Analyses of Specialty Alaska Seafood Products

Prepared for:

Alaska Seafood Marketing Institute

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McDowell GROUP

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Executive Summary

The Alaska Seafood Marketing Institute (ASMI) commissioned McDowell Group to compile reference information and identify development challenges/opportunities for specialty seafood products from Alaska. The scope of this project was intentionally broad, covering 10 low-value species and specialty (ancillary) product categories. Categories were selected based on their potential as an ancillary product form that could utilize current waste streams, or because the species currently produces low values but could be harvested in greater quantities.

This report is intended to serve as a resource document for ASMI, industry, economic development professionals, and fishery managers. Key takeaways from each species/product are provided below:

FISH HEADS

- Alaska produces an estimated 1 billion pounds of fish heads per year. Heads likely account for the majority of processing waste created by Alaska commercial fisheries.
- Some fish heads are used in meal/oil production, and approximately 1 percent are sold as frozen heads. The volume of heads discharged each year is unknown, but represents a substantial amount of raw material.
- Export markets for frozen fish heads exist, but markets tend to be relatively limited in size and most favor cod/salmon heads from approximately 10-lb. fish. Depending on the species, fish heads can be used to produce fishmeal and oil. However, not all species carry much oil in the head area and since heads contain a high percentage of bone, meal, and hydrolysate products tend to have higher ash percentages (which greatly reduces value).

FISHMEAL & OIL

- Alaska processors produce approximately 70,000 metric tons (MT) of fishmeal and 90,000 MT of fish oil. Most large fishing ports in Alaska have meal/oil facilities, but collectively there is much meal/oil which could be produced from smaller ports (and/or those with more seasonal landings). However, industry experts believe meal/oil production is near its feasible limit in Alaska. Increasing the number of meal/oil plants will probably require a change in investment/operational costs, technology, raw material supply, or product value.
- The pet food sector shows promise as a market for Alaska fishmeal and other products derived from waste streams as the Alaska seafood brand resonates strongly with consumers and provides a point of differentiation for pet food manufacturers.
- The majority of fish oil produced in Alaska is burned as a diesel fuel substitute or sold into lower value commodity markets. Supplement grade fish oil commands much higher prices and the value of Alaska seafood resources could be increased by successfully selling more oil into the supplement market.

ROE PRODUCTS

- Alaska faces many challenges in key roe markets, including: a strong U.S. dollar, changing eating patterns in core Asian markets, access to Russia, competition from Russian producers, oversupplied markets, and inherent variability in Alaska roe supply and quality. Roe is a critical product for the industry, but its value has generally been in decline over the past decade.
- Increasing the value of Alaska roe products will require the industry to do one or both of the following:
    - Develop alternative markets for traditional roe products, either in existing or new markets
    - Develop new roe products or find new markets that make use of low to medium grade roe, such as roe oil products.

INTERNAL ORGANS

- Internal organs are usually discharged or used as raw material for fish meal/oil production. Cod and pollock livers are especially high in valuable omega-3 fatty acids. Niche markets also exist for cod milt and stomachs.

SPECIALTY CRAB PRODUCTS

- Alaska's crab fisheries produce an average of 10.6 million lbs. of crab shells. Crab and other arthropods shells contain chitin, a relatively valuable material used in a variety of industries. Until recently, shells were typically discarded but that is changing as Tidal Vision has plans to scale up chitin and chitosan production using waste crab shells from Alaska fisheries.

HERRING FILLETS

- Male herring are essentially a by-product of Alaska's sac roe fisheries, but larger fish from the Togiak fishery could be used to produce a herring fillet product; up to an estimated 10 million lbs. is available for that purpose.
- Alaska herring promotions in the Pacific Northwest have been successful. Competing on fillet quality with other global herring producers who target fish well before spawning is challenging for Alaska, but the regional allure of Alaska herring may connect with "foodie" consumers on the West Coast.

ARROWTOOTH FLOUNDER

- Arrowtooth flounder look similar to Pacific halibut and live in similar habitats, but whereas halibut flesh is sweet and dense, Arrowtooth meat often contains an enzyme that results in very soft, poor fillet quality. As a result, Arrowtooth flounder is one of Alaska's lowest priced commercial species, whereas halibut is one of the most valuable.
- Arrowtooth and halibut compete for habitat and food and the imbalance in their populations have shifted dramatically over the past 20 years. In 1996, there was 3.1 metric tons of Arrowtooth/Kamchatka flounder for each metric ton of exploitable Alaska halibut biomass. That figure increased nearly 250 percent to 10.7 metric tons by 2017, as Arrowtooth populations continued to rise and halibut populations declined.
- A concerted effort to significantly increase Arrowtooth harvests, while minimizing halibut bycatch mortality, could increase the value of Arrowtooth and provide better growth prospects for halibut populations.

SPINY DOGFISH

- Developing markets for dogfish (i.e. sharks) is challenging for several reasons:
    - There is no directed fishery, leading to inconsistent supply
    - Dogfish require specialized handling and retention techniques in order to maintain quality, which costs fishermen time that could be spent targeting other, more valuable species
    - The FDA advises pregnant women and children to limit dogfish consumption because the fish contain toxins, including relatively high amounts of mercury
    - Public awareness campaigns aimed at exposing cruel shark fin harvesting methods has reduced demand for all shark, including dogfish from Alaska.
- Alaska fishermen typically catch 3 to 5 million lbs. of dogfish per year, but only a small amount is retained. If properly handled, dogfish can produce quality fillets. As a type of shark, cartilage-based products also hold potential. Alaska dogfish products may fill a niche for responsibly harvested shark products, but Alaska dogfish is not certified as sustainable.

SKATES

- Skates are harvested in substantial quantities in Alaska (generally over 60 million lbs. per year), but only about a third of the harvest is retained for processing.
- Skate meat comes from the animal's "wing." Skate wings are prized for fish and chips in the UK and often sautéed in butter with decadent accompaniments in upscale French restaurants. However, the value of the species suffers due to:
    - Relatively low yield of skate wings (compared to fish fillets)
    - More costly retention/processing procedures to ensure quality
    - Limited demand from retail or high-volume food service operators.
- Due to its unique physiology, skates have nutraceutical benefits that are the subject of increasing research.

Common Challenges

Increasing production of specialty products and low-value species will require Alaska's seafood industry to overcome a plethora of challenges. Several common production hurdles are:

- Capacity limitations
- Economies of scale
- Lower production and investment priority for specialty products and low value species
- Production costs
- Market development costs

In many cases, in may be necessary to aggregate product from several facilities or ports in order to make production feasible. Production can be aggregated by selling raw material to a third-party firm or creating a separate cooperative that performs value-added processing but is owned by the raw material suppliers.

Table 1. Summary of Alaska Seafood Specialty Products and Selected Low-Value Species

Potential for Increased Total Value	Species/ Product	Challenges	Opportunities	Alaska Supply (Million Lbs.)		First Wholesale Value (2011-2015 Avg., $Millions)
				2011-2015 Avg.	Potential	
Highest	Fish Oil	- Refining product to supplement grade - Accessing new markets	- Supplement market offers much higher value - Significant supply	54	201	$30
↑	Roe	- Oversupply of some species and stagnant demand in key markets - Variable production and quality	- New products in traditional markets - U.S. & Europe - Roe oil	40	N/A	$413
↑	Fishmeal & Bonemeal	- Creating economies of scale for new production - Commodity product	- Pet food market - Soil remediation - Large potential supply	142	N/A	$108
↑	Skates	- More difficult to retain and process with quality - Competing supply - Mostly bycatch species	- Niche markets - Great product if high quality, need more consumption	21 (Total Retained)	69 (Total Catch)	$7
↑	Arrowtooth Flounder	- Low quality meat - Halibut bycatch limits harvest potential	- Huge biomass in Alaska - Harvesting more AF is good for halibut - Meal/oil/engawa focus	81	661	$26
↑	Fish Heads	- Limited market, size/species dependent - Processing costs for higher value products - Freezing capacity	- Large available supply - Pet food producers - Asia/Africa as frozen or dried product - Meal/oil production, particularly salmon	10	1,002	$6
↑	Crab Shells	- Shipping costs - Competing with low cost Asian shrimp shells	- Specialized chitin products/markets - Product of U.S.A.	N/A	11	N/A
↑	Herring Fillets	- Processing costs and seasonality of fishery - Sac roe fishery produces softer meat - Competing supply	- Significant potential supply (i.e. males) - Regional demand for herring fillets on West Coast	Several thousand lbs.	$10	N/A
↑	Crab Tails	- Supply limited to king crab - Added processing costs	- High crab prices creates better market for tails	N/A	0.3	N/A
↑	Internal Organs	- Limited markets - Synthetic enzyme reproduction	- Livers for oil - Large available supply - Cod milt	N/A	699	N/A
Lowest	Dogfish	- No directed fishery - Toxins/mercury	- Potential substitute for shark products from irresponsible fisheries	0.3	3.0	N/A

Future Research Suggestions

In addition to research suggestions specific to product/species, this project identified several topics/issues which could benefit from further research, including:

- Comprehensive yield database and raw material analysis
- Development of a directory of potential buyers
- Assessment of marketing Alaska seafood produced by foreign, value-added processors

Introduction & Methodology

Study Approach

This project summarizes available research and supply chain information about Alaska specialty products and low value species. It is intended to serve as a reference document for ASMI, industry, buyers, and economic development professionals.

The report consists of nine chapters summarizing information about selected Alaska seafood products, as well as a chapter discussing common challenges and future research needs. The specialty products and species covered in this report where chosen based on their potential for increased production and/or value. The project began in late 2016 and ended in April 2017.

Methodology

A primary goal of this project was to compile relevant information from throughout the supply chain and amongst many disparate data sources into a single document for a range of Alaska specialty products and low value species.

McDowell Group interviewed a broad range of people for this project, including harvesters, processors, buyers, fishery managers, and independent researchers. Interviews were supplemented with production volume/value statistics from fishery management agencies. Trade data and wholesale market data was also utilized whenever possible. The study team reviewed specialized research publications and incorporated the findings about the feasibility of product/market development into the document.

Key Takeaways

- Alaska's fisheries produce approximately one billion pounds of fish heads each year, but only about one percent are sold to wholesale buyers as fish heads. Most fish heads are used in fishmeal and/or oil production, or ground up and either discharged as waste or sold to pet food manufacturers.
- Fish heads likely account for the majority of waste created by Alaska fisheries. Increasing fish head utilization, for use in any product form, may represent the largest opportunity to turn waste into revenue.

Production Volume and Value

Fish heads are a versatile by-product available nearly year-round. They are high in nutrition and rich flavor and many consumers around the world use dried and frozen heads in soups or simply cook them for consumption. Alaska's annual statewide fish head sales averaged 10 million pounds over the 2011 to 2015 period, with an average wholesale value of $6.2 million. This production does not include the many pollock and pink/chum salmon heads converted into fish meal/oil, or the other species discarded as waste. A relatively small percentage of heads and frames from some species, primarily cod and salmon, are ground, frozen, and sold to pet food manufacturers.

Table 2. Fish Head Production, 5 Year Average, 2011-2015

	Wholesale Volume (Million lbs.)	Wholesale Value (in $Millions)
Pacific cod	5.9	$3.6
Salmon	2.5	$0.3
Greenland turbot	1.0	$1.9
Other	0.5	$0.2
Black cod	0.3	$0.1
Rockfish	0.1	$0.1
Average Annual Production	**10.3**	**$6.2**

Note: Value is based on FOB Alaska. Does not include discarded fish heads.
Source: ADF&G (COAR).

Over the last five years, there have been nearly six million pounds of Pacific cod heads produced annually worth $3.6 million. Salmon heads are the second most commonly processed fish head in Alaska, followed by Greenland turbot. Between 2011 and 2015, average annual wholesale volume included 2.5 million pounds of salmon heads and 1.0 million pounds for Greenland turbot heads. Annual first wholesale value of these products was $0.3 million and $1.9 million, respectively.

Greenland turbot (also known as Greenland halibut) heads are a popular product in China. Turbot heads are widely utilized across the country and valued for their tender meat. Turbot heads also have soft bones with a relatively high oil content, which makes them a very flavorful product. The heads are sold mostly in restaurants

and some higher-end supermarkets. They are often prepared by cooking in a wok with spices or as protein/flavor source in soups.

Production Practices

As fish moves through the processing line, it is headed and gutted, with head and entrails discarded. Depending on the freezer capacity and the types of fish heads that have markets, additional processing is required to make fish heads a saleable product. After a vigorous rinse and gill removal, the heads are placed into a plate freezer. General cod head production does not have a size requirement, although larger sizes are preferred. Korean buyers require the gills be removed and the residual backbone chopped by a specialized mini-cleaver. Most processors retain Greenland turbot heads for additional value from Chinese markets, as they fetch a higher price than most other Alaska fish heads. Retained salmon heads generally come from fish larger than 10 pounds, which is problematic as most salmon caught in Alaska are smaller than 10 pounds. Only Chinook average over 10 pounds, though some coho and chum salmon do exceed 10 pounds.

Heads are used for a variety of products fit for human consumption, as well as animal feed and fertilizer. Pet food material usually goes through a grinding and drying process and is either frozen or chilled as raw material for pet food manufacturers.

In processing facilities that lack a meal and oil plant, heads are usually discarded with other by-products due to constraints from limited freezer capacity and/or or insufficient market prices to support processing and transportation of heads. Processing facilities with meal plants convert heads, frames, and other fish parts into fish meal, as well as oil in many cases. On average, a shoreside plant without fish meal technology could discard over 25 percent of its round weight volume, totaling hundreds of millions of pounds statewide. A large portion of this waste consists of fish heads.

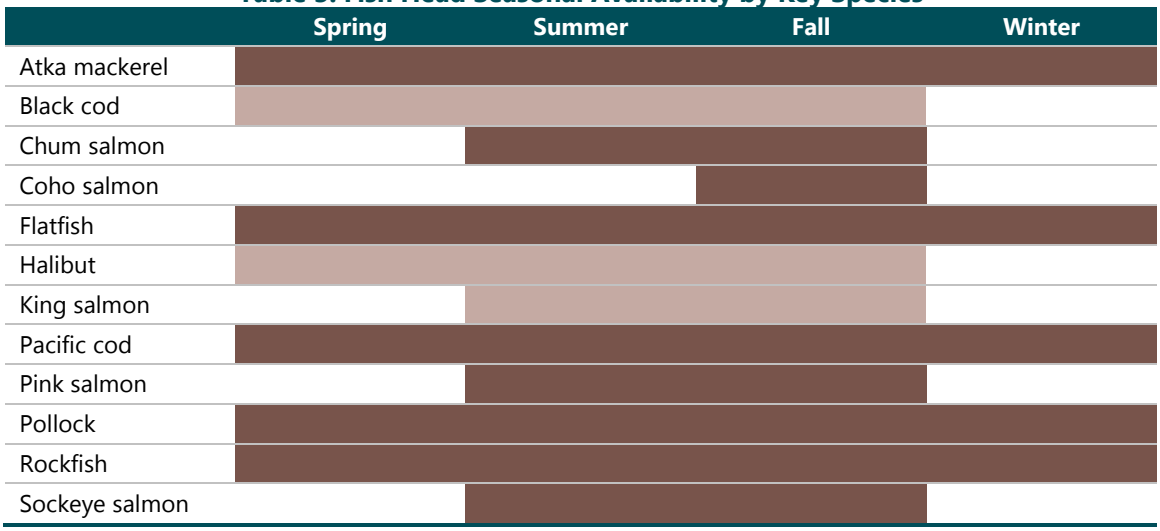
Seasonal Availability & Suppliers

Fish heads are available year-round but there is seasonal variability by species. Groundfish (Pollock, Pacific cod, flatfish, Atka mackerel and rockfish) are available nearly year-round. Halibut and black cod heads typically are available for a nine-month fishing season from March through November, but most of the fishing occurs in the first half of the season.

Salmon heads are abundant during the peak summer and fall harvest seasons. There is fishing for king salmon in the winter and spring, but the supply is low. Pink and chum salmon heads have relatively high oil content and are caught in larger volumes than coho and Chinook, so they are readily used for fish oil extraction in places with necessary production facilities.

See table on following page.

Table 3. Fish Head Seasonal Availability by Key Species



Source: North Pacific Seafoods.

There are several at-sea catcher processors that fish nearly year-round for groundfish. Since there is limited freezer capacity onboard, these vessels typically grind fish heads and discard them at sea. Some larger catcher-processors have on-board fish meal plants to capture additional value; virtually all these boats utilize pollock as the primary raw material.

Resource Potential of Fish Heads

Across the state, over 36 percent of seafood volume harvested was sold in first wholesale as head and gut (H&G). The average round weight harvest of key species in the last five years (2011-2015) was 5.6 billion pounds. Approximately 0.2 percent (10.3 million lbs.) was processed and sold as whole fish heads.[1] Over 1 billion pounds of fish heads are potentially available for value-added products (see Table 4).

Table 4. Potential Production of Fish Heads, in Million lbs., 2011-2015

		Total Harvest (Million lbs.)						
Major Species	**Head Yield%**	**2011**	**2012**	**2013**	**2014**	**2015**	**Avg. Harvest Volume**	**Avg. Potential Heads Available**
Pollock	17%	2,826.1	2,888.5	3,020.6	3,180.9	3,286.6	3,040.5	516.9
Cod	18%	673.1	725.1	703.0	736.8	707.9	709.2	127.7
Flatfish	19%	720.7	707.0	729.9	713.3	542.0	682.6	129.7
Pink salmon	18%	390.5	246.3	678.6	324.5	631.5	454.3	81.8
Sockeye salmon	18%	239.2	211.6	178.4	241.8	288.0	231.8	41.7
Rockfish	26%	113.1	122.3	131.9	143.0	151.4	132.3	34.4
Chum salmon	15%	111.4	150.7	150.1	92.4	129.0	126.7	19.0
Atka mackerel	19%	117.8	108.1	53.9	70.5	120.1	94.1	17.9

[1] McDowell Group estimates based on SAFE, ADFG (COAR) data.

Other	19%	81.2	83.1	100.9	98.6	100.5	92.9	17.6
Black cod	24%	30.2	32.2	32.0	27.0	25.8	29.4	7.1
Coho salmon	17%	20.0	17.9	33.7	41.8	22.7	27.2	4.6
Halibut	16%	30.5	23.4	22.0	15.3	15.5	21.3	3.4
King salmon	16%	5.6	5.7	3.8	5.3	5.5	5.2	0.8
Total	**19%**	**5,359.4**	**5,322.0**	**5,838.8**	**5,691.3**	**6,026.5**	**5,647.6**	**1,001.8**

Note: Flatfish includes sole species, flounder species, and Greenland turbot.
Source: ADFG (COAR), NMFS SAFE, and McDowell Group estimates.

Major Production Areas

Most salmon species are available across the state, but only during summer and fall months. Groundfish are typically available year-round, but with the highest concentration is in Western and Central Alaska.

Table 5. Fish Head Availability by Key Region

	West (Bristol Bay, Bering Sea, Aleutian Chain)	Central (Kodiak, Cook Inlet, Prince William Sound)	Southeast (Yakutat to Ketchikan)
Atka mackerel	■		
Black cod	■	■	■
Chum salmon	■	■	■
Coho salmon	■	■	■
Flatfish	■	■	
Halibut	■	■	■
King salmon		■	■
Pacific Cod	■	■	
Pink salmon		■	■
Pollock	■	■	
Rockfish	■	■	
Sockeye salmon	■	■	■

Source: North Pacific Seafoods.

Fish Head Utilization

Fish heads from Alaska commercial fisheries are generally handled in one of four ways: processed in fish meal/oil plants, sold to pet food manufacturers, sold in fish head export markets, or ground up and discharged.

Pollock accounted for 54 percent of Alaska's total commercial seafood harvest volume in 2014/2015. Most pollock heads are used as raw material for fishmeal and fish oil, but smaller shoreside plants and at-sea processing vessels do not have meal/oil capabilities and therefore discard the heads and viscera. For pollock byproducts, meal/oil is currently the most profitable product form and producers have invested substantially in meal/oil plants. It is unlikely that other fish head markets will offer the scale of demand and prices needed to shift production away from meal/oil in the near future.

Alaska's harvest of non-pollock fish species totals between two and three billion pounds per year - leaving a significant supply of heads for potential use. Most of Alaska's largest ports have fishmeal and/or oil plants; however, many do not. Fish head buyers might find supplies from many fisheries around the state, but especially

those areas where fish heads are currently being ground and discharged. Please refer to the fish meal/oil profile for more information about meal/oil production in Alaska.

Fish heads and other fish parts left over after primary processing can also be used to create frozen blocks of fish paste or chunks for use in pet food, other animal feeds, or organic fertilizers. High-end pet food products are an appealing market, as consumers and manufacturers recognize the benefits of ingredients derived from Alaska seafood. The pet food market is large, but secures most of its protein from terrestrial sources. The top seven pet food companies in the United States have combined revenues of $38 billion.[2] Most of these sales come from dog and cat food. The dog treat market is estimated at $8 billion.[3] Alaska fish heads and other fish meat products can be a marketable ingredient for pet food manufacturers. A list of pet food manufacturers is provided at the end of this profile.

Production Opportunities and Challenges

The Alaska seafood industry discharges substantial volumes of seafood waste and fish heads account for a large portion of fish waste. This represents a potential opportunity for both buyers and suppliers. Outside of fish head and fish oil markets, there are other promising markets, which are not well developed, such as collagen, peptides/nutraceuticals, food additives, fertilizers, and animal food hydrolysates. Alaska's vast source of fish waste means these products could be produced in mass quantities.

While Alaska's marketing cache and abundant, sustainable seafood resources provide opportunities, there are challenges facing product development ventures. Production costs, storage capacity, and transportation costs all plague specialty products like fish heads because of the relatively low values. Both fishmeal and pet food production represent industrial-scale ways to extract value from a resource that would otherwise be dumped back into the ocean. For most of the resource, however, processors cannot currently generate enough revenue for fish heads to cover the costs of additional labor, machinery, freezer capacity, transportation, and marketing.

A key challenge is Alaska's relatively remote location. Most of Alaska's fishing ports are not accessible by road and are located far from larger population centers. This means most product must be shipped as frozen product over long distances via barge or container ship, which adds cost. This is especially important to consider for products that have low yields or lower value as a finished product. Energy and labor costs can also be significant hurdles to development. Finally, there can be production constraints. Many fisheries are seasonal and production volumes can vary widely from day to day. Freezing, processing, storage, and labor must be allocated within each plant to maximize the daily value of production. In some cases, this means that there is not enough capacity available to pack/freeze fish heads or run them through secondary processing lines on site.

While there are fundamental challenges associated with increasing fish head utilization and production values, several suppliers of Alaskan product have demonstrated that profitable utilization of the resource is possible.

[2] http://www.petfoodindustry.com/articles/6054-top-10-us-based-pet-food-companies?v=preview
[3] Personal communication with industry contact.

These suppliers (listed at the end of this profile) will be in the best position to address production challenges unique to specific areas or fisheries.

Markets and Uses

Fish heads that are not discarded or transformed into other products are usually sold into wholesale markets as a frozen or dried product. Primary processors sell fish heads in large quantities to local seafood traders/distributors. Frozen heads are typically sent to Asian countries, such as Korea and China, where they are sold as whole, IQF or individually wrapped heads. Consumers boil them in soups or cook them and pick out the meat. Dried heads and frames are often sent to Southern Europe and Asia as "stock fish" for soups. The heads create rich, flavorful broth, resulting from the oily nature of the head meat.

Southern European countries such as Italy, Spain, and Portugal have traditionally used cod heads to make soup, but the most common destination for Alaska fish heads is Asia, where they also use heads as soup stock. Cod head prices and demand are the highest in Korea. Korean traders/distributors also buy farmed salmon, as well as black cod and Greenland turbot heads. Heads are sold frozen in retail outlets and by street vendors, who prepare them by steaming or pan-frying. Elderly and low-income residents in China and Hong Kong purchase fish heads as a low-cost protein resource.

Drying cod heads is a cost-effective stabilization or preservation method that Norway and Iceland have used for centuries. In modern times, the heads and bones are dried over racks and sold into Spain, Portugal, Italy, Nigeria and other East African countries.[4] Dried frames and heads are sold in markets as a dehydrated soup stock called "okporoko" in Africa. The Nigerian market imports dried heads for approximately $3 per kilo.[5] (Entire dried fish are called "stock fish" and are sold around the world in traditional markets for soup.)

In Nordic countries, the cod tongue, which consists of the entire bottom jaw muscle, is cut out and pan-fried.[6] The texture and flavor of the cod tongue is like a mild-flavored fish or scallop. Frozen cod tongue from Iceland is currently priced at $8 per kilo in wholesale markets.[7]

Product Value and Shipping Costs

The price of Alaska fish heads depends on the species, processor, and other product specifications.

[4] http://www.dryfish.no/books/Engelsk.pdf
[5] http://nsgl.gso.uri.edu/aku/akuy12002.pdf
[6] https://nutsvilleinnorway.wordpress.com/2012/02/11/cod-tongue-a-norwegian-delicacy/
[7] https://www.alibaba.com/product-detail/Cod-Tongues_50000661501.html

Table 6 below provides an approximate range of average prices from recent years. Current market prices may differ from these ranges due to numerous factors. As mentioned earlier, the volume of fish heads sold represents a small fraction of the available supply. Many processors may also be able to deliver heads from species not listed below.

Table 6. First Wholesale Price Range of Frozen Alaska Fish Heads, FOB Alaska, 2011-2015

Species	Price/kg. Range
Cod (mix of frozen/dried)	$1.00 - $2.00
Salmon	$0.20 - $0.40
Greenland Turbot	$3.75 - $4.50
Halibut	$0.70 - $1.60
Black Cod	$0.85 - $1.15

Note: Prices do not reflect the cost of freight to move product out of Alaska ports.
Source: ADF&G (COAR), approximated by McDowell Group.

Shipping costs are a critical aspect of fish head market development. A list of approximate shipping costs is the Appendix (page 100). Prices shown in Table 6 do not include shipping-related costs necessary to move product out of Alaska.

Potential Value of Alaska Fish Heads

Selling fish heads into global markets could add approximately $100 million to the first wholesale value of Alaska seafood, assuming five-year average harvest volumes, full utilization of the species listed below, and sales prices roughly equivalent to those seen over the past five years (2011-2015, see Table 7). Currently, only turbot heads are fully utilized. Anecdotal information suggests the vast majority of heads from cod, sockeye, coho, Chinook, black cod, and halibut are discarded (though cheeks from larger halibut and black cod collars are often retained and fetch premium prices). The potential increase in cod value is particularly attractive. However, whether markets could absorb the additional supply at recent price levels is unknown, as is the potential for market acceptance of smaller head sizes (from cod and sockeye).

Table 7. Potential Value of Selling All Fish Heads from Selected Alaska Species

Species	Potential Head Value ($Millions)	Actual Head Value ($Millions)	Total Species Value ($Millions)	Pct. Potential Increase
Cod	$83.0	$4.1	$465.9	17%
Salmon[1]	$9.5	$0.4	$746.4	1%
Black Cod	$4.9	$0.2	$110.1	4%
Halibut	$2.6	$0.2	$143.3	2%
Greenland Turbot	$1.9	$1.9	$9.6	-
Total	$101.9	$6.7	$1,475.3	6%

[1] Does not include pink or chum salmon, which is commonly used to make fish oil and meal.
Note: Prices used to estimate potential value approximately reflect 5-year average price from 2011-2015.
Source: McDowell Group estimates.

Market Opportunities

Alaska has a year-round supply of fish heads from a variety of species. However, the state's most abundant species are also found in Norway and Iceland, countries that are at the forefront of resource utilization. With

growing demand for fish heads in Asia and East African countries, Alaska suppliers may find an opportunity to supplement Nordic fish head sales in global markets.[8]

Exploring niche markets for tongues or finding North American chefs looking to utilize fish heads could generate more sales. Some buyers may be interested in using Alaska fish heads for collagen, oil, or peptide production. Finally, pet food/treat manufacturers could be a good fit for Alaska fish heads and frames.

A discussion of established fish head markets for human consumption is provided below.

Frozen Fish Heads

Frozen fish heads are sold in markets all over the world. Alaska processors are already well-equipped to handle shipments of frozen fish heads in cartons alongside other products. However, transportation costs and competing supply would likely exceed the benefit of accessing markets in Europe. The greatest potential is likely in Korea, China, and other Asian markets with large populations, such as the Philippines, Indonesia, Thailand, and Vietnam.[9]

Dried Fish Heads

Dried fish heads are currently produced in Norway, Scotland, and Iceland, which have similar climates to Alaska. The process takes several weeks to dry and operations require large open spaces to air dry the product to industry standards.[10] There is a grading scale for dried fish heads. Higher quality products typically go to Spain and lower-grade products are sent to Asia and Africa.

Cod and Pollock Tongues

Cod tongues are a delicacy in Northern Europe and Canada.[11] The tongue and lower jaw is cut out of the fish and shipped frozen. There are no size requirements, which allows for the use of smaller sized cod. In fact, some recipes prefer small tongues, such as pollock. Pollock and cod tongues could be extracted and sold frozen as additional ready-to-eat delicacy. Alaska suppliers may consider the possibility of selling head-on frozen product to secondary processors along North America's northeastern seaboard, where declining cod harvests have resulted in a greater dependence on imported product from Europe and Alaska.

Under-utilized Species

The domestic seafood market is predominantly designed for convenient preparation and standardized fish products such as shrimp, fish sticks, and fillets. However, within the last few years, consumption of less common species and unique seafood products has increased. High profile chefs have showcased other species ("trash fish") in their dishes to attract attention to what Americans discard and to demonstrate delicious creativity in

[8] http://www.fao.org/news/story/en/item/214442/icode/
9 http://www.angsarap.net/2012/10/29/sinigang-na-ulo-fish-head-in-tamarind-broth/
[10] http://www.dryfish.no/books/Engelsk.pdf
[11] http://eatyourworld.com/destinations/canada/newfoundland_and_labrador/photos/cod_tongues

uncommon seafood dishes.[12] Increased interest in exploring ethnic meal choices and in sustainable food sourcing make the domestic market worth exploring as well.[13,14] Pho is one example of a popular ethnic recipe which could be enhanced through using fish heads.

Market Challenges

Low market prices and high operating/transportation costs have deterred further development of many fish products from Alaska. Creating a profitable seafood product in Alaska generally requires markets meet a scale that allows for container-load volumes to minimize the impact of transportation costs and obtain economies of scale within production facilities. These challenges make it more difficult to grow markets organically by starting with small volumes. Buyers and suppliers might partner with others in the area to combine shipments wherever possible.

Trident Seafoods produced dried cod at its Akutan plant in the 1980s but halted operations when it became evident that market conditions did not support diverting floor space and labor from the higher-value fillet line.[15] Producers of species abundantly available in Alaska, such as yellowfin sole and salmon, have struggled to gain market share abroad due to low prices from competing supply and consumer preference in size.

Salmon head production is challenged by the cost of production during Alaska's busy summer season and competition from salmon farms. Buyers prefer the gill removed by hand and rinsed, which is labor-intensive and creates additional labor cost for producers. Further, the Korean market prefers a 10-pound round fish, which eliminates much of Alaska's supply for cod or salmon heads.

Cod heads are a notable challenge for Alaska processors. In the rest of the world, cod heads have a variety of end markets, including dried cod heads in Nigeria, whole/frozen heads in Korea, and cod tongue products in Northern Europe. However, transportation costs often eliminate the potential profit margin for buyers and Alaska suppliers. In addition, producers may be leery about supplying a volatile market. Cod head prices shift enough to discourage producers from suppling labor and production towards the product line, using the necessary freezing capacity, and incurring international freight charges.

[12] http://civileats.com/2015/06/10/chefs-please-stop-calling-it-trash-fish/
[13] http://www.npr.org/sections/thesalt/2014/03/07/286881659/why-we-should-quit-tossing-fish-heads-and-eat-em-up-instead-yum
[14] http://modernfarmer.com/2014/07/fishheads-rolly-polly-delicious/
[15] http://www.afdf.org/wp-content/uploads/promise_profits_white_fish.pdf

List of Potential Buyers

Fish Head Buyers

BUYER	PRODUCT NEEDS	COUNTRY
Qingdao Fortune Seafoods	Turbot heads	China
Dandong Taihua Foodstuff Co., Ltd.	Cod heads	China
Amaze Seafood Trade	Salmon heads	India
Marvest Ltd.	Salmon heads	China (HK)
Mirine International	Turbot heads	South Korea
Fuzhou Woos International Co., Ltd.	Salmon & Turbot heads	China
Live Online Seafood (Frank Allen)	Cod heads	United States

Pet Food Manufacturers

COMPANY	Country	Website
Mars Petcare	United States	www.mars.com/global/brands/petcare
Nestle Purina PetCare	United States	www.purina.com
Big Heart Pet Brands	United States	www.bigheartpet.com
Hill's Pet Nutrition	United States	www.hillspet.com
Diamond Pet Foods	United States	www.diamondpet.com
Blue Buffalo	United States	www.bluebuffalo.com
Spectrum Brands (United Pet Group)	United States	www.unitedpetgroup.com
Unicharm Corp.	Japan	www.unicharm.co.jp/english
Deuerer	France	www.deurer-france.com
Heristo AG	Germany	www.heristo.de/en
Alaska Naturals	United States	www.alaskanaturalspet.com
American Nutrition	United States	www.animanufacturing.com
Raw Advantage	United States	www.rawadvantage.org
Peterson Company	United States	www.thepetersoncompany.com

Names of other pet food and pet treat manufacturers are available at the following link:

http://www.petfoodindustry.com/directories/211-top-pet-food-companies

Key Takeaways

- Internal organs are usually discharged or used as raw material for fish meal/oil production.
- Cod and pollock livers are especially high in valuable omega-3 fatty acids. Niche markets also exist for cod milt and stomachs.

Production Volume

Alaska's fisheries produce approximately 700 million pounds of internal fish organs per year.[16] Not surprisingly, pollock accounts for the majority of internal organ production, followed by cod, flatfish, and the rockfish & Atka mackerel complex. Salmon organs yield relatively little production, compared to their overall harvest volume. Halibut and Black cod yield 5 to 8 million pounds of internal organs, combined. Fish organs, along with fish heads, comprise the vast majority of discharged seafood waste in Alaska.

Estimated Production of Internal Organs of Selected Alaska Species, in Million lbs., 2011-2016

	2011	2012	2013	2014	2015	2016P	2011-2015 Avg.	Internal Organ Yield Pct.
Pollock*	409.6	418.8	437.9	461.1	476.4	488.5	440.8	~15%
Cod*	100.8	108.8	105.4	110.5	106.2	101.1	106.3	~15%
Sole/Flounder/etc.	101.0	99.2	102.2	99.9	75.9	79.6	95.6	~14%
Rockfish & Atka Mackerel	27.7	27.6	22.3	25.6	32.6	33.4	27.2	~12%
Salmon*	20.4	16.6	29.2	18.3	29.1	14.7	22.7	2-3%
Halibut & Black Cod	8.3	7.4	7.0	5.6	5.6	5.1	6.8	11-12%
Total	**667.7**	**678.4**	**703.9**	**720.9**	**725.8**	**722.5**	**699.4**	**-**

*Does not include roe.
Note: 2016 estimates are based on preliminary harvest data.
Source: McDowell Group estimates.

It is not possible to get more detailed information about how much of each type of organ is available from Alaska's fisheries. This would require a more comprehensive yield guide than currently exists. Developing such a guide would make for a useful research project - particularly if each fish part was analyzed

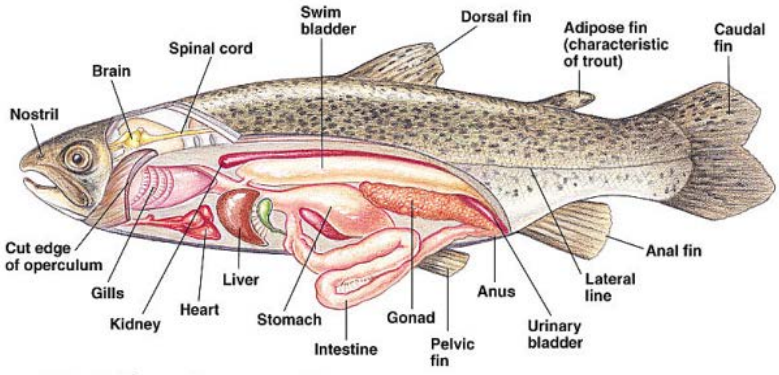


Image Credit: Oceanclassrooms.com.

[16] Including gills, hearts, livers, stomachs, intestines, some gonads, swim bladders, kidneys, and other internal viscera/parts.

for nutritional and proximate (e.g. water, protein, fats, etc.) content.

Markets and Uses for Internal Organs from Alaska Fish

Aside from roe and milt (to a much lesser extent), there is virtually no market for internal fish organs. The vast majority of internal organs derived from Alaska fish are either transformed into fish meal/oil or ground up and discharged as gurry. Fish meal/oil markets are covered extensively in a separate chapter; however, there are a few non-roe organ markets and uses worth mentioning.

Milt Markets & Uses

Markets for milt, the male fish gonad, are less common than those for roe, but do exist for some species, namely cod and salmon to a lesser extent. The Japanese word for cod milt is *shirako,* which translates to "white children" in English. Cod milt is an oddity in the United States, but is well respected in Japanese and Korean cultures. *Shirako* is often used in miso soups, sushi, or prepared tempura-style (breaded). Some chefs use it as a toast or cracker topping, similar to roe. Cod milt is uncommon in the U.S., but it certainly has a mystique and is occasionally referenced as one of the weirdest but tastiest things foodies report eating. One chowhound.com review calls it a "seminal dining experience." U.S. food writers are unanimous in their praise for the taste of cod milt preparations, and equally quick to point out the difficulty of marketing fish semen on a wider basis.

Nonetheless, it is a valuable niche product. At the right time of year (around February), processors can fetch a nice price for fresh cod milt if they are willing to airship product to Asia or niche buyers in the U.S. Edmonds, WA-based Tatoosh Seafoods sells frozen cod milt for about $1.20 per pound.[17] That may sound good for something that would otherwise be headed for the outflow pipe, but it takes a lot of cod milt to add up to something. At $1.20 per pound, it would take about 555 three-pound, male cod to produce $100 worth of cod milt. For further context, consider the value of cod milt relative to the flesh. A three-pound cod would produce two loins of approximately eight ounces, worth about $3.25 in wholesale markets. Milt from the same fish would be worth approximately $0.18, if it was the right time of year.

Livers

Fish livers are prized for their high oil content. This makes them excellent sources of raw material for supplement-grade fish oil products. Fish oil markets are discussed in greater detail in a separate chapter, beginning on page 19. Lipid (i.e. oil) content from Alaska fish livers vary widely by species. Peter Bechtel and Alexandra Oliveira published a useful analysis of Alaska fish livers in the Journal of Food Science in 2006 (link).

[17] http://www.seafoodnews.com/Story/961959/Alaska-Fish-Processors-Chase-Japanese-Market-For-an-Unusual-Product-Cod-Milt

Stomachs & Enzymes

Fish stomachs and intestinal tracts can be used to isolate potentially valuable enzymes, with unique properties. The problem, from a business standpoint, is that these compounds can often be synthetically copied in a lab after the fact, without the need for much, if any, additional raw material.

Niche markets for cod stomachs exist in Europe.

Key Takeaways

- Alaska fisheries have the volume to produce more fishmeal and fish oil. However, increasing production significantly may not be feasible given current technology and product value.
- The market for pet food/treats represents an intriguing growth opportunity. Alaska seafood is a highly marketable ingredient and processors can supply pet food manufacturers with several product forms made from waste streams: frozen/ground blocks, hydrolysates, or meals/powders. However, these products generally sell for very low prices, barely enough to cover the cost of shipping the frozen product. Raising the value of these minimally processed products by 10-20 cents/lb. or more could convert a significant volume of Alaska seafood waste into saleable product.
- There may be significant opportunity to expand the value of fish oil by directing the material into higher value markets/uses. Alaska processors burn over 70 percent of fish oil production as a diesel fuel supplement, and most of the unburned whitefish oil is sold as lower value product to animal feed manufacturers. Most fish oil is burned by at-sea processors, which allows ships to cut down on refueling trips and remain at sea longer.
- The market for fish oil supplements is growing rapidly, from annual sales of $130 million in 2002 to $1.15 billion in 2014.[18] The retail value of encapsulated fish oil products is on the order of $50,000/MT or more – far higher than the $1,169/MT average value of pollock oil in 2015. Producing refined fish oil for human consumption holds potential to increase the value of Alaska's fish oil production several fold (oil was worth $34 million in first wholesale terms in 2014). However, it is not clear 1) how much more wholesale value could be added, 2) whether the market could handle a large influx of fish oil supplement supply, and 3) how much it would cost Alaska processors to meet the requirements of fish oil supplement manufacturers and retailers.

Fishmeal and Fish Oil Production

The vast majority of Alaska fish meal/oil production utilizes pollock (81% of meal and 95% of oil by volume in 2015). Salmon is the next largest raw material species, and production is generally growing – particularly for salmon meal. Alaska produces approximately 60,000 to 80,000 MT of fishmeal and 20,000 to 30,000 MT of fish oil per year (not including fish oil burned as fuel, which is a significant volume – see next section).[19]

Fishmeal and oil production facilities are present in most large Alaska ports and large catcher-processors. The process requires specialized equipment to cook, filter, dry, grind, and press raw material (see Figure 1).

[18] https://www.washingtonpost.com/business/economy/claims-that-fish-oil-boosts-health-linger-despite-science-saying-the-opposite/2015/07/08/db7567d2-1848-11e5-bd7f-4611a60dd8e5_story.html?utm_term=.fa500f805692

[19] Data shown in Table 8 does not include meal/oil produced at the Kodiak Fishmeal Facility, which is considered a secondary producer that combines raw material from several Kodiak processors.

Interviews with processors suggest that Alaska has maximized shoreside meal/oil production in places where it is feasible. Some catcher-processors may benefit from adding meal/oil plants, and recent years have seen new or upgraded vessels feature meal/oil plants. However, based on current technology, vessel configuration, and product value there may be limited potential for additional production. Shoreside processors accounted for 60 percent of Alaska fishmeal production in 2014, with the remaining portion occurring at sea (catcher-processors and floating processors).

Table 8. Alaska Fishmeal and Oil Production, in Metric Tons, 2011-2016

	2011	2012	2013	2014	2015	2016
Meal (Fish+Bone)						
Pollock	52,930	52,529	53,869	56,852	61,027	64,819
Salmon	-	-	5,683	4,108	13,579	N/A
All Other	8,109	8,802	1,974	2,530	973	N/A
Total	**61,039**	**61,331**	**61,527**	**63,490**	**75,579**	**N/A**
Fish Oil						
Pollock	21,264	19,304	24,011	28,106	24,119	28,592
Cod	89	124	99	378	-	-
Salmon	410	1,022	990	943	1,403	**N/A**
Total	**21,763**	**20,450**	**25,100**	**29,427**	**25,522**	**N/A**
Meal+Oil Total	**82,802**	**81,781**	**86,627**	**92,917**	**101,101**	**N/A**

Notes: Value is based on FOB Alaska. "-" means data was not available due to confidentiality. See spreadsheet work file for more info. All Other category includes salmon in 2011+2012. Does not include production from the Kodiak Fishmeal Plant.
Source: ADFG (COAR) & NMFS - Alaska Region.

In 2015, Alaska harvesters caught 2,740 thousand MT of (round-weight) seafood. Not including meal/oil, Alaska processors sold 1,300 thousand MT, a yield of 47.5 percent. Alaska meal/oil operations utilized an estimated 395,000 to 483,000 round MT, or 14-18 percent of the total harvest volume (in round terms).[20] A rough estimate using these figures suggests that 28-34 percent of Alaska's 1.42 MMT of estimated seafood waste is directed to meal/oil plants, producing roughly 87,000 MT of meal and 28,000 MT of oil (after including production from Kodiak Fishmeal plant).

Table 9. Estimated Amount of Round Weight Utilized by Fishmeal Production, 2015

Fishmeal Yield	Estimated Round MT	Estimated Round Million Lbs.	Pct. Retained Harvest
18%	483,000	1,066	18%
20%	435,000	959	16%
22%	395,000	872	14%

Note: Figures have been rounded. Based on estimated 2015 total production of approximately 87,000 MT, including production from Kodiak Fishmeal Plant.
Source: McDowell Group estimates.

However, the estimate regarding the percentage of waste which undergoes meal/oil processing is likely on the low side, given that so much oil is captured for purposes of burning in generators. In these situations, the

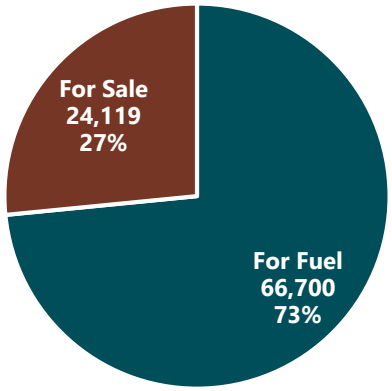
[20] Excluding fish oil produced for use as fuel.

remaining material may be converted to meal, sold as a hydrolysate, or discarded. More research is needed to compile actual data regarding the volume and nature of seafood waste. The figures in this section are rough estimates using disappearance calculations from ex-vessel and first wholesale data (as well as data supplied by Kodiak Fishmeal Company).

Fish Oil as Fuel

Most fish oil produced in Alaska is not sold, but is rather blended with diesel fuel and burned in diesel generators powering shoreside plants and large fishing/processing vessels. The vast majority of this fuel oil comes from pollock. Processors reported total pollock oil production of 90,813 MT to ADF&G (COAR) in 2015; however, NMFS records show only 24,119 MT of oil were produced for sale (27 percent of total production). This relationship may even be understated, as COAR figures tend to be underreported for federal fisheries.

Figure 1. Composition of Fish Oil Production in Alaska, in Metric Tons, 2015



Source: McDowell Group estimates, based on ADF&G and NMFS fish oil production data.

Fish oil is approximately 75 percent as efficient as low-sulfur #2 diesel (though if varies slightly depending on generator load and RPMs).[21] Therefore, it takes 100 gallons of fish oil to generate the same power/performance as 75 gallons of diesel. According to a study commissioned for the Alaska Industrial Development and Export Authority (AIDEA), fish oil used as fuel rarely has to be processed further, making it a convenient way to obtain better fuel efficiency.

Alaska pollock producers made approximately 17.8 million gallons of pollock fish oil in 2015 not intended for sale (but to be burned as boiler fuel). This amount of fish oil offsets approximately 13.4 million gallons of diesel fuel.

Fish oil burned as fuel has very real value. Diesel costs in Dutch Harbor ranged from $3.00-$3.50/gallon in 2015 (data link). Therefore, offsetting 13.4 million gallons of diesel fuel saved operators approximately $44 million (at

[21] ftp://ftp.aidea.org/BiomassEnergy/DemonstratingUseofFishOilasFuel.pdf

$3.25/gallon). The fuel value of fish oil depends on the price of diesel. Table 10 shows the value/MT of fish oil used as fuel at varying diesel prices.

The value of fish oil used as fuel compared to the market value of pollock fish oil suggests processors should be selling as much oil as possible (as opposed to using it as fuel) so long as diesel prices remain under $5.00/gallon. At $3.00/gallon, pollock fish oil producers gave up approximately $450 per MT by burning the oil as fuel.

However, industry interviews suggest that some at-sea processors often burn fish oil because they lack the storage space necessary to hold oil. Also, burning fish oil as it is produced allows vessels to remain at sea for longer periods of time and maximize fishing time. Shoreside processors may burn fish oil depending on the plant configuration, storage limitations, lack of markets, or other constraints.

Table 10. Value/MT of Alaska Pollock Fish Oil Used as Fuel Depending on Diesel Prices

Diesel Price/Gallon	Fish Oil as Fuel Value/MT
$2.50/gallon	$582
$3.00/gallon	$699
$3.50/gallon	$815
$4.00/gallon	$932
$4.50/gallon	$1,048
$5.00/gallon	$1,164

Source: McDowell Group estimates.

Fishmeal and Fish Oil Value

Fishmeal and fish oil generates approximately $120 to $150 million per year for Alaska processors (excluding production value stemming from the Kodiak Fishmeal Plant). The majority of the value is created by fishmeal, but fish oil is more valuable product on a per ton basis and generally part of the fishmeal production process.

Pollock meal tends to be more valuable than salmon meal, whereas salmon oil is usually two to three times more valuable than fish oil made from pollock. This is likely because a larger percentage of salmon oil is currently produced for human consumption, and even lower grade salmon oil fetches a higher value from pet food producers compared to pollock oil. Fish oil derived from pollock is generally used in lower value animal feed production or other less valuable uses (compared to salmon). However, several Alaska processors have recently begun to further refine whitefish oil for human consumption and this trend is expected to continue.

See table on following page.

Table 11. Alaska Fishmeal and Oil First Wholesale Value, in $000s, 2011-2015

	2011	2012	2013	2014	2015
Meal (Fish+Bone)					
Pollock	85,142	87,287	100,956	101,985	110,560
Salmon	-	-	5,683	4,108	13,579
All Other	12,949	7,946	4,169	3,913	1,693
Total	**98,090**	**95,233**	**110,808**	**110,006**	**125,832**
Fish Oil					
Pollock	24,256	22,056	28,406	31,165	28,195
Cod	-	-	-	-	-
Salmon	1,203	2,540	3,196	2,866	4,408
Total	**25,459**	**24,596**	**31,602**	**34,031**	**32,603**
Meal+Oil Total	**123,550**	**119,829**	**142,411**	**144,037**	**158,435**

Notes: Value is based on FOB Alaska. "-" means data was not available due to confidentiality. See spreadsheet work file for more info. All Other category includes salmon in 2011+2012. Does not include production from the Kodiak Fishmeal Plant.
Source: ADFG (COAR) & NMFS - Alaska Region.

Table 12. Alaska Fishmeal and Oil First Wholesale Value per Metric Ton, 2011-2015

	2011	2012	2013	2014	2015
Meal (Fish+Bone)					
Pollock	1,609	1,662	1,874	1,794	1,812
Salmon	-	-	1,671	1,558	925
All Other	1,597	903	2,112	1,547	1,740
Total	**1,609**	**1,662**	**5,657**	**4,899**	**4,476**
Fish Oil					
Pollock	1,141	1,143	1,183	1,109	1,169
Cod	-	-	-	1,394	1,749
Salmon	2,938	2,486	3,227	3,038	3,143
Total	**1,170**	**1,203**	**1,259**	**1,156**	**1,277**

Notes: Value is based on FOB Alaska. "-" means data was not available due to confidentiality. See spreadsheet work file for more info. All Other category includes salmon in 2011+2012. Does not include production from the Kodiak Fishmeal Plant.
Source: ADFG (COAR) & NMFS - Alaska Region.

Retail vs. Wholesale Fish Oil Estimates

Information about retail Costco prices and estimates about Costco markups was used to estimate the wholesale value of fish oil products, both from Alaska and generic varieties. According to Wikipedia and several other online sources, Costco Kirkland Signature products have a 15 percent markup.

There is a considerable difference in price for Alaska salmon oil (Pure Alaska Omega brand) versus generic Alaska fish oil (Kirkland Signature brand). While the fact that Pure Alaska Omega is a manufacturer brand could partly explain the higher price, salmon oil is still clearly more valuable than other oil products. The data below suggest the wholesale value of Alaska fish oil is extremely high; however, some additional explanation is required. It is important to note the figures below reflect estimated gross wholesale value. The estimated wholesale value for supplement products includes the following costs: processing, shipping, marketing, regulatory, administrative, or research. The potential to convert roughly 90,000 MT of fish oil to human grade

product at $50,000-$75,000/MT is tantalizing. Selling 90,000 MT of Alaska fish oil for $50,000 to $75,000 would roughly double the first wholesale value of all Alaska seafood; however, there are supply/demand forces to consider even outside the obvious production challenges in Alaska. Significant increases in supply almost always result in lower prices. It is unlikely that the supplement fish oil market could quickly absorb such a large increase in supply. Still, the difference in fish oil value is an interesting finding.

REGULAR KIRKLAND SIGNATURE FISH OIL (1000MG/PILL – 400CT.) – UNIT PRICE: $11.49

- Product net weight in grams: 400g
- Retail Cost per 100g: $2.87
- Estimated Costco Markup: 15%
- Estimated Wholesale Value per 100g: $2.44
- Daily Servings per Bottle: 200
- Cost per Daily Serving: $0.06
- Species Used: Anchovy and Sardines

REGULAR KIRKLAND SIGNATURE FISH OIL (1200MG/PILL – 180CT.) – UNIT PRICE: $16.99

- Product net weight in grams: 216g
- Retail Cost per 100g: $7.87
- Estimated Costco Markup: 15%
- Estimated Wholesale Value per 100g: $6.69
- Daily Servings per Bottle: 180
- Cost per Daily Serving: $0.09
- Species Used: Anchovy and Sardines

PURE ALASKA OMEGA SALMON OIL (1000MG/PILL – 180CT.) – UNIT PRICE: $16.99

- Product net weight in grams: 180g
- Retail Cost per 100g: $9.44
- Estimated Costco Markup: 20%
- Estimated Wholesale Value per 100g: $7.55
- Estimated Wholesale Value per MT: $75,511
- Daily Servings per Bottle: 90
- Cost per Daily Serving: $0.19
- Species Used: Alaska Salmon

KIRKLAND SIGNATURE ALASKA FISH OIL (1400MG/PILL – 180CT.) – UNIT PRICE: $16.99

- Product net weight in grams: 322g
- Retail Cost per 100g: $6.21
- Estimated Costco Markup: 15%
- Estimated Wholesale Value per 100g: $5.28
- Estimated Wholesale Value per MT: $52,769
- Daily Servings per Bottle: 230
- Cost per Daily Serving: $0.09
- Species Used: Alaska pollock, cod, and salmon

Specific information regarding encapsulation costs could not be found, though anecdotal reports suggest fish oil is often encapsulated in Canada. The wholesale values above are likely on the high side, as they include all costs outside of the retail markup.

Bone Meal: Fertilizers and Soil Remediation

Alaska processors also produce bone meal products derived from leftover ash after fishmeal processing. Since Alaska fishmeal generally involves using heads and frames, there is a substantial bone (i.e. ash) content in the raw material. Fishmeal buyers prefer to minimize the amount of ash, generally less than 20 percent.

NMFS pollock fishmeal statistics aggregate fishmeal and bone meal into one figure for publication. Based on COAR data, pollock bone meal accounts for an estimated 14 percent of total pollock meal production by volume.

Based on COAR data, bone meal products derived from pollock are much less valuable than whitefish fishmeal. Bone meal was quoted at roughly $100-$300/MT in recent years, while fishmeal was valued at $1,800-$1,875/MT.

Contextual Information

Fishmeal and oil are important products for pollock producers. Meal/oil accounted for 10.1 percent of first wholesale pollock value in 2015. The relative importance of meal/oil has grown in recent years.

Table 13. Alaska Fishmeal and Oil, Pct. of Production and Value, 2011-2015

	2011	2012	2013	2014	2015
Total FW Production (MT)					
Pollock	513,750	510,890	546,410	580,200	580,710
Salmon	244,226	207,924	324,970	232,926	340,617
Total	**1,216,594**	**1,191,141**	**1,317,253**	**1,279,596**	**1,350,551**
Total FW Value ($M)					
Pollock	1,424	1,468	1,335	1,407	1,378
Salmon	1,421	1,287	1,801	1,393	1,451
Total	**4,588**	**4,505**	**4,563**	**4,277**	**4,255**
MEAL - Pct. of Volume					
Pollock	10.3%	10.3%	9.9%	9.8%	10.5%
Salmon	-	-	1.7%	1.8%	4.0%
Total	**5.0%**	**5.1%**	**4.7%**	**5.0%**	**5.6%**
MEAL - Pct. of Value					
Pollock	6.0%	5.9%	7.6%	7.2%	8.0%
Salmon	0.1%	0.2%	0.2%	0.2%	0.3%
Total	**2.1%**	**2.1%**	**2.4%**	**2.6%**	**3.0%**
OIL - Pct. of Volume					
Pollock	4.1%	3.8%	4.4%	4.8%	4.2%
Salmon	0.2%	0.5%	0.3%	0.4%	0.4%
Total	**1.8%**	**1.7%**	**1.9%**	**2.3%**	**1.9%**
OIL - Pct. of Value					
Pollock	1.7%	1.5%	2.1%	2.2%	2.0%

Salmon	0.1%	0.2%	0.2%	0.2%	0.3%
Total	**0.6%**	**0.5%**	**0.7%**	**0.8%**	**0.8%**
MEAL+OIL - Pct. of Volume					
Pollock	14.4%	14.1%	14.3%	14.6%	14.7%
Salmon	-	-	2.1%	2.2%	4.4%
Total	**6.8%**	**6.9%**	**6.6%**	**7.3%**	**7.5%**
MEAL+OIL - Pct. of Value					
Pollock	7.7%	7.4%	9.7%	9.5%	10.1%
Salmon	0.2%	0.4%	0.4%	0.4%	0.6%
Total	**2.7%**	**2.7%**	**3.1%**	**3.4%**	**3.7%**

Notes: Value is based on FOB Alaska. "-" means data was not available due to confidentiality. See spreadsheet work file for more info. All Other category includes salmon in 2011+2012. Does not include production from the Kodiak Fishmeal Plant.
Source: ADFG (COAR) & NMFS - Alaska Region.

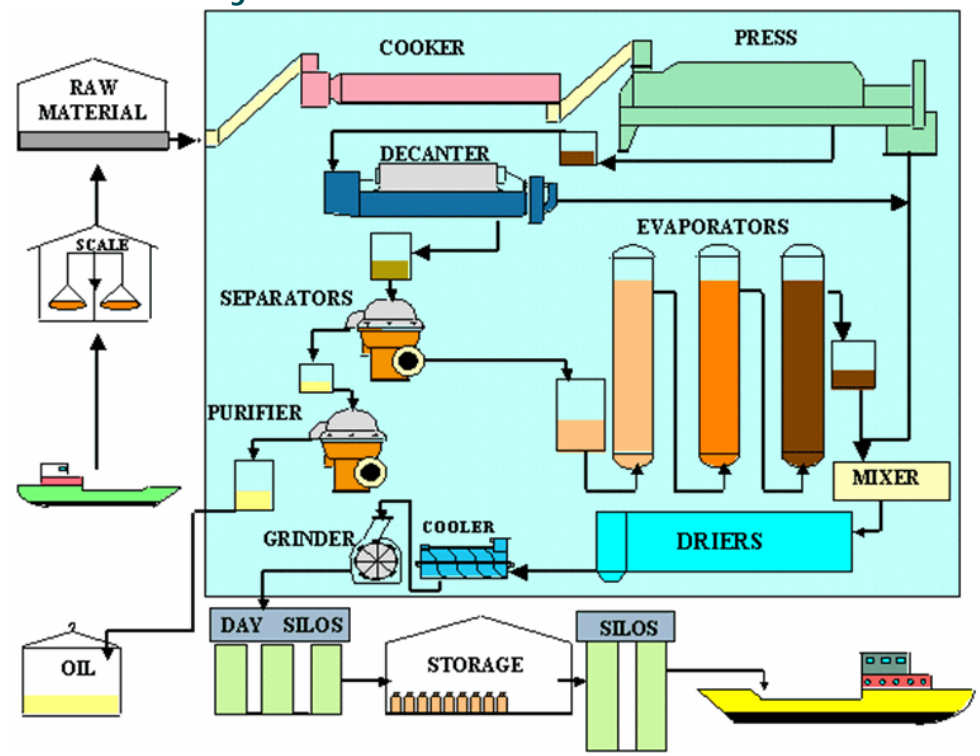
Seasonal Availability & Suppliers

Fishmeal and oil are shelf-stable products which do not require refrigeration and as such are available year-round. Production timing is a function of wild fishery seasons. Fish paste is available as a frozen product, generally during or shortly after fishery seasons, so availability and timing is dependent upon the species/area and storage capacity for the product.

The Alaska Seafood Suppliers Directory (link), hosted by the Alaska Seafood Marketing Institute, contains contact information for Alaska fishmeal and fish oil suppliers.

Technical Information

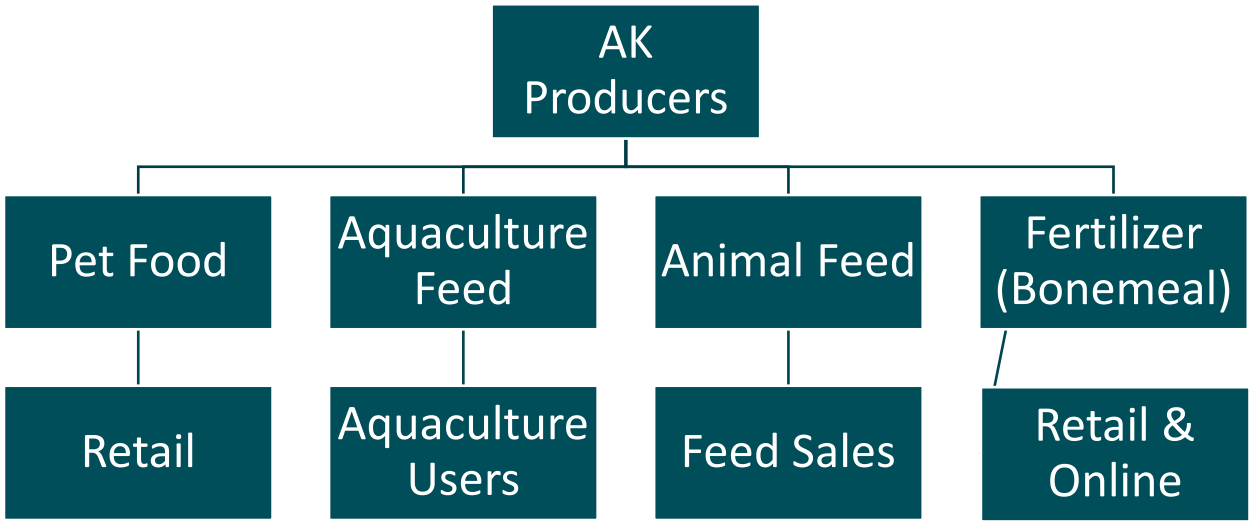
Figure 2. Fishmeal and Oil Production Process



Source: IFFO.

Supply Chain

Figure 3. Alaska Fishmeal & Pet Food Paste Supply Chain



Uses and Supply Chain for Alaska Fishmeal

1. On-site boiler/generator fuel

2. Aquaculture Feed Manufacturers -> Aquaculture Users

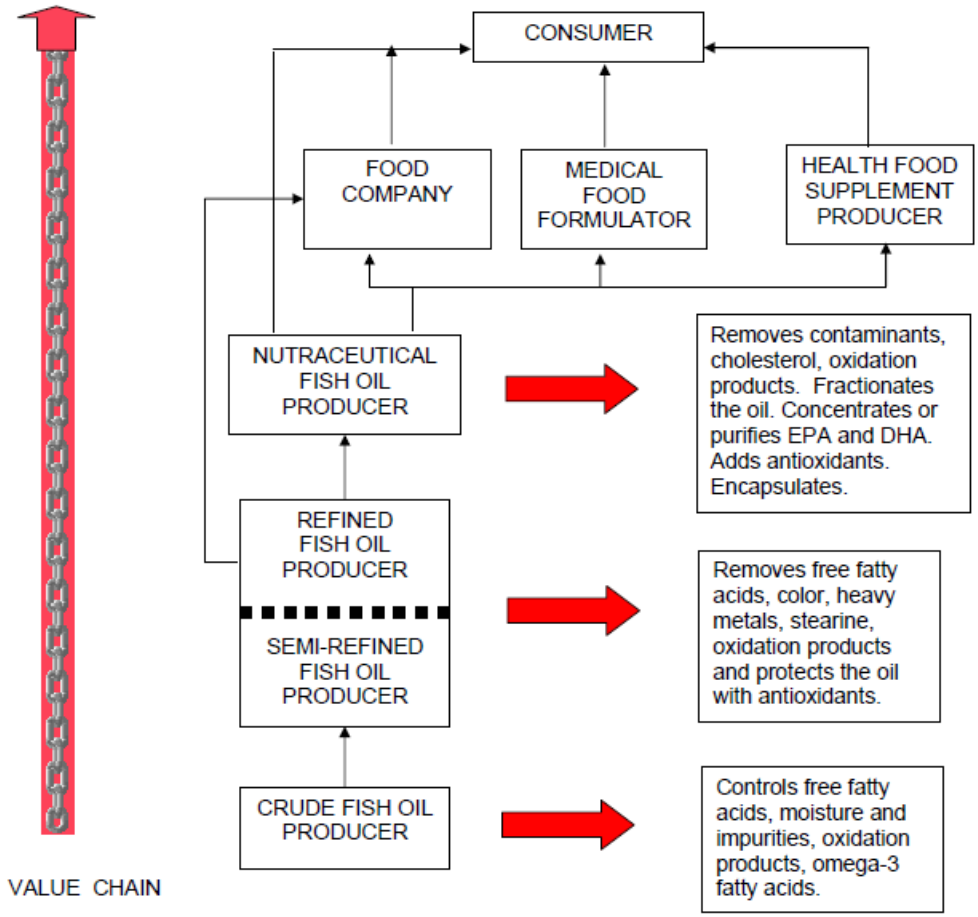
3. Fish Oil Refiners -> Retailers

4. At least two Alaska processors produces fish oil for retail (Trident for Costco's Kirkland Brand and AGS), some others may also produce oil for store/other branded products.

The supply chain for human grade fish oil supplements is complex and adds a tremendous amount of value. Commodity grade whitefish oil can sell for $1,100-$1,200/MT while similar grade salmon oil is worth 40-50 percent more. However, the retail value of fish oil can exceed $80,000/MT. Unlike other seafood products which lose a considerable amount of weight as it travels from raw material to retail product, oil (once produced) does not lose much weight as finished product.

See following page for fish oil supply chain diagram.

Supply Chain for Human Grade Fish Oil



Source: Anthony Bimbo (link).

Markets and Uses for Fishmeal and Fish Oil

Based on interviews with industry members, a large portion of Alaska's pollock fishmeal is sold to Asian farmed eel producers. Some Alaska whitefish meal producers also sell fishmeal to farmed turtle producers in Asia. The binding properties of pollock fishmeal creates a product that can be formed into balls which work well for feeding eels. It is likely that Alaska whitefish meal is also used in other aquaculture feeds or those used to feed pigs/chickens.

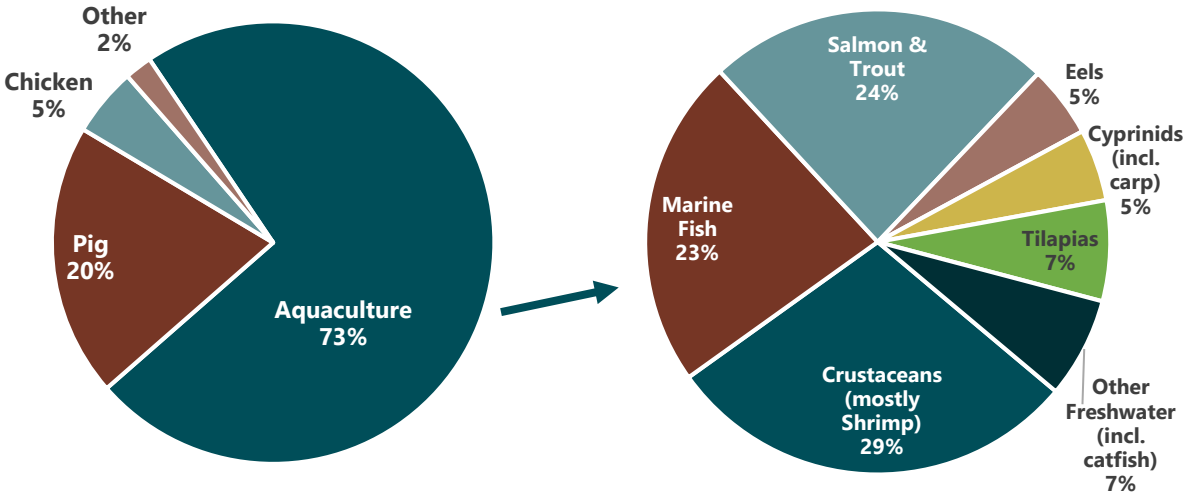
Salmon meal and other less refined salmon by-products are often sold to pet food manufacturers, though may also be sold to other animal feed manufacturers as well. Salmon meal generally sells at a discount to pollock meal, probably due to the fact that salmon meal often contains a higher percentage of ash and some products have a lower protein content.

Fish bones have been shown to have beneficial properties for remediating and fertilizing soil. A July 2011 New York Times article chronicled the unique ability of pollock bone meal to bind to toxic lead contamination within soil and create a new compound which is safe for humans even if consumed. A project in a West Oakland

neighborhood remediated soil in a six-block area at a cost of $4 million. Lead contamination is a widespread problem in urban areas, as well as some federal lands.

Figure 4 summarizes the use of fishmeal worldwide. Aquaculture uses the majority of fishmeal, and the composition of aquaculture users is diverse.

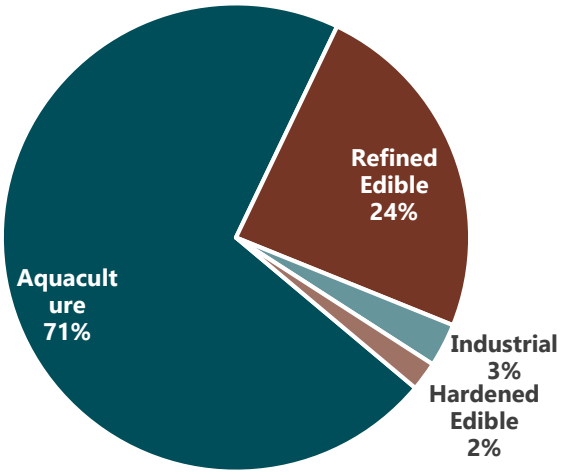
Figure 4. Global Fishmeal Use by Sector, 2010



Source: IFFO Statistical Yearbook, 2016 (via Seafish).

Most fish oil is also consumed by aquaculture producers who mix it into feeds, especially for species such as salmon which require feeds with higher oil content. Interestingly, the volume of refined fish oil, generally in the form of liquid omega 3 products, has increased substantially. Twenty years ago, the majority of fish oil was converted into "hardened edible" products that were used almost entirely in margarines and shortenings. See Figure 5 for fish oil use by sector.

Figure 5. Global Fish Oil Use by Sector, 2010



Source: IFFO Statistical Yearbook, 2016 (via Seafish).

Pet Food Markets

Scott Lehouiller from the Peterson Company (a pet food manufacturer) provided informative comments pertaining to selling Alaska seafood into pet food markets:

- Pet food manufacturers require low cost protein sources. Sourcing product from responsible fisheries or those with positive social/marketing aspects can also add value.
- Peru, Chile, and Norway currently supply a significant volume of meal to U.S. pet food manufacturers. These large scale producers convert raw material to meal in order to eliminate moisture and make the product shelf stable so it can be shipped without refrigeration (which adds significant cost for ocean freight), also then you're paying less to essentially ship water.
- Some producers will grind and freeze raw material into blocks. While this product is cheaper, it also contains lower percentages of protein and buyers essentially pay a lot of shipping costs to transport water.
- Ash content of 16-17 percent or more can be problematic. Higher ash content leaves less room for protein for pet food manufacturers. Salmon meal is a good material for pet food in one regard, because of the higher omega-3 content of the oil in the meal, however ash levels in Alaska salmon tend to range from 20-23 percent (based on specifications from the Kodiak Fishmeal Company). Norsildmel, a Chilean Salmon Meal producer, sells a product with 15 percent maximum ash (link).
    - However, other Alaska seafood industry members have said that a lot of Alaska salmon meal does go to pet food markets. It is likely that these buyers value the marketability and are willing to accept more ash in the meal in order to leverage the branding attributes of Alaska salmon.

Alaska industry contacts report that ground/frozen raw material can fetch prices of 22-27 cents/lb. delivered to the U.S. Midwest (where many pet food manufacturers operate). Alaska producers selling minimally processed frozen products may have better luck selling to pet food manufacturers in the Pacific Northwest, as doing so could decrease shipping costs somewhat (perhaps 2-6 cents/lb.).

Given the price of shipping frozen blocks/totes is around 20-30 cent/lb., Alaska producers would likely need to receive CIF prices of 40 cents/lb. or better to stimulate a significant volume of sales. This might not sound like much, but retail prices of dry dog food generally range from $0.45 to $2.00 per pound (though some organic/boutique brands can $5.00). So adding 20 cents/lb., or $4.00 to a 20 lb. bag is a significant cost for pet food producers.

In general, Alaska producers would be well served to understand the protein content of potential product forms, as that will drive value in the pet food market. It is also important to understand shipping costs and price differences for various product forms: unground/frozen, ground/frozen, frozen paste (concentrates/etc.), or dried meal.

The Pet Food Institute (www.petfoodinstitute.org) is good place to find pet food manufacturers, who may be interested in buying raw materials from Alaska producers. The group has a large list of members.

FURTHER RESEARCH POTENTIAL

Obtaining Nielsen retail sales data regarding sales of specific pet food products could provide valuable marketing material. If the "Alaska premium" can be quantified in terms of price premium and growth prospects, by market, versus other pet food/treats, this could provide a measure of willingness on the part of buyers to pay more for Alaska seafood/salmon thus elevating Alaska product above the basic commodity value. Competing against commoditized protein products from around the world may prove challenging for Alaska producers.

Research Findings about the Health Benefits of Fish Oil

Many studies have been conducted aiming to learn more about the health benefits of fish oil supplements. The following studies support health benefit claims for fish oil:

- Mayo Clinic article summarizing the strongest benefits of Omega-3 supplements supported by research (graded A-D, according to research findings)… "A" grade benefits include: coronary heart disease, high blood pressure, and rheumatoid arthritis.
- Optometrists often encourage patients with dry eyes to take fish oil supplements to increase tear production. With people looking at electronic screens more and more, this can be an important source of fish oil demand. Supportive research. AAO Endorsement.
- Not formal research, but there are scores of comments on Alaska fish oil products; most are overwhelmingly positive: Amazon Pure Alaska Omega.
    - A few people mentioned improved nail growth after taking fish oil supplements. It would be interesting to study whether fish oil could improve hair thickness as well. Obviously, the value of hair-thickening properties would be quite valuable.

Not all studies about fish oil benefits are supportive, the following links generally contain negative information about the link between health benefits and fish oil supplements:

- Correlation between higher omega-3 in blood and prostate cancer (link).
- NYT ran a story entitled "Fish Oil Claims Not Supported by Research" (link).
- The NCCIH website is generally dismissive of benefits (link).

Alaska Fish Oil and Meal Products

Most Alaska fishmeal products are sold to industrial customers and are not branded, or simply utilize the name of the producing company. However, consumer fertilizer products are branded. Alaska processors generally sell bone meal and fishmeal to secondary production companies which sell their products to retailers or online.

Table 14. Retail Products Containing Alaska Meal/Oil

Consumer Product	AK Company	Product Type	Retail Cost/lb.	WebLink
Glacier Harvest Fish Oil	Silver Bay Seafoods	Fish Oil	N/A	N/A
Kirkland Signature Wild Alaskan Fish Oil	Trident Seafoods	Fish Oil	$28.34	Link
Pure Alaska Omega Wild Alaska Salmon Oil	Trident Seafoods	Fish Oil	$42.80	Link
Alaska Fish Bone Fertilizer	Alaska Sea-Ag LLC	Fertilizer	$1.80	Link

Competing Fishmeal and Fish Oil Supply

- Algae generally contain higher ratios of LC Omega 3's. Using a 30 percent EPA/DHA equivalence, algae O3 oil production was 5,000 MT in 2011, and is projected to be 30,000 MT by 2017 (source).
- KRILL: Antarctic krill biomass estimated to be 200-400 million metric tons. Managed by CCAMLR who have set a TAC of 5 million MT with a "trigger" level of 620,000 MT. Current catches are around 200,000 MT/year. Aker Biomarine has obtained MSC certification.
- GM Oil Seeds: Monsanto sells an "Omega-3-Enhanced Soybean Oil" (source). Large biotech firms are working on finding a plant-based Omega-3 source for the aquaculture industry. Fish oil is a critical limiting factor for aquaculture. "If you look back only 15 years ago, we were using 100% fish oil in salmon feed. Today almost 70% of fish oil is being replaced by vegetable derived oils in Europe such as rapeseed oil and poultry oil in Americas/Asia" according to a Alex Obach, managing director of Skretting Aquaculture Research in this article.
- GM free feed vs. GMO feed is also an issue. Using GM free feed produces a premium product for aquaculture producers. Still, it seems if a plant-based Omega-3 oil can be brought to market at a lower price than fish oil, it could stimulate a large increase in aquaculture production.
- This link provides a good summary of competing fishmeal and oil production.

Opportunities

Fish oil has a significant range of value, depending on the market product is sold into. From $1,100-$1,200/MT for industrial feed use (even lower for biodiesel) to perhaps over $50,000 for human supplements. However, industry members we spoke with did not feel that the industry would be converting significant volumes of fish oil to supplement-grade quality any time soon. Despite the pessimism, demand for fish oil supplements is growing (from $130 million in 2002 to $1.15 billion in 2014, according to Euromonitor via this Washington Post article). Selling more Alaska fish oil to the fish oil nutraceutical supplement market would likely add more value to the state's seafood resource, but would create additional costs that may require further study.

The pet food industry is extremely competitive and many manufacturers use ingredient quality and sourcing as key marketing points. Quantifying the premium value of using Alaska seafood may provide encourage buyers to use Alaska fishmeal or hydrolysate/paste products, and justify a higher value for Alaska products.

Alaska's seafood industry creates vast quantities of waste which could be transformed into meal and oil. However, conventional meal and oil processing methods are not capable of achieving full resource utilization profitably. Advancing meal/oil processing techniques to deal with smaller or more volatile waste streams could unlock a significant volume of additional meal/oil production in Alaska.

Challenges

Meal and oil production requires large volumes of fish and ideally entering the plant each day in consistent volumes. Unfortunately, wild fishery harvests are inherently variable, especially for salmon. Meal and oil plants are also expensive. Producers noted meal/oil plants typically cost between $25-$35 million. Due to the size of the investment, annual production must be significant to make new meal/oil plants feasible.

One industry veteran interviewed for this project was very clear that Alaska meal/oil production is at or near its maximum now. He did not believe there is much additional supply sitting out there that would be feasible, at least for meal/oil. He also noted that feasibility, cost and product value, varies greatly depending on the place and the product. "Everyone wants to do human grade fish oil, but doesn't understand the complexity of getting into that market," the contact added.

There is not a standard type of equipment or meal/oil process used across Alaska. The variation in equipment and species makes it inherently hard to do generic marketing because different processors are likely to have different markets.

Alaska's remote location and spread out activities makes it difficult to add value to fish oil products. Whereas if all or most of Alaska's production centered around a specific area or port, processors could focus more intently on producing high quality, human-grade oil.

Key Takeaways

- Roe value, in absolute terms and as a percentage of total first wholesale value, has declined significantly over the past decade (outside of exceptional circumstances in 2012 and 2013). Still, roe remains a critical, high value product for Alaska seafood producers. Unlike tradeoffs between pollock fillets vs. surimi, or canned salmon vs. frozen H&G production, there is no offsetting value for losing roe value.
- Alaska faces difficult challenges in roe markets:
    - A strong U.S. dollar, which makes Alaska product more expensive to foreign buyers and foreign competitors product relatively less expensive
    - A rise in Western eating habits in core Asian markets that results in less roe consumption per capita
    - Russian embargo and political/fiscal turmoil in the Ukraine
    - Competition for Russian producers
    - Oversupply in pollock roe markets
    - Variability in supply and quality for salmon roe
- Increasing the value of Alaska roe products will require the industry to do one or both of the following:
    - Develop alternative markets for traditional roe products, either in existing or new markets
    - Develop new roe products that make use of low to medium grade roe.

Alaska Fisheries with Emphasis on Roe

- Pollock roe – BSAI/GOA – A season (beginning in late Jan through early March) & B season (Sep/Oct)
- Cod roe – BSAI/GOA - March
- Rock sole roe – February/March
- Herring Sac Roe Fisheries – Sitka Sound, Togiak, Kodiak - March/April
- Herring Spawn on Kelp "Pound" Fisheries – Southeast, PWS, and Norton Sound - March/April
- Salmon roe – Various, timing depends on species/region
- Sea Urchins – Southeast Dive Fisheries – October/November

Japanese Names of Roe Products

Japan is the primary market for Alaska roe products, although they are consumed in South Korea and other niche markets. Japanese names for popular roe products are shown below.

Alaska Species

Ikura	Salted salmon roe separated from skeins
Kazunoko	Herring roe (usually pickled)
Komochi konbu	Herring roe on kelp
Mentaiko	Marinated/spiced pollock roe (same name used for cod roe)
Sujiko	Salted salmon roe, prepared in skein

Tarako	Salted pollock roe (same name used for cod roe)
Uni	Sea urchin roe

Non-Alaska Species

Ebiko	Shrimp roe
Karasumi	Mullet roe
Masago	Capelin roe
Tobiko	Flying fish roe

Alaska Roe Production & Value

The following tables show production volume and first wholesale value for Alaska roe products.

Table 15. Alaska Pollock Roe Production and Value, 2005-2016

Year	RW Harvest (MT)	Roe Volume (MT)	FW Roe Value ($Millions)	Roe Pct. of Value	FW Value/MT	Roe Yield	FW Value in JPY/KG
2005	1,545,500	26,130	354.8	26.7%	13,578	1.69%	1,426
2006	1,561,800	29,970	291.5	22.4%	9,726	1.92%	1,022
2007	1,409,700	30,470	262.0	20.5%	8,599	2.16%	1,014
2008	1,044,400	20,790	241.9	17.6%	11,635	1.99%	1,405
2009	856,800	18,490	162.9	15.3%	8,810	2.16%	945
2010	888,400	16,450	98.0	8.9%	5,957	1.85%	550
2011	1,281,900	19,290	152.9	10.7%	7,926	1.50%	715
2012	1,310,200	18,160	169.2	11.5%	9,317	1.39%	770
2013	1,370,100	16,120	115.6	8.7%	7,171	1.18%	562
2014	1,442,900	24,120	148.2	10.5%	6,144	1.67%	572
2015	1,490,800	21,870	103.6	7.7%	4,737	1.47%	484
2016	1,528,196	14,785	N/A	N/A	N/A	0.97%	N/A

Note: 2016 data is preliminary.
Source: NMFS Economic SAFE Reports.

Table 16. Alaska Cod Roe Production and Value, 2011-2016

Year	RW Harvest (MT)	Roe Volume (MT)	FW Value ($Millions)	FW Value/MT	FW Value in JPY/KG
2011	305,300	3,170	$4.9	$1,546	162
2012	328,900	3,860	$7.1	$1,839	193
2013	318,900	4,380	$9.1	$2,078	218
2014	334,200	5,250	$11.7	$2,229	234
2015	321,100	3,710	$6.3	$1,698	178
2016	286,898	2,860	N/A	$1,546	N/A

Note: Data was unavailable prior to 2011. 2016 data is preliminary.
Source: NMFS Economic SAFE Report (2015).

Table 17. Alaska Herring Roe Production and Value, 2005-2016

Year	Sac Roe GHL (ST)	Sac Roe Harvest (R.Wt - ST)	Est. Sac Roe Yield (ST)	FW Value* ($Millions)	FW Volume (ST)	FW Value in JPY/KG
2005	1,545,500	32,278	3,408	$45.2	37,098	141
2006	1,561,800	33,920	3,364	$33.7	36,376	107
2007	1,409,700	28,703	3,080	$38.8	27,594	163
2008	1,044,400	34,820	3,516	$53.9	37,829	165
2009	856,800	31,347	3,446	$57.5	39,200	170
2010	888,400	44,230	4,821	$59.5	51,980	133
2011	1,281,900	42,306	4,928	$43.4	45,660	110
2012	1,310,200	30,252	3,270	$46.1	31,208	171
2013	1,370,100	33,298	3,381	$46.9	40,888	133
2014	1,442,900	42,969	4,768	$41.1	43,951	108
2015	1,490,800	30,350	3,463	$30.4	30,619	115
2016	1,528,196	24,929	2,528	N/A	N/A	N/A

* Includes food/bait and pound fisheries, which are relatively small compared to sac roe fisheries.
Source: ADF&G (Annual Management Reports and Management Announcements), compiled by McDowell Group.

Table 18. Alaska Salmon Roe Production and Value, 2005-2016

Year	RW Harvest (MT)	Roe Volume Sold (MT)	FW Value ($Millions)	FW Value/MT	Roe Produced (MT)	FW Value in JPY/KG
2005	425,197	11,541	$97.9	8,487	12,381	939
2006	323,733	10,391	$110.4	10,625	9,774	1,231
2007	418,765	10,972	$127.2	11,591	12,002	1,355
2008	311,105	8,589	$203.8	23,723	8,603	2,594
2009	319,785	10,435	$134.0	12,846	10,539	1,221
2010	360,863	12,321	$187.6	15,224	12,264	1,303
2011	347,811	10,031	$179.1	17,852	12,530	1,376
2012	287,457	9,256	$247.9	26,783	9,603	2,108
2013	473,953	15,697	$353.6	22,528	17,419	2,205
2014	320,232	9,814	$168.9	17,213	9,703	1,772
2015	488,394	15,483	$179.7	11,607	15,671	1,431
2016	270,573	8,042	$147.9	18,390	8,119	1,862

Note: Roe yield based on roe production, not roe sales.
Source: ADOR (Alaska Salmon Production Reports).

Table 19. Alaska Pink Salmon Roe Production and Value, 2005-2016

Year	RW Harvest (MT)	Roe Volume Sold (MT)	FW Value ($Millions)	FW Value/MT	Roe Yield	FW Value in JPY/KG
2005	247,689	7,018	$53.1	$7,564	3.0%	837
2006	121,907	4,520	$41.2	$9,125	3.1%	1,057
2007	224,734	6,482	$71.4	$11,014	3.0%	1,287
2008	131,129	4,040	$92.3	$22,850	3.2%	2,499
2009	139,887	5,146	$53.3	$10,365	3.5%	985
2010	180,415	6,586	$96.1	$14,594	3.7%	1,249
2011	177,122	5,067	$79.9	$15,760	4.0%	1,215
2012	111,739	3,799	$93.5	$24,616	3.4%	1,937
2013	307,791	10,057	$209.4	$20,820	3.7%	2,038
2014	147,176	5,245	$81.1	$15,462	3.6%	1,592
2015	286,462	9,307	$83.9	$9,019	2.9%	1,112
2016	72,680	2,051	$34.8	$16,962	2.6%	1,718

Note: Roe yield based on roe production, not roe sales.
Source: ADOR (Alaska Salmon Production Reports).

Table 20. Alaska Chum Salmon Roe Production and Value, 2005-2016

Year	RW Harvest (MT)	Roe Volume Sold (MT)	FW Value ($Millions)	FW Value/MT	Roe Yield	FW Value in JPY/KG
2005	40,135	1,568	$21.2	$13,539	4.7%	1,498
2006	76,403	3,275	$50.6	$15,459	4.5%	1,791
2007	54,122	2,012	$35.2	$17,508	4.9%	2,047
2008	63,720	2,228	$75.3	$33,815	3.4%	3,698
2009	53,282	2,413	$48.5	$20,094	5.0%	1,909
2010	57,724	2,790	$58.1	$20,823	4.9%	1,782
2011	50,519	2,153	$62.2	$28,874	4.8%	2,226
2012	68,357	3,125	$116.6	$37,293	5.0%	2,935
2013	68,067	3,214	$103.1	$32,077	5.3%	3,139
2014	41,930	1,859	$50.9	$27,384	3.7%	2,819
2015	58,519	3,009	$68.4	$22,714	6.5%	2,800
2016	53,698	2,462	$71.8	$29,155	4.7%	2,952

Note: Roe yield based on roe production, not roe sales.
Source: ADOR (Alaska Salmon Production Reports).

Table 21. Alaska Sockeye Salmon Roe Production and Value, 2005-2016

Year	RW Harvest (MT)	Roe Volume Sold (MT)	FW Value ($Millions)	FW Value/MT	Roe Yield	FW Value in JPY/KG
2005	118,981	2,732	$21.8	$7,977	2.4%	883
2006	107,259	2,173	$14.8	$6,808	2.0%	789
2007	126,058	2,321	$19.1	$8,225	1.9%	961
2008	99,686	2,009	$29.8	$14,816	2.0%	1,620
2009	112,951	2,678	$29.9	$11,157	2.5%	1,060
2010	108,016	2,642	$29.7	$11,255	2.3%	963
2011	108,481	2,652	$34.4	$12,984	2.7%	1,001
2012	95,981	2,190	$34.7	$15,854	2.3%	1,248
2013	80,934	2,109	$35.0	$16,596	2.7%	1,624
2014	109,672	2,466	$33.0	$13,379	2.2%	1,377
2015	130,635	2,922	$24.6	$8,405	2.5%	1,036
2016	129,800	3,311	$37.1	$11,203	2.6%	1,134

Note: Roe yield based on roe production, not roe sales.
Source: ADOR (Alaska Salmon Production Reports).

Alaska Roe Suppliers

The Alaska Seafood Suppliers Directory (link), hosted by the Alaska Seafood Marketing Institute, contains contact information for Alaska fish roe suppliers.

Global Supply and Market Value Trends

Roe production generally tracks trends in overall harvest volume; however, this is not always the case. For instance, Alaskan pollock roe production fell 32 percent in 2016 despite a larger harvest. Total harvest volume can be used to estimate competing roe supply in lieu of data on roe production, which is not widely available outside the U.S.

Table 22. World Production of Selected Roe-Bearing Species, in Metric Tons, 2010-2016

	2010	2011	2012	2013	2014	2015	2016
World Production by Species							
Pollock	2,769,570	3,146,513	3,209,426	3,186,756	3,179,482	3,308,503	3,447,696
Chum Salmon	318,175	276,451	316,110	357,958	336,677	350,726	N/A
Pink Salmon	384,473	585,355	406,085	570,352	297,882	444,230	N/A
Sockeye Salmon	173,811	158,581	151,293	138,758	186,925	187,538	N/A
Pacific Herring[1]	87,123	81,608	77,792	104,622	98,665	82,152	N/A
Pct. from Alaska							
Pollock	32%	41%	41%	43%	45%	45%	44%
Chum Salmon	18%	18%	22%	19%	12%	17%	N/A
Pink Salmon	47%	30%	28%	54%	49%	64%	N/A
Sockeye Salmon	62%	68%	63%	58%	59%	70%	N/A
Pacific Herring	46%	47%	35%	29%	40%	34%	N/A

Note: Total figures include production from Canada, Japan, South Korea, Russia, and the U.S. (with the exception of herring).

[1] Does not include Russian harvest because the amount roe produced/exported from the fishery to Asian markets appears to be limited, relative to Russia's large Pacific herring harvest.
Source: FAO (2010-2015) and McDowell Group estimates (Pollock 2016).

Trade data can be used to estimate supply for pollock roe markets. Most pollock roe is imported by Japan and South Korea. Import data on pollock roe (obtained from Global Trade Atlas) from the U.S. and Russia into these markets provides information about roe market supply and value.

Table 23. Frozen Pollock Roe Imports by Japan and South Korea from U.S. and Russia, 2006-2016

	Japan Imports			South Korea Imports			Total		
Year	MT	Pct. U.S.	$/MT	MT	Pct. U.S.	$/MT	MT	Pct. U.S.	$/MT
2006	43,772	68%	$9,735	7,293	25%	$6,979	51,065	62%	$9,342
2007	38,251	68%	$9,081	7,085	40%	$6,707	45,336	64%	$8,710
2008	41,958	53%	$12,198	4,368	27%	$7,323	46,326	50%	$11,738
2009	34,007	53%	$9,462	7,786	25%	$6,204	41,793	47%	$8,855
2010	38,747	35%	$8,201	6,923	23%	$6,853	45,670	33%	$7,997
2011	38,256	38%	$9,309	10,073	22%	$8,234	48,329	35%	$9,085
2012	40,439	38%	$11,907	12,333	20%	$8,115	52,772	33%	$11,020
2013	34,166	39%	$9,010	15,263	22%	$5,749	49,429	34%	$8,003
2014	42,836	42%	$7,400	15,069	20%	$4,985	57,905	36%	$6,771
2015	40,398	46%	$5,637	15,157	19%	$4,131	55,555	39%	$5,226
2016	34,767	41%	$7,013	14,605	16%	$4,096	49,372	34%	$6,150

Source: Global Trade Atlas.

Frozen pollock roe exports to Japan have fluctuated since 2006, but have generally been flat on average. Meanwhile, South Korea has become a larger importer of frozen pollock roe over the past decade. South Korea is an important location for cold storage and pollock roe auctions, but import statistics do not reliably indicate the supply of roe being sold into the Korean market. A significant volume of pollock roe is first exported to South Korea before going on to Japan; however, that supply is not typically included in Korean import statistics. Despite increasing Korean demand, the market generally buys lower priced, lower grade pollock roe.

Alaska's position as the primary pollock roe exporter to Japan has also changed over the past decade. Russia now exports more pollock roe to Japan and South Korea. Based on industry interviews, competing with Russian pollock roe producers is increasingly difficult due to a weak Russian ruble, lower operating costs, and differences in fishery management structure which generally provide for larger harvests of high quality pollock roe. With no foreseeable decline in pollock roe production, the need to find alternative pollock roe markets is critical.

Low Grade Roe Production Volume

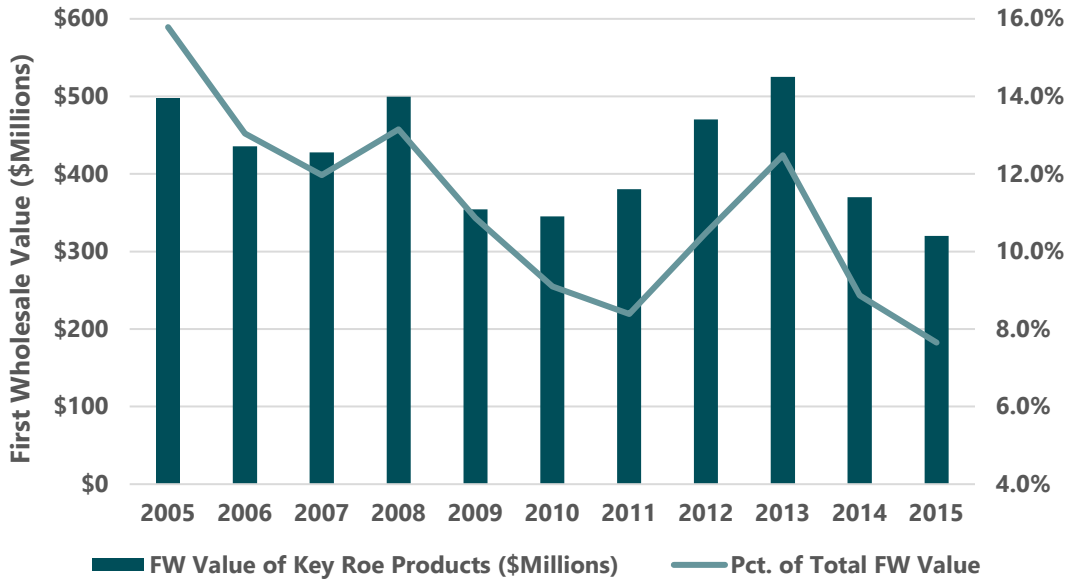
The study team attempted to quantify the volume of low quality roe production in Alaska, but was not able to compile enough responses from processors to produce a reliable figure. However, interviews revealed several interesting points:

- Roe quality is largely subjective and highly influenced by market supply. In years where supply is plentiful, buyers are more discerning about quality attributes as compared to years with less supply. Inventory positions also play a role in demand and quality grading temperament.
- This factor suggests that demand for Alaska roe products is somewhat inelastic, where the volume demanded is relatively static but price adjusts significantly depending on supply. Intuitively, this makes sense as there are few markets capable of consuming large volumes of Alaska roe products outside of Japan, Korea, and Eastern Europe (which is mostly closed due to the Russian embargo). So in years of large supply, primary buyers negotiate for lower prices on higher grades and leave the rest. The situation can be reversed in years of tight supply, however.
- Pollock egg maturation varies by stock/area. This impacts the supply of high-medium quality roe. If fishing is good during the right time, larger supplies of high quality roe will be available. Pollock roe yield is also influenced by fish size. Smaller fish – which has been more predominant in recent years – tend to produce less roe.
- Not surprisingly, pollock roe processed at-sea tends to be of higher quality than pollock roe produced in shoreside plants. At-sea processors generally obtain higher average pollock roe prices. This means shoreside processors have more downside exposure to oversupplied pollock roe markets.
- Salmon roe quality and yield can vary significantly by area, species, and year, making a quantification of off grade roe across all producers virtually impossible. Salmon processors consistently pointed to poor PWS pink roe quality in 2015, however. Pink roe prices declined after the 2014 Russian embargo closed a significant pink roe market, but low pink roe prices the following year were also a reflection of poorer quality. In contrast, pink roe quality and yield was quite good in 2013 and processors obtained high prices.
- Russian pollock producers are in a better competitive position to obtain premium roe prices. Due to differences in fishery management structure the Russian pollock fleet can be more selective about harvesting stocks with mature roe. A lower cost structure also allows Russian producers to be profitable while only selling high quality roe and discarding the rest.
- Obtaining information about herring roe quality is difficult because almost all Alaska herring roe is sold with the skein still in the fish. Some fish are cut open and sampled to estimate roe yield.

Importance of Alaska Roe Products

Roe products are a very important part of Alaska's seafood industry. Salmon and pollock roe generally command high prices and unlike meat products, there is no product form trade off (e.g. salmon processors can produce canned salmon or frozen products but not both from the same fish). Roe tends to be a high margin product for processors who are in turn able to use roe revenue to pay higher fish prices or fund other operational investments. In many years, roe products account for over 10 percent of total first wholesale value; however, that percentage has been trending down since the mid-2000s (aside from a bump in 2012 and 2013). This is a critical point, because roe prices have a significant bearing on processor profitability – which drives ex-vessel pricing.

Figure 6. First Wholesale Value of Key Alaska Roe Products, 2005-2015

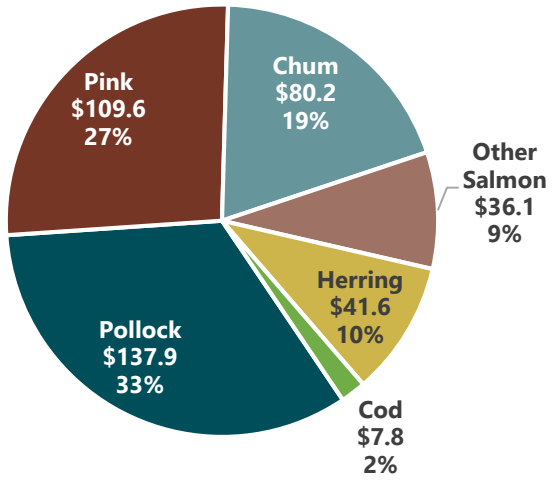


Note: Includes salmon, pollock, herring, and cod roe only.
Source: McDowell Group estimates, based on ADF&G and NMFS data.

Data for 2016 is not yet available but will likely show another sharp drop in roe value. Pollock roe production was down 32 percent and pink harvests declined 75 percent in 2016. An increase in roe prices for these species will slightly offset the lost production volume, but regardless 2016 will likely be the worst roe season in recent memory.

Pollock accounts for more roe value than any other single species, averaging $138 million in first wholesale value between 2011 and 2015. Collectively, salmon roe is more valuable with an average value of $226 million. Pink and chum make up 84 percent of salmon roe value. Pollock, pink salmon, and chum salmon accounted for 79 percent of total Alaska roe value between 2011 and 2015.

Figure 7. Average First Wholesale Roe Value by Species, in $Millions, 2011-2015 Average



Notes: Does not include all Alaska roe products (such as rock sole or urchin roe). Herring value includes a relatively small amount of food/bait production.
Source: McDowell Group estimates, based on ADF&G and NMFS data.

Roe Quality: Specifications and Ramifications

- Salmon ikura is graded according to a #1, #2, or #3 quality scale. Sujiko is graded into #1 or #2 groups.
- Salmon ikura is sold frozen, usually in 500g, 1 kg, or 14 kg containers/trays, but can also be sold in pails or in block form.
- Sujiko is graded into #1 or #2 quality categories. It is frozen and usually packed in containers/trays, but is also shipped in pails or frozen blocks.
- Green salmon roe is typically sold in frozen blocks to secondary processors.
- Pollock roe has many grades, some companies offer over twenty quality grades but there are some general Japanese names which apply to various types of roe conditions:
    - Mako: Mature eggs. Highest quality roe consisting of a whole matched pair of roe masses without any defects (or very small defects).
    - Gamko: Immature eggs.
    - Mizuko: Overripe eggs.
    - Kireko: Eggs with broken skeins.
    - Barako: Eggs that have broken loose from the skeins
- Roe grading is also influenced by the volume of roe produced and the quality of the year's production from Alaska and competitors. In a year with low production, buyers are worried more about accessing supply and may be more willing to give favorable grades (up to a point) than in a year where supply of quality roe is plentiful and they can afford to be choosier.
- The spread between low/high quality roe varies depending on the year, and the volume of high quality roe available. For salmon ikura, the typical spread is approximately 1,250 yen/kg (or $5/lb.). The spread between low and high quality pollock roe is generally about 750 yen/kg (or $3/lb.). Price spreads for low/high quality roe are highly dependent upon the supply of roe at various quality grades.

Trends in Japanese Wholesale Markets

The Tsukiji Wholesale Fish Market is Japan's largest fish market and publishes monthly data on the volume and value of products sold at the market. McDowell Group has worked with ASMI's Japan office to translate and compile the data.

Wholesale prices of Alaska roe prices declined significantly between 2012 and 2016 in U.S. dollar terms. However, much of the decline is due to the changing value of the Japanese yen. For example, the average price of ikura sold at the Tsukiji Wholesale market declined 27.4 percent during the five-year period when denominated in U.S. dollars, but only fell 1.7 percent in yen terms.

It is unlikely that the wholesale value of pollock and herring roe products sold into Japan will increase substantially in the near future, barring a resurgence in demand. Pollock roe supply has increased with rising harvest volumes and herring demand has steadily declined over the past decade. In fact, the volume of herring roe sold at the Tsukiji market was lower in 2016 than at any year since at least 2005. Lower herring roe volumes resulted in slightly higher prices in 2016, but the total sales value of herring roe still declined. Prices of herring roe on kelp increased in 2016 at the Tsukiji market, but the market for Komochi konbu is significantly smaller than herring roe from sac roe fisheries (kazunoko).

Table 24. Sales Volume, Value, and Average Prices of Selected Roe Products at Japan's Tsukiji Wholesale Fish Market, 2010-2016

	2010	2011	2012	2013	2014	2015	2016
Sales (in Metric Tons)							
Sujiko	967	749	610	503	479	690	706
Ikura	2,619	2,184	1,865	1,629	1,733	1,728	1,705
Pollock Roe – Not Marinated	2,174	1,915	2,091	2,025	1,805	1,694	1,415
Pollock Roe - Marinated	2,455	2,218	2,308	2,394	2,209	2,232	2,188
Kazunoko	1,044	1,128	1,069	1,102	1,096	1,087	883
Komochi konbu	431	516	277	193	252	281	242
Yen/KG							
Sujiko	1,868	2,086	2,573	3,224	3,007	2,382	2,200
Ikura	3,055	4,044	5,009	5,006	4,598	4,586	4,923
Pollock Roe – Not Marinated	1,655	1,568	1,380	1,370	1,422	1,423	1,480
Pollock Roe - Marinated	1,580	1,625	1,562	1,509	1,546	1,486	1,481
Kazunoko	2,410	2,026	2,163	2,093	1,941	2,032	2,241
Komochi konbu	1,901	1,957	2,794	4,134	2,921	2,766	3,149
$USD/MT							
Sujiko	21,648	26,422	32,246	32,739	27,752	19,674	20,194
Ikura	35,317	50,913	62,325	50,854	42,710	37,844	45,219
Pollock Roe – Not Marinated	18,906	19,691	17,246	13,999	13,399	11,754	13,581
Pollock Roe - Marinated	18,038	20,419	19,518	15,412	14,576	12,272	13,616
Kazunoko	28,699	25,945	26,362	20,762	16,925	16,714	20,046
Komochi konbu	22,044	24,747	34,908	41,789	27,366	22,791	29,090

Source: Tokyo Metropolitan Government, compiled by McDowell Group and ASMI Japan Office.

The March 2011 tsunami, which devastated parts of Eastern Japan, likely explains at least part of the spike in salmon roe prices from 2011 to 2013. The tsunami destroyed many salmon roe inventories, salmon fishing boats, and chum salmon hatchery operations. Prices retreated after 2013 as production facilities were rebuilt. A weaker yen and the Russian embargo also were contributing factors to lower salmon roe values in ensuing years.

Addressing Roe Market Challenges

Roe consumption in Japan, Alaska's primary roe market, is steadily declining. The industry also sells substantial amounts of roe into the Korean market. Increasing roe values requires expanding consumption, either in its primary markets (Japan/Korea) or by developing new markets or uses.

- *CHALLENGE: Supply is outstripping demand for Alaska roe products, particularly in the case of pollock.*
- *SOLUTION: Increase consumption of key roe products, particularly pollock roe which has a more consistent supply than salmon roe products.*

Roe markets for pollock, salmon, and cod generally demand stable quantities each year, but Alaska's wild fisheries often produce volatile swings in production. Roe prices can go very high when supply is low. However,

when supply is plentiful prices fall precipitously as there is not a lot of demand which can tapped into simply by lowering prices.

- *CHALLENGE: Rigid demand with no alternative market when supply spikes and prices fall.*
- *SOLUTION: Find alternative markets/products, such as roe-based oil or sport bait, that can provide an outlet for years which produce large quantities of roe and/or low quality roe.*

Not all roe is appropriate for sale into roe markets. It could be immature, over-mature, discolored, have soft membranes (leading to breakage), or other defects. Further, lower quality roe can drag down the value of higher quality roe and damage consumer perception if they consume products using waste grade roe. Roe quality is driven by many factors. Many fisheries target fish outside of spawning periods, so the roe will be immature. Sometimes fish are caught at the right time but for some reason the roe is not high quality, as was the case during 2015 in the Prince William Sound pink salmon fishery. The fishery produced an enormous pink harvest but most of the eggs had thinner than normal membranes causing eggs to break leading to poor yields and poor prices on product that was sold. In cases where the roe is not saleable, some plants send the waste grade material to the fish meal/oil plant. However, this can be problematic as roe membranes tend to "gum up" screens the meal/oil equipment.

- *CHALLENGE: Utilization of "waste grade" roe.*
- *SOLUTION: Develop uses and markets for low quality roe, such as roe-based oil (with a custom process designed to solve the gumming problem) or other products.*

The study team interviewed several industry members in an attempt to understand how much low grade roe is produced for various species. Unfortunately, without full access to confidential information it is not possible to estimate. Quantifying past waste volumes may not be very useful in any case, as the volume of low quality roe can vary significantly from year to year.

Alternative Product Possibility: Roe-based Fish Oil

Roe-based fish oil generally has superior attributes to conventional human-grade fish oils and would likely command a higher value in the fish oil market hierarchy. Fish oil derived from roe has higher percentage DHA omega-3 fatty acid compared to conventional fish oil products. Oil derived from roe is also a phospholipid form of DHA which some studies have shown is more bioavailable in the body and improves brain development over triglyceride DHA (found in conventional fish oils).[22] The only known materials to produce phospholipid binding DHA are krill, squid skin, and fish roes. Further, salmon roe lipids are high in Phosphatidylcholine (PC) and there is evidence that PC supplements may help stimulate growth of new brain cells and neural connections. Salmon roes are also very high in astaxanthin, a powerful antioxidant offering numerous health benefits.[23]

[22] https://www.ncbi.nlm.nih.gov/pubmed/24470588
[23] http://www.uofmhealth.org/health-library/hn-10011674

Krill oil is a growing market segment that is expected to double in value by 2022.[24] The appeal of krill oil is primarily the presence of phospholipid DHA and some consumers say it does not produce "fishy burps" as is occasionally experienced with other fish oil capsules. However, krill is a key food source for many fish and marine mammals. MSC certified the Antarctic krill fishery in 2015, but some consumers may still be wary about sustainability claims given that so much marine life is dependent upon abundant krill stocks. By comparison, processing low grade fish roe represents an efficient use of a resource which might otherwise go to waste.

Norwegian producers have recently begun marketing a roe-based oil using immature roe from the country's large Atlantic herring fishery. This is an effort to utilize a raw material that has no current market in established roe markets.

As discussed in this report's fishmeal and fish oil chapter, estimating a first wholesale value for human grade fish oil supplements is difficult. However, it is important to understand what the potential value of roe oil could be, even if only based on an approximate estimate.

Potential wholesale value can be inferred by examining the retail value of krill oil and herring roe oil, which typically ranges from $50,000-$75,000/mt ($23.67-$34.02/lb.). Production would face a myriad of other costs, but it is still instructive to calculate a potential wholesale value per unit of raw material (metric tons). Table 25 estimates the wholesale value of low grade roe used in a high-end fish oil product, assuming an oil yield of 15 percent.

Table 25. Estimated Wholesale Value of Alaska Roe Oil

Wholesale Value/MT of Human Grade Roe Oil Product	Wholesale Value/MT of Roe Used for Oil Production[1]	Wholesale Value of 1,000 MT of Roe ($Millions)
$10,000	$1,500	$1.50
$20,000	$3,000	$3.00
$30,000	$4,500	$4.50
$40,000	$6,000	$6.00
$50,000	$7,500	$7.50

[1] Wholesale value/MT of human grade roe oil * 15 percent oil recovery rate.
Source: McDowell Group estimates.

The potential wholesale value of fish oil derived from salmon roe could be worth as much as $50,000/MT, but how does that compare to the value of roe sold into roe markets? Salmon roe would likely yield approximately 15-18 kilograms of oil for every metric ton of roe used in production.[25] The wholesale value of roe used for oil production would therefore be the wholesale value of roe oil multiplied by a conservative yield of 15 percent. Due to the low yield, the relative value of roe used to produce oil would be much lower than the wholesale value of the oil product. It is possible that additional products could be produced from the leftover material,

[24] http://www.nutraceuticalsworld.com/contents/view_breaking-news/2016-11-10/growth-predicted-for-the-global-krill-oil-market
[25] Based on personal communication with industry contacts.

but that would require further research. It is estimated that waste grade roe could be worth $1,500 to $7,500/MT. This is a significant amount if the roe used for oil comes from roes which are otherwise discarded, but is substantially lower than medium to high grade salmon roe. Further, there are hurdles at a plant level. Ideally, most salmon roe is retained and sold to roe markets leaving relatively little low quality roe available for roe oil production. This amount will vary significantly from year to year, but these factors make it difficult to justify creating a new roe oil product based on an unknown level of supply. However, if low quality salmon roe can be aggregated from multiple processors it makes the prospects for investment and product development more favorable. Branding and marketing a singular Alaska salmon roe oil product may be easier than putting forth multiple products in smaller volumes. While a cooperative structure may be the most efficient development option, creating an equitable framework that properly allocates costs and benefits among the entity's owners might be challenging.

Historically, processors put considerable focus on products with longer shelf-stable periods. Extending the time over which Alaska salmon products can be sold is important because it can smooth out variations in harvest volume. Roe oil is shelf stable for several years and provides the opportunity to smooth out variations in raw material supply.

What is the relative value of producing a roe-based oil product from Alaska salmon? Alaska processors typically sell 8,000 to 16,000 metric tons of salmon roe each year. In addition, there may be several thousand metric tons of waste grade roe available which could be used to produce oil. Therefore, it could be estimated that perhaps as much as 5,000 metric tons of salmon roe could be available for oil production in a large year. The total wholesale value of such a volume could be worth $7.5 to $37.5 million. This is a substantial sum, but represents only a fraction salmon roe sold into roe markets, which averaged $220 million per year between 2012-2016.

Available research and interviews with industry suggests salmon roe provides the best raw material for producing high quality roe oil. However, salmon harvests, roe yield, and roe quality varies tremendously by region, species, and year. If a valuable roe oil product can be made using pollock, cod, or other species, the volume of raw material could be significantly increased.

Other Roe Products

In addition to current roe products and roe oil, there are other products which could be created from Alaska fish roe. Industry and academic institutions in Alaska are continually investigating new roe products, and the Symphony of Seafood – a competition highlighting new Alaska seafood products – introduced a new category called "Beyond the Egg" this past year specifically focused on new roe products.

Other potential roe products include, but are not limited to:

- Sport bait – typically uses cured salmon roe for sale in bait and sporting goods stores in the Pacific Northwest. For example, Cabela's sells a 7 ounce package of cured salmon roe bait produced by Pro-Cure for $11.99 per package. Anecdotal reports suggest some Alaska processors already sell salmon roe to bait manufacturers.
- Bottarga – Salted/cured roe sack of Italian origin. Historically, bottarga is produced using grey mullet or bluefin tuna, but some have attempted using pollock, cod, and salmon roe. The product is typically

grated and used as a topping on pasta or cooked vegetables. Karasumi (salted and dry-cured mullet roe) is a similar product used in Japan and East Asia, although it is softer than Mediterranean bottarga.

Sport bait and bottarga are high value products, but the market is relatively small. In each case, a little raw material goes a long way. While using Alaska roes in a bottarga-like product is still in the experimental phase, bait manufacturers have used Alaska salmon roe for years and it is unlikely that much could be done to expand this market channel.

Increasing Roe Consumption and Value

It may be possible to increase the value derived from Alaska roe by producing alternative products from low grade roe; however, the costs of creating new products such as roe oil are substantial, leaving less potential for increasing profits. By comparison, increasing the average price of Alaska roe products by 10 percent could create over $40 million of additional first wholesale value with minimal capital expenses. While increasing resource utilization and product development in Alaska's seafood industry is an important long term goal that should be supported to the greatest extent possible, it should not come at the expense of increasing the value of existing production.

As the supply of marketable quality roe produced in Alaska's fisheries cannot be easily increased, the only way to add value is to increase demand. To increase demand, the product requires broader, more frequent consumption by more consumers. Secondary roe processors in Japan and Korea have had some success introducing updated formulations, but as eating habits in these countries continue to trend toward Western tastes increasing the number of consumers regularly eating traditional Japanese/Korean foods will be challenging.

Broader eating habits in core market areas present opportunities for increasing the number of consumers seeking out roe products. Sushi, Chinese, and Korean-inspired recipes have become commonplace in North America, and increasing the utilization of roe in Asian dishes, as well as pasta preparations, could be the next hot food trend. The health benefits of eating roe are an additional selling point.

However, increasing roe consumption in new markets faces several challenges, including retail penetration/availability, food service incentives, and consumer awareness/education. The typical North American consumer is likely unaware of how to use roe in home cooking preparations and would be hard pressed to find any Alaska roe products sold at mainstream grocery stores. In instances where products like "salmon caviar" are available in North America, they are often sold in relatively large quantities (~1 lb.) or contain smaller amounts at high prices (North American online specialty retailers often sell tinned or jarred salmon caviar for $50 or more per pound). Prices are high, relative to what consumers might pay in Japan, Korea, or Eastern Europe because the product occupies such a narrow niche in the North American market.

Convincing conventional restaurants to utilize roe without a significant consumer education/marketing effort could be met with resistance. Restaurants are not willing to add cost to dishes unless it is likely to have a significant benefit to the business's bottom line, and the ability to increase pricing on dishes with a high-priced ingredient like roe is uncertain at best.

While there are challenges regarding the North American supply chain, there is undoubtedly a growing "foodie" sub-culture that seeks out authentic dishes. In fact, this group will likely represent the majority of U.S. consumers in a few years, as 47 percent of American restaurant patrons consider themselves to be "foodies" including 68 percent of consumer age 25-34.[26] This segment is very interested in learning more about international dishes and the story about where their food comes from. It is likely that U.S. "foodies" would try a variety of roe products and preparations, if they were aware of the benefits/story and presented with the opportunity. ASMI and industry could play a substantial role in this endeavor.

Increasing utilization of Alaska roe products in North American sushi restaurants/stands may be the most direct method for increasing consumption in alternative markets. Sushi chefs already utilize a variety of roe products and would likely find it easier to source product than restaurants with less experience using roe. Finding ways to increase the use of pollock and herring roe as a supplement in sushi preparations could be a way to increase demand.

STRATEGY FOR MARKETING ROE PRODUCTS IN THE U.S.

A potential marketing campaign centered on introducing roe products to U.S. retail consumers is presented below:

1. Identify retail partner(s) in markets with "foodie" customers who are highly motivated to offer customers something different than their competitors. Stress that this is a unique, high value product producing a high margin per unit of dedicated store space. Ideally, the retail partner would have in-store restaurants (e.g. HyVee) which could feature roe products in a variety of food preparations on-site and/or offer in-store demonstrations of simpler uses. Negotiate for ability to track sales performance, this is critical to future promotions and scalability.

2. Work with partner chefs to develop a several dishes featuring Alaska roe products likely to appeal to the target audience, or utilize existing recipes/dishes.

3. Identify species and product forms to be used in the promotion, and how they may need to be processed/packed for a retail setting with a focus on creating accessible unit volumes and price points. Offerings should be small enough that consumers will likely not let product go to waste or spoil.[27]

4. Create a marketing strategy that highlights the history of roe in ethnic dishes, the Alaska story, and health benefits. Create print media content for local and retailer publications, perhaps work with a food writer to place a story in a regional newspaper. Create in-store signage/assets (Roe: what, why, recipe, and ingredient list). Produce brief video explaining dish history and Alaska origin stories for the chain's seafood counter (or other) monitors.

[26] http://www.mintel.com/press-centre/food-and-drink/half-of-american-restaurant-goers-consider-themselves-foodies
[27] This is a crucial point, as many consumers are less likely to purchase something that they did not fully utilize as opposed to something they liked but could have even used more. Better to leave them wanting more than feeling guilty about buying too much.

5. Create an efficient social media strategy to encourage new roe consumers to share their dishes and connect with info about Alaska, ASMI, and recipe ideas. Perhaps incentivize Facebook/Twitter shares with defined hashtags by offering prizes (such as store gift cards or Alaska Seafood swag).

6. Work with Alaska processor(s) and retailers' distributors to arrange for product. May need to offer training materials or assistance to retail staff.

7. Gather qualitative feedback from retail partners about event. Analyze sales performance. If the event leads to permanent store placement, repeat.

Specialty Crab Products

Key Takeaways

- Utilizing crab shells and tails could add an estimated $9.3 million in first wholesale value, based on full utilization of chitin production and king crab tails.[28]
- Crab shells contain chitin, a versatile polymer that has anti-bacterial and anti-fungal properties. Chitin is a material used in biomedical, agricultural, and food service industries in an assortment of products including technical fabrics, sponges, and fertilizers.
- King crab tails contain sweet, rich meat similar to leg/claw sections. Removing it by hand is costly but due to current high prices ($15/lb. in 2016) for the tail meat, processors are now extracting the meat. The greatest challenge is the limited, highly-seasonal supply. The largest markets for tail meat are secondary processors that use the tail meat as a lower-cost ingredient for value-added products such as crab cakes, soups/bisques, or other preparations.

This chapter focuses on specialty crab products and does not address markets or production for frozen crab sections. For more information on traditional crab production and markets, please see: Wholesale Market Profiles for Alaskan Groundfish and Crab Fisheries.

Production Volume and Value

Total Alaska crab harvests averaged 88.9 million pounds worth $269 million in ex-vessel value from state and federal fisheries over the last five years (2011-2015). Crab is one of the highest valued seafood species in Alaska. Frozen sections of red king crab often fetch over $15/lb., while opilio and snow crab usually sells for over $5/lb. at the first wholesale level.

Four primary species of crab are commercially-harvested in Alaska, including snow (opilio), tanner (bairdi), king, and Dungeness. Most of the harvest is concentrated in the Bering Sea, with smaller fisheries occurring from Norton Sound to Southeast. Crab are harvested using pot gear. Only males above a species-specific size threshold may be retained.

Snow and tanner crab are distributed primarily in the Bering Sea, accounting for 79 percent of the total crab harvest in the last five years (2011-2015). Tanners typically weigh 2 to 4 pounds each. Snow crab average 1 to 2 pounds.[29]

King crab are the largest crab species, typically between 6 to 10 pounds, and are distributed primarily in the Bering Sea. Red king crab are historically the most commercially important shellfish in Alaska and are found in

[28] https://www.afsc.noaa.gov/News/pdfs/Wholesale_Market_Profiles_for_Alaskan_Groundfish_and_Crab_Fisheries.pdf
[29] http://www.adfg.alaska.gov/index.cfm?adfg=tannercrab.main

both the Bering Sea and the Gulf of Alaska. Blue king crab are less widely distributed and are concentrated in the Bering Sea. Golden king crab are smaller than blue and red crab, and found from the Aleutian Islands to Southeast.[30]

Dungeness crab are harvested primarily in Southeast, Kodiak, and near the Alaskan Peninsula but are widely distributed along the coast from the Aleutians Islands to Mexico. The largest Dungeness fishery is not in Alaska but in Washington and Oregon. They weigh an average of 2 pounds.[31]

Table 26. Alaska Crab Harvests, in Million Lbs. and $Million, 2011-2015

Species	2011	2012	2013	2014	2015	5 Year Average
Snow Crab	51.3	82.1	66.6	51.4	57.6	61.8
Tanner Crab	5.9	4.7	3.4	10.0	15.8	8.0
Red King Crab	8.2	7.9	8.8	9.9	9.6	8.9
Golden King Crab	5.5	5.4	6.3	6.4	5.8	5.9
Dungeness Crab	3.3	2.5	2.6	5.2	3.5	3.4
Blue King Crab	1.9	1.5	-	0.3	0.1	1.0
Total Harvest Volume (Million Lbs.)	**76.1**	**104.1**	**87.7**	**83.3**	**92.4**	**88.9**
Snow Crab	$130.1	$181.3	$152.8	$121.5	$117.9	$140.7
Red King Crab	$87.2	$56.7	$60.2	$66.7	$76.8	$69.5
Tanner Crab	$16.0	$12.1	$8.8	$23.8	$37.0	$19.5
Golden King Crab	$27.6	$23.0	$27.7	$28.2	$26.7	$26.6
Dungeness Crab	$7.6	$6.3	$6.3	$15.7	$10.5	$9.3
Blue King Crab	$8.7	$6.7	-	$1.0	$0.5	$3.4
Ex-Vessel Value ($Million)	**$277.2**	**$286.1**	**$255.8**	**$256.9**	**$269.4**	**$269.0**

Note: Values have been rounded.
Source: ADF&G (COAR).

Ocean acidification and climate change have been linked to declines in Alaska's crab stocks and heightened mortality rates.[32] Concurrently, and possibly related, crab Total Allowable Catches (TACs) are below their recent averages. The 2016/17 Bering Sea tanner crab fishery was closed entirely and the Bering Sea snow crab fishery was reduced nearly in half of its 2015/16 TAC. Other crab fisheries near the Alaska Peninsula, Kodiak, and Southeast have experienced years of closures.

See table on following page.

[30] http://www.adfg.alaska.gov/index.cfm?adfg=bluekingcrab.main
[31] http://www.adfg.alaska.gov/index.cfm?adfg=dungenesscrab.main
[32]http://seagrant.noaa.gov/Portals/0/Documents/what_we_do/climate/AK%20SG%20Fisheries%20Adaptations%20to%20Climate%20Change.pdf

Table 27. Total Allowable Catch in Selected Bering Sea Crab Fisheries, 2016/2017

Fishery	2015/16 TAC (Million lbs.)	2016/17 TAC (Million lbs.)	Percent Change
Bristol Bay Red King Crab	9.97	8.47	-15%
Aleutian Island Golden King Crab	6.29	5.55	-12%
St. Matthew Blue King Crab	0.41	Closed	-100%
Bering Sea Snow Crab	40.61	21.57	-47%
Bering Sea Tanner Crab	19.67	Closed	-100%
Total Crab TAC	**76.95**	**35.59**	**-54%**

Source: ADF&G and NMFS.

In the last five years (2011-2015), an annual average of 61.8 million pounds of crab were processed, worth $387.3 million in first wholesale value.

Table 28. Production of Alaska Crab Species, in Million Lbs. and $Million, 2011-2015

Species	2011	2012	2013	2014	2015	5 Year Average
Snow Crab	35.6	59.0	47.5	37.3	39.2	43.7
Tanner Crab	3.9	3.1	1.9	6.9	11.4	5.4
Red King Crab	6.0	5.3	6.5	7.1	6.9	6.4
Golden King Crab	4.2	3.3	4.2	3.4	3.4	3.7
Dungeness Crab	2.2	1.6	0.9	3.3	2.2	2.0
Blue King Crab	1.2	1.1	-	0.2	0.1	0.5
Production Volume (Million Lbs.)	**53.1**	**73.4**	**61.0**	**58.2**	**63.2**	**61.8**
Snow Crab	$190.2	$278.5	$236.1	$194.7	$170.3	$214.0
Red King Crab	$106.2	$78.1	$81.9	$81.9	$93.3	$88.3
Tanner Crab	$25.5	$19.1	$11.7	$38.5	$53.3	$29.6
Golden King Crab	$45.7	$29.7	$36.4	$32.8	$34.3	$35.8
Dungeness Crab	$11.8	$9.1	$4.5	$23.4	$15.5	$12.9
Blue King Crab	$17.0	$13.9	$0.0	$2.0	$0.7	$6.7
First Wholesale Value ($Million)	**$396.5**	**$428.4**	**$370.6**	**$373.4**	**$367.5**	**$387.3**

Note: Values have been rounded.
Source: ADF&G (COAR).

Crab are delivered alive to shoreside facilities where they are processed into sections, brine-frozen, and graded by size. Larger crab sections are worth more per pound than smaller sections. Cooked crab sections constitute 52 to 60 percent of the round weight, depending on the species. The cooked meat yield is between 20 to 25 percent of round weight.[33] While most smaller primary processors sell direct to retail markets, the majority of crab is first sold to wholesale distributors for both domestic and international markets.

[33] http://seafood.oregonstate.edu/.pdf%20Links/Recoveries-and-Yields-from-Pacific-Fish-and-Shellfish.pdf

Table 29. Average Wholesale Value of Crab, by Species

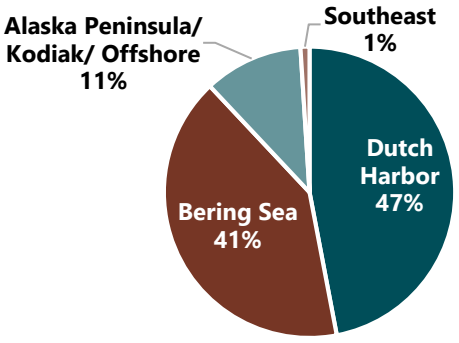
Product	Average Yield	Red King Crab	Blue King Crab	Golden King Crab	Snow Crab	Tanner Crab	Dungeness Crab
Frozen legs/claws	58%	$54.64	$24.18	$26.56	$5.65	$5.40	$8.19
Frozen tail	2%	$1.82	$1.30	$1.17	-	-	-
Frozen shell	12%	$0.07	$0.30	$0.27	$0.08	$0.12	$0.12
Total Value per Avg. Crab	**72%**	**$56.53**	**$25.78**	**$28.00**	**$5.73**	**$5.52**	**$8.31**

Note: Prices are based on 2015 ADF&G COAR first wholesale prices, average weights, and industry estimates for crab shells tails.
Source: NMFS and ADF&G data, industry sources, and McDowell Group estimates.

Major Production Areas and Alaska Crab Suppliers

While crab harvests are seasonal, frozen crab products are available year-round. The majority of Alaska crab is harvested from the Bering Sea in the winter months between October to March. The largest crab processing facilities are in Dutch Harbor, St. Paul, Akutan, Kodiak, and Sand Point.

Figure 8. Top Crab Processing Regions, by Volume



Source: ADF&G (COAR) compiled by McDowell Group.

The Alaska Seafood Suppliers Directory (link), hosted by the Alaska Seafood Marketing Institute, contains contact information for Alaska crab suppliers.

Markets and Product Uses

The United States is the most important market for snow, tanner, and king crab sections. They are sold in retail and wholesale grocery stores (Costco), chain restaurants (Red Lobster), upscale restaurants, and into food service through wholesale distributors. China is the largest export market, where crab is reprocessed for consumption in other countries, as well as fulfilling its own growing domestic demand. Japan is easily the largest export market for finished Alaska crab products.

Potential Markets for Crab Shells

Crabs carry an inedible exoskeleton shell that contains chitin, which is one of the most abundant biodegradable materials in the world. Chitin has anti-bacterial, anti-fungal, and anti-viral properties and is insoluble in water.[34] The amount of chitin present in the shell is determined by the type and quality of the shell.

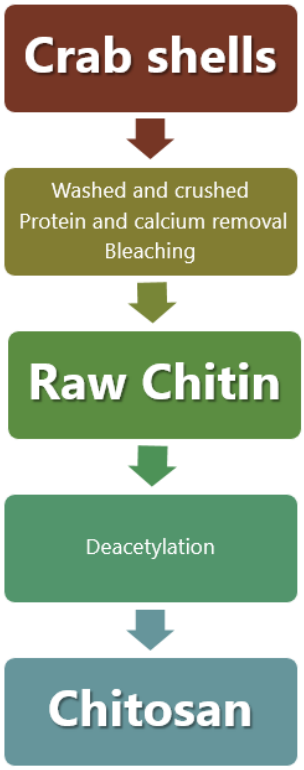
Chitin is worth approximately $3-6 per kilo and chitosan, a refined derivative of chitin, is worth approximately $15-20 per kilo.[35] Chitin/chitosan prices have ranged from $10 to $3,000 per pound, depending on the quality grade.

Chitin from Alaska crab shells has the potential to be one of the most lucrative by-products due to its high demand in a diverse set of industries.[36] Uses for chitin and chitosan products include, but are not limited to:

- Blood clotting products in the medical field[37]
- Craft brewing fining agent[38]
- Pool water clarifier[39]
- Food preservation[40]
- Textile treatment[41]
- Antibacterial fabric component[42]
- Weight loss supplement[43]
- Agricultural fungicide treatment[44]

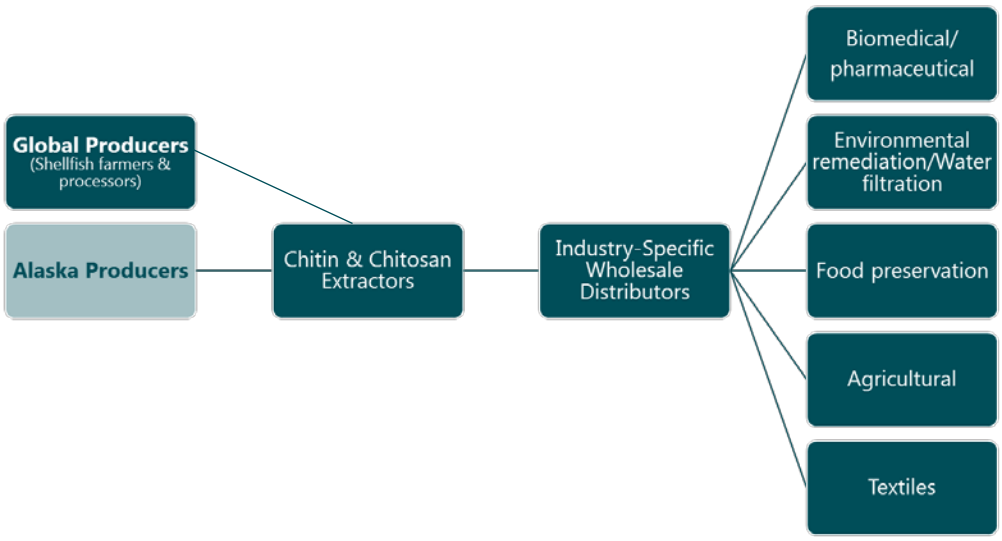
New uses for chitin-based products are being discovered which could enhance the value of raw material.

Overview of Chitin and Chitosan Extraction Process



[34] http://www.sumanfoodconsultants.com/pdf/pdf_chitosan_abstract_ensymm.pdf
[35] http://www.sumanfoodconsultants.com/pdf/pdf_chitosan_abstract_ensymm.pdf
[36] https://www.adn.com/business-economy/2016/06/24/wringing-profit-from-crab-shells-starts-with-tidal-grow/
[37] http://www.globalindustrial.com/p/safety/first-aid/bandages-dressings/hemostatic-gauze-pad-8-x-8-pad-0711gzp?infoParam.campaignId=T9F&gclid=CMOb6Oi47dICFZJffgodHiEDmg
[38] http://tidalvisionusa.com/fining-agent/
[39] http://tidalvisionusa.com/crystal-clarity/
[40] http://waset.org/publications/6320/a-review-on-application-of-chitosan-as-a-natural-antimicrobial
[41] http://www.teonline.com/knowledge-centre/chitin-chitosan.html
[42] https://www.adn.com/business-economy/2016/06/24/wringing-profit-from-crab-shells-starts-with-tidal-grow/
[43] http://www.xtend-life.com/information/ingredients/chitin
[44] http://o2yscorp.com/o1-ys/

Figure 9. Crab Shell Supply Chain



Chitin can be extracted from several Alaska species, including crab and shrimp. To extract chitin, the shell is crushed and dried, then soaked in acid and alkaline to remove protein and calcium. Chitosan is extracted from chitin through an additional deacetylation step and is used for finer grade requirements. It is often sold as flakes or powder.

Based on a five-year harvest average, there are over 10 million pounds of crab shells available annually for chitin extraction in Alaska. Based on crab shell yields and anecdotal prices, processing unused crab shells (not including shells from legs) could add $4-6 million in first wholesale value each year.

Table 30. Crab Shell Potential Volume and Value, 2011-2015

Year	Crab Harvest (Million Lbs.)	Crab Ex-Vessel Value ($Millions)	Crab Shell Yield (%)	Est. Crab Shell Volume (Million Lbs.)	Est. Crab Shell Price/Lb.	Est. Wholesale Value ($Millions)
2011	76.2	$277.1	12	9.1	$0.50	$4.6
2012	104.1	$286.0	12	12.5	$0.50	$6.2
2013	87.7	$255.8	12	10.5	$0.50	$5.3
2014	83.2	$256.9	12	10.0	$0.50	$5.0
2015	92.4	$269.3	12	11.1	$0.50	$5.5
5-Year Average	**88.7**	**$269.0**	**-**	**10.6**	**$0.50**	**$5.3**

Source: ADF&G (COAR) and McDowell Group estimates.

Tidal Vision is the lone chitin and chitosan supplier in the U.S. that utilizes Alaska crab species. The Washington-based company provides chitin-based products to several industries including water treatment, agriculture, food preservation, and textiles. The company is expanding facilities and hopes to buy 1 million pounds of crab shells from Alaska processors by 2018.

Retaining crab shells for chitin processing only occurs when there is a sizable supply available, which would cover high shipping costs. Currently, Trident Seafoods' St. Paul plant is the only Alaska facility that sells crab shells.

The shells are ground down using a series of specialized grinders, rinsed, and flash-frozen in large (super) sacks and held at the processing plant until they can be shipped out as one lot to save on shipping costs.[45]

King crab and snow crab shells have yields of chitin between 14-35 percent (depending on species). Crab has a higher molecular weight in comparison to shrimp chitin products. Overall, the chitin market is a commodity market and there is rarely differentiation among where the product was sourced. It has been reported that the agricultural industry values high molecular weight more than the consumer products industry.

Based on interviews with Tidal Vision, the company currently pays $0.50-$0.60 per pound for large bags of frozen, ground crab shells. Shipping the bags to Washington from St. Paul adds $0.25 per pound to the cost of product.[46]

CHITIN MARKETS

Table 31. Global Supply of Chitin-Producing Species, in MT, 2011-2015

	2011	2012	2013	2014	2015	5-Year Average
Asia	9,586,105	10,037,405	10,379,398	10,970,592	11,119,615	10,418,623
Americas	1,830,332	1,836,688	1,870,539	1,918,423	2,076,913	1,906,579
Europe	432,241	406,298	439,484	507,882	495,076	456,196
Africa	139,918	149,139	165,610	175,391	173,292	160,670
Oceania	51,691	46,256	46,847	50,959	48,988	48,949
Total	**12,040,287**	**12,475,787**	**12,901,878**	**13,623,248**	**13,913,885**	**12,991,017**

Note: Includes all crustaceans (shrimp, crab, lobsters) which contain chitin.
Source: FAO.

Chitin derivatives are a $60 billion industry with massive overseas competition, due to the wide range of industrial applications from medical to agriculture.[47] China and India have been extracting chitin, primarily using farmed shrimp shells, for several decades. Asia produced over 80 percent of chitin-producing species over the past five years (2011-2015). Alaska crab shells are a small sliver of the overall chitin/chitosan market, but they are ideal for the domestic agricultural and environmental industries due to their natural properties. Being competitive in the chitin market is challenging for Alaska and U.S. producers, as the market is already well supplied by low cost producers with established supply chains.

[45] Personal communication with industry contact.
[46] Personal communication with industry contact.
[47] http://www.prweb.com/releases/chitin_chitosan/derivatives_glucosamine/prweb4603394.htm

One of the largest challenges for the domestic market is to dispel the belief that chitin products still contain allergens. The process of extracting chitin removes the shellfish allergen, making it hypoallergenic.[48] However, chitin producers are required by law to display that their product is produced in a facility that handles shellfish. This is a larger issue for food preservation products.

KEY CHITIN/CHITOSAN COMPANIES

- Some of the major buyers of chitin and chitosan products:
    - **Tidal Vision, USA**: Environmentally-friendly chitin and chitosan producer that sources crab shells from Alaska. Only current buyer of Alaska crab shells. Plans to scale up production.
    - **GTC Bio Corporation, China**: Likely the largest and most diverse chitin and chitosan product supplier for all industries.[49]
    - **Heppe Medical Chitosan GmbH, Germany**: medical products derived from chitin and chitosan.[50]
    - **JRW Bioremediation, USA**: environmentally friendly products to remediate contaminated soil that includes a chitin buffering agent for excavations and mine drainage.[51]
    - **Dungeness Environmental, USA**: chitosan-based water purification polymers for construction and industrial markets.[52]

Potential Markets for Crab Tails

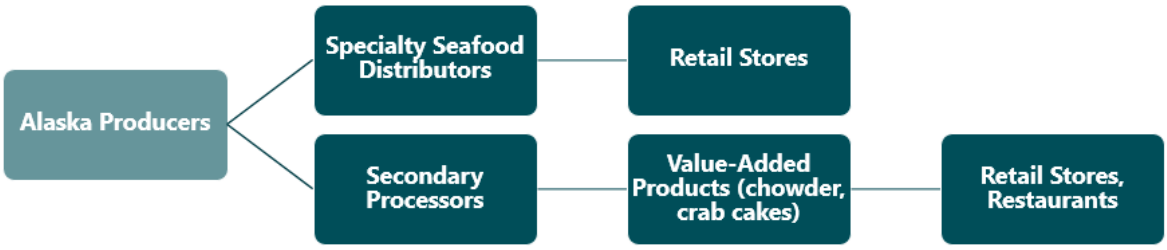
There is limited data available on crab tail prices, export volume, and demand. This analysis is based largely on discussions with industry insiders.

King crabs have a section of meat lining the shell (referred to as the "tail") that is processed by hand and contains edible meat. In recent years, demand for all crab products has increased, leading to a sharp price increase for crab tails. More processing companies have recently begun to extract crab tails now that there are industry reports of crab tails priced at $15 per pound.

King crab tail meat pulled from tail.
Source: ideasinfood.com.

[48] Hypoallergenic means it is unlikely to cause an allergic reaction.
[49] http://www.bestchitosan.com/e_products/
[50] https://www.gmp-chitosan.com/en/company.html
[51] https://www.environmental-expert.com/products/chitorem-chitin-complex-inherent-buffering-agent-191130
[52] https://www.environmental-expert.com/companies/dungeness-environmental-37790

Figure 10. Crab Tail Meat Supply Chain



Only king crab have a tail section large enough to process and it had not been commercially utilized until five to six years ago.

In the last five years, there have been 15.8 million pounds of king crab harvested per year in Alaska. Crab tail yield, based on interviews with industry experts, is approximately 2 percent of king crab round weight. Prices have been reported as low as $3 per pound before growing popularity pushed prices up to $15 per pound in 2016, but the latter is the peak and industry is assuming the price will decline due to markets resisting crab tails at that price point. Assuming a wholesale price of $13/lb. and full crab tail utilization, the potential first wholesale value of selling king crab tails is approximately $4 million.

In the past, it has been hard to maintain a supply of crab tails for two reasons: processors do not think it is lucrative to pull and freeze crab tails, and the demand is inconsistent. Crab tails are picked at St. Paul, Akutan, and Kodiak when it is available.

Table 32. King Crab Tail Volume and Potential Value, 2011-2015

	King Crab Harvest (Million Lbs.)	Crab Ex-Vessel Value ($Millions)	Crab Tail Yield (%)	Crab Tail Volume (Million Lbs.)	Crab Tail Price/Lb.	Est. Wholesale Value ($Millions)
2011	15.6	$123.5	2%	0.3	$13	$4.1
2012	14.8	$86.3	2%	0.3	$13	$3.9
2013	15.1	$87.8	2%	0.3	$13	$3.9
2014	16.6	$95.9	2%	0.3	$13	$4.3
2015	15.6	$104.0	2%	0.3	$13	$4.0
Average	**15.6**	**$99.5**	**-**	**0.3**	**$13.0**	**$4.0**

Source: ADF&G (COAR) and McDowell Group estimates.

Processors typically cook the tail meat, pack it into blocks that are frozen in a plate freezer, and ship it. Most crab is frozen in a brine, which is preferred in the U.S. market because it gives the crab a salty taste and makes the meat easier to remove.

MARKETS

There is limited information on end markets for crab tail meat, but it is a highly versatile product that freezes well and is an economical substitute for crab leg meat in dishes. Alaska processors sell 100 percent of crab tail meat into the U.S. market.

Crab tails are distributed as a gourmet seafood product and it is used as a lower cost ingredient in popular crab meat dishes such as soups/chowders, crab cakes, and as a topping for salads. It has been used as a surimi ingredient.[53]

Pickled Willy's in Kodiak has a specialty crab tail product priced at $29 for 2 to 3 oz.[54]

Market Opportunities for Additional Crab Products

Other specialty products from crab have been developed in Asia, including crab miso from crab blood, snow crab paste in Korea, and minced crab product for value-added products like crab cakes.

[53] Personal communication with industry contact.
[54] Pickled Willy's in Kodiak has a specialty crab tail product priced at $29 per 2-3 oz. container.

Key Takeaways

- Supported by consumers' increasing interest in locally-caught seafood, Alaska herring fillets have experienced some moderate market success, particularly in Seattle during Northwest Herring Week.
- Herring fillets from Togiak (two to three times larger than other Alaska herring) offer the most opportunity for commercial production.
- Herring roe value has declined, and development of herring fillet products provides a potential opportunity to add value to one of Alaska's key fisheries. It is estimated that herring fillet production could increase the first wholesale value of Alaska herring by $11.0 million annually.

Production Volume and Value

Found in Alaska from Dixon Entrance to Norton Sound, herring are schooling pelagic fish with a high oil content. The Alaska commercial harvest of herring includes the sac roe, food/bait, and spawn-on-kelp fisheries. Purse seine gear is used in herring food/bait fisheries and sac roe fisheries.[55] Herring are caught by gillnet, but this is less common (particularly when prices are low). The main herring fisheries in Alaska are in Sitka, Kodiak, and Togiak. Other sac roe and food/bait fisheries that are open depending on biomass health are Port Moller, Dutch Harbor, Tenakee Inlet, Seymour Canal, Ernest Sound, and Craig.[56]

Table 33. Alaska Herring Harvest and Wholesale Production, 2011-2015

	2011	2012	2013	2014	2015	5-Year Average
Ex-Vessel						
Volume (in Short tons)	47,940	33,829	41,793	48,088	33,885	41,107
Volume (Million lbs.)	95.9	67.7	83.6	96.2	67.8	82.2
Value ($Millions)	$10.5	$21.8	$16.6	$10.6	$6.4	$13.2
Est. Price per Lb.	$0.11	$0.32	$0.20	$0.11	$0.10	$0.16
Wholesale						
Volume (in Short tons)	45,660	31,208	40,888	43,951	30,619	38,465
Volume (Million lbs.)	91.3	62.4	81.8	87.9	61.2	76.9
Value ($Millions)	$43.4	$46.1	$46.9	$41.1	$30.4	$41.6
Est. Price per Lb.	$0.48	$0.74	$0.57	$0.47	$0.50	$0.54

Source: ADF&G (COAR).

[55] http://www.adfg.alaska.gov/index.cfm?adfg=commercialbyfisheryherring.main#geartypes
[56] http://www.adfg.alaska.gov/static/fishing/PDFs/commercial/active_herring_map.pdf

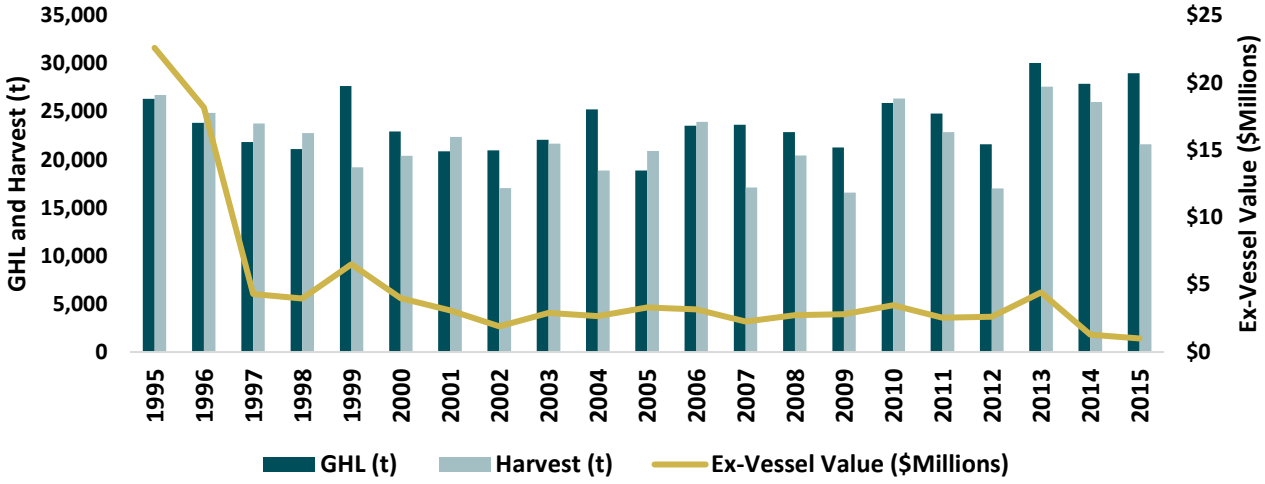
In the last five years (2011-2015), an annual average of 41,107 short tons (82.2 million lbs.) of herring were harvested in Alaska worth an average of $13.2 million and $41.6 million at the ex-vessel and wholesale levels, respectively.[57]

Most herring caught in Alaska are targeted for their roe. This means the males essentially have no value; however, processors typically do not sort herring by sex prior to sale. The majority of product is sold as a frozen whole fish, ocean run product. Later, secondary processors in Asia sort the fish by sex and "pop" the female roe sacks for processing. Males are often ground into fishmeal, sold as bait, or discarded. Historically, herring roe was a highly valuable export product. In recent years, prices for herring roe have fallen considerably and much of the value has disappeared.

Togiak herring are the only herring in Alaska large enough to develop products like herring fillets. Herring in Togiak are 2-3 times as large as herring in the Gulf of Alaska: Togiak herring are between 400-450 grams in round weight and herring in the Gulf of Alaska are between 120-130 grams.[58] Herring fillets (primarily from Togiak) are between 80-100 grams, and the recovery weight is 40 percent from round weight.[59] The Togiak sac roe herring fishery is usually the largest in Alaska by volume; 21,594 short tons were harvested in 2015, nearly 64 percent of the total Alaska harvest.[60]

In 2015, four buyers in Togiak purchased herring from 24 vessels. In the last decade, processors have utilized cooperative fleets for the purse seine fishery to maximize efficiency under current market conditions and biomass estimates.[61]

Figure 11. Togiak Sac Roe Herring Fishery Volume and Value, 1995-2015



Note: Values are nominal. Volume figures are denominated in short tons.
Source: ADF&G.

[57] Tons refers to short tons (2,000 pounds), not metric tons (MT).
[58] Personal communication with industry contact.
[59] Personal communication with industry contact.
[60] https://www.adfg.alaska.gov/static/applications/dcfnewsrelease/535393070.pdf
[61] http://www.adfg.alaska.gov/FedAidPDFs/FMR16-13.pdf

Alaska Supply, Seasonality, and Suppliers

Herring harvests in Alaska are highly seasonal. Commercial harvest of herring take place in the spring when the fish begin to school near shore prior to spawning. Due to State of Alaska budget cuts, the 2017 Togiak herring GHL was based on previous years' biomass estimates and a cautionary decrease of 10 percent, instead of a current stock assessment.[62]

Table 34. 2015 Commercial Herring Seasons by Major Production Area

Area	2015 Harvest (t)	2015 GHL (t)	Value ($Millions)	Season
Sitka	8,756	8,712	$2.2	Mid-March
Kodiak	357	3,190	$0.04	Mid-April
Togiak	21,594	29,013	$1.1	Late April to Mid-May

Source: ADF&G.

The Alaska Seafood Suppliers Directory (link), hosted by the Alaska Seafood Marketing Institute, contains contact information for Alaska herring suppliers.

Nutritional profile

Pacific herring typically have less oil content than Atlantic herring. While oil content varies with the spawning cycle, the average Togiak herring fillet has a 10 percent oil content.[63] Sac roe herring have less oil content than the food and bait herring. A 100-gram herring consists of 2.3 g ash and 72 g water.[64]

Table 35. Pacific Herring Nutrition

	Amount per 100g portion
Calories	195
Protein	16 g
Total Fat	14 g
Saturated Fat	3.3 g
Carbohydrate	0 g
Sugar	0 g
Fiber	0 g
Cholesterol	77 mg

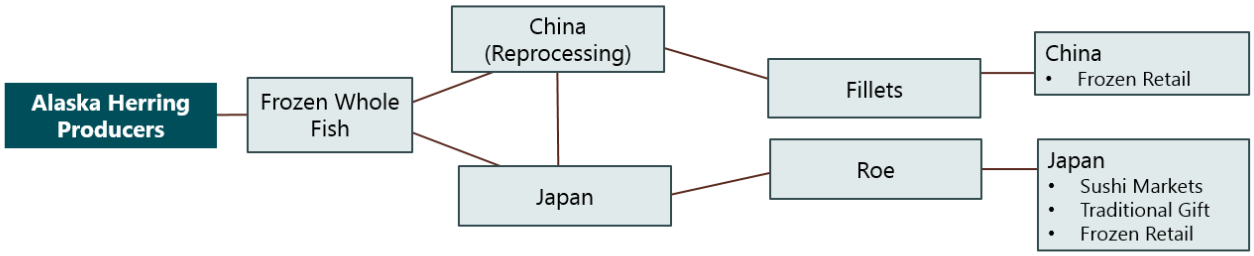
Source: Nutritionvalue.org.

[62] https://www.undercurrentnews.com/2016/10/12/alaska-herring-quota-reduced-amid-budget-cut/
[63] Personal communication with industry contact.
[64] https://www.nutritionvalue.org/Fish,_raw,_Pacific,_herring_nutritional_value.html

Supply Chain

Sac roe herring are typically transported from Alaska in 15 lb. bags. Due to the cost of shipping and processing, herring are frozen whole and shipped to Seattle, China, or Japan, where they are distributed to secondary processors, roe producers, or bait manufacturers. Not all Alaska processors sex-sort, which is more commonly used when roe prices are high.

Figure 12. Alaska Herring Supply Chain



Secondary processing, which includes roe-popping, occurs in China if prices are low, and Japan, if prices are high. Ultimately, roe product is sent to Japan, where it is graded by quality and distributed among domestic markets for traditional gifts, global sushi suppliers, and grocery stores. The accompanying fillets are sold as inexpensive staples in Japan and China.

Shipping costs vary, but the average price per pound can be $0.20 or more from Bristol Bay to Seattle, more than the 2015 ex-vessel value $0.06 per pound for the sac roe fishery.[65,66]

Herring Fillet Production

Estimates for herring fillet prices range from $1.00 to $3.00 per pound at the first wholesale level. It is estimated that fillet production in Togiak could bring an additional $14.5 million in first wholesale value. This is built on the assumption that all males (half of the harvest) would be filleted with a yield of 40 percent and sold for $1.50 per pound (FOB Bristol Bay).

See table on following page.

[65] http://www.adfg.alaska.gov/index.cfm?adfg=commercialbyfisheryherring.herringcatch_statewide
[66] Personal communication with industry contact.

Table 36. Potential Additional First Wholesale Value from Togiak Herring Fillets

Togiak Herring Harvest*	21,956 t
Primary Product	Frozen Whole Fish
Recovery Rate	40% of Males
Est. Wholesale Price Per Lb.	$1.50
Wholesale Volume	4,391 t
Est. Wholesale Value	**$14.5 million**

Notes: Togiak harvest volume is based on a 10-year average. Assumes only males are filleted.
Source: ADF&G, McDowell Group Estimates.

Ocean Beauty Seafoods and the Alaska Seafood Marketing Institute purchased a herring fillet machine from an Eastern Canadian seafood producer several years ago. The machine is operating in Togiak as a small, experimental fillet line. It was originally purchased to fillet herring prior to canning. Current production of Alaska herring fillets is relatively small, with several thousand pounds being produced to support market development efforts.

Due to high oil content, herring fillets do not freeze well. Herring fillets are often cured, a process which firms and shrinks the flesh. Shipping and processing costs are major hurdles to developing a fillet production line. In addition to high shipping costs, investing in a fillet machine can cost upwards of $150,000 alone.

Herring Fillet Markets

The largest markets for herring are in Scandinavian and Northern and Eastern European countries, including Poland, Russia, Germany, and Norway, where it is a traditional mainstay.[67] Demand for herring fillet products is highest during the holiday season (November-January).[68] In Europe, herring fillets are commonly sold in a lightly brined vacuum pack. Europeans typically consume herring fillets after thawing frozen product, which reduces the firmness of the meat.

North Americans do not have the same taste preferences and herring is typically sold as pickled product in jars or in tins as kippered or smoked product. Most of the herring consumed in the U.S. comes from Northeast states or is imported from Canada. In the last five years (2010-2014), the U.S. imported an annual average of 21,287 MT, with 66 percent sourced from eastern Canada (see Table 37). Regionally, the Northeast and Midwest are the largest markets for kippered/smoked and pickled herring. The Midwest also has a small market for fresh herring fillets from Lake Superior fish.[69] Niche herring markets also exist on the West Coast.

Table 37. U.S. Herring Imports, in MT and $Millions, 2010-2014

Region	2010	2011	2012	2013	2014	5 Year Average
Canada	17,381	14,878	13,546	12,838	11,906	14,110

[67] http://www.foodandwine.com/recipes/herring-under-fur-coat
[68] Personal communication with industry contact.
[69] http://www.olsenfish.com/

Germany	1,202	1,362	2,072	2,866	986	1,698
Norway	3,543	2,026	669	668	557	1,493
Poland	524	547	407	732	741	590
Other	4,229	2,633	2,891	2,589	4,642	3,397
Total	**26,880**	**21,446**	**19,584**	**19,693**	**18,831**	**21,287**
Canada	$32.7	$35.0	$36.0	$37.0	$36.4	$35.4
Germany	$5.8	$6.9	$7.8	$5.4	$5.4	$6.3
Norway	$11.3	$6.1	$1.6	$1.5	$1.3	$4.4
Poland	$1.6	$1.9	$1.5	$2.8	$3.0	$2.2
Other	$19.4	$14.0	$10.3	$10.0	$12.6	$13.2
Total	**$70.7**	**$63.9**	**$57.1**	**$56.8**	**$58.8**	**$61.5**

Note: Number may not sum due to rounding.
Source: NMFS trade data.

Northwest Herring Week is a weeklong promotion in Seattle where participating grocers and restaurants create herring dishes using Togiak herring.[70] With a nod to its iconic fishing history, Seattle's restaurant scene has recreated traditional herring dishes with a modern twist. Togiak herring is sent in IQF fillets to Seattle restaurants for $3.50/lb. One of the participating restaurants, Old Ballard Liquor Co., sells several herring products by the pound: $5.00 for frozen, $7.00 for salted, $9.00 for pickled. Promoters of Herring Week have plans to expand to the greater Pacific Northwest.

Herring fillets are also consumed in Japan, where pickled and fresh herring are used as sushi toppings.[71] Herring is called *nishin* in Japan. Fillets are also used in noodle soups (e.g. Nishin soba recipe). Like other small pelagic fish, herring are grilled whole in Japan (often with the entrails remaining in the fish). Alaska herring fillets have been sold to Japanese buyers in 15 lb. boxes in small batches.

ASMI's Role

- Alaska is a minor herring producer, compared to other regions. Promoting Alaskan herring in the U.S. market (particularly the West Coast) likely provides the best potential, as the attributes of Alaska seafood resonate well with U.S. consumers and the fish has a historic aura in West Coast cities.
- The biggest challenges for fillet production in Alaska is competing with low prices of Canadian suppliers. In addition, the softer flesh quality of Alaska herring, high transportation costs, and the lack of infrastructure in Alaska to handle herring fillet production are major obstacles.
- Companies that use Canadian herring in their product line are not aware of the supply, size grades, and the quality of Alaska herring.[72] ASMI's role could be to bring awareness to major distributors on the West Coast.

[70] https://nwherringweek.com/
[71] http://www.oprah.com/own-anna-kristina-grocery-bag/bo-sushi-with-herring
[72] Personal communication with industry contact.

Competing Supply

Over five years (2010-2014), herring harvests averaged 2.9 million MT (6.5 billion lbs.) globally, with approximately one-fifth (22 percent) attributed to Chilean herring that is used in fish oil reduction. Major Atlantic herring producers have seen a decline in TACs in the last few years, resulting in a slight price increase for herring markets in Europe. European countries, as a block, are the largest herring producers in the world.

Table 38. World Herring Production, in MT, 2010-2014

Region	2010	2011	2012	2013	2014	5-Year Average
Chile	750,750	887,272	848,466	236,968	543,278	653,347
Norway	923,741	633,103	610,713	507,465	407,424	616,489
Russia	430,771	450,464	487,740	476,191	440,568	457,147
Iceland	254,476	198,463	115,181	157,537	157,895	176,710
Canada	159,411	142,219	123,379	140,134	137,787	140,586
USA	114,520	125,015	122,203	134,865	139,420	127,205
Alaska	**47,156**	**39,455**	**27,841**	**34,396**	**39,576**	**37,685**
Denmark	77,445	85,934	125,117	141,028	135,580	113,021
Finland	92,757	98,002	117,866	122,318	131,116	112,412
United Kingdom	66,891	61,570	90,419	93,570	97,683	82,027
Other	414,477	382,938	432,074	554,250	462,486	449,245
Total	**3,285,239**	**3,064,980**	**3,073,158**	**2,564,326**	**2,653,237**	**2,965,873**

Source: FAO, ADF&G (COAR).

In North America, Canada and the U.S. produce similar quantities of herring. Most herring caught in Canada and the U.S. is harvested from the Atlantic Ocean during the winter months, long before herring begin to spawn. However, both countries have fisheries for Pacific Herring that primarily focus on roe products. East Coast producers (in Canada and the U.S.) produce both fresh and frozen herring fillets. Eastern Canadian producers (Barry Group) offer a brined fillet product that is shipped in a drum to secondary processors for $1.00/lb.[73,74]

[73] Personal communication with industry contact.
[74] http://www.barrygroupinc.com/pdf/Herring.pdf

Key Takeaways

- Arrowtooth flounder is one of the most abundant groundfish in Alaska, with the largest biomass of any groundfish species in the Gulf of Alaska.
- Arrowtooth flesh often contains an enzyme that is activated when the fish experiences even low levels of heat resulting in extremely soft, poor flesh quality. Low value fillets are practically a by-product of processing engawa, a thin strip of outer frill meat from flatfish highly valued by sushi chefs. However, because the fish is generically marketed as "flounder" poor consumer experiences with Arrowtooth lowers demand for other Alaska flatfish, such as sole and plaice.
- Arrowtooth flounder oil is an untapped opportunity. Its oil has been described as translucent, high quality oil that could make an attractive source for nutraceutical or cosmetic products.
- For every metric ton of age-6+ (exploitable) Pacific halibut in Alaska waters in 2016, there was an estimated 10.7 metric tons of Arrowtooth flounder. In 2000, there was only 3.1 metric tons of Arrowtooth flounder per ton of exploitable halibut. The ratio of Arrowtooth-to-halibut has increased 250 percent since 1996.
- Arrowtooth's large population likely suppresses Pacific halibut populations in numbers and fish growth rate due to competition for habitat and food. A concerted effort by industry and fishery managers to significantly increase Arrowtooth harvests, while minimizing halibut bycatch mortality, could raise Arrowtooth value and provide better growth prospects for halibut populations.

Arrowtooth Flounder Harvest, TACs, and Biomass Estimates

A large biomass of Arrowtooth flounder exists in the Gulf of Alaska and Bering Sea. TACs are typically set well below the Acceptable Biological Catch (ABC) for several reasons. In the Bering Sea, the 2 million metric ton limit on all groundfish harvests limits the amount of TAC allocated to Arrowtooth. Harvests are generally well below the TAC in both regions due to the relatively high rate of halibut bycatch, as well as the species' low value. Improvements to fishery management and operational practices have increased the percentage of biomass harvested in recent years.

Table 39. BSAI and GOA Arrowtooth Flounder TAC and Biomass, 2006-2016

Year	Catch (MT)	TAC (MT)	ABC (MT)	Biomass (MT)	Pct. TAC of Biomass
2006	41,014	51,000	313,844	3,028,997	1.7%
2007	37,281	63,000	342,008	3,097,355	2.0%
2008	51,177	118,000	470,470	3,146,778	3.7%
2009	53,851	118,000	377,512	3,173,005	3.7%
2010	61,896	118,000	371,882	3,145,910	3.8%
2011	61,056	86,600	366,150	3,074,914	2.8%
2012	52,598	146,000	362,882	3,017,642	4.8%
2013	49,887	138,300	362,451	2,999,852	4.6%
2014	60,593	135,400	301,957	3,018,362	4.5%

2015	35,315	131,800	273,468	3,017,799	4.4%
2016	35,790	123,800	266,889	3,025,547	4.1%

Note: Data includes Kamchatka flounder.
Source: NMFS Stock Assessments.

Table 40. Gulf of Alaska Arrowtooth Flounder TAC and Biomass, 2006-2016

Year	Catch (MT)	TAC (MT)	ABC (MT)	Biomass (MT)	Pct. TAC of Biomass
2006	27,653	38,000	177,844	2,040,080	1.9%
2007	25,364	43,000	184,008	2,073,070	2.1%
2008	29,293	43,000	226,470	2,090,960	2.1%
2009	24,937	43,000	221,512	2,109,820	2.0%
2010	23,015	43,000	215,882	2,098,620	2.0%
2011	30,890	43,000	213,150	2,070,550	2.1%
2012	20,714	103,300	212,882	2,028,960	5.1%
2013	21,620	103,300	210,451	2,033,570	5.1%
2014	35,026	103,300	195,358	2,073,910	5.0%
2015	19,054	103,300	192,921	2,093,010	4.9%
2016	19,830	103,300	186,188	2,103,860	4.9%

Source: NMFS Stock Assessments.

Table 41. BSAI Arrowtooth Flounder TAC and Biomass, 2006-2016

Year	Catch (MT)	TAC (MT)	ABC (MT)	Biomass (MT)	Pct. TAC of Biomass
2006	13,361	13,000	136,000	988,917	1.3%
2007	11,917	20,000	158,000	1,024,285	2.0%
2008	21,884	75,000	244,000	1,055,818	7.1%
2009	28,914	75,000	156,000	1,063,185	7.1%
2010	38,881	75,000	156,000	1,047,290	7.2%
2011	30,166	43,600	153,000	1,004,364	4.3%
2012	31,884	42,700	150,000	988,682	4.3%
2013	28,267	35,000	152,000	966,282	3.6%
2014	25,567	32,100	106,599	944,452	3.4%
2015	16,261	28,500	80,547	924,789	3.1%
2016	15,960	20,500	80,701	921,687	2.2%

Note: Data includes Kamchatka flounder.
Source: NMFS Stock Assessments.

Production Volume and Value

Arrowtooth flounder (*Atheresthes stomias*) is one of the most abundant groundfish species in the Bering Sea/Aleutian Islands (BSAI) area and the Gulf of Alaska (GOA). Based on the best available data, in the last five years, harvests averaged 36,857 MT (81 million lbs.) per year. Most of the harvest takes place in Alaska but there is some flounder harvested on the West Coast. Alaska accounts for 95 percent of the U.S. harvest.

Table 42. Alaska and U.S. Arrowtooth Flounder Harvest, in Metric Tons, 2011-2015

	2011	2012	2013	2014	2015	5 Year Average
BSAI Catch	20,133	22,378	20,537	19,105	11,267	18,684
GOA Catch	30,950	20,573	21,619	36,290	19,054	25,697
Total Alaska Catch	**51,083**	**42,951**	**42,156**	**55,395**	**30,321**	**44,381**
Total Alaska Retained Harvest	**40,247**	**34,908**	**33,013**	**49,583**	**26,534**	**36,857**
West Coast Harvest	2,237	2,182	1,963	1,214	1,331	1,785
Total U.S. Harvest	**42,484**	**37,090**	**34,976**	**50,797**	**27,865**	**38,642**
Pct. Alaska of Total Harvest	95%	94%	94%	98%	95%	95%

Note: Alaska Catch includes entire catch with both discards and retained arrowtooth flounder catch.
Source: NMFS FAKR Catch Reports, NMFS FAKR Groundfish Retained and Discarded, NMFS Landings.

The Amendment 80 fleet harvests most of the Arrowtooth flounder in the Bering Sea and the Gulf of Alaska as part of a portfolio of target species. Other trawl catcher vessels also harvest significant volumes of Arrowtooth flounder in the Gulf of Alaska.

In the last five years, an average of 17,047 MT (47 million lbs.) were processed, worth $26.3 million in first wholesale value. Fishermen receive between $.05 to $.07 per pound for Arrowtooth delivered shoreside, or $164/MT.[75] Processed Arrowtooth (typically headed/gutted and tail removed) averaged $1,453 per metric ton between 2011-2015.

Table 43. Alaska Arrowtooth Flounder Production Volume and First Wholesale Value, 2011-2015

	2011	2012	2013	2014	2015	5 Year Avg.
Processed Volume (Million lbs.)	47.0	40.4	24.7	46.5	29.4	37.6
Processed Volume (MT)	21,335	18,308	11,195	21,070	13,325	17,047
First Wholesale Value ($Millions)	$31.3	$31.2	$13.5	$32.5	$17.9	$26.3
First Wholesale Value ($/MT)	$1,467	$1,704	$1,204	$1,543	$1,346	$1,453

Source: ADFG (COAR).

The Arrowtooth flounder TAC-to-biomass ratio is one of the lowest of all groundfish species, approximately 4 percent in 2015. In contrast, the ratio for Pacific cod and pollock was 14 and 13 percent, respectively, in 2015.[76] Arrowtooth flounder is the most abundant groundfish species in the Gulf of Alaska and has a substantial biomass in the Bering Sea, but TACs do not reflect the species's abundance for several reasons:

- In the BSAI, the total groundfish TACs are capped at 2 million MT per year, regardless of the size of the collective biomass of BSAI commercial groundfish species. If current Arrowtooth TACs were to increase,

[75] ADFG (COAR) Reports
[76] NMFS SAFE

other species' TACs would have to decrease.[77] As Arrowtooth flounder are one of the lowest value Alaska species, the species's TAC is usually set well below its Acceptable Biological Catch (ABC).

- Arrowtooth flounder catch is also limited by low Kamchatka flounder TACs, which is harvested with Arrowtooth flounder. Kamchatka flounder is less abundant (for 2015, 6,500 MT TAC in BSAI).[78]
- Halibut bycatch caps severely limit harvests of Arrowtooth flounder. Both Arrowtooth and Pacific halibut are relatively large flatfish species that can inhabit the same territory, and are often similar in size (although older halibut can grow much larger). Halibut excluder devices generally are not effective when fishermen target Arrowtooth. Therefore, it is challenging to get even close to harvesting the GOA TAC of 103,300 metric tons, for instance, given that the GOA trawl halibut bycatch limit is 1,706 metric tons. If the halibut bycatch limit is exceeded, the Arrowtooth trawl fishery is closed for the year by regulation.
- Traditional fishing grounds for Arrowtooth flounder have shifted in recent years and fishermen face a tradeoff of spending additional time searching for new locations of Arrowtooth or targeting a more valuable species.

Although Arrowtooth flounder closely resemble smaller halibut, there is a critical difference in meat quality that results in the former being one of Alaska's most valuable species and Arrowtooth being one of the lowest. Halibut meat has a dense, white texture that lends itself well to a variety of preparations, especially frying. Arrowtooth flounder carry a myxosporean parasite that release a proteolytic enzyme which softens the fish's flesh upon landing. Not all Arrowtooth carry the meat-softening parasite, but most do. The only way to counteract the enzyme is to treat the fish with an additive that partially offsets the enzymatic process, or to keep the fish just above freezing and then cooking quickly under high heat (such as frying). Unfortunately, both practices do not completely fix the enzyme problem, and makes harvest and processing much more costly. Kamchatka flounder is a similar to Arrowtooth flounder, and in fact was treated as Arrowtooth by federal fishery managers until it was broken out as a distinct species in the Bering Sea flatfish complex several years ago. Kamchatka flounder has the same enzyme issue as Arrowtooth flounder.

Processing Methods and Alaska Products

Arrowtooth flounder is usually processed onboard as frozen headed/gutted product with the tail removed, or "HGT." It has priority onboard catcher-processors to process as soon as possible to limit the enzymatic breakdown of the flesh. The two factors that greatly reduce the enzymatic breakdown are maintained cold temperatures and rapid processing to freezing time.

All processing is done through an automated system. Removing the tail is a common market preference for several flatfish, including Arrowtooth flounder, Greenland turbot, and Kamchatka flounder. The average yield

[77] Personal communication with industry contact.
[78] NMFS SAFE

for H&G is 74 percent.[79] A typical Arrowtooth flounder weighs approximately 17 pounds.[80] Processors typically have six size grades, ranging from 400 to 3,000 grams.[81]

Table 44. Arrowtooth Flounder Yield Rates

	Avg. Percent from Round Weight
Gutted only	90
H&G	74
Kirimi	48
Skinless fillet	34
Skinless, boneless fillet	25
Surimi	11
Frill (Engawa)	1-2

Source: Crapo (2004) and the Canadian Utilization of Fish Discards Program (1996).

Major Production Areas

Arrowtooth flounder is abundant in the North Pacific, with the highest concentration harvested in the Central Gulf of Alaska. In 2015, the TAC was over 103,300 MT (227 million lbs.) for the Gulf of Alaska and 22,000 MT (48.5 million lbs.) for the Bering Sea and Aleutian Islands.[82]

Arrowtooth flounder quality is the best near the Aleutian Island Chain; however, the availability of Arrowtooth in this area has been limited by unknown environmental circumstances or possibly overfishing.[83]

Seasonal Availability and Suppliers

The Amendment 80 fleet, the primary harvesters of Arrowtooth flounder, operate in the Bering Sea and Gulf of Alaska nearly year-round.

Interested buyers can easily locate Alaska Arrowtooth flounder suppliers by using the Alaska Seafood Suppliers Directory (link), hosted by the Alaska Seafood Marketing Institute.

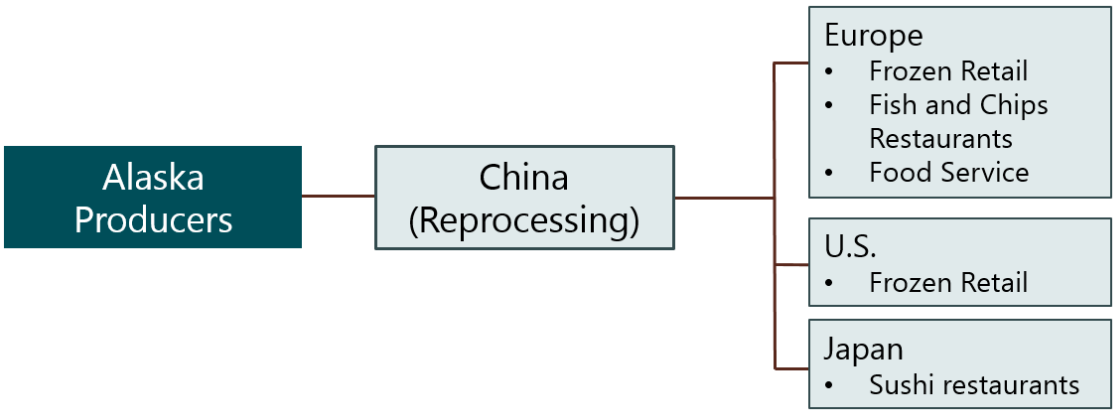
Supply Chain and Markets

Arrowtooth flounder is generally exported to China as frozen whole fish, H&G or HGT product for reprocessing. It is then re-exported as frozen fillets or breaded/frozen product to Europe, the U.S., and other markets as a low cost flounder or whitefish product. Finished Arrowtooth fillet product is commonly marketed simply as

[79] http://seafood.oregonstate.edu/.pdf%20Links/Recoveries-and-Yields-from-Pacific-Fish-and-Shellfish.pdf
[80] http://www.iquiqueus.com/fresh-catch/primary-species/arrowtooth-flounder/
[81] Personal communication with industry contact.
[82] http://www.npfmc.org/wp-content/PDFdocuments/resources/SpeciesProfiles2015.pdf
[83] Personal communication with industry contact.

"flounder." This has caused consumer confusion and disappointment in some cases, as fillets containing the flesh-softening enzyme are typically much lower quality than other flounder species.

Figure 13. Arrowtooth Flounder Supply Chain



Frill meat (engawa) is connective muscle that runs along the outer fins and is sliced from under the fin and packed in frozen shatterpack blocks. Frill yield is estimated at 1-2 percent from round weight.[84] Engawa is a low yield, high value product that has been reportedly sold at $22 per kilo for vacuum sealed product.[85] Chinese reprocessors separate engawa and sell frozen product to distributors that supply sushi restaurants, mostly in Japan. Larger engawa strips receive higher prices. Engawa is the major profit driver for Chinese Arrowtooth buyers. However, Chinese processors must utilize the rest of the fish in some manner to cover costs, so this typically means freezing the fillets and selling them at a low price as generic "flounder." Unfortunately, poor quality Arrowtooth fillets give frozen fillets from other flatfish species (e.g. sole) a bad reputation with consumers, affecting the value for other Alaska sole products.

Arrowtooth flounder is also used as a raw material by Japanese and Korean processors in surimi seafood products. Utilizing Arrowtooth in surimi products allows producers to work around the effects of the fish's flesh-softening enzymatic process.

Table 45. Top Export Destinations of Alaska Flounder, in Metric Tons, 2011-2015

	2011	2012	2013	2014	2015	Average Volume	5-Year Average Value ($Millions)
China	10,110	7,428	10,677	16,317	9,239	10,754	$19.4
Japan	3,955	1,547	1,938	2,550	1,399	2,278	$4.1
South Korea	1,372	3,078	1,216	922	1,218	1,561	$2.7
Russia	383	74	183	177	0	163	$0.3

[84] http://www.dfo-mpo.gc.ca/Library/197343.pdf
[85] Personal communication with industry contact.

Other	5,722	678	412	274	223	1,462	$2.3
Total	**21,542**	**12,805**	**14,426**	**20,240**	**12,079**	**16,218**	**$28.8**

Note: Data pertains to exports of "Flatfish NSPF Frozen" from Districts 30 and 31. These exports include a variety of flatfish species, primarily caught in Alaska, but are believed to be comprised mostly of Arrowtooth flounder based on industry interviews.
Source: NMFS Trade Data.

Global Supply

- Arrowtooth flounder are found in the North Pacific Ocean and are harvested by the U.S., Russia, and Canada. The U.S. makes up the majority of global harvests (94 percent, on average between 2010-2014).

Table 46. Global Production of Arrowtooth Flounder, in Metric Tons, 2010-2014

	2010	2011	2012	2013	2014	5 Year Average
U.S.	49,555	42,592	37,187	34,956	50,811	43,020
Canada	25	7	18	3	11,821	2,375
Russia	376	303	298	394	437	362
Total	**49,956**	**42,902**	**37,503**	**35,353**	**63,069**	**45,757**

Note: Include Kamchatka flounder production.
Source: FAO Global Capture Production.

Arrowtooth Flounder Impact on Pacific Halibut

There is considerable evidence that growing Arrowtooth flounder populations are having an adverse impact on Pacific halibut stocks in Alaska. Before examining data supporting this claim, it is instructive to understand economic differences of the two species.

Arrowtooth flounder is one of the lowest value species caught in Alaska's commercial fisheries, both in terms of pricing and total first wholesale value. The average first wholesale value per round metric ton of harvested Arrowtooth was $508 in 2015, and the fish accounted for 0.4 percent of Alaska's total first wholesale value. By contrast, Pacific halibut is one of the state's most valuable species. The average first wholesale value per round metric ton of harvested halibut was $12,650 in 2015. Halibut accounted for 3.1 percent of total first wholesale value in 2015 and only six other species had a higher first wholesale value than halibut, despite historically low halibut TACs. In 2005, the peak of halibut harvests in recent decades, the fish accounted for 6.2 percent of total first wholesale value. The halibut fishery has lost approximately $100 million in annual value over the past 10 years, principally due to lower harvests (driven by smaller TACs/population).

Pacific Halibut

Arrowtooth Flounder

Meat quality aside, halibut and Arrowtooth flounder are very similar species. They are both relatively large bottom-dwelling flatfish that prefer similar habitats and have similar foraging habits. Given the declining trends of halibut stocks and growth rates, and historical increase in Arrowtooth flounder stocks, it is appropriate to consider the complex issue of whether Arrowtooth flounder stocks are having an adverse impact on halibut stocks in Alaska. A comprehensive exploration of the relationship is beyond the scope of this project, however, a summary of biomass trends of the two species may suggest potential solutions for future consideration.

Summary of Key Trends for Arrowtooth Flounder and Pacific Halibut Stocks

Halibut stocks have been in decline since 1997. The age-6+ biomass of Pacific halibut in 1997 was 843,815 metric tons, including Alaska, Canadian, and Pacific Northwest areas. That figure has fallen steadily in subsequent years, declining to 284,308 metric tons in 2017. In addition to declining populations, the growth rate of Pacific halibut has also declined in recent decades. The average weight of a 20-year old female declined from 55 kilograms in 1988 to 20 kilograms in 2014.[86]

Arrowtooth flounder stocks in the Bering Sea and Gulf of Alaska have increased dramatically over the past 40 years. In 1976, the total Arrowtooth flounder biomass in Alaska was estimated at 997,498 metric tons. By 1997, the estimated Arrowtooth biomass had increased to 2,445,645 metric tons and peaked at 3,173,005 metric tons in 2009. Since 2009, estimated Arrowtooth biomass has remained steady at approximately 3 million metric tons.

The correlation between halibut spawning biomass and total Arrowtooth flounder biomass from 1996 to 2016 is -0.95, a nearly perfect negative correlation (see Table 47). As one biomass decreases, the other increases. The absolute differences in biomass are also important. In 1996, for every metric ton of age-6 or greater Pacific halibut there was an estimated 3.1 metric tons of Arrowtooth flounder in Alaska waters competing for habitat and food.[87] By 2017, that figure had increased nearly 250 percent to 10.7 metric tons.

Table 47. Comparison of Arrowtooth Flounder and Pacific Halibut Biomass, in Metric Tons, 1996-2016

Year	Total Arrowtooth Biomass	Halibut Biomass (Age 6+)	AF Biomass to Halibut Age 6+ Biomass Ratio
1996	2,464,216	219,403	3.1
1997	2,445,645	236,231	2.9
1998	2,446,432	232,920	3.0
1999	2,463,574	226,071	3.3
2000	2,503,193	213,098	3.7
2001	2,593,929	196,814	4.3
2002	2,686,891	177,990	4.7
2003	2,798,137	157,533	5.2
2004	2,878,908	140,523	5.8
2005	2,957,160	125,056	6.7

[86] https://scholarworks.alaska.edu/bitstream/handle/11122/6857/Sullivan_uaf_0006N_10528.pdf?sequence=1
[87] Age-6+ halibut are a reasonable proxy for the volume of fish available to various halibut fisheries (personal communication with IPHC staff).

2006	3,028,997	112,310	7.2
2007	3,097,355	102,784	7.5
2008	3,146,778	96,162	7.9
2009	3,173,005	87,861	8.7
2010	3,145,910	84,459	8.9
2011	3,074,914	83,234	9.1
2012	3,017,642	84,005	8.8
2013	2,999,852	87,044	8.2
2014	3,018,362	90,764	8.7
2015	3,017,799	94,937	9.2
2016	3,025,547	99,337	9.8
Correlation	**-0.95**		

Note: Arrowtooth biomass refers to estimates of age (+1) Arrowtooth flounder and Kamchatka flounder in the BSAI and GOA. Halibut biomass figures pertain the CW short model for all regions managed by the International Pacific Halibut Commission (most of the halibut biomass is in Alaska waters). Halibut figures are converted from net weight to round weight basis using a 0.72 conversion factor.
Source: McDowell Group computations based on NMFS and IPHC.

Is it possible that decades of selectively fishing pressure favoring halibut has resulted in an imbalance in halibut and Arrowtooth stocks to a point where Arrowtooth became so numerous that the species began to outcompete halibut for habitat and forage. A recent thesis paper by Jane Sullivan, a recent University of Alaska Fairbanks graduate, considered a range of factors impacting halibut growth. The study supports the notion that competition from Arrowtooth has had an adverse impact on halibut growth, but found a weaker correlation when examining biomass trends of the two species over a longer period. Prior to 1996, there were periods where the biomass of each species trended in the same direction.

However, the complexity of the issue requires more than regression analysis. With ample food and space, the presence of Arrowtooth is likely not a significant factor in halibut population growth. Further the average size of each fish matters a great deal. Smaller Arrowtooth provide a food source for larger halibut, and vice versa. It is possible that the size of Arrowtooth populations in the 1970s, 1980s, and early 1990s was simply not large enough to have much impact on halibut. As the two species approach a limit on environmental carrying capacity, the effects of competition and predation would likely be more severe.

Because of Arrowtooth flounder's low value and large numbers, the fish is essentially a nuisance species. Arrowtooth consume small halibut and eat food which might otherwise be consumed by halibut and other, more valuable bottom-dwelling species. In addition, Arrowtooth consume significant volumes of pollock and maybe a limiting factor for other commercial species as well.[88]

Halibut bycatch and allocation battles garner a lot of attention, but the scale of Arrowtooth biomass in relation to halibut receives less focus. Arrowtooth is not one of the top species for trawl companies and it's considered a trash fish by commercial and sport fishermen. It may be more constructive for fishery groups to focus less on

[88] https://seagrant.uaf.edu/map/gap/fish/publications/knoth2006.pdf

allocation, and more on finding ways to help the trawl fleet catch more Arrowtooth (while still minimizing halibut mortality).

Further research on the topic may be warranted, if fishery managers wish to better understand how Arrowtooth impact halibut stocks and where these interactions are most intense. Subsequent analysis would be needed to investigate the role overlapping abundance plays for each species and investigate how foraging and inter-species predation affects population and/or fish growth. Specifically, it would be helpful to know how important young Arrowtooth are as a food source to mature halibut.

Potential Solutions for Increasing Halibut and Arrowtooth Value

Although additional research would likely provide valuable information about the nature and scale of Arrowtooth effects on halibut, available data strongly suggests that Arrowtooth abundance is a negative factor for halibut populations and growth rates.

As halibut are a high value species and Arrowtooth are not, the optimal (value-maximizing) strategy would be to harvest more Arrowtooth flounder, thereby reducing competitive pressure on halibut in the hopes that halibut stocks will rebound. This approach faces two major challenges:

- Halibut and Arrowtooth flounder often inhabit the same territory and can be equal in size, so Arrowtooth fishing typically results in a relatively high rate of halibut bycatch. Removing Arrowtooth is important, but it must be done without doing more harm to the much smaller halibut population.
- Arrowtooth are a very low value species and the economics of harvesting them at current harvest levels is not particularly attractive. Even for those boats that do catch Arrowtooth, it is often not the target species or is done during periods when more valuable species are not available.

Halibut are a notoriously tough species, able to survive extreme changes in depth during landing and relatively long periods out of water. Fishery managers and companies have recently studied the practice of "deck sorting" where flatfish trawl vessels sort the harvest upon landing and return halibut to the water as quickly as possible. Data from deck sorting experiments suggests the practice does result in lower halibut mortality, though more study may be required to create a more accurate picture of mortality and the role different handling factors play in mortality rates.

Though it is well beyond the scope of this study to examine in detail specific fishing and/or management strategies to increase Arrowtooth values while insuring (or enhancing) halibut values, the following strategies might be possibilities:

1. Establish deck sorting protocols for trawl vessels that prioritize halibut survival. Allow vessels with deck sorting and monitoring capabilities (DSM, see below) to factor improved halibut mortality into their bycatch limits. Require DSM vessels to also use gear modifications which exclude the harvest of large halibut. Use existing research to quantify the impact of halibut size on mortality and trawl tow length/time on mortality rates. Consider incentivizing deck sorting and monitoring for trawl fleet by creating a separate halibut bycatch limit for those vessels that deck sort and those that do not.
2. Remove Arrowtooth flounder from the 2 million metric ton groundfish harvest cap in the Bering Sea.

3. Increase Arrowtooth flounder TACs in the Gulf of Alaska and Bering Sea to a specified volume greater than the overfishing limit (OFL), for example set TACs at 20 percent above OFL until the biomass reaches a predetermined target.
4. Initiate a strategy for fleet/harvest optimization, with consideration of the following components:
    a. Extend Arrowtooth access to additional vessels/companies capable of following DSM protocols
    b. Require the use of electronic video monitoring (EM) and vessel design that ensures video recording of all retained species, the number of halibut returned to the water, and the time expended during deck sorting. Using EM is more efficient, particularly on smaller vessels, and reduces the number of paid observers required to monitor the fishery.
    c. Revisit fishery management regulations that encourage industry to utilize Arrowtooth flounder in at-sea and onshore fishmeal and oil production. It is likely that meal/oil production will be a major component in making Arrowtooth harvest profitable, as increasing the harvest volume would likely result in lower prices (potentially below-even levels) for H&G or meat products.
5. Fund research aimed at maximizing the value of Arrowtooth fish oil and market development for Arrowtooth fish oil. Again, it is very likely that efficiently processing Arrowtooth flounder into meal/oil and engawa will be a key part of any strategy to profitably harvest more Arrowtooth. Fishmeal is a highly-commoditized product, but preliminary research on Arrowtooth oil suggests that refined product may be suitable for higher-value markets.

Potential Value of a Meal/Oil/Engawa Fishery for Arrowtooth Flounder

Substantially increasing Arrowtooth flounder harvests would likely have a beneficial long-term impact on halibut stocks and the value of the halibut fishery, but it could also directly increase the value of Alaska seafood resources in the near term. The analysis below provides a hypothetical first wholesale value which may be realized from increasing Arrowtooth flounder harvests only (not including the potential for increased halibut value).

Assuming Arrowtooth harvests could be increased to 300,000 metric tons and based on certain assumptions about product yield, product mix, and pricing, it is estimated that the Arrowtooth flounder fishery could produce $254 million in first wholesale value. This equates to a first wholesale value per round metric ton of $847. Much of the estimated value comes from processing and retaining engawa (55 percent of the estimated first wholesale value).

Table 48. Potential First Wholesale Value from Increasing Arrowtooth Flounder Harvests and Meal/Oil/Engawa Production

New Harvest Level (in MT)	300,000
First Wholesale Value by Product, (in $Millions)	
Engawa (assumes 1.75% yield and $12/lb. value)	$139
Fishmeal (assumes 18% yield and $1,800/MT value)	$97
Fish oil (assumes 5% yield and $1,200/MT value)	$18
Total First Wholesale Value	**$254**
Average Actual First Wholesale Value (2011-2015)	**$25.3**
First Wholesale Value per Round MT	**$847**

Source: McDowell Group estimates.

Increasing Arrowtooth flounder harvests to 300,000 MT would represent a greater than eight-fold increase in current harvests, so such a change is a tall order given the difficulty in avoiding halibut mortality. However, it is necessary to raise commercial harvests rates to such a level if Arrowtooth populations are to be curbed through human intervention.

Opportunities and Challenges

- The greatest challenge for Arrowtooth flounder is the heat-activated enzyme breakdown in its flesh, which softens the flesh and makes it unpalatable. Catcher processors have sought to address this issue by keeping the product at a low temperature and rapidly running the flounder through the processing line before the flesh deteriorates. Additionally, Chinese re-processors have stabilized the raw material with food additives.[89]
- Arrowtooth flounder is marketed as flounder. While this helps sell Arrowtooth fillets in the short term, it has adversely affected other higher-quality Alaska sole/flounder prices.
- Surimi and protein powder products are currently being explored as additional ways to utilize Arrowtooth flounder.[90]
- Arrowtooth flounder produce an oil that is translucent and highly stable. The oil yield is about 4-6 percent and it is ideal for cosmetic products.[91]

MARKET	OPPORTUNITIES
Domestic and Europe	Surimi products
	Protein powder
	Value-added frozen products
China	Value-added frozen products
Japan	Engawa/frill meat for sushi
Nutraceutical/Cosmetics	Fish oil
	Collagen products

Future Research Suggestions

- How does the impact of halibut deck sorting impact the quality of Arrowtooth flounder?
- Could Arrowtooth flounder fishmeal and oil be a lucrative alternative to HGT production?
- Continued research and optimization of deck sorting techniques to minimize halibut bycatch mortality.
- A better understanding of halibut and Arrowtooth flounder interactions including:
    - Foraging consumption of Arrowtooth flounder, including any evidence of a predatory relationship with juvenile halibut and how this interaction impacts both species' survival rates and recruitment levels.

[89] Personal communication with industry contact.
[90] https://www.commerce.alaska.gov/web/Portals/6/pub/Fisheries/DCCED%202009%20Undeveloped%20commercial%20fisheries.pdf?ver=2016-08-19-141837-487
[91] Personal communication with industry contact.

- Evidence that Arrowtooth flounder are overtaking productive halibut grounds and the possibility of crowding out halibut through competition for resources.

Key Takeaways

- The popularity of spiny dogfish among consumers and processors has been challenged by several factors:
    - The species' slow growth rate and the lack of directed fishery is a challenge for processors who prefer a consistent supply.
    - The FDA advises pregnant women and children to limit dogfish consumption because the fish contain toxins, including trace amounts of mercury.
    - They are not certified under RFM or MSC, and campaigns against illegal shark harvests have reduced demand for all shark, including dogfish from Alaska.
- Despite these challenges, dogfish products could gain popularity as a substitute for whitefish in niche markets in Europe and the U.S., especially in "sea to table" restaurants. Alaska dogfish could also provide a uniquely sustainable source of shark fins for Asia markets, where illegal harvests are becoming an increasing point of concern.
- Improving market development and retention of Alaska dogfish could result in an estimated $1.45 million in additional first wholesale value.

Alaska Production

Spiny dogfish (*Squalus suckleyi*) is the market name for a genus of shark species found in temperate areas of the Pacific and Atlantic Oceans.[92] They are more common in the Gulf of Alaska than the Bering Sea. Dogfish are slow to mature, have low reproduction rates, and are susceptible to overfishing. They can grow to a maximum size of 160 cm (63 inches), but market size is about 90m (3 feet) and 3 to 4 kilos (7 to 10 lbs.).[93]

Photo courtesy of Zeus Packing Company.

Alaska dogfish catches averaged 1,371 MT (3 million lbs.) from groundfish fisheries over the last five years (2011-2015), but only an average of 15 MT was retained. There is not a directed fishery for dogfish in Alaska. Dogfish are caught as bycatch in longline, trawl, and jig fisheries. They are also caught incidentally in salmon fisheries (mostly troll fisheries) but that amount

[92] Spiny dogfish are one of three shark species that are assessed in the Gulf of Alaska. The others are Pacific sleeper shark, salmon shark, and other/unidentified sharks.
[93] http://www.afsc.noaa.gov/REFM/Docs/2015/GOAshark.pdf

is unknown as there is no data on dogfish bycatch in state salmon fisheries. Reliable biomass estimates, spawning biomass, or stock status information are not available.

Table 49. Alaska Dogfish Harvest, in Metric Tons, 2011-2015

	2011	2012	2013	2014	2015	5-Year Average
BSAI Shark (Dogfish) Catch	107	96	117	137	107	113
GOA Shark (Dogfish) Catch	522	661	2,170	1,526	1,414	1,259
Total Alaska Catch	**629**	**757**	**2,287**	**1,663**	**1,521**	**1,371**
Total Alaska Retained Harvest	**17**	**14**	**14**	**14**	**18**	**15**
East Coast Retained Harvest	9,701	10,290	7,224	9,992	8,407	9,123
West Coast Retained Harvest	561	150	149	205	202	253
Total U.S. Retained Harvest	**10,279**	**10,454**	**7,386**	**10,212**	**8,626**	**9,392**
Pct. Alaska of Total U.S. Harvest	0.2%	0.1%	0.2%	0.1%	0.2%	0.2%
Potential Alaska Share of Total Harvest	6%	7%	31%	16%	18%	16%

Note: Includes several species of shark, but the most frequently harvested is the spiny dogfish. Does not include incidental bycatch in Alaska salmon fisheries.
Source: NMFS FAKR Catch Reports, NMFS FAKR Groundfish Retained and Discarded, NMFS Landings.

Trawl-caught dogfish are worth $0.09 to $0.11 per pound in ex-vessel terms.[94] Longline dogfish are closer to $0.15 per pound.[95] Wholesale prices are between $0.60 to $1.00 per pound for edible portions, which have a recovery rate of 36 percent. Fins, which have a 4 percent yield, can fetch relatively high prices in Asian export markets.

Finning (stripping shark fins without retaining the whole fish) at sea is not allowed in Alaska fisheries; fishermen must transfer the whole fish in a transaction. Finning is a disturbing practice where live, finless sharks are discarded at sea and left to starve on the sea floor or get consumed by other fish. Finning is illegal in most countries; however, the international waters are unregulated and as such there is no enforcement mechanism to prevent the practice in these areas. Environmental groups have increased public awareness of the practice in recent years.

Processing Challenges

Shark species lack a urinary tract and excrete waste through their skin. Dogfish must be gutted, bled, and chilled as soon as it is brought onboard or it will develop an ammonia smell.[96] Processing spiny dogfish is done by hand and is labor-intensive. Their fins, guts, and skin are removed, leaving a skinless fillet that can be shipped fresh or frozen. Not only does this make value-added production costly, it also limits fishing trip length before the skin quality begins to deteriorate. As dogfish is a not a target species, it is often easier for both fishermen and processors to avoid dealing with dogfish lest it interfere with business operations focused on other species.

[94] Personal communication with industry contact.
[95] Gaspar, J. (2011). Policy and Market Analysis of World Dogfish Fisheries and an Evaluation of the Feasibility of a Dogfish Fishery in Waters of Alaska, USA (Doctoral Thesis).
[96] http://www.seafoodsource.com/seafoodhandbook/finfish/dogfish

Often the dogfish that is delivered to shoreside plants is ground into fish meal. Not all processors in Alaska accept dogfish because it is a low value product and they are not equipped to process it.

Seasonal Availability and Suppliers

Dogfish are incidentally caught year-round, but a high concentration are caught during halibut and sablefish longlining, which runs from March to November. They are also harvested in salmon fisheries, which occur from June to September.

The Alaska Seafood Suppliers Directory (link), hosted by the Alaska Seafood Marketing Institute, contains contact information for Alaska dogfish suppliers.

Major Production Areas

Dogfish are concentrated in the Gulf of Alaska and are caught in high numbers near Yakutat and Kodiak. Between 2001 to 2008, a small set gillnet fishery for dogfish occurred in Yakutat. Harvests were sporadic and the fishery has not reopened in recent years.

Nutritional Profile

Dogfish meat has a sweet, mild flavor and a higher oil content than other sharks and they are a good source of selenium and vitamins B6 and B12. The Food and Drug Administration advises pregnant women and children not to eat shark due to its elevated mercury content.[97]

Spiny Dogfish Nutrition Profile

	Amount per 100g portion
Calories	130
Fat Calories	41
Total Fat	4.5 g
Saturated Fat	0.9 g
Sodium	79 mg
Protein	20.9 g
Omega-3	0.9 g
Cholesterol	51 mg

Source: Seafoodsource.com.

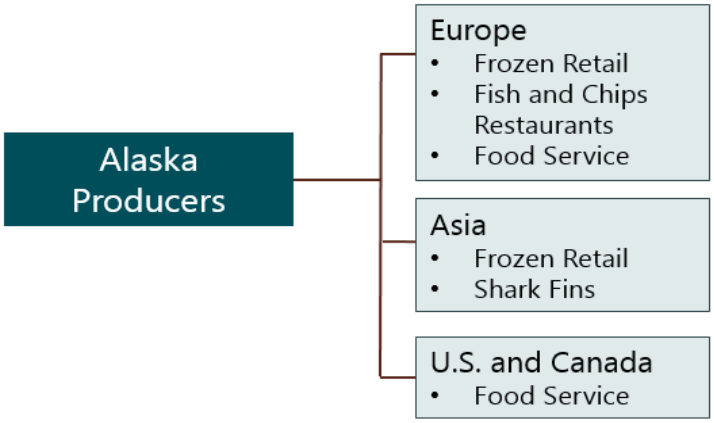
Supply Chain

The primary market for dogfish is Europe. Most dogfish is processed immediately and transshipped to wholesale distributors who supply to European and Asian markets.

See figure on following page.

[97] http://www.seagrant.umaine.edu/maine-seafood-guide/dogfish

Figure 14. Dogfish Supply Chain



Global Supply

From 2010-2014, global dogfish harvests averaged 25,937 MT. The U.S. is the largest producer, accounting for 36 percent of global harvests, followed by New Zealand with 21 percent.

The East Coast region supplies 98 percent of U.S. dogfish exports, but according to industry reports, Atlantic dogfish supply was down in the last few years and distributors have had more difficultly filling orders for dogfish products, including fins and fillets.[98]

Table 50. Global Production of Dogfish, in Metric Tons, 2010-2014

	2010	2011	2012	2013	2014	5-Year Average
USA	6,696	10,940	10,971	7,396	10,959	9,392
Alaska	**N/A**	**17**	**14**	**14**	**14**	**15**
New Zealand	4,725	3,820	6,574	5,502	6,524	5,429
Libya	7,300	4,400	5,100	5,100	3,550	5,090
Indonesia	710	1,497	1,782	2,499	2,675	1,833
Other	6,512	3,948	3,773	2,500	4,233	4,193
Total	**25,943**	**24,605**	**28,200**	**22,997**	**27,941**	**25,937**

Note: For Alaska, sharks were grouped together as "other species" until 2011.
Source: FAO Global Capture Production, NMFS FAKR Region (Retained Harvest), and NMFS (OST).

Markets and Uses

Most dogfish meat is consumed in Europe and Asia. Fins are sold primarily in Asia for their alleged pharmaceutical qualities.[99] Several European countries use dogfish in a variety of ways. The fish is most often

[98] Personal communication with industry contact.
[99] http://capecodfishermen.org/images/documents/Campaign_Materials/Dogfish/2015_Seafood_Expo_Notes.pdf

sautéed in France, smoked in Germany, or fried in the U.K. European buyers typically pay higher prices for dogfish than Asian buyers.

Consumption of dogfish has been negatively impacted by media campaigns discouraging consumption of any shark species. The campaigns have spurred a greater decline in dogfish consumption in Europe than in Asia.

Exports of dogfish averaged 3,531 MT a year from 2011-2015, with the East Coast supplying 98 percent of U.S. exports. Alaska exports of dogfish varied widely in the same time period, but averaged 60.7 MT.

Table 51. Exports of U.S. Dogfish by Region, in Metric Tons, 2011-2015

U.S. Region	Export Destination	2011	2012	2013	2014	2015	Average Volume	5-Year Average
Alaska	Europe	0	0	86	29	71	37	$216,333
	Other	0	22	57	15	26	24	$21,153
Total Alaska Exports		**0**	**22**	**143**	**43**	**96**	**61**	**$237,486**
East Coast	Europe	3,315	2,331	2,649	2,695	2,710	2,740	$11,249,933
	China	478	367	247	343	507	388	$1,464,706
	Thailand	0.0	100	161	339	239	210	$611,225
	Other	174	164	114	211	101	111	$464,788
Total East Coast Exports		**3,967**	**2,962**	**3,171**	**3,588**	**3,557**	**3,449**	**$13,790,651**
West Coast (& Other)	Canada	3	16	9	3	4	7	$16,710
	Other	1	44	20	0	10	15	$41,694
Total Other U.S. Exports		**4**	**61**	**29**	**3**	**14**	**22**	**$58,404**
Total U.S. Exports		**3,971**	**3,044**	**3,342**	**3,633**	**3,667**	**3,531**	**$14,086,542**

Notes: Districts 30 and 31 are designated as Alaska product ports. Totals may not sum due to rounding.
Source: NMFS Trade Data.

In the U.S., dogfish is sometimes substituted in restaurant dishes such as fish tacos, fish sandwiches, and fish and chips.[100] Institutions like schools and prisons have used Atlantic dogfish in meals.

In China and other Asian countries, dogfish is substituted for more expensive shark species. Thailand uses it in shark fin soup. Hong Kong eats the fin and tail. Several Asian countries have cracked down on illegal shark imports. Asian demand for Alaska dogfish might increase because it is a sustainable option for other shark species, since Alaska has a reputation for responsibly managed fisheries.

[100] http://www.npr.org/sections/thesalt/2017/01/07/508538671/would-you-eat-this-fish-a-shark-called-dogfish-makes-a-tasty-taco

Opportunities and Challenges

Challenges

Marketing spiny dogfish from Alaska poses several challenges:

- They are not sustainably certified by either MSC or RFM
- Dogfish and other sharks are known to contain high levels of contaminants/toxins
- Dogfish do not have a directed fishery, creating inconsistent supply
- Dogfish flesh is susceptible to spoilage and expensive to process

Dogfish values are limited by negative consumer perceptions. Dogfish are grouped in with all sharks, which are characterized by environmental groups as non-sustainable. Alaska dogfish are not certified by MSC or RFM. However, British Columbia and the Atlantic dogfish fisheries are currently MSC certified.

Spiny dogfish can have high levels of contaminants dioxin and PCBs. Shipments from the East Coast have been denied entry on occasion into the Eurozone, which has traditionally been the primary market for dogfish meat. Dogfish from both the Atlantic and Pacific Oceans are known to contain relatively high levels of mercury and public health agencies generally discourage consumption by pregnant women and children.[101,102]

Due to their biology, dogfish are not a high-volume fishery and consistent supply is a challenge. Processing is labor-intensive and additional training is needed for handling dogfish, which require different cuts for back, bellies, fins, and a unique skinning technique.

Opportunities

Alaska dogfish needs to be differentiated from other shark species using eco-labeling and marketing to inform consumers. It is a highly versatile fish that has potential to be a great fish and chips substitute and a niche "sea to table" product in the restaurant industry in both Europe and the U.S.

MARKET	OPPORTUNITIES
Europe	Fish and chips, sustainably marketed under the Alaska Seafood brand.
U.S. Domestic Market	Sea to table and "eat local" movements[103] Collaboration with East Coast for marketing promotions
Asia	Sustainably sourced shark fin products
Nutraceuticals	Collagen as a cosmetic anti-aging treatment

[101] http://www.seafish.org/industry-support/legislation/contaminants/dioxins-and-pcbs
[102] http://seafood.edf.org/shark
[103] http://capecodfishermen.org/item/pbs-newshour-features-dogfish

In Asia, there has been a crackdown in illegal shark product imports. Alaska's sustainably harvested dogfish could potentially see premium prices with the lowered global supply for shark products, including shark fins.

There has recently been less dogfish harvested on the East Coast, partially owing to lowered harvest and to low market prices. There is potential to collaborate with the East Coast on supplying the European market.

Due to its high lipid content, dogfish cartilage could be used for gelatin products and dogfish collagen could be used in cosmetic skin aging treatments.

Potential for Additional First Wholesale Value

The average dogfish is approximately 3 pounds, and is worth $0.30 in ex-vessel value and $1.44 in wholesale value, based on typical recovery yield of edible portions and fins.

Approximately 3 million pounds of dogfish are harvested in Alaska each year and the small amount retained is usually processed into fish meal. If this volume could be diverted to fins and edible products, there would be an additional $1.45 million in first wholesale value, assuming fins could be sold for $3/lb and edible portions could be sold for $1/lb. The value of processing retained dogfish harvests into fish meal is negligible, by comparison. However, processing Alaska dogfish into fins and edible portions would have higher processing costs and could pose challenges for fishermen.

Table 52. Potential Dogfish Value

	Dogfish Harvest	
Total Dogfish Harvest (in Lbs.)	3,023,388	
Ex-Vessel Price/Lb.	$0.10	
Ex-Vessel Value	**$302,339**	
Product Yields	Edible Portions 36%	Fins 4%
Wholesale Volume (in Lbs.)	1,088,420	120,936
Wholesale Price/Lb.	$1.00	$3.00
Wholesale Value	**$1,088,420**	**$362,807**
Total Additional Value	**$1,451,227**	

Note: Values are based on industry estimates, pounds landed are a 5-year average of harvests, and recovery rates are based from Crapo (2004).
Source: McDowell Group estimates.

Key Takeaways

- Skates are harvested in substantial quantities in Alaska (generally over 60 million lbs. per year), but most of the harvest is not retained.
    - Skates secrete urea through their skin after the fish expires, which can negatively affect meat quality for both skates and any other fish present in the same fish hold. Not all catcher-processors are equipped to process skate wings. As a result, many catcher-vessels and some catcher-processors do not retain skates.
- Skates are an underutilized species in Alaska that are popular in restaurants and as a frozen retail product in Europe. The species may have potential in the U.S. as a higher-end, domestic, sustainable restaurant menu item.
- Due to their unique physiology, skates have nutraceutical benefits that is the subject of increasing research.

Production Volume and Value

Skates are cartilaginous fish with large pectoral wings. The typical Alaska skate is 3 feet long and between 20 to 30 pounds, although average size varies by species.

In the last five years (2011-2015), Alaska harvests of skates averaged 33,085 MT (68.7 million lbs.) with approximately one-third retained for processing. Over 80 percent of the harvest is attributable to big skates and longnose skates. The remainder of the harvest consists of 12 other species.[104]

Table 53. Current Skate Harvest, in Metric Tons, 2011-2015

	2011	2012	2013	2014	2015	5-Year Average
BSAI Skate Catch	23,154	24,824	27,024	27,511	28,117	26,126
GOA Skate Catch	4,687	4,124	6,179	5,199	4,968	5,031
Big Skate	2,305	1,998	2,520	1,673	1,515	2,002
Longnose Skate	1,031	925	1,780	1,585	1,671	1,398
Other Skate	1,351	1,201	1,879	1,941	1,782	1,631
Total Alaska Catch	**27,841**	**28,948**	**33,203**	**32,710**	**33,085**	**31,157**
Total Alaska Retained Harvest	**8,251**	**9,700**	**10,170**	**9,480**	**9,060**	**9,332**
West Coast Harvest	1,081	1,188	1,029	1,181	1,021	1,100
East Coast Harvest	16,384	16,523	13,999	15,192	14,493	15,318
Total U.S. Harvest	**25,716**	**27,410**	**25,197**	**25,853**	**24,574**	**25,750**
Pct. Alaska of Total Harvest	**24%**	**26%**	**29%**	**27%**	**27%**	**27%**

[104] http://access.afsc.noaa.gov/pubs/posters/pdfs/pRace01_skates-of-Ak.pdf

Potential Alaska Share of Total Harvest	**52%**	**51%**	**57%**	**56%**	**57%**	**55%**

Note: Alaska Catch includes entire catch with both discards and retained skate catch.
Source: NMFS Alaska Region Catch Reports, NMFS Alaska Groundfish Retained and Discarded Data, NMFS Landings.

Skates are distributed throughout the Gulf of Alaska and the Bering Sea, with a higher concentration of marketable species (big and longnose) in the Gulf of Alaska. There is not currently a directed fishery for skates in Alaska. They are caught incidentally in the longline fisheries for cod, halibut, and sablefish, as well as groundfish trawl fisheries.

Approximately 73 percent of the Alaska skate catch was discarded at sea in 2015.[105] While both discards and retained species count towards a species' TAC, skate retention rates could improve if market conditions improved for Alaska producers.

Big and longnose skates receive higher prices due to firmer meat and thicker wings, followed by Alaska, Aleutian, and Bering skate species. Skates found at lower depths typically have softer flesh. Some processors refuse to buy small skates which lack a viable market.

Table 54. Alaska Skate Production Volume and Value, 2011-2015

	2011	2012	2013	2014	2015	5-Year Average
Big skate	363	272	181	91	91	181
Longnose skate	272	227	408	272	318	318
Other skates	1,497	1,950	2,223	2,177	1,905	1,950
Total Volume (MT)	**2,132**	**2,449**	**2,858**	**2,586**	**2,313**	**2,449**
Big skate	$1.7	$1.7	$1.1	$0.4	$0.4	$1.1
Longnose skate	$1.4	$1.6	$2.4	$1.3	$2.0	$1.7
Other skates	$3.4	$5.1	$5.4	$3.7	$3.3	$4.2
Total Value ($Millions)	**$6.5**	**$8.3**	**$8.9**	**$5.4**	**$5.7**	**$7.0**

Note: Skate wings are the primary product. Not all processors sort by skate species.
Source: ADF&G (COAR) and McDowell Group estimates.

Skate wings, the most common finished product type sold, account for 23 percent of the fish's round weight and average approximately 5 pounds. Skate wings are frozen flat and stacked in 50 pound boxes.[106] Skates are typically processed after target species, such as halibut and cod, which reduces the quality of skates. Skate cheek meat is also processed, similar to cheek meat from other species, such as halibut. Fishermen can earn around $0.30 a pound for selling skates to Alaska processors.[107]

Skate livers, like shark livers, have high fat content and must be immediately frozen to maintain their consistency. While they have market value in nutraceuticals, the requirements of immediate freezing and additional processing deter extraction. Estimated liver yield is between 10 to 15 percent.

[105] NMFS FAKR Catch Reports, 2015
[106] Personal communication with industry contact.
[107] Personal communication with industry contact.

Seasonal Availability & Suppliers

Skates are available nearly year-round as bycatch in longline and trawl fisheries. Larger skates are typically harvested in longline fisheries and smaller skates are caught in trawl fisheries. Halibut and sablefish are harvested from March to November and Pacific cod is harvested nearly year-round.

The Alaska Seafood Suppliers Directory (link), hosted by the Alaska Seafood Marketing Institute, contains contact information for Alaska skate suppliers. Suppliers can work with their fleets to retain skates and coordinate with buyers on product specifications.

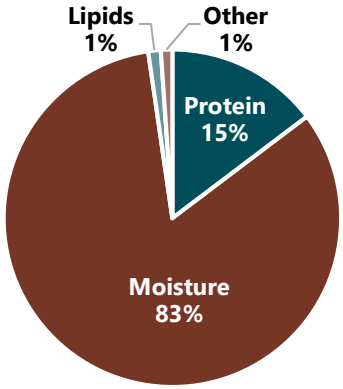
Nutritional Profile

Skate wings consist of mild-flavored, white meat with a stringy texture. Skates are low in fat and cholesterol, and have slightly more protein than cod.[108,109]

Table 55. Skate Wing Nutrition

	Amount per 100g portion
Calories	95
Fat	1 g
Sodium	90 mg
Protein	20 g

Source: Great Northern Products and Farrugia et. al (2015).



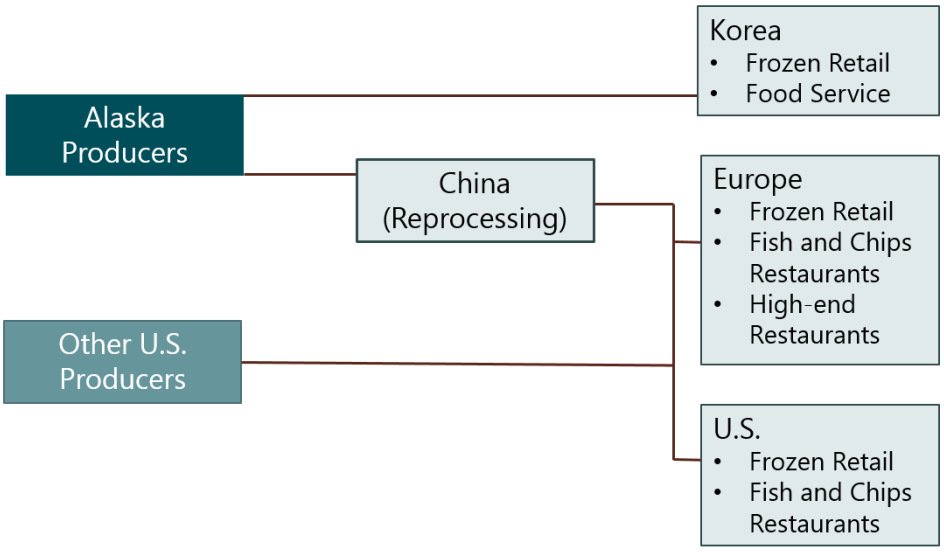
Supply Chain

Most of Alaska's skates are sent to China for reprocessing and re-exported to Europe and the U.S. for frozen value-added products, fish and chips restaurants, and high-end cuisine in France and Germany. From Alaska, skate wings are flash-frozen and shipped in 50 pound boxes, typically worth about $1 per pound.[110]

Alaska skate wings sent to Asia for secondary processing are typically re-exported as value-added frozen fish finger-sized slices.[111] The U.S. East Coast directly ships larger skates to Europe, where it is a popular seafood item. Small skates are sold as lobster bait.

[108] http://www.seagrant.umaine.edu/maine-seafood-guide/skate
[109] http://www.northernproducts.com/products/#sthash.Flt8MMQm.dpbs
[110] Personal communication with industry contact.
[111] Personal communication with industry contact.

Figure 15. Skate Supply Chain



Competing Supply

During the most recent five years with available data (2010-2015), global harvests of skates and rays averaged 469,099 MT (1 billion lbs.), with Asian countries accounting for the majority of global production. The U.S. share of the global skate/ray harvest was approximately 6 percent over the five-year period. India is the world's largest producer of skates and rays, averaging 71,342 MT (154.2 million lbs.) between 2010-2014.

Table 56. Global Production of Skates and Rays, in Metric Tons, 2010-2014

	2010	2011	2012	2013	2014	5 Year Average
Asia	**218,092**	**244,688**	**263,917**	**254,501**	**261,983**	**248,636**
India	60,313	70,994	75,681	71,342	71,342	69,934
Indonesia	44,478	48,430	56,403	56,067	61,772	53,430
Malaysia	20,621	19,106	22,148	23,607	24,664	22,029
Other	92,680	106,158	109,685	103,485	104,205	103,243
Americas	**119,686**	**119,840**	**117,940**	**107,365**	**107,951**	**114,556**
U.S.	29,234	27,375	27,931	25,537	26,236	27,263
Alaska Harvest	**8,709**	**8,251**	**9,700**	**10,170**	**9,480**	**9,262**
Mexico	27,455	22,272	21,929	30,010	26,975	25,728
Brazil	18,596	17,093	19,513	17,236	19,156	18,319
Other	44,401	53,100	48,567	34,582	35,584	43,247
Africa	**67,498**	**61,182**	**67,105**	**73,640**	**63,688**	**66,623**
Nigeria	21,625	18,491	19,032	19,324	20,238	19,742
Tanzania	5,383	6,132	8,756	8,465	7,846	7,316
Other	40,490	36,559	39,317	45,851	35,604	39,564
Europe	**34,437**	**34,331**	**32,861**	**30,155**	**32,758**	**32,908**
Spain	11,932	11,586	9,539	7,944	9,449	10,090
France	7,370	6,966	6,403	6,114	6,586	6,688

Other	15,135	15,779	16,919	16,097	16,723	16,131
Oceania	**7,755**	**6,204**	**6,240**	**6,012**	**5,664**	**6,375**
New Zealand	2,608	2,344	2,266	2,754	2,688	2,532
Australia	3,659	3,411	3,081	2,691	2,504	3,069
Other	1,488	449	893	567	472	774
Total Skate and Ray Harvest	**447,468**	**466,245**	**488,063**	**471,673**	**472,044**	**469,099**

Note: Numbers include skate, ray, and some sharks.
Source: FAO Global Capture Production, NMFS Alaska Region (Retained Harvest), and NMFS (OST).

Markets and Uses

Since 2012, Alaska has exported an estimated 1,957 MT (4.3 million lbs.) of skates each year worth $5 million, primarily to South Korea, where it is a popular seafood product and may also be held in cold storage for re-export to other markets.

In comparison, the East Coast has exported 2,292 MT (5 million lbs.) of skates worth $6.8 million, with 86 percent of exports sent to European markets.

Table 57. Top Exports of U.S. Skates by Region, in Metric Tons, 2012-2015

U.S. Region	Export Destination	2012	2013	2014	2015	Average Volume	5-Year Average Value ($Millions)
Alaska	South Korea	1,638	1,718	1,841	2,121	1,830	$4.8
	China	11	36	115	75	59	$0.1
	Japan	6	27	114	82	57	$0.1
	Other	19	0.7	0.5	23	11	$0.03
Total Alaska Exports		**1,674**	**1,782**	**2,070**	**2,301**	**1,957**	**$5.0**
East Coast	Europe	2,697	1,789	2,022	1,409	1,979	$6.3
	China	394	120	72	96	170	$0.2
	South Korea	97	22	0.6	24	36	$0.1
	Other	209	47	109	62	107	$0.24
Total East Coast		**3,396**	**1,977**	**2,204**	**1,591**	**2,292**	**$6.8**
West Coast & Other	Canada	118	113	161	133	136	$0.4
	South Korea	52	-	237	31	91	$0.3
Total West Coast & Other		**170**	**113**	**399**	**164**	**227**	**$0.7**
Total U.S. Exports		**5,240**	**3,872**	**4,673**	**4,056**	**4,476**	**$12.5**

Note: Districts 30 and 31 are designated as Alaska product ports.
Source: NMFS monthly export data.

Skates are common in Europe and Asia both as high-end delicacies and as value-added products, depending on the size, quality, and skate species. Skate wings sometimes function as a lower cost substitute for scallops or monkfish.

Skate wings are popular in France where they are pan-sized to be buttered and sautéed. European grocery stores source North Atlantic skates in the frozen aisle of the supermarkets, next to, for instance, Alaska pollock

products. Skate dishes are also a high-end item in French and German restaurants on the East Coast, mirroring European preferences.[112]

Skates are very popular in South Korea, where skate wings are consumed raw, sautéed, and fermented.[113] Kinunot na Pagi is a Filipino dish that uses coconut milk and flaked skate wings.[114] Grilled skate and stingray are used in Malay, Chinese, and Singapore curry, sambal, and assam pedas (sour-spicy seasoning).[115] Dried skate preparations are also used in Asia. China and other Asian countries use skate cartilage for medicinal purposes.

Opportunities

MARKET	OPPORTUNITIES
Europe	Frozen Value-Added Product
Asia	Frozen Skate Wing
U.S. Domestic Market	Niche high-end markets for local harvest (Community-Supported Seafood Shares)
Nutraceutical/Medical	Collagen: Since skates are cartilaginous fish, there are currently studies looking at using collagen from its skin as material for bone regeneration.[116] Mucus: There are microbial properties, similar to shark, that have the potential to be a natural source of sterilization.[117] Liver: There is a small developmental nutraceutical market for skate liver pills.[118]

Challenges

- Since there is not a directed fishery, skates are harvested only as bycatch and is not always retained nor is there a steady supply available of any given species.
- High shipping costs and low skate prices do not justify an increase in Alaska skate production to established markets.

[112] Personal communication with industry contact.
[113] https://seoulfoodyy.wordpress.com/2012/03/27/fermented-skate/
[114] http://www.pinoyhapagkainan.com/kinunot-na-pagi/
[115] Personal communication with industry contact.
[116] http://link.springer.com/article/10.1007/s13770-014-0075-y
[117] http://www.dtic.mil/dtic/tr/fulltext/u2/a600463.pdf
[118] https://www.amazon.com/Blue-Fermented-Skate-Liver-120/dp/B004PAP9E8/ref=sr_1_fkmr0_3_a_it?ie=UTF8&qid=1481247319&sr=8-3-fkmr0&keywords=boodoo+ice+liver+oil

Specialty Product Challenges and Opportunities

Alaska's commercial fisheries produce significant volumes of seafood products, but rarely utilize and create value from the entire fish. As one long-time product development advocate stated in a recent interview, "Alaska's seafood industry has a butcher shop mentality when it should have an oil refinery mentality." However, several significant challenges commonly hinder the viability of producing specialty seafood products in Alaska. These general themes are explored in this chapter. Overcoming these core challenges and focusing on key opportunities are critical for Alaska to increase utilization and value from its sustainable fishery resources.

Production Challenges

Production priority: Shoreside plants and processing vessels of all sizes in Alaska have capacity constraints. Higher value products get priority access to processing resources, including capital investment, labor, and freezer/storage space. Plant managers allocate processing resources according to product value in order to maximize the production value of available resources.

Capacity limitations: Plants typically do not have freezing capacity to simply freeze unused raw material, or buy larger volumes of "trash fish", during peak harvest periods. Increasing resource utilization on the shoulder seasons may be part of the answer, but most plants employ less labor during the shoulder season. In some cases, the additional labor and freezing costs may exceed the value of specialty product production.

Economies of scale: Alaska's seafood industry produces large volumes of unused or undervalued marine resources. However, this production is spread over a vast area, and supply is inconsistent because many fisheries are seasonal in nature. This makes it difficult to create a manufacturing process capable of efficiently transforming lower-value marine resources into marketable products. In addition, Alaska's fishing communities are often not connected to the road system, so moving product from one community to another is costly.

Larger ports with enough volume to support a fish meal/oil plant generally have facilities already in place. However, there is a still a significant volume of product which is located in smaller ports with more seasonal production. Processing and marketing specialty products from these smaller facilities results in higher unit costs of production.

Cost of production: Finally, operating costs in Alaska tend to be higher than most other places due to the cost of labor, energy, and the remote nature of Alaska ports. Manufacturing process typically cost significantly more in Alaska than in other countries or the Lower 48. Unless Alaska offers some particular access or production advantage, it is generally more cost-effective to produce it elsewhere.

Marketing Challenges

Many specialty products are sold into markets that are unfamiliar to Alaska producers, such as pet food manufacturing, specialty exports markets, or nutraceutical/pharmaceutical producers. Alaska seafood processors primarily sell food products to seafood distributors or secondary seafood manufacturers. Only recently has there been interest in specialty products sourced from Alaska's waste. For example, Bering Select

in Dutch Harbor began distilling oil from Pacific cod livers for the nutraceutical supplement market and Tidal Vision began to source crab shells from St. Paul to supply the chitosan market in the U.S.

Developing sales relationships and hiring the expertise to market specialty products is an added cost for Alaska seafood products, and one that carries no guarantee of return. For smaller companies, often the value and volume of material in question does not justify the investment in human resources and other marketing assets.

A key marketing challenge is to bridge the gap between potential buyers who are unaware of Alaska's under-utilized specialty resources and Alaska producers who may not yet have awareness of or access to markets that value those resources.

The Case for Cooperation & Aggregation

The costs and technical difficulties associated with producing and selling specialty products can be daunting for individual firms. In general, most Alaska processors have increased resource utilization through investments and modifications made within the company. Cooperatively handling raw material and waste in Alaska could create economies of scale that could lower costs for individual firms and improve utilization rates. This can be done by selling to a third party firm that has the resources to utilize the specialty product or by creating a cooperative. The two models, by which Alaska processors might increase resource utilization, are discussed below.

Selling Raw Material to a Third-Party Firm

The industry as a whole could increase its resource utilization if smaller companies sold waste to larger companies for specialty product manufacturing. This already occurs in Alaska, but the practice is not widespread. Trident Seafoods, on occasion, collects salmon waste from smaller plants with its floating salmon oil processing vessel then processes oil onsite. This keeps more waste out of the outflow pipe and creates a valuable product at the same time. Typically, a floating processing vessel will travel to smaller ports where it will process onsite the salmon waste into salmon oil.

As noted in this report, the unit value of supplement-grade Alaska salmon oil is very high. However, the fact that Trident Seafoods or other large Alaska processors have not expanded salmon oil production by buying larger volumes of salmon waste from competitors suggests that salmon oil demand has its limits. Expanding production by leveraging salmon waste from smaller ports would likely require marketing efforts to expand consumption of salmon oil or other products derived from the additional raw material.

In addition to demand limitations, the seasonal nature of salmon runs complicate the situation. Most small salmon processors create waste at approximately the same time of year. Collecting and processing waste from many ports would require those processors to freeze raw material, which is often not practical during periods of heavy supply.

A principal consideration and challenge is the cost associated with collecting and transporting the waste product to a centralized processing facility. Those costs, plus processing and distribution costs, could exceed the value of low-end products.

This model creates more value out of the resource, but currently has little impact on the ex-vessel value of Alaska salmon. Unless a larger market for salmon by-products or other waste emerges, with competition from multiple buyers, smaller processors will not receive much value from selling waste streams. Therefore, there is very little additional first wholesale value which could be passed onto fishermen or retained by smaller processors. Trident Seafoods has made significant investments in developing a salmon oil product and the market for it. If other large processors actively pursue fish waste from smaller plants, a more competitive market could be created for waste products, a market possibly capable of raising ex-vessel values. However, that distant possibility will require much investment and product/market development by other large processors.

One such example where specialty product investments may have wider impacts is in Dutch Harbor. Clipper Seafoods, one of the largest Pacific cod quota shareholders in the Bering Sea, recently began producing cod liver oil. Clipper controls its own supply, but could easily source additional supply from other processors, if needed.[119]

Raw material could also be purchased and consolidated by companies which are not part of the Alaska seafood processing industry. For example, Juneau-based Tidal Vision buys salmon skins for manufacturing accessories such belts and wallets. To support this kind of manufacturing, raw material may be frozen and shipped out for processing elsewhere or processed locally (in the port of origin).

Creating a Specialty Product Cooperative

Companies can create efficiencies by forming a cooperative that aggregates raw material and benefits from economies of scale in production and sales. This model also has precedent in Alaska; The Kodiak Fishmeal Company (KFC) is jointly owned by a group processors with Kodiak plants. Beginning operations in 1995, the facility transforms waste into marketable products without the need for fishmeal plants at each processing facility.

Kodiak is a unique Alaska seafood port. It has landings nearly year-round and includes several shoreside processing plants in close proximity. With the exception of Dutch Harbor, most other Alaska seafood ports have fewer processors or more seasonal production. Still, KFC may be a model worth considering in other Alaska ports, even if supply is only seasonal.

New cooperatives do not necessarily need to focus on fishmeal and fish oil as their primary products. The only requirement is that the new entity be capable of profitably transforming fish waste in marketable product(s). In addition to producing commodity-grade fishmeal and oil, this could include isolating collagen or other high-value compounds, or providing feeds/fertilizer for a local farm. Further research and planning is necessary to determine the best use of fish waste in each situation.

[119] https://www.adn.com/business/article/pioneering-effort-sell-pacific-cod-liver-oil-not-what-your-grandma-ordered/2015/06/07/

Quantifying Production of Specialty Products

Confidentiality regulations make it difficult to fully quantify the volume of raw material available for specialty production, as well as the amount of finished products. Individual processing company production records are proprietary information.

The inability to document available supply hinders specialty product marketing. Confidentiality measures also make it difficult to verify production volumes and values for purposes of lending or economic development projects.

To the extent possible, this report quantifies actual and potential supply of specialty products based on production data reported to the state and/or by using product recovery rates and harvest volumes. Quantifying supply and unit value is critical to developing markets for Alaska specialty seafood products.

Future Research Suggestions

This section describes potential general and species/product specific research opportunities that would further inform efforts to add value to Alaska's varied specialty seafood products.

Comprehensive Yield Database and Raw Material Analysis

A common data gap for this project was the lack of information on the specific yield of fish/shellfish parts. A booklet published by Alaska Sea Grant entitled "Recoveries and Yields from Pacific Fish and Shellfish" is very helpful in providing information about how much fillets, or headed/gutted fish weigh as a percentage of the whole fish. However, in some cases it is useful to have a more detailed analysis. For example, how much does a frame or a liver weigh, as a percentage of the whole fish?

Further, it would be instructive to conduct chemical analyses on each fish part. Proximate analyses are often conducted on the entire fish, when in many cases the raw material in question contains only certain fish parts. Therefore, it is important to know what prospective waste material a fishery provides, and the chemical and nutritional nature of those parts.

Compiling this data will require multiple dissections of many fish and shellfish species, as well as a thorough chemical analysis of each part. Although this is a large undertaking, the research would produce a comprehensive reference database capable of providing technical data on every fish part. Once completed, the data could be aggregated to match the waste stream of any processing operation.

Connecting with Buyers

This document provides a wealth of information about the types of markets specialty products are sold into; however, developing extensive lists of specific buyers is often difficult and very time consuming. Alaska seafood suppliers are, understandably, unwilling to share names and contact information for their buyers, lest they lose business to another supplier. Finding buyers for specialty products without having product to sell can also be challenging. For some products, the number of potential buyers is massive, for others it may consist of a few specialty distributors.

To better connect buyers and sellers, the Alaska Seafood Marketing Institute could host a Buyers Directory on its website, similar to their Supplier Directory. This would provide potential buyers with a free, highly-visible online space to advertise their demand for specific Alaska seafood products. This way, suppliers who have product to sell could find interested buyers through the ASMI Buyers Directory. Buyers could be placed in the directory by providing ASMI staff with contact information and indicating the types of products they are interested in buying.

Further, Alaska seafood suppliers might utilize this report as a guide towards helping them locate potential buyers. For example, a processor seeking to find markets for cod milt may consider contacting specialty seafood distributors in large U.S. urban areas or Japanese importers who buy a wide range of species. Finding companies who fit those descriptions can easily be found using online search tools.

Extending the Reach of the Alaska Seafood Brand

Many of Alaska's seafood products function as a raw material for secondary seafood processors, often times located in other countries. Alaska seafood is sometimes combined with product from other countries and as a result loses its place of origin, and the ability to market based on positive attributes of the Alaska Seafood brand. In these situations, Alaska seafood product is a pure commodity, interchangeable with similar products from anywhere else, with none of the intrinsic value associated with the Alaska seafood brand.

In some cases, value can be added to species or products simply by creating informational materials that allow processors or fishermen to improve the quality of their product, or become more efficient. One example is the ASMI salmon color guide, which easily allows processing workers to grade salmon – even if they are unfamiliar with the product.

Continuing to work with Alaska seafood suppliers and buyers to create informational tools is important, improving the ability of everybody in the supply chain to produce and market Alaska seafood. Additional ideas include:

- Video explaining how to properly retain, process, and store dogfish
- Updating existing ASMI processing guides with visual image prompts, as opposed to text (many processing workers do not speak or read English)
- Bulletin summarizing improvements in packaging
- Checklist of what is needed to produce supplement-grade fish oil

Future Research Suggestions by Species and Product

Along with industry-wide research topics, further species-specific research opportunities could include the following:

ARROWTOOTH FLOUNDER

- How does the impact of halibut deck sorting impact the quality of Arrowtooth flounder?
- Could Arrowtooth flounder fish meal and oil be a lucrative alternative to Head/Gut/Tail production?
- A better understanding of halibut and Arrowtooth flounder interactions including:

- Foraging consumption of Arrowtooth flounder, including any evidence of a predatory relationship with juvenile halibut and how this interaction impacts both species' survival rates and recruitment levels.
- Evidence that Arrowtooth flounder are overtaking productive halibut grounds and the possibility of crowding out halibut through competition for resources.
- Potential correlation of size-at-age trends between the two species.

DOGFISH

- Could training in handling, transporting, and processing dogfish improve species' value and retention?
- Is there additional value in selling cartilage to collagen manufacturers?
- What would the ex-vessel price need to be for fishermen to consider dogfish a worthwhile retained catch?
- What shark fin sizes are preferred by various international markets?

HERRING

- Herring promotions targeting ethnic communities in the U.S., including Russian, Eastern European, and Scandinavian.
- The costs of curing herring in Alaska and shipping drums to the domestic market.
- Identifying alternative funding sources for herring management.

SKATES

- Develop a "Best Practices" guide for retaining and processing skates.

FISHMEAL/OIL

- A study investigating how much Alaska seafood waste is discarded versus processed into specialty products, and the trends of commercial seafood resource utilization.
- Producing refined fish oil for human consumption could increase the value of Alaska's fish oil production several fold (oil was worth $34 million in first wholesale terms in 2014); however, it is not clear 1) how much more value could be added, 2) whether the market could handle a large influx of fish oil supplement supply, or 3) how much it would costs companies to do so.
- Obtaining Nielsen retail sales data regarding sales of specific pet food products could provide valuable marketing material. If the "Alaska premium" can be quantified in terms of price premium and growth prospects, by market, versus other pet food/treats, this could provide a justification on the part of buyers to pay more for Alaska seafood/salmon thus elevating Alaska product above the basic commodity value. Competing against commoditized protein products from around the world may prove challenging for Alaska producers.
- Study the impact of fish oil supplements on hair and nail growth/health. Some people report stronger nails after taking fish oil supplements. Quantifying a beneficial impact on hair and/or nails could increase demand for fish oil supplements.

FISH HEADS

- Head yield and oil content by species.

- Proximate analysis for heads.
- Volume of heads discharged as processing waste.

ROE PRODUCTS

- Yield and nutritional composition of roe-based fish oil.
- Quantify success of 1) marketing new roe products in traditional markets and/or 2) marketing roe products in new markets.
- Investigate methods to maximize omega-3 retention from roe oil, specifically how to utilize roe membranes and prevent them from clogging up oil processing equipment.

INTERNAL ORGANS

- Yield by type of organ from each commercial species.

Table 58. Estimated Shipping Costs for Frozen Product

Origin	Destination	Mode	Cost per 40' Container	Cost per Pound[1]
Naknek	Seattle	Barge or Ocean Freight	$10,100	$0.20
Naknek	Qingdao, China	Barge or Ocean Freight	$12,780	$0.25
Dutch Harbor	Qingdao, China	Barge or Ocean Freight	$5,500	$0.11
Dutch Harbor	Busan, South Korea	Barge or Ocean Freight	$5,500	$0.11
Kodiak	Seattle	Barge or Ocean Freight	$7,700	$0.15
Kodiak	Qingdao, China	Barge or Ocean Freight	$7,800	$0.15
Kodiak	Busan, South Korea	Barge or Ocean Freight	$7,800	$0.15
Kodiak	Hamburg, Germany	Barge or Ocean Freight	$8,900	$0.18
Southcentral AK	Seattle	Barge or Ocean Freight	$5,500	$0.11
Southeast AK	Seattle	Barge or Ocean Freight	$6,000	$0.12
Southeast AK	Qingdao, China	Barge or Ocean Freight	$6,600	$0.13
Southeast AK	Hamburg, Germany	Barge or Ocean Freight	$7,800	$0.15
Seattle	Qingdao, China	Barge or Ocean Freight	$3,400	$0.07
Seattle	Busan, South Korea	Barge or Ocean Freight	$3,400	$0.07
Seattle	Hamburg, Germany	Barge or Ocean Freight	$5,400	$0.11
Seattle	Midwest U.S.	Truck	$6,000	$0.12
Seattle	Southeast U.S.	Truck	$9,000	$0.18
Seattle	Eastern U.S.	Truck	$8,500	$0.18

[1] Estimated cost per pound assuming a full shipment weighing 23 MT per 40' container.
Source: Industry interviews.