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.

Photo credit: Bob Koenitzer.

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 was to create an industry in the state that would 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 limited 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 principals and sustained yield requirements. The State of Alaska Constitution require 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.

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

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.

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.

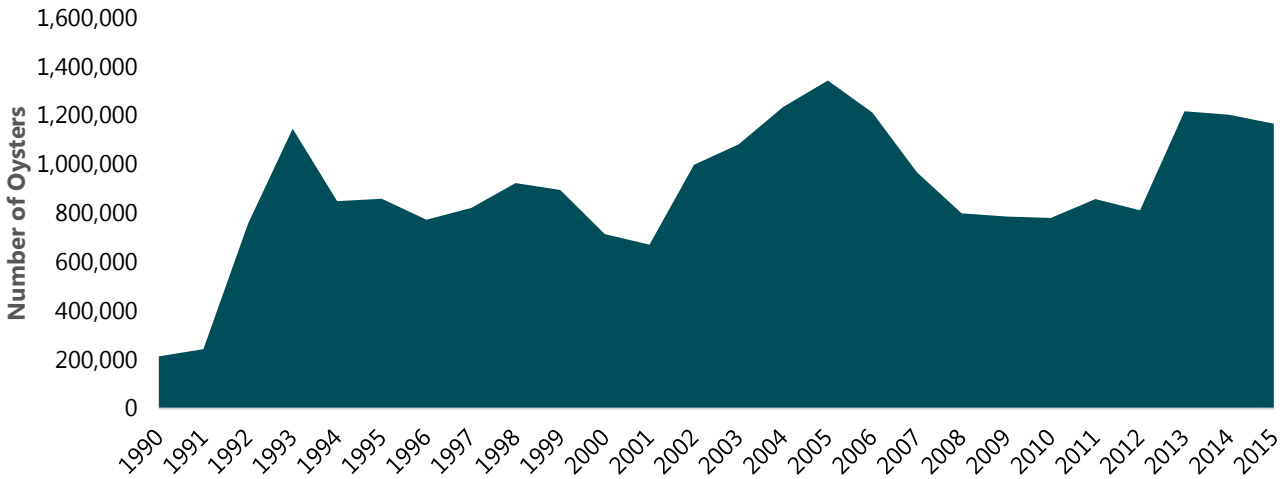
Production

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 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.

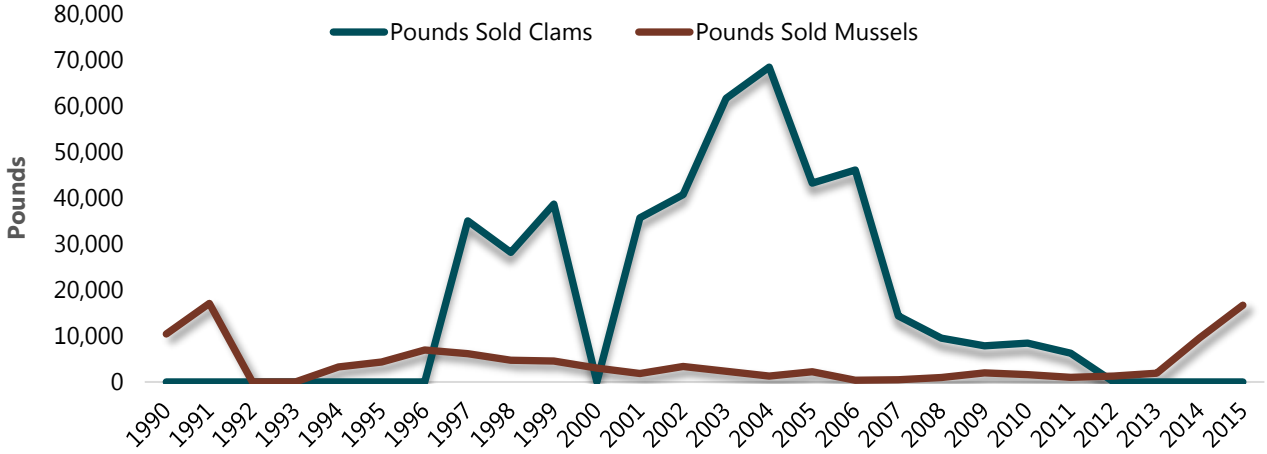
In addition to these shellfish species, sugar kelp harvests are planned for spring 2017.

Figure 1. Oyster Production in Alaska, 1990-2015



Source: ADF&G.

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

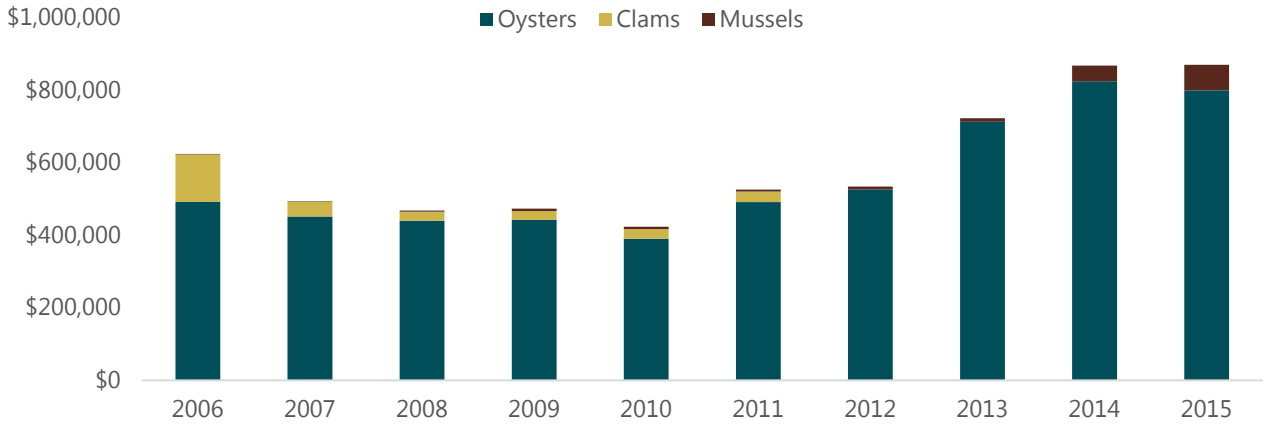


Note: For years with fewer than three operators reporting, production numbers are confidential and reported as zero.
Source: ADF&G.

Sales

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.

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



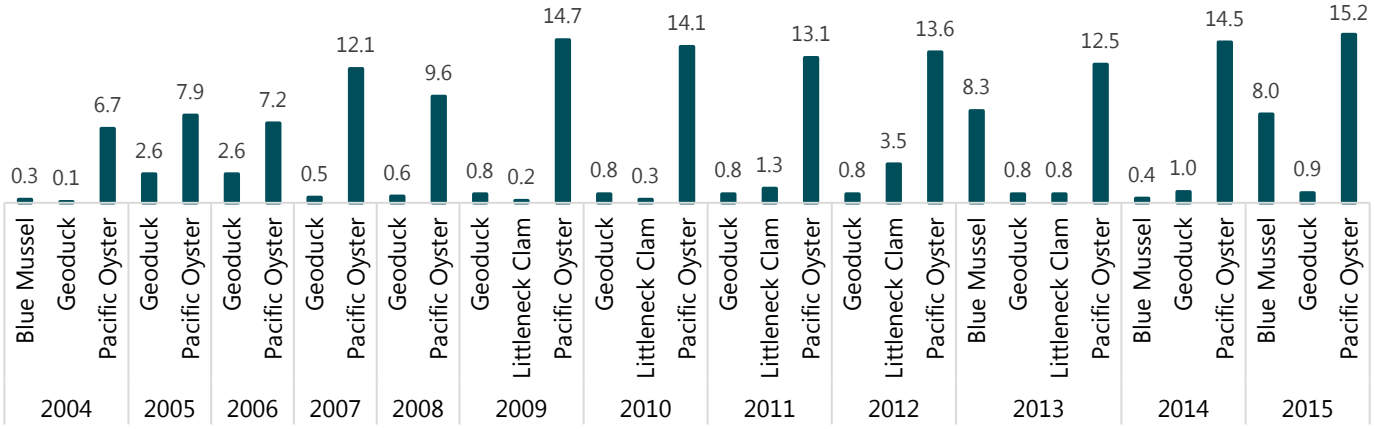
Note: For years with fewer than three operators reporting, production numbers are confidential and reported as zero.
Source: ADF&G and DNR.

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.

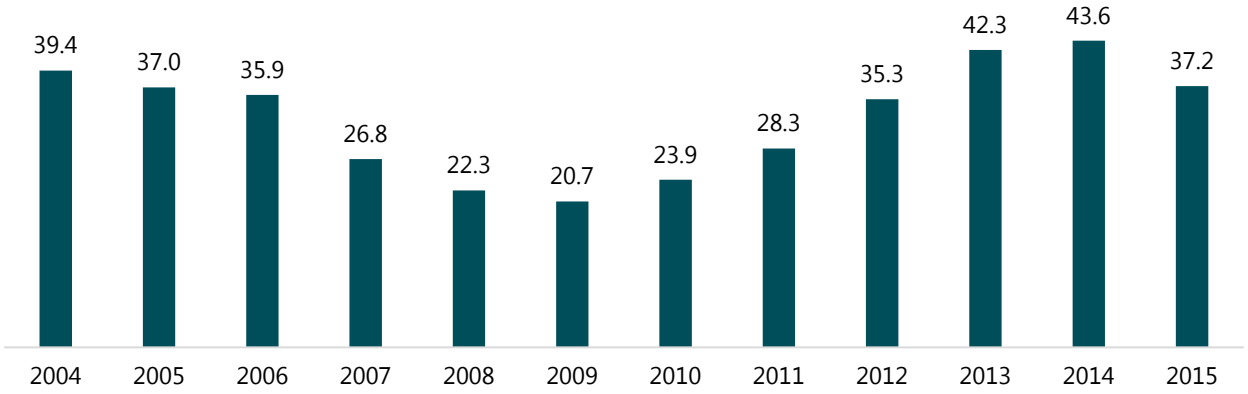
Employment

Alaska aquatic farm employment included a total of 138 positions in 2015, down from 185 in 2014. Two-thirds of these positions were employees, with permit holders and owners making up most of the other positions. In

total, workers worked a total of 9,664 workdays 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. Nine out of ten (92 percent) of hatchery and nursery positions were filled by employees

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



Source: ADF&G.

Organization of the Chapter

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 sections 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, oyster 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. Among the 31 farms permitted in 2015, 22 reported oyster sales that year, the most recent year for which harvest data is available.

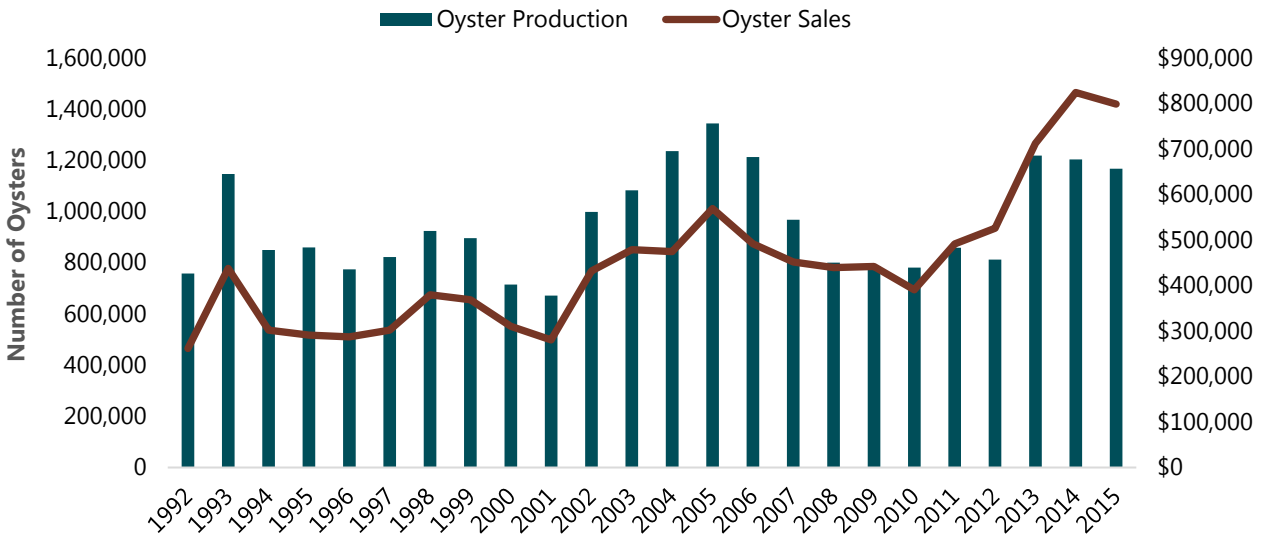
Table 2. Alaska Farms with Oyster Sales, 2011-2015

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 produced an annual average of 954,000 oysters between 1992 and 2015. Oyster production in Alaska peaked in 2005, when 1,334,934 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 in the 2003 to 2006 period. 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 Production and Value, 1992-2015

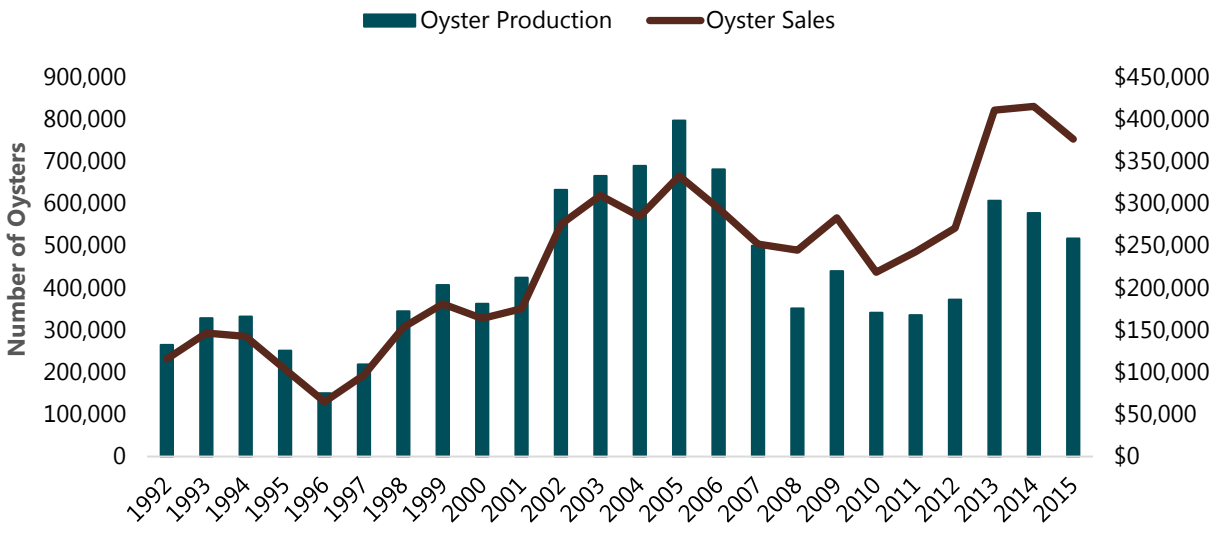


Source: ADF&G and DNR.

REGIONAL PRODUCTION AND SALES

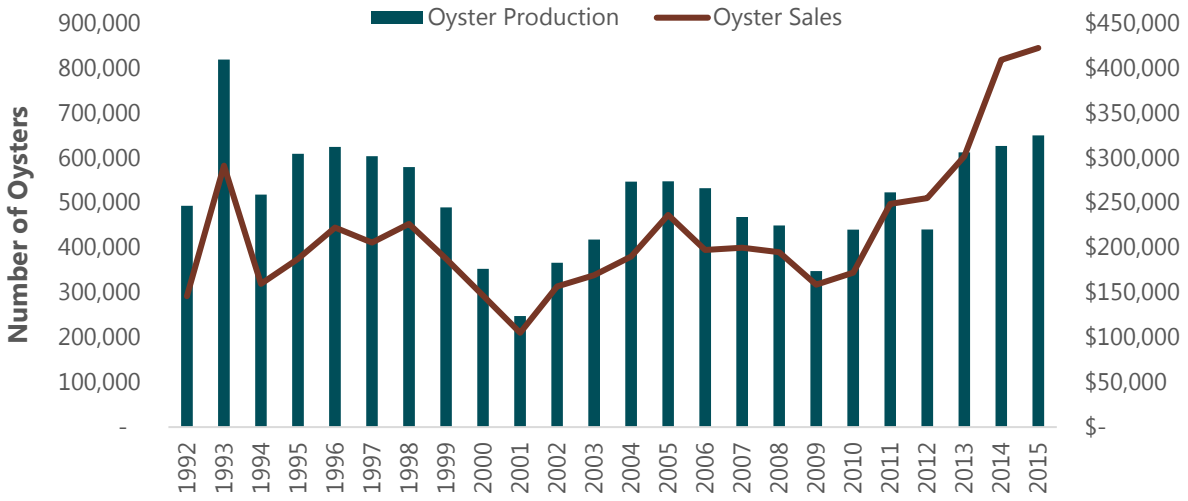
Slightly more than half of the state's oysters produced from 2011 to 2015 (54 percent) came from Southeast, while 46 percent were grown in Southcentral. For the same period, Southcentral generated 51 percent of statewide oyster sales revenue.

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



Source: ADF&G and DNR.

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



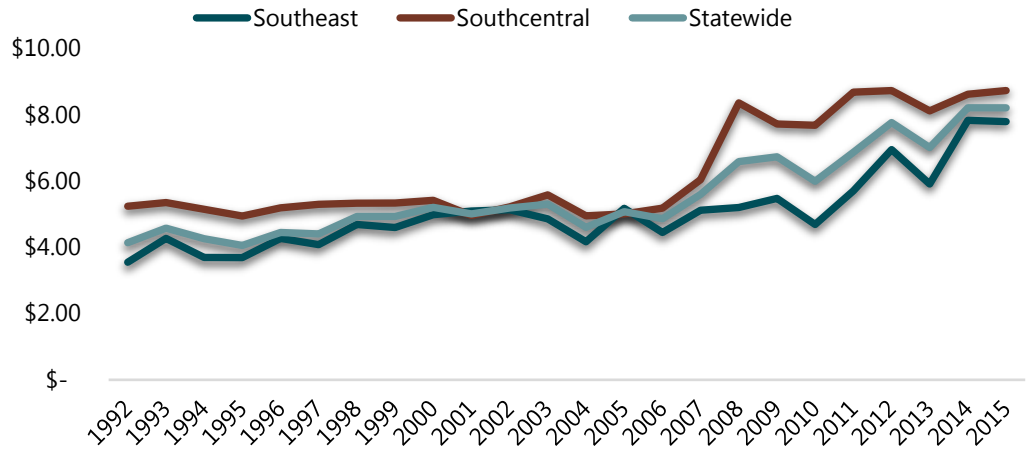
Source: ADF&G and DNR.

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.

[2] Based on Anchorage CPI.

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.

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 mechanized 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 the specific processes used 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 a total of 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 abductor 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. This means that 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.

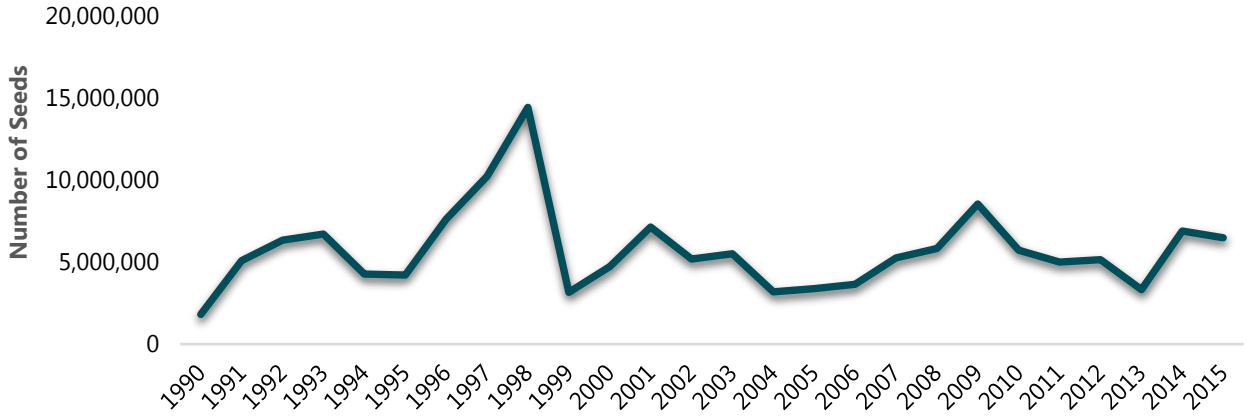
Oyster Seed

Three permitted shellfish hatcheries operate in the state, OceansAlaska, Katchemak Shellfish Mariculture Association, and Alutiiq Pride Shellfish Hatchery (APSH). OceansAlaska has never successfully spawned oysters. 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. APSH will produce oysters when the demand for 2-3 mm seed exceeds 8 million.

All oyster seed purchased by Alaskan farmers comes to Alaska 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. As of 2015, only 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 2007 (10.2 million) and 2008 (14.5 million), then declined precipitously. The lowest level of seed acquisition between 2011 and 2015 was 3.3 million in 2013. Acquisition increased significantly in 2014 (6.9 million) and 2015 (6.5 million).

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

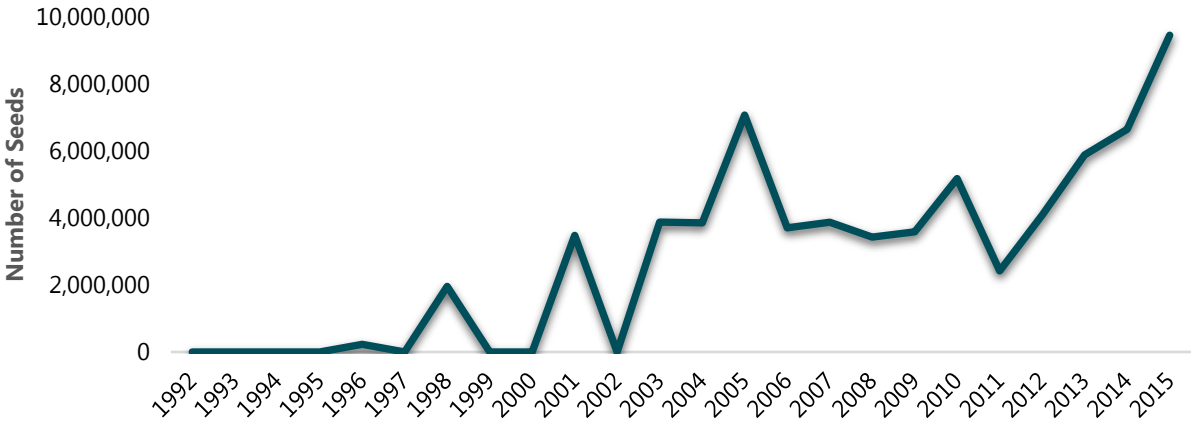


Note: Acquisitions includes data for count of permits 3 and greater.
Source: ADF&G.

OYSTER SEED STOCK

Pacific oyster seed inventory for hatchery and nursery operations reached the highest ever recorded at 10.3 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.

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.

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

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, of oysters 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 kg	2012 Value	2013 kg	2013 Value	2014 kg	2014 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. The majority of 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.

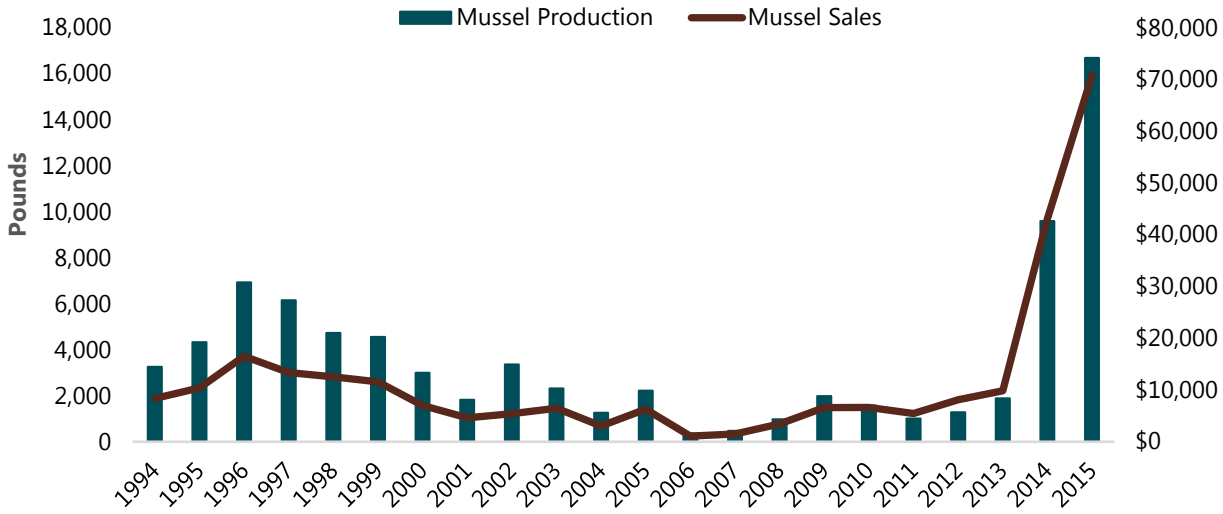
Mussel Production and Value

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.

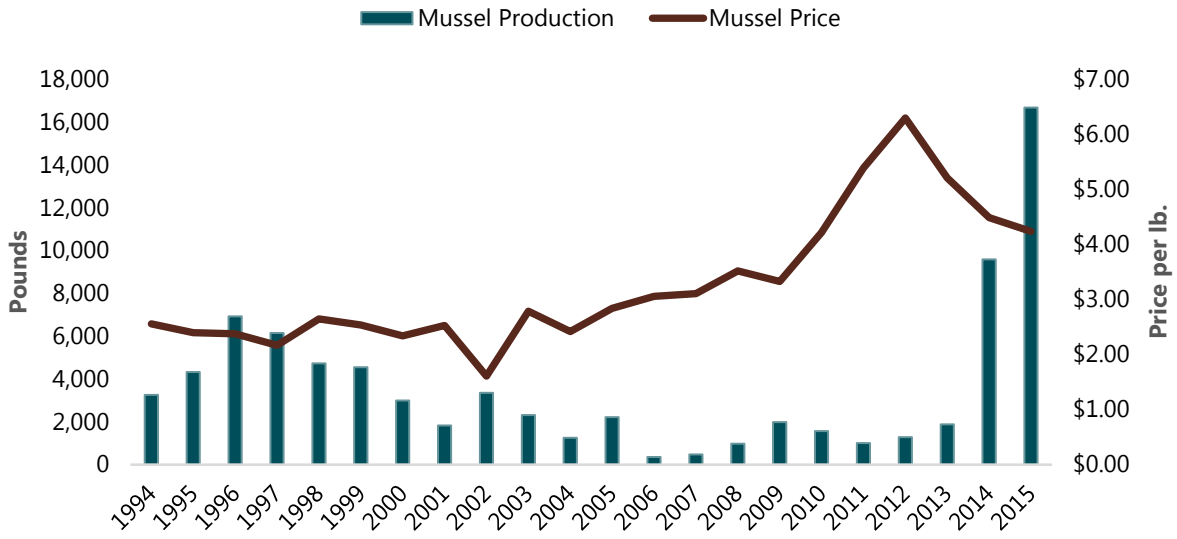
Figure 12. Alaska Mussel Production and Sales, 1994-2015



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 naturally by filtering

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

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)

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

Photo Credit: NOAA.

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 be capable of producing 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. 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 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.

Photo credit: SARFDA.

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 but has not been successful in spawning.

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, Calendar Year, 2006-2015

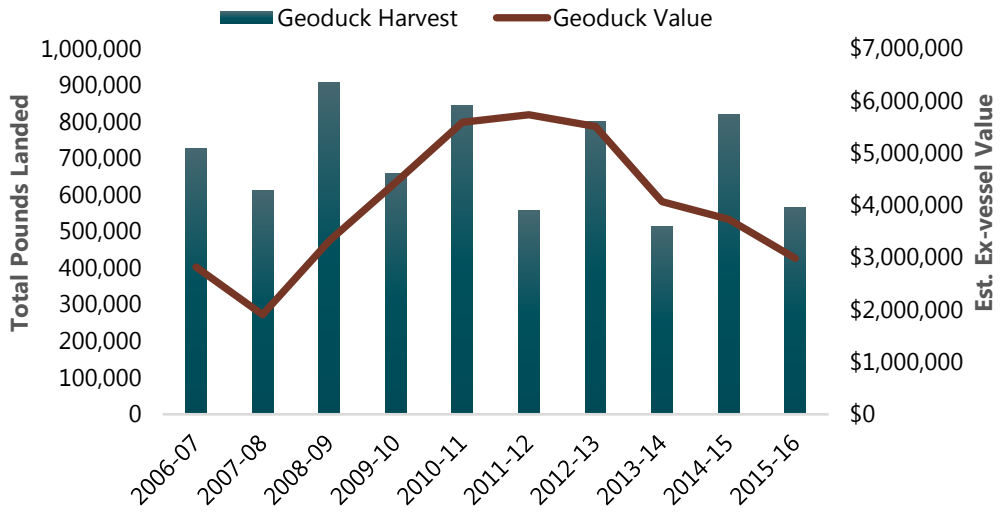
Year	Total Permits Fished
2015	60
2014	61
2013	69
2012	70
2011	61
2010	69
2009	55
2008	57
2007	62
2006	61

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

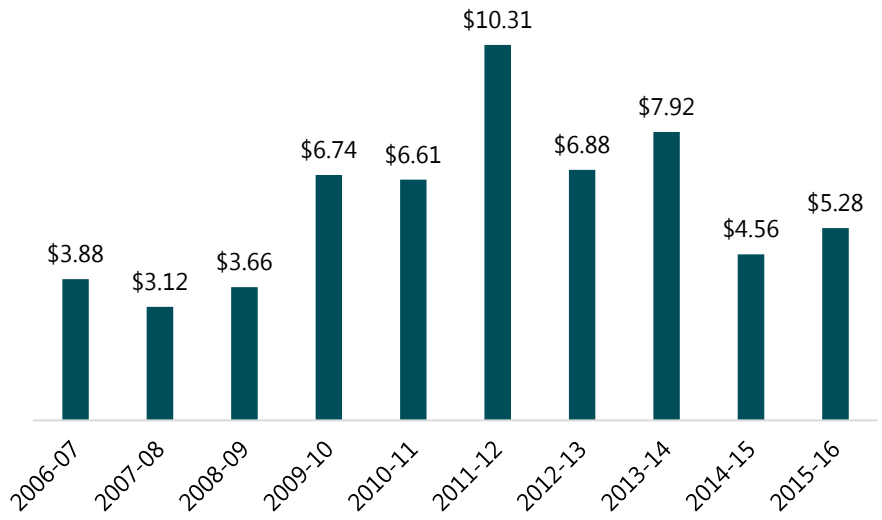


Source: ADF&G.

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 clams are called spat or seed. 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. Spat 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 spat 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 using pressurized hoses to blast the bottom material away from the clam.

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. However, 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. Table 16 outlines one range of possible production values.

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	$0.60	$0.60	$0.60
Farm Revenue	$470,250	$940,500	$1,881,000
First Wholesale Value of Dried Powder per Metric Ton	$12,000	$12,000	$12,000
Dried Powder Produced (Metric Tons)	71	142	284
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)	$382,958	$768,075	$1,536,150
First Wholesale Revenue	**$853,208**	**$1,708,575**	**$3,417,150**

[1] Assumes 209 ft. rows producing 7.5 pounds of wet product per linear foot.
[2] Assuming 20 percent yield, going from wet product to dried powder.
Source: McDowell Group estimates.

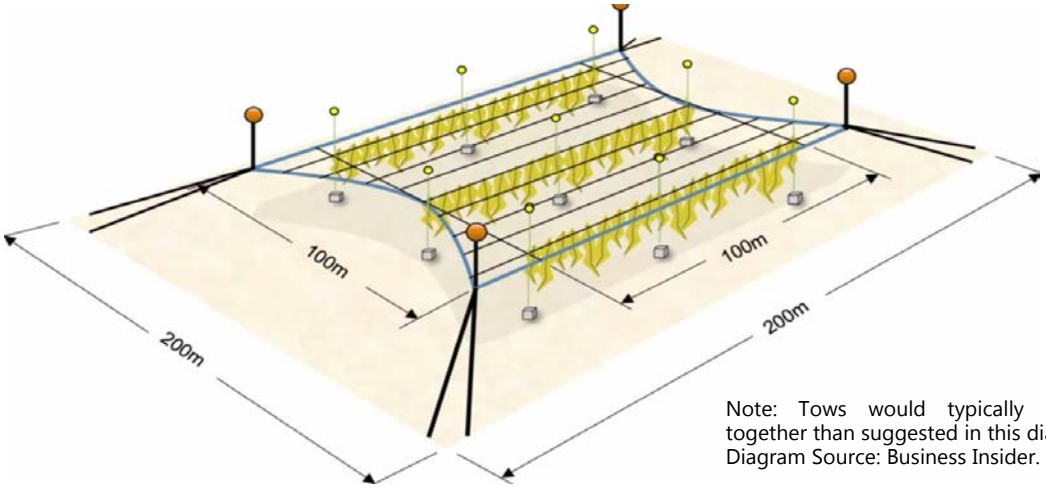
[5] Perry, personal communication.
[6] Lenstra, Jip; Van Hal, Jaap; and Reith, Hans. "Economic aspects of open ocean seaweed cultivation." Energy Research Center of the Netherlands. Presented at the Alg'n Chem 2011, Montpellier, France.

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. 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.

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 capable of transforming mass quantities of wet Alaskan kelp into a stable powder format. The company reports 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 eastern U.S. states, 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 in their native markets. With virtually no domestic production, most seaweed utilized in the U.S. (and Canada) comes from imports. Last year the U.S. imported 40,259 metric tons of seaweed and

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

intermediate products derived from seaweed worth $205 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; however, as carrageenan is typically derived from Asian green or red seaweeds (such as Euchema and Elkhorn Sea Moss).

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	10,711	8,701
Seaweed Carrageenan-based Thickeners	10,245	9,105	9,965	9,981	9,216
Total	**39,002**	**40,547**	**36,592**	**37,084**	**40,259**
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	58
Seaweed Carrageenan-based Thickeners	89	88	102	96	76
Total	**$212**	**$230**	**$244**	**$244**	**$205**

Source: NMFS Trade Data.

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 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.

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 seaweed'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

[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.
[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

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]
- 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.

[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

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 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.

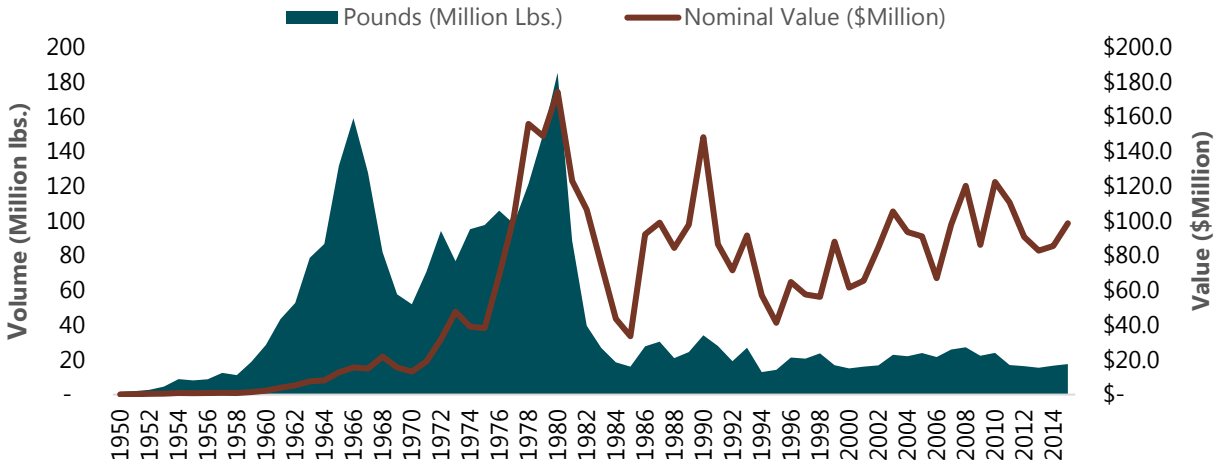
One of the challenges before commercial hatcheries can operate is developing genetic marking and monitoring methodology to differentiate wildstock from hatchery-raised crab. Scientists are unsure on how hatchery crab would impact natural stocks. The experimental outstocking conducted in the Kodiak basin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

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.

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

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 (*Lithodes aequispinus*) 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]

[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.

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

[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
[28] https://seagrant.uaf.edu/research/projects/kingcrab/docs/akcrrab-strategic-plan-2015-2019.pdf

- 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. The Alutiiq Pride Shellfish Hatchery monitors and cares for the adult broodstock and their offspring. Thousands of eggs hatch in early spring and the larvae become juveniles two months later. Survival rates for king crab were 31 percent in 2013.[29] Hatchery startup required $600,000 in equipment. Hatchery operations currently cost between $305,100 to $333,800 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 has been collected from Alitak Bay and Old Harbor on Kodiak Island, the Pribilof Islands, and Little Diomede. Currently, broodstock comes from Alitak Bay. From broodstock, larvae are raised in tanks at APSH in Seward for two months and then released before the juveniles become cannibalistic. 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

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).
Source: Glaser (2009). Rehabilitation of the Alaskan red king crab through large-scale hatchery culture and restock: Cost-Benefit Analysis.

[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

From 2008-2010 costs for AKCRRAB research and development totaled $2.5 million in Alaska Sea Grant funds and included many other contributors.[32]

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.[33] Since its infancy, AKCRRAB has supported eight University of Alaska Fairbanks graduate students and produced numerous scientific publications.[34] 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.[35]

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.

[32] https://seagrant.uaf.edu/factsheets/kingcrab/kingcrab-financial-web.pdf
[33] https://seagrant.uaf.edu/research/projects/kingcrab/docs/presentations/Persselin-2009-comfish.pdf
[34] https://seagrant.uaf.edu/research/projects/kingcrab/general/graduate-students.php
[35] 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.[36] 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.[37] Concurrently, a growing Southeast Alaska sea otter population placed pressure on the abalone biomass, further limiting its capacity to rebuild.[38] 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.[39] Subsistence harvests of abalone in Alaska are limited to 5 abalone a year with a minimum size of 3.5 inches.[40]

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.[41] 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.[42,43,44]

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.

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

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.[45]

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

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.
- 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 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.

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[46]. 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.

[46] 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.[47] Giant red sea cucumbers reach adult size and sexually maturity after 4 years.[48]

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 occur.

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.[49] 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, other Asian countries, and the Pacific Islands including Australia and New Zealand.[50] In 2015, China produced 98

[47] http://www.adfg.alaska.gov/index.cfm?adfg=redseacucumber.main
[48] http://peninsulaclarion.com/news/2011-07-17/spawning-sea-possibilities?utm_source=Morris%20Digital%20Works&utm_medium=email&utm_campaign=Recurring_Daily%20Headlines
[49] http://alutiiqpridehatchery.com/sea-cucumber/
[50] http://seagrant.umaine.edu/files/pdf-global/SeaCucumberManual_062614.pdf

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 concentrated in Southeast, with smaller fisheries in Kodiak and Chignik.[51] Divers use scuba gear to hand pick sea cucumbers off benthic (sea floor) habitats and transport them to the surface in mesh bags.[52] ADF&G rotates fishery areas every three years to prevent overharvest. Stock assessments are partially-funded by SARDFA.

[51] http://www.adfg.alaska.gov/index.cfm?adfg=CommercialByFisheryDive.seacucumber
[52] http://www.adfg.alaska.gov/index.cfm?adfg=redseacucumber.main

Statewide harvests averaged slightly over 1.6 million pounds per year between the winter 2011/12 and 2015/16 seasons.[53] 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.[54] 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.

Photo credit: Kirsten Shelton.

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.

[53] 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.
[54] http://alutiiqpridehatchery.com/sea-cucumber/

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.[55]

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.

[55] 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.

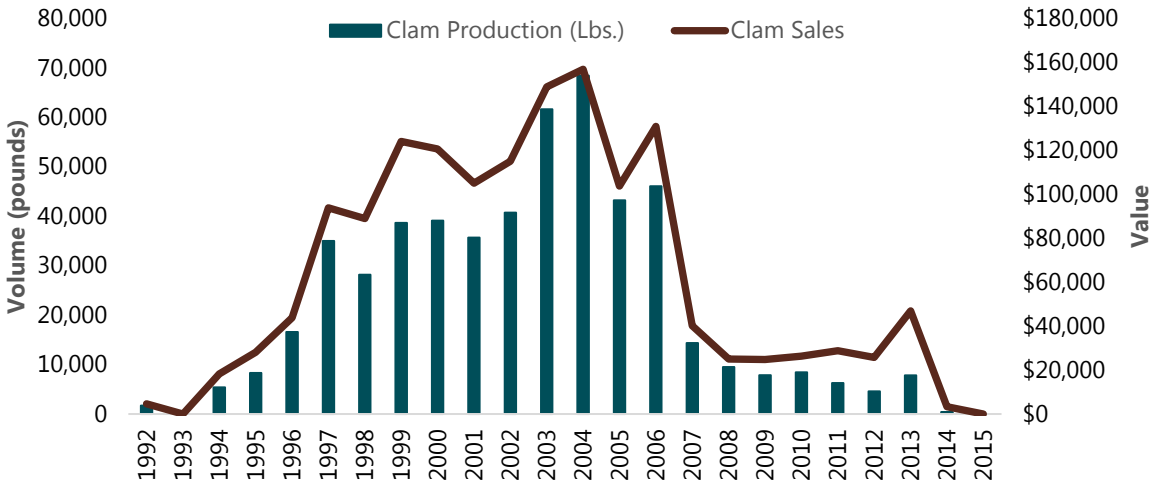
PRODUCTION AND VALUE

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.[56] 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 Sales, 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.

[56] 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.[57]

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.[58] 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.[59] 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.[60] The species is fished commercially for crab bait and for consumption.[61] The most recent data available shows the ex-vessel price for razor clams at $0.65/lb.[62]

In 2004, razor clams produced at APSH were planted near the village of Eyak, near Cordova, for enhancement purposes.[63]

[57] https://seagrant.uaf.edu/map/aquaculture/shellfish/presentations/Introduction%20to%20clam%20farming.pdf.
[58] http://www.sf.adfg.state.ak.us/FedAidPDFs/RIR.5J.2004.05.pdf.
[59] http://www.adfg.alaska.gov/static/fishing/PDFs/aquaticfarming/razor_clam_pws.pdf.
[60] http://www.adfg.alaska.gov/index.cfm?adfg=ByAreaSouthcentralLowerCookInlet.research.
[61] http://www.adfg.alaska.gov/index.cfm?adfg=razorclam.uses.
[62] ADF&G (COAR).
[63] 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 in sandy beaches in protected bays. The clam burrows deeper than littleneck clams, up to 12 inches.[64] 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 for two years (2015-2017), 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.[65] 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.[66]

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.[67] Including farmed and wild-caught clams, 90.7 million pounds of clams were commercially landed, worth $214.7 million.[68]

[64] https://www.adfg.alaska.gov/static-sf/Region2/pdfpubs/HardshellClams.pdf
[65] http://nsgl.gso.uri.edu/aku/akug98002.pdf
[66] http://www.adfg.alaska.gov/index.cfm?adfg=fishingaquaticfarming.aquaticfarminfo_permit_status
[67] https://www.st.nmfs.noaa.gov/Assets/commercial/fus/fus15/documents/03_%20Aquaculture2015.pdf.
[68] 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.[69] 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.[70] 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. [71]

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.[72] Edible meat yield is 10 percent from live weight. Prices are higher for larger scallops.

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.[73]

Photo credit: Joth Davis.

Scallops are produced in aquaculture around the world, including Canada and Washington.[74] In Alaska, there have been attempts to farm all three types of scallops that live in Alaska waters. Weathervane, the largest and the only ones 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.[75] Rock scallop spat can be hatchery produced. The one downside to rock scallops is their habit of cementing to hard surfaces, which can destroy gear during harvest.[76]

In 2015, four Alaska farms were permitted to raise rock scallops.[77] 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.

[69] Purple-hinged rock scallops, giant rock scallops, and rock scallops all refer to the same species *Crassadoma gigantea.*
[70] http://nsgl.gso.uri.edu/aku/akug98002.pdf.
[71] http://nsgl.gso.uri.edu/aku/akug98002.pdf.
[72] https://www.st.nmfs.noaa.gov/Assets/commercial/fus/fus15/documents/02_Commercial2015.pdf.
[73] https://www.npfmc.org/wp-content/PDFdocuments/resources/SAFE/ScallopSAFE/ScallopSAFE2016.pdf.
[74] http://www.dfo-mpo.gc.ca/aquaculture/farmed-elevage/listing-eng.htm.
[75] http://alutiiqpridehatchery.com/alaska-shellfish-farming/.
[76] http://www.adfg.alaska.gov/static/fishing/PDFs/aquaticfarming/growing_shellfish_in_alaska.pdf.
[77] 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.[78] 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.[79] 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.[80] 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.[81,82] 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, 2012-2017

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.

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