November 2017

Alaska Mariculture Initiative
Economic Analysis to Inform a Comprehensive Plan
PHASE II

Prepared for
Alaska Mariculture Task Force

Prepared by
McDOWELL GROUP

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Executive Summary

The Alaska Fisheries Development Foundation contracted with McDowell Group to develop an economic framework for Alaska mariculture industry development. This framework, based on analysis of the current industry and potential industry growth scenarios, is designed to inform the Alaska Mariculture Task Force's comprehensive planning process and establishment of a more viable and sustainable industry.

Key Findings

Oysters dominate today's Alaska mariculture industry. Potential is growing for other species.

- Alaska mariculture industry today is focused on four main species: Pacific oysters, blue mussels, geoducks, and sugar kelp.
- Alaska mariculture production is dominated by oysters, accounting for over 90 percent of Alaska aquatic farm sales in 2015.
- Additional species with potential for mariculture/enhancement in Alaska include king crab, sea cucumbers, abalone, clams, purple-hinged rock scallops, weathervane scallops, and sea urchins.

Photo credit: Bob Koenitzer.

Alaska mariculture industry production and value is trending up.

- Oyster farm size and inventory, and oyster seed inventory, are increasing in Alaska, which suggests oyster production may increase substantially in the near future.
- While current farmed geoduck harvests are minimal in Alaska, geoduck farm inventory is potentially highly valuable, with over 900,000 clams to reach harvestable size over the coming decade.
- Most mussel production and sales in Alaska are incidental, as farmers of other species harvest mussels that naturally set on their gear. Mussels may serve as a source of supplemental income on oyster farms. In-state demand for mussels appears robust, and well above current production, at potentially 70,000 pounds or more annually.
- Kelp farming is just developing in Alaska, with harvests beginning in 2017 and one large-scale seaweed buyer operating in the state. Permit applications for 2017 indicate increasing kelp production on the horizon.

Seed security, profitability, regulations, market access, and data/information needs are critical challenges to industry growth.

The Alaska mariculture industry is small in scale, at approximately $1 million in output, relative to Alaska's commercial fisheries and seafood processing sectors and to mariculture industries in other states and nations. Investment in overcoming these hurdles for the industry will require a balance of private and public resources.

SEED SECURITY

- Investment, perhaps through public/private partnerships, in securing viable and consistent in-state sources of quality seed, particularly for oysters, kelp, and geoducks is critical for industry growth.

OPERATING COSTS/PROFITABILITY

- Start-up costs, financing constraints, long product grow-out times, logistical challenges in remote locations, and regulatory factors are some of the many challenges that can result in expenses that challenge the profitability of many operations.

REGULATIONS

- No Alaska statutes currently authorize shellfish stock restoration, rehabilitation, or enhancement other than for research.
- Some State regulations impacting mariculture operations are not aligned with operating realities, such as long product grow-out times.
- Seaweed-specific permitting needs revision.

Photo credit: NOAA.

ACCESS TO MARKETS

- Most Alaska mariculture product is currently sold to in-state markets. Growth will require much greater market penetration outside of Alaska.
- To reach out-of-state markets, Alaska farmers will need to provide a dependable supply of high-quality product, utilize affordable transportation options to reach markets, and develop capacity to produce product forms, such as frozen product, suitable for lower-cost transport to more distant market.

INFORMATION NEEDS

- Reliable access to data on environmental conditions, product growth factors, economics, and food safety considerations (such as PSP) allows users to analyze sites for productivity, conflicting uses, and efficiency and more effectively plan and operate businesses.

A balance of public and private investment focused on overcoming key industry challenges can position the Alaska mariculture industry for expansion in the coming decades.

- While private investment in mariculture will be critical to industry growth, some required investment, such as hatchery development to enhance seed security, or to support king crab hatchery R&D, does not or may not offer the profit incentive needed to attract private investment.
- Government support for the industry, such as that which has resulted in mariculture industry expansion in other countries and can lead to private investment, is essential for the industry to expand at a pace and scale commensurate with its full potential.

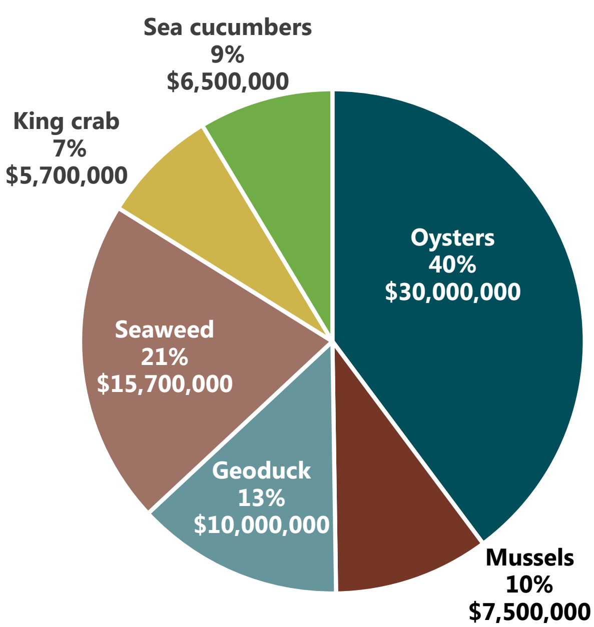
With strategic investment in overcoming current challenges, the Alaska mariculture industry could grow to a $100 million industry in the next 20 years.

- Species with greatest mariculture development potential (both farming and enhancement) in Alaska in the next 20 years include oysters, mussels, geoduck, kelp, king crab, and sea cucumbers.
- The economic framework outlined in this report establishes 20-year revenue and production goals that result in $105 million in annual output, including all direct, indirect, and induced effects.
- This 20-year goal includes $75 million in industry sales and an employment impact of 1,100 direct jobs and 1,500 total jobs.

Long-Range (20-Year) Annual Production Goals

- Pacific oysters (count): 45 million
- Geoducks (count): 500,000
- Kelp (lbs./wet): 19.2 million
- Kelp (lbs./dried): 2.9 million
- Blue mussels (lbs.): 1.8 million
- Red king crab (lbs.): 565,000
- Sea cucumbers (lbs.): 1.9 million

Twenty-Year Annual Revenue Goals



- At 20 years, annual labor income would include approximately $38 million in direct wages and a total of $49 million in direct, indirect, and induced labor income.
- 30-Year output associated with goals in this economic framework is projected at $274 million, while 50-Year output totals $571 million.
- This analysis concludes with a table of priority investments to grow the mariculture industry.

Introduction and Methodology

Introduction

The Alaska mariculture industry produces shellfish and aquatic plants along Alaska's coastline, benefitting the state's economy and communities. To strengthen the industry and enhance the benefits it brings to the state, the Governor-appointed Alaska Mariculture Task Force (MTF) is developing recommendations to establish a more viable and sustainable industry.

As part of this effort, the Alaska Fisheries Development Foundation contracted with McDowell Group to analyze the industry and develop an economic framework for potential industry growth scenarios. This framework aims to understand the economic costs, benefits, and impacts of potential approaches to industry development. Findings from this analysis make up Phase 2 of a three-phase process the MTF is undertaking. Results of this report will be incorporated into MTF recommendations.

Methodology

Project Process

This project was established as an iterative process between the McDowell Group project team, the MTF, and MTF advisory committees. The resulting document is a result of research, analysis, and discussion between these project groups, as well as industry and public input.

Report Organization

Alaska Mariculture Industry Phase II: Economic Framework is organized into the following chapters.

Chapter 1. Overview of Alaska's Mariculture Industry Today provides a discussion of baseline conditions in the industry. It includes a description of current mariculture production practices for all actively farmed species, including production volumes, sales, participation and employment, markets, trends, and other relevant information as available, as well as status reports on mariculture research and development efforts.

Chapter 2. Alaska's Mariculture Development Opportunities and Challenges discusses barriers and opportunities for mariculture development. This chapter incorporates research and recommendations from the MTF Advisory Committees and identifies the most important factors limiting growth in the industry.

Chapter 3. Economic Model for Development of Alaska's Mariculture Industry presents an economic framework for development of the Alaska mariculture industry in the next two decades and beyond. The chapter builds on information in the first two chapters to present development scenarios.

The report concludes with potential strategic development goals and a discussion on investments necessary to move forward.

Sources

A variety of information sources were used to develop a description of baseline conditions in Alaska's mariculture industry. Secondary sources for information include MTF advisory committee input, industry reports and plans, academic literature, presentations, meeting minutes, and other documents. Most recently available production and value data is provided, with specific data sources noted throughout the report as relevant. Findings were supplemented by interviews with farmers, regulatory agency personnel, processing companies, buyers, and retailers. The team talked with approximately fifty individuals during this analysis in addition MTF members and advisory committee members.

Chapter 1. Alaska's Mariculture Industry Today

This chapter describes the mariculture industry in Alaska, with a focus on current production and research and development activity.

The Aquatic Farm Act[1] authorizes the Commissioner of Alaska Department of Fish and Game (ADF&G) to issue permits for construction or operation of aquatic farms, and hatcheries to supply aquatic plants or shellfish to aquatic farms. The intent of the program is to create an industry in the state that will contribute to the economy and strengthen competitiveness of Alaska seafood in the world marketplace, broadening the diversity of products and providing year-round supplies of premium quality seafood. The law limits aquatic farming to shellfish and aquatic plants, prohibiting farming of finfish in the state.

The statewide Aquatic Farm Program is jointly administered by three state agencies: Department of Natural Resources (DNR), ADF&G, and Department of Environmental Conservation (DEC). Each of these agencies plays a specific role in authorizing and managing aquatic farm activities within Alaska.

ADF&G certifies and permits seed entering the state for aquatic farming, ensures mariculture operations do not significantly alter established fishery resources, determines wild stock populations prior to permitting aquatic farm species, and issues permits for the transport of seed and mariculture products.

The DNR authorizes the use of tide and submerged land and seeks to balance use of the land for mariculture with traditional uses of the area, upland owner access, public access, and navigation of public waters as required under Article VIII of the Alaska State Constitution.

The DEC certifies water quality for areas where aquatic farm products are produced and tests and certifies products before they are permitted to enter the commercial market to ensure they are safe for human consumption.

Most tide and submerged lands within Alaska's coastline are a common property resource managed upon multiple use principles and sustained yield requirements. The State of Alaska Constitution require resource decisions to be vetted through a public process and noticed for public input to balance resource management decisions with the best interests of the State of Alaska.

As of 2016, mariculture activity in Alaska consists of approximately 75 operations, including 65 authorized farms, seven nurseries, and three hatcheries. Most operations are located along the coastline in either Southeast or Southcentral.

[1] Section 19, Chapter 145, SLA 1988.

Current organisms permitted for mariculture include shellfish species and macroalgae, though few of these species are produced for market in Alaska at this time.

Table 1. Organisms Approved for Culture at Permitted Operations

Aquatic Farms and Nurseries	
Shellfish	Pacific Oyster, Blue Mussel, Geoduck, Littleneck Clam, Purple-Hinged Rock Scallop, Pink Scallop, Spiny Scallop, Cockle, Green Sea Urchin, Purple Sea Urchin, Red Sea Urchin, Sea Cucumber, Abalone
Macroalgae	Sugar Kelp, Giant Kelp, Bull Kelp, Ribbon Kelp, Red Ribbon Kelp, Three Ribbed Kelp, Nori, Sea Lettuce
Hatcheries	
Shellfish	Pacific Oyster, Blue Mussel, Geoduck, Littleneck Clam, Purple-Hinged Rock Scallop, Cockle, Pacific Razor Clam, Butter Clam, Blue King Crab, Red King Crab
Macroalgae	Dark Sea Lettuce, Dulse, Kombu, Nori, Ribbon Kelp, Sea Lettuce, Three Ribbed Kelp, Sugar Kelp, Bullwhip Kelp

Source: ADF&G.



Photo credits (from left to right): Alutiiq Pride Shellfish Hatchery, Bob Koenitzer, and Bob Koenitzer.

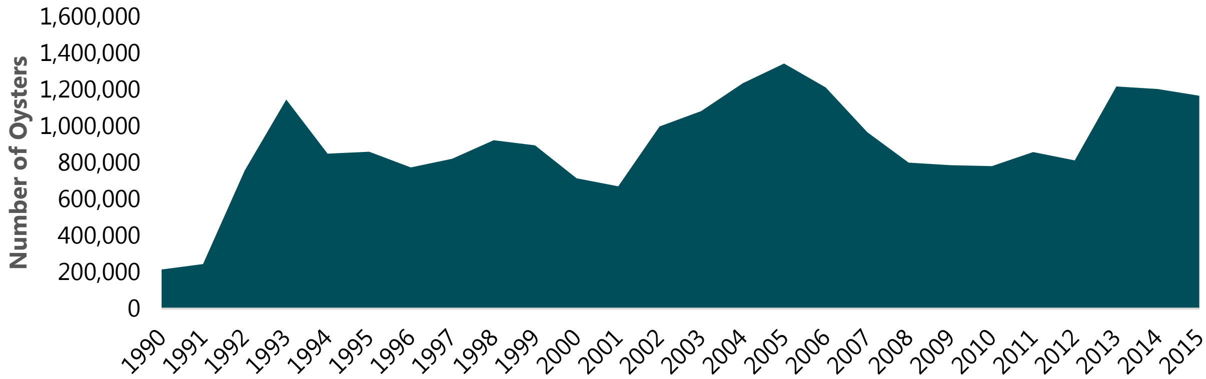
Production and Sales

Over the past 25 years, many organisms have been produced and sold from Alaska mariculture operations, though some at a very small scale. Since 1990, production has included Pacific oyster, geoduck, blue mussel, green sea urchin, littleneck clam, pink scallop, purple-hinged scallop, spiny scallop, red ribbon, sea cucumber, bull kelp, and sugar kelp.

Today, mariculture production in Alaska is primarily focused on oysters, with 31 permitted oyster farms in 2015, almost 1.2 million oysters sold, and statewide inventory of 15 million. In 2017, 43 oyster farms are permitted. In terms of production volume, oysters are followed by blue mussels, with four permitted farms, almost 17,000 pounds sold in 2015, and an inventory of 8 million mussels. In 2015, 16 permitted operations for geoducks accounted for 910,000 in inventory for this slow-growing species. Finally, while Pacific littleneck clam production once topped 68,000 pounds sold, there were no sales in 2015.

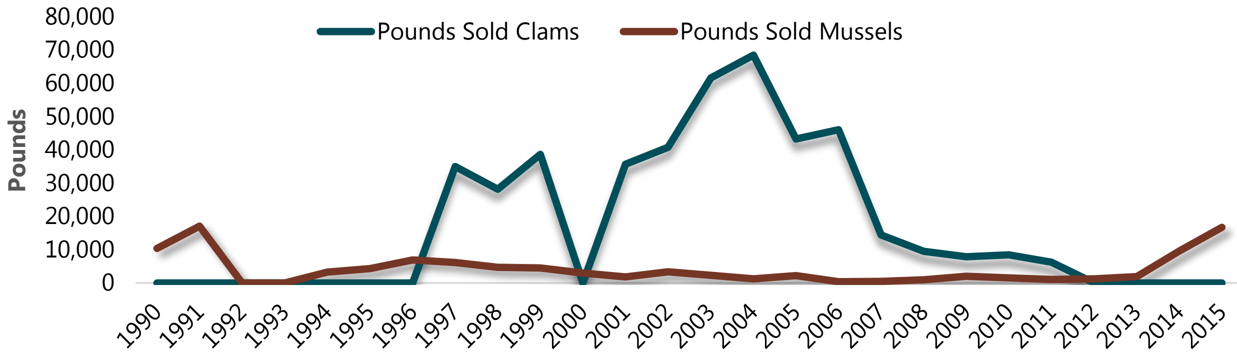
In addition to these shellfish species, sugar kelp harvests began to occur in spring 2017.

Figure 1. Oyster Sales in Alaska, 1990-2015



Source: ADF&G.

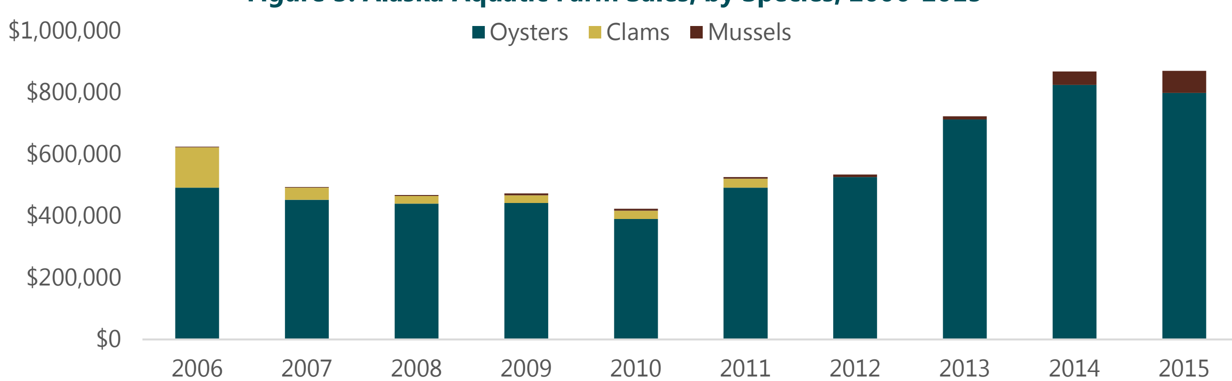
Figure 2. Clam and Mussel Sales in Alaska, 1990-2015



Note: For years with fewer than three operators reporting, production numbers are confidential and reported as zero.
Source: ADF&G.

Overall sales of shellfish and aquatic plants, including seed, topped $1.1 million in 2015. Aquatic farm oyster sales totaled almost $800,000, along with $71,000 in mussel sales, for a combined total of $870,000 in shellfish sales. Of that value, $421,000 in sales occurred from oyster production in Southeast, with the remainder (oyster and mussel) in Southcentral. No sales of farmed clams (including geoducks) occurred in 2015 and 2016.

Figure 3. Alaska Aquatic Farm Sales, by Species, 2006-2015



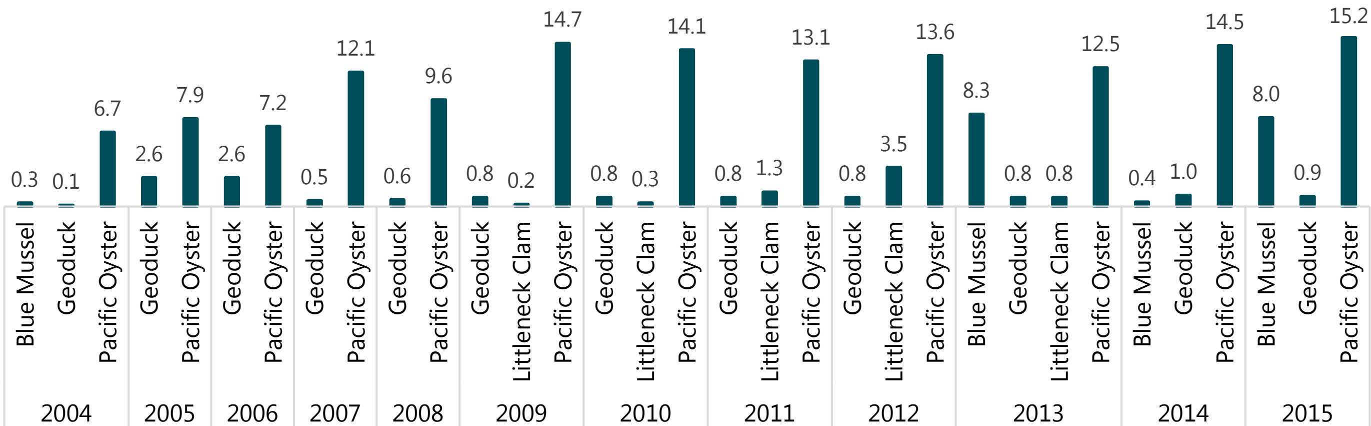
Note: For years with fewer than three operators reporting, production numbers are confidential and reported as zero.
Source: ADF&G and DNR.

In addition to farm sales, hatcheries and nurseries logged $267,000 in sales statewide, all of oyster larvae or seed. This included $215,000 in sales from Southeast operations, and $51,000 from Southcentral.

Inventory

Since 2004, mariculture product inventory has mostly consisted of Pacific oysters, blue mussels, littleneck clams, geoducks, and a small number of purple-hinged rock scallops. Kelp inventory began to grow in 2016.

Figure 4. Alaska Aquatic Farm Shellfish Inventory, Number in Millions, 2004-2015



Note: For years with fewer than three operators reporting, production numbers are confidential and reported as zero. Data is not reported above for species with less than .1 million in inventory.
Source: ADF&G.

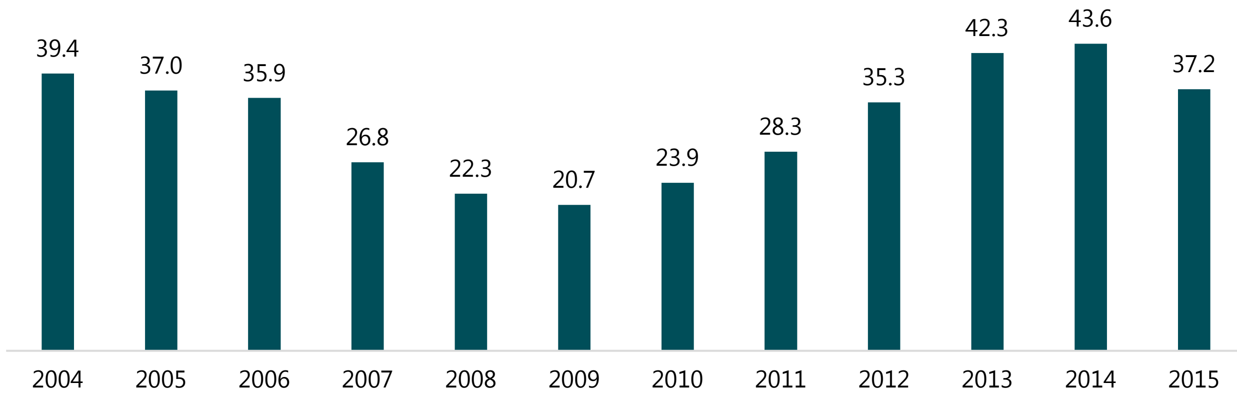
While no other species are currently in production, several are or have been in research and development stages, including kelp, king crab, abalone, sea urchin, and sea cucumber.

Employment

Alaska aquatic farm employment included a total of 138 positions in 2015, down from 185 in 2014. About one-third of the positions are permit holders and owners, with paid and volunteer labor making up the remaining two-thirds of the workforce. In total, a total of 9,664 workdays occurred in the industry in 2015, down from 11,345 in 2014. A combined 37.2 FTE were employed in 2015, down from 43.6 in 2014.

Mariculture employment in hatcheries and nurseries totaled 36 in 2015, with 3,420 total workdays.

Figure 5. Total Annual Alaska Aquatic Farm FTE, 2004-2015



Source: ADF&G.

Status of Industry by Species

The following sections of this report detail the status and important trends for each species in the Alaska mariculture industry. Particular attention is given to species currently in production and with inventory. Research and development on other species with promise for Alaska are also discussed. Each species is in different stages of development in the state and, therefore, each section is organized to convey the most current available information for that species. When possible, costs of production, volumes produced, values of product, and current and potential markets are addressed.

The following species are included in this chapter, in order of current production volume. The final section provides an overview of research and development efforts for king crab, abalone, and other mariculture species.

- Oyster Industry
- Mussel Industry
- Geoduck Industry
- Kelp Industry
- Species in Development

Oyster Development Status and Potential

Oyster farming is the most well-developed component of the mariculture industry in the state. Oyster sales represented slightly less than three-quarters of all mariculture revenue in 2015.

Oysters (*Crassostrea gigas)* do not spawn in the wild in Alaska. Thus, seed is sourced from outside the state for grow-out in Alaska nurseries and farms. The 31 farms permitted in 2015 may be classified into three size categories based on 2015 revenue; there were 13 small farms (less than $25,000 in sales), three medium farms ($25,000 to $49,999) and, six large farms ($50,000 to $200,000).

Photo credit: ADF&G.

While total industry net profit is unknown, individual businesses profits are likely modest, particularly for small farms. Many of these small farms are considered hobby or lifestyle farms, allowing the operators to work and perhaps live in remote locations and supplement other sources of income. Following is a more detailed analysis of Alaska's oyster industry.

Oyster Production and Value

As of February 2017, 43 farms were permitted to grow oysters in Alaska. In 2015, the most recent year for which harvest data is available, 22 of 31 permitted farms reported oyster sales.

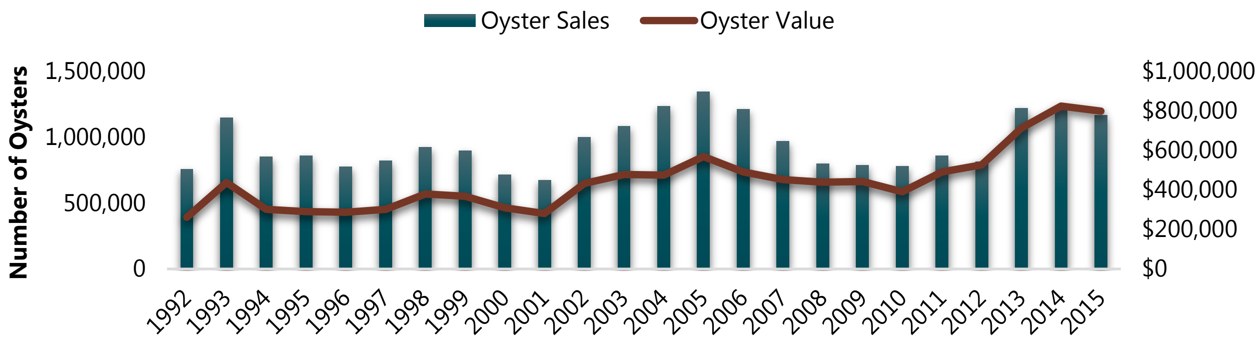
Table 2. Alaska Farms with Oyster Sales, 2011-2015

Year	Permitted Farms	Farms Reporting Sales
2015	31	22
2014	32	26
2013	35	27
2012	34	26
2011	32	27

Source: ADF&G.

In total, farmers sold an annual average 954,000 oysters between 1992 and 2015. Oyster production in Alaska peaked in 2005, when 1.3 million oysters were produced, then declined to 781,000 in 2010. It is unclear what led to the peak and subsequent decline, though closure of a farm and lack of oyster seed may have been a factor. Oyster production and sales have increased significantly since 2012. Annual sales from 2013 to 2015 were close to 1.2 million oysters, slightly below industry production between 2003 and 2006. Statewide oyster production in 2015 totaled 1.17 million. Revenue from oyster sales increased steadily to about $800,000 in 2014 and 2015.

Figure 6. Statewide Oyster Sales and Value, 1992-2015

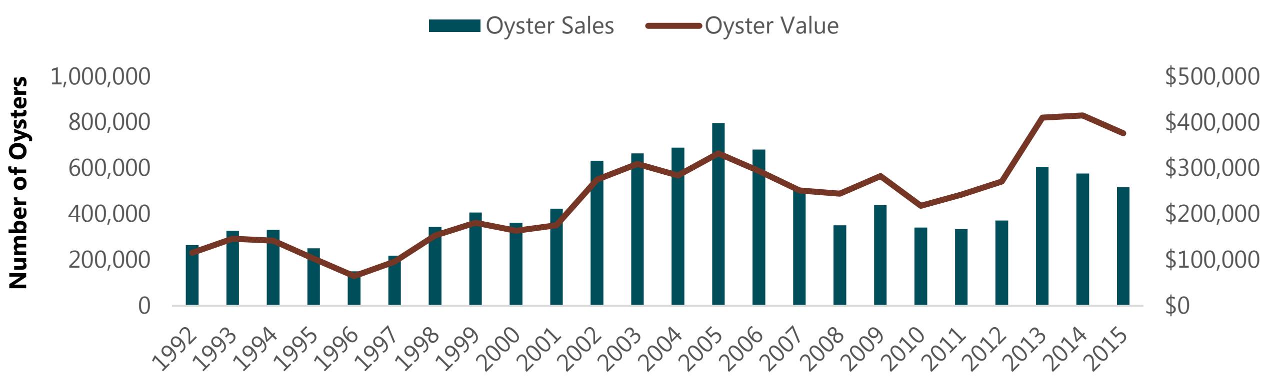


Source: ADF&G and DNR.

REGIONAL PRODUCTION AND SALES

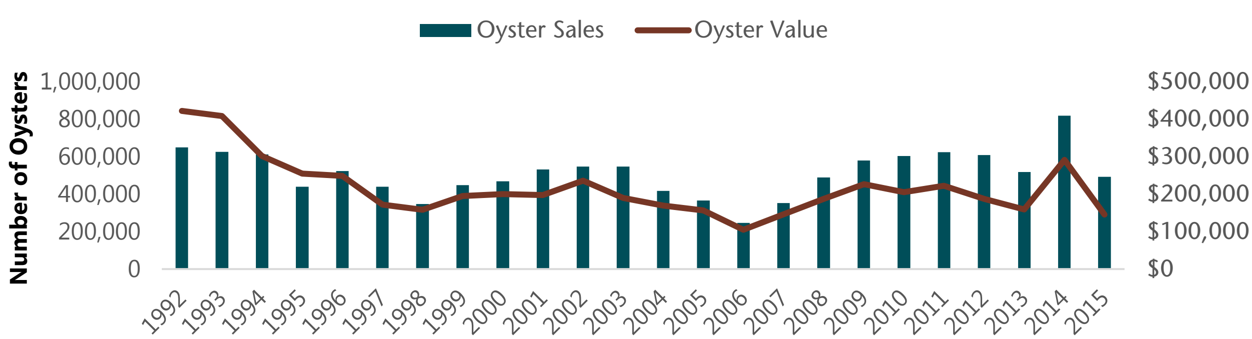
Slightly more than half of the state's oysters produced from 2011 to 2015 (54 percent) came from Southeast, while 46 percent were grown in Southcentral. For the same period, Southcentral generated 51 percent of statewide oyster sales revenue.

Figure 7. Southcentral Oyster Production and Value, 1992-2015



Source: ADF&G and DNR.

Figure 8. Southeast Oyster Production and Value, 1992-2015



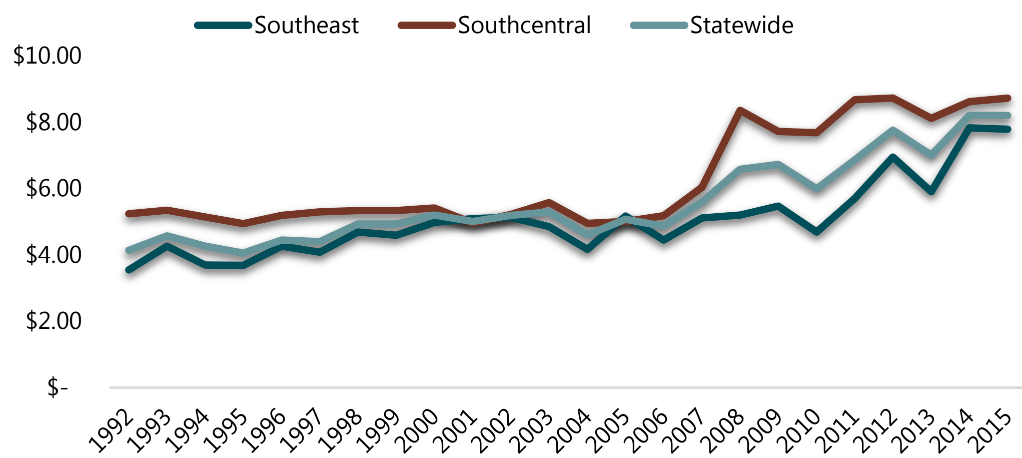
Source: ADF&G and DNR.

Oyster Prices

The average price per dozen Alaskan oysters was $8.21 in 2015. Southcentral farmers sold oysters for an average $8.73 per dozen, while Southeast farmers sold for an average $7.80. Prices statewide have risen relatively steadily from $4.86 per dozen oysters in 2006.

Between 2000 and 2005, oyster prices in Southcentral and Southeast were relatively similar. In 2006, Southcentral prices began to significantly outpace prices received by Southeast farmers. The price gap between the regions narrowed in 2014 and 2015. Statewide, from 1992 to 2015, price per dozen has outpaced inflation (98 percent increase versus 68 percent inflation).[2]

Figure 9. Alaska Oyster Price per Dozen, Statewide and by Region, 1992-2015



Note: Prices are nominal.
Source: ADF&G and DNR.

Oyster Inventory

Alaska oyster farm inventory as of 2015 was slightly more than 15.2 million oysters, an increase of about 22 percent over 2013. A relative abundance of oyster seed, and a new large grower in Southeast, suggests inventory may continue to increase in the near future.

Table 3. Alaska Statewide Oyster Inventory, 2011-2015

Year	Inventory
2015	15,211,352
2014	14,494,889
2013	12,522,981
2012	13,585,632
2011	13,134,556

Source: ADF&G.

[2] Based on Anchorage CPI.

Oyster Farm Operations

Most Alaska oysters are grown in lantern nets (hung from buoys or from ropes strung from buoy-to-buoy), or in trays suspended from rafts. One farm grows oysters on the ocean floor in the intertidal zone (areas where the sea floor is exposed at low tide). Each farm in the state operates somewhat differently. Farmers learn over time what equipment and techniques work best for their specific location. Availability of funding for equipment such as tumblers, sorters, and other machinery is also a factor in operational efficiency. The following description generally reflects the process of growing, harvesting, and processing oysters, though it may not reflect all specific processes on all farms.

Photo Credit: Tom Henderson.

Oysters typically take two to five years to grow from seed (generally 5mm to 20mm) to a saleable size. Growth rates depend on a variety of factors including; quality of seed, water temperature, food availability, density of oysters, amount of handling, time of year the seed is planted, and other environmental factors. Producers interviewed for this study stated that grow-out times have declined over the last decade as farming practices have evolved.

During the grow-out period, oysters must be periodically inspected and cleaned to remove barnacles, tube worms, and other growth from the shell. Unhealthy product is discarded. Currently, many farmers use tumblers to clean and sort oysters. In addition to removing growth, tumbling trims the shell edges, resulting in a deeper cup which is more desirable in the marketplace. Oysters can be hand scrubbed, though that process is laborious and inefficient. After cleaning, the oysters are sorted by size and returned to trays or nets. The cleaning and sorting process occurs multiple times before oysters reach marketable size.

LABOR REQUIREMENTS

Oyster farms in Alaska are primarily small operations. Many farms are tended solely by the owner, while larger operations employ additional labor. According to ADF&G, for oyster farms with sales in 2015, on average, 3.95 workers (including owners) were employed per farm, working 329 days per farm. Average FTE per farm was 1.26.

Table 4. Alaska Oyster Farms with Sales, Production and Employment, 2011-2015

Year	Number of Farms Reporting*	Total Oysters Sold	Average Number of Workers	Average Days Worked	Average Number of Days per Worker	Average FTE's
2015	21	1,167,254	3.95	329	83	1.26
2014	26	1,203,904	3.42	266	78	1.02
2013	27	1,218,861	3.89	281	72	1.06
2012	26	812,448	3.27	285	87	1.10
2011	25	858,357	3.36	215	64	0.83

*Note: Not all farms with sales reported employment data in 2011 and 2015.
Source: ADF&G.

FARM SIZE

Oyster farms may be measured in terms of acreage or volume of production and sales. However, farm size by sales provides the best measure to evaluate the current industry in Alaska, as some larger farms by acreage are only producing a small number of oysters, while some smaller farms are achieving higher production. The following tables highlight a variety of measures by farm size for both acreage and sales.

Farm Size by Acreage

Of the 22 farms selling oysters in 2015, slightly more than half (55 percent) were permitted for up to four acres, nearly one-third were between four and 12 acres, and 14 percent were over 12 acres. The three largest farms produced more than one-third of oysters and sales in 2015.

Table 5. Alaska Oyster Farm Size by Acreage, 2015

Farm Size	Number of Permits	% of Total Permits	Average Farm Acreage	Total Production (no. of oysters)	% of Total Production	Total Sales	% of Total Sales
Small (0-3.99 acres)	12	55%	1.64	332,810	29%	$228,545	29%
Medium (4-11.99 acres)	7	32%	6.21	421,032	36%	$284,643	36%
Large (12-24 acres)	3	14%	19.57	413,404	35%	$285,546	36%
Total	**22**	**100%**	**5.54**	**1,167,246**	**100%**	**$798,733**	**100%**

Source: ADF&G, including farm categories, and DNR.

Farm Size by Sales

In 2015, six farms reported sales between $50,000 and $200,000. These farms were responsible for slightly more than three-quarters of all oyster production and sales.

Table 6. Alaska Oyster Farm Size by Sales, 2015

Total Sales	Number of Permits	% of Total Permits	Average Farm Acreage	Total Production	% of Total Production	Total Sales	% of Total Sales
$50,000 - $200,000	6	27%	12.08	893,812	76.6%	$603,604	76%
$25,000 - $49,999	3	14%	5.94	146,082	12.5%	$103,721	13%
$10,000 - $24,999	4	18%	3.74	78,173	6.7%	$57,111	7%
$5,000 - $9,999	3	14%	2.50	32,673	2.8%	$20,365	3%
$1 - $4,999	6	27%	1.51	16,506	1.4%	$13,933	2%
Total	**22**	**100%**	**5.54**	**1,167,246**	**100.0%**	**$798,733**	**100%**

Source: ADF&G and DNR.
Note: Columns may not add due to rounding.

HARVESTING, PROCESSING, AND PACKAGING

When oysters have reached a marketable size, operators often (but not always) "harden" the oysters. Hardening involves holding oysters in bags in intertidal areas. As the tides come and go, the oysters strengthen their adductor muscles. This results in tighter shells and better moisture retention, and longer shelf life. After hardening, the oysters are again sorted and returned to trays or nets for a period of recovery. Hardening produces a higher-quality oyster, though the process increases labor costs as the process can take up to two months. An exception to this methodology is the single permitted intertidal farm. This operation spreads seed directly onto the ocean floor and the oysters are naturally hardened by the tides.

Photo credit: ADF&G.

Once hardened and allowed to recover, oysters are ready for testing and sale. Typically, the farmer pulls enough oysters to cover anticipated demand for the next two weeks. The oysters are removed from trays or nets and moved to an ADEC approved processing area (either on location or land-based). Oysters are typically held in a cooler either boxed, ready for shipping, or in bulk. A sample from the lot is sent to an approved lab in Anchorage for PSP testing. Typically, test results are returned within 36 to 48 hours. Once the operator has approval, oysters are packaged and prepared for shipping.

Packaging and shipping is dependent on the location of the buyer. Packaging is generally done in wet-lock boxes with liners and freezer gel packs included. If shipping duration is longer than 12 hours, insulation may be added to the box. Oyster temperatures are measured when they reach their final destination to assure proper handling. The farmers generally bear the cost of packaging materials.

TRANSPORTATION

Two primary hurdles for growers attempting to sell to the Lower 48 are transportation cost and logistics. While Alaska oysters are a premium product, added cost of freight drives prices up to a point where they become less competitive with Washington or British Columbia oysters. Shipping oysters from a remote dock in Alaska to destinations in the lower 48 can incur shipping charges of $2 to $4 per pound, and perhaps more for East Coast destinations. Additionally, some buyers incur delivery charges from the nearest airport to their location. The result is that buyer's cost for Alaska oysters can exceed the cost of other high-quality Pacific Northwest oysters by $3 or more per dozen depending on the destination. Alaska growers operate on relatively thin margins and it can be a challenge to reduce prices to offset transportation expenses and still generate a profit.

Photo credit: OceansAlaska.

Multiple modes of transportation may be utilized in delivering oysters to market, depending on destination. Alaska oyster farms are primarily located in remote areas, requiring water transport to the nearest dock. Oysters are either processed and packed at the remote facility or sent to a shore-based facility for packaging. Most oysters are landed in small communities where the product must then be shipped via small plane or ferry to a hub community for sales or to be transferred to jet aircraft to be delivered to the final destination. Typically, oysters are priced per dozen, FOB the closest dock to the aquatic farm. Generally, but not always, this means transportation costs between the dock and the destination are the responsibility of the buyer.

Some oysters are shipped in bulk to wholesalers, others are shipped directly to end users such as restaurants, grocery stores, and other retailers. Multiple factors affect shipping costs for the purchaser, including number of boxes, oysters per box, number of carriers, and distance to destination.

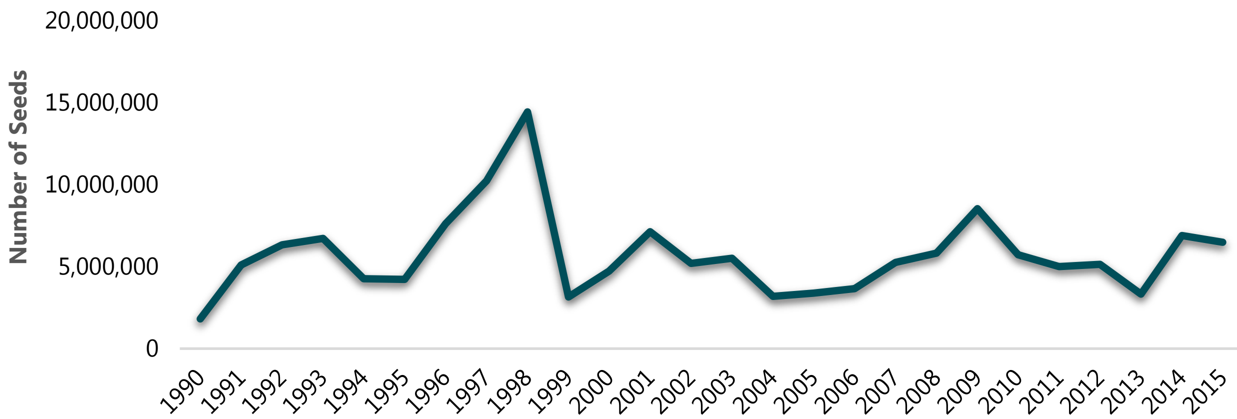
Oyster Seed

Three permitted shellfish hatcheries operate in the state, OceansAlaska, Katchemak Shellfish Mariculture Association, and Alutiiq Pride Shellfish Hatchery (APSH). APSH has successfully spawned oysters, though due to the high cost of production they are currently not hatching oyster seed. APSH does not intend to spawn oysters in the foreseeable future as it is cost prohibitive at low production levels (mainly due to the cost of heating water) compared to purchasing larvae from out of state.

All oyster seed purchased by Alaska farmers comes as larvae from an ADF&G-certified source outside of the state. Currently, there is only one certified source of larvae for Alaska, Hawaiian Shellfish, LLC. OceansAlaska is importing larvae and growing oyster seed for sale. OceansAlaska sets the larvae and grows them out until they are ready for sale to a permitted nursery. There are seven ADF&G permitted nurseries in the state, four of them are permitted for seed sales to farmers. Nurseries hold the small seed in a floating upweller system (FLUPSY) for further grow-out. Seed size at the time of sale to a farmer varies but is generally 5mm to 20mm. Seed availability has been an issue for farmers in the past and some have concern that with only one provider of larvae and one hatchery producing seed, the state's seed security is tenuous.

Seed acquisition by farmers peaked in 1997 (10.2 million) and 1998 (14.5 million), then declined precipitously. The lowest level of seed acquisition between 2011 and 2015 was 3.3 million in 2013. Acquisition increased in 2014 (6.9 million) and 2015 (6.5 million).

Figure 10. Alaska Aquatic Farm Pacific Oyster Seed Acquisitions, 1990-2015

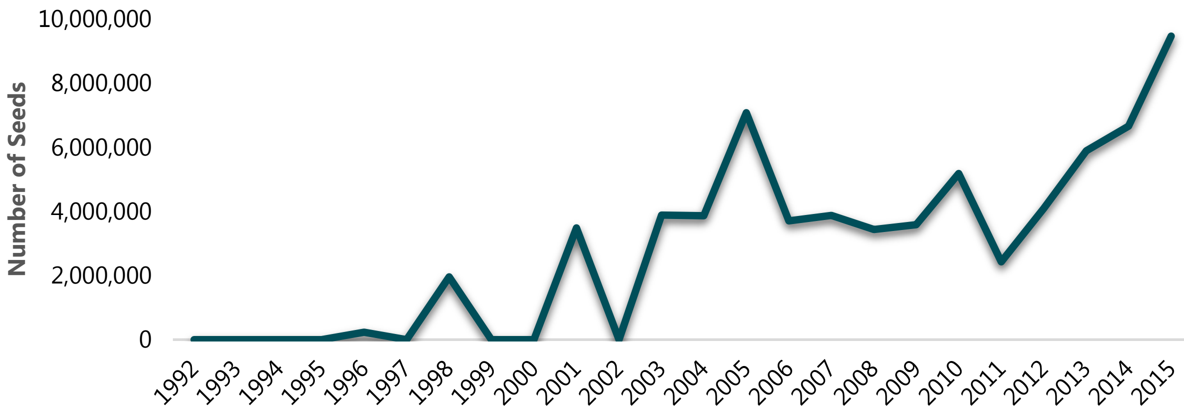


Note: Acquisitions includes data for count of permits 3 and greater.
Source: ADF&G.

OYSTER SEED STOCK

Pacific oyster seed inventory for hatchery and nursery operations reached the highest ever recorded at 9.5 million in 2015, an increase of 42 percent from 2014.

Figure 11. Statewide Hatchery and Nursery Operations Seedstock Production, 1992-2015



Note: Seedstock production includes data for count of permits 3 and greater.
Source: ADF&G.

Oyster Markets

Globally, oysters are sold live, shucked, frozen, cooked and canned, brined, smoked and canned in oil, dried, breaded and frozen, reduced for oyster sauce, and in a range of other value-added products. The highest value for an individual oyster is when sold fresh on the half-shell, though most world oyster production is sold in processed form rather than on the half-shell or fresh shucked market. Nearly all of Alaska's current oyster production is sold on the half-shell market.

Photo credit: Virginia Sea Grant.

MARKETS FOR ALASKA OYSTERS

The State of Alaska does not track oyster sales by location. Interviews with farmers and other knowledgeable sources resulted in an estimate that three-quarters of Alaska oysters are sold and consumed within the state.[3] Consumption of oysters increases significantly in the summer months when Alaska hosts roughly 1.8 million visitors. Concurrently, the volume of oysters produced in the summer months is significantly higher than for the remainder of the year.

Primary markets outside Alaska are located on the West Coast, with less volume sent farther east. These markets include both wholesale distributors and restaurants. Little or no Alaska oysters are currently shipped to locations outside the U.S.

[3] Based on interviews with a selection of Alaska oyster farmers and wholesale buyers. Not all farmers were interviewed for this report.

Growers interviewed for this study report that, at this point, they can sell all their product in the state. However, there is some concern in the industry that demand within Alaska may be reaching a saturation point. This is especially the case during fall, winter, and spring, as in-state oyster demand is significantly lower that time of year. Historically, there have been fewer farmers harvesting in the winter months, though some evidence suggests that winter production may be increasing.

Additionally, a new farm entering production in Southeast plans to produce a significantly higher volume than current industry participants. If the operation produces oysters at the volume anticipated, it may impact Southeast markets in terms of price.

If Alaska oyster production increases significantly beyond 1.2 million oysters, at some point growers will likely need to expand to markets outside of Alaska and/or look for new product forms.

Markets for Oysters Outside Alaska

Oyster Production in Canada

The Canadian oyster industry is active on Prince Edward Island, in Nova Scotia, New Brunswick, and British Columbia. Canada produced 11,153 metrics tons, live weight, of oysters in 2015, valued at $36.5 million (CAD). British Columbia produced 6,587 metrics tons, live weight, in 2015, valued at $14.4 million (CAD).

Table 7. Canada and British Columbia Oyster Production, Metric Tons, and Value (CAD), 2010-2015

	Canada		British Columbia	
Year	Production (mt)	Value (000's)	Production (mt)	Value (000's)
2015	11,153	$36,547	6,587	$14,425
2014	10,662	$30,646	6,184	$13,015
2013	10,835	$28,469	6,452	$12,498
2012	10,497	$24,228	6,487	$10,251
2011	9,779	$18,541	6,242	$8,380
2010	11,113	$18,876	7,550	$8,957

Source: Statistics Canada.

United States Oyster Production

The U.S. produced 124,986 metric tons of live weight oysters in 2014. Exports of live oysters from the U.S. grew from 2.6 million kilos, with a value of nearly $18 million in 2012, to 3.1 million kilos, with a value of $22.6 million in 2014.

Table 8. U.S. Oyster Exports, 2012 – 2014 (Value in USD)

	2012		2013		2014	
	kg	Value	kg	Value	kg	Value
Live/Fresh Oysters	2,554,610	$17,988,360	2,661,708	$18,945,423	3,099,486	$22,594,774
% Change			**4%**	**5%**	**16%**	**19%**

Source: National Marine Fisheries Service, Fisheries Statistics and Economics Division.

U.S. Oyster Exports by Country

In 2014, nearly half (46 percent) of U.S. exports of live oysters by weight were to Canada. The second largest U.S. market was China at 23 percent. The third and fourth largest markets for live oysters were Malaysia (9 percent) and Singapore (8 percent).

Table 9. U.S. Live/Fresh Oyster Exports, by Country, 2014

Country	Volume Exported kg	Value (USD)	% of Total Volume Exported
Canada	1,420,347	$12,955,148	46%
China	723,547	$4,844,729	23%
Malaysia	265,459	$1,219,855	9%
Singapore	262,178	$1,373,638	8%
All Others	427,955	$2,201,404	14%
Total Export	**3,099,486**	**$22,594,774**	

Source: National Marine Fisheries Service, Fisheries Statistics and Economics Division.

U.S. Oyster Imports

Most U.S. oyster imports (89 percent) were farmed product in 2014. The U.S imported a total of 4.1 million kilos of live weight oysters in 2014, a 15 percent increase from 2012. Total 2014 import value was $24.6 million (USD).

Table 10. U.S. Oyster Imports in U.S. ($), 2012-2014

	2012 kg	2012 Value	2013 kg	2013 Value	2014 kg	2014 Value
Live/fresh farmed	3,384,475	$17,871,139	2,958,376	$18,766,401	3,666,561	$21,770,034
Live/fresh wild	195,537	$1,019,249	578,200	$3,281,567	436,429	$2,800,816
Total	3,580,012	$18,890,388	3,536,576	$22,047,968	4,102,990	$24,570,850
% Change			**-1%**	**17%**	**16%**	**11%**

Source: National Marine Fisheries Service, Fisheries Statistics and Economics Division

In 2014, more than half (57 percent) of U.S. farmed oyster imports, by weight, came from Canada. Mexico also provided a significant volume of U.S. oyster imports at 41 percent.

Table 11. U.S. Oyster Imports, Live/Farmed by Country, 2014

Country	Volume Imported (kg)	Value	% of Total Volume Imported
Canada	2,092,639	$15,725,111	57%
Mexico	1,498,148	$5,473,806	41%
South Korea	56,078	$503,602	2%
All Others	19,696	$67,515	1%
Total Imports	**3,666,561**	**$21,770,034**	

Source: National Marine Fisheries Service, Fisheries Statistics and Economics Division.

Global Oyster Production

World oyster production totaled nearly 5.2 million metric tons, live weight, in 2015, a 15 percent increase from 2010. Most oysters harvested globally are farmed. China produced 85 percent of the world's oyster supply in 2015, while the U.S. ranked fourth in production with 125,000 metric tons.

Table 12. World Oyster Production, Metric Tons, 2010-2014

Land Area	2010	2011	2012	2013	2014
China	3,642,829	3,756,310	3,948,817	4,218,644	4,352,053
Republic of Korea	267,776	281,022	284,856	239,779	283,232
Japan	200,298	165,910	161,116	164,139	184,100
United States of America	137,630	97,889	131,853	128,658	124,986
France	96,040	84,454	82,910	77,511	76,610
Taiwan Province of China	36,056	34,643	26,923	27,793	25,276
Philippines	22,525	21,462	20,648	22,070	22,355
Thailand	28,090	8,377	16,129	17,595	17,187
Canada	11,114	9,779	10,497	9,975	12,604
Australia	14,931	13,927	12,559	12,530	11,403
All Others	29,766	28,760	28,054	29,889	35,142
Total production	**4,487,055**	**4,502,533**	**4,724,362**	**4,948,582**	**5,144,948**

Source: FAO.

Mussel Development Status and Potential

Blue mussels (*Mytilus trossulus*) are viewed by many in the Alaska aquatic farm industry as an area with significant growth potential. Mussels have a shorter grow-out period to marketable size than oysters. For oyster growers, adding mussels to their operation may provide supplemental income while the oysters grow to a saleable size. Mussels also naturally reproduce in Alaska, providing free spat for farmers and, therefore, reducing operational expenses. Significant demand for mussels also makes this product appealing to growers.

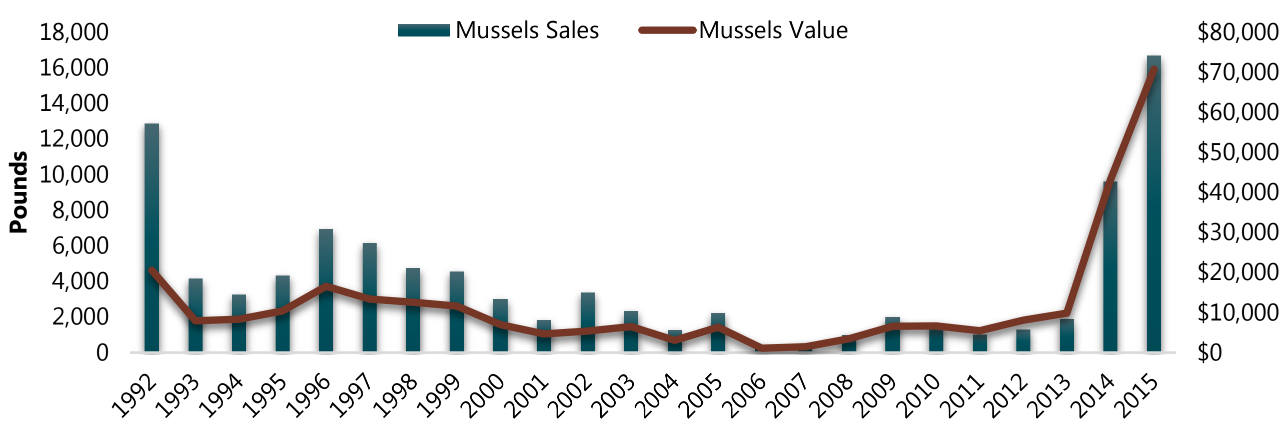
Mussel Production and Value

Between 1992 and 2014, an average 2,700 pounds of mussels were harvested and sold annually in Alaska. Most of those sales were incidental rather than cultivated, meaning that farmers harvested product that naturally set on their floats or other equipment, rather than trying to grow mussels. In 2015, only four farms were permitted to produce mussels, down from five in 2013 and 2014.

Photo Credit: Alutiiq Pride Shellfish Hatchery.

In 2012, a project was launched to better understand mussel growing technology and jump-start the industry (see Alaska Mussel Technology Transfer Project [AMTTP] following the tables below). As a result, mussel production increased from 1,889 pounds in 2013 to 9,594 pounds in 2014, and jumped to 16,688 pounds in 2015. Revenues from mussel sales increased from $9,837 in 2013 to $43,112 in 2014 and to $70,800 in 2015.

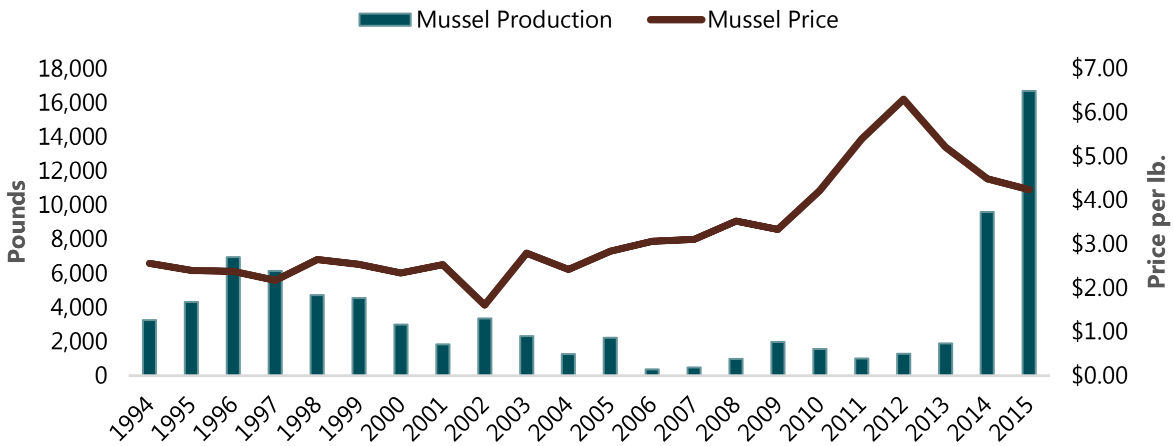
Figure 12. Alaska Mussel Production and Value, 1994-2015



Note: For years with fewer than three operators reporting, production numbers are confidential and reported as zero
Source: ADF&G and DNR.

The average price per pound declined from $5.21 in 2013 to $4.49 in 2014 and to $4.24 in 2015. The decline was likely related to the significant increase in supply over that period.

Figure 13. Alaska Mussel Production and Average Price per Pound, 1994-2015



Source: ADF&G and DNR.

Mussel Inventory

Alaska's cultivated blue mussel inventory as of 2015 was slightly more than 8 million. The inventory has grown significantly since 2011, when it totaled only 7,198. Mussel inventory rose in 2013 to 8 million, fell to 425,000 in 2014 and rose again to 8 million in 2015.[4] It is unknown why inventory fluctuated year to year, though possible reasons include variation in volume of natural larval sets (that can vary significantly from year to year) and possible variations in farm counting methodology.

Table 13. Statewide Mussel Inventory, 2011-2015

Year	Inventory
2015	8,017,400
2014	424,520
2013	8,269,540
2012	10,200
2011	7,198

Source: ADF&G.

Mussel Farm Operations

Mussels typically spawn during the summer months in Alaska. Following spawning, the shelled larvae are free swimming. The larvae will eventually attach itself to any surface available but prefer rough textured surfaces. Synthetic ropes are a favorable medium for the larvae to attach. As they grow, they are transformed into "spat." Spat can move about until they locate a suitable location with adequate food. Mussels feed

[4] Data provided by ADF&G is self-reported by farmers.

naturally by filtering food from the water. If grown too closely, competition for food may inhibit growth. Water temperature also is a factor in mussel growth.

Purposeful mussel farming in Alaska involves capturing the spat after it sets. Ropes suspended from rafts capture the set. Once mussels have grown to a certain size, they are mechanically stripped from the ropes and stored in mesh bags hung from a raft by ropes to grow to a saleable size. To process efficiently, pulling the ropes, harvesting, cleaning, and sorting a large volume of mussels requires mechanical lifting devices and sorters.

Mussels must undergo the same testing process for PSP as oysters and other shellfish.

ALASKA MUSSEL FARMING DEMONSTRATION PROJECT (AMFDP)


Photo Credit: NOAA.

In 2012, Halibut Cove Community Organization received a $300,000 state grant to develop a large-scale test farm for mussel production.

The project was intended to demonstrate the economic and technical feasibility of large-scale mussel farming in Alaska. Alaskan Shellfish Growers Association (ASGA) and Alaska Shellfish Farms (ASF) were to implement the project with technical assistance from the Alaska Sea Grant Marine Advisory Program (MAP), including marketing and business planning. Grant recipients estimated they would produce $560,000 in annual gross sales within two years and eventually produce 1.2 million pounds annually of high quality mussels worth $2 million. They also estimated the operation would employ ten local residents. ASGA and MAP were to write a mussel farmer's manual designed to assist with future mussel farm development in the state.

Alaska Sea Farms was tasked with construction and operation of four 40' x 40' mussel rafts, from which mussels would be grown suspended on lines hung from the rafts, surrounded by predator nets. Initially, two rafts were to be used for seed collection in July from wild sets before all four were stocked with seed for grow-out to market size. Each raft was estimated to can produce 70,000 pounds of mussels in 18 to 24 months.

Project plans state that mussel processing equipment is necessary for production of any volume of product, as harvesting and processing can be labor-intensive without equipment. A hopper feed conveyer is used to declump and grade mussels. This equipment provides market sized product for a debysser to remove seed mussels. Mussels are then graded and placed in harvest sacks in mussel roll sizer equipment and then stored in containers with flowing seawater until shipping time. Such equipment allows for harvest of one ton of mussels in 4 hours.

The current and future status of the demonstration project and production are not known. The growers involved in the project were not available to be interviewed for this study. The first crop of mussels was scheduled to be harvested in late 2014, and data shows an increase in mussel inventory and sales around that time. According to a wholesaler report no mussels have been sold by the grower since mid-to-late 2016.

MUSSEL MARKETS AND DEMAND

Based on interviews for this study, there appears to be significant in-state demand for mussels. One wholesaler estimated that the Southcentral market alone could absorb 1,500 to 2,000 pounds of mussels per week during the summer. Assuming significantly lower fall, winter, and spring sales, annual statewide demand could reach 60,000 to 70,000 pounds or more, significantly higher than 2016 production of about 17,000 pounds.

With short self-lives (approximately 5 days), and transportation hurdles, selling product outside the state will be challenging, and freezing technology may be key to overcoming these challenges. The premier mussel grower on the West Coast, Penn Cove, harvests mussels to order and ships them quickly. It would be a logistical challenge for Alaska growers to replicate that business model.

Geoduck Development Status and Potential

Geoducks (*Panopea generosa*) are a species of large saltwater clam prized in Asia for the meat of its siphon (long neck), which can exceed three feet in length. Geoducks are indigenous to the West Coast of the U.S. and Canada, with commercially harvested and farmed product available from Washington, British Columbia, and Alaska. Juveniles will dig up to three feet deep in the ocean bed and live their entire lives in that position. The clam extends its siphon up to the ocean bottom and acquires nutrients by filtering seawater. Mature live geoducks typically weigh from two to four pounds but can grow larger. The clams are long-lived, with some specimens living more than 140 years. The average age of commercially harvested geoducks in Alaska is 44 years. The highest value is received for the sale of live product.

Geoduck Harvest and Value

FARMED

As of February 2017, 19 aquatic farms in Alaska were permitted for geoducks, as well as two permitted hatcheries and two nursery operations. All but one permitted farm sites are in Southeast, with the majority in the Ketchikan/ Prince of Wales (POW) area. One site is located near Sitka, one north of Juneau, and one south of Juneau. One farm is in Southcentral.

Photo credit: SARDFA.

There is one permitted nursery located in Ketchikan and one near Sitka. Nurseries serve as holding facilities to allow juvenile seed to acclimate to local waters and grow-out before being planted.

The Alutiiq Pride Shellfish Hatchery developed methods to hatch and rear geoduck seed. OceansAlaska in Ketchikan is permitted as a hatchery and has successfully spawned geoduck.

Since 2010, ADF&G has reported farmed geoduck harvest and value combined with all other clam harvests and value. Because of strict confidentially regulations, ADF&G cannot report production or sales when less than three growers report. This has resulted in no useable data for analysis of farmed geoduck production and sales. Following is an analysis of the commercial dive harvest of geoducks in Alaska. The data provides some insight into the level of effort and value of geoducks.

WILD

The number of geoduck permits fished between 2006 and 2015 ranged from a high of 70 in 2012 to a low of 55 in 2009. The annual average number of permits fished for the ten-year period was 63.

Table 14. Commercial Geoduck Permits Fished, CY 2006-2015

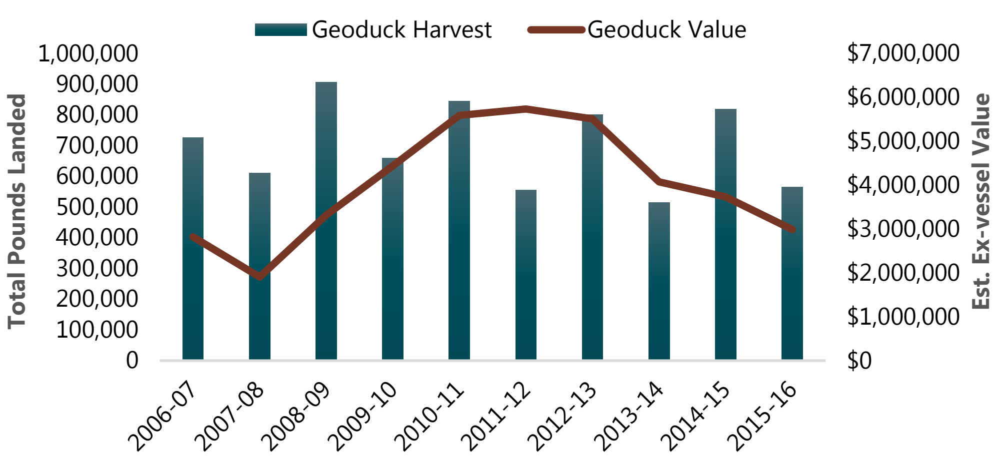
Year	Total Permits Fished
2015	60
2014	61
2013	69
2012	70
2011	61
2010	69
2009	55
2008	57
2007	62
2006	61

Source: CFEC.

Between 2006 and 2016, wild geoduck harvest volume varied significantly, ranging from a high of nearly 907,000 pounds in 2008-2009, to a low of 514,000 pounds in 2013-2014. Seasonal harvest for the ten-year period averaged 700,000 pounds.

Estimated ex-vessel value ranged from a high of $5.7 million in the 2011-2012 season to a low of $1.9 million in the 2007-2008 season. Average annual harvest value for the ten-year period totaled $4 million. Ex-vessel value for the 2015-2016 season was $3 million.

Figure 14. Alaska Wild Geoduck Harvest and Value, 2006-2015

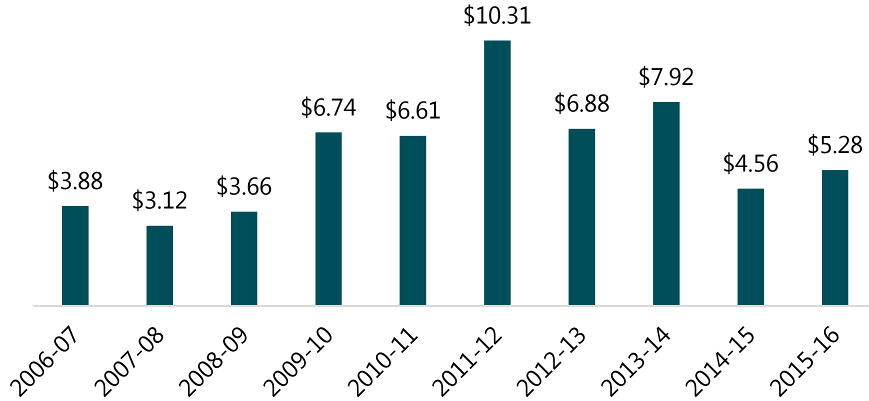


Source: ADF&G.

GEODUCK PRICES

Average geoduck prices vary widely. Between 2006/2007 and 2015/2016, price per pound ranged from a high of $10.31 in 2011-2012 to a low of $3.12 in 2007-2008. Average price per pound for the ten-year period was $5.90. Price for the 2015-2016 season was $5.28 per pound.

Figure 15. Geoduck Wild Harvest Average Price per Pound, 2006-2016



Source: ADF&G.

Geoduck Farm Inventory

ADF&G reports geoduck farm inventory totaled 910,926 in 2015, a 6 percent decrease from 968,526 in 2014.

The current volume of harvestable geoducks in unknown. Due to the slow growth of the clams, inventory will reach harvestable size over a period of many years. Farmers also have the option of harvesting when market prices are favorable.

Table 15. Geoduck Inventory, 2011-2015

Year	Number of Animals
2015	910,926
2014	968,526
2013	837,296
2012	832,244
2011	819,976

Source: ADF&G.

For purposes of understanding total resource value, if the total 2015 inventory were harvestable and weighed an average of 2.5 pounds, the farm inventory would be about 2.3 million pounds. At a price of $5 per pound, this inventory would have a total value of approximately $11.4 million. This estimated value could be significantly higher or lower depending on clam size at harvest and prevailing market prices at the time of sale.

Geoduck Farming Operations

Farming the giant clams began in the early 1990s in Washington and in 2000 in Alaska. Geoduck larvae are raised in hatcheries to an approximate size of one to three millimeters. The small seed can be planted, but in most cases, spend additional time in a nursery to allow for acclimation to local waters and grow-out to a larger size. Seed is generally three to 20 mm in size when planted. Growers report that larger and healthier seeds have a better chance of survival. Poor quality seed can result in significant mortality rates.

Geoduck farming in Alaska can occur in intertidal or subtidal areas (where the sea floor is never exposed). Intertidal farming involves placing the seed in PVC tubes inserted in the seabed. Two to five seed are usually planted in each tube with hope of one to four surviving to maturity. Tube openings are covered with protective nets to discourage predators. The nets are removed when the clam has burrowed into the ocean floor.

Subtidal farming involves planting the seed directly in the ocean floor (without tubes), covered with a predator exclusion device. The exclusion devices are mats or mesh tarps that covers the seabed and keep predators away from the clams. The exclusion device is removed when the clam has burrowed into the ocean bottom.

Research related to time required for a geoduck to reach harvestable size is ongoing. Anecdotally, geoducks could reach a harvestable size in eight to ten years. The clams appear to be slower growing in northern Southeast than in southern Southeast.

Subtidal geoducks are harvested by divers by fluidizing the substrate.

Geoduck Seed

Growers interviewed for this study report seed availability in Alaska has varied. Alaska hatcheries with geoduck seed report there is little to no demand for their product or that they did not sell in 2015 or 2016. This resulted in no current source for geoduck seed.

OceansAlaska had a successful spawn in 2016. The seed grew well for 22 days. Unusually warm weather resulted in higher than normal water temperatures and the spat died. OceansAlaska plans to acquire spat from APSH in 2017 and attempt to grow them to plantable size. They hope that will allow the spat to acclimatize better to local waters and provide a higher quality product. A facility representative reported that there is not a huge demand for geoduck seed, perhaps 500,000 currently. The market for geoduck seed outside Alaska is very limited. They plan to start with a small volume of spat and work on the process. Additionally, OceansAlaska has limited space to grow geoduck, without hindering their ability to expand oyster production.

Geoduck Markets

Most of the geoduck harvest is sold in China and other Asian markets. A smaller, unknown quality is sold within Alaska, the U.S., and to other international markets. In December 2013, China banned importation of shellfish from Alaska and Washington citing inorganic arsenic found in a shipment of Washington geoducks. The ban severely impacted geoduck markets, divers, and farmers in Alaska and Washington. The ban was lifted in June 2016.

In 2014, the U.S. produced 5,534 metric tons of geoducks (farmed and wild), while Canada produced 1,494 metric tons (farmed and wild). Overall harvest in 2014 was 7,028 metric tons, up 18 percent from 5,997 metric tons in 2012, but only slightly higher than the 6,949 metric tons harvested in 2010.

Table 16. Pacific Geoduck Harvest, U.S. and Canada, in Metric Tons, 2010-2014

Year	Canada	U.S.	Total
2014	1,494	5,534	**7,028**
2013	1,346	5,194	**6,540**
2012	997	5,000	**5,997**
2011	1,562	5,114	**6,676**
2010	1,330	5,619	**6,949**

Note: Includes wild and farmed product.
Source: Food and Agriculture Organization of the United Nations, Fisheries and Aquaculture Department.

Seaweed Development Status and Potential

A variety of seaweed species are currently approved for cultivation on aquatic farms and nurseries in Alaska, including sugar kelp, giant kelp, bull kelp, ribbon kelp, red ribbon seaweed, three ribbed kelp, nori, and sea lettuce. Species approved for hatchery operations include dark sea lettuce (*Ulvaria obscura)*, dulse (*Palmaria mollis)*, kombu, nori (*Pyropia sp.)*, ribbon kelp (*Alaria marginata*), sea lettuce (*Ulva lactuca)*, three-ribbed kelp (*Cymathaere triplicata)*, sugar kelp (*Saccharina latissima)*, and bull kelp (*Nereocystis luetkeana)*.

Photo credit: Bob Koenitzer.

Kelp, a name that applies to many subtidal brown seaweed species, is the only type of seaweed currently in production in Alaska; 2017 will mark the state's first material cultured harvest volume. Alaska's seaweed farmers are currently focusing on sugar kelp (*Saccharina latissima*) and ribbon kelp (*Alaria marginata)*. Though kelp species are not the most valuable type of seaweed, they grow fast, thrive in Alaska waters, and are cultured during a time of year that may complement the fish harvest season.

With growing market demand, seaweed appears to have a lot of potential in Alaska. The industry presents numerous attractive attributes for development in the state:

- Plentiful, accessible undeveloped coastline
- A potential workforce with necessary marine skills
- Local fleets that could provide effective harvesting platforms
- A product that grows quickly, can be planted in the fall and harvested in the spring (times of the year when fishermen are typically in between fisheries)

At the same time, many unknowns exist in this nascent Alaska industry, such as growth rates, actual market demand/prices, processing procedures, and best industry practices for growing/harvesting/processing.

Kelp Production and Value

In 2017, fourteen aquatic farmers in Alaska are permitted to grow kelp, though only three are actively culturing plants. Kodiak is home to two kelp farms, with the other active site located near Ketchikan.

In addition to farm production, a small volume of wild kelp is harvested in Southeast for use in locally produced niche products/markets. Coastal areas are occasionally opened for commercial harvest, though achieving any significant scale or schedule of production will likely occur via permitted farms. For example, Wild Alaska Kelp Company, which currently produces products from wet kelp, such as salsa, currently harvests wild kelp and is transitioning into a kelp farm model.

KELP PRICES

According to Premium Oceanic, sugar kelp prices range from $0.25 to $1.00 per pound (for wet kelp), though "if you can produce wet (sugar) kelp in Alaska for less than $0.50 per pound, the world is your oyster."[5]

More generally, seaweed pricing works according to a market hierarchy similar to seafood. Pharmaceutical products, which are specialized and almost always sold in small volumes, can be the highest priced at over $100,000 per metric ton. Food and nutritional supplements offer the next highest value. Dried seaweed products fit for human consumption can fetch over $10,000 per metric ton. Seaweed powders are also valuable ingredients for livestock and aquaculture feed manufacturers, though they are usually valued at less than $4,000 per metric ton. Biofuels are at the bottom of the market hierarchy. Kelp can be used to produce biofuels like ethanol; however, the yield is such that dried kelp powder prices would probably have to be around $50 per metric ton to be competitive with petroleum-based fuels.[6] Many projects have looked at creating systems capable of producing kelp biofuels efficiently, but none has achieved commercial success.

The human ingredient/food market may make the most sense for Alaska farmers, as it offers the best mix of higher prices and larger market volumes. Seaweed fit for human consumption imported from China and South Korea (likely powder-like material) averaged $11,400 per metric ton and $10,500 per metric ton, respectively, in 2016. A price of $11,000 per metric ton of dried kelp powder is equivalent to $5.00 per pound. Applying a yield of 20 percent and converting the price to a wet basis produces a wet value of $1.00 per pound. This is not an ex-vessel proxy price, as it does not include costs involved with processing, storage, shipping, and sales.

KELP PRODUCTION VALUES

As seaweed farming is just developing in Alaska, no historical value and production volume data exist. Interviews with industry participants and research on farms in other regions provide some basis for estimating a range of potential production values. In addition to prices (which will fluctuate with market conditions), another critical variable is yield per acre. The following table outlines one range of possible production values.

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[5] Perry, personal communication.
[6] Lenstra, Jip; Van Hal, Jaap; and Reith, Hans. "Economic aspects of open ocean seaweed cultivation." Energy Research Center of the Netherlands. Presented at the Alg'n Chem 2011, Montpellier, France.

Table 17. Estimated Kelp Production Value per 100 Acres

	5 rows/acre	10 rows/acre	20 rows/acre
Wet Pounds Produced[1]	783,750	1,567,500	3,135,000
Estimated Ex-Vessel Wet Price per Pound	$0.50	$0.50	$0.50
Farm Revenue	$391,875	$783,750	$1,567,500
First Wholesale Value of Dried Powder per Metric Ton	$12,000	$12,000	$12,000
Dried Powder Produced (Metric Tons)	53.3	106.7	213.3
First Wholesale Value of Dried Powder per Pound	$5.44	$5.44	$5.44
First Wholesale Value per Wet Pound[2]	$1.09	$1.09	$1.09
First Wholesale Revenue (less ex-vessel payments)	$248,031	$496,062	$992,125

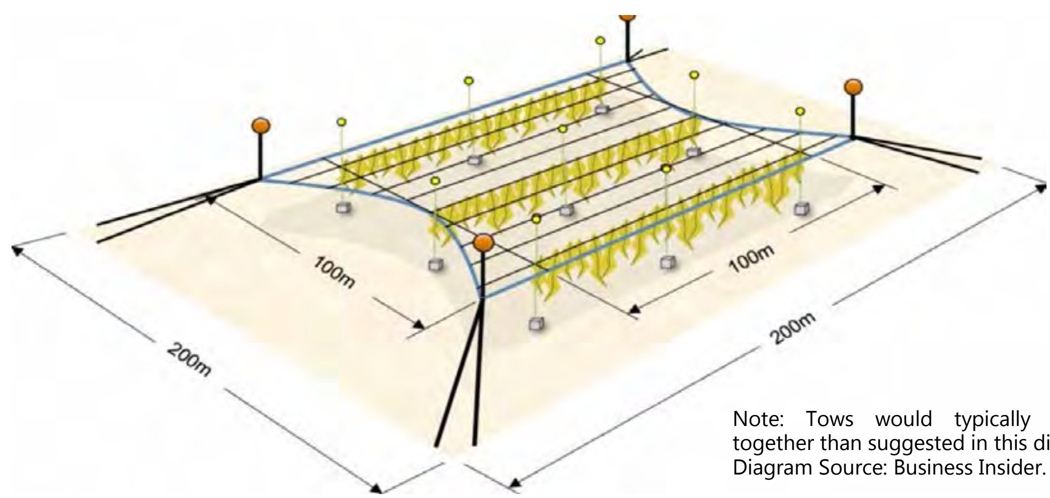
[1] Assumes 209 ft. rows producing 7.5 pounds of wet product per linear foot.
[2] Assuming 15 percent yield, going from wet product to dried powder.
Source: McDowell Group estimates.

Kelp Farming Operations

Kelp are grown from partially submerged longlines attached to floats (see diagram below). Kelp seeds are spread onto small diameter twine at a nursery facility. Several Alaska providers are currently developing seeded lines. Seeded twine is sent to farms spooled around PVC pipe. Farmers wrap twine around partially submerged longlines (usually 4-8 feet). Kelp is usually planted in the fall (September or October) and typically take five to seven months to reach harvestable size.

Plants are harvested prior to spore production to achieve optimal quality. Harvests typically employ winches, hooks, rollers, or net bags. Boats with a block and plenty of deck space, like seiners, are an excellent harvest platform. Some farms in Maine and Connecticut practice "3-D" farming, which is essentially a polyculture approach where kelps, mussels, scallops, and oysters are grown along the same line.

Figure 16. Kelp Farming Operations



Note: Tows would typically be closer together than suggested in this diagram.
Diagram Source: Business Insider.

Once harvested, wet kelp may be cut and frozen or processed into a dry, stable powder with a grinding/drying machine. Kelp powder may be stored for over a year without refrigeration, allowing for drastically lower shipping and storage costs compared to frozen or fresh products.

Research is ongoing into how well kelp will grow in Alaska, and on ideal density per unit of space. Some aquatic farms space rows only a few yards apart while others may leave over 40 feet between rows, depending on the harvesting methods and equipment used. This growing density presents major implications for yields per acre.

As operations scale up, there will likely be greater capital investments in processing equipment and new or refurbished buildings where seaweed may be processed and stored. Initially, Alaska's lone kelp buyer plans on using a mobile, trailer-mounted processing unit that will be transported to farm sites around the state. This approach makes greater use of the processing unit, though if volumes increase another processing machine may be necessary. Farmers may also decide to become wholesalers and process their own product, which would require localized processing facilities.

Initial capital expenditure requirements for kelp farming include buying lines/buoys and processing machinery used to dry and grind seaweed. Relatively low capital investment requirements and ability to utilize existing labor and vessels outside of the fishing season are reasons many are optimistic the industry can flourish in Alaska.[7]

Kelp Markets

ALASKA MARKETS

All three Alaska kelp farms plan to sell 2017 production to San Francisco-based Premium Oceanic, LLC, a company with seaweed production facilities in Mexico. The company, which is the only large-scale seaweed buyer operating in Alaska, operates under the brand name Blue Evolution. The company produces a CPG (consumer packaged good) pasta product line that includes sea lettuce.[8]

Photo credit: Blue Evolution.

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[7] Future projections concerning value and economic costs/benefits will rely heavily on hypothetical assumptions gleaned from interviews with industry.
[8] Blue Evolution.

Premium Oceanic, which also sources seaweed from onshore grow-out facilities in Mexico, has identified potential for high volume production in Alaska.[9] Alaska has access to more undeveloped coastline than other areas in the lower 48, where achieving larger farm sizes would likely meet with resistance. Marine skills of coastal Alaskans and vessels potentially available for use are also important advantages over other areas in North America or Europe. To expand its product line beyond pasta, Premium Oceanic is also investigating other markets where kelp powder could be an ingredient.

The company owns a mobile drying/processing unit to transform wet kelp into a stable powder format. They report a desire to expand production in Alaska, although producing seed is challenging due to strict regulations about sourcing plants from local areas. If kelp ventures succeed, Alaska could face competition from British Columbia and the eastern U.S., which may dilute the market and lead to lower prices.

U.S. and Global Markets

Alaska producers will likely target North American markets, rather than compete with low-cost Asian producers or European producers. With virtually no domestic production, most seaweed utilized in the U.S. (and Canada) comes from imports. Last year the U.S. imported 40,138 metric tons of seaweed and products derived from seaweed worth $203 million.[10] Seaweed imports fell 16 percent by value in 2016 but were relatively stable in previous years. Carrageenan-based thickeners have trended down in volume and value since 2014, possibly due to research linking them to a myriad of health problems.[11] This downward trend is likely to accelerate following a November 2016 ban by the National Organic Standards Board that stipulates carrageenan-based additives will no longer be allowed for use in foods carrying the "USDA Organic" label. The ban and research findings should not impact demand for kelp.

Table 18. U.S. Seaweed Imports by Product Type, 2012-2016

Volume (Metric Tons)	2012	2013	2014	2015	2016
Agar	1,428	1,420	1,417	1,565	1,383
Seaweed/Algae (not for Human Consumption)	19,539	23,652	18,030	14,826	20,959
Seaweed/Algae (for Human Consumption)	7,789	6,370	7,180	10,695	8,560
Seaweed Carrageenan-based Thickeners	10,245	9,105	9,965	9,981	9,236
Total	**39,002**	**40,547**	**36,592**	**37,067**	**40,138**
Value ($Millions)	**2012**	**2013**	**2014**	**2015**	**2016**
Agar	$29	$32	$34	$38	$32
Seaweed/Algae (not for Human Consumption)	43	49	47	36	38
Seaweed/Algae (for Human Consumption)	51	61	61	73	56
Seaweed Carrageenan-based Thickeners	89	88	102	96	76
Total	**$212**	**$230**	**$244**	**$244**	**$203**

Source: NMFS Trade Data.

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[9] Personal communication.
[10] NMFS Trade Data.
[11] http://www.npr.org/sections/thesalt/2016/12/12/504558025/carrageenan-backlash-why-food-firms-are-ousting-a-popular-additive.

The U.S. imported seaweed products from 38 different countries in 2016. These import statistics provide some indications of potential value of Alaska kelp. It is likely that much of the kelp the U.S. imports from China consists of dried kelp powder or flakes. The U.S. imported 1,922 metric tons of seaweed and other algae fit for human consumption from China in 2016, worth $21.9 million. This works out to $11,369 per (dried) metric ton, or $0.77 per wet pound assuming a 15 percent dry/wet yield. It is important to again note that $0.77 per pound may not be a good proxy for "ex-vessel" Alaska kelp prices, as the import unit value includes processing, storage, shipping, and other operating costs. Still, the value of Chinese product (fit for human consumption) would likely represent at least the lower end of Alaska's potential wholesale value range because it is likely almost exclusively dried product.

Asian countries account for most seaweed consumption, though the market for kelp and other sea vegetables is expanding rapidly in the U.S. and Europe. This expansion is fueled by changing consumer eating patterns, broadening palates, and subpeaweed's anointment as a "superfood." Plant based diets, specifically veganism, are on the rise – up 360 percent in the last decade - and that trend shows no sign of slowing down.[12] U.S. retail sales of kelp chips and crackers were valued at over $250 million in 2014.[13]

Kelp is growing in popularity, from nutritionists who tout its many health benefits, to chefs who welcome its unique taste profile, to environmentalists who value its ability to absorb carbon dioxide and reduce ocean acidification. In addition, nutraceutical and cosmetic companies are also using kelp and other marine plants more.[14] Kelp's list of marketable qualities includes:

- Food – Detoxification, Anti-Oxidants, and Chelating Properties: helps the human body draw out waste, toxins, and heavy metals and reduces inflammation. Also helps to purify blood.
- Food – Healthy Thyroid, Healthy Waistlines: kelp contains relatively high levels of iodine, which is essential for the thyroid gland and regulating metabolism. Iodine deficiency is a concern in both developing and developed countries, especially with people consuming more sea salt (and less iodized salt) as well as the addition of bromine to some foods, which blocks iodine absorption.[15]
- Food – Alkalizing Acidic Bodies: seaweeds can help alkalize blood, neutralizing the effects of our modern diet as well as reducing the acids in foods where they are added as an ingredient.
- Food – Bioavailable Nutrients: kelp contain high amounts of potassium, magnesium, calcium, iron, vitamins, amino acids, omega-3 fats, and fiber which are absorbed easier by human bodies than pill-based supplements.
- Skin – High-end Elixirs: popular skin creams can reduce wrinkles and reduce skin blotches.
- Environment – Cleaning the Air and Oceans: kelp absorbs five times as much carbon dioxide as land-based plants, filters nitrogen/phosphorus, and reduces ocean acidification.[16]

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[12] http://www.telegraph.co.uk/wellbeing/diet/say-goodbye-kale-superfood-trends-2017-five-new-ingredients/
[13] http://www.nbcnews.com/news/us-news/red-tape-slows-bloom-seaweed-farming-s-green-revolution-n613526
[14] http://www.cosmeticsdesign.com/Formulation-Science/Researchers-at-work-on-new-kelp-source-for-natural-cosmetics
[15] https://www.ncbi.nlm.nih.gov/pubmed/19460960
[16] http://e360.yale.edu/features/new_breed_of_ocean_farmer_aims_to_revive_global_seas

- Environment – Habitat Supports Life: kelp farms provide habitat for fish, increasing local ocean productivity
- Infrastructure – Protection from the Storms: kelp farms can slow down storm surges.
- Biofuel – Kelp-anol: Researchers around the world have been working with macroalgaes like kelp on biofuel production methods.
- Animal Feeds – Growing Healthier Everything: kelp/seaweed can produce demonstrable benefits when added to feeds for aquaculture and animals, even at low percentages (2 percent), making it a valuable feed additive.

Species in Research and Development

While little or no production is occurring in the Alaska mariculture industry for species other than oysters, mussels, geoducks, and kelp, several other species are under consideration for potential development. Only a few species have advanced into substantial research and development stages. A great deal of resources have been placed on king crab enhancement, while some effort is also going into sea cucumbers and abalone. Clams (aside from geoduck), purple-hinged scallops, sea urchins, and cockles are being researched.

King Crab

King crab are an important commercial species in Alaska, though stocks have declined and not rebounded in the Gulf of Alaska since the 1980s. A statewide collaborative research effort, *Alaska King Crab Research, Rehabilitation, and Biology* (AKCRRAB), is currently underway to rehabilitate stocks. Recent experimental releases of crab stock are under observation and the next and final phase of the research effort is underway. Next steps will be to attract industry investment and ensure the Alaska regulatory environment will allow for crab enhancement.

King crab enhancement has the potential to be immensely profitable. Ex-vessel prices are at a record high and king crab products are in high demand around the globe. In addition, fishing operations and processing operations already harvest and process crab, so there wouldn't be an issue with establishing new relationships, distribution channels, or markets. Most major processing centers (Kodiak, Bering Sea, and Southeast) purchase king crab regularly and would likely welcome enhanced crab stocks due to their high market value.

Crab enhancement research is in its infancy yet has produced a wealth of information. Funding, primarily for research grants, has been shared between Community Development Quota (CDQ) groups, public agencies, and industry. Maintaining funding now will be a key factor for future success.[17] AKCRRAB's third and final phase is to invoke industry and community participation, now that they've developed the pathway to red king crab rearing. The AKCRRAB team has proven that gathering broodstock, incubating king crab in salt water tanks for 2 months, and outstocking them is a relatively low-cost effort.

One of the challenges before commercial hatcheries can operate is developing genetic marking and monitoring methodology to differentiate wildstock from hatchery-raised crab. Scientists are unsure on how hatchery crab would impact natural stocks. The experimental outstocking conducted in the Kodiak basin remain in localized populations and the natural crab population is so depleted around Kodiak Island that scientists are unable to observe stock interactions.

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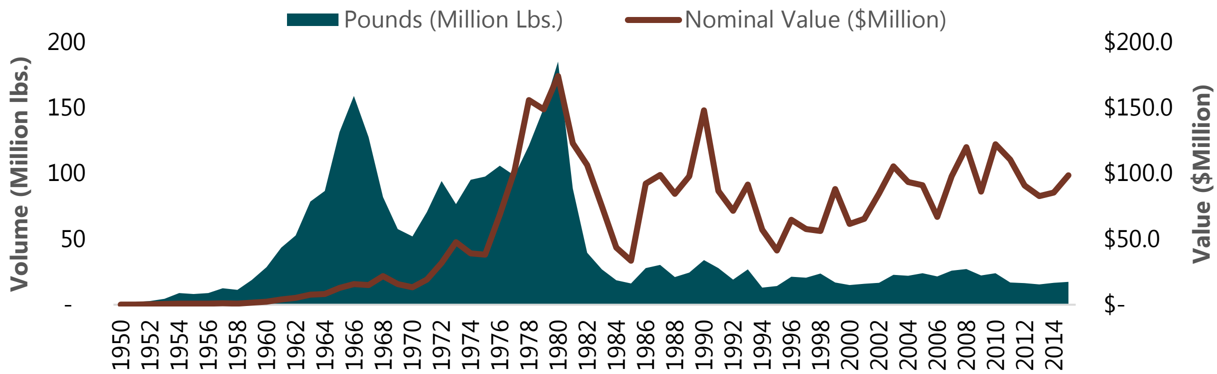
[17] http://www.bsfrf.org/pdf/DraftAKCRRAB_1pager.pdf

INDUSTRY OVERVIEW

King crab, the largest crab species in the U.S., harvested in the Bering Sea, are a highly valuable commercial species. In 2015, king crab harvests totaled 17.5 million pounds worth $98.6 million. Crab fishing is jointly managed by NMFS and ADF&G.

Figure 17. King Crab Harvests and Value, 1950-2015



Source: NMFS Landings.

Red king crab (*Paralithodes camtschaticus*) inhabit a continuous, wide range from the Aleutian Chain, Bering Sea, and the Gulf of Alaska.[18] Blue king crab (*Paralithodes platypus*). inhabit discrete areas in the Bering Sea, and tend to live in shallower water than red king crab. Both species are long-lived, typically not large enough to harvest until 7 to 9 years of age.[19] Both red and blue king crab commercial fishing peaked in the mid-1980s and stocks have not fully recovered from overfishing. Blue king crab near the Pribilof Islands are the only federally-listed overfished species in Alaska. Recently, ocean acidification and ocean temperature fluctuations have been linked to lowered king crab survival rates.[20]

RESEARCH AND DEVELOPMENT IN ALASKA

In response to declining stocks and potential environmental changes, and the highly lucrative king crab commercial fishery, king crab wild stock enhancement has been a research priority for ADF&G since 1991.[21] In particular, near the Pribilof Islands, enhanced blue king crab populations would potentially allow as a red king crab fishery this is currently closed to avoid blue king crab bycatch.[22] Additionally, coastal Alaskan communities would benefit from crab enhancement through quota allocations held by shoreside processors, fishermen, crew members, and CDQ groups.[23]

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[18] http://www.afsc.noaa.gov/Education/factsheets/10_rkc_fs.pdf
[19] http://www.adfg.alaska.gov/index.cfm?adfg=wildlifenews.view_article&articles_id=544
[20] https://access.afsc.noaa.gov/pubs/posters/pdfs/pFoy02_ocean-acid-research.pdf
[21] http://www.adfg.alaska.gov/index.cfm?adfg=wildlifenews.view_article&articles_id=544
[22] http://www.nmfs.noaa.gov/sfa/fisheries_eco/status_of_fisheries/archive/2015/2015_status_of_stocks_updated.pdf
[23] The Western Alaska Community Development Quota (CDQ) Program allocates a percentage of all Bering Sea and Aleutian Islands quotas for groundfish, prohibited species, halibut, and crab to eligible communities. The purpose of the CDQ Program is to (i) to provide eligible western Alaska villages with the opportunity to participate and invest in fisheries in the Bering Sea and Aleutian Islands Management Area; (ii) to support economic development in western Alaska; (iii) to alleviate poverty and provide economic and social benefits for residents of western Alaska; and (iv) to achieve sustainable and diversified local economies in western Alaska. (NMFS)

NMFS operates a shellfish research laboratory in Kodiak, where scientists conduct research on king crab habitat, life cycle, behavior, and response to climate change.

Crab aquaculture operations occur around the world, though enhancement is less frequent. Examples of enhancement operations include: Maryland blue crab enhancement that began in 2002, with subsequent release of 150,000 crab. Japan attempted king crab enhancement research in the 1980s, though efforts did not continue.[24] Russians introduced king crab in the Barents Sea, where it was not native, to increase commercial fishing opportunities in the 1980s.[25]

Alaska King Crab Research, Rehabilitation, and Biology (AKCRRAB)

The first crab restoration project in Alaska, the AKCRRAB Program, is a collaborative research program with partners that include Alaska Sea Grant, fishery associations, CDQ groups, NOAA, the UAF College of Fisheries and Ocean Sciences, and private industry. This long-term research effort, which commenced in 2006, focuses on raising and releasing red and blue king crabs to enhance depressed king crab populations throughout Alaska. [26] The project also includes monitoring of ocean acidification impacts on crustaceans, such as juvenile shell growth rates.

Alutiiq Pride Shellfish Hatchery, located in Seward, is the only hatchery in Alaska that has produced crustacean larvae. When the larvae reach a certain age, they are shipped to the NOAA Kodiak Laboratory where they have recently (in 2013-2015) been released near Kodiak and Old Harbor (Kodiak Island) and monitored for survival rates. Only red king crab have been released; blue king crab efforts are behind the red crab program by three to four years due to biological differences between the species and ability to collect broodstock. Hatchery production increased from 1,000 juveniles to 100,000 juveniles between 2007 and 2010.[27] In 2014-2015, 21,000 juveniles were released. Currently the mortality rate after release is 15 percent. Since Kodiak lacks any local king crab population, monitoring efforts can assume all observed juvenile crab are AKCRRAB experiments. The next release is anticipated for 2018 and will release 100,000 juvenile crab near Kodiak. A project near Seward is under development.

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[24] https://seagrant.uaf.edu/research/projects/kingcrab/docs/presentations/Eckert-lobster-crab-enhancement.pdf
[25] http://flseagrant.ifas.ufl.edu/newsletter/2012/07/an-amazing-story-red-king-crab-introduced-to-barents-sea/
[26] https://seagrant.uaf.edu/research/projects/kingcrab/docs/presentations/Persselin-2009-comfish.pdf
[27] http://www.adfg.alaska.gov/index.cfm?adfg=wildlifenews.view_article&articles_id=544

AKCRRAB operates in three phases to achieve its goal of eventual rehabilitation of king crab that it hopes to accomplish by 2019.[28]

- Phase I: Developing and improving methods of hatchery rearing juvenile king crab.
- Phase II: Understanding optimal release strategies, appropriate habitat, and potential impacts on existing ecosystems.
- Phase III: The final phase aims to transition AKCRRAB from a research coalition to implementation by different industry user groups.

AKCRRAB Operations

Since 2007, king crab broodstock have been collected under ADF&G research permits. APSH monitors and cares for the broodstock and offspring. Thousands of eggs hatch in early spring and the larvae become juveniles two months later. Survival rates were 31 percent in 2013.[29] Hatchery startup required $600,000 in equipment. Hatchery operations currently cost over $300,000 a year.[30]

Juvenile red king crab.
Photo credit: Celeste Leroux, Alaska Sea Grant.

Broodstock for hatchery production is developed from wild crab. In past years, it was collected from Kodiak Island, the Pribilof Islands, and Little Diomede. Currently, broodstock comes from Alitak Bay. A 10 percent survival rate at the juvenile stage could produce 100,000 juveniles annually.[31] Raising larvae in a controlled environment greatly reduces natural mortality.

Table 19. Estimated Costs of King Crab Enhancement, 2009[32]

Operating Costs	$250,000
Start Up Cost	$150,000
Cost to Produce 1 Million Juveniles	$0.25/juvenile
Survival Rate	8%
Number of Survivors	80,000
50% Male	40,000
Exploitation of 15%	6,000
Typical King Crab (in lbs.)	6.5
Typical King Crab Price/lb.	$8.00
Potential Future Value	$312,000

Note: Survival rate refers to juveniles reaching adulthood (seven years).

[28] https://seagrant.uaf.edu/research/projects/kingcrab/docs/akcrrab-strategic-plan-2015-2019.pdf
[29] http://alaskaberingseacrabbers.org/article.php?article=90
[30] https://seagrant.uaf.edu/factsheets/kingcrab/kingcrab-financial-web.pdf
[31] https://seagrant.uaf.edu/research/projects/kingcrab/docs/presentations/Persselin-2009-comfish.pdf
[32] Glaser (2009). Rehabilitation of the Alaskan red king crab through large-scale hatchery culture and restock: Cost-Benefit Analysis.

From 2008-2010 costs for AKCRRAB research and development totaled $2.5 million in Alaska Sea Grant funds and included many other contributors.[33]

Research and Development

There is a comprehensive body of knowledge published on king crab species, including diet, effects of water temperature, effects of light, molting, and survival that contributes to a better understanding of how to successfully enhance wild stocks.[34] Since its infancy, AKCRRAB has supported eight University of Alaska Fairbanks graduate students and produced numerous scientific publications.[35] In addition, more than 30 visiting scientists have contributed to the ongoing body of research. Three Alaska Sea Grant staff and three NMFS researchers have also worked on AKCRRAB efforts.[36]

Community Investment

As AKCRRAB phases out public investment and seeks private interest, tribes and CDQ groups stand out as potential catalysts for bringing crab enhancement to fruition. CDQ groups receive crab allocations and would benefit from an increased supply of crab. Tribes representing rural communities, such as St. Paul, would greatly benefit from increased economic activity through hatchery efforts as well as fishing activity.

King crab culture requires obtaining broodstock, a facility, equipment, and expertise to hold crab for two months, and the ability to release them. St. Paul Island has a NOAA facility and expertise in crab biology. In addition, Central Bering Sea Fishermen's Association, the region's CDQ group, holds sizeable amounts of crab quota and APICDA has been involved in AKCRABB throughout the life of the project and continues to have interest in its development.

Kodiak Island's current involvement in crab enhancement and its sizable commercial crab fleet and processing facilities makes it an ideal candidate for long-term investment. The NOAA Kodiak Laboratory, which is currently extensively involved in king crab outstocking research, also houses the federal shellfish stock assessment scientists.

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[33] https://seagrant.uaf.edu/factsheets/kingcrab/kingcrab-financial-web.pdf
[34] https://seagrant.uaf.edu/research/projects/kingcrab/docs/presentations/Persselin-2009-comfish.pdf
[35] https://seagrant.uaf.edu/research/projects/kingcrab/general/graduate-students.php
[36] https://seagrant.uaf.edu/research/projects/kingcrab/staff/index.php

Pinto Abalone

The pinto abalone (*Haliotis kamtschatkana*), or the northern abalone, is the only abalone species found in Alaska. This single-shelled mollusk inhabits shallow kelp beds from Southeast Alaska to California.[37] In Alaska, this species is typically found between Dixon Entrance and Icy Straits in outside waters of Southeast Alaska. This abalone species is slow-growing, with the length of time required to grow to a commercial size unknown.

A commercial fishery for pinto abalone existed in Southeast Alaska from the 1970s to the late 1990s, when it was closed due to overfishing.[38] Concurrently, a growing Southeast Alaska sea otter population placed pressure on the abalone biomass, further limiting its capacity to rebuild.[39] Pinto abalone have been listed as a "species of concern" under the Endangered Species Act, since 2004, which allows proactive conservation action to limit further stock declines.[40] Subsistence harvests of abalone in Alaska are limited to 5 abalone a year with a minimum size of 3.5 inches.[41]

INDUSTRY OVERVIEW

Abalone mariculture was developed in response to rapidly declining stocks around the world due, in part, to high demand for this mollusk. China produces most of the world's commercial abalone grown in aquaculture operations, while very little is grown in the U.S. On the U.S. West Coast, abalone mariculture is a cottage industry with several small-scale farms producing live and canned abalone that sell for up to $100 per pound.

The Alutiiq Pride Shellfish Hatchery in Seward is the only Alaska mariculture facility actively growing pinto abalone seed in an experimental basis. The current purpose of that seed would be for conservation purposes only.[42] Potential exists for abalone production to increase in Alaska, given high market prices for wild and fresh abalone and a pristine environment that is optimal for growers.

PRODUCTION AND SUPPLY

In 2014, the U.S. produced 750,000 pounds of abalone, worth $4.8 million. Abalone producers on the West Coast market their products as fresh, either as steaks or whole. Depending on the species and product form, abalone market prices range from $15-$30 for a single abalone, $125 for 1 pound of abalone steaks, and $15 for a 4.8 oz. can.[43,44,45]

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37 http://www.adfg.alaska.gov/index.cfm?adfg=abalone.main
38 http://www.fisheries.noaa.gov/pr/species/Status%20Reviews/pinto-abalone-status-review-2014.pdf
39 http://www.haidagwaiiobserver.com/news/413095193.html
40 http://www.fisheries.noaa.gov/pr/species/invertebrates/abalone/pinto-abalone.html
41 http://www.adfg.alaska.gov/index.cfm?adfg=PersonalUsebyAreaSoutheastSCA.regs
42 http://alutiiqpridehatchery.com/pinto-abalone/
43 http://bigislandabalone.com/buyonline.html
44 https://www.giovannisfishmarket.com/seafood-online/abalone/live-abalone.aspx
45 https://www.giovannisfishmarket.com/seafood-online/abalone/abalone-steaks-one-pound.aspx?IID=816308

To supplement domestic production, the U.S. imported approximately 1 million pounds of abalone in 2016, worth between $9 to $17 per pound. Australia accounted for 34 percent of total supply, followed by Hong Kong with 22 percent.

Table 20. Top U.S. Abalone Import Source, 2016

Country	Value ($Millions)	Quantity (Lbs.)	Avg. Price Per Lb.
Australia	$4.3	359,350	$11.97
Hong Kong	$2.5	240,301	$10.20
Mexico	$2.1	154,322	$13.55
Chile	$1.3	141,094	$9.04
China	$1.7	141,094	$12.17
South Korea	$0.2	11,023	$17.83
Other	$0.2	22,046	$9.61
Total	**$12.2**	**1,069,230**	**$11.45**

Note: Includes live, fresh, chilled, and non-specified abalone products.
Source: Global Trade Atlas.

Global Production

Abalone mariculture operations produce approximately two-thirds of the annual world commercial abalone supply. In 2014, global mariculture supply of abalone totaled 516,618 metric tons, of which 70 percent was produced in farming operations.

U.S. domestic abalone production is minor in comparison to China and Korea. Chinese producers supplied 348,246 metric tons of farmed abalone, worth $678 million in 2014, or 96 percent of total farmed abalone. Korea produced 8,977 metric tons worth $39 million.

Table 21. Global Aquaculture Supply of Abalone, in Metric Tons and $000s, 2010-2014

Region	2010	2011	2012	2013	2014
China	264,349	280,052	305,040	323,224	348,246
Korea	6,228	6,779	6,564	7,479	8,977
South Africa	1,015	1,036	1,111	1,100	1,150
Chile	794	841	853	1,134	1,146
Australia	1,985	491	605	724	859
U.S.	250	250	250	201	341
Other	80	114	101	77	87
Total Aquaculture Volume (mt)	**274,701**	**289,563**	**314,524**	**333,939**	**360,806**
Total Aquaculture and Wild (mt)	**431,806**	**435,487**	**472,796**	**500,291**	**516,618**
Pct. Aquaculture	**64%**	**66%**	**67%**	**67%**	**70%**

Note: Data contains some conches and winkles.
Source: FAO Fish Stats.

Globally, abalone are typically sold alive, which is when they are the freshest. Farmers have sold them deshelled in frozen vacuum packs and in cans. China and Japan consumers use dried abalone for its alleged medicinal and aphrodisiac qualities, in addition to a wide variety of other dishes. Abalone flavor is so popular in Asia that there is a faux vegetarian version available.[46]

Table 22. Global Aquaculture Supply of Abalone, in $000s, 2010-2014

Region	2010	2011	2012	2013	2014
China	$389,557	$481,047	$552,478	$643,102	$678,634
Korea	$197,708	$215,713	$213,237	$226,285	$282,115
South Africa	$48,596	$40,867	$49,509	$41,710	$38,702
Chile	$26,202	$29,274	$65,833	$81,018	$105,266
Australia	$14,197	$16,917	$19,879	$22,937	$24,195
U.S.	$8,818	$8,818	$8,818	$8,538	$4,818
Other	$2,020	$3,788	$2,756	$2,305	$2,870
Total Value ($000s)	**$687,098**	**$796,424**	**$912,509**	**$1,025,896**	**$1,136,599**

Note: Data contains some conches and winkles.
Source: FAO Fish Stats.

ALASKA ABALONE FARMING

Alutiiq Pride Shellfish Hatchery is producing seed for pinto abalone with a focus on species preservation. However, there may be potential for mirroring commercial mariculture efforts for abalone that California and British Columbia farmers have successfully developed.

Since abalone farming is not occurring in Alaska, operating cost information is not available. However, potential farmers might consider several factors:

- Abalone farmers in California see a profit margin of 15-18 percent per abalone above their operating costs and the common price they receive per live abalone is $15.
- Abalone are a slow-growing species. Based on industry interviews, shellfish farmers would see more success with abalone rearing after first building a base of a faster growing species like oysters or mussels.
- Careful planning to protect farmed abalone from natural predators, like sea otters, could be important.

The Cultured Abalone Farm

The Cultured Abalone Farm (Goleta, CA) is a land-based operation that consists of 400 1,000-gallon tanks that produce 1,500 pounds of abalone each week. They are fed a composite diet of local kelp and are sold at $15 per pound whole and live to buyers. They typically operate at a 15-18 percent margin on gross sales.

[46] https://giantonline.com.sg/catalog/product/view/name/vegetarian-abalone-285g-5016909

- Costs to grow abalone are likely comparable to other shellfish operations, like geoducks, which take several years to mature but are more valuable on a per pound basis than oysters or clams.

The following table provides a hypothetical operating model for abalone production. It is based on interviews with California abalone farmers, who are permitted to grow up to 500,000 abalone each. Prices were assumed to be approximately $20 per pound with producers growing between 60,000-80,000 with seed purchased from Alutiiq Pride Shellfish Hatchery[47]. Based on these assumptions, annual gross revenue from abalone sales would be between $1.2-1.6 million per farm. In California, the cost of producing one abalone is $3.50-$12, depending if operations are ocean or land-based.

Table 23. Potential Alaska Abalone Production

Annual Production	60,000-80,000 abalone
Average Farmgate Value per Pound	$15-23/lb. $20/lb. average
Annual Earnings	$1.2-1.6 million
Profit Margin	15-18% of Revenue
Annual Labor Cost	50% of operating costs
Employment	9-12 year-round employees

Source: McDowell Group estimates.

Alaska producers could anticipate entering a market where abalone prices range between $15 to $30 per pound. It is likely that Alaska-produced abalone prices could be in the upper range due to their quality and the price premium that Alaska seafood can often demands.

[47] Abalone would need to be added as a permitted species for culture to APSH' operational permit before they could sell seed.

Sea Cucumbers

Sea cucumbers, also known globally as bêche-de-mer, are a delicacy in Asian countries. Commercially, hundreds of sea cucumbers species are priced and graded by size, species, and imperfections. In addition to food consumption, they are also used in biomedical and pharmaceutical applications.

Giant red sea cucumbers (*Parastichopus californicus*) are the only commercially harvested sea cucumber in Alaska. The species, found in the Pacific Ocean from Mexico to the Aleutian Islands, can grow up to 50 cm (19 inches) long.[48] Giant red sea cucumbers reach adult size and sexually maturity after 4 years.[49]

Photo credit: ADF&G.

In 2015, sea cucumber mariculture contributed 83 percent to the world supply. The remaining 17 percent was wild harvest. Sea cucumber mariculture operations vary, with many regions practicing "poly-culture." As sea cucumbers are filter-feeders, they consume detritus from other species, making them potentially useful for minimizing waste from farms or processing plant discharge zones. Sea cucumber mariculture may also be used to enhance wild stocks.

PRODUCTION AND VALUE

Currently no commercial sea cucumber mariculture operations exist in Alaska, though a wild harvest does.

Farmed Sea Cucumbers

Sea cucumber mariculture is in its infancy in Alaska and the rest of the U.S., with most U.S. production from wild harvest. In Alaska, sea cucumber mariculture efforts are in the research and development phase.50 Southeast Alaska Regional Dive Fisheries Association (SARDFA) supports sea cucumber enhancement research in Seward at APSH and in Ketchikan.

SARDFA is interested in developing mariculture to address sea cucumber population declines due to a rise in sea otter populations in Southeast. SARDFA is concerned sea otter depredation of sea cucumbers will decimate the population to the extent that commercial fishing access will close entirely in Southeast. Since poly-culture has been successful with sea cucumbers, SARDFA has expressed interested in working with oyster farms or salmon hatcheries.

Operations in other areas of the world may help inform efforts in Alaska. Many countries produce hatchery-raised sea cucumbers for both enhancement and commercial production, with much of the effort in China,

[48] http://www.adfg.alaska.gov/index.cfm?adfg=redseacucumber.main
[49]http://peninsulaclarion.com/news/2011-07-17/spawning-sea-possibilities?utm_source=Morris%20Digital%20Works&utm_medium=email&utm_campaign=Recurring_Daily%20Headlines
[50] http://alutiiqpridehatchery.com/sea-cucumber/

other Asian countries, and the Pacific Islands including Australia and New Zealand.[51] In 2015, China produced 98 percent of total sea cucumber global supply, totaling 205,791 metric tons, worth $715 million. In China, sea cucumbers are raised in artificial ponds and man-made tide pools.

Table 24. Global Supply of Farmed Sea Cucumbers, in Metric Tons, 2011-2015

Region	2011	2012	2013	2014	2015
China	137,754	170,830	193,705	200,969	205,791
Indonesia	219	475	206	138	2,029
Other	213	211	237	918	128
Total Mariculture Volume (mt)	**138,186**	**171,516**	**194,148**	**202,025**	**207,948**
Total Mariculture and Wild (mt)	**181,092**	**211,670**	**232,909**	**238,137**	**250,940**
Pct. Mariculture	**76%**	**81%**	**83%**	**85%**	**83%**

Source: FAO Fish Stats.

Table 25. Value of Global Supply of Farmed Sea Cucumbers, in $000s, 2011-2015

Region	2010	2011	2012	2013	2014
China	$478,006	$592,780	$672,156	$697,362	$714,095
Indonesia	$3,119	$6,328	$2,473	$1,455	$18,817
Other	$1,586	$1,576	$1,711	$5,906	$1,274
Total Value ($000s)	$482,712	$600,684	$676,340	$704,723	$734,186

Source: FAO Fish Stats.

Wild Harvest Sea Cucumbers

The U.S. only produces wild harvest sea cucumbers and contributes a small fraction to global supply. Alaska harvests the most sea cucumbers in the country, followed by Washington, Maine, and California. Global wild sea cucumber harvest information may be found in Appendix A.

Table 26. U.S. Wild Sea Cucumber Landings, Metric Tons and Value, by Region, 2013–2015

	2013 mt	2013 Value	2014 mt	2014 Value	2015 mt	2015 Value
Alaska	752	$6,523,020	546	$4,815,197	740	$5,747,153
East Coast	483	$305,580	230	$177,080	9	$18,511
West Coast	477	$3,811,179	444	$3,846,897	505	$5,182,903
Total Harvested	**1,712**	**$10,639,779**	**1,220**	**$8,839,174**	**1,253**	**$10,948,567**

Source: National Marine Fisheries Service, Fisheries Statistics and Economics Division.

In Alaska, commercial dive harvests began near Ketchikan in 1983. In addition to harvest in the commercial dive fishery, the species is a traditional subsistence food. Commercial diving for sea cucumbers is largely

[51] http://seagrant.umaine.edu/files/pdf-global/SeaCucumberManual_062614.pdf

concentrated in Southeast, with smaller fisheries in Kodiak and Chignik.[52] Divers use scuba gear to hand pick sea cucumbers off benthic (sea floor) habitats and transport them to the surface in mesh bags.[53] ADF&G rotates fishery areas every three years to prevent overharvest. Stock assessments are partially-funded by SARDFA.

Statewide harvests averaged slightly over 1.6 million pounds per year between the winter 2011/12 and 2015/16 seasons.[54] Harvests in Southeast Alaska averaged 1.5 million pounds per year, with about 186 divers participating. In 2016, the season average price per pound for sea cucumbers in Southeast was $4.00. The fishery's value has increased recently due to rising prices in China, the top importer of Alaska's sea cucumbers.

Table 27. Southeast Alaska Sea Cucumber Harvests, 2011-2016

Season	Guideline Harvest Level (lbs.)	Total Landed (lbs.)	Average Price/lb.	Ex-vessel Value	Number of Divers
2011/12	999,000	1,023,834	$5.06	$5,180,600	189
2012/13	1,476,000	1,512,895	$4.05	$6,127,225	199
2013/14	1,472,600	1,556,983	$3.97	$6,181,223	198
2014/15	1,084,800	1,073,554	$4.00	$4,294,216	171
2015/16	1,439,900	1,525,387	$3.50	$5,338,855	175

Source: ADF&G Commercial Fishing Division.
Note: Some harvest data is not included in this table due to confidentiality restrictions.

Sea Cucumber Processing and Operations

China and Japan were the first to develop successful hatchery technology for sea cucumbers. Operations require broodstock and tanks with circulating seawater. The animals are held in shallow pens and cages on the seafloor in open water or grown in ponds. In China, large concrete ponds with natural tidal flows hold sea cucumbers that feed on algae and other natural food sources. In New Zealand, many aquaculture farms combine mussels and sea cucumbers. Sea cucumbers subsist on the detritus of mussels.

In Alaska, SARDFA provides APSH adult sea cucumbers as broodstock, from which the hatchery develops seed and then ships juveniles to Alaska Shellfish Hatchery in Ketchikan where the seed grow in a controlled environment.[55] In 2016, APSH successfully shipped a batch of young cucumbers to Ketchikan, and after a period of acclimation, the cucumbers were reared in a pen on the ocean floor near the facility as part of a research project. The test was successful and the cucumbers grew to three or four inches over a summer. No hard data is available on mortality rates or on time to grow sea cucumbers to marketable size.

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[52] http://www.adfg.alaska.gov/index.cfm?adfg=CommercialByFisheryDive.seacucumber
[53] http://www.adfg.alaska.gov/index.cfm?adfg=redseacucumber.main
[54] Based on annual ADF&G harvest data for years not confidential. Kodiak and Chignik harvests are purchased by a single buyer, which makes harvest data confidential. According to an ADF&G contact, GHL of 140,000 lbs. in Kodiak and 20,000 lbs. in Chignik is consistently met each year.
[55] http://alutiiqpridehatchery.com/sea-cucumber/

Sea cucumbers are processed into frozen or fresh muscle strips and dried skins or sections. The skin is cooked and then dried into a product known as trepang or bêche-de-mer. Sea cucumbers are sold in a variety of product forms, the predominant being frozen, salted, or dried.

MARKETS

Sea cucumber products are marketed primarily in Asia, with a small niche in Asian food markets in the U.S. Primary markets are China and Japan, where the sea cucumber is valued for "aphrodisiac qualities." Wild Alaska sea cucumbers tend to be much larger and have higher nutritional value, and therefore command a premium price in the Chinese market.[56]

Photo credit: Kirsten Shelton.

Table 28. U.S. Sea Cucumber Exports, by Product Type, 2013 – 2015

	2013 kg	2013 Value	2014 kg	2014 Value	2015 kg	2015 Value
Frozen/Salted/Dried	1,198,566	$30.8	428,688	$16.1	435,009	$13.6
Live/Fresh	277,677	$3.5	137,619	$1.8	95,985	$1.1
Prepared/Preserved	804,197	$6.7	452,760	$4.3	179,261	$1.6
Total Exports	**2,280,440**	**$41.0**	**1,019,067**	**$22.2**	**710,255**	**$16.3**

Source: National Marine Fisheries Service, Fisheries Statistics and Economics Division.

Table 29. U.S. Sea Cucumber Exports, by Country, 2013 – 2015

	2013 kg	2013 Value	2014 kg	2014 Value	2015 kg	2015 Value
China	1,854,415	$33.7	672,325	$14.7	444,668	$10.2
Canada	134,757	$1.6	101,003	$1.5	103,359	$1.8
South Korea	169,825	$3.8	144,836	$3.8	99,974	$3.1
Vietnam	93,741	$1.6	31,077	$0.7	44,625	$0.8
Other	27,702	$0.3	69,826	$1.5	17,629	$0.4
Total	**2,280,440**	**$41.0**	**1,019,067**	**$22.2**	**710,255**	**$16.3**

Source: National Marine Fisheries Service, Fisheries Statistics and Economics Division.

[56] https://www.scribd.com/document/74857876/MCDOWELL-GROUP-2011-Sea-Otter-Impacts-Report

Clams

Several clam species, aside from geoducks, are of interest for mariculture in Alaska. These include Pacific littleneck clams, razor clams, butter clams, and cockles.

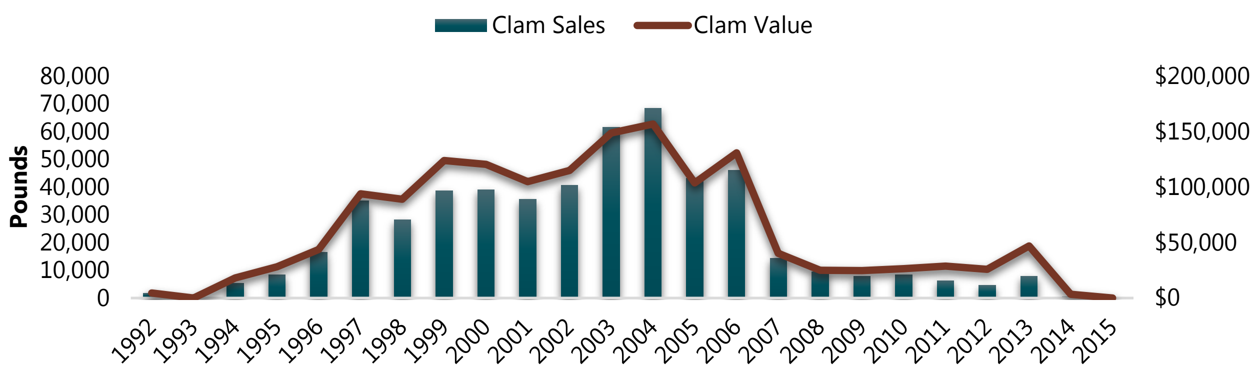
PRODUCTION AND VALUE

ADF&G has approved on-bottom aquatic farm sites for clams since 1999. In 2015, there were four permits in Alaska to culture clam (aside from geoducks) and one hatchery was permitted to grow seed.[57] Alutiiq Pride Shellfish Hatchery has developed a process to rear and grow clams.

Littleneck clams, also known as steamer clams, have been farmed more than other clam species in the state, with a peak of $157,000 worth of littleneck clams sold in 2004. Since 2004, clam production and sales have declined significantly. In 2010, ADF&G began reporting farmed geoduck harvest in combination with other clams, complicating analysis of harvest trends for both species. It is known, however, that no littleneck clams were sold in 2015. Anecdotally, farmers have identified several potential issues related to declining clam mariculture harvests after 2004:

- Predation, especially by sea otters and sea stars, has been a factor at some sites.
- Farms can harvest wildstock on farm sites. After a period, the amount of wildstock available may have declined.
- Survival rates of hatchery raised clams has been variable.
- Slow growth rates for hatchery reared clams can delay return on investment, reducing interest in farming this product.

Figure 18. Alaska Clam Production and Value, 1994-2015



Note: All clam sales through 2009 are for Pacific littleneck clams. Beginning in 2010, clam sales include both Pacific littleneck clams and Pacific geoduck clams.
Source: ADF&G and DNR.

[57] http://www.adfg.alaska.gov/index.cfm?adfg=fishingaquaticfarming.aquaticfarminfo_permit_status

LITTLENECK CLAMS

Interest in farming Pacific littleneck clams (*Protothaca staminea*) in Alaska is focused on diversifying product lines in current mariculture operations, as well as enhancing wild stocks.[58]

Littleneck clams grow in protected, mud beaches, burrowing about 6 inches deep. Clam farm sites exist on swathes of these non-rocky beaches, with a potential challenge being to contain farmed clams from wild populations.

Grow-out time for aquatic farm stock from seedstock to a marketable size is three to seven years. Recent research conducted by ADF&G suggests predator exclusion netting can enhance Pacific littleneck clam survival and growth in Southeast Alaska.

Spat is not currently commercially available for littleneck clams, though, as noted above, APSH has sold seed in the past and produced clams for many years. The hatchery has developed culture and grow out techniques for this species. The hatchery also seeded over 1 million clams at Tatitlek and other villages in lower Cook Inlet in 2000 and 2001, with variable success and growth, for research and bioenhancement purposes.[59] Current research and bioenhancement is occurring in Port Graham.

RAZOR CLAMS

Razor clams (*Siliqua patula*) can grow up to 7 inches and are found in sandy beaches from California to the Aleutian Islands.


Photo credit: ADF&G.

Historically, razor clams were harvested commercially near Cordova from 1916 until the 1950s.[60] The species was a popular canned shellfish item in grocery stores until less expensive substitutes outcompeted them. The local Cordova population was overexploited during this period.

Today, the largest commercial wild fishery for razor clams in the state occurs in lower Cook Inlet, where the harvest has ranged between 625,000 and 1.3 million clams annually since 1973.[61] The species is fished commercially for crab bait and for consumption.[62] The most recent data available shows the ex-vessel price for razor clams at $0.65/lb.[63]

In 2004, razor clams produced at APSH were planted near the village of Eyak, near Cordova, for enhancement purposes.[64]

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[58] https://seagrant.uaf.edu/map/aquaculture/shellfish/presentations/Introduction%20to%20clam%20farming.pdf.
[59] http://www.sf.adfg.state.ak.us/FedAidPDFs/RIR.5J.2004.05.pdf.
[60] http://www.adfg.alaska.gov/static/fishing/PDFs/aquaticfarming/razor_clam_pws.pdf.
[61] http://www.adfg.alaska.gov/index.cfm?adfg=ByAreaSouthcentralLowerCookInlet.research.
[62] http://www.adfg.alaska.gov/index.cfm?adfg=razorclam.uses.
[63] ADF&G (COAR).
[64] http://www.adfg.alaska.gov/static/fishing/PDFs/aquaticfarming/eyak_razorclam_report.pdf.

APSH has raised this species from seed with success, though it is assumed razor clams would fulfill local enhancement goals rather than be farmed for commercial harvest.

BUTTER CLAMS

Butter clams (*Saxidomus gigantea*) are found from Alaska to California. This species grows up to five inches in length. Ideal butter clam habitat occurs on sandy beaches in protected bays. The clam burrows deeper than littleneck clams, up to 12 inches.[65] Katchemak Bay hosts a notable concentration of butter clams.

Like razor and littleneck, butter clams are popular for personal use and subsistence. A commercial fishery for butter clams does not currently occur in the state. APSH has grown butter clams successfully, with high survival and growth rates. The hatchery expects butter clams to be a viable product for aquatic farming in Alaska. APSH's first experimental outstocking of butter clams for research and bioenhancement purposes will occur in spring 2017. One challenge with butter clams is their propensity to retain PSP.

COCKLES

Cockles (*Clinocardium nuttallii*) are a traditional subsistence and personal use shellfish resource in Alaska. Cockles range from the Bering Sea to Southern California and can grow up to 6 inches.[66] A variety of cockle species around the world are in demand for their sweet, mild-flavor that can be used in a variety of dishes.

Cockles are not typically a target for commercial harvest because they occur in low concentrations that have not been profitable to harvest. In the U.S., no commercial fishery for cockles occurs, only personal use and subsistence. In Alaska, cockles are often harvested with a rake or garden shovel in shallow water.

APSH raised cockles, both commercially and for research, with promising results. The species grows quickly, reaching market size in 12 to 16 months, and does well in lantern nets. Cockle shelf-life is short, which will be a hurdle if the species is developed commercially. They are a mobile species, making containment for a commercial operation an issue to address as well.

Three Alaska farms are currently permitted to raise cockles, though due to confidentiality restrictions it is unclear whether they are producing.[67]

U.S. PRODUCTION

Like oysters and mussels, clam mariculture is common throughout the world. In the U.S., approximately 11 percent of clams are farmed. In 2014, 10.4 million pounds of clams were produced on farms in the country, worth $120.7 million.[68] Including farmed and wild-caught clams, 90.7 million pounds of clams were commercially landed, worth $214.7 million.[69]

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[65] https://www.adfg.alaska.gov/static-sf/Region2/pdfpubs/HardshellClams.pdf
[66] http://nsgl.gso.uri.edu/aku/akug98002.pdf
[67] http://www.adfg.alaska.gov/index.cfm?adfg=fishingaquaticfarming.aquaticfarminfo_permit_status
[68] https://www.st.nmfs.noaa.gov/Assets/commercial/fus/fus15/documents/03_%20Aquaculture2015.pdf.
[69] https://www.st.nmfs.noaa.gov/Assets/commercial/fus/fus15/documents/02_Commercial2015.pdf.

Purple-Hinged Rock Scallops

Purple-hinged rock scallops (*Crassadoma gigantea*) are intertidal bivalves that range from Southeast Alaska to Mexico.[70] This species of scallop is smaller, at up to 10 inches in height, than the only commercially harvested scallop species in Alaska, the Pacific weathervane scallop.[71] Unlike the weathervane, purple-hinged rock scallops may be successfully reared in mariculture because of their unique ability among scallop species to permanently attach to rocky substrates. [72]

Scallops, common in the U.S. and worldwide, are delicacies, consumed for their sweet, mild meat. In 2015, over 35.8 million pounds of wild-harvest scallops were landed in the U.S., worth $440.5 million.[73] Edible meat yield is 10 percent from live weight. Prices are higher for larger scallops.

Photo credit: Joth Davis.

In Alaska, most wild scallop harvest occurs near Kodiak with dredge gear. Additional beds in Cook Inlet, Prince William Sound, and Southeast are closed or limited to fishing due to low yields. Alaska scallops are directly marketed to food service businesses, restaurants, and retail establishments. Harvest for the 2014/15 season totaled 308,888 pounds of shucked meat.[74]

Scallops are farmed around the world, including Canada and Washington.[75] In Alaska, there have been attempts to farm all three types of scallops that live in state waters. Weathervane, the largest and the only one commercially harvested, are difficult to farm and remain only wild-caught. Bay scallops, commonly sold live and whole, have also not been commercially produced in Alaska through mariculture. Rock scallops have the most potential for hatchery production because they readily attach to substrate and grow to marketable size in approximately three to five years.[76] Rock scallop spat can be hatchery produced. The one downside to rock scallops a habit of cementing to hard surfaces, which can destroy gear during harvest.[77]

In 2015, four Alaska farms were permitted to raise rock scallops.[78] Alaska Sea Grant and APSH collaborated on two batches of rock scallop seed production for research purposes. A research endeavor for lantern net grow-out was successful for bay scallops. Rock scallop research is currently underway using similar techniques to grow seed to maturity.

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70 Purple-hinged rock scallops, giant rock scallops, and rock scallops all refer to the same species *Crassadoma gigantea.*
71 http://nsgl.gso.uri.edu/aku/akug98002.pdf.
72 http://nsgl.gso.uri.edu/aku/akug98002.pdf.
73 https://www.st.nmfs.noaa.gov/Assets/commercial/fus/fus15/documents/02_Commercial2015.pdf.
74 https://www.npfmc.org/wp-content/PDFdocuments/resources/SAFE/ScallopSAFE/ScallopSAFE2016.pdf.
75 http://www.dfo-mpo.gc.ca/aquaculture/farmed-elevage/listing-eng.htm.
76 http://alutiiqpridehatchery.com/alaska-shellfish-farming/.
77 http://www.adfg.alaska.gov/static/fishing/PDFs/aquaticfarming/growing_shellfish_in_alaska.pdf.
78 http://www.adfg.alaska.gov/index.cfm?adfg=fishingaquaticfarming.aquaticfarminfo_permit_status.

Sea Urchins

Fresh whole sea urchins are consumed in many countries, including Chile, Hong Kong, and Southern Europe.[79] Sea urchin 'uni' (gonads) are prized in Japan, served primarily in sushi restaurants. Urchins are sourced from many countries, including Chile, China, Mexico, Russia, and the U.S.

Sea urchin mariculture research efforts have emerged in response to overfishing in less-regulated countries. China and Chile are two of the largest commercial producers of farmed sea urchins.

All sea urchin harvests in the U.S. are by divers. In 2015, over 11.1 million pounds of wild-harvest sea urchins were landed in the U.S., worth $13.1 million.[80] California produces the most sea urchins, followed by Maine.

Three varieties of sea urchins grow in Alaska, green, purple, and red. In 2015, four farms were permitted to culture green sea urchins. One farm was permitted to culture purple and one to culture red sea urchins.[81] Due to confidentiality, the status of these efforts is not included in published data.

The red sea urchin (*Strongylocentrotus franciscanus*), the larger sea urchin species in Alaska, is the target of the state's largest urchin fishery in Southeast Alaska. A commercial fishery for green sea urchin (*Strongylocentrotus droebachiensis)* in Southeast was assessed in 1999, though a biomass survey deemed the population too small for commercial harvest.[82,83] According to available data, fisheries for sea urchins in Kodiak and other regions have opened intermittently, though no current harvests occur outside of Southeast.

Since 2012, the annual Guideline Harvest Level for sea urchins averaged 3.5 million pounds, with total harvest landed by divers at approximately 550,000 pounds. For the 2015/16 season, 12 divers participated.

Table 30. Southeast Alaska Red Sea Urchin Harvests, 2012-2016

Season	Guideline Harvest Level (lbs.)	Total Landed (lbs.)	Average Price/lb.	Ex-vessel Value	Number of Divers
2012/13	3,275,300	357,679	$0.37	$133,082	8
2013/14	3,275,300	544,591	$0.47	$253,410	10
2014/15	3,310,700	634,430	$0.37	$231,758	12
2015/16	3,838,900	677,202	$0.49	$336,513	12

Source: ADF&G Commercial Fishing Division.

[79] http://nsgl.gso.uri.edu/casg/casgr05025.pdf
[80] https://www.st.nmfs.noaa.gov/Assets/commercial/fus/fus15/documents/02_Commercial2015.pdf
[81] http://www.adfg.alaska.gov/static/fishing/PDFs/aquaticfarming/2015_af_highlights.pdf
[82] http://www.adfg.alaska.gov/index.cfm?adfg=CommercialByFisheryDive.seaurchin
[83] https://www.nationalfisherman.com/alaska/market-report-alaska-sea-urchins/

Chapter 2: Alaska Mariculture Development

Alaska, with over 34,000 miles of predominantly undeveloped coastline, an established seafood industry, and culture of sustainable fisheries resource management is in many respects an ideal location for development of a robust mariculture industry. In turn, new mariculture operations offer Alaska's coastal communities a chance for jobs and economic activity that is often compatible with current seafood industry-related knowledge and infrastructure.

While potential for growth is high, as reported in Chapter 1 of this report, total mariculture commercial sales (almost exclusively oysters, clams, and mussels) remain below $1 million per year with little sustained growth over the past few decades. Most mariculture activity in Alaska beyond oysters is in the research and development stage, with no other species in significant commercial production. The 2017 commercial kelp harvest may mark an important milestone for mariculture, signaling an upswing for this new species in an industry that has otherwise struggled to achieve its potential.

The variety of operations and complexities of farming each species translate into a wide variety of challenges to industry growth beyond current operations. This chapter provides insight into barriers to mariculture development in Alaska, and opportunities to break down those barriers and realize a thriving mariculture industry in the state. Identified areas in which actions focused on mariculture may help grow the industry include:

- Initial entry into the Alaska mariculture industry
    - Knowledge Transfer and Information Resources
    - Access to Capital
    - Site Selection, Availability, and Access
- Operating factors
    - Seed Security
    - Infrastructure
    - Environmental Factors
    - Workforce Development
    - Access to Markets and Market Development
    - Regulatory Framework
- Research and development

The Alaska Governor's Mariculture Task Force (MTF) advisory committees analyzed all main facets of the mariculture industry to develop recommendations and priorities for industry growth. The committee work is summarized in this chapter, with complete lists of committee recommendations and priorities included in Appendix A. In addition to a discussion of these elements, a summary of the most important factors limiting growth in the industry is provided at the end of this chapter. This summary analysis is based on MTF advisory committee recommendations and McDowell Group analysis.

Entry into the Alaska Mariculture Industry

Looking ahead, Alaska's mariculture industry may include a range of new entrants as production grows, from small and mid-sized independent businesses, to existing seafood processing companies, to industry participants from other areas, such as the Pacific Northwest, who may expand operations into Alaska. Each type of entrant may need to overcome a variety of barriers to operate in Alaska. Potential barriers include need for information on the biology, growing conditions, and factors impacting production of species; financing, site selection, and permitting; transportation and infrastructure; operating regulations; and markets.

Knowledge Transfer and Information Resources

Alaska mariculture industry participants, researchers, and policymakers have endeavored to bridge barriers to successful mariculture business operation in the state for decades. Such work has led to a wide-ranging, and still expanding, body of knowledge about species, operating models, and systems influencing mariculture operation outcomes. Such knowledge is extremely valuable for new entrants into the industry, particularly during business planning and permitting and loan application processes.

Information of interest to new entrants may include financing options, financial planning strategies, site selection parameters, gear and equipment choices and farm layout, logistics, growing and harvesting practices, labor requirements and training, marketing options, and other industry best practices. Consolidation of such information into documents accessible to new entrants and into training and professional development programs will assist with knowledge transfer important to growth of the industry.

ADVISORY COMMITTEE RECOMMENDATIONS

1. **Update/Develop Mariculture Industry Literature**
   Publicly available manuals that document existing information useful to starting a mariculture business in Alaska will provide a means for researchers and experienced industry professionals to share information with new entrants. Such "how-to" manuals may be species specific and some may focus on more industry-wide issues, such as the logistics of business operations in remote locations. In many cases this information has already been produced and will need to be updated.

2. **Continue and Expand Mariculture Professional and Business Development**
   An Alaska mariculture business development training program could help new producers apply for loans and develop business plans. The program, as currently envisioned, would include a set of training modules to develop skill sets and teach best practices to prospective operators and employees, and to enhance knowledge for those already in the industry. Such modules will build on current knowledge and materials that have been developed by mariculture specialists in Alaska. A demonstration farm may be an effective part of this effort.

A certificate or credential for completing such a program may be useful for farmers in attracting loans and securing leases, and when recruiting and training employees. As many mariculture operations in Alaska are located in remote areas, an online distance-learning component to the training will be necessary. Additionally, from a workforce development standpoint, such a program would support and train existing participants in the mariculture industry as well as act as a tool for recruitment of new entrants.

3. **Institute a Seafood Industry Outreach Program**
   Mariculture presents potential business diversification opportunities for Alaska seafood industry participants, including processors and hatcheries. While synergies between fishing and mariculture operations exist, information on compatible and conflicting operating conditions need to be better understood. Outreach to the seafood industry may help kindle interest in mariculture. Such outreach could be augmented by an informative map of mariculture sites and specifications as discussed below in the *Site Selection, Availability, and Access* section of this chapter.

4. **Establish Mariculture Business Planning Tools**
   A web-based tool, or series of tools, to improve on existing planning tools[84] could provide new entrants with information on the existing mariculture industry, such a number of farms, years of operation, species grown, farm size, region, etc. This tool could include capability for break-even analysis planning to explore the effects of farm scale, production intensity, scope, and location on financial viability of operations. A concurrent tool could provide risk management analysis to integrate consideration of production risk (survival, growth, etc.) and financial risk (input costs, price volatility, etc.).

Access to Capital

For some species, such as mussels, capital costs associated with specialized equipment may be prohibitively high for small growers. Others find it hard to secure loans for species with long grow-out periods. There is a need for realistic loan programs that offer consistent and stable funding sources suited to mariculture operations.

ADVISORY COMMITTEE RECOMMENDATIONS

1. **Gather and Distribute Investment Information**

   An information manual on securing investment may be helpful to new entrants into mariculture, as discussed above in the Knowledge Transfer section of this report. The manual could include basic statistics, information on the regulatory process, identification and evaluation of potential funding sources, and other relevant information.

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[84] https://seagrant.uaf.edu/bookstore/pubs/AN-19.html and http://aquaculture.seagrant.uaf.edu/.

2. **Analyze and Plan for Industry Capital Needs**
   Several public sources of funding currently assist mariculture operations. These include the State of Alaska Mariculture Revolving Loan Fund, Alaska Industrial Development and Export Authority (AIDEA) programs, and U.S. Department of Agriculture (USDA) loans.

   While the State revolving loan fund is currently not fully utilized, additional, and perhaps more flexible, sources of capital may also be needed as the industry grows. A first step toward understanding capital needs for a growing mariculture industry may be a closer analysis of existing programs to understand how they meet the needs of industry participants and potential entrants. Once industry needs are better understood, a combination of private and public sources of capital may be explored. Two options identified during the MTF advisory committee are private/public revolving loan funds and cooperative investment structures (see the following two recommendations for details).

3. **Establish Private/Public Revolving Loan Funds**
   A private/public revolving loan fund program to assist with mariculture business planning and start-up costs may provide revenue needed to help new entrants access the industry at a feasible scale. Such a fund could provide a flexible source of capital for use in combination with more conventional sources and help borrowers leverage additional funding from private sources.

4. **Develop Cooperative Investment Structures**
   Cooperative structures—that share benefits and risks and provide participants access to industry information and advancements, infrastructure, and markets that would otherwise be more difficult to acquire—could enhance individual mariculture operations and the overall industry. Identified during the MTF committee process as a potential means of building financial resiliency in an emerging Alaska mariculture industry, a cooperative structure may also help counter barriers involving economies of scales, equipment needs, and selling product.[85]

Site Selection, Availability, and Access

Availability and access to suitable sites for operation are key factors in the success of a mariculture industry. As discussed in Chapter 1, Alaska's geography and limited infrastructure present significant challenges to often remote mariculture operations, especially related to transportation, high energy costs, and access to labor and markets. Additionally, environmental conditions for product growth and harvest are important, and often site-specific, factors for operators to consider when choosing a location for operations.

[85] The Intertribal Agriculture Council may serve as a good source for development of a mariculture cooperative in Alaska. The Alaska Oyster Grower's Manual also addresses cooperatives.

When choosing a site, operators need accurate and accessible information about the site, as well as a means of analyzing site specifications relative to their operation. A clear and accessible method to secure permits and comply with regulations for the site is also necessary.

ADVISORY COMMITTEE RECOMMENDATIONS

Information Resources

1. **Develop an Interactive Information Map**

   The Alaska Department of Fish and Game provides resources for mariculture industry participants, including a handout on selecting a site for shellfish growers and maps with the location of existing operations. This information could be enhanced through development of an interactive map tool designed to inform site and species selection. Such a product, as currently proposed by Sea Grant, would provide information on ocean conditions, bathymetry, existing support infrastructure for processing and shipping, and other factors important to site selection. A comprehensive map of mariculture sites could also help identify research needs.

2. **Access to Data**

   Whether part of the interactive map described above, or separate, public access to an active list of environmental data currently collected at mariculture sites would be useful to mariculture industry participants and researchers. A lack of open access to environmental data hinders the ability of mariculture operators to plan, select appropriate sites, and problem-solve. DEC has been developing an open data exchange/viewing site since April 2016. If completion of this site is not feasible with DEC resources, industry may be able to establish an authorized industry-wide database or assist DEC with creating one that can provide this service.

3. **Expand Data Collection**

   Collection of physical and biological data that is currently not available may enhance site selection and mariculture operation success. Data necessary for site selection by species or production method of interest could include information to avoid areas with PSP, large wildlife populations, anadromous streams, higher freshwater influx, and other important factors for the industry. Such information could be collected by State personnel and by farmers and be included in online information and mapping tools as previously described in this section.

4. **Conduct Research on Biophysical Factors**

   Further research could help define and refine what data is especially important for mariculture operations. Oceanography studies of existing growing areas, in cooperation with the farmers, may help increase understanding of biophysical factors contributing to operations, such as shellfish growth rates and meat yields, as an example.

Statutes and Regulations

Aquatic farming is the only legal form of mariculture in Alaska. In addition, small scale research and ADFG projects are currently underway on stock restoration, rehabilitation, and enhancement for a number of species, including king crab and abalone. Legislation introduced and considered in the State legislature in 2017, though not yet passed, would allow for shellfish rehabilitation and enhancement. See Appendix A for a discussion of the constitutional, legal, and administrative framework for mariculture in Alaska.

Regulatory and legal hurdles create barriers for mariculture in a number of ways, as identified by the MTF advisory committees, and summarized below with recommendations for addressing the barriers.

1. **Support Commercial Shellfish Enhancement and Restoration and Continue Research**
   Mariculture enhancement and restoration projects, for species such as king crab and abalone, are currently in the research phase in Alaska as described in Chapter 1 of this report. Legislation that allows for research to progress to commercial application in the state could provide important opportunities for common property fisheries.

2. **Account for Varied Species Grow Out Periods in Regulation**
   In current Alaska regulation, farmers must demonstrate commercial viability by year five of a lease. As some species grow to marketable size after five years, amendment of this benchmark to reflect a realistic timeline for slower growing species would make such operations more feasible.

3. **Expand Possibilities for Importation of Seed from Outside of Alaska**
   Currently, seed importation from outside of Alaska is limited to only Pacific oysters from the Pacific Northwest and weathervane scallops produced from parents taken from SE Alaska and Yakutat areas. Amendments to State regulations prohibiting release of live fish could allow for seed important for other species.[86]

4. **Adopt Regulations to Allow for Use of Sterile Stock or Other Species that Will Not Reproduce**
   At this point, State regulations limit the distance from the donor stock acquisition location that progeny may be grown. Large minimum donor stock numbers to ensure genetic diversity in progeny are also required. Such genetic requirements limit wide distribution of indigenous organisms for farm stock.

   a) Adoption of regulation to clearly state that sterile stock, and species that do not occur or reproduce naturally within a significant distance of a farm growing area, are not subject to the ADF&G genetic policy would allow for use of these stocks.

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[86] The MTF Regulatory Issues Advisory Committee recommends following the weathervane scallop model.

b) At times, a lack of genetic stock structure data for a species forces precautionary restrictions on transport of indigenous organisms used as mariculture seed. If a timeline for action to gain information is required in regulation when such a situation occurs, such restrictions may at times be safely lifted.

5. **Amend Regulations to Assist with Start-Up Bonding, Insurance, and Lease Fees**
Bonding, insurance, and annual land use fees present a hurdle for mariculture operations, particularly for farms that are not yet at a stage to sell product.

a) A mechanism to offset lease costs could be tied into aquatic farm loan programs and provide start up financing for new farmers. An amended regulation to allow for deferring a portion of fees, or for a graduated increase in lease fees, could be instituted until a site is producing.

b) Maintenance of a consistent lease fee during a farm lease period, only changing it if necessary when the lease is renewed or transferred, would provide a more consistent business environment for operators.

c) Farmers with demonstrated training or experience, or new farmers that locate near an established farm, might be considered for a reduced bond amount since they will be lower risk.

d) Commercial Liability Insurance and Worker's Compensation Insurance requirements are expensive for mariculture operators. Legislation to create insurance coverage for commercial farmers or encourage broad insurance policies to be adopted by industry-sponsored groups or organizations that cover members could help provide a more cost-effective option.

Permitting and Fees

1. **Amend Aquaculture Permit Applications to Simplify and Allow for Operations Flexibility**
The current aquaculture permit application process is viewed as requiring excessive detail and speculative information in applications and plans. This issue, in turn, results in inflexibility for species and gear diversification during operations. A simplified application process that adheres to language in statute and regulation and requests only information with an identified purpose and need could ease this burden for operators and new applicants.

2. **Incorporate Allowances for Mariculture Training in Permit Applications**
One reason for the oversight requirements imposed upon mariculture permit applicants is the challenge of determining if a potential operator has the knowledge and/or experience to run a mariculture operation. Agency regulations could be amended to accept trainings that includes a standardized set of skills and knowledge, as qualification.

3. **Amend the Lease Fee Structure to Account for Surface Acreage**
   In regulation, mariculture farm lease size includes the entire foot print of the farm site, as well as anchors and scope of lines. Such a calculation method expands lease sizes, particularly for larger farms, which increases cost per surface acre farmed and ties up additional surface area not actually being farmed. Regulations that separate actively farmed lease acreage, such as surface water footprints, from on bottom acreage needed to secure infrastructure may improve this situation.

Mariculture Operating Factors

Operating costs and logistics, environmental factors, infrastructure, workforce development, access to markets, and regulations can all present challenges to mariculture operations. Though Alaska's mariculture industry is in its early stages of development, successful operations in the state provide valuable information to help break through some barriers and grow the industry. In addition, the MTF and others have gathered industry knowledge from around the world to help inform Alaska's efforts.

Seed Security

Many Alaska mariculture operations struggle with seed security and quality due to historical fluctuations in both availability and quality, limited sources for seed, and research and development needs.

Advisory Committee Recommendations

1. **Develop Alaska-Grown Seed Capacity for the Oyster Industry**
   Funding to develop capacity to set sufficient quantities of oyster seed to satisfy Alaska demand and to provide for sales outside of Alaska, with the primary goal of generating an in-state source of larvae, is an important step in oyster seed security for Alaska operators.

2. **Continue Research and Development of Seaweed Seed Production**
   Ongoing research in Alaska addresses seed production, best practices for obtaining parent plants for seed production, and strain selection.

3. **Develop a Source for Geoduck Seed**
   Continued development of a source for seed will be essential to development of this industry.

Infrastructure

ADVISORY COMMITTEE RECOMMENDATIONS

Location/Partnerships

1. **Explore Efficiencies in Location of Operations**
   The concepts of cluster farms and regional processing centers may provide methods to efficiently transport and process product.

2. **Explore Synergies with Existing Seafood Industry Infrastructure**
   Many aspects of the seafood industry, including equipment, knowledge, location, and skills, overlap with mariculture needs. As the seafood industry is well established in the state, there may be opportunities to share infrastructure for mariculture during the off-season for other seafood operations.

Nurseries

1. **Develop More Efficient and Low-Cost Oyster Nursery Options**
   Expansion of existing research and development efforts to establish methods and equipment to increase efficiencies in oyster nursery systems could help provide lower-cost options for mariculture operators.

Production Technology

1. **Publish and Disseminate Current Production Techniques and Technologies**
   Production technology specific to each mariculture species continues to be improved and refined. While further research and development needs continue, dissemination of current information and continuation of research on production technology are both important factors for new entrants and existing operators in the Alaska mariculture industry.

2. **Support Production Technology Research Priorities**
   Identified production technology research topics include:

   a) Strategies and best practices to reduce labor and time necessary to produce product.
   b) Improvements in production and processing methods to increase throughput.
   c) Value-added product forms, including freezing techniques to extend shelf life.
   d) Hatchery production of mussel seed.
   e) Predator control methods (see discussion below in Environmental Factors).

Environmental Factors

Environmental influences can significantly affect mariculture operations by impacting human health and/or growth conditions for products. Such impacts may translate to significant financial implications for operators.

ADVISORY COMMITTEE RECOMMENDATIONS

Shellfish Sanitation

Biotoxins can inflict significant economic consequences on Alaska mariculture industry participants. Producers must supply a consistent and reliable product to markets. Thus, market disruptions due to human health concerns are a critical issue for industry growth. Operators throughout Alaska have experienced closures due to the shellfish toxicity, with some customers discontinuing business with Alaska producers because of unexpected closures. Also, as the mariculture industry matures and expands to areas of the world with different sanitation standards, such as Europe, the list of biotoxins of concern may grow.

Alaska shellfish products must meet National Shellfish Sanitation Program requirements and Alaska must maintain membership in the Interstate Shellfish Sanitation Conference (ISSC). Membership in the ISSC allows shellfish dealers to ship product out of state and export to many countries. Toward this end, DEC classifies growing areas, issues permits, conducts inspections, investigates complaints, conducts outreach and training, and monitors bacteria and toxins in shellfish harvest areas and products. The DEC Food Safety and Sanitation program (FSS), the state's Shellfish Sanitation Authority, with support from the DEC Environmental Health Laboratory (EHL), establishes sanitation requirements for harvesters, dealers, and shucker/packers so that shellfish grown and harvested in Alaska.

1. **Ensure adequate resources for the Alaska Sanitation Authority.**

   Should the Alaska mariculture industry expand, resources constraints in Alaska's shellfish sanitation program would render the program incapable of meeting national requirements with existing staffing. Resources must be allocated to adequately support this keystone to Alaska's mariculture industry growth.

Biotoxin Management

According to DEC, industry-wide, biotoxins (including emerging biotoxins such as domoic acid) are an increasing issue. Operators have seen paralytic shellfish toxins in shellfish in areas that had no previous history of problems. In addition, domoic acid has closed entire fisheries in the Pacific Northwest and California, and has been detected in marine mammals in Alaska.

Unfortunately, limited resources prevent DEC from being able implement a robust statewide regulatory HAB monitoring program to provide early warning of toxic blooms as well as a routine surveillance program in shellfish meats to detect domoic acid. Alaska's biotoxin management plan relies on pre-harvest sampling that detects toxicity after a bloom has already occurred.

Paralytic Shellfish Poisoning (PSP)

PSP issues continue to cause concern in the Alaska shellfish industry. Testing for PSP is often slow and expensive, causing significant production delays as samples are sent to the DEC lab, located in Anchorage. Additionally, it is challenging for remote operators to transport water samples to the laboratory within required time and temperature constraints.

2. **Improve PSP Testing**

   While it is important to retain consumer confidence in testing results, new testing methods and sites approved by DEC as the State regulatory body may help remedy current logistical issues. Research on a new PSP field test in Sitka is particularly promising. Recommended improvements to the PSP testing situation include:

   a) Support certification of additional private labs and testing methods in the state to facilitate ease of transport, faster results, and more cost-effective testing.

   b) Support research into holding samples for depuration and certification of process.

   c) Identify appropriate regions to increase spatial extent of PSP testing (e.g. Kodiak Island) to address potential for underdeveloped opportunities for shellfish farms.

   d) Identify and support research to assess mechanism of PSP loading (cyst density) in mariculture species.

3. **Collect and Distribute Data on PSP in Alaska**

   Aside from testing improvements, a wider understanding of PSP occurrence and causation will assist mariculture operators. Such understanding may be accomplished through further data collection on where and when PSP occurs and research into causes. Also, establishment of a public platform to access Paralytic Shellfish Poisoning (PSP) data will provide wider understanding of this issue.

Vibrio Parahaemolyticus Bacteria

Alaskan oysters can host a form of bacteria which causes gastroenteritis, and in rare cases can be fatal. The bacteria can also be carried by marine organisms such as shrimp and crabs.

1. **Research and Communicate Vibrio Bacteria Findings**

Development of methods to monitor and mitigate Vibrio bacteria occurrences are important for human health and marketing. While methods are being developed, distribution of DEC's Vibrio plan for farmers may be useful.[87]

Other Genetic and Disease Issues

1. **Blue Mussel Research**
   Genetic and disease issues that prohibit/inhibit blue mussel growth to market size in Southeast Alaska need to be investigated.

2. **Fecal Coliform**
   Research and develop methods to mitigate harvest disruptions due to wild animal fecal coliform in remote areas will be useful to mariculture operators.

Predation

1. **Improve Predation Protection Techniques and Technologies**
   Natural predators, including otters, sea ducks, and sea stars prey on some forms of unprotected mariculture product. Physical protections and regular monitoring can be used to abate predation. However, predator protection technology could be improved and refined for situations specific to Alaska's marine environment.

Ocean Acidification

Research into the impacts of ocean acidification on shellfish spat and on ocean conditions is ongoing.[88]

1. **Monitor Ocean Conditions**
   Continuation or initiation of ocean condition monitoring in all Alaska coastal regions with feasible mariculture opportunities will provide more information about this issue and help understand impacts on mariculture.

Workforce Development

Workforce development efforts are needed for new operators as well as farm and hatchery workers for a variety of mariculture operation skills, including growing, harvesting, processing, marketing, and managing regulations and finances.

Remoteness, seasonality, physical demands, often low earning potential, and lack of resources for training and professional development present difficulties for mariculture operations in attracting and maintaining high-quality labor. An increase in the number and size of mariculture operations in Alaska will require

[87] http://dec.alaska.gov/eh/fss/seafood/Shellfish_Home.html.
[88] https://seagrant.uaf.edu/map/aquaculture/shellfish/techtraining/2016/ocean-acidification-foy.pdf.

development of a cohort of skilled owners and laborers who are available for work at these often-remote sites. In addition, to grow the industry, new operators must be attracted through raising awareness about mariculture careers, without compromising existing businesses. To develop a workforce with the skills and knowledge necessary to run mariculture operations, investment in training opportunities will be important. Such workforce development may be accomplished through the following recommendations.

ADVISORY COMMITTEE RECOMMENDATIONS

1. **Establish an Alaska Mariculture Specialist Position**
   A Mariculture Specialist position could function, as this position has in the past in Alaska, as a point person for industry training, research, recruitment, and support of new farmers in the state. The position, which could continue as a Sea Grant position, would require understanding needs of the industry and help direct industry-driven research to meet workforce objectives.

2. **Institute a Mariculture Workforce Development Training Program**
   Mariculture operators and hatchery workers in Alaska are not required to hold any consistent certification or training to operate or work at a business. However, training and professional development is a critical part of recruiting a quality workforce and ensuring self-employed farmers gain the most value from their business.

   Currently, there are limited opportunities for professional development and training in mariculture in Alaska. A training program, as described above in the Knowledge Transfer section of this chapter, could help grow and educate the mariculture workforce.

   Additionally, an intensive boot camp or an apprenticeship/mentorship/internship program could provide more in-depth understanding of the industry for potential participants and serve as a labor source for existing operations. The hands-on "boot camp" could also provide real world exposure to mariculture as a career through a partnership with Central Council of Tlingit and Haida Indian Tribes of Alaska, other tribal workforce programs, Alaska Sea Grant, growers, and others.

3. **Track and Evaluate Workforce Training Efforts**
   To improve and refine effectiveness of workforce development efforts, it will be important to track participation in training programs. Subsequent placement into mariculture-related positions and careers should also be tracked. Evaluation of programs by participants, mariculture industry owners and operators who hire trained employees, can also provide useful feedback.

4. **Raise Awareness about Mariculture Careers**
   Targeted industry career awareness efforts, including to high schools and universities, may be incorporated into mariculture public education efforts. Also, mariculture may be incorporated in STEM education. Efforts may focus on key populations, such as Alaskans used to weather the state's conditions, veterans, fishermen, and rural youth.

Access to Markets and Market Development

While Alaska's "wild" mystique, coupled with the image of pristine waters, provide an important marketing platform for tapping a market for high-quality Alaska products, consistent production and reliable delivery of a high-quality product are essential for sustained market development. Reliable and efficient distribution with competitive pricing will be the biggest challenges for Alaska's mariculture industry as it seeks to profitably expand into new and larger markets.

Market development will occur at wholesale and retail levels. Wholesale markets offer the potential to sell large volumes of product, reducing the unit cost of marketing, harvesting, testing, packaging, handling, and shipping. These wholesale markets require growers to settle for lower prices than direct sales to retail buyers.

Competitive pricing will depend on efficient, cost-effective, and reliable transportation of product to buyers. The cost of shipping can represent a significant constraint on the net unit price earned by operators. For Alaska producers, freight costs might represent one-third of the delivered cost in some out-of-state markets.

Investment in cooperative marketing programs may be required to build on Alaska's inherent brand value and generate the price premiums necessary to overcome higher costs of operating in Alaska and moving product to distant markets.

MARKET INTELLIGENCE

It is important to recognize that no single marketing strategy or market development plan can serve all the varied mariculture species or products potentially produced in Alaska. Nevertheless, further development of markets for Alaska's mariculture products must begin with a detailed understanding of potential markets, including:

- Current local, regional, domestic buyers/consumers and their specific needs
- Competing producers and competitive advantages/disadvantages
- Consumption and production trends
- Current prices and price trends
- Cost barriers associated with serving various markets

Gathering this kind of market intelligence is often beyond the resources of start-up operators. Cooperative or publicly-supported research can serve to inform new entrants and established operators alike.

ADVISORY COMMITTEE RECOMMENDATIONS

1. **Develop Downstream Market Support**
   Continued engagement with ASMI will be very important in evaluating new products/species marketing strategies to fit within the broader Alaska seafood market.

2. **Conduct Market and Product Research**
   Outlook and trends for product prices and demand for Alaskan mariculture products will help inform marketing plans.

Regulatory Framework

Many mariculture operators report the Alaska regulatory environment has improved over recent years, though the process can still be laborious and has reportedly significantly impacted profits margins for some operations, particularly small ones.

1. **Ensure Sufficient Bonding to Adequately Clean Up Abandoned Sites**
   State statutes require bonds to pay for potential defaulted lease fees on mariculture sites and cleanup for abandoned sites. The current minimum bond amount is not adequate surety.

   a) Legislation that would create a bond pool to be utilized for cleanup of abandoned site and pay default fees could, if adequately funded, provide adequate coverage for site clean-up and potentially reduce individual bond requirements.

   b) Create legal authority for agreements with other operators to clean up a defaulted site. Incentives for successful site restoration could include site security bonds from the defaulted site, and the site gear and inventory.

2. **Establish Representation for the Mariculture Industry**
   Currently, no entity is authorized to represent mariculture operators and the industry. An entity established through legislation could coordinate outreach within the industry and interaction with regulatory agencies and marketing bodies.

Research and Development

The MTF Research, Development, and Environmental Information Advisory Committee developed a list of near-term priorities. Many of these are discussed throughout this chapter. The committee's work is summarized in this section as well.

Current Species

OYSTERS, PACIFIC

1. **Explore oyster spawning in Alaska.**
   a) Develop capacity to spawn oysters in Alaska.
   b) Research and develop methods and ability to buffer incoming seawater with calcium aragonite (a form of $CaCO3$).
   c) Develop region specific broodstock breeding program.

2. **Research focused on oyster larvae setting and growth to nursery size in Alaska.**
    a) Develop capacity to set sufficient quantities of oyster seed to satisfy Alaska growers' demand and to provide for sales outside of Alaska.

    Alaska Sea Grant submitted a grant proposal to NOAA to support further development of oyster larvae setting capacity and best practices and researching b, c, d, and e below.

    b) Research efficacy of seed fluidizers.
    c) Research live feed vs. commercially available algae concentrate.
    d) Research and develop methods to combat colonial ciliates in the hatchery.
    e) Research comparison of differing sea water filtering systems.
    f) Compare growth rates and survival of over wintered oyster seed to farm market size vs. newly set oysters.
    g) Determine economic viability of shellfish hatcheries.

3. **Research focused on oyster nursery stage**
    a) Research and develop low cost nursery options for farmers.
    b) Research and develop methods and equipment to increase efficiencies of nursery systems.
    c) Develop and disseminate ability to raise smaller seed than is currently standard.

4. **Research focused on oyster farms**
    a) Develop improvements in production technology.
    b) Research and develop value added products aimed at export markets.

MUSSELS, BLUE

1. **Identify genetic and disease issues that prohibit/inhibit the growing of blue mussels to market size in Southeast Alaska.**

2. **Continue research on production technology.**
    a) Publish and disseminate current production techniques already researched in Alaska.
    b) Develop hatchery production of mussel seed.
    c) Develop predator control methods.

3. **Develop frozen product form and other value-added products and methods.**

4. **Develop improvements in production and processing methods to increase throughput.**

SEAWEED

1. **Research the population genetics of seaweeds of current and future commercial importance to better understand how seaweed farms might affect the natural populations.**

a) Priorities should be the population genetics of *Saccharina latissima* and *Alaria marginata* especially in the areas along the Gulf of Alaska.

2. **Determine the best practices for obtaining parent plants for seed production.**
   a) Research on collecting parent seed stock from natural populations.
   b) Research on using parent seed stock from maricultured outplants.
   c) ADF&G ongoing genetic research will partly address some of these issues.

3. **Research on strain selection.**
   a) Currently this can only be done as non-commercial research with limitations on outplanting select strains.

4. **Market and product research for sugar and ribbon kelp.**

5. **Research on hatchery optimization for large scale production of seeded string**

6. **Research needed on optimal timing of outplanting and harvest (at different sites in Alaska).**

7. **Research on the optimal conditions for growth (depth of outplant, nutrients, temperature, light, salinity, current).**

8. **Site selection research.**

9. **Oceanographic monitoring at existing growing sites, including nitrogen, phosphate, salinity, temperature, turbidity and currents.**

KING CRAB

While legislative changes are attempted to allow for commercial application of shellfish enhancement and restoration, research may proceed. In part, such research could occur through the priorities developed by the Alaska King Crab Research Rehabilitation and Biology Program.

1. **Refine rearing protocols for red and blue king crab.**
   a) Optimize rearing conditions and hatchery techniques to both improve survival rates and reduce production costs.
   b) Optimize rearing conditions and hatchery techniques to reduce behavioral, morphological, and physiological differences between hatchery and wild crabs to minimize potential competitive interactions with future outplanting.

2. **Understand the behavioral, morphological, and physiological differences between hatchery-reared and wild juvenile king crab and potential competitive interactions.**

a) Determine if morphological and behavioral differences are present between hatchery-reared and wild king crab juveniles and identify any potential competitive interactions or advantages.
b) Continue to compare bioenergetics of hatchery-reared and wild king crab juveniles to understand health and energy allocation and identify any potential competitive interactions or advantages.

3. **Determine optimal nursery habitats to maximize growth and survival of juvenile king crab in both the hatchery and once outplanted.**
   a) Identify the habitat requirements of juvenile king crab through their first year of life, including foraging, structural, and biological habitat attributes, as well as ontogenetic shifts, with continued laboratory and field studies.
   b) Develop best practices for transporting large numbers of juvenile king crab to remote sites without incurring high mortalities or harming their health.

4. **Assess likelihood of outplanting success based on biological and environmental interactions. Transport to and successfully maintain live juveniles in a shore-based facility in the Pribilof Islands.**
   a) Conduct tethering experiments in the Pribilof Islands to assess optimal habitats, crab size, relative predation and seasonal conditions for outplanting success.
   b) Quantify predation pressure at potential release sites in the Pribilof Islands and during experimental releases in Kodiak.
   c) Survey habitat, environment, and juvenile red and blue king crab density at potential release sites in the Pribilof Islands.
   d) Monitor predation, prey availability, and competitive interactions before and after controlled release events and evaluate predator control devices.

5. **Investigate fate of hatchery-produced juvenile king crab during release experiments.**
   a) Design and test in the lab, nursery structures that may provide an artificial habitat to reduce initial mortality upon release for hatchery-produced juvenile king crab in the marine environment.
   b) Continue to assess the behavior and marine survival of hatchery-produced juvenile king crab released into the wild at sites with appropriate habitat near Kodiak Island.
   c) Investigate larger controlled releases (~100,000 juveniles per site) to evaluate if crabs can be rehabilitated on an embayment scale in Kodiak.
   d) Assess the behavior and marine survival of hatchery-produced juvenile king crab released into the wild at sites with appropriate habitat near the Pribilof Islands.

6. **Project operational costs for producing juvenile red and blue king crab for enhancing depressed wild crab stocks, including hatchery, nursery, and stocking phases.**
   a) Continue to document hatchery operational costs from acquiring broodstock through production of C3 juveniles.

b) Develop and publish cost projections for the culture of C3 juveniles for different survival rates and levels of production.

c) Develop and publish projected costs of operating various stocking and nursery projects.

7. **Determine funding mechanisms and identify any potential changes in state law and regulations necessary to allow crab harvesters and/or coastal communities to conduct king crab rehabilitation activities.**
   a) Work with legislators and state agencies to research the potential legal framework for crab harvesters or coastal communities to form an association, such as a private-nonprofit corporation, to conduct rehabilitation activities.
   b) Work with legislators and state agencies to research the following: Who will pay? What changes to state law are necessary to provide for a voluntary assessment similar to the salmon rehabilitation program? Is it possible to have cost recovery harvests of enhanced king crab to offset costs? If so, what changes in statutes are necessary?
   c) Begin implementation of any necessary changes in law and policy.
   d) Legislation defining enhancement management processes was introduced but not passed in 2016 and 2017.

8. **Work with potential user groups to develop preliminary collaborations with community and/or industry groups interested in forming rehabilitation associations.**

New Species

The industry may benefit from identification of new species that present potential economic opportunity in Alaska based on previous studies or successful mariculture in other regions and encouragement of private and public research and development.

Industry-Wide Research and Development

In addition to research to address specific barriers or take advantage of opportunities in Alaska mariculture, there is also an identified need for industry-wide research to inform and grow the industry in the state.[89]

ENVIRONMENTAL DATA COLLECTION

Bivalves and Public Health Issues

1. Research and develop methods to monitor and mitigate Vibrio P. and harvest disruptions due to wild animal fecal coliform.

[89] Recommendations in this section come from both the Investment and Infrastructure and the Research Advisory Committees.

2. Develop low-cost PSP testing methods and a public platform to access Paralytic Shellfish Poisoning (PSP) data, including occurrence of PSP and causation in Alaskan waters.

3. Identify appropriate regions to increase spatial extent of PSP testing (e.g. Kodiak Island) to address potential for underdeveloped opportunities for shellfish farms.

Site selection and site-specific measurements

1. Develop prioritized physical and biological data collection necessary for site selection and operation by species or method of interest.

2. Conduct basic oceanography studies of existing growing areas in cooperation with farmers to understand biophysical factors contributing to shellfish growth rates and meat yields.

3. Identify and support research to assess mechanism of PSP loading in different species.

Regional Measurements

1. Develop prioritized physical and biological data collection necessary to provide regional and seasonal information to assist with farm or enhancement operations.
    a) Include an active list of data currently being monitored at each site and work with regional groups (e.g. AOOS) to host a database and website for public data access.

2. Develop or maintain carbonate chemistry monitoring in all coastal regions with feasible mariculture opportunities that may be affected by ocean acidification.

ECONOMIC DATA AND PARTNERSHIPS

1. **Develop mariculture business planning tools.**
   Development of a web-based break-even analysis and risk management planning tools can assist operators and those considering entry into the industry.

2. **Create regional and social impact models.**
   Development of regional and social impact models to highlight the role of mariculture operations in local and regional economies, including employment and income impacts, will help identify the importance of mariculture and to increase awareness of the industry.

3. **Identify management strategies.**
   A need for research to identify strategies for production and price risk has been identified.

4. **Explore horizontal and vertical integration.**
   Horizontal and vertical integration or coordination studies may illuminate these strategies as mechanisms for developing stronger markets, reducing input factor costs, and mitigating risk in the mariculture industry.

5. **Encourage industry partnerships.**
   Partnerships with state and local governments, industry, Alaska Native tribes, Community Development Quota organizations, NGOs, and communities can help leverage local expertise, knowledge, and funding sources for growing the mariculture industry. Following examples of other countries that have developed a successful mariculture industry, an appointed lead organization tasked with coordinating private, public, and governmental relationships can be critical in carrying industry strategies forward. Such strategies would likely include the comprehensive plan developed by the Mariculture Task Force.

6. **Continue to learn from mariculture industries around the world.**
   Alaska mariculture industry participant and policymaker tours to other areas around the world may help provide lessons learned from mariculture businesses to be applied in Alaska. Information sharing in the early stages of mariculture development between existing growers and potential investors may also play an important role in efficient growth of the industry.

EDUCATION TO PROMOTION OF REGIONAL SCALE OPPORTUNITIES

1. **Identify educational opportunities in coastal communities.**

2. **Identify and develop workshops on mariculture opportunities and provide training opportunities in multiple aspects of farms or enhancement operations.**

3. **Develop demonstration farms for seaweed and shellfish mariculture.**

4. **Identify mechanisms for technology transfer to interested entities.**

5. **Integrate mariculture into STEM education.**

Summary of Key Factors Limiting Alaska's Mariculture Industry

While all the actions in this chapter have been identified to help boost the mariculture industry in Alaska, several address critical impediments to growth that must be overcome for the industry to change significantly. These primary factors for industry growth are seed security, profitability, a favorable regulatory environment, market access, and availability of necessary data/information.

To most effectively address these factors, one or more entities dedicated to developing the industry could oversee these efforts, as well as other industry priorities as they arise. For example, in the past, this service was provided by a Mariculture Specialist position in Alaska Sea Grant's Marine Advisory faculty. As Sea Grant interacts with industry and public funding sources, reinstatement of funding for this position may make sense to continue as this advocate and organizing point for industry growth. Another example is the NOAA Aquaculture Coordinator position that is currently staffed in each region except for Alaska.

Seed Security

Investment in securing viable and consistent sources of quality seed, particularly for oysters, kelp, and geoducks is essential to industry growth. Hatchery production of blue mussel seed is also of longer term interest to the industry. As hatcheries are essential to development of seed security, short-term financial support for hatcheries to stabilize operations and provide seed security will be necessary to allow the industry to grow. Also, hatchery operations that focus on seed production for multiple species may be more efficient.

OYSTERS

Though oyster seed supply in Alaska is currently matching demand from in-state operators, security is still considered tenuous. Oysters (*Crassostrea gigas)* do not spawn in the wild in Alaska. Thus, most oyster seed is grown out in Alaska nurseries using larvae sourced from ADF&G-certified suppliers outside the state. Currently, only one certified out-of-state source provides larvae for Alaska, partly because of additional costs involved in meeting Alaska regulations for out-of-state suppliers. Seed availability continues to be a concern for farmers, as in 2017 when the only larvae supplier declined to sell to Alaska nurseries and an alternative supplier had to be found.

Establishment of a dependable source of larvae is a high priority for the industry. Systems to spawn and set oysters do exist in Alaska, home to three permitted shellfish hatcheries, where most current activity is either occurring on a test basis or in need of increased demand to make production feasible.[90] Once established, oyster seed may be grown out in in-state nurseries.[91]

Alaska Sea Grant has submitted a grant proposal to NOAA to support further development of oyster larvae setting capacity and best practices. This research may not only help establish oyster seed hatchery operations but also improve oyster seed availability and quality. Such research includes comparison of growth rates to farm market size and survival of over-wintered oyster seed versus newly set oysters. This issue affects hatcheries' ability to supply in-state seed prior to the Alaska growing season, which is much more restrictive for juvenile oysters than in lower 48.

KELP

ADF&G is employing a precautionary approach when managing seaweed resources. Until more is known on seaweed populations and genetics, kelp seeds are required to be propagated from parent plants within a 50-kilometer radius of a farm. This regulation presents a challenge for seed acquisition; as of right now,

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[90] OceansAlaska, Katchemak Shellfish Mariculture Association, and Alutiiq Pride Shellfish Hatchery (APSH). There is also with some reported interest in development of additional private setting facilities.
[91] Four Alaska nurseries permitted to sell seed are currently in operation.

no aquatic farm hatcheries or nurseries are permitted to create their own seed source for grow-out as a commercial product (like bivalves). Research is ongoing in Alaska on seed production, with two hatcheries currently developing seed for Alaska growers.[92]

Next steps in developing kelp seed sources and security include performing underlying data collection on kelp stocks and genetics to better inform regulatory decisions, researching strain selection, and developing hatchery and nursery infrastructure.

GEODUCK

While there is currently no source for geoduck seed in Alaska, by regulation seed must be produced inside Alaska, and quality of seed available in the state has reportedly varied, OceansAlaska is currently working with APSH to acquire seed and grow them to plantable size. Grant applications are in process for continued development of a source for seed, which will be essential to development of this industry.

Operating Costs/Profitability

Entry into the mariculture industry can be challenging due, in part, to start-up costs, including equipment, permitting, bonding, insurance, annual lease fees, and other investments. Financing for operations can be difficult to secure as well. Once an operation commences, profits may take years to be realized because of product grow out, and can be diminished by costs associated with logistical challenges in remote locations. Also, remote locations, requiring transportation and housing, and low pay can make it difficult to recruit labor, while alternative labor-saving equipment can be expensive.

Public investment is currently moving the industry toward a regulatory and financial environment more conducive to mariculture start-up and operation through investment in the Mariculture Task Force.

Currently identified regulatory changes and financial supports are discussed below. In addition to regulatory and financial investment, cooperative farming models may provide the shared risk and reward necessary to support small-scale operations.

REGULATORY COSTS

Public investment in regulatory changes can provide a more dependable operating environment for mariculture businesses. Lease fees for mariculture operations currently vary during the effective period of a lease, making it difficult to plan for this aspect of operating expenses. A regulation requiring maintenance of the same lease fee amount during the life of a lease would help. Also, how lease size is calculated can impact lease fees at the outset of permit issuance. This aspect of current regulation can also be amended to support mariculture operators.

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[92] University of Alaska Southeast and OceansAlaska.

Commercial liability and worker's compensation insurance are expensive for farmers. Legislation to create or encourage methods for commercial farmers, perhaps like the State Workers' Compensation Fishermen's Fund, to more readily obtain affordable insurance coverage will be of use to the industry.

MARICULTURE LOAN FUND

The State of Alaska Mariculture Loan Fund assists mariculture businesses with planning, construction, and operating costs, though only if other sources are not available. Continued investment in this loan fund (and potential additional federal investment in the fund), and assurance that loan requirements can be met, will provide a means for new businesses to obtain start-up costs they need until their business begins to profit. This loan fund requires experience or training in the industry and a business/marketing plan.

Further investment in professional development programs to provide training and experience and assist with business planning will help potential operators secure mariculture loans.[93] Such investment has the added benefit of training a potential workforce for the industry.

Regulatory Factors

Regulatory factors influence all mariculture operations, however some activities are currently not allowed for commercial purposes. Current Alaska statutes prohibit shellfish stock restoration, rehabilitation, or enhancement other than for research purposes. Legislation to change this prohibition will allow for enhancement efforts for many species, including king crab that may benefit farmers, commercial fisheries, and public users of the resource.

Some State of Alaska regulations impacting mariculture operations are not aligned with actual operating realities in mariculture businesses. Regulations that impose timelines, such as requirements for profitability within a given number of years, are misaligned with grow-out periods specific to each species that may preclude farmers from meeting time-sensitive regulatory requirements. Slower growing species such as the geoduck, are particularly impacted. Also, mariculture permits focus on shellfish farming. With the relatively new upsurge in seaweed farming in Alaska, seaweed-specific permits need to be developed to more effectively regulate this industry and to allow for reasonable time, cost, and reporting requirements for seaweed farming operations.

Access to Markets

To grow, the Alaska mariculture industry will need to move beyond in-state markets to achieve much greater market penetration outside of Alaska. For this to occur, markets will need to be identified and communicated with, the industry will need a dependable supply of product, affordable transportation options to reach markets, and capacity to produce product forms that can be transported to market.

[93] Training manuals and courses have been developed and offered regarding shellfish industry methods. These resources may be updated and amended for use in future professional development programs.

Additional investment in expansion of marketing programs for new species will be required to build on Alaska's inherent brand value and effective public-private partnership (the Alaska Seafood Marketing Institute). Shellfish farming in Alaska may demand price premiums to overcome higher costs of farming and transporting product in Alaska that will need to be overcome.

Product forms conducive to more affordable transport will be important developments in opening new markets and expanding existing ones. Dried kelp and kelp powders are one example. Also, development and market acceptance of frozen oysters specifically, a frozen whole oyster product form could reduce transportation costs.

Environmental and Economic Information

It is important operators have access to data that may impact planning and continued operation of their business. Such information includes environmental conditions, product growth factors, and food safety considerations (such as PSP). A public, open access database of environmental data specific to mariculture operating needs is in the process of development at the Alaska Department of Environmental Conservation. Completion of such a resource will provide for data collection as well for better management of environmental considerations. As this process has been underway since April 2016, it is possible that private investment may be needed to complete and operate this resource. Such information would also be useful in an interactive GIS mapping tool which layers relevant existing oceanographic, satellite, and economic and social data and allows users to analyze new sites for productivity, conflicting uses, and efficiency.

Chapter 3: Mariculture Economic Development Framework

The purpose of this chapter is to present an economic framework for how Alaska's mariculture industry might develop over the next 10 to 20 years, and beyond. Though rich in natural assets, the industry today in Alaska is small in scale relative to the state's commercial fisheries and seafood processing sectors, and relative to mariculture industries in other states and nations. Chapter 1 of this report described in detail Alaska's mariculture industry today, in terms of production scale and values. Chapter 2 described the many challenges facing the industry, and how those challenges might be addressed. This chapter builds on that information to lay out development scenarios that illustrate how the industry might grow from its current $1 million annual output to $100 million in 20 years, and over $500 million in 50 years.

Building the Mariculture Economic Development Framework

The MTF has articulated three possible high-level investment approaches to support development of the Alaska mariculture industry:

- Limited government involvement: attraction of private business
- Public-private partnership
- Significant public investment initially, followed by private investment

With these three approaches in mind, McDowell Group constructed a mariculture industry development framework through a sequential process that began with identifying a reasonable long range (20 year) development goal for the product categories with greatest development potential in Alaska. The framework includes farming and enhancement components. Species currently in production or with active investment in product and market development are included in this 20-year horizon, as they are the product categories most likely to realize significant growth in the next two decades. These species are oysters, mussels, geoduck, kelp, king crab, and sea cucumbers. While other species are under consideration for development in the Alaska mariculture industry, potential for meaningful production is more long-term and does not factor into development goals for this analysis.

Twenty-year goals identified in this analysis are each linked to a benchmark level of production. These benchmarks are informed by production attained in other regions outside of Alaska with longer histories and more thoroughly developed mariculture sectors. For each goal, the framework identifies necessary intermediate production milestones at five and ten years.

The framework provides the following metrics at five, ten and 20 years into the future:

- Production volume, value, and farm inventory for oysters, mussels, geoduck, and kelp
- Hatchery production and value for oysters, geoduck, and king crab

- Total mariculture industry employment, labor income, and output, including multiplier effects

A variety of assumptions about prices and price trends, survival rates, economic impact multipliers, and other factors support the framework. Detailed information about these assumptions are included in the following descriptions of each component of the model.

Oyster Farming

An annual average 950,000 oysters were produced in Alaska between 1992 and 2015, ranging from a low of 672,000 in 2001 to a high of 1.33 million in 2005. In 2015, 1.17 million oysters were sold at a farm-gate value of approximately $800,000. The preliminary estimate of the 2016 harvest is 1.32 million oysters.

A number of indicators, including farm size and inventory, and oyster seed inventory, suggest oyster production is set to increase substantially in Alaska in the near future. Oyster farm permit applications show an increase in farm size. Permit applications in 2017 include nine new entrants into oyster farming, three for farms over 100 acres and another four in the 12 to 24-acre size category. Additionally, oyster farm inventory and seed inventory are increasing. Farm inventory in 2015 was 22 percent above 2013, increasing to slightly more than 15.2 million oysters. Oyster seed sales (number sold) from hatcheries and nurseries reached a high of 9.5 million in 2015, an increase of 42 percent from 2014. The previous high was 7.1 million in 2005.

Oyster Production Benchmark Goals

Washington state's 2013 annual production of 8.8 million pounds of Pacific oysters valued at $34.8 million is used to guide establishment of a 20-year future production goal for Alaska. Washington also produced approximately 500,000 pounds of Eastern and Kumamoto oysters with total value of $6.5 million in 2013.[94] That production is not considered in establishing an Alaska goal. Another point of reference is British Columbia's Pacific oyster production, which in 2015 totaled 14.5 million pounds valued at C$14.4 million.[95] Washington and B.C. famers sell a mix of shucked and in-shell products.

Alaska oyster production 20-year revenue goal: $30 million in total gross farm-gate revenue. Intermediate goals include $3 million by year 5 and $7.5 million by year 10.

Oyster Farm Economic Framework Inputs and Assumptions

PRICES

In 2015, the average farm-gate value of Alaska oyster sales was $9.84 per dozen.[96]Based on total 2015 production of 1,165,518 oysters with total farmgate value of $975,945, the implied price is $8.21 per dozen,

[94] https://devseagrant.s.uw.edu/wordpress/wp-content/uploads/Shellfish-Aquaculture-Washington-State.pdf
[95] http://www.dfo-mpo.gc.ca/stats/aqua/aqua15-eng.htm
[96] ADF&G.

however production volume may include unsold inventory.[97][98] For purposes of estimating production volumes necessary to achieve future sales goals, average oyster prices are held constant in this framework at $8.00 per dozen through the outlook period (in real, un-inflation adjusted dollars). Some departure from this price level could reasonably be expected, resulting from a variety of compounding or offsetting forces. The oyster farm economic model supports price adjustments at the five, 10, and 20-year outlook points.

Marketing a steadily increasing volume of production may require development and sale of lower-margin products with longer shelf-lives, such as frozen on the half shell, refrigerated shucked, or canned products. Increasing production volume might also result in greater efficiency and lower per unit production costs. Finally, increased production could result in increased competition among farmers and result in lower prices as farmers attempt to gain market share.

Average prices in the Washington oyster farming industries provides a point of reference. In 2013, the average price of Washington oysters was $10.70 per dozen.

INVENTORY

To calculate oyster farm inventory necessary to support production at targeted levels, an inventory-to-annual production ratio of 3, with 70 percent survival, was used. This means, for example that annual production of 5 million oysters will require an inventory of approximately 31 million oysters, distributed across various age classes. Inventory includes oysters held in nurseries and farms.

Table 31. Alaska Oyster Production Goals

	Baseline	Year 5	Year 10	Year 20
Farm Inventory (# of oysters)	15,200,000	19,286,000	48,214,000	192,857,000
Annual Production (# of oysters)	1,165,518	4,500,000	11,250,000	45,000,000
Annual Revenue	$796,945	$3,000,000	$7,500,000	$30,000,000

Oyster Hatchery Production

Seed security is seen as an essential ingredient in the growth and sustainability of oyster production in the state. However, Alaska's oyster hatchery industry is in early stages of development. In 2015 all Pacific oyster seedstock (eyed larvae and smaller juvenile seed) came from outside the state, including 104 million eyed larvae and 8.9 million juveniles. Hatchery and nursery seedstock sales totaled $266,669 in 2015. Hatchery seedstock prices averaged $11.82 per thousand and nursery prices averaged $31.94 per thousand.

In this analysis, the conceptual development goal modeled for oyster hatchery production focuses on establishment of sufficient in-state propagation and seed supplies to fully supply the Alaska oyster farming industry as it grows over the next 20 years. Hatchery production for out-of-state seed sales is also a significant growth opportunity for Alaska, with strong demand resulting from potential ocean acidity-

[97] 2015 Annual Aquatic Farm Status Report, Fishery Management Report No. 16-23. Alaska Department of Fish and Game, June 2016.
[98] The 2015 Annual Aquatic Farm Status Report notes an average oyster price of $9.84 per dozen.

related constraints on West Coast hatchery production. In this economic model, larvae and seed production for the out-of-state market represents the majority of Alaska production and revenue. While total revenue related to sale of Alaska-grown larvae and juvenile seed is small relative to total farmgate sales of market-size oysters, it may represent an essential component is sustaining those farmgate revenues.

The initial larvae supply, then seed supply, necessary to support an industry with annual production of 11 million oysters (the 10-year goal) and 45 million oysters (20-year goal) is a function of survival rates. The year 5 goal of 10 million seed 4-6 mm for in-state farms and 20 million seed 3-4 mm for out-of-state farms are based on seed sales projections outlined in the OceansAlaska 2015 Commercial Shellfish Hatchery Business Plan.[99]

Estimates of larvae and juvenile seed production needs and annual revenue are based on:

- Oyster survival rate, set to 4 mm: 60%[100]
- Oyster survival rate, 4 mm to harvest: 70%[101]
- Eyed oyster larvae price, $300/million[102]
- 3-4 mm oyster seed price, $10.50/1,000[103]
- 4-6 mm oyster seed price, $14.00/1,000

Table 32. Alaska Oyster Hatchery Production Goals

	Year 5		Year 10		Year 20	
	Annual Production	Annual Revenue	Annual Production	Annual Revenue	Annual Production	Annual Revenue
Larvae	R&D	R&D	80,357,000	$24,000	321,429,000	$96,000
Seed Production (4-6 mm, in-state buyers)	10,000,000	$140,000	16,071,000	$225,000	64,286,000	$900,000
Seed Production (3-4 mm, out-of-state buyers)	20,000,000	$210,000	32,143,000	$338,000	128,571,000	$1,350,000

Geoduck Farming

In 2017, 19 aquatic farms are permitted for geoducks. Two hatcheries are permitted to produce geoduck seed and two geoduck nurseries are also in operation. No new permit applications for geoduck operations occurred in the first half of 2017. As less than three farms have produced and sold geoduck during a year, confidentiality restriction preclude public release of production and sales data. Though the current volume of harvestable geoducks is unknown, statewide geoduck inventory data provides insight into the value and

99 OceansAlaska Marine Science Center Commercial Shellfish Hatchery Business Plan, September 14, 2015.
100 Source: FOA Technical Fisheries Paper 471, Hatchery Culture of Bivalves, A practical manual, 2004. Notes range of 50% to 70%.
101 McDowell Group estimate.
102 McDowell Group estimate.
103 Seed prices are based on OceansAlaska posted prices as of July 2017. https://oceansalaska.org/inventory-stock-availability/

size of the current industry. Geoduck farm inventory totaled 911,000 in 2015, down from the 2014 inventory of 969,000 though up from the 2010 to 2014 average of 852,000.

If total 2015 inventory were harvestable and weighed an average of 1.5 pounds, the inventory would total about 1.4 million pounds. At a price of $5 per pound, this inventory would have a total value of approximately $6.8 million. This estimated value could be significantly higher or lower depending on clam size at harvest and prevailing market prices at the time of sale. Inventory will reach harvestable size over a period of years for these slow growing clams. Farmers also have the option of waiting to harvest until market prices are favorable.

Washington state provides a benchmark for establishing a long-range Alaska geoduck production goal. Washington accounted for about 90 percent of global farmed production in 2013, when the state produced 1.6 million pounds of geoduck valued at $24.5 million (about $15 per pound).[104] Washington also has a wild geoduck fishery, which produces 4 to 5 million pounds annually with an annual ex-vessel value of $40 to $50 million.[105]

Based on 2013 data, geoduck farming in Washington produces total revenue equal to about two-thirds of total Washington oyster farming revenue. Many factors will dictate the pace at which geoduck farming grows in Alaska, though production in Washington and geoduck's relative importance (in terms of revenue) in that state's shellfish farming industry can guide long-term goal-setting for Alaska. Another guide for the Alaska geoduck industry will be availability of seed.

Alaska geoduck production 20-year revenue goal: $10 million in total gross farm-gate revenue. Intermediate goals include $1 million by year 5 and $2.5 million by year 10.

Geoduck Farming Economic Framework Inputs and Assumptions

PRICES

Over the past decade geoduck prices for Alaska's wild harvest have varied widely, ranging from a high of $10.31 in 2011-2012 and a low of $3.12 in 2007-2008. Average price per pound for the ten-year period was $5.90. The average price for the 2015-2016 season was $5.28 per pound. The latest available price data for Alaska's wild geoduck fishery indicates a price of about $9 per pound, for a harvest of 500,000 pounds valued at $4.5 million.[106] The most recent available data for Washington farmed geoduck is for 2013, when prices averaged approximately $15 per pound.[107] In Washington, farmed geoduck prices in 2013 were about 50 percent higher than wild-harvest prices. In this economic framework, a price of $9 per pound is used,

[104] Monterey Bay Seafood Watch, Farmed Pacific Geoduck, Dec. 5, 2016.
[105] http://wdfw.wa.gov/fishing/commercial/geoduck/geoduck_historic_landings_value_table.pdf
[106] https://www.cfec.state.ak.us/gpbycen/2011/00_ALL.htm
[107] https://devseagrant.s.uw.edu/wordpress/wp-content/uploads/Shellfish-Aquaculture-Washington-State.pdf

and held constant at that level. Conversions from gross revenue to number of geoduck harvested and in inventory are based on 2.25 pounds per geoduck.[108]

INVENTORY

Calculation of geoduck farm inventory necessary to support production at targeted year 10 and year 20 levels are based on an inventory-to-annual production ratio of 8, with a 25 percent survival. That survival rate is based on 70 percent losses from all causes over an eight-year grow-out period and 85 percent harvest efficiency, resulting in 25 percent recovery at harvest stage.[109]

Table 33. Alaska Geoduck Production Goals

	Baseline	Year 5	Year 10	Year 20
Farm Inventory (# of geoduck)	910,000	289,000	247,000	988,000
Annual Production (# of geoduck)	0	50,000	125,000	500,000
Annual Revenue	0	$1,000,000	$2,500,00	$10,000,000

Geoduck Hatchery Production

Similar to oyster hatchery production goals, the conceptual development goal modeled in this analysis for geoduck hatchery production is to produce enough in-state seed supplies to fully supply the Alaska geoduck farming industry as it grows over the next 20 years towards the goals described in the table above. This is a particularly important goal, as Alaska geoduck farmers can only use Alaska-produced seed.

The year 5 goal, described in the following table, of 500,000 seed sold at $0.20 each, and generating $100,000 in annual revenue, is equal to 50 percent of the seed sales projections described in the OceansAlaska 2015 Commercial Shellfish Hatchery Business Plan.[110] Year 10 and Year 20 hatchery production goals are based on amounts needed to maintain farm production goals during those years, factoring in a 25 percent survival rate.

The OceansAlaska business plan notes potential for geoduck seed sales to out-of-state farmers. If hatchery production of geoduck seed is successful and sufficient to meet the needs of a growing in-state farm industry, it is likely that outside markets will develop over time. There is also potential for developing seed for wild stock and enhancement and rehabilitation. Hatchery seed production for those purposes are not considered in this economic framework.

Table 34. Alaska Geoduck Hatchery Production Goals

	Year 5		Year 10		Year 20	
	Annual Production	Annual Revenue	Annual Production	Annual Revenue	Annual Production	Annual Revenue
Seed Production (4 mm)	500,000	$100,000	500,000	$100,000	2,000,000	$400,000

[108] The total 2006 to 2015 harvest of wild stock geoduck on 15 permitted subtidal farms was 90,170, calculated to be the equivalent of 40,056 geoduck.

[109] Geoduck Aquaculture, Estimated Costs and Returns for Subtidal Culture in BC, June 2005.

[110] OceansAlaska Marine Science Center Commercial Shellfish Hatchery Business Plan, September 14, 2015.

Mussel Farming

Sales volume of Alaska mussels averaged 2,677 pounds between 1994 and 2013, but increased sharply in 2014 to 9,594 pounds and again in 2015 to 16,688 pounds. Most sales were of product that naturally set on oyster floats or other equipment, rather than being intentionally grown. In 2015, only four farms were permitted to produce mussels, down from five in 2013 and 2014.

Revenues from mussel sales increased to $43,112 in 2014 and $70,800 in 2015. While harvest numbers have increased, mussel production is still a small part of the Alaska shellfish mariculture industry and it is not clear that further investment in mussel farming will be occurring in the near future. No new applications for mussels occurred in 2017. However, with healthy natural sets and quick grow-out (two years of less), mussel farming can reasonably be expected to play a role in the long-term development of Alaska's shellfish aquaculture industry.

In Washington state and British Columbia, mussels account for about 25 percent of total farmed shellfish production value. Washington farms produced 3.7 million pounds of mussels in 2013, with a total value of $7.9 million. B.C. farm production totaled 2.8 million pounds in 2015, with a total value of C$6.5 million.

Using 25 percent of total shellfish farm production value as a goal for Alaska, at the 20-year mark the mussel farming industry in the state would be $7.5 million in total gross revenue.

Alaska mussel production 20-year revenue goal: $7.5 million in total gross farm-gate revenue. Intermediate goals include $750,000 by year 5 and $1.9 million by year 10.

Mussel Farming Economic Framework Inputs and Assumptions

PRICE

Production, in terms of pounds harvested, are based on an average price of $4.25 per pound. That is the price earned in Alaska in 2015, when 16,688 pounds were harvested and sold for $70,800.[111]

INVENTORY

Alaska's recorded historical mussel inventory has had little connection with actual mussel sales, for a number of reasons. Natural set and rapid grow-out have resulted in uncertain inventory and somewhat opportunistic harvest. Looking ahead, more purposeful seeding and inventory control may be required to establish a consistent and growing presence in the market.

Estimates of seeding requirements to support predetermined harvest levels are not available. For purposes of this study it is assumed that a known inventory of three times annual production will be required. This

[111] 2015 Annual Aquatic Farm Status Report, Fishery Management Report No. 16-23. Alaska Department of Fish and Game, June 2016.

would account for an 18 to 24 month grow-out period and loss rate of 50 percent, due to predation and damage during harvest and other handling.

Table 35. Alaska Mussel Production Goals

	Baseline	Year 5	Year 10	Year 20
Farm Inventory (lbs. of mussels)	--	706,000	1,765,000	7,059,000
Annual Production (lbs. of mussels)	16,688	176,000	441,000	1,765,000
Annual Revenue	$70,800	$750,000	$1,875,000	$7,500,000

Seaweed Farming

As seaweed farming is just developing in Alaska, no historical value and production volume data exist. In 2017, 14 aquatic farms in Alaska were permitted to grow kelp, though only three actively cultured plants. Six additional kelp farming permit applications were submitted in 2017, indicating that interest in farming kelp is increasing in the state. Assuming regulations evolve to better accommodate kelp farming, industry representatives have identified potential for high volume production in Alaska.

As results from the first material harvest in Alaska are not yet available, future production and value for kelp farming is challenging to predict. Few benchmarks exist to guide goal setting for Alaska's nascent seaweed farming industry. Globally, seaweed production is a diverse industry with many farmed species and product forms. The U.S. imported 40,000 tons of various seaweed products in 2016, worth $203 million. This included 8,560 metric tons of products fit for human consumption, with a total value of $56 million.

The seaweed production goals outlined below are based on assumptions about acreage under cultivation and intensity of per-acre production.

Alaska seaweed production 20-year farm-gate revenue goal: $9.6 million in total gross farm-gate revenue. Intermediate goals include $600,000 by year 5 and $2.4 million by year 10. 20-year first wholesale value of dried product: $15.7 million, with intermediate goals of $1 million by year 5 and $3.9 million by year 10.

Seaweed Farming Economic Framework Inputs and Assumptions

Currently, about 60 acres in Alaska are permitted for seaweed cultivation. Production goals are based on the assumptions that:

- By year 5, 150 acres will be under cultivation, producing 8,000 pounds per acre.
- By year 10, 300 acres will be under cultivation, producing 16,000 pounds per acre.
- By year 20, 600 acres will be under cultivation, producing 32,000 pounds per acre.

These per acre production rates are consistent with those outlined in chapter 1 of this report. Estimates of dry-weight production assume that 1 pound of wet kelp converts to 0.15 pounds of dried product.

PRICE

Sugar kelp and ribbon kelp production are of most interest to Alaska farmers. There is not yet an established farm-gate price for wet kelp harvested in Alaska, or for dried product that can be produced from that harvest. As noted in chapter 1, sugar kelp prices are reported to range from $0.25 to $1.00 per pound, wet. Prices used to calculate annual revenue within this economic framework include:

- $0.50 per pound wet, farm-gate
- $5.45 per pound dry, first wholesale

Table 36. Alaska Kelp/Seaweed Production Goals

	Year 5	Year 10	Year 20
Annual Production (lbs. of wet)	1,200,000	4,800,000	19,200,000
Annual Production (lbs. of dried)	180,000	720,000	2,880,000
Annual Revenue (wet, farm-gate)	$600,000	$2,400,000	$9,600,000
Annual Revenue (dried, first wholesale value)	$981,000	$3,924,000	$15,696,000

Other Mariculture and Enhancement Activities

Red King Crab

As noted in chapter 1, development of king crab hatcheries to support commercial production is in early R&D stages. While the outcome of R&D cannot be clearly foreseen, work to date is promising, and assuming necessary funding is available, it is reasonable to include hatchery-supported commercial king crab harvest in a long-term mariculture economic framework, though enhancement is not yet legal in Alaska.

Given the early-stage status of hatchery R&D, and king crab's long growth cycles (7 to 8 years to maturity), it will be at least ten years before revenue might be generated from commercial harvest. This economic framework assumes that by year 10 commercial harvests will have not yet commenced, but that by year 20 the harvest will have reached 500,000 pounds annually with a value of $5 million. Assumptions underlying this estimate include:

- Juvenile survival rate: 8 percent
- Exploitation (harvest) rate: 15 percent
- Average weight (per crab): 6.5 pounds
- Ex-vessel price of $10 per pound

Table 37. Alaska King Crab Hatchery Production Goals

	Year 5	Year 10	Year 20
Juveniles produced annually	500,000	2,000,000	4,000,000
Survivors at maturity*	-	-	1,160,000
Number harvested	-	-	87,000
Pounds harvested	-	-	565,500

*Based on total juveniles produced between year 5 and year 13.

Table 38. King Crab Hatchery Production Goals

	Year 5		Year 10		Year 20	
	Annual Production	Annual Revenue	Annual Production	Annual Revenue	Annual Production	Annual Revenue
King Crab Catch (lbs.)	R&D	R&D	R&D	R&D	565,000	$5,650,000

Sea Cucumber

Partially in response to wild sea cucumber harvest declines in Alaska due to predation by sea otters, sea cucumber mariculture is in the research and development phase. Anticipated research in the coming years in Alaska will investigate the feasibility of sea cucumber farming in the state, including market size, estimated demand and revenue potential for farm-raised sea cucumbers, estimated annual operating costs of production, and required capital investment needed for mariculture facility construction.

Until this more detailed investigation occurs, production goals may be set to maintain and grow revenue currently gained from wild harvests. Since 2011, the largest ex-vessel value for the Southeast Alaska sea cucumber industry occurred during the 2013/14 season, at $6.2 million. Taking into account small harvests elsewhere in Alaska, it is assumed annual revenue at $6.5 million represents a strong sea cucumber harvest year.

While it is likely sea cucumber mariculture will still be in the R&D phase in 5 years, 10-year revenue goals may supplement the wild catch by half, with a 20-year goal that produces enough sea cucumbers to encompass the entirety of the $6.5 million in revenue. At an average $3.50 per lb., farmed sea cucumber production would need to reach 928,500 pounds at Year 10 and 1.86 million lbs. at Year 20 to reach these goals.

Table 39. Sea Cucumber Production Goals

	Year 5		Year 10		Year 20	
	Annual Production	Annual Revenue	Annual Production	Annual Revenue	Annual Production	Annual Revenue
Sea Cucumber Production (lbs.)	R&D	R&D	928,500 lbs.	$3,250,000	1,857,000 lbs.	$6,500,000

Summary

The economic framework outlined in this chapter produces a year 20 mariculture industry gross revenue total of just over $75 million. Oyster sales account for about 40 percent of that total, seaweed 21 percent, geoduck 13 percent, and mussels 10 percent. Hatchery-produced king crab and sea cucumber account for the remainder of mariculture industry revenue, at 7 and 9 percent respectively.

Table 40. Alaska Mariculture Farm Production and Revenue Goals

	Year 5		Year 10		Year 20	
	Annual Production	Annual Revenue	Annual Production	Annual Revenue	Annual Production	Annual Revenue
Oysters (count)	4,500,000	$3,000,000	11,250,000	$7,500,000	45,000,000	$30,000,000
Mussels (lbs.)	176,000	$750,000	441,000	$1,875,000	1,765,000	$7,500,000
Geoduck (count)	50,000	$1,000,000	125,000	$2,500,000	500,000	$10,000,000
Kelp/seaweed (lbs., wet)*	1,200,000	$600,000	4,800,000	$2,400,000	19,200,000	$9,600,000
Kelp/seaweed value-added (lbs., dried)*	180,000	$381,000	720,000	$1,524,000	2,880,000	$6,096,000
King crab (lbs.)	-	-	-	-	565,000	$5,650,000
Sea cucumber (lbs.)	-	-	928,500	$3,250,000	1,857,000	$6,500,000
Revenue Totals		**$5,731,000**		**$19,050,000**		**$75,350,000**

*Note: Total first wholesale value of kelp/seaweed production is $15.7 million in year 20, which includes $9.6 million in farm-gate value and $6.1 million in value added in the drying process.

The value in developing this type of economic framework results from identifying production and revenue milestones along the path to reaching long-term industry goals. The economic framework cannot account for challenges the industry may have in reaching these goals, in terms of available investment capital, market development, trained labor supply, and other potential barriers to industry growth.

Growth from the current one-million-dollar industry to an almost $6 million industry within five years is an ambitious challenge and may be the most difficult phase along the trajectory toward a $75 million industry. To achieve growth of any significant scale, expansion into new markets will be required, along with new product development.

The Excel-based economic framework supports adjustments to key assumptions as new information becomes available, such as survival rates and farm-gate prices underlying the production and revenue targets outlined in the framework. Long-term price trends in particular are uncertain and would be an important subject for additional research related to this framework. Such additional research will assist with developing a greater understanding of where Alaska's opportunity might be greatest.

Economic Impact of Mariculture Development

The objective of developing Alaska's largely untapped opportunity in mariculture is to create economic activity in Alaska, including jobs and income for Alaskans. The economic framework developed for this project includes analysis of the employment, labor income, and output impacts associated with the 5, 10, and 20-year mariculture industry production and revenue goals. Projections for 30, 40, and 50 years are also calculated. Economic impact modeling is based on industry-wide multipliers. While there are differences in the economic impact of oyster farming versus kelp faming, for example (because of different labor requirements and purchasing patterns), and differences in small-scale versus large-scale operations, there is enough commonality to use a single set of multipliers to measure direct, indirect, and induced economic effects.

ECONOMIC IMPACT DEFINITIONS

Economic impacts are generally measured in terms of employment, labor income, and output, and are typically defined as either direct, indirect, or induced:

- **Direct impacts**: jobs on the farm and labor income earned by workers holding those jobs. Owners and their income are included in direct impacts. Direct output is equal to total gross farm sales.
- **Indirect impacts**: jobs and labor income generated as a result of farmers purchasing goods and services in support of their farming operations.
- **Induced impacts**: jobs and labor income generated as a result of farm workers and owners spending their earnings in support of their households.

ECONOMIC IMPACT MULTIPLIERS

The economic impact multipliers used in this analysis are McDowell Group estimates based on review of employment and wage practices on existing farms, analysis of mariculture's multiplier effects in other states, review of economic impacts models such as IMPLAN, and the firm's many years of studying local and regional economies in Alaska. The following multipliers were used to estimate total direct, indirect and induced employment, labor income, and output:

- Direct jobs per million in gross sales: 15
- Direct labor income: 0.5 x total gross sales
- Total employment (direct, indirect and induced) per million in gross sales: 20
- Total labor income: 0.65 x total gross sales
- Total output: 1.4 x total gross sales

Table 41. Economic Impact of Mariculture Development in Alaska

	Baseline	Year 5	Year 10	Year 20	Year 30	Year 40	Year 50
Gross Revenue	$1,000,000	$5,731,000	$19,049,000	$75,351,000	$195,441,000	$318,353,000	$407,519,000
Total Direct Employment		86	286	1,100	2,900	4,800	6,100
Total Direct Labor Income		$2,865,500	$9,524,500	$37,676,000	$97,721,000	$159,176,000	$203,759,000
Direct, Indirect, and Induced Employment		115	381	1,500	3,900	6,400	8,200
Direct, Indirect, and Induced Labor Income		$3,725,000	$12,382,000	$48,978,000	$127,037,000	$206,929,000	$264,887,000
Direct, Indirect, and Induced Output		$8,023,000	$26,669,000	$105,491,000	$273,618,000	$445,694,000	$570,526,000

This analysis indicates that a $75 million mariculture industry (as described in Year 20 in the table above) would generate 1,100 direct jobs and 1,500 total jobs. Annual labor income would include approximately $38 million in direct wages and a total of $49 million in direct, indirect, and induced labor income. Output, including all direct, indirect and induced effects, would total just over $100 million. Year 30 output $274 million, Year 40 $446 million, and Year 50 $571 million.

Washington state's shellfish mariculture industry generated approximately 1,900 direct jobs and $37 million in wages in 2010 (the most recent available estimate) from $100 million in gross sales. The total impact, including multiplier effects, was measured at 2,710 jobs and $40 million in labor income.[112] California's $12 million shellfish mariculture industry accounted for 20 direct jobs and 280 total jobs, along with $5.4 million industry wages and $10 million in total wages.

[112] The Economic Impact of Shellfish Aquaculture in Washington, Oregon and California, Pacific Shellfish Institute, April 2013.

Conclusions and Recommendations

The purpose of creating a mariculture industry economic framework is to have a tool to "analyze economic costs and benefits as well as the speed and scale of development resulting from implementation of a comprehensive plan."[113] It was also envisioned that the economic framework would help "the MTF understand …. impacts of different potential approaches to a comprehensive plan and its implementation."

The economic framework focuses on segments of the Alaska mariculture industry that are currently most viable. The framework describes 5, 10, and 20-year production and revenue goals that represent one potential scenario for the pace and scale of industry growth. The framework can be extended beyond 20 years, though uncertainty increases along with the extent of the forecast period. Actual speed and scale of development will depend on Alaska's collective ability to address and mitigate the barriers that have and may continue to constrain industry growth.

Private investment is essential for Alaska's mariculture industry to grow, and public investment, though perhaps not essential, would facilitate that growth. The spectrum of potential approaches to investment in mariculture, as outlined by the MTF, includes:

- Limited government involvement with an emphasis on attraction of private business
- Public-private partnership
- Significant public investment initially, followed by private investment

It is evident from this study that with limited government involvement, the mariculture industry will not expand at a pace and scale commensurate with its full potential. Some investments, such as oyster hatchery development to enhance seed security or king crab hatchery R&D for example, may not have the profit incentive needed to attract private investment. As a result, public-private partnership or significant initial public investment are likely necessary for the mariculture industry to reach its full potential.

As outlined previously in the report, the principal challenges facing the industry include:

- Seed security
- Market development/access to markets
- Access to investment capital
- Operating cost control

Public investment that benefits a full spectrum of producers can address aspects of these challenges. The planning challenge is to prioritize public investment at a time when public resources are scarce. The following table provides a framework for identifying and prioritizing potential targets for public investment

[113] Project Scope of Work Alaska Mariculture Initiative: Economic Analysis to Inform Comprehensive Plan – Phases 2 and 3, Alaska Fisheries Development Foundation, January 1, 2017.

to spur mariculture industry development in Alaska. The table summarizes a broad range of potential public investments in the mariculture industry. Costs, where known, are provided, along with a brief description of benefits. A time frame for achieving benefits is provided, described as near-term (within five years), mid-term (five to 10 years), and long-term (more than ten years to realize benefits in terms of increased industry production). A variety of factors, as described in Chapter 2, may influence the speed at which barriers are overcome. A subjective measure of priority is also included, from high priority to low priority.

The full cost of public investment to overcome industry development barriers is not determined at the level of detail required to fully understand return on investment and prioritize use of public funds. With more fully developed estimates, it will be possible to measure net benefits of a range of public investments.

Table 42. Public/Private Investment Priorities

Investment	Cost	Benefits	Timeframe to Achieve Production Benefits	Priority
		Seed Security		
Capital and operating funds for in-state oyster seed hatchery R&D	Yet to be determined	Alaska seed security, Lower cost seed, Privatization potential, In-state hatchery operations economic impact	Near-term	High
Kelp R&D on seed sources and strain selection	Yet to be determined	Determination of best practices for obtaining parent plants for seed production, and development of hatchery and nursery infrastructure capable of supplying industry demand	Near-term	High
Mitigate barriers to access associated with securing out of state seed, including incentives for out of state producers as appropriate	Yet to be determined	Seed security	Near-term	Medium-High
Geoduck R&D on a dependable seed source	Yet to be determined	Greater availability of seed and more accurate business planning	Near-term	Medium-High
King crab hatchery research and development	Yet to be determined	Determine economic and technical viability of hatchery development	Mid-term	Medium-High
King crab hatchery construction and operation at commercial scale	Yet to be determined	Additional high-value product in common property fishery	Mid-term	Medium-High
Blue mussel hatchery research and development	Yet to be determined	Determine economic and technical viability of hatchery development	Long-term	Low-Medium
Blue mussel hatchery construction and operation at commercial scale	Yet to be determined	Additional product	Long-term	Low-Medium

(Continued on next page)

Table 41. Public Investment Priorities (cont'd)

Investment	Cost	Benefits	Timeframe to Achieve Production Benefits	Priority
Operating Cost Control				
Continue and improve access, including for hatcheries, to the Mariculture Loan Fund	$10 million in the next five years	Increased utilization of the fund to support businesses	Near to Mid-term	High
R&D for improved environmental testing and mitigation methods (PSP, *Vibrio p.*, and fecal coliform)	$50,000 to several hundred thousand dollars depending on environmental issue and level of importance to public health and economics.	Food safety, streamlined and more affordable testing, and improved harvests	Near to Mid-term	High
Market Access				
Value-added product form research and development	Varies with species/product	Increased production and revenue for current and future farmers	Mid-term	High
Market development, research, and planning	$50,000 to $100,000	Better understanding of market barriers and opportunities. Market intel many individual operators cannot afford on their own	Near-term	High
Development of industry data sources	$50,000	Data for business planning and public information. GIS planning tools	Near to Mid-term	Medium-High
Professional development and mariculture business planning services	$50,000 to several hundred thousand depending on volume of materials and number of programs	Business qualification for funding and stronger start-ups	Near to Mid-term	Medium
State-sponsored marketing of mariculture products based on market research and planning	Likely to be included in an expanded ASMI budget	Access to out-of-state markets	Near to Mid-term	Medium
REGULATORY ISSUES	The following regulatory changes are considered important for provide a more affordable, predictable, or reasonable regulatory environment for mariculture businesses.			
Provide adequate resources for the Alaska shellfish sanitation authority as the industry grows		Human health/access to markets	Near to Mid-term	High
Stabilize lease fees over the lifetime of mariculture leases	Unknown, depends on complexity of regulatory change and State of Alaska resources available.	A more dependable operating environment.	Near-term	High
Allowance for species-specific grow-out periods in regulations		Alignment between regulations and operating realities.	Near-term	High
Evaluate lease size and fee calculations		Reduced operating fees, especially for new businesses.	Near-term	Medium-High
Create options for commercial farmers to obtain affordable insurance		Reduced start-up fees and operating costs.	Near-term	Medium
Administration				
Finish Mariculture Task Force tasks, comprehensive plan implementation	$200,000 to $250,000	Finish the MTF work and implement plan for the industry	Near-term	High

Appendix A: Regulatory and Legal Framework for Mariculture in Alaska

The following discussion, authored by the MTF Regulatory Advisory Committee, provides an overview of the regulatory and legal framework for mariculture in Alaska.

Constitution

Alaska is a common property resource state and the Alaska Constitution includes provisions relating to common use. Most tide and submerged lands within Alaska's 40,000 miles of coastline are a common property resource managed upon multiple use principals and sustained yield requirements. The State of Alaska Constitution requires resource decisions to be vetted thru a public process and noticed for public input to balance resource management decisions with the best interests of the State of Alaska. Management of replenishable resources for sustained yield is enshrined in Article 8, Section 4, of the constitution. Article 8, Section 15, specifically prohibits exclusive right of fishery; however, this section was amended in 1972 to provide exemptions for the state to both limit entry into fisheries for conservation and economic reasons, and to provide for the efficient development of aquaculture in Alaska. Article 8 also provides for the use of state lands and waters, with certain assurances, in Sections 8 and 14. Article 7 requires that the legislature provide for the promotion and protection of the public's health.

Statute

Several statutes have been approved by the Alaska Legislature that provide for mariculture activities in the State. The fisheries rehabilitation, enhancement and development statute (AS 16.05.092) went into effect in 1971, directing the Alaska Department of Fish and Game (ADFG), in part, to encourage private investment in the development and economic utilization of fisheries resources, and through rehabilitation, enhancement and development programs, do all things necessary to ensure perpetual and increasing production and use of the aquatic resources of the state.

The Aquatic Farm Act (Section 19, Chapter 145, SLA 1988) was signed into law on June 8, 1988, authorizing the Commissioner of ADFG to issue permits for the construction or operation of aquatic farms, and hatcheries to supply aquatic plants or shellfish to aquatic farms (AS 16.40.100 - 199). The intent was to create an industry that would contribute to the state's economy and strengthen the competitiveness of Alaska seafood in the world marketplace, broadening the diversity of products and providing year-round supplies of premium quality seafood. The law limited aquatic farming to shellfish and aquatic plants and in 1990 CSHB 432 became law, prohibiting farming of finfish in the state (AS 16.40.210).

Statute also authorizes Alaska Department of Natural Resources (DNR) to make land and water available through lease for aquatic farming subject to bonding or other security (AS 38.05.083). All lease applications and proposed decisions are required to be noticed for public comment per AS 38.05.945 before a final decision is rendered by DNR.

Statutes that direct the Alaska Department of Environmental Conservation (DEC) to provide for food safety are found in the Alaska Food, Drug, and Cosmetic Act in AS 17.20.

There is currently no statutory authorization to issue permits for shellfish rehabilitation and enhancement projects, however, bills were introduced in 2016 and again in 2017 to achieve this.

Administration of the Alaska Aquatic Farm Program

Three State agencies jointly administered the Alaska Aquatic Farm Program: the Department of Natural Resources (DNR), the Alaska Department of Fish and Game (ADFG), and the Department of Environmental Conservation (DEC). Each of these agencies has a specific role in authorizing and managing aquatic farm activities within Alaska.

The DNR authorizes the use of tide and submerged land and seeks to balance use of the land for the development of aquatic farming with traditional uses of the area, upland owner access, public access, and navigation of public waters as required under Article VIII of the Alaska State Constitution. The department is required to balance disposal of interest (lease) decisions with traditional and existing uses within a given area to ensure proposed farm sites are compatible. If approved, leases authorize a specific footprint and infrastructure to remain on state land to support aquatic farming activities. DNR is required to charge no less than appraised fair market value for lease fees which require annual land use fees. Lease holders are also required to post a bond to cover the costs to the department of restoring leased sites in the event the site is abandoned. Other requirements include providing proof of commercial liability insurance and meeting the commercial use requirements outlined within 11 AAC 63.030(b) within five years of lease issuance. DNR aquatic farm regulatory guidance is contained in 11 AAC 63.010 – 050.

The ADFG issues permits for the operation of aquatic farms and aquatic farm hatcheries, acquisition of stock, and transport of seed and aquatic farm products; certifies and permits seed coming into the state and transported within state for aquatic farming, ensures aquatic farming does not significantly alter established fishery or other existing uses of resources, does not significantly affect fisheries, wildlife or their habitats in an adverse manner, and determines wild stock populations prior to permitting aquatic farm species. ADFG employs the "precautionary principle" when authorizing use of resources to ensure sustained natural productivity of common property resources. Specific ADFG aquatic farm regulatory guidance is contained in 5 AAC 41.001 – 400.

To protect human health, the DEC classifies growing areas, issues permits, conducts inspections, investigates complaints, conducts outreach and training, and monitors bacteria and toxins in shellfish harvest areas (growing waters) and shellfish products. Primarily, two programs within DEC are involved: the Food Safety and Sanitation program (FSS), the state's Shellfish Sanitation Authority, and the Environmental Health Laboratory (EHL), which provides the FSS program analytical support to carry out its responsibilities. DEC regulates the shellfish industry through adoption by reference at 18 AAC 34 of a document called the

National Shellfish Sanitation Program Model Ordinance (NSSP MO). The NSSP MO specifies sanitation requirements for harvesters, dealers, and shucker/packers and outlines State regulatory program requirements so that shellfish grown and harvested in Alaska may be sold interstate.