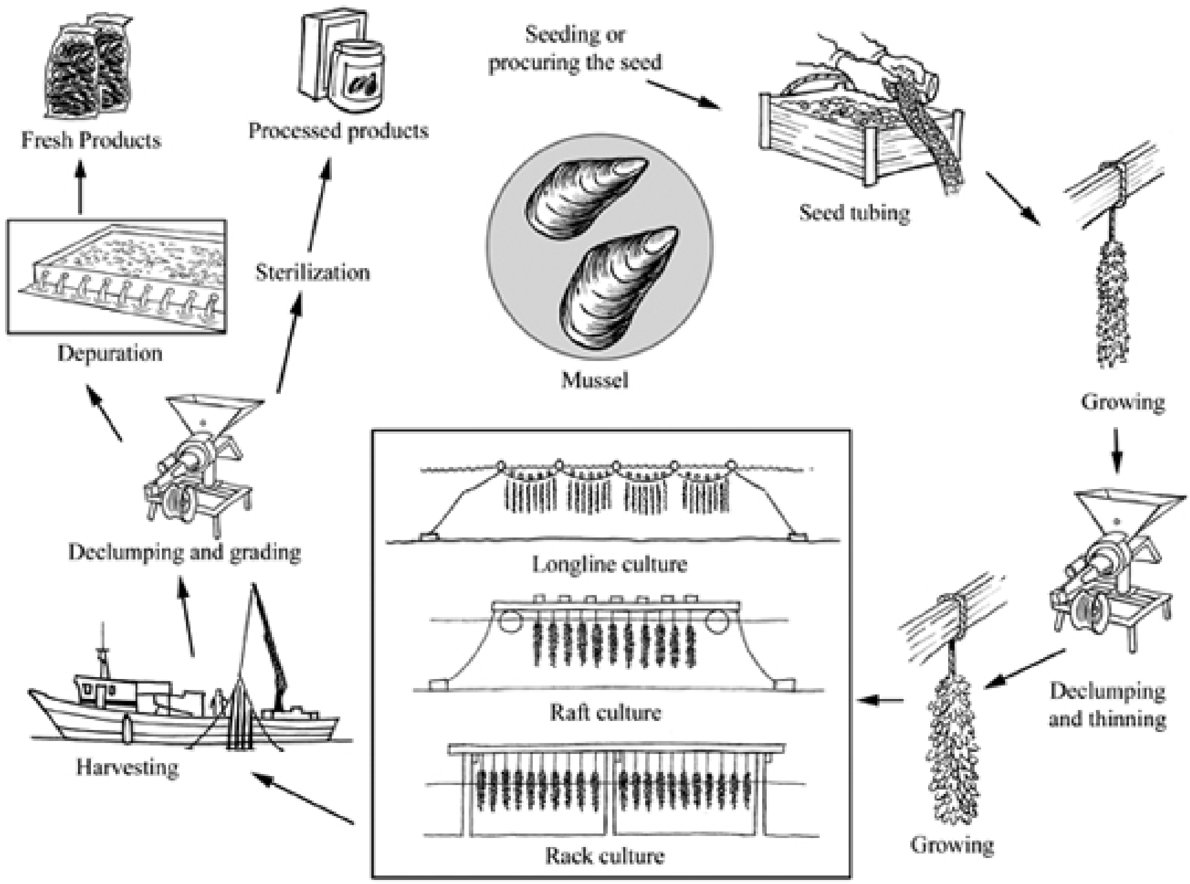
The mussel farmers collect the mussel seed from the coastal rocks. Afterwards, the seed are attached to thick ropes made from discarded fishing nets (Figure 26) using a hydraulic "retubing" machine with a small mesh biodegradable sock material. The ropes are hung from the rafts for about 4–6 months. After this period of time, these ropes are brought back up to the surface, graded, and retubed onto grow-out ropes that contain a less-dense mussel concentration in order for the mussels to grow about a year and to a market size of 75-100 mm.

Figure 26. Mussel Ropes, Retubing Machine, and Bulk Bags

Source: Carter Newell photos, 2015

The standard Spanish mussel raft has an area of 5,382 ft^2, and has 500 ropes 39 ft long each (Figueiras et al. 2002). The rafts are composed of local eucalyptus wood and large steel floats, and assembled at the rias where they are used. Often any given raft will have about 1/3 seed ropes and 2/3 grow-out ropes at any given time. The harvesting and processing occurs on 66-82 ft specialized vessels. Mussels are harvested using the basket and brush stripper, and dumped on a net which is lifted up to feed a conveyor which goes into a brush declumping and grading machine. Mussels are landed in 2,205 lb bulk bags, and smaller seed mussels are attached to the ropes by holding the bulk bags over the retubing machine (Figure 26). The mussels are sold at about $0.85 a lb to depuration plants since the growing areas are not approved due to bacteriological classifications, and then sold in Spain (over 75 percent), and processed in canneries, freezing plants and for other value added products. The production cycle is summarized in Figure 27.

Figure 27. Mussel aquaculture cycle on rafts in Spain



Source: FAO.

The 66-82 ft boats (Figure 28) incorporate state of the art mussel harvesting and processing equipment, supplied by Talleres Aguin (aguin@aguin.com) and ropes, pegs, nets, and biodegradable cotton are supplied by J.J. Chicolino (Chicolino 2014).

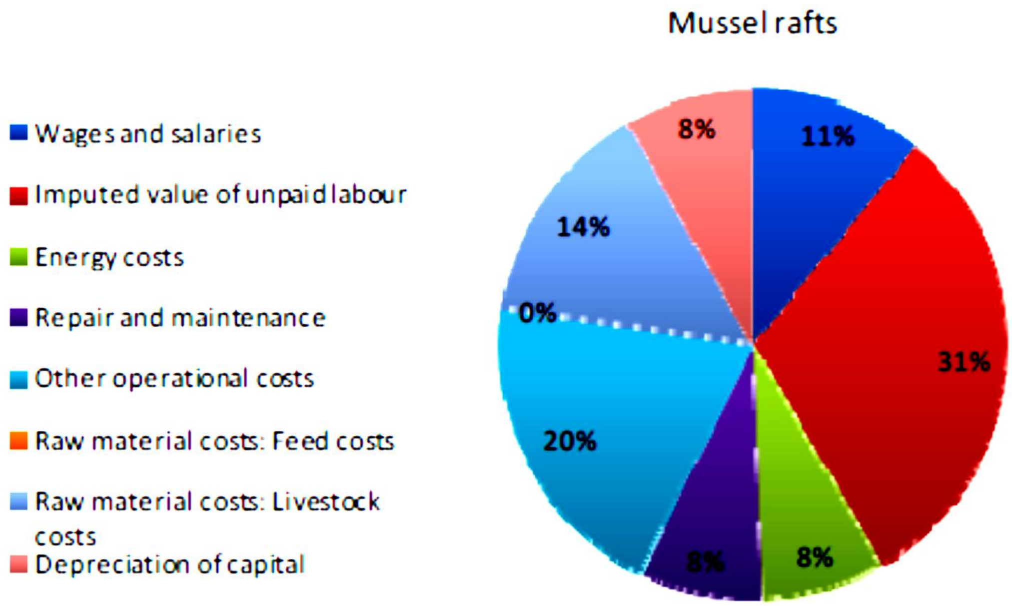
Figure 28. Mussel harvest vessel in Spain

Source: Carter Newell photo, 2013

7.2.11 Cost/benefit analysis

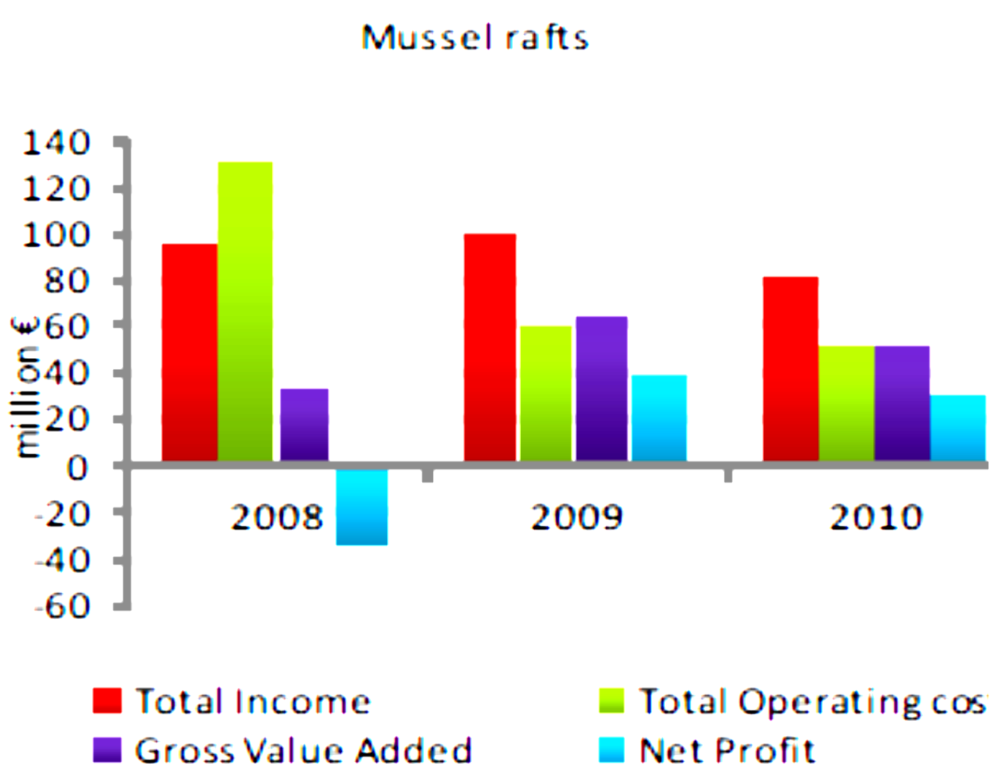
The mussel raft cultivation sector, which is comprised mostly of family entities with 1-2 rafts each, has the unusual cost structure where 31 percent of the expenses are the value of upaid labor (Figure 29). Most years are profitable (Figure 30), although occurrences of toxic algal blooms can reduce marketing during periods when prices or demand from other european countires are high.

Figure 29. Spanish mussel raft expenses



Source: STECF, 2013

Figure 30. Profit/loss of Mussel Raft Industry in Spain (2008-2010)



Source: STECF, 2013
2010 euro exchange rate 1.327386=1 USD

7.3 Relevancy to Alaska Mariculture Initiative

Galician mussel mariculture offers a valuable case study to the AMI because it represents a world leader in mussel production. The technology of raft cultivation is relevant to Alaska where predation of sea ducks and sea otters would require a protected (i.e. predator nets) culture system, and the system is in institutional equilibrium. It is also relevant because Spain, like Alaska, has huge wild fisheries and an extensive seafood processing industry and therefore has the advantage of private infrastructure which could be using in aquaculture production, processing, marketing and distribution.

The most relevant aspects of this case study to Alaska are the culture technology, the economic impact, the existence of large wild fishery and related production and processing infrastructure, the establishment of parks for large scale development, and the recent efforts of a strategic plan (and its potential pitfalls). The persistence of small, family owned businesses is also an interesting business model. This is facilitated by industries supporting seed gathering, mussel processing, depuration, and canning, allowing for growers to not have to be vertically intergrated. Also, integration into CZM can be a model (see section 7.2.7). The consumption of most of the mussel production within Spain is not, however, applicable to Alaska, where an export model would probably be more appropriate. The recent development of an aquaculture plan for Spain, and some of its potential pitfalls by not engaging all of the stakeholders in its early development, are also relevant (see section 7.2.6).

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8 Case study: Prince Edward Island, Canada mussels *(Mytilus edulis)*

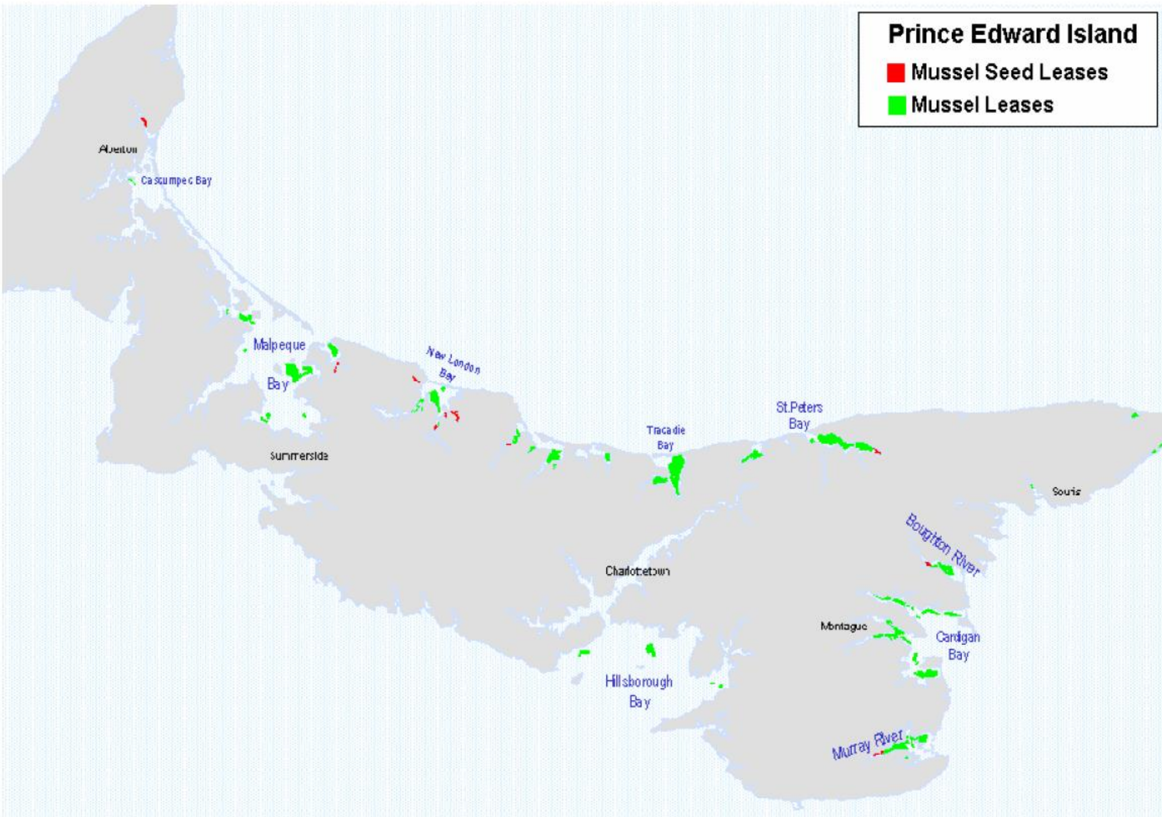
8.1 Overview of the current status of the industry and its current economic impact

Mussel culture occurs in many of the rivers and estuaries in Prince Edward Island (PEI) (Figure 31). The majority of the culture areas are concentrated along the Northern and Eastern coasts. Mussel leases account for a total of 10,932 acres. In 2013, PEI produced 22.9 million lb of mussels, with a farm gate value of $29.43 million (Fisheries & Oceans Canada 2013). Prince Edward Island's aquaculture industry contributes significantly to the PEI tax base, contributing $24 million in gross value added to local economies annually. The industry is also a vital component of the Island economy providing approximately 2,500 direct and indirect jobs. Many of these jobs provide year-round employment in local rural communities. In fact, in PEI's aquaculture industry paid approximately $10.7 million in salaries, wages and employer contributions. PEI's annual mussel exports are $29.1 million (Prince Edward Island Aquaculture Alliance 2015). Figures from 2010 gave mussel farm gate value at $29.3 million, processing at $26.8 million, with a total value of $56.1 million (Prince Edward Island Dept. of Fisheries, Aquaculture & Rural Development 2010).

In 2006, the Policy and Economics Branch, Gulf Region Department of Fisheries and Oceans (DFO) Moncton, New Brunswick, published a study of the economics of the PEI mussel industry (Fisheries & Oceans Canada 2006). During that period, when harvest volumes were at their highest, the activities generated over $6.2 million in annual tax revenues (Table 9).The socioeconomic impact of all of Canadian aquaculture was published in 2013 (Gardner Pinfold Consultants Inc. 2013). Figures from 2010 showed that for total aquaculture in PEI (of which mussels is the majority of economic activity), about $41.5 million (direct) resulted in an additional $11.5 million (indirect) and $10.7 million (induced), for a total of $63 million in economic activity (Table 10).

Industry growth was aided by a supportive federal leasing program, technical support from provincial, university and federal scientists, and shellfish research and technology loans and grants, which financed early development of numerous farms around the island.

Figure 31. Mussel lease sites and mussel seed leases in PEI



Source: Fisheries and Oceans Canada, 2006.

Table 9. 2006 Aquaculture Impact of the Mussel industry in PEI

Category	Amount
Gross Production (Sales) or Expenditure Generated (million $)	94.09
Employment in Person-Years	548.64
Gross Domestic Product at Market Price (million $)	32.01
Federal Government Tax Revenues (million $)	3.44
Provincial Government Tax Revenues (million $)	0.31

Source: An Economic Analysis of the Mussel Industry in Prince Edward Island Gulf Region, DFO, Moncton, N.B. 2006.

Table 10. 2010 Economic Impacts of Aquaculture in the Canadian Maritimes

	Newfoundland and Labrador	Prince Edward Island	Nova Scotia	New Brunswick
	Value in $000s except Jobs (Full Time Equivalent [FTE])			
Value of Output	**112,902**	**56,151**	**44,400**	**258,541**
GDP				
Direct	45,472	41,570	16,492	46,494
Indirect	32,079	11,562	23,410	46,361
Induced	11,685	10,853	10,099	26,187
Total	**89,237**	**63,986**	**50,002**	**119,040**
Jobs (FTE)				
Direct	619	867	199	1,454
Indirect	345	188	385	718
Induced	131	138	129	326
Total	**1,096**	**1,193**	**713**	**2,498**
Labour income				
Direct	17,817	24,103	6,229	43,445
Indirect	21,067	7,419	16,270	30,497
Induced	6,029	6,064	5,695	14,762
Total	**44,912**	**37,586**	**28,194**	**88,705**

Source: Gardner Pinfold Consultants Inc. 2013
Note: A conversion from Canadian to U.S. dollars has been made.

8.2 History and growth of the industry

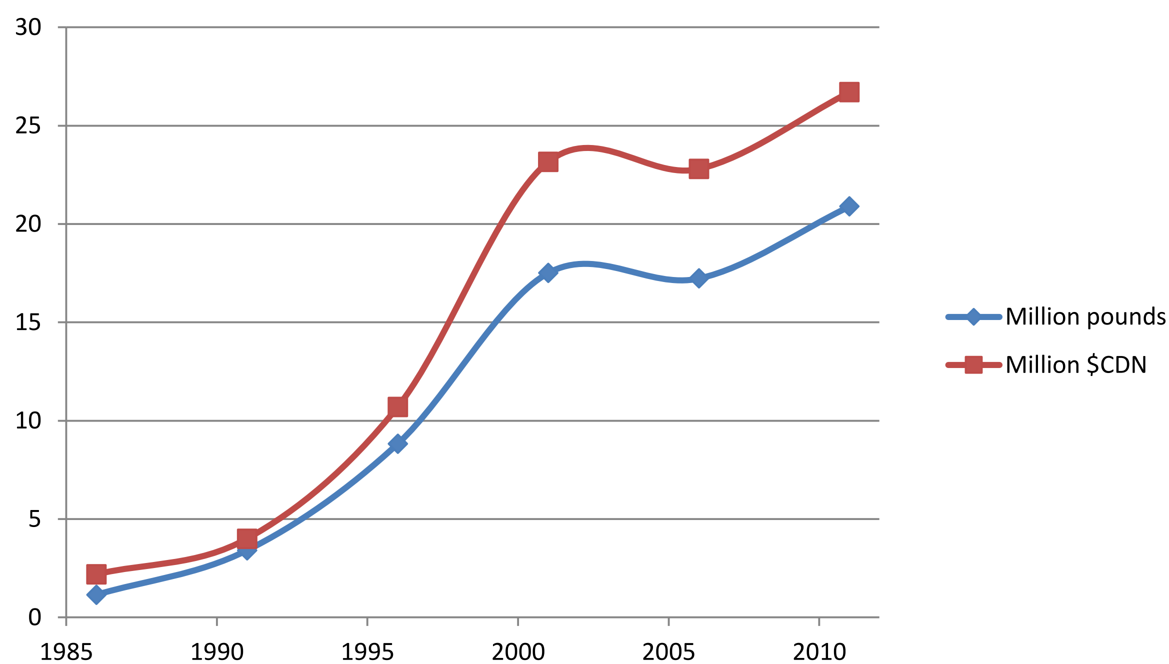
Experiments began in mussel seed collection in the 1970s, and the longline method was established in the early 1980s. A handful of entrepreneurs, like Russell Dockendorff, were responsible for the early developments. The following excerpt from his obituary (Lawlor 2009)

> A pioneer of Prince Edward Island's mussel industry, Russell Dockendorff first harvested the shellfish in the late 1970s to supplement his income as a lobster fisherman. Over the next 30 years, he helped to not only put the product on the international market, but make PEI the largest producer of North America's cultured mussels. “It was back in the days when people thought we were crazy,” said John Sullivan, who started in the island's fledgling industry around the same time. “It [a mussel] was something that people used to kick out of the way.” But Mr. Dockendorff, who would later became known as the king of PEI mussels, saw a future in the cheap, plentiful shellfish - so much so that he sold the family home in order to buy equipment for his new venture. Since there wasn't any mussel machinery on the island at the time, Mr. Dockendorff had manufacturers modify potato grading equipment to suit his needs. “It was all trial and error in the beginning,” said Len Knox, a friend and former competitor in the mussel industry. “He had so much trust and faith.” After a couple of years the island's industry took off and orders started flooding into his business, PEI Mussel King. His daughter Esther Dockendorff remembers the first shipment of mussels that left the island bound for Calgary. “He was a risk taker,” said Esther Dockendorff. “And he wasn't scared of work.”

PEI production has not grown much since 2000, when landings were nearly 18 million lb. Most of the growth of the industry took place between 1986 and 2001 (Figure 32), due to entrepreneurs like Brian Fortune, founder of Canadian Cove mussels. During the last decade, there has been consolidation of numerous smaller operations resulting in 5 large companies with an economy of scale (Canadian Cove, Prince Edward Aquafarms, Confederation Cove, Green Gables Mussels, and P.E.I. Mussel King). The utilization of long-line technology (see also New Zealand Case study) allowed for efficient seeding and harvesting, and adaptation to the relatively shallow waters in the enclosed PEI bays. Canada (and the maritime provinces) benefit from a strong federal aquaculture development policy, regional development centers, and financial support for outcome based research and development.

According to Richard Gallant, who was the PEI aquaculture development officer during the rapid growth period of the industry, a combination of factors helped move the development of the PEI mussel sector along. These included a supportive Aqua Leasing Program, financing through the provincial loan board (PEI Lending Agency), some grant assistance from federal provincial programs in the 1990's, technical support from the province on spatfall monitoring and many other technical issues, favorable growing conditions, the ability for the sector to grow incrementally, and margins that supported expansion (Gallant 2014).

Figure 32. PEI mussel production and value from 1986-2011



Source: Carter Newell using data from Fisheries and Oceans Canada, 2013

Initial bottlenecks of seed collection, production technology, winter harvesting, summer mortality (Mallet et al. 1990) and processing were dealt with collaboratively in a working group fashion, where individual farmers tried things and then shared with the group their successes and failures. Initially, lobster boats and existing commercial fisheries vessels were adapted to mussel farming and processing equipment was imported. Eventually, specialized equipment was developed, and local companies (like Charlottetown Metal Products (CMP Stainless Steel Technology 2015) began to fabricate the equipment needed in the industry. A large wild fishery $110.52 million, 8500 jobs), a large agriculture sector $452.96 million, existing vessels, machinery and processing infrastructure provided a positive background to the development of the mussel aquaculture industry.

The following elements contributed to the growth of the industry:

1. Supportive federal aquaculture **leasing program**.
2. **Loan programs**: *Aquaculture technology program* (technology transfer fund, supports 60% of project cost with a maximum assistance of $9,060); *Aquaculture and Fisheries Research Initiative* (funds $18,118 with a 1/1 industry match or up to $54,354 with a 3/1 industry match. Nearly 100 percent of loans paid off. These small loans and grants all for proof of concept (i.e. small boats, booms, hydraulic power packs).
3. Businesses had **good margin** and were able to fund growth once they got started (good seed, good quality, no ducks so could use longline system).
4. Had regular meetings of the *Great **Atlantic Shellfish Exchange*** to compare notes and build on successes.
5. Early growers were from a variety of disciplines (from commercial fishing to insurance to entrepreneurs). No specific training programs were sponsored for the industry. However, the island was home to **innovative fishermen and farmers.**
6. **Technical support**: Atlantic Veterinary College, PEI Department of Fisheries, Aquaculture and Rural Development, Canadian Department of Fisheries and Oceans, DFO Gulf Region Canada, Aquanet.
7. When problems occur: i.e. invasive tunicates the industry received $1.8 million in funding to come up with a **rapid response solutions** which included a high pressure water spray.
8. All companies had managers that also worked on the water – ***owner/operator model.***
9. PEI has 40 **harbors with wharves**. Aquaculture utilized those, as well as fixing up some abandoned ones.

8.2.1 Investment climate

Invest PEI provides financial incentives to eligible companies, which include tax rebates, labor rebates and/or interest-free unsecured loan (Invest PEI 2015). While the mussel industry in PEI, like Spain, is at its maximum productivity, investments are being made in value added processes (modified atmosphere packaging, frozen products), and new species development. In some cases, mussel growers are investing in oyster farming on some of their sites due to new methods of oyster farming in subtidal waters and a larger return on investment. There is a vast system of government support for the aquaculture industry.

8.2.2 Private and public investment and capitalization

Over the past few years, significant public/private investments have been made in mussel aquaculture technology and processing plants in PEI. Starting in the early 1980s (see Section 8.2), and in the present and future, Canada invests in its aquaculture industry. For example, in 2012 and 2013, P.E.I. Mussel King received over $6.8 million in federal and provincial funds to modernize their mussel processing plant. Similarly, Canadian Cove Mussel Company received $0.5 million to improve an optical grading system for a processing plant. The Aquaculture Innovation and Market Access Program (AIMAP) provides about $4.8 million a year to the Canadian aquaculture industry in marketing and innovation. See section 8.2.4.

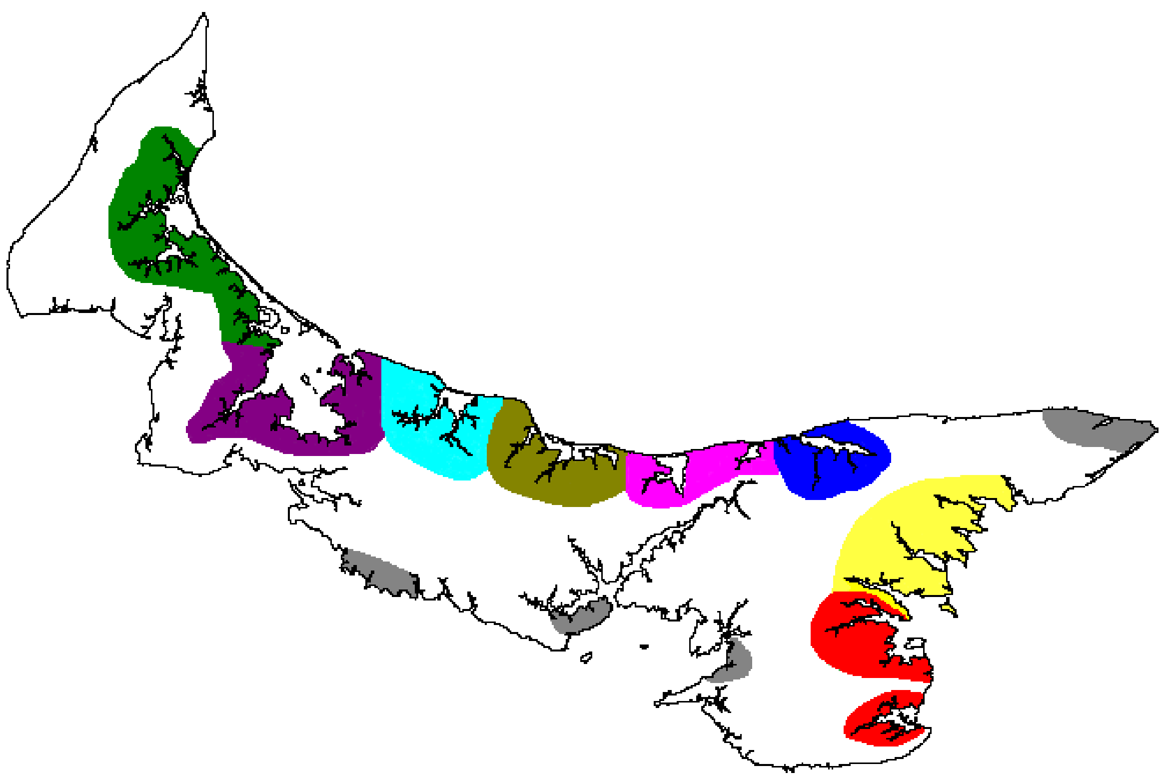
8.2.3 Lead state agency support

There is a strong aquaculture lead agency support at federal, regional and provincial levels. The roles and responsibilities are outlined in the National Aquaculture Strategic Plan Initiative (see section 8.2.4).

The Prince Edward Island Mussel Monitoring Program (MMP) is a service provided to cultured mussel growers and processors by the Department of Fisheries, Aquaculture and Rural Development. The MMP has operated annually since 1982 during the ice free season providing mussel growers with a variety of information to assist them in the management of their operations. The MMP focuses primarily on mussel spatfall prediction, mussel meat yield analysis, water temperature evaluation, the detection and estimation of the numbers of potentially toxic algae species and the monitoring of predators and fouling organisms. The program also provides mussel processing plants with information such as mussel meat quality at harvest which assists the processor in providing the consumer with a quality product (Prince Edward Island Dept. of Fisheries, Aquaculture & Rural Development. 2014a).

An example of the MMP is the mussel larval monitoring program, which tells growers what time of year is the optimal for placing ropes out to collect mussel seed (Figure 33). When a user clicks on the map, it gives up-to-date information on mussel larval abundance and stage of maturing. Whether it is dealing with nuisance species, obtaining financing, developing or importing state-of-the-art processing equipment, marketing, workforce training, or health certifications, the Canadian government is there to support their industry.

Figure 33. Mussel spat survey weekly results



Source: Prince Edward Island Dept. of Fisheries, Aquaculture & Rural Development. 2014b.

8.2.4 Level of coordinated research and development

Coordinated research and development strategies are part of the overall Canadian Aquaculture Development Strategy and the corresponding strategy for east coast shellfish aquaculture (including PEI).

In PEI, the PEI Aquaculture Alliance and its members work in partnership with a number of partners to ensure development and sustainability of PEI aquaculture. Some of these partnerships include:

- Aquaculture & Fisheries Research Initiative (AFRI)
- Aquaculture Collaborative Research and Development Program (ACRDP).
- Aquaculture Association of Canada (AAC)
- Atlantic Canada Opportunities Agency
- Atlantic Veterinary College
- Canadian Agriculture and Food International Program
- Canadian Aquaculture Industry Alliance
- Canadian Centre for Fisheries Innovation
- Fisheries and Oceans Canada (DFO)
- National Research Council Industrial Research Assistance Program
- National Sciences and Engineering Research Council of Canada
- PEI Department of Fisheries, Aquaculture and Rural Development
- PEI Atlantic Shrimp Corp Initiative

The DFO also have a targeted AIMAP for the maritime provinces in Canada. For 2013 in the Shellfish: Mussels category, funded projects include:

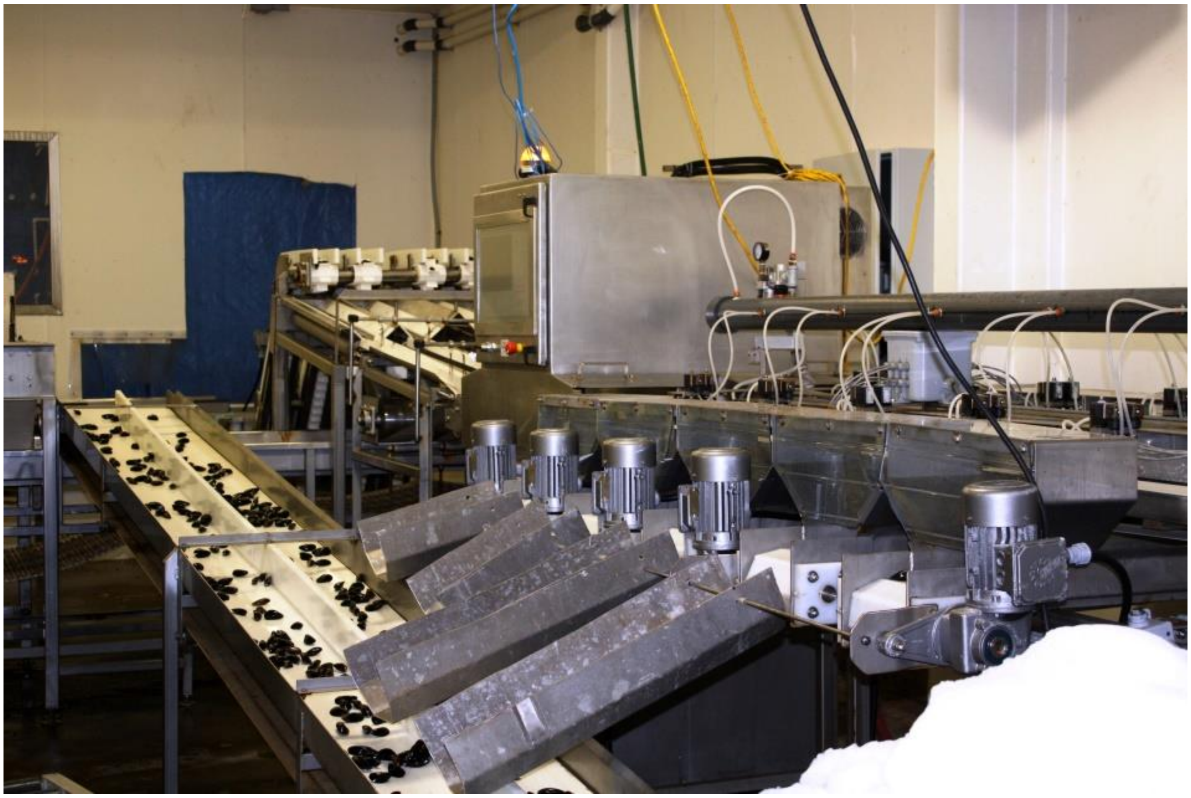
- Proof of concept of a scalable hatchery system using modular principles to increase production and survival for commercially important Mytilus species (British Columbia [B.C.])
- Design, installation and assessment of an innovative duck deterrent system to reduce predation of high value aquaculture Mytilus product and minimize duck mortality
- Development of genomic health assessment tools for marine mussels
- Increasing vacuum packaging efficiencies in Blue Mussel processing (PEI)
- Improvement of quality and productivity associated with live Blue Mussel inspection through the installation of automated sorting equipment (PEI)
- Arctic ice boom innovation for mussel farm protection (Newfoundland)
- An investigation of the lipid and fatty acid composition of the Blue Mussel with reference to palatability and taste during conditions of extended holding
- Comparison of the health and condition of cultured mussels from deep and shallow water sites in Newfoundland with reference to environmental conditions, condition index, physiological stress and lipid biochemistry
- New and innovative equipment for mussel processing industry (PEI) (Figure 35)

- A project to develop and introduce automated, digital imaging technology to the grading process in Canadian mussel plants
- Evaluation of Blue Mussel processing plant holding systems in PEI.
- Mussel larvae production enhancement by restocking mussel beds in Bassin du Havre-Aubert, Magdalen Islands
- Technical-economic assessment of an integrated mussel post-harvest process
- Genomic and physiological processes during the larval ontogeny of the Blue Mussel: impact of eicosanoid precursors
- The Eider Spider: Development and experimental testing of a novel method to deter sea duck predation on mussel farms
- Developing an innovative treatment system for Vase Tunicate fouling on cultured Blue Mussels (PEI).
- Impact of biotic and abiotic factors on the mechanical properties of the byssus of the Blue Mussel: a marketable biomaterial
- Culture density, biomass-density relationship, and self-thinning in molluscs
- Bioenergetics and mollusc food ingestion.

Figure 34. Innovative water pressure system funded by DFO to solve tunicate fouling problem on PEI

Source: Fisheries & Oceans Canada, 2010.

Figure 35. Blue Mussel imaging sorter



Source: Confederation Cove Mussels Co. Ltd. 2014E

8.2.5 Regulatory process

The PEI aquaculture lease process is described in the Prince Edward Island Aquaculture Leasing Policy, 2011 (PEI 2011). The Canadian Department of Fisheries and Oceans (DFO) is the federal agency which regulates aquaculture in order to protect wild fish and its habitat through the Fisheries Act. In 2008, DFO developed an aquaculture policy framework (DFO 2008):

> DFO's vision for aquaculture development is to benefit Canadians through the culture of aquatic organisms while upholding the ecological and socio-economic values associated with Canada's oceans and inland waters.
>
> As the lead federal agency for aquaculture development, and consistent with its departmental mandate, DFO will act and discharge its responsibilities in a manner that adheres to the following policy principles:
>
> 1. DFO will support aquaculture development in a manner consistent with its commitments to ecosystem-based and integrated management, as set out in departmental legislation, regulations and policies.
> 2. DFO will address issues of public concern in a fair and transparent manner, based on science and risk-management approaches endorsed by the Government of Canada.

3. DFO will communicate with Canadians and be informed by their views on issues pertaining to aquaculture development.
4. DFO will respect constitutionally protected Aboriginal and treaty rights and will work with interested and affected Aboriginal communities to facilitate their participation in aquaculture development.
5. Recognizing that aquaculture is a legitimate use of land, water and aquatic resources, DFO will work with provincial and territorial governments to provide aquaculturists with predictable, equitable and timely access to the aquatic resource base.
6. DFO will strive to ensure that its own legislative and regulatory frameworks enable the aquaculture sector to develop on an even footing with other sectors.
7. In partnership with other federal departments, the provinces and territories, the academic sector and industry, DFO will support responsible development of the aquaculture sector.
8. DFO will make every effort to understand the needs of the aquaculture industry and to respond in a manner that is solutions oriented and supportive of aquaculture development.
9. DFO will work with other federal departments and with provincial and territorial governments to coordinate policy development, integrate regulatory frameworks, and improve service delivery.

Through this policy framework DFO has committed itself to being both an enabler and a regulator of aquaculture development, affirming its role as a department of sustainable development. *Enabling means improving the business climate for aquaculture development, to benefit Canadians*. DFO will do this by:

- ensuring that DFO's laws and regulations relating to aquaculture are clear, efficient, effective, consistently applied and relevant to the sector;
- investing in aquaculture science and research and development;
- working in partnership with provinces and territories to develop a proactive siting process; and
- considering support for industry development programs consistent with DFO's mandate and objectives.

DFO will play an important role in aquaculture development by using this policy framework to help increase both sector competitiveness in global markets and the public's confidence that aquaculture is being developed in a sustainable manner. By building on FADS and supporting the department's vision and mandate, DFO's Aquaculture Policy Framework will foster vibrant and sustainable development, generating wealth and opportunities for Canadians.

Creating enabling conditions for aquaculture development is the responsibility of all DFO sectors and regions. Giving effect to the principles identified in this policy framework will require the commitment of resources and the development and implementation of specific sectoral and regional strategies, including the review of current applicable legislative and regulatory frameworks, policies and programs to

> ensure that they are consistent with this policy. To ensure that the policy framework remains relevant, DFO will engage stakeholders in evaluating the effectiveness of the framework in fostering the sustainable development of the aquaculture sector and will make necessary adjustments as external conditions change.

In order to carry out the federal aquaculture policy framework at the provincial level, the Provincial Minister of Fisheries, Aquaculture and Rural Development, under the Fisheries Act (Legislative Council Office, PEI 2009) is given power to administer and enforce the act, and furthermore is charged with helping to develop the aquaculture industry. In this capacity:

> 5. (1) The Minister may
>
> (a) **develop, plan, co-ordinate and carry out programs and projects relating to the maintenance and development** of the fishery;
>
> (b) with the approval of the Lieutenant Governor in Council, coordinate the work and efforts of other departments and agencies of the province respecting any matter relating to the maintenance and development of the resources of the fishery;
>
> (c) enter into agreements with the Government of Canada or the government of any other province on matters relating to the management or development of the fishery;
>
> (d) develop scientific data bases and engage in consultations with the Government of Canada to ensure equitable access to the resources of the fishery;
>
> (e) gather, compile, publish and disseminate information including statistical data relating to the maintenance and development of the resources of the fishery;
>
> (f) engage the services of experts or persons having special technical or other knowledge to advise him or her;
>
> (g) **enter into agreements to provide training** for fishers, aquaculturists, processors, pound operators, their employees and students, establish the required curriculum and provide assistance to fishers, aquaculturists, processors, pound operators, employees and students engaged in studies related to the fishery;
>
> (h) **convene conferences and conduct seminars and educational programs** relating to the development of the resources of the fishery;
>
> (i) maintain a current list of fishers, aquaculturists, buyers, pedlars processors and pound operators;
>
> (j) undertake development projects
>
> > (i) for the exploration, development and enhancement of the resources of the fishery,
> >
> > (ii) for the promotion and marketing of fishery products,
> >
> > (iii) for the introduction and demonstration to fishers and aquaculturists and others of new types of fishing and aquaculture vessels, gear, equipment, methods, techniques and operations,

(iv) for the **introduction of more efficient methods** including handling, transporting, processing and storage of fish,

(v) for the improvement of the quality of fish products, and for the encouragement of value-added processing,

(vi) for the improvement of fishing ports and aquaculture landing sites under provincial jurisdiction, and their facilities and services. 1995, c.14, s.5.

6. Notwithstanding anything in this Act, the Minister may authorize any action or invoke any measure

(a) to encourage the maintenance and development of the resources of the fishery;

(b) relating to fish buying and processing;

(c) to integrate and co-ordinate programs, planning and projects of the province with those of the Government of Canada or of other provinces

if he or she considers it in the public interest to do so. 1995, c.14, s.6 (*ed.: **bold text** emphasis added)*

8.2.6 Development strategies and key stakeholders involved

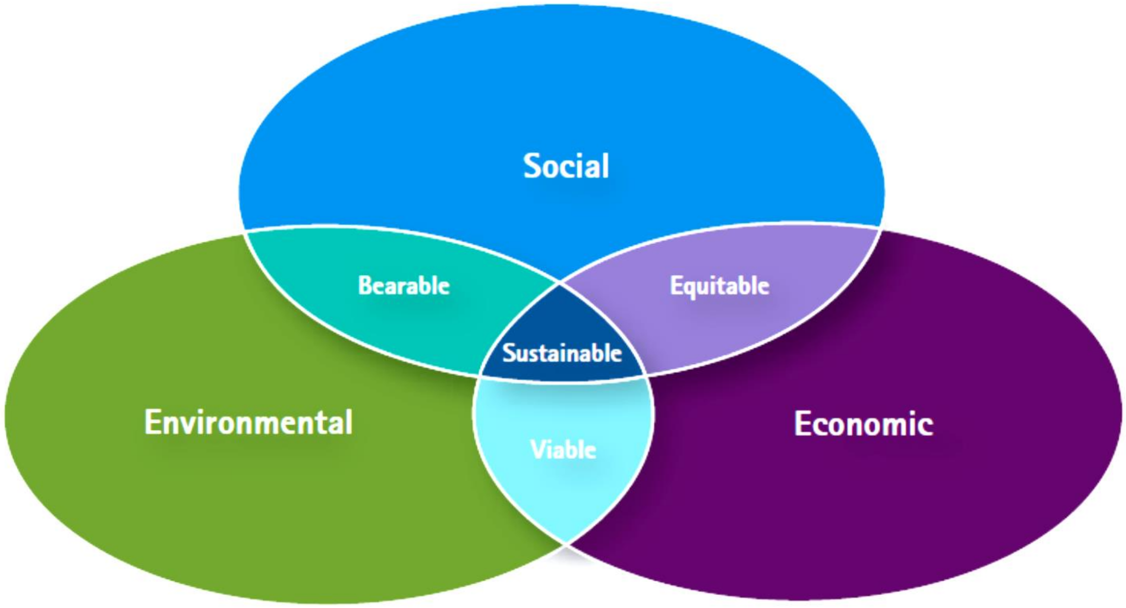
The federal government produced a federal aquaculture development strategy (FADS) in 1995, and more recently an updated aquaculture development strategy (National Aquaculture Strategic Plan Initiative 2010a). One of the major themes is sustainability (Figure 36).

For each of the sectors, east and west coast shellfish and finfish sectors, and inland fresh water sectors, there are separate plans. The east coast shellfish sector plan (Canadian Council of Fisheries & Aquaculture Ministers (CCFAM). 2010) includes **governance, social license and reporting, and productivity and competitiveness**. It is amazingly comprehensive and well thought out, and backed up by funding and government commitment to aquaculture.

The comprehensive *productivity and competitiveness* section for the east coast shellfish plan covers the following areas:

- Shellfish health
- Aquatic invasive species
- Emerging technologies
- Alternative species development
- Risk management and access to financing
- Infrastructure such as wharves and piers
- Marketing and certification
- Labor and skills development.

Figure 36. Three inter-related components of sustainable development



Source: CCFAM 2010b

8.2.7 Coastal zone management plans

Prince Edward Island has been the home of several CZM case studies, such as a project in Malpeque Bay which includes a community-based approach (Harvey 2009). PEI has developed a public engagement strategy for aquaculture development (Figure 37). Many of the issues of land use management, effects of sea level rise, climate change and ocean acidification are being dealt with in all the Atlantic Provinces of Canada, but issues of the shellfish growers in the mussel mariculture industry are addressed specifically in *the National Aquaculture Strategic Plan East Coast Shellfish Sector 2011-2015* under the Governance section:

- Environmental Management
- Introductions and Transfers of Aquatic Organisms
- Navigable Waters Protection Act
- On-Site Inspection
- Access to Wild Aquatic Resources for Aquaculture Purposes
- Canadian Shellfish Sanitation Program
- Other Regulatory and Governance Issues
- Public Engagement and Communications (example Figure 37)

Figure 37. Excerpt from Public Engagement and Communications strategy for PEI governance and integrated coastal zone management

SL–2. Research and prepare regional aquatic resource maps to optimize aquaculture development in public waters in a manner that is respectful of the interests of other resource user groups

DFO, EC, Provinces/Territories, Research Organizations, Industry	- Outline mechanisms to include local interests in informed dialogue, collaboration & communication □ outline procedures for evaluating and communicating objective information about the social, economic and biological costs and benefits of aquaculture development to support informed decision-making	Year 1 Year 2	Ongoing
	- Develop a resource-use geographical information system (mapping) tool to facilitate the identification of suitable areas for aquaculture development in public waters □ incorporate traditional ecological knowledge amongst the parameters used to evaluate areas for aquaculture development □ establish objectives for sector development on a regional (watershed) basis □ utilize existing databases and knowledge repositories, where they exist	Year 3	Ongoing in some areas
	- Where Integrated Coastal Zone Management initiatives are underway, assure that regional aquaculture interests are appropriately represented	Year 4	

Source: CCFAM 2010b

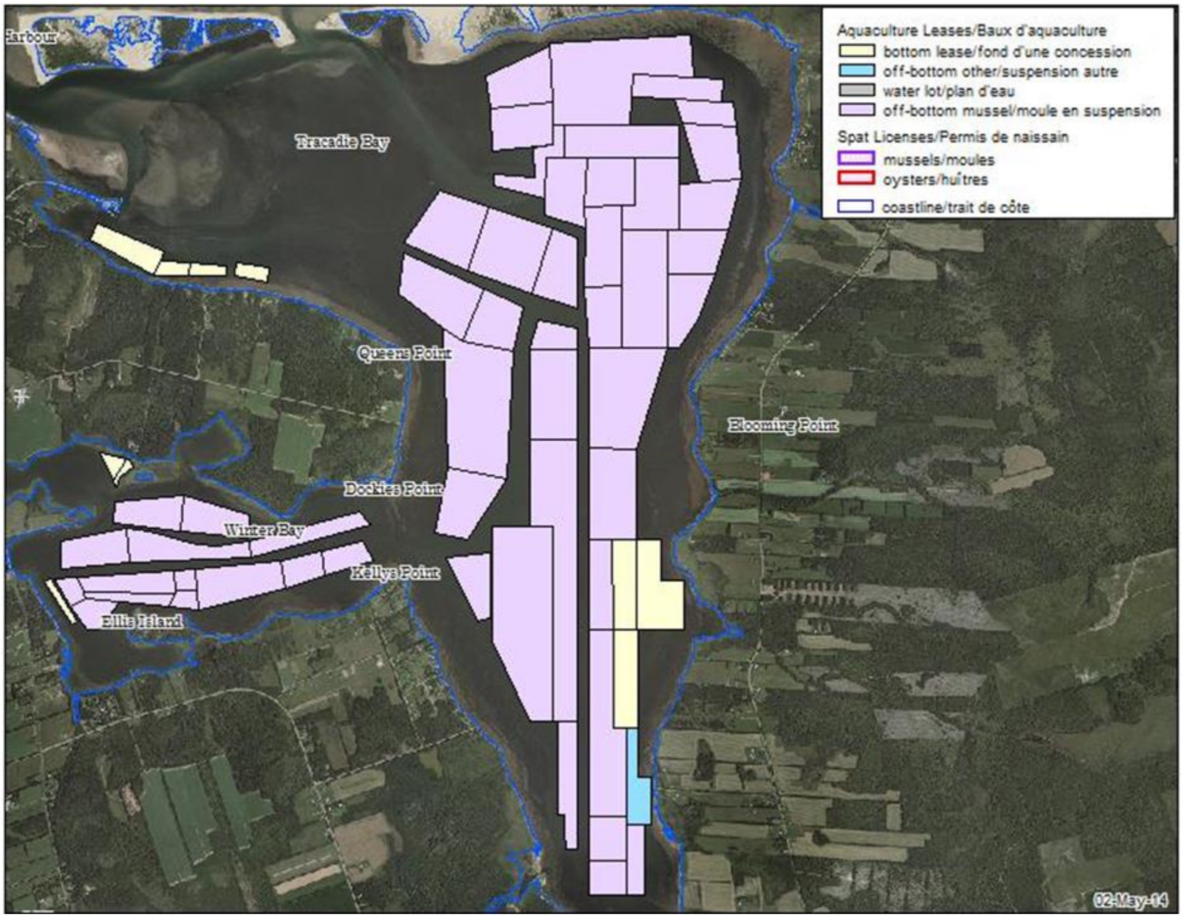
8.2.8 Species present

The native blue mussel, *Mytilus edulis*, is cultivated in PEI. The advantage of natural spatfall and adaptation to local growing conditions helps make the industry more competitive in the export market. Introduced species of ascidians, or sea squirts have hampered production but solutions have been found which mitigate some of the effects.

8.2.9 Biophysical characteristics

Mussels are grown in shallow bays and inlets on PEI ranging from estuaries on the east side of the Island to barrier beach lagoons on the north shore. Water temperatures range from –2°C in winter to 24°C or higher in the summer, while salinities range between 23 to 29 parts per thousand (Prince Edward Island Aquaculture Alliance 2014). Most of the mussel growing areas in PEI are shallow embayments with limited tidal exchange, such as Tracadie Bay (Figure 38), and because large areas of the bays were permitted for aquaculture, as the industry expanded, there were reductions in meat yields because the mussel biomass was exceeding the carrying capacity of the embayments for phytoplankton. These problems, relating to mussel meat yields and benthic impacts of high intensity mussel culture in poorly flushed estuaries, have been the subject of numerous scientific studies (Waite et al. 2005; Lauzon-Guay et al. 2005; Filgueira & Grant 2009) However, the large agricultural areas on PEI, and the nutrient laden runoff, helps to maintain adequate levels of phytoplankton for good quality mussel growth. While the water temperatures in the summer are near the lethal range for blue mussels, the freezing water in the winter requires special techniques for harvesting through the ice.

Figure 38. Tracadie Bay in PEI



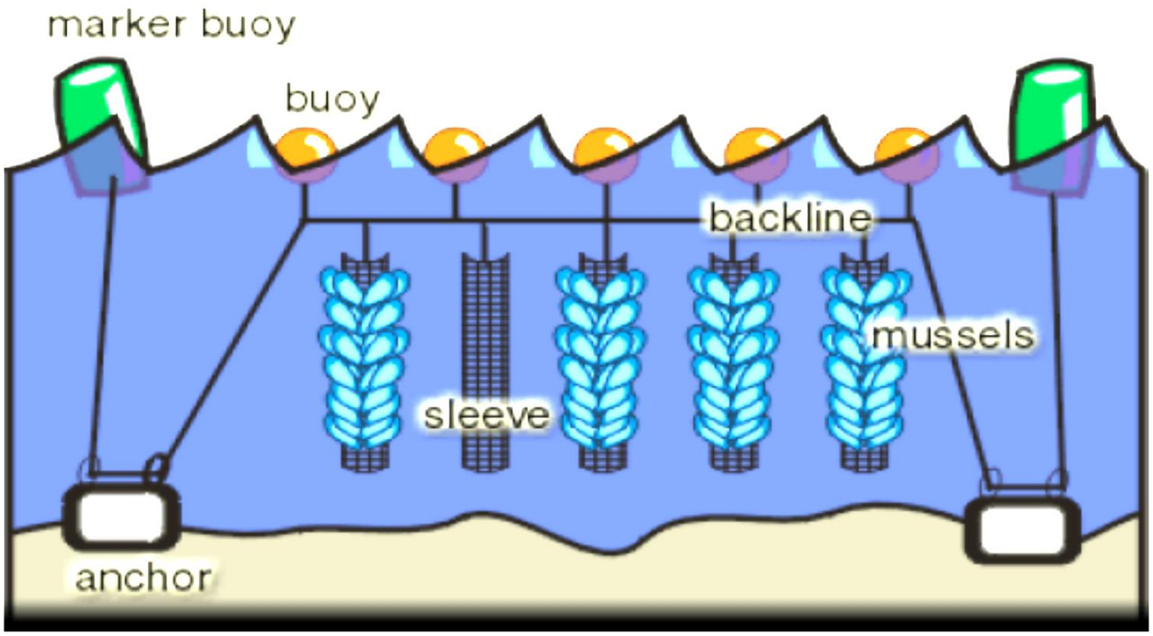
Source: Fisheries and Oceans, Canada, 2014

The first reported occurrence of shellfish poisoning from blue mussels (Mytilus edulis) cultured in Cardigan Bay, eastern Prince Edward Island (Canada) occurred in the fall of 1989. The neurotoxin domoic acid was (DA) identified as the responsible agent, and was traced to a diatom *Pseudo-nitzschia multiseries*. Rapid development of a new analytical method allowed monitoring of DA in shellfish in Atlantic Canada to start in the spring of 1988, within a year of the first documented outbreak. Since 1987, the levels of DA in PEI shellfish have dropped considerably (Anderson et al. 2001).

8.2.10 Culture and processing technology

Mussels are cultivated using a longline system (Figure 39). A boat moves along the longline using a hydraulic star wheel and an idler pulley, such that mussels can be seeded on to the ropes, or harvested. This method is efficient because the boat never stops moving until it is full. Mussels are also harvested through the ice during the winter by cutting a hole in the ice and pulling the whole longline onto trucks using a winch.

Figure 39. Schematic of a PEI mussel longline



Source Fisheries & Oceans Canada. 2006

PEI mussel farmers hang out ropes to collect seed in the inner bay regions of the growing areas. The timing of seed collection is aided by the Mussel Monitoring Program. Mussel seed is collected (Figure 40) at seed farms in the warmer regions at the head of the bays, stripped off the ropes, graded, socked, purged to byss to the plastic mesh socks, then hung out on longlines for grow-out. A video of the process is available at: https://www.youtube.com/watch?v=DpUaYTZTaTk.

The growers have developed shallow draft skiffs (Figure 40 and Figure 41) rigged with hydraulic booms for harvesting. It is common to see dozens of these small boats bringing in 800 lb totes of mussels on any given day. They also use standard lobster style boats for harvesting (Figure 42).

Figure 40. Harvesting Seed

Source: Carol & Lynton 2011

Figure 41. Harvesting Skiff

Source: Carol & Lynton 2011

Figure 42. Harvesting with a lobster boat

Source: Canadian Cove Mussels Ltd.

After the mussels are harvested, they are brought to shore and purged in large bins, stripped off the mussel sock material, declumped, debyssed, graded, and packed. Recently, the large PEI processors have been utilizing a mussel Modified Atmosphere Package (Figure 43) originally developed in Europe which increases shelf life and is drip free, but is not currently allowed in the U.S.

Figure 43. Modified Atmosphere Pack

Source: Smokey Bay Mussels, Ltd.

8.2.11 Cost/benefit analysis

Some of the costs involved in setting up a PEI-style longline system are presented in Table 11.

Table 11. Costs involved in setting up a PEI style longline system

Equipment	Cost ($)
Hydraulics	$4,408 - $8,817
Floatation Devices	$2.42 - $2.65 each
Anchors	$17 - $22 each
Insulated Boxes (with covers)	$441 - $529 each
Declumper	$8,818 - $13,227
Sock Mesh	$0.06 - $0.11 cents per meter
Mussel Boat	$22,044 - $35,271
24’ aluminum boat	$61,724 - $88,177
40’ mussel boat	$176,354 - $264,532
Lease (annual fee)	$8.82 per acre
Aluminum socking table	$2,645 - $4,409

Source: Fisheries and Oceans, 2006
Note: Canadian dollars converted to U.S. dollars

No profit figures were available for individual companies in PEI, but their production is stable and appears to be profitable. Part of that profitability is aided by the extensive federal government support mentioned in this case study, and resulting in over $6.7 million in annual tax revenue.

8.3 Relevancy to Alaska Mariculture Initiative

The PEI case study is relevant to Alaska because it demonstrates a very effective shellfish aquaculture development strategy, an efficient and improving production and processing sector, the key involvement of local growers, government support and development based research, and how an aquaculture research and development policy can pay off in jobs and economic development. Mussel farming has great potential for aquaculture development in Alaska, and developing a cost-effective growing technology, processing industry, and workforce is essential to achieving that potential. In addition, three key aspects of this case study stand out as an example to Alaska:

History of development: 1. Supportive federal aquaculture leasing program. 2. Loan programs: *Aquaculture technology program* (technology transfer fund, aquaculture and fisheries research initiative) 3. Businesses had good margin and were able to fund growth (successful business model). 4. Had regular meetings of the *Great* Atlantic Shellfish Exchange to compare notes and build on successes. 5. The island was home to innovative fishermen and farmers. 6. Technical support (federal, provincial universities). 7. Rapid response solutions to ongoing problems. 8. Owner-operator business models. 9. Adequate harbors, wharves and distribution networks.

Lead agency support: Canada has a strong federal, regional, and provincial support for aquaculture, resulting in strong and consistent growth of the industry. Under the National Fisheries Act and DFO’s Aquaculture Policy Framework, PEI is encouraged to develop aquaculture and it has done an excellent job.

Level of coordinated research and development: As part of the coordinated national aquaculture development plan, where PEI is included in the east coast shellfish plan, a number of programs, including the AIMAP, providing for continuous innovation, the Mussel Monitoring Program, and numerous other programs provide a model of successful government support of the industry.

PEI utilized the local blue mussel for its farming. This allows for spat collection in a cost-effective manner in the inner embayments. Due to an already established agricultural and seafood economy, an extensive network of transportation already existed, and was enhanced by the construction of the PEI bridge (completed in 1997). PEI and Canada in general shines in its government support programs, a favorable regulatory environment, and a hardworking, maritime work force.

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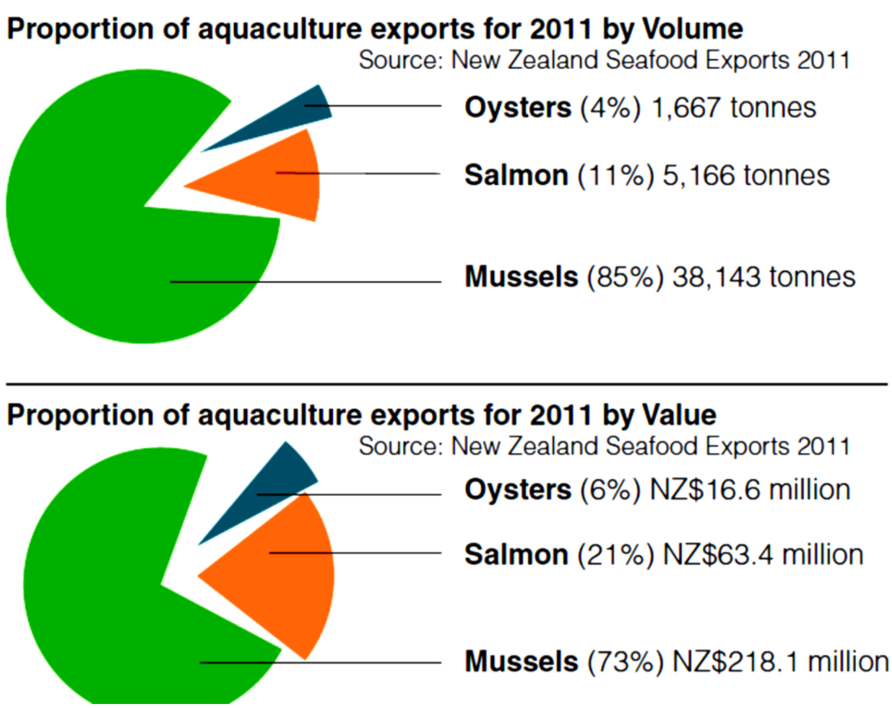
9 Case study: New Zealand mussels (*Perna canaliculus*)

9.1 Current Status and Economic Impact of the Industry and its Relevance to Alaska

In 2011, New Zealand produced 101,000 mt of mussels, worth $197 million, providing three-quarters of their seafood export value (Figure 44) (New Zealand Aquaculture 2011). The mussel industry has developed over 30 years (Figure 45) to become the world's leader in efficiency of mussel farming technologies, value added processing, and mussel research and development. There are approximately 645 mussel farms in New Zealand over seven major regions (Figure 46) The industry has a direct employment of approximately 1,000 people. In 2008–2009, The direct total impact of mussel aquaculture constituted two-thirds of gross output (67 percent), indirect was 26 percent and induced was 7 percent (Auckland Regional Council 2010). In the Coromandel region, which produced 92,000 mt in 2010, over 75 percent of the mussels were processed into frozen mussels (mostly half shell frozen), comprising over 95 percent of the mussel exports (Table 12) where the harvesting and processing sectors employed similar numbers of workers. In 2011, exports to the U.S. were $45.8 million. This highly evolved industry has also created specialized industries in which seed collection, mussel farm setup and maintenance, seeding, harvesting and processing occur using specialized vessels and machinery (i.e. harvest vessels cost $0.83 to $1.66 million[2] or more). Often the growers contract harvesting to specialized vessels and are paid on final yield.

Figure 44. New Zealand aquaculture export in 2011 by volume and value



Source: New Zealand Aquaculture, 2012
Conversion $1NZ=$0.792322 US in 2011

[2] Note that conversion from $NZ to $US use the 2014 exchange rate until otherwise specified.

Figure 45. New Zealand aquaculture exports over time

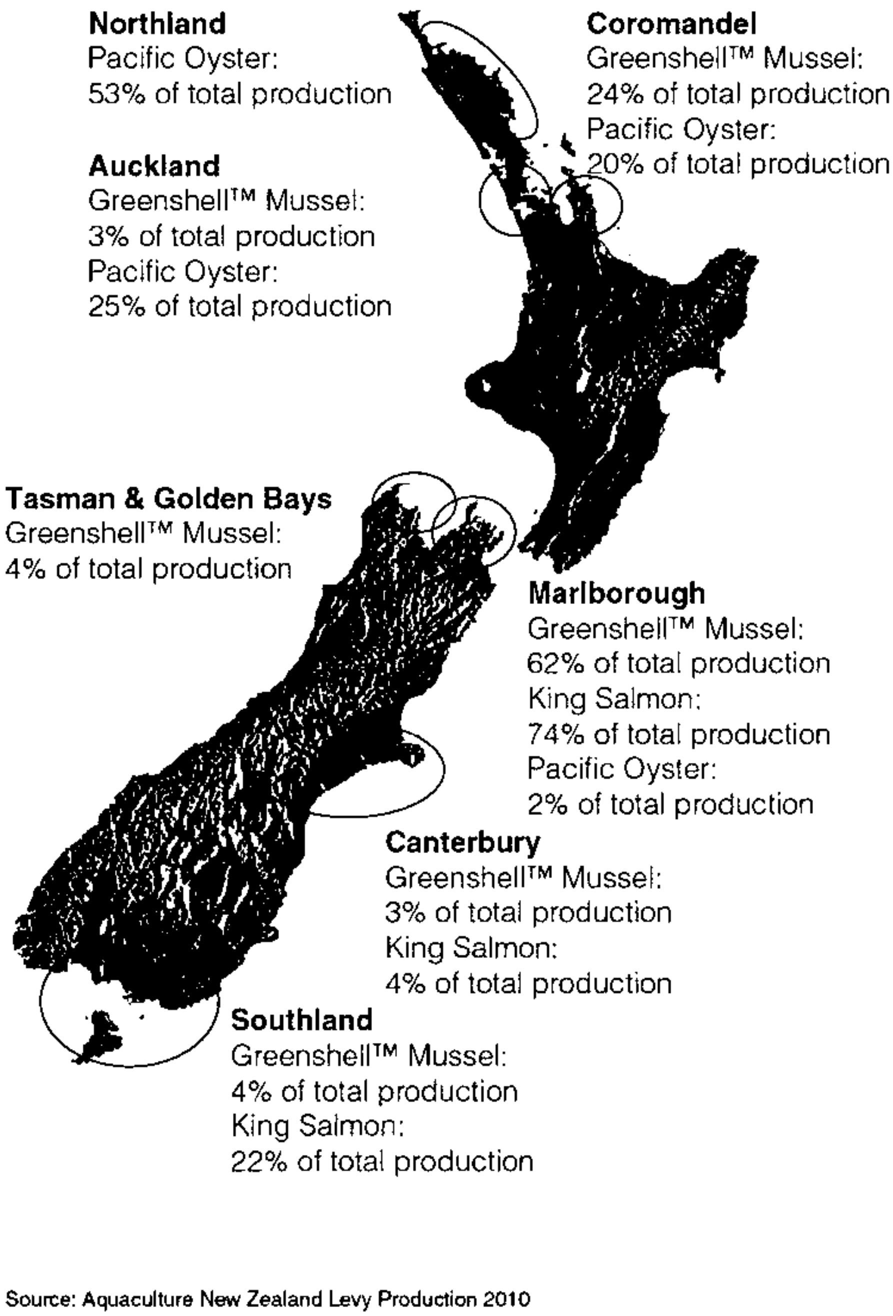
Source: New Zealand Aquaculture, 2012.
Note: Conversion $1NZ=$0.792322 US in 2011

Table 12. New Zealand export forms

Product Category	Export Weight (lb)	Percent of Exports (%)
Half Shell Frozen	70,263,920	83.56
Meat Frozen	8,179,965	9.73
Whole Frozen	3,060,083	3.64
Preserved/Marinated	1,080,819	1.29
Freeze-dried Powder	555,406	0.66
Live	547,689	0.65
Processed in Can, Jar	181,899	0.22
Other not Live/Chilled/Frozen	66,899	0.08
Powder in capsule	56,747	0.07
Whole Chilled	33,135	0.04
Smoked	23,069	0.03
Crumbed, battered	17,769	0.02
Meat Chilled/Fresh	15,263	0.02
Half Shell Fresh/Chilled	8,281	0.01

Source: New Zealand Aquaculture, 2011

Figure 46. Major Aquaculture Areas in New Zealand



Source: New Zealand Aquaculture, 2011

9.2 History and growth of the industry

The New Zealand Ministry for the Environment (2014) provided this history of the industry in the context of environmental risk management:

> The New Zealand aquaculture industry began in the mid-1960s with marine farming of oysters and then mussels, typically by *small, innovative operations*. It quickly

> established a domestic market and began making inroads into export markets in the 1970s. As aquaculture techniques and value chains became more sophisticated in the 1980s, small owner-operator farms became less common and *aquaculture/seafood-related companies* expanded and consolidated. *Production efficiency, control of stock and cost reduction* dominated industry thinking as export markets expanded. During the 1990s global competition in seafood products intensified, driving further consolidation of the industry in an attempt to achieve increased production and marketing efficiencies. With the introduction of the Resource Management Act in 1991, the expanding industry began to focus on sustainable production, acknowledging its associated environmental and social issues. The aquaculture industry was also threatened by biotoxin events, which gave rise to both water and food quality monitoring programmes. With pressures on the market for oysters and mussels, the sector began to diversify and the 1980s and 1990s saw the establishment and growth of the salmon industry. New Zealand's aquaculture sector has grown steadily since the late 1980s at an average annual rate of 11.7% by volume over the 20 years up to 2005. Despite this expansion, the sector retains considerable potential for profitable growth. New Zealand's aquaculture industry today has three mature sectors - mussels, oysters and salmon - and a range of other sectors at varying stages of development. Constraints to growth are the key challenges. Broadly speaking, the industry is meeting these challenges through attempts to access new water space and by generating greater value from the existing water space. The former can be achieved by working in partnership with government, councils and the public, while the latter can be achieved by focusing on innovation in production, processing and marketing.

A thorough and detailed history of the mussel farming industry in New Zealand was published in 2004 (Dawber 2004). The history is divided into a chronology with birth of the industry (1960–71), from rafts to longlines (1971–74), learning the ropes (1975–78), mechanization and mass-production (1979–81), processing and promotion (1981–84), contractors and companies (1985–88), Coromandel (1979–2002), marketing the Greenshell™ (1989–1993), mussel boats and mussel people (1994–98), and aquaculture for the future (1999–2002).

The birthplace of the New Zealand mussel aquaculture industry is the Marlborough Sounds region, where mussels had been harvested by the native Maori since at least the thirteenth century. The indigenous greenshell mussel was the basis of a wild dredge fishery, with peak landings in 1961 of approximately 1,000 tons (over 2 million lb). As the demand increased, and the dredged populations declined, people hand-picked mussels off the rocks, and there was interest in the commercial fishing sector. During the decline in the mid-1960s, the British scientist Duncan Waugh from the Ministry of Agriculture, Fisheries and Food visited Spain at an International Council for the Exploration of the Sea meeting in 1963 and then brought information on the mussel rafts there to New Zealand in 1966. A commercial fisherman Stuart McFarlane began experimenting with mussel rafts, with help from the Marine Department and the Fishing Industry Board, and in 1968 the Marine Farming Bill became law. The first rafts were put in the water in 1969, and the first harvest of over 20 tons of fresh mussels, with higher quality than bottom harvested wild mussels, encouraged the pioneers of the New Zealand Mussel industry. After some development of mussel rafts, Jim Jenkins, a graduate of the University of Washington's School of Fisheries under Dr. Ken Chew, got a job with the Fishing Industry Board, and with the Yealands family and others, formed the Marlborough Sounds Marine Farming Association, with the idea that collaborative efforts would provide much more results than independent companies working on their own.

An international network of early scientists, including Dr. Dan Quayle from British Columbia, developed a mussel spat forecasting program. Early efforts went into sourcing seed, identifying reliable locations for seed collection and in 1974 the Wellington Fisheries Research Division scientist Bob Hickman discovered an abundant and rich source of mussel seed washing up on 90 mile beach each year, which eventually became the foundation of the present industry. Jim Jenkins also imported the longline technology from Japan in the mid-1970s, which allowed for rapid growth and mechanization in the years to come. In the 1960s Victor Loosanoff from the U.S. also discovered the benefits of green-lipped mussel for an arthritis pill, and this biomedical demand, which rose to 20,000 tons of meat per year in the mid-1970s, created a great incentive for more investments in mussel aquaculture in New Zealand. As the industry mechanized from traditional fishing boats to harvesting and processing barges in the 1980s, marketing, promotion and value-added processing was increasing demand. A summary of the major developments which resulted in the current New Zealand industry is outlined in Table 13.

Table 13. A summary of the major developments which resulted in the current New Zealand industry

Development	When	How things had been done before	Advantages of the new approach
Using spat from Ninety Mile Beach (Kaitaia spat) to seed mussel farms throughout New Zealand.	1974	Individual farmers had collected spat or put out ropes to encourage spat to seed onto them.	Plentiful supply of spat for mussel farming. High-density supply (up to 2 million spat per kilogram of seaweed).
Using longlines attached to buoys as support structures for mussel ropes (droppers).	1970s	Square concrete rafts had been moored in the water and used to hang mussel lines, but there were concerns about collision with boats. Also, mussels hanging from droppers in the centre of rafts tended to have limited access to phytoplankton and therefore to grow more slowly.	Cheaper and safer way to farm mussels. Additional buoys can be added as the mussels on the lines become heavier.
Using ‘mussock’ (cotton stocking) to seed spat onto ropes.	1980s	Spat seeding was laborious. One approach was to wrap Kaitaia spat (on seaweed) around ropes by hand then wrap a lacy bandage around it.	Spat can be seeded very rapidly by placing it inside mussock along with a length of rope. The filled mussock is placed in the water, where spat transfers to the rope. Mussock degrades over time, leaving a mussel rope covered in spat.
Mussels seeded onto continuous rope.	1980s	Mussels were seeded onto individual (short) dropper ropes, which were hung off longlines.	Seeding onto continuous rope (a kilometre or more) meant mussels could be stripped from ropes by machine.

Source: Biotechnology Learning Hub 2013a

9.2.1 Investment climate

In the early years, it was established fishing companies—one of the first being Wairau Fisheries limited established in 1969 with 75 trawlers, an extensive distribution network and 2 processing plants—that started mussel farming. After a successful financial model of a profitable, efficient, and sustainable mussel operation was demonstrated, there has been adequate investment by investors knowledgeable about the sector. Investment New Zealand (through New Zealand Trade and Enterprise) offers incentives for foreign investments in aquaculture and for new companies starting up there

(Aquaculture New Zealand 2011). This Aquaculture New Zealand Investment Brochure is a key document. Published figures from Investment New Zealand indicate an annual revenue from a longline mussel farm of $30,100 per hectare per year.

9.2.2 Private and public investment and capitalization

The current level of investment and capitalization in the New Zealand mussel industry is related to the profitable and consistent expansion of the profitable farming, processing and export of Greenshell™ mussels over the past 3 decades. For example, the Sandford and Sealord group purchased a processing plant in Tauranga which was the first in the world to operate an automated mussel-opening machine as part of a $14.6 million investment to expand the facility in 2009. Current mussel harvesting and processing vessels cost over $1.66 million.

The Ministry of Primary Industries (MPI) currently has three programs to support aquaculture development, the Aquaculture Planning Fund for regional councils, the Sustainable Farming Fund, and the Primary Growth Partnership. A current project of the Primary Growth Partnership is SPATnz which involves a $10.8 million MPI grant matched by $10.8 million in industry contributions, the goal of which is to produce reliable and higher performing mussel seed for the industry. They currently are building a pilot scale hatchery and testing the performance of 50 families in New Zealand waters. The Planning Fund has funded the following projects (Table 14).

Table 14. Projects funded by the Planning Fund

No.	Project title	Council	APF grant ($)	Total budget ($)
12/01	Sea Change: Hauraki Gulf Marine Spatial Plan(PDF, 52.6kB)	Waikato Regional Council	$456,830	$2,086,467
12/03	Marine Management Model (PDF, 56.7kB)	Waikato Regional Council	$207,650	$456,830
12/04	Guidance for Aquaculture Monitoring in the Waikato Region (PDF, 54.3kB)	Waikato Regional Council	$74,754	$149,508
13/01	Marlborough Sounds Hydrodynamic and Ecological Modelling (PDF, 57.8kB)	Marlborough District Council	$175,187	$350,374
13/02	Aquaculture Zoning in the Southland Region(PDF, 70.2kB)	Southland Regional Council	$20,765	$41,530

Note: Dates are year/month

9.2.3 Lead state agency support

In 2012, the Ministry for Primary Industries developed a five-year action plan for federal coordination and an aquaculture development goal of in New Zealand of $1 billion NZD ($0.81 billion) by 2025 (New Zealand Government. 2012). This action plan is a model for federal and state legislation aquaculture coordination toward achievable development goals both for Alaska and for the United States. The strategy has strong support from the Minister of Fisheries and the Minister for Economic Development. It clearly identifies the role of each agency in the development of aquaculture (New Zealand Government 2012):

> ***Agency Roles***
>
> For marine-based aquaculture, the Ministry of Fisheries' responsibilities include providing information, advice and formal assessments to regional councils on fisheries matters for coastal plans and aquaculture applications. The Ministry of Fisheries is responsible for determining whether a proposed aquaculture site will have an undue adverse effect on fishing (commercial, recreational and customary fishing). The

Ministry of Fisheries is also the lead Crown agency responsible for implementing the Māori Aquaculture Settlement.

The Ministry of Fisheries manages land-based farming under the provisions of the Freshwater Fish Farming Regulations 1983. FishServe, on behalf of the Ministry of Fisheries, is responsible for managing the Fish Farmer Register. The aquaculture reforms that took effect from January 1, 2005 require all persons carrying out the activity of fish farming to be registered under the Fisheries Act 1996.

The Department of Conservation works to ensure sustainable management of the coastal environment through good coastal planning that gives effect to the New Zealand Coastal Policy Statement 2010 and the Resource Management Act 1991 (RMA). Aquaculture management areas (AMAs) must be established in regional coastal plans.

DOC contributes to the planning for AMAs by providing preliminary information and advice to councils on coastal management and marine issues before plans are notified, and by participating in the statutory process for AMA/coastal plan development.

DOC also prepares a briefing with recommendations to the Minister of Conservation concerning the approval of regional coastal plans in accordance with the RMA.

The Ministry for the Environment is responsible for legislative reforms associated with the Aquaculture Reforms, as well as for the implementation of the Resource Management Act. The Ministry also provides guidance and support for good planning process and decision making.

The Ministry of Economic Development is the lead agency for advising on, and giving effect to, the Government's economic transformation objective. In this role our aim is to coordinate and enable a range of government agencies to work collaboratively to identify, advise on, and implement the suite of priorities and actions that collectively comprise the economic transformation agenda. Aquaculture is a key part of that agenda. Enhancing the number and importance of innovative and globally competitive firms is central to the work of the Ministry. The Industry and Regional Development Branch provides advice on the key issues they face in lifting their productivity performance and develops programs, largely delivered by New Zealand Trade and Enterprise to address these issues.

New Zealand Trade and Enterprise is the New Zealand government's national economic development agency. Through our network of offices worldwide, NZTE aims to build New Zealand's economy by boosting the capability of businesses and regions and facilitating their sustainable and profitable participation in overseas markets. Aquaculture is one of New Zealand's key food and beverage sectors, and NZTE is working with the sector as it develops its international market plan – to determine areas of focus over the next five years.

Te Puni Kōkiri promotes increases in levels of achievement attained by native tribal Māori with respect to education, training and employment, health and economic resource development; monitors and liaises with each department and agency that provides, or has a responsibility to provide, services to or for Māori, for the purpose of ensuring the adequacy of those services. It also offers services and information to assist in the development of Māori businesses. Since 2004, Te Puni Kōkiri's strategic direction and associated efforts have been focused on 'Māori succeeding as Māori'.

> This desired outcome recognizes the importance of Māori achieving a sustainable level of success that is underpinned by the cultural fabric that is part of being Māori. This desired outcome state is supported by the Māori Potential Approach, which is the Ministry's overarching policy framework and basis for all of its operations.
>
> New Zealand Industry Training Organization (NZITO) provides a model for workforce development in industry trades of aquaculture, seafood processing, vessel operation, and wholesale and retail seafood industries. Industry training is based on unit standards and qualifications on the National Qualifications Framework (NQF) for over 800 jobs. For example, certification 1456 is for the Farm Management of Single Seed Pacific Oysters involving competency in selective breeding, grading, farm managing, fattening, and nursery culture and grow-out with classroom and work experience. It also provides support to industry via grants and resources for training to national standards.

9.2.4 Level of coordinated research and development

Aquaculture New Zealand provides a key role in articulating the aquaculture R&D framework for New Zealand. In the five-year aquaculture development plan initiated in 2012, the government's role, led by the MPI but with the Ministry of Fisheries as the lead permitting and regulating body, is articulated, with R&D a key component of industry development.

Many of the projects are carried out at the Cawthron Institute (2015), including the 20 hectare Cawthron aquaculture park, which hosts aquaculture industry firms, teaching labs operated by the Nelson Marlborough Institute of Technology, and Cawthron's own aquaculture and biotechnology research group. Funding for R&D goes from all federal support (for pure research) to all industry support (for pure applied research), depending on the industry bottleneck. The Cawthron Institute also helps prepare farm site applications and environmental analyses.

The National Institute of Water and Atmospheric Research Limited (NIWA) has the largest team of coastal marine scientists in New Zealand. NIWA Science provides the underlying research capability, through its National Centre for Fisheries and Aquaculture, to assist clients with the technical aspects of aquaculture in New Zealand and to promote sustainable resource management. NIWA Natural Solutions is the commercialization vehicle of NIWA. Its principal role is to transform the knowledge base and intellectual property generated by NIWA Science into product-based commercial opportunities. This is achieved by undertaking commercial feasibility studies, identifying market opportunities and partnering or facilitating commercial development activities.

9.2.5 Regulatory process

Farmers do not own their farms, but are granted a coastal permit by Regional Councils to use the water space. By 2001, over 4,000 hectares were being farmed and due to a supposedly "haphazard" permitting policy and the overwhelmed status of Regional councils to a flood of applications, there was an aquaculture moratorium to new farms in New Zealand in 2002. This two-year moratorium required new legislation to examine the effects of aquaculture on the environment and fisheries, and the status of native Maori. After a lengthy process, in 2011 the Aquaculture Reform (Repeals and Conditional Provisions) Amendment Act (New Zealand Legislation. 2011) was passed, and has gone a long way to define government jurisdictions, streamline the regulatory environment and increase investor confidence. The Maori settlement allocated 20 percent of the aquaculture lease sites to the natives, and the 2011 Aquaculture Reform act provides a solid base for aquaculture expansion over the next decade. The following text was obtained from Aquaculture New Zealand (2014), and it provides a summary of governmental roles and how they relate to industry regulation.

> The New Zealand Government is committed to environmentally sustainable aquaculture development. Although the Aquaculture Unit within the Ministry of Fisheries is the lead for aquaculture in New Zealand, aquaculture is a whole-of-government initiative. This is because sustainable aquaculture involves a range of considerations, e.g. coastal planning, customary rights and environmental management.

The Ministry for the Environment (2014) provided a summary of the regulatory history and applicable laws:

> **Aquaculture regulation before the Aquaculture Reform Act**
>
> Until 1991 (when the RMA was passed), permits for marine farming were issued by Fisheries authorities solely for farming and spat-catching activities. There was a two-year period between 1991 and 1993 when a resource consent could authorize occupation and the placement of marine farming structures, but there was no legislative provision allowing fish stock to be taken and held on those structures, or harvested from them. In 1993, the amendment to the Fisheries Act 1986 enforced a dual permitting system, requiring an RMA coastal permit from councils first (for occupation, structures and, if necessary, discharges), and then a marine farming or spat-catching permit under the Fisheries Act.
>
> Under the Marine Farming Act 1971 the Ministry of Fisheries had the power to take forfeiture action against marine farms that breached the conditions on their lease or license (typically if abandoned, undeveloped or in a state of disrepair). The Fisheries Act does not include a provision for forfeiture action, and neither does the RMA. Instead, councils have the responsibility for managing any adverse effects under the RMA and the ability to take enforcement action against consent holders who breach their consent conditions.
>
> The Government instituted a moratorium on new marine farm consents at the end of 2001 to abate the large number of applications for marine farm space that were over-burdening the previous legislative and planning framework. There is still a backlog of such marine farming applications from the date of the moratorium, and these are being processed under the old legislative system.
>
> ***Aquaculture reform legislation***
>
> The aquaculture reform legislation sought to create a more integrated aquaculture management regime in New Zealand, balancing economic development, environmental sustainability, Treaty of Waitangi obligations and community concerns. The reforms reduced the dual permitting system to a one-step process managed under the RMA, giving councils full responsibility for managing aquaculture in their regions.
>
> The aquaculture reform legislation created a new process for aquaculture planning under the RMA. New marine farms can now only be established in areas specifically zoned for that use in regional coastal plans. These areas are called aquaculture management areas, often referred to as AMAs. The establishment of aquaculture management areas in regional coastal plans is by a plan change undertaken in accordance with the first Schedule of the RMA; i.e. involving a full public process.

Plan changes to establish aquaculture management areas can be initiated by regional or unitary councils, or by private interests.

Existing marine farm leases and licenses issued under the Marine Farming Act or a marine farming or spat-catching permit issued under the Fisheries Act have been deemed to be RMA coastal permits by transitional provisions.[3] The transitional provisions also deem the areas with deemed coastal permits to be aquaculture management areas.

The roles and responsibilities of regional and unitary councils have been clarified. They are responsible for managing all the environmental effects of marine farming, including any effects on fisheries and other marine resources through the RMA process. There are also new provisions relating to the allocation of space in the coastal marine area.

Before the reform of the legislation, individual applications for new marine farms were assessed in terms of their effects on fishing and fisheries resources (i.e. the wider ecosystem) through an undue adverse effects test under the Fisheries Act. The reform legislation has narrowed the scope of the undue adverse test to customary, recreational and commercial fishing, and the test is undertaken on the proposed aquaculture management area as part of the aquaculture management area planning process before it is publicly notified (not on individual consent applications).

The aquaculture reform legislation also addressed Treaty of Waitangi claims to commercial aquaculture after 21 September 1992 by allocating 20% of new space and 20% of "pre-commencement space" to iwi. Pre-commencement space is space that was granted between 21 September 1992 and 31 December 2004, and includes space consented to after 31 December 2004 if the consents were applied for under the old legislation. The aquaculture reform legislation allows the Government to meet its obligation for 20 percent of pre-commencement space in three ways:

- it can require an additional 20 percent from new space where the plan change to establish the aquaculture management area was council initiated, or
- it can purchase existing marine farming space from 1 January 2008 onwards, or
- from January 2013 any remaining obligation to iwi can be covered by a financial equivalent.

Resource Management Act

The Resource Management Act 1991 aimed to create an integrated and legal framework for the management of environmental effects from all uses of land, air, fresh and marine waters, with the purpose of "promoting the sustainable management of natural and physical resources". Sustainable management of natural and physical resources, as defined in the purpose of the Act, means managing the use, development and protection of natural and physical resources in a way, or at a rate, that enables people and communities to provide for their social, economic and cultural wellbeing and for their health and safety while:

[3] Aquaculture Reform (Repeals and Transitional Provisions) Act 2004, sections 10, 20, 21 and 45.

1. sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations;
2. safeguarding the life-supporting capacity of air, water, soil and ecosystems; and
3. avoiding, remedying and mitigating the adverse effects of activities on the environment.

The aim of the Act is permissive rather than prescriptive in the sense that the use and development of resources is permitted provided that the environmental outcomes are acceptable and sustainable.[4]

From a risk management perspective the RMA has given rise to a government agency (the Environmental Risk Management Authority), whose business is to assess the environmental impacts and risks of hazardous substances, as well as to a substantial body of case law and advisory documentation for councils from government departments such as the Ministry for the Environment and the Department of Conservation. This activity substantially reduces the risk of a council making a wrong decision with respect to consenting conditions, or the allocation of aquaculture management areas.

The creation of a new aquaculture management area, whether a council-initiated plan change or from a private plan change, is undertaken in accordance with the First Schedule of the RMA, involving a full public process. In some regions there is fierce competition for the use of space in the coastal marine area, and it is realistic that aquaculture management area creation could take five years or more.

All consents for marine farming are now under the RMA. Deemed coastal permits and new consents will have a finite consent duration, although the underlying aquaculture management area remains in the regional coastal plan unless specifically removed. Before the consent expires, the marine farmer will need to apply for a new consent. The holder of a deemed coastal permit from a former lease or license has one preferential right of application for a further term of occupation under section 49 of the Transitional Act.

The RMA also provides a preferential right of application to the incumbent so long as the permit was in force at the time of application, applies to an area located in an aquaculture management area, and complies with section 124 of the RMA.

New Zealand Coastal Policy Statement

The New Zealand Coastal Policy Statement (NZCPS) is the only mandatory national policy statement under the RMA. The purpose of the NZCPS is to state policies to achieve the purpose of the RMA – to promote the sustainable management of natural and physical resources – in relation to the coastal environment of New Zealand.

The NZCPS sets out policies regarding the management of natural and physical resources in the coastal environment. Local authorities are required by the RMA to give effect to the NZCPS through their plans and policy statements. Resource consent decision-makers must also have regard to relevant NZCPS policies.

[4] MAF 2002. The Role of On-Farm Quality Assurance and Environmental Management Systems (QA/EMS) in Achieving Sustainable Agriculture and Sustainable Land Management Outcomes.

The Department of Conservation is currently reviewing the NZCPS as part of the statutory requirement under the RMA. Part of this review will give consideration to whether and how the NZCPS contributes to the Government's goals for aquaculture by directly or indirectly addressing aquaculture activities. Another significant area of review is developing coastal water quality standards that may reduce the risks to aquaculture operations from coastal water contamination.

One of the key approaches being considered for this work is to use a risk assessment approach similar to that advocated in this report.

Regional coastal plans

Each regional council and unitary authority must prepare a regional coastal plan. Coastal plans are the only mandatory regional plans under the RMA. In the case of unitary authorities, the regional coastal plan may be part of the district plan. The rules within regional coastal plans define what type of activities can take place in that region's coastal marine area, including types of marine farming. New aquaculture management areas are established as a plan change in accordance with Schedule 1 of the RMA and will be developed and consulted upon by councils or private interests accordingly.[5]

The Government's aquaculture implementation team has almost completed a guide to aquaculture provisions in regional coastal plans.[6] This guide provides support and advice on the aquaculture reform and its implications for new aquaculture provisions in regional coastal plans prepared under the RMA.

Local Government Act 2002

The Local Government Act 2002 is a key piece of reform relating to the powers and intent of local authorities. The Act states the purpose of local government as being:

1. to enable democratic local decision-making and action by, and on behalf of, communities; and
2. to promote the social, economic, environmental, and cultural wellbeing of communities, in the present and for the future.

Section 14 of the Act establishes a number of principles relating to the role and performance of local authorities. Those with particular relevance to sustainable development of resources are noted below:

7. a local authority should ensure prudent stewardship and the efficient and effective use of its resources in the interests of its district or region; and
8. in taking a sustainable development approach, a local authority should take into account:

1. the social, economic, and cultural well-being of people and communities; and
2. the need to maintain and enhance the quality of the environment; and

[5] Instructive examples include Marlborough District Council's zoning of the Marlborough Sounds (see http://www.marlborough.govt.nz/rma/imagemap_template.cfm) and Northland Regional Council's aquaculture management area proposals (see http://www.nrc.govt.nz/upload/1850/Aquaculture%20Timeline%20(Jun%2007).jpg).

[6] The guide will be available at http://www.aquaculture.govt.nz.

3. the reasonably foreseeable needs of future generations.

The Sector Strategy states that aquaculture is an industry that sets out to be sustainable in the long term. In applying these Local Government Act principles to the resource consents for aquaculture activity, local authorities must finely balance consent conditions so social and economic wellbeing goals are achievable. They must also consider coastal communities where environmental quality may be at stake.

The Local Government Act gives specific direction to councils on collaboration to achieve outcomes:

5. a local authority should collaborate and co-operate with other local authorities and bodies as it considers appropriate to promote or achieve its priorities and desired outcomes, and make efficient use of resources.

The wishes of Maori with respect to aquaculture and the special consultative provisions of both the Local Government Act and the Aquaculture Reform legislation also bring with them interesting aspects of consent provisioning to meet their specific requirements.

Fisheries regulation

For plan changes to establish new aquaculture management areas, the Ministry of Fisheries undertakes an assessment of undue adverse effects (UAE) of proposed aquaculture management areas on recreational, customary and commercial fishing. This is called an aquaculture decision. Councils request the Chief Executive of the Ministry of Fisheries to make an aquaculture decision before publicly notifying a proposed plan change to establish an aquaculture management area. The Ministry of Fisheries has six months to make this decision, with a further three months during which the decision-making process can be contested (i.e. a judicial review). The Ministry of Fisheries can have input into aquaculture consent processes as a submitter if the consent application is publicly notified.

The Ministry of Fisheries also maintains a register of all freshwater and marine farms to track the movement of farmed products. The register keeps information such as the name of the fish farmer; the location and boundaries of the fish farm, and the species of fish, aquatic life or seaweed that may be farmed.

Other regulatory and legislative considerations

Maritime New Zealand guidelines

Maritime New Zealand has developed guidelines for the aquaculture industry and consent authorities on navigation-related matters. These guidelines cover the lighting and marking of marine farm structures in designated aquaculture management areas, but do not cover the location of designated aquaculture management areas. It is the responsibility of councils to ensure that existing and new aquaculture management area locations do not result in marine farms becoming navigational hazards, and to monitor farms for ongoing compliance. This makes up a significant component of councils' compliance monitoring of marine farms.

New Zealand Food Safety Authority

The New Zealand Food Safety Authority (NZFSA) sets standards, regulations and specifications for human health acceptability for all commercial shellfish products for sale from New Zealand waters. Standards are implemented through sampling of harvested shellfish and routine testing of farm environments. This is a user-pays service to the industry, which delivers proof of market acceptability. The regulations and specifications were developed in 2006 and represent an exacting standard, which means that New Zealand shellfish products meet or exceed the food safety requirements of markets worldwide.

NZFSA can also classify areas as restricted or prohibited from harvesting shellfish due to the potential for human health impacts from waterborne contaminants. These classifications can be long term due to site conditions, or short term due to events (e.g. NZFSA sets the site-specific restrictions on harvesting due to rainfall events). The prohibited classification has never been imposed on an existing marine farm site.

Building Act

This Act, administered by local authorities, provides for the regulation of building work, the establishment of a licensing regime for building practitioners, and the setting of performance standards for buildings.

While at first it may not be apparent that there is a link between coastal marine aquaculture and this Act, a visit to any part of the industry will show quite clearly the operational importance of buildings. Onshore these include warehouses, processing plants, equipment stores, workshops and offices. In the case of finfish farms, the structures in the water may include living quarters. Future structures, especially if further offshore, may also include sizeable building structures to support their operations.

The Building Act has made new building or modifications more demanding, and it is taking longer to get them authorized. The risks related to the timing of new marine farm businesses now have an added planning complexity with the workings of this Act.

9.2.6 Development strategies and key stakeholders involved

Aquaculture New Zealand was formed in 2007 as a single voice for the New Zealand aquaculture sector to protect the current industry, enhancing its profitability and providing leadership to facilitate transformational growth. The goal of Aquaculture New Zealand is "to see the New Zealand aquaculture sector recognized within New Zealand and around the world as producing healthy, high quality, environmentally sustainable aquaculture products" (Aquaculture New Zealand 2014). It brings together all of the three major species industry groups (New Zealand Mussel Industry Council, New Zealand Salmon Famers Association and New Zealand Oyster Industry Association). Mostly funded through an industry levy, the organization's chief role is the implementation of the industry strategy which will see the sector grow from $1 billion NZD ($0.81 billion) annually by 2025. Some documents aiding in the achievement of the industry's goals include:

Aquaculture New Zealand Research Strategy (2009). This is a key document which provides a framework for public investment in R&D.

It provides an excellent conceptual framework on how to develop Alaska. The main elements are Growth: Diversification and Efficiency; Maintenance: Sustainability and Security and Capability: Expertise and Infrastructure (Aquaculture New Zealand 2009).

Diversification: Key Elements

- New farming, harvesting and processing systems are developed

- New species - finfish, shellfish and others are brought into commercial production
- New high value products are developed from current and future aquaculture species and production systems
- Novel aquaculture technologies are developed.

Efficiency: Key Elements

- Optimal production capacity and profitability is attained for existing and future production systems within a framework of sustainable management
- Automation of processing systems

Sustainability: Key Elements

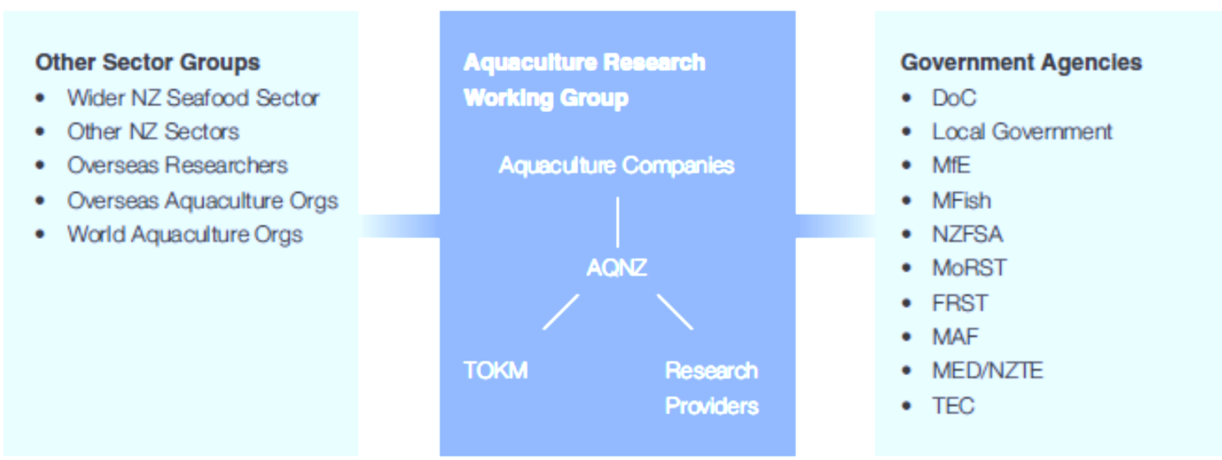
- Ecological foot prints and ecosystem interactions of current and future production systems are understood, quantified, managed and verifiable.

Security: Key Elements

- Strong risk management systems and tools protect current and future production systems from existing and emerging threats.

Implementation of the research strategy involves a strong industry lead in an Aquaculture Research Working Group, a network of national and international sectors, and 10 government agencies (Figure 47).

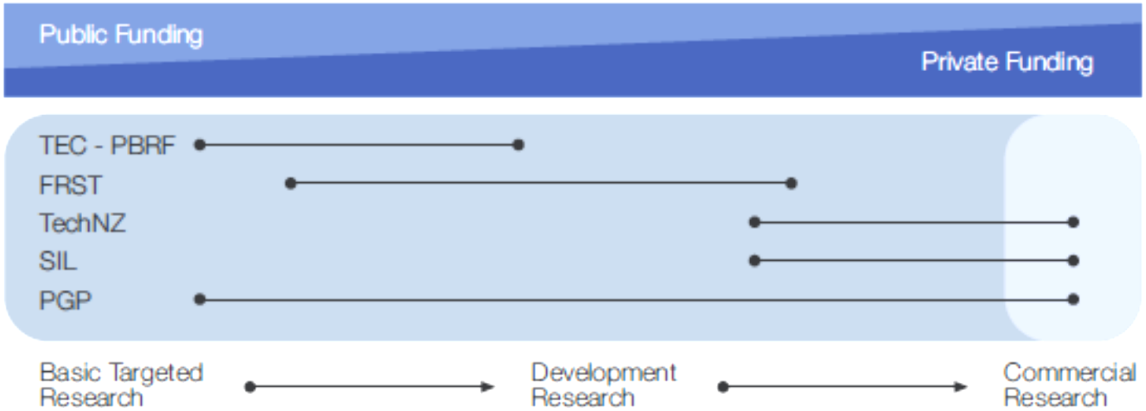
Figure 47. Aquaculture research and development implementation network for New Zealand with Aquaculture New Zealand in the center of the aquaculture strategy working group



Source: Aquaculture New Zealand, 2009

Funding for the strategy covers a range from applied industry funded projects to more basic projects funded by the universities. This range is captured, with a listing of 5 major New Zealand funding agencies, in Figure 48.

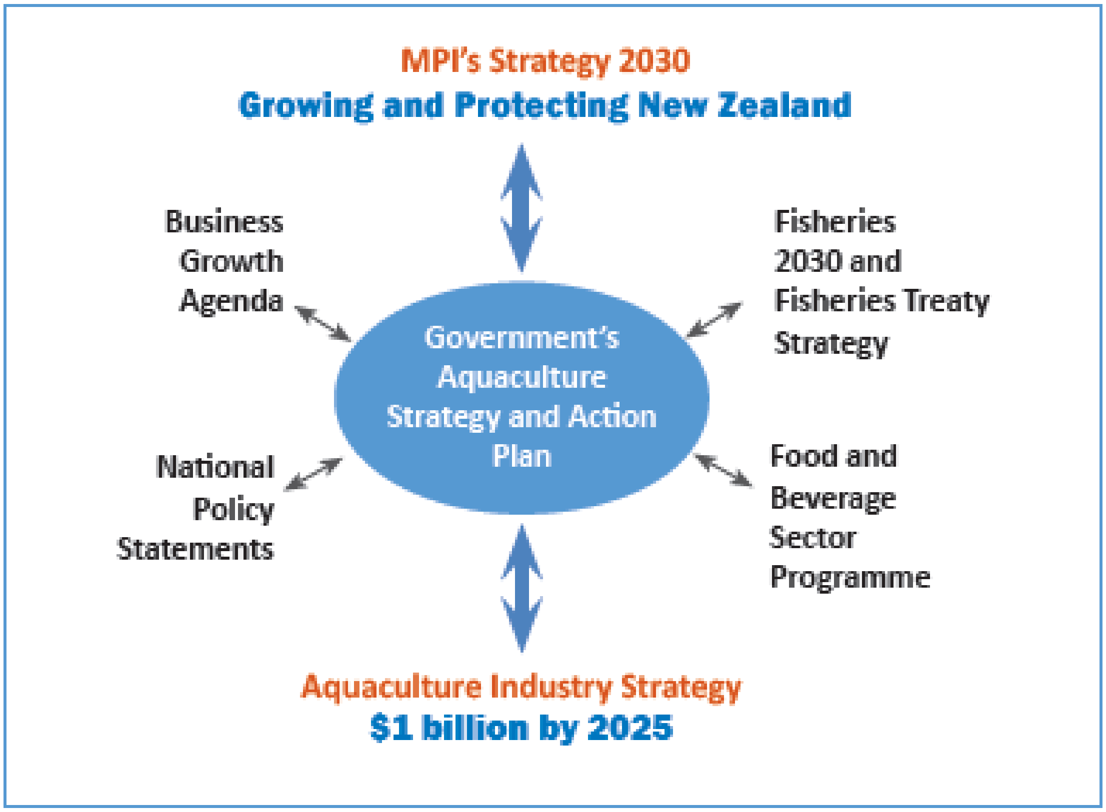
Figure 48. Funding for research and development of aquaculture in New Zealand



Source: Aquaculture New Zealand, 2009

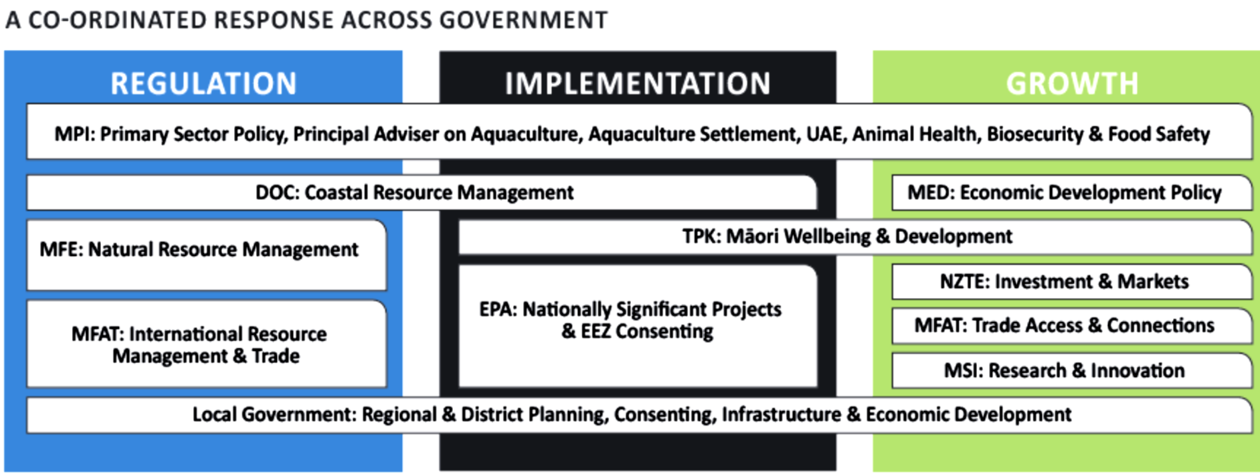
Growth of the aquaculture sector and a coordinated government response (Figure 49) is captured in the Government's five year action plan started in 2012 and managed by the government (MPI 2012). This is a key document. The plan shows a major role of industry in articulating the needs for R&D (Figure 49), and the government's role in regulation and implementation (Figure 50). In the plan, there are clearly outlined objectives, actions and activities with work plans, department leads, timelines, and performance measures. The five-year action plan meshes with the New Zealand coastal and fresh water policy statements and integration guidelines with the native Maori. in the growth section of the plan, the Ministry of Science and Innovation granted the Cawthron Institute in 2013 $19.7 million for a project "The Cultured Shellfish Programme: Enabling, Growing, and Securing NZ's Shellfish Aquaculture Sector".

Figure 49. MPI's aquaculture strategy, driven by business growth agenda



Source: MPI, 2012

Figure 50. Role of government agencies in regulation, implementation of the development plan, and growth of the industry



Source: MPI, 2012

Public Perceptions New Zealand Aquaculture (2014). This is a key document which describes New Zealand's perceptions about aquaculture, and a method for dealing with contentious issues.

For a good example of the sophistication of their industry and public messaging, see https://www.youtube.com/watch?v=1c4Hv5t5QNk

Engagement of coastal stakeholders, shipping, critical habitats and other elements in aquaculture development marine spatial strategies are occurring in some regions.

9.2.7 Coastal zone management plans

For each of the regions of New Zealand, aquaculture must be compatible with other marine uses. New lease sites may only be obtained in AMAs. A revision of the aquaculture laws, completed in 2012, allows for local, regional, and federal participation in the process. A marine spatial planning process is taking place in the Hauraki Gulf (Sea Change 2014), utilizing the GIS platform SeaSketch which has a comprehensive overlay of AMAs, ocean uses and activities, marine environment (biodiversity, goods and services, marine habitats, physical properties, swimming water quality), land use, and administrative boundaries.

9.2.8 Species present

The primary species cultured are native Greenshell mussels, the pacific oyster (Crassostrea gigas) and king salmon (Chinook salmon Oncorhynchus tschawytscha). An emerging species is the abalone (Haliotis iris, australis and virginea), where the New Zealand abalone farmer's association describe 14 farms throughout New Zealand and a production goal of $16.6 million in sales by 2015 New Zealand Abalone Farmers Association 2014).

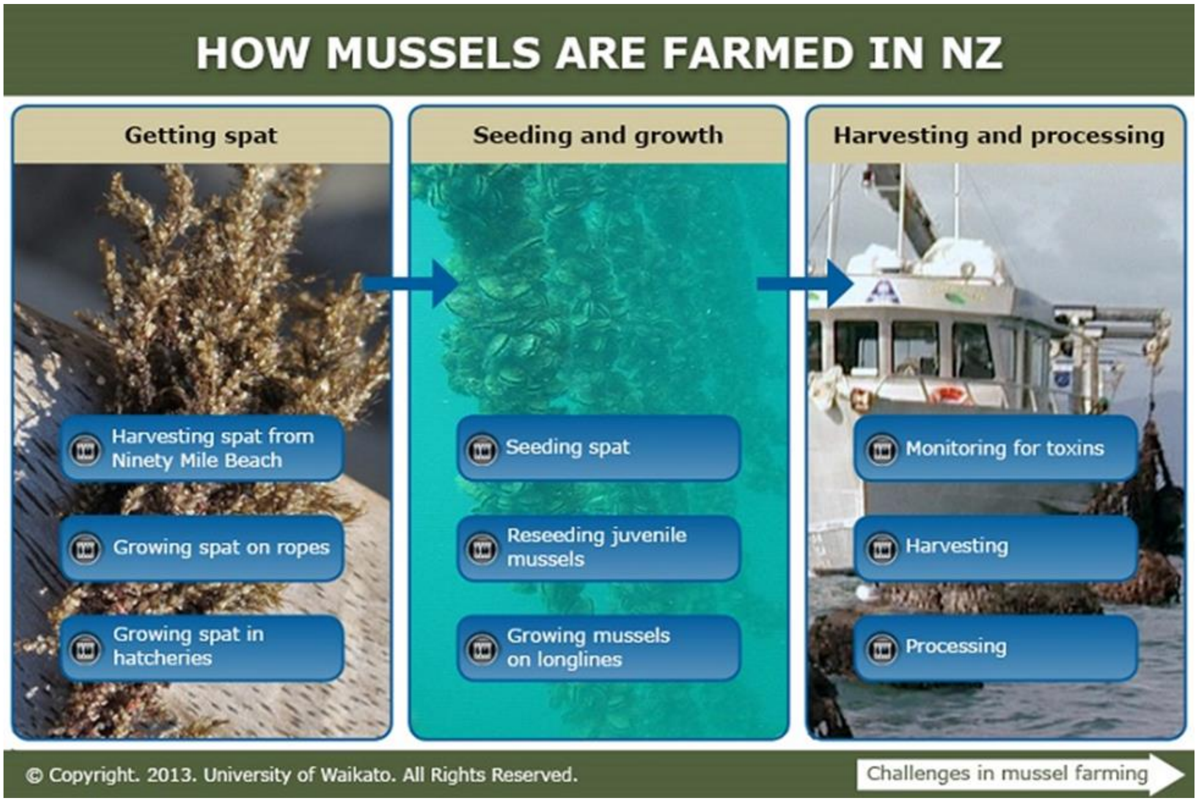
9.2.9 Biophysical characteristics

Of the 13,000 hectares designated for aquaculture in New Zealand's AMAs, 5,800 hectares have ideal characteristics for rapid growth of mussels, from spat to 3-4.5 inches in 12 to 18 months from fall seeding. The industry has developed in protected sites, and now offshore areas are being developed as modifications of the longline technology are being made. Water temperatures (10–18 C), salinity, and chlorophyll concentrations are adequate for rapid growth, but productivity of the farms (and meat yields) varies in part due to availability of nutrients from remineralized bottom sediments, advection from the open ocean, and riverine inputs. The problem of occasional toxic algal blooms has been dealt with through an extensive harmful algal bloom and mussel tissue monitoring program. There is ongoing research in oceanography, gear technology, and ecological interactions to expand the industry into offshore areas.

9.2.10 Culture and processing technology

A demonstration of how mussels are farmed and processed in New Zealand is presented in a video on the Biotechnology Learning Hub website (Figure 51).

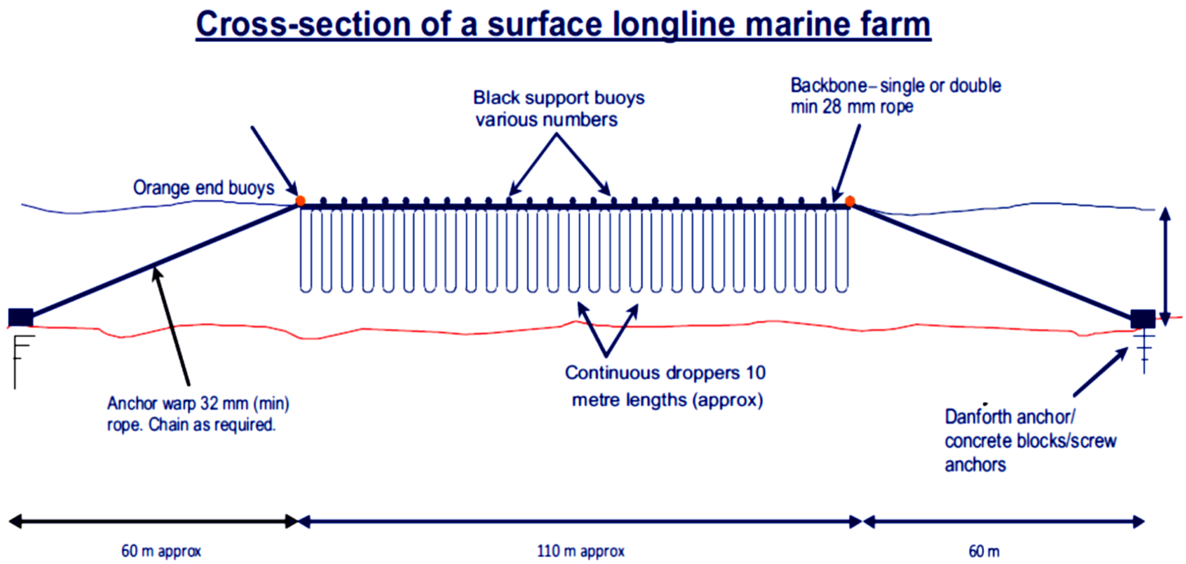
Figure 51. How mussels are farmed in New Zealand



Source: Biotechnology Learning Hub 2013b

The average lease is between three and five hectares although farms may vary from one hectare to 20 or more. Each three hectare farm has nine longlines (Figure 52) of 360 feet each. Each longline supports 11,483 to 13,123 feet of crop line. Each long line is supported by 50 to 70 polypropylene floats, each of which can support one metric ton (Marine Farming Association 2014a). Typical farms are anchored with auger anchors; special mussel rope is used for the grow-out lines; seeding is mechanized and controlled using a continuous socking machine; harvesting is continuous and accomplished with a stripping machine; and mussels are washed, declumped, graded and bagged on boat (Figure 53) before being brought to shore. Over 75 percent of the mussels are processed into frozen products (Figure 54).

Figure 52. Typical 110 m longline



Source: Marine Farming Association 2014b.

The best source of current mussel harvesting and processing technology is a company, Quality Equipment, which has the products outlined in their brochure "Mechanization and continuous Harvest Practice of the Modern Mussel Industry" (Quality Equipment 2014). They have vessels that harvest over 100,000 pounds of mussels a day, which cost about $2 million. Another source of equipment is Ansco Engineering (Ansco 2014).

Figure 53. Mussel harvesting boat in New Zealand

Source: Kenepuru, 2015

Figure 54. A Modern Mussel Processing Plant at North Island Mussels, Ltd.

Source: North Island Mussels, 2015

9.2.11 Cost/benefit analysis

The economic impact of aquaculture has been studied in three regions of New Zealand, in the Coromandel Region (Sapere Research Group 2011), in the Auckland region (Murray & McDonald 2010), and the Waikato Region (Auckland Regional Council 2010).

The following cost/benefit analysis of New Zealand Mariculture was provided by Ministry for the Environment (MFE 2014a):

> ***Investment and profitability***
>
> Marine farms represent significant investment in structures and stock. Industry participants have provided estimates for investment in structures on a per hectare

basis. While these have been quoted for species, it is likely that other species will use culture technology (racks, long lines and sea cages) that will not be dissimilar in cost to those used for oysters, mussels and finfish, respectively.

Table A2: Marine farming structure investment

Culture technology	Investment in structures per hectare	Notes
Rack culture	$20–40,000	Range reflects use of sticks or bags
Long-line culture	$30–40,000	Three to four long lines per hectare
Sea cage culture	$3.5–4 million	Major investment in sea cages

Source: Estimates from Risk Assessment Workshop, 13 July 2007

The recent market for water space has seen prices of up to $166,100 paid per hectare. A conservative intrinsic value of marine space has been estimated as $24,918 per hectare. High site value has made farm sale an attractive exit strategy for less committed marine farmers.

Stock values can vary significantly, depending on maturity, productivity and market price. Estimates of values per hectare at harvest include $41,530 for oysters, $49,836 for mussels and up to $3.3 million for salmon. Importantly, the productivity of aquaculture per hectare is significant in comparison to other primary industries.

Table A3: Marine farming average revenues

Species	Revenue per annum per hectare
Greenshell™ mussels	NZ$43,000
Pacific oysters	NZ$35,000
King salmon	NZ$1,130,000

Source: Courtesy New Zealand Marine Farmers Association, 2007

The high productivity is to some extent offset by the significant initial capital costs and operating costs of marine farming. However, marine farming has been profitable for many and has attracted significant investment in the development, commercialization and expansion of species and sites during its 40-year history in New Zealand.

A number of external factors can and have affected marine farming profitability. International competition has periodically driven down the international price of seafood sharply. This has been a driver for increasing production and marketing efficiencies in the shellfish sectors throughout New Zealand's marine farming history.

With the New Zealand dollar as high as $0.79 USD during the time of writing, aquaculture ventures are seeing export revenues eroded. This, too, is driving investment towards higher added value from existing space, and to better establishing points of difference for New Zealand seafood products in international markets. It has also driven further development of the domestic market for aquaculture products. While many businesses have adapted, there has been further attrition of smaller operators. However, marketing has paid off resulting in recent prices for frozen, half shell mussels of $2.90 per pound.

Biosecurity threats to production and market acceptability have also affected profitability in the past. Pests, diseases and biotoxins can deliver a range of impacts, from small productivity losses to massive stock mortality. The New Zealand aquaculture industry has not been hit by a particularly severe biological event in its history, and has developed effective collaborative programs to minimize the impacts of previous and ongoing biosecurity risks.

Protection of farm sites from pollution from land-based activities is an ongoing challenge to profitability, particularly for farmers operating near coastal property developments. Where pollution events occur, such as at the Waikare Inlet, Northland, in 2001, water quality around the farms does not meet sanitation requirements and the site is classified as restricted, with considerable limits placed on harvesting. It is difficult for farmers to manage the risk of pollution because it lies outside their farm management systems.

Despite a history of fluctuating profitability and current pressures, industry players have few concerns about the ongoing viability of their operations, and there is widespread confidence in the industry's ability to withstand future external pressures. With industry concentration continuing, the typical aquaculture venture is well resourced and resilient.

There is only limited anecdotal evidence of the failure of individual operators due to lack of profitability. Typically, these situations have been resolved by larger farmers partnering or buying out the struggling farmer.

The profitability and viability of aquaculture are likely to increase as industry focuses move away from commodity sales to increasing added value. Although it is likely that many New Zealand marine farms can still wring further efficiency from their operations, the preferred approach is to develop high-value products to meet demand in robust markets that are less subject to external pressures. Stakeholders note a major role for R&D throughout the value chain in maintaining and increasing the profitability of aquaculture in New Zealand.

9.3 Relevancy to Alaska Mariculture Initiative

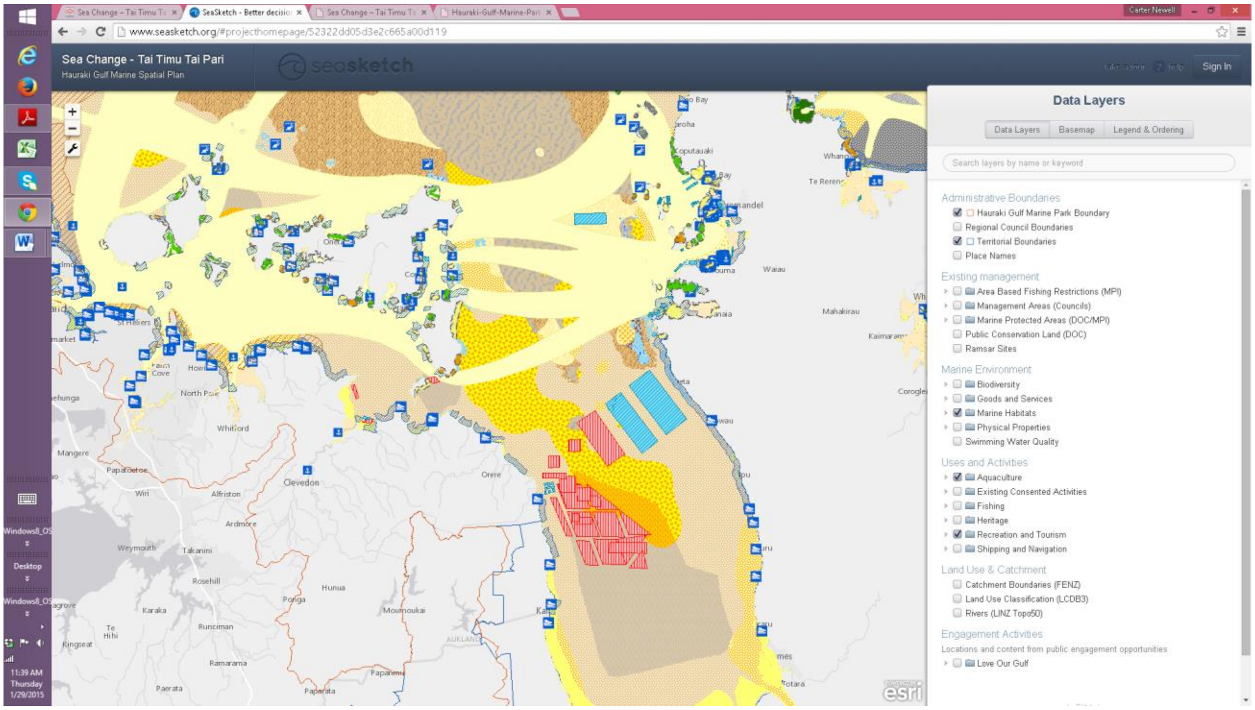
Alaska can use the successful development model in New Zealand as a guide for moving its mariculture initiative forward, as well as benefit from specific workforce development programs, farming and processing technology, and coordinated research and development initiatives. Participation of some key commercial fishing individuals and companies early on in Alaska, as was true in New Zealand, combined with improvements in technology (both in growing, harvesting, and processing) and the removal of bottlenecks, along with successful marketing, can make Alaska a success story too.

A summary of the key elements in the successful development of the New Zealand Greenshell™ mussel industry were presented in a 2011 analysis done by SeaFish in the United Kingdom (Bignell 2011):

- Establish a new national sector organization
- Strengthen the partnership with government
- Strengthen other stakeholder partnerships
- Secure and promote investment in aquaculture
- Improve public understanding and support for aquaculture
- Promote success in aquaculture
- Develop markets for New Zealand aquaculture products
- Maximize opportunities for innovation
- Promote environmental sustainability and integrity of aquaculture
- Invest in training, education and workforce promotion

The history of New Zealand has shown that the development of a profitable business model in the Marlborough Sounds area of New Zealand and facilitated expansion of the industry to other areas of the country. There are several characteristics that make this a good case study for the AMI to embrace in developing its strategic plan. Both the transportation and seafood infrastructure in New Zealand are enhanced by a $1 billion NZD ($0.81 billion) wild fishery with the sixth largest fishing zone in the world. This industry, with over 1,300 vessels, 200 processors and employing over 7,000 people, provides the backbone under which the aquaculture industry has developed over the past 40 years. In the early days, seafood harvesting and processing companies purchased shorefront facilities (wharves and piers) for aquaculture operations, where today it is cited that 0.8 hectares of land is needed for every 20 hectares of ocean farm area. In addition, New Zealand has been very successful in preparing the workforce for mussel farming and aquaculture trades. The Nelson Marlborough Institute of Technologyoffers a two-year diploma, a bachelor's degree (involving at least three different work placements and applied research projects) or a one-year post-graduate diploma in sustainable aquaculture. Auckland University of Technology also has a B.S., a B.A., an M.S. and a Ph.D. program in aquaculture. The Bay of Plenty Polytechnic and Mahurangi Technical Institute also offers aquaculture training. The New Zealand Industry Training Organization has an extensive training program in aquaculture, seafood processing, vessel operations, and wholesale and retail seafood trades. Finally, the history of the regulatory climate demonstrated that an interactive process (which is still continuing) resulted in the development of an expansion of the industry while simultaneously resulting in an improvement in public attitudes about aquaculture. A marine spatial plan occurring in the Hauraki Gulf region, including aquaculture, is part of a comprehensive management exercise involving all stakeholders including the native Maori (Sea Change 2014). Using the GIS platform SeaSketch, AMAs can be shown in relation to such layers as marine habitat, and recreation and tourism (Figure 55).

Figure 55. Screenshot of AMAs in the Hauraki Gulf Region near Auckland, New Zealand (Blue and Red Shapes) in Relation to Marine Habitat and Recreation and Tourism



Source: SeaSketch 2014

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10 Case study: First Nations aquaculture in Canada, with a focus on shellfish in British Columbia

10.1 Current status and economic impact of the industry

Canada's First Nations communities are uniquely positioned to benefit from aquaculture due to hunting, fishing and gathering rights, and access to aquaculture development sites. In many cases, the necessary skills and infrastructure for aquaculture development already exist because of past involvement in traditional fisheries (Parker 2014). The term "First Nations" is a widely accepted term used generally, but is increasingly used specifically to refer to status Indians who are members of a First Nation, while "Aboriginal" is less contentious and the most inclusive general term currently used in Canada (Kesler 2009). There are currently 50 Aboriginal groups from across Canada that have developed aquaculture business ventures and partnerships, with many more expressing interest and a desire to get involved in new aquaculture sector opportunities (Parker 2014). Aquaculture in Canada occurs in every province and the Yukon Territory (Figure 56).

Figure 56. Canada's Ten Provinces and Three Territories, and Their Capitals

Source: E Pluribus Anthony, 2007

In British Columbia (B.C.), 21 First Nations are engaged in shellfish aquaculture activities and 14 First Nations are engaged in finfish aquaculture. There are currently 56 different species of finfish, shellfish and aquatic plants commercially cultivated, generating about $1.81 billion in total economic activity, much of which takes place in rural and coastal communities (Parker 2014). Immediate opportunities exist for further development of finfish, shellfish and freshwater aquaculture endeavors, with additional longer-term opportunities for species such as geoduck, scallop, sablefish, sea cucumber and rockfish, where culture technology is under development (Parker 2014). In coastal B.C., First Nation communities have great potential for salmon and sablefish farming and processing, for oysters and clams, and emerging aquaculture species such as geoduck, abalone, cockles, scallops, sea urchins and possibly sturgeon, walleye and perch (Parker 2014). Kingzett et al. (2002) succinctly described why shellfish aquaculture in particular holds promise for B.C. Aboriginal communities:

> Shellfish culture may also appeal to aboriginal leaders seeking to develop economic strategies for their communities. A developed aquaculture industry has high labor demands year round and creates a wide diversity of full-time and part-time jobs. Moreover, expanding shellfish operations into processing further increases the number and the diversity of these jobs, including an increasing number of managerial and skilled positions. Aboriginal communities are also aware that further economic benefits may be realized through the development of a vertically integrated economic program.

First Nations participation in aquaculture was also recently well-articulated by the Canadian Department of Fisheries and Oceans (DFO 2010b):

> Several First Nations, such as Kitasoo/Xiaxias on the central coast of British Columbia, Aundeck Omni Kaning on Manitoulin Island, Ontario, Mi'kmaq in Nova Scotia, and Miawpukek in Newfoundland, have elected to become directly engaged in aquaculture production to generate employment and prosperity in their communities.
>
> In contrast, some other First Nations have been more reluctant to become involved in aquaculture as they are uncertain about the effects of aquaculture development or do not have the capacity to evaluate and implement opportunities in aquaculture. Still other communities are vocally opposed to aquaculture development within their traditional territories. Nevertheless, First Nations and other aboriginal communities have access to some of the best sites for aquaculture development in Canada, and many have an undeniable need for sustainable economic development opportunities. Furthermore, the current participation of aboriginal communities in aquaculture is not commensurate with the opportunities available. Aboriginal aquaculture development is often precluded by insufficient awareness of potential opportunities, misinformation regarding the environmental effects of aquaculture, the lack of capacity to develop opportunities, and difficulty with accessing capital.

According to the Canadian Department of Fisheries and Oceans (DFO), aquaculture employs approximately 14,500 people full-time, primarily in smaller coastal and rural communities (DFO 2013). Canada's farmed-salmon industry provides more than 10,000 jobs alone, the majority of which are in coastal areas of B.C. and New Brunswick. A 2004 survey estimated that Canada's aquaculture industry generated over half a billion dollars in labor income, with one-third of industry laborers earning between $19,256-26,958 annually (Mathews 2004).

A recent input-output analysis (DFO 2010a), reported that the aquaculture industry created 14,500 full-time-equivalent (FTE) jobs, and additional seasonal labor, in 2007. Direct employment in hatcheries, on farms, in processing plants and administration was estimated at 4,900 FTE, with another 6,400 FTE created in indirect activities supplying aquaculture with goods and services, and induced activity creating an additional 3,200 FTE. Furthermore, the aquaculture industry was responsible for just over half a billion dollars in labor income in 2007, which accounts for about half of total GDP. Total direct labor income was $152.2 million, resulting in average income of $31,062 per FTE employed in direct aquaculture activities. Indirect income earned by those employed in support industries was $234.1 million, with average incomes of about $36,595. Those employed in induced activities in the broader economy earned $104.7 million.

In B.C., output was valued at $523.4 million in 2007, accounting for about half the national value. The gross value of economic activity generated to produce this output was $884.7 million, while the industry makes an overall contribution to provincial GDP of $397.7 million, comprised of $141.3 million in direct, $157 million in indirect and $99.4 million in induced impacts. Aquaculture in B.C. generates about 6,000 FTE of employment, comprised of 2,220 FTE in direct activities, 2,330 FTE in indirect jobs and 1,410 FTE in induced activities, and was responsible for $208.8 million in labor income in 2007. Total direct labor income was $78.4 million, resulting in average income of $32,963 per FTE employed in direct aquaculture activities. Indirect income earned by those employed in support industries was $89 million, with average incomes of about $38,248. Those employed in induced activities in the broader economy earned $47.1 million, for an average income of $33,384.

10.2 History and growth of the industry

Canadian aquaculture production has increased four-fold over the past 20 years. Aquaculture represents 34% of Canada's total marine value and 14% of total seafood production. According to DFO statistics, the value of aquaculture production has increased by 52% over the last ten years, to $900 million in 2010 from $410 million in 2000 (DFO 2013). Atlantic salmon is Canada's top aquaculture export, accounting for a farm-gate value of CAD 670.7 million in 2010, while blue mussel is the top shellfish export, accounting for CAD 35.2 million in 2010 (DFO 2013). National aquaculture production output is divided about equally between the Pacific and Atlantic coasts. In 2010, B.C. accounted for about 51% of total production volume, followed by New Brunswick at 17%, Prince Edward Island at 13%, Newfoundland and Labrador at 10% and Nova Scotia at 5% (DFO 2013). Shellfish production has doubled since 1990, increasing from 4,000 to 8,000 tonnes, while farm gate value of output has increased about six-fold (from $2.9 to $17.5 million, CAD), reflecting strengthening markets and higher prices (DFO 2010a).

B.C.'s oyster industry, along with Prince Edward Island and New Brunswick oyster industries, had become well established by the late 1980s, and flourished during the 1990s and early 2000s (DFO 2010a). Similarly, a mussel industry emerged on the east coast during the 1970s, expanded rapidly during the 1990s, and today is Canada's leading shellfish species by weight and value (DFO 2010a). According to Kingzett et al. (2002), significant growth in B.C.'s shellfish aquaculture industry has occurred since the late 1970s, due to a number of factors that include:

- Production improvements through research, technology transfer, and developments (such as inexpensive and consistent hatchery seed stocks, mechanization, new suspended culture technologies, etc.).
- A shift in the structure of the industry to younger companies with production and business oriented approaches to aquaculture.
- A shift in regulatory and agency focus to recognize the importance of aquaculture potential.
- Global air freight services opening up strong international export markets.
- Diversification of the industry into new species and higher value product forms.

A provincial Shellfish Development Initiative (SDI) was announced for B.C. late 1998. The SDI set as its goal to double the amount of foreshore Crown land to be made available for shellfish aquaculture, providing an additional 2000 hectares to the present land under tenure, and coastal First Nations were identified as specific target groups to benefit from the initiative (Kingzett et al. 2002). B.C.'s plan to expand shellfish aquaculture included a commitment to enter into agreements with aboriginal communities to reserve sites within their traditional territories for their exclusive future use, as set-aside for ten years, during which time the First Nations can make an application for tenure (Kingzett et al. 2002).

By 2003, the Aboriginal Aquaculture Association (AAA) was established in response to high unemployment rates in First Nation communities and the decline of traditional resource industries such as forestry and fishing (Parker 2014). At the same time, aquaculture was one of the fastest growing sectors in B.C. The AAA was established to serve as a focal point for First Nations to develop renewed community economies based on sustainable, responsible aquaculture, and to assist and support the meaningful participation of First Nations in sustainable aquaculture development (Parker 2014).

In 2009, a new "Federal Framework for Aboriginal Economic Development" focused federal programs, legislation and partnership development to increase the participation of First Nations, Inuit and Métis peoples in the Canadian economy and improve economic actions for Aboriginal peoples in all parts of Canada. The framework emphasized strategic partnerships with Aboriginal groups, the private sector, and the provinces and territories and sought to maximize federal investments by: strengthening Aboriginal entrepreneurship; enhancing the value of Aboriginal assets; forging new and effective partnerships to maximize economic development opportunities; developing Aboriginal human capital; and better focusing the role of the Federal Government (Aboriginal Affairs and Northern Development Canada 2010). In 2014, the framework facilitated establishment of the "Aboriginal Aquaculture in Canada Initiative" (AACI) to support economic development opportunities. AAA coordinates the delivery of the support services of the AACI in B.C., Alberta and Canada's North (Yukon, Northwest Territories, Nunavut), including a Regional Aquaculture Business Development Team to provide business and technical services to Aboriginal communities and entrepreneurs interested in developing a sustainable business in aquaculture. Services include assistance with development and preparation of business plans, feasibility studies, preparation of project funding proposals, and help with the provision of advisory and aftercare support (Parker 2014).

10.2.1 Investment climate

In the late 1990's, one of the most pressing issues identified by B.C.'s shellfish growers trying to start a business was a lack of available funding (Salmon and Kingzett 2002). The report's authors went on to assert that difficulty in raising equity capital via traditional methods was due to the lack of tenure security, with existing operators only recently able to borrow against the value of their tenure holdings. Few financial institutions are prepared to lend funds based on a short tenure term and because the farmers have no security on the tenure, the tenure cannot be used as collateral for loans. In addition, lenders are often concerned that tenures could be cancelled during the term, or not renewed at the end, making it difficult to maintain financing over a long period.

In general, raising investment capital remains a problem for aquaculture operations. Salmon and Kingzett (2002) suggest that the opportunity for investment in the industry will either help existing farms become more profitable or will provide new entrants into the industry, both of which will create jobs in coastal communities and help diversify and grow the B.C. shellfish aquaculture industry. Specifically, the authors envisioned that attracting investment dollars to the shellfish aquaculture industry may take the form of:

- Developing promotional materials about the industry for generic and individual (corporate basis) to lending and capital investment groups.
- Working directly with traditional lenders (i.e. major banks) to inform them about the industry and strengthen investment confidence.
- Working directly with traditional lenders to assist in securing financing or other programs, which reduce the real or perceived risk to lenders.
- Working directly with non-traditional lenders such as community development agencies (such as community futures) to assist in lending directly to shellfish aquaculture or assisting with traditional lenders.
- Attracting non-traditional equity investment or specific projects such as fund-based programs, private investors or investment groups.
- Facilitating specific development projects involving specific new or existing farm(s) or companies and investment groups.
- Facilitating specific projects in secondary or processing sectors which will create regional support or value added.
- Working directly to secure or finance developing shellfish aquaculture operations.

DFO (2010a) has a more pessimistic view of Canada's shellfish aquaculture industry landscape:

> With some notable exceptions, the industry is composed of many small family-owned enterprises. While this is a good thing from the perspective of indigenous development in rural areas, because the industry is composed of small production units it lacks the financial resources to support technological innovation, resulting in low productivity, low margins and difficulty attracting and retaining a labour force. A fragmented industry also faces challenges in conducting its marketing effectively. These characteristics combine to create a poor investment climate.
>
> The opportunities for improved performance would appear to rest on securing greater productivity from existing sites and developing the market, both local and export. There is also a need to address public concerns about expansion based on environmental and aesthetic concerns. Public education and innovation are key to resolving these issues. And finally, improved performance is also going to hinge on resolving the difficulty the industry faces in meeting its labour needs. This will require time as the industry improves its margins through technological innovation and market development, allowing it to offer more attractive wages while also reducing labour dependence.

10.2.2 Private and public investment and capitalization

One prominent example of First Nations shellfish aquaculture investment is Coastal Shellfish, based in Prince Rupert, B.C. Both private and public investments established the Coastal Shellfish Corporation in 2011, with a multi-million dollar investment from the Coastal First Nations and other partners. Coastal First Nations is an alliance of nations from B.C.'s north and central coast and Haida Gwaii, from the Alaskan border in the north to Vancouver Island in the south. Member nations include Metlakatla, Gitga'at, Kitasoo/Xaixais, Heiltsuk, Nuxalk Nation, Wuikinuxv Nation, Old Massett, Skidegate, and Council of the Haida Nation. Along with a Chinese scallop aquaculture company, Coastal Shellfish built a shellfish hatchery and established seafood processing operations. In 2014, Coastal Shellfish raised an additional $5.4 million in investment capital through the Capital for Aboriginal Prosperity and Entrepreneurship (CAPE) Fund and the Metlakatla Development Corporation, and has since been rapidly expanding its farming capacity and supplying seed to other scallop farms (Coastal Shellfish 2014).

CAPE Fund is a $45 million private-sector investment fund founded by Canada's 21st Prime Minister, Paul Martin, and 21 of Canada's leading companies, individuals and international foundations. CAPE Fund's mission is to further a culture of economic independence, ownership, entrepreneurship, and enterprise management among Aboriginal peoples, on or off reserve through the creation and growth of successful businesses (CAPE Fund undated). CAPE Fund is focused on mid-market opportunities with a strong degree of Aboriginal involvement and connection to Aboriginal communities throughout Canada. The Fund partners in businesses by providing equity and quasi equity investment in varying amounts in the range of $820,665 to $6,155,038 (with most investments expected to be in the $2,461,997 to $4,103,418 range). These investments may be "one time" or "staged" depending on the growth and business requirements of the Fund's investee companies (CAPE Fund undated). CAPE Fund is a prime example of a funding instrument designed to bring new money into business development. This kind of inbound investment may be critical to bringing investment, management, and technology transfer to economically viable aquaculture development projects (Kingzett et al. 2002).

The Aboriginal Aquaculture in Canada Initiative, or AACI, also provides business development assistance, most directly through "Aboriginal Technical Business Experts". Through the AACI, Aboriginal communities and entrepreneurs can receive support for economic development opportunities in aquaculture. According to the AAA's website (AAA 2015), Aboriginal Technical Business Experts provide support with planning, development and implementation of economic development opportunities in the aquaculture sector, including:

- Identification of Opportunities
    - New or expanded commercial production: shellfish, finfish and freshwater
    - Development and operation of businesses in the aquaculture supply and services sector.
- Planning, feasibility analysis and preparation of business development plans.
- Identify new innovations, approaches and best practices.
- Implementation of Business Plans.
- Identify and facilitate partnership and joint venture opportunities.
- Advisory services and support.
- Linkages to government, industry, academia and non-government organizations bringing additional expertise to the initiative.

10.2.3 Lead state agency support

DFO supports aquaculture research and national strategic planning, primarily through programs and initiatives detailed in section 2.2.4, below. With regards to Aboriginal aquaculture development, the AAA was established to serve as a focal point for First Nations to develop renewed community economies based on aquaculture, and to support the meaningful participation of First Nations in sustainable aquaculture development. The AAA coordinates the delivery of the support services established through the Federal Framework for Aboriginal Economic Development (see sections 10.2 and 10.2.2, above).

10.2.4 Level of coordinated research and development

Aquaculture research is supported through DFO and regional aquaculture research facilities. The Aquaculture Collaborative Research and Development Program (ACRDP) is a DFO initiative to increase the level of collaborative research and development activity between the aquaculture industry and DFO researchers. The key goals of the program are to improve the competitiveness of the Canadian aquaculture industry through collaborative research with industry and to facilitate technology transfer (FAO 2015). ACRDP has an annual fund of $4 million for collaborative research projects that are proposed and jointly sponsored by aquaculture producer partners (FAO 2015).

Aquaculture regulatory research was recently summarized by DFO (DFO 2011). Significant programs include DFO's AIMAP, and the Centre of Expertise for Integrated Aquaculture Science (CIAS). The overall goal of AIMAP was to catalyze aquaculture industry investment from the private sector, and other sectors, to: 1) Improve the competitiveness of the Canadian aquaculture industry by encouraging an aquaculture sector that continuously develops and adopts innovative technologies and management techniques to enhance its global competitiveness and environmental performance; and 2) Position Canadian aquaculture products as having high value in the marketplace based on their environmental performance, traceability, and other considerations. AIMAP funded DFO research scientists between 2008 and 2013, with the purpose of supporting priority aquaculture, addressing regulatory knowledge gaps and supporting ecosystem-based environmental regulation and decision making (DFO 2011). Over the five years, DFO contributed $21 million to 163 projects with a total project value of $102.5 million. CIAS, a virtual center of aquaculture research expertise, leads the national integrated aquaculture research program, focused on four key areas: 1) the fate and impact of nutrient and organics released from fish farms; 2) disease interactions; 3) genetic interactions between farmed and wild organisms; and 4) the development of aquaculture methods that minimize environmental impacts. Of particular interest is the CIAS focus on development of integrated multi-trophic aquaculture, or "IMTA", to fulfill its goal of developing aquaculture methods that minimize environmental impact.

Specific to First Nations development support, the Strategic Partnerships Initiative funds the AACI to support Aboriginal economic development in Canada's aquaculture sector (see Section 2.2 for additional description). AACI provides technical business expertise to develop viable aquaculture business development plans and to help bring those plans to fruition (DFO 2015b).

10.2.5 Regulatory process

The aquaculture industry in Canada is overseen by a combination of federal, provincial and local authorities. Federal authority to regulate the aquaculture industry is shared between 17 departments and agencies, with the DFO as the lead. DFO is responsible for issuing licenses for the importation into Canada and movement between provinces of live fish (salmonids), eggs, and dead, uneviscerated fish under the 1985 Federal Fisheries Act and for fish health under the federal Fish Health Protection

Regulations (FAO 2015). DFO or Transport Canada manages the environmental assessment process in coordination with Environment Canada and the Canadian Environmental Assessment Agency under the Canadian Environmental Assessment Act of 1992 (FAO 2015). In B.C., the Department of Fisheries and Oceans Canada (DFO) is responsible for most aspects of the aquaculture industry, including licensing sites, data collection for production volume, species to be produced, fish health, sea lice levels and fish containment and waste control. However, the Province of B.C. issues tenures where operations take place in either the marine or freshwater environment, licenses marine plant cultivation, and manages business aspects of aquaculture such as work place health and safety.

Aquaculture policy in B.C. is contained within the Land Act and the Crown Land Use Operational Policy: Aquaculture. Licensing regulations are contained within the Fisheries Act, most importantly, the Pacific Aquaculture Regulations (SOR-2010-270) (Government of Canada Justice Laws Website 2015). To meet the requirements of the Aquaculture Regulation, all applications for a new aquaculture site or facility in B.C. must be accompanied by a completed management plan, with information outlining the location, layout and proposed production levels of the facility; the proximity of the site to other marine and upland resources; and the oceanographic and meteorological conditions experienced at the site (FAO 2015). Furthermore, the Minister may refer the management plan to other government departments and agencies for review and comment before making a decision on licensing. The departments and agencies include DFO, Transport Canada, the B.C. Ministry of Aboriginal Relations and Reconciliation, the B.C. Ministry of Environment, and local governments. Where the application has a potential to impact a First Nation's rights or interests, First Nations are to be consulted in accordance with the applicable First Nations consultation protocols.

Through the Fisheries Act, DFO regulates the aquaculture industry throughout Canada. The Act sets out authorities on fisheries licensing, management, protection, and pollution prevention. As summarized by DFO (2014), the following regulations are relevant for aquaculture:

- *Atlantic Fishery Regulations*: The aquaculture industry is subject to these wild capture fisheries Regulations. Through the Aquaculture Regulatory Reform, amendments to these Regulations would be brought forward to address aquaculture's unique regulatory requirements.
- *Fishery (General) Regulations*: They set out DFO's authorities for approving the release of fish into fish habitat and the transfer of live fish to fish rearing facilities. They also support DFO's management of aquaculture in B.C in conjunction with the Pacific Aquaculture Regulations. Through the Aquaculture Regulatory Reform, amendments to these Regulations would be brought forward to address aquaculture’s unique regulatory requirements.
- *Management of Contaminated Fisheries Regulations*: They authorize the Minister to close areas to recreational and commercial fishery harvests and to take other management measures when biotoxins, bacteria, chemical compounds or other substances are present in fish habitat to a degree that may constitute a danger to public health. Through the Aquaculture Regulatory Reform, amendments to these Regulations would be brought forward to address aquaculture’s unique regulatory requirements.
- *Marine Mammal Regulations*: They set out authorizations for the management and control of aquatic mammals that cause a nuisance to fisheries activities.
- *Maritime Provinces Fishery Regulations*: At present, aquaculture operators are constrained by these wild capture Regulations and unable to use current farming practices. Through the Aquaculture Regulatory Reform, amendments to these Regulations would be brought forward to address aquaculture’s unique regulatory requirements.

- *Pacific Aquaculture Regulations*: They set out DFO's licensing and management authorities for aquaculture in B.C. Through the Aquaculture Regulatory Reform, amendments to these Regulations would be brought forward to establish a license fee schedule for multi-year licenses for B.C. aquaculture operators.
  - *Past consultations*: Proposed B.C. Aquaculture License Fees
- *Pacific Fishery Regulations*: They set out DFO's authorities respecting fishing in the Pacific Ocean and the Province of B.C. Through the Aquaculture Regulatory Reform, amendments to these Regulations would align and clarify federal responsibilities with respect to fish importation and movement.

Although only applicable to finfish aquaculture, of interest is that B.C. has established specific siting criteria. Proposals for new salmon farms must meet certain requirements and minimum separation distances, including: distance from First Nations reserves (unless consent is received from the First Nation), salmon bearing streams, herring spawning areas, and intertidal shellfish beds that would be exposed to water flow from a salmon farm and which have regular or traditional use by First Nations, recreational, or commercial fisheries (FAO 2015). New tenures must also be located a specified distance away from all other wild shellfish beds and commercial shellfish growing operations, areas of "sensitive fish habitat", and areas used extensively by marine mammals, as determined by DFO and the province. Salmon farming operations must also not infringe on the riparian rights of an upland owner, without consent, for the term of the tenure license or in areas that would pre-empt important Aboriginal, commercial or recreational fisheries or areas of cultural or heritage significance (FAO 2015).

Aboriginal rights were established through the Natural Resources Transfer Agreement, part of the 1930 Constitution Act, which specifically provided that Indian people: "have the right, which the Province hereby assures to them, of hunting, trapping and fishing game and fish for food at all seasons of the year on all unoccupied Crown lands and on any other lands to which (they) may have a right of access." Treaty and Aboriginal rights relating to hunting, fishing and gathering are recognized and affirmed as part of the Constitution of Canada by Section 35 of the Constitution Act, 1982 (Province of Manitoba 2009). With respect to aquaculture development sites, FAO (2015) explains that where an "Economic Measures Memorandum of Understanding" (MOU) is in place with First Nations and where community criteria for tenure selection has been established for aquaculture, new applications will be accepted for suitable sites where they do not conflict with sites identified in the MOU. In the absence of an MOU, tenure applications are to be subject to consideration of First Nations interests and rights, any completed coastal resource plans, standard referral processes and community input as part of the public consultation process.

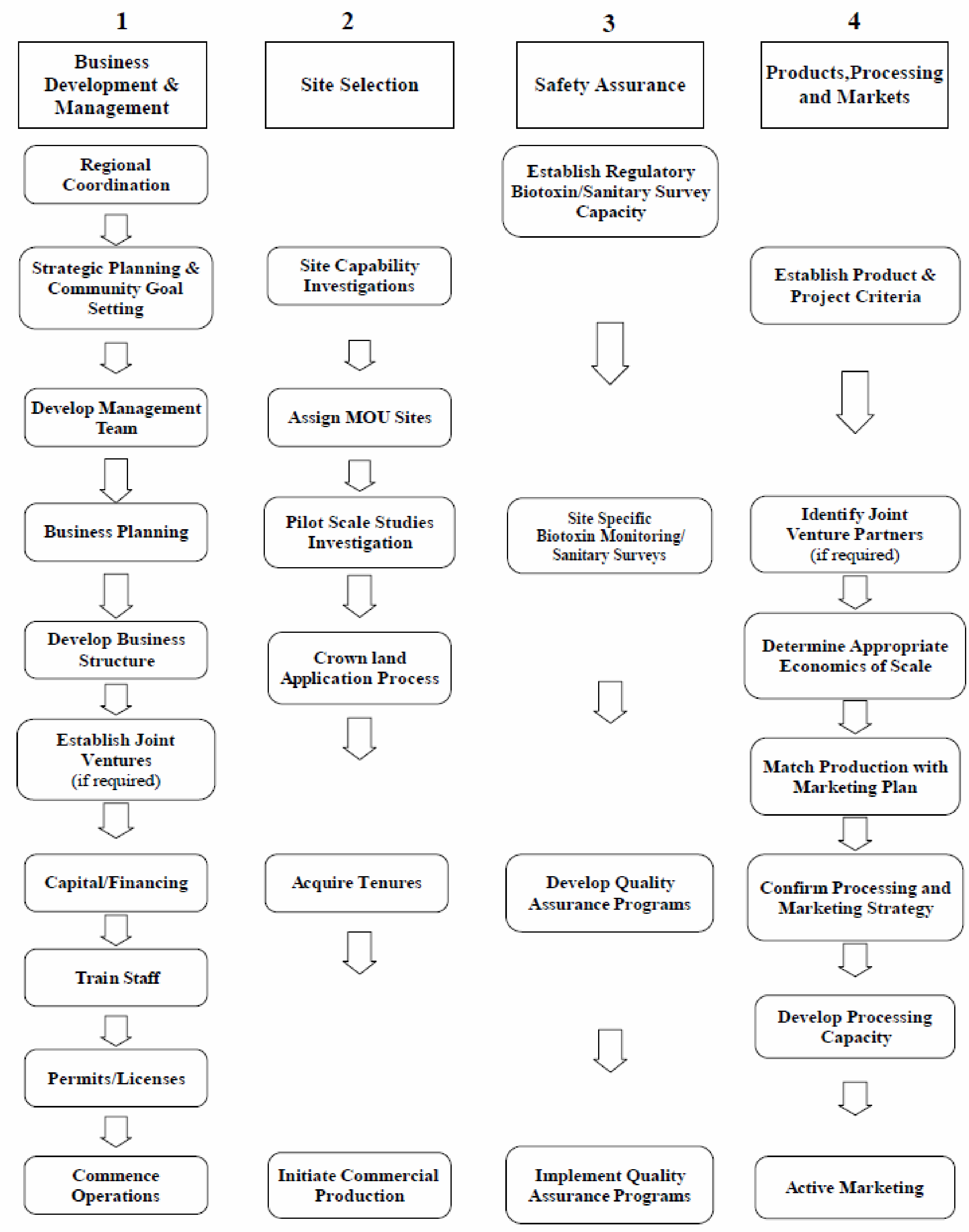
10.2.6 Development strategies and key stakeholders involved

The National Aquaculture Strategic Action Plan was developed through consultations with federal, provincial/territorial, industry, fish feed suppliers, First Nations and other Aboriginal groups, non-government organizations, academia, and other stakeholders (DFO 2010b). The action plan sets out a strategic vision for the future sustainability of the aquaculture sector, based on environmental protection, social well-being and economic prosperity. Three key areas: Governance; Social License and Reporting; and Productivity and Competitiveness, have specific action plans with steps currently underway for east coast marine finfish, west coast marine finfish, east coast shellfish, west coast shellfish, and freshwater (DFO 2010b). Current initiative actions include development of commercially viable alternative species such as cod, halibut, Arctic char, sturgeon, bay scallop, giant scallop, soft-shelled clam, walleye, geoduck, black cod and sea cucumber. The overarching aim is to prepare a comprehensive business case and developmental plan for alternate species aquaculture that includes a review of: market opportunities; investment opportunities and challenges; technological needs/obstacles/critical constraints; and realistic 5 and 10 year projections for sector development (DFO 2012).

The Aboriginal Aquaculture Engagement Initiative (AAEI) was a specific action identified, through the National Aquaculture Strategic Action Plan Initiative, to help increase Aboriginal engagement in aquaculture. This initiative was a partnership between DFO and Aboriginal organizations across Canada who represented the interests of Aboriginal communities related to fisheries and aquaculture, including the Aboriginal Aquaculture Association (see section 2.2). AAEI held a series of 20 meetings across Canada to seek the views of Aboriginal Canadians about aquaculture, and to determine their level of interest in the economic development opportunities available in the Canadian aquaculture sector (DFO 2015c). The 2009 Federal Framework for Aboriginal Economic Development also focused federal programs, legislation and partnership development to increase the participation of First Nations, Inuit and Métis peoples in the Canadian economy and improve economic actions for Aboriginal peoples in all parts of Canada.

Significant effort was put forth by Kingzett et al. (2002) to develop a First Nations Shellfish Aquaculture Regional Business Strategy. The business strategy was prepared for Land and Water British Columbia (a former B.C. government entity whose programs were integrated to various ministries in 2005) to aid development of economic measures supporting First Nations' entry into the shellfish farming industry along the Central and North coasts. The framework was intended to: a) identify the best sites and best species for farming in each First Nations community, using existing baseline biophysical and economic information, and; b) establish a template for business planning through which First Nations will apply for tenure, obtain seed and equipment, train staff and management, and develop the processing, transportation, and marketing infrastructure necessary for success (Kingzett et al. 2002). The authors stressed the need for a strategic framework for sustainable development and economic recovery (Figure 57).

Figure 57. Schematic and relative order of tasks for a regional development strategy



Source: Used with permission from Kingzett et al. 2002.

10.2.7 Coastal zone management plans

Despite some success at the regional level, a coordinated national strategy for CZM remains unrealized in Canada. In contrast to the United States, where concern for coastal zone problems led directly to the proposal of a Coastal Zone Management Act of 1972, Canada took the approach that coastal zone problems could be addressed through the Canada Water Act, which provided for joint federal provincial agreements (DFO 1998). However, a 1973 departmental reorganization resulted in the loss of the marine component of the Water Management Service, eliminating the unified marine and freshwater coastal zone strategy and the emerging network of bureaucrats and scientists who could be central to the creation of a federal CZM program (DFO 1998).

10.2.8 Species present

Across Canada, there are 26 different species of finfish and 16 species of shellfish cultured (DFO 2015a). Finfish represents the largest component of the aquaculture sector. Salmon is the most significant finfish in terms of volumes produced and sold, and among shellfish, mussels and oysters are the most significant. Marine algae farming is a small, yet growing sector in Canada, with many species of kelp, moss and seaweed cultivated in the Atlantic provinces.

Aquaculture in B.C. currently includes a wide variety of finfish and shellfish (Table 15). Cultured shellfish species include: Geoduck, Littleneck, Manila and Varnish clams; crayfish; Mediterranean, Eastern Blue, and Western Blue mussel; Pacific oyster; and Japanese and Pacific hybrid scallop. Finfish include: sablefish (Black cod); Chinook, Coho, Sockeye and Atlantic salmon; tilapia; White sturgeon; and steelhead/rainbow trout. Among these, First Nations corporations are actively rearing: Geoduck, Butter, Littleneck and Manila clam; Western Blue mussel, Pacific oyster, Pacific scallop, and Atlantic salmon. Furthermore, although no commercial culture currently exists in B.C., there is growing interest and support for the development of a cockle (*Clinocardium nuttalli*) aquaculture industry (AAA not dated).

Table 15. Finfish, shellfish and seaweed species cultivated in Canada

Common Name	Scientific Name	Province or Territory
Bigmouth Buffalo Fish	*Ictiobus cyprinellus*	Alberta
Carp, Grass (Triploid)	*Ctenopharyngodon idella*	Alberta
Trout, Brook/ Speckled	*Salvelinus fontinalis*	Alberta, Manitoba, Ontario, Quebec, New Brunswick, Nova Scotia
Char, Arctic	*Salvelinus alpinus*	Alberta, Manitoba, Ontario, Quebec, New Brunswick, Nova Scotia, Newfoundland and Labrador, Yukon
Clam, Geoduck	*Panopea generosa*	British Columbia
Clam, Littleneck	*Protothaca staminea*	British Columbia
Clam, Manila	*Venerupis philippinarum*	British Columbia
Clam, Varnish	*Nuttalia obscurata*	British Columbia
Crayfish	*Pacifastacus leniusculus*	British Columbia
Mussel, Gallo/ Mediterranean	*Mytilus galloprovincialis*	British Columbia
Mussel, Western Blue	*Mytilus trossulus*	British Columbia
Oyster, Pacific	*Crassostrea gigas*	British Columbia
Sablefish (Black Cod)	*Anoplopoma fimbria*	British Columbia
Salmon, Chinook	*Oncorhynchus tschawytscha*	British Columbia
Salmon, Coho	*Oncorhynchus kisutch*	British Columbia

Common Name	Scientific Name	Province or Territory
Salmon, Sockeye	*Oncorhynchus nerka*	British Columbia
Scallop, Japanese	*Pecten yessoensis*	British Columbia
Scallop, Pacific Hybrid	*Patinopecten caurinus x yessoensis*	British Columbia
Sturgeon, White	*Acipenser transmontanus*	British Columbia
Tilapia	*Tilapia spp.*	British Columbia, Alberta, Ontario
Trout, Rainbow/ Steelhead	*Oncorhynchus mykiss*	British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, New Brunswick, Prince Edward Island, Nova Scotia, Newfoundland and Labrador
Salmon, Atlantic	*Salmo salar*	British Columbia, New Brunswick, Prince Edward Island, Nova Scotia, Newfoundland and Labrador
Mussel, Eastern Blue	*Mytilus edulis*	British Columbia, Quebec, New Brunswick, Prince Edward Island, Nova Scotia, Newfoundland and Labrador
Cunner	*Tautogolabrus adspersus*	New Brunswick
Sturgeon, Atlantic	*Acipenser oxyrhynchus*	New Brunswick
Sturgeon, Short-nose	*Acipenser brevirostrum*	New Brunswick
Algae, Brown (Kelp)	*Phaeophyceae spp.*	New Brunswick, Nova Scotia
Algae, Red (Irish Moss, Dulse)	*Rhodophyceae spp.*	New Brunswick, Nova Scotia
Eels, American	*Anguilla rostrata*	New Brunswick, Nova Scotia, Newfoundland and Labrador
Clam, Hard (Quahog)	*Mercenaria mercenaria*	New Brunswick, Prince Edward Island, Nova Scotia
Scallop, Bay	*Argopecten irradians irradians*	New Brunswick, Prince Edward Island, Nova Scotia
Cod, Atlantic	*Gadus morhua*	Newfoundland and Labrador
Bass, Striped	*Morone saxatilis*	Nova Scotia
Bass, Largemouth	*Micropterus salmoides*	Ontario
Bass, Smallmouth	*Micropterus dolomieu*	Ontario, Quebec
Perch, Yellow	*Perca flavescens*	Ontario, Quebec
Clam, Soft Shell	*Mya arenaria*	Prince Edward Island, Nova Scotia
Halibut, Atlantic	*Hippoglossus hippoglossus*	Prince Edward Island, Nova Scotia
Salmon, Landlocked Atlantic	*Salmo salar*	Quebec
Trout, Brown	*Salmo trutta*	Quebec
Trout, Lake (Char)	*Salvelinus namaycush*	Quebec
Walleye/ Pickerel	*Stizostedion vitreum vitreum*	Quebec
Algae, Green (Sea Lettuce)	*Chlorophyceae spp.*	Quebec, New Brunswick, Nova Scotia
Scallop, Sea	*Placopecten magellanicus*	Quebec, New Brunswick, Nova Scotia
Oyster, American	*Crassostrea virginica*	Quebec, New Brunswick, Prince Edward Island, Nova Scotia

Source: DFO, 2015d.

10.2.9 Biophysical characteristics

The physical environment of coastal British Columbia is very similar to that of Alaska, especially southeast Alaska, due to proximity. As such, many species successfully reared for mariculture in B.C. (see Table 15) could likely be reared successfully in Alaska. In many instances, this is already the case and future efforts could therefore focus on identification of suitable production sites, and expanded culture of these species.

Biophysical characteristics that must be considered for production of shellfish species include: temperature, salinity, dissolved oxygen, pH, food availability, suspended sediments, tidal flow, wave height, substrate and beach slope. Additional important considerations include biofouling potential and predation. A summary of the main biophysical characteristics required for optimal mariculture of species with potential for Alaska, and currently reared in B.C., are included in Table 16. These include six shellfish species and Green sea urchin (*Strongylocentrotus drobachiensis*), as previously summarized by Kingzett et al. (2002). Geoduck are not included here since they are covered in the Washington case study.

Table 16. Key biophysical parameters for optimal production of six shellfish species and sea urchin

Species	Substrate (intertidal culture)	Depth (suspended culture)	Optimal Temperature	Optimal Salinity	Oxygen
Pacific oyster	firm	5-15 m	13-18°C	15-32 ppt	> 30 ppm
Blue mussel	n/a	5-15 m	8-18°C	15-32 ppt	> 30 ppm
Mediterranean mussel	n/a	5-15 m	10-20°C	15-32 ppt	> 30 ppm
Scallop	n/a	10-50 m	7-13°C	28-32 ppt	> 30 ppm
Manila clam	Shell, gravel, sand, mud	n/a	>13°C for 6 months	24-28 ppt	benthic
Sea urchin	Rocky	<50 m	9 - 20°C	28 – 35 ppt	6 ppm at 80% saturation
Cockle	Sand, mud	<30 m	10 – 20°C	28 -33 ppt	benthic

Source: PSI analysis using date from Kingzett et al., 2002

10.2.10 Culture and processing technology

Because most of Canada's shellfish products are sold live in the shell, minimal processing is required. Shellfish are simply cleaned, graded, packed and shipped. Kingzett et al. (2002) suggest that while automation and improved technology has been increasing (e.g., hydraulic lifts for harvest and product handling), most shellfish aquaculture activities are still highly labor intensive. The authors also cite a shellfish marketing survey (Ecotrust Canada 2002) which tallied a total of 31 licensed seafood processors able to process and/or ship B.C. shellfish. On Vancouver Island, 10 companies process primarily oysters and clams, with one company, Fanny Bay Oysters, handling more than 50% of the Island's current oyster shucking activity (Kingzett et al. 2002).

10.2.11 Cost/benefit analysis

Data or information providing a cost/benefit analysis of First Nations shellfish aquaculture operations in B.C. was not encountered for inclusion in this report.

10.3 Relevancy to Alaska Mariculture Initiative

This case study illustrates the impact of significant public investments in aquaculture planning and development, and its impacts on small rural coastal economies that are such an integral part of Alaska. The physical environment of coastal British Columbia is very similar to that of Alaska, especially southeast Alaska, due to proximity. As such, many species successfully reared for mariculture in B.C. (see Table 15) could likely be reared successfully in Alaska. In many instances, this is already the case and future efforts could focus identification of suitable production sites and expanded culture of these species. Remoteness of most aquaculture operations in B.C., and the associated challenges of access to transportation and a suitable workforce, also parallels the realities of Alaska's mariculture development potential.

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