SUSTAINABLE MARINE RESOURCES FOR ORGANIC AQUAFEEDS

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ABSTRACT

Utilization of marine protein and oil from wild-caught sources in organic aquafeeds is feasible and conforms to several principles of organic production, namely using feed ingredients from sustainable sources; recycling of waste products and ensuring healthful products to the consumer that are equivalent to those of natural origin. However, it conflicts with the organic principle of having complete knowledge of all feed inputs throughout their production; hence the topic is controversial. Information is presented regarding the availability and sustainability of Alaska pollock (*Theragra chalcogramma*), five species of Pacific salmon in Alaska (*Oncorhynchus* sp.), gulf menhaden *(Brevoortia patronus)* and Peruvian anchovy *(Engraulis ringens)* to demonstrate that sustainable marine sources exist within the USA and elsewhere. Sourcing guidelines for wild-caught fishmeal and fish oil are discussed. In particular the most appropriate criteria for selection of fish species are presented, including the assessment of stock health and sustainability as part of responsible management of reduction fisheries, as well as the options available for monitoring and verification. The use of 'trimmings' or processing waste for manufacturing fishmeal and fish oil derived from sustainably-fished wild fish species is practiced on a large scale in Alaska. Alaska pollock and Pacific salmon are managed as targeted fisheries, making issues of segregation and traceability of fish meal and oil produced from their trimmings relatively minor. Utilizing processing waste from conventionally or organically-reared fish to produce fish meal and oil for organic aquafeeds is also feasible. The main priority is to avoid recycling of fish pathogens. Therefore fishmeal and fish oil derived from farmed fish must be subjected to appropriate thermal treatment and should ideally not be used in aquafeeds used to feed the same or closely related farmed species of fish.

Aside from the issue of sustainability of wild-caught fish used to produce fish meal and oil, the main point of controversy is the lack of control over their life cycle leading to unknowns concerning their quality. Wild-caught fish swim freely in the ocean and theoretically may be exposed to persistent organic pollutants (POPs). However, analytical testing can detect minute amounts of POPs in fish meal and oil, making it possible to test for the presence of POPs in fish meal and oil, and select products of consistently high quality for use in organic aquafeeds. As one would expect fishmeal and oils from Alaskan and South-East Pacific waters are very low in POPs due to their distance from sources of contamination

A final issue concerning the use of fish meal and oil in organic aquafeeds is the nutritional quality of farmed fish for the consumer, specifically their content of omega-3 fatty acids. Farmed fish fed diets containing primarily plant oils cannot be nutritionally comparable to fish fed feeds containing fish oil, the primary source of long chain omega-3 fatty acids. The presence at slaughter of sufficient quantities of the fatty acids EPA and DHA in fish fed diets containing fish meal and oil confers clear and well

documented health advantages to the consumer. There is no evidence that the presence of omega-6 or short chain omega-3 fatty acids, which would result from feeding vegetable meals and oils, confers such health advantages – rather the opposite.

INTRODUCTION

Expanding organic production rules from terrestrial livestock to fish and other aquatic animals produced by aquaculture is complicated by ecological reality pertaining to food sources available to land animals and birds compared to sources available to fish. On land, plants use sunlight to convert CO_2, nitrogen and other soil nutrients into plant tissue that animals eat, e.g., leaves and seeds. The primary form of stored energy in plants is starch, a polymer of glucose. In the aquatic environment, algae and aquatic macrophytes also use sunlight to convert CO_2, nitrogen and other nutrients into algae/plant tissue but there is a major difference in how energy is stored in that starch is not the primary form of stored energy, and there are no seeds (grains) in the aquatic environment at the base of the animal (fish) food chain. Put simply, algae are consumed by zooplankton which are, in turn, consumed by pelagic fish. The pelagic fish are the food source for so-called carnivorous fish, but technically speaking, the pelagic fish are themselves carnivores in that they consume zooplankton rather than algae. This fundamental difference between the terrestrial and aquatic food chains complicates the direct application of organic rules pertaining to ingredients used in livestock feeds to some important ingredients used in aquafeeds, specifically fish meal and fish oil derived from pelagic fish. This difference also complicates the distinction made in terrestrial food webs between herbivorous, omnivorous and carnivorous animal species when it is applied to the aquatic food web and various trophic levels. Essentially, all fish species, with very few exceptions, are carnivores; although a more accurate term would be piscivorous (primary food source in nature is other fish). Even species of fish commonly thought to be omnivorous, such as channel catfish, tilapia and carp, require high protein feeds at first feeding through the fingerling stage because their digestive tract is not fully developed at first feeding. In nature, these fish consume zooplankton as their primary food source. In aquaculture production, these species are fed fish meal-based feeds until they reach the stage of development where they can be converted to grain and oilseed-based feeds. Contrary to the assertions of some that there would be no need to use fish meal in aquafeeds if only catfish, tilapia and carp were produced by aquaculture rather than salmon, trout, cod, halibut, red sea bream, European sea bass and other piscivorous fish species, the reality is that if fish meal were eliminated from all aquafeeds, production of nearly all species of fish would be difficult if not impossible. At our current level of knowledge in the area of fish nutrition and aquafeeds, fish meal is an essential component of aquafeeds to promote normal growth and health of most species of fish. Growth performance and feed efficiency is reduced in most species of farmed fish fed aquafeeds in which fish meal is completely replaced with plant proteins. This observation is not limited to piscivorous species but extends to omnivorous species at the fry and fingerling stages of growth.

Another aspect of the aquatic food web compared to the terrestrial food web is the presence of highly unsaturated fatty acids (HUFAs) of the omega-3 family in the aquatic food web and the absence of HUFAs in leaves and seeds of plants. Leaves and seeds do contain omega-3 fatty acids, but they are limited to shorter chain versions, specifically linolenic acid (C18:3 n-3) and stearidonic acid (C18:4 n-3). Some species of fish have a limited capacity to convert linolenic and/or stearidonic acid to HUFAs, but most species, notably marine fish, cannot convert the omega-3 fatty acids found in plant oils to HUFAs at a rate essential for normal growth and health.

Omega-3 fatty acids are important nutrients in the human diet and essential nutrients in the diet of fish (Simopoulos, 2000). Animals, birds, humans and fish cannot synthesize omega-3 fatty acids, but obtain them in their diet (Tocher, 2003). Marine and freshwater algae synthesize omega-3 fatty acids and are the source of all long-chain omega-3 fatty acids in aquatic food webs. Consumers obtain most of their long-chain omega-3 fatty acid intake from fish. Most animals including fish exhibit fatty acid profiles that reflect their diet. Fish fed feeds containing primarily plant oils will have fatty acid profiles in their tissues that resemble plant oils, whereas fish fed feeds containing fish oil have tissue fatty acid profiles will resembling fish oil (Sargent et al., 2002). Fish oils are therefore essential dietary ingredients in aquafeeds to supply the dietary requirement for fatty acids of the omega-3 family, preferably as HUFAs, and also essential ingredients in aquafeeds to ensure that fillets destined for human consumption contain healthful levels of omega-3 fatty acids expected by consumers, especially those consuming organic products. Fish also require a dietary source of HUFAs to prevent deficiency signs; HUFAs are essential dietary nutrients for fish. However, between 1% and 2% HUFAs in aquafeed is sufficient to prevent essential fatty acid deficiency signs in farmed fish (NRC, 1993), and this level of HUFAs supplementation is insufficient to ensure adequate HUFA levels in fillets for the consumer. A dietary level of at least 12% over the production cycle is needed in salmon and trout to achieve desired levels of HUFAs in fillets.

The importance of fish meal and fish oil in aquafeeds is not in doubt and aquafeeds used in non-organic aquaculture production will continue to contain both fish meal and fish oil. Strict application of organic rules developed for crop or livestock production to stocks of fish traditionally used to produce fish meal and to aquaculture production will likely result in severe limits on the percentage of fish meal and oil allowed in organic aquafeeds in the USA. Such an outcome will simply illustrate the inappropriateness of applying rules developed for terrestrial animal production to aquatic animal production. Interestingly, other countries, notably the UK, have faced the same problems and found ways to allow fish meal and oil into organic aquafeeds without abandoning the principles of organic production. They have done so by recognizing inherent differences between the terrestrial and aquatic ecosystems, and by applying organic principles in ecosystem-appropriate ways to deal with the main issues associated with production and use of fish meal and fish oil in aquafeeds, namely sustainability, traceability, and quality. In addition to the UK, most international organic standards allow the use of meal and oil produced from fish processing by-products in organic aquafeeds.

SUSTAINABILITY OF WILD STOCKS USED TO PRODUCE FISH MEAL AND FISH OIL

Sustainability has many interpretations, but in fisheries, sustainability refers to the way in which harvests of wild stocks are managed to maintain stock abundance at healthy, sustained levels. Stocks of fish are subject to a variety of environmental factors that determine spawning and year-class recruitment success, and large variations in stock abundance unrelated to harvest pressure are well documented. Thus, stocks must be managed conservatively to avoid compounding the effects of variable recruitment success with excessive harvest, thereby reducing stock abundance. Further, harvest management must consider recruitment into spawning populations, and allow sufficient escapement of maturing fish to perpetuate the stock. In the Americas, two species of pelagic fish dominate the production of fish meal and fish oil, Peruvian anchovy *(Engraulis ringens)* and gulf menhaden *(Brevoortia patronus)*. Both stocks are managed to maintain sustainability by restricting harvest, and both have relatively long histories of stock assessment to document population abundance and variability in year-class strength (Vaughan et al., 2006; IFFO, 2007a,b). Landings of the Peruvian anchovy are the highest of any species of fish in the world, ranging from 11, 276,000 metric tons (mt) in 2000 to 6,204,000 mt in 2003, an El Niño year. Because the Peruvian anchovy is a short-lived fish, maturing at about one year of age and having an average longevity of three years, the effects of El Niño are also short-lived; stock abundance typically exceeds average values in the year following an El Niño event. Further, extensive research on Peruvian anchovy stocks was conducted in the 1990s, leading to the establishment of strict harvest quotas and modified fishing techniques to reduce harvest of juvenile fish. Illegal fishing is minimized by aggressive surveillance methods and, as a result, stock biomass has remained healthy. Harvest rates of Peruvian anchovies have been adjusted to prevent overharvesting during fishing seasons when fish are less abundant (Shepherd et al., 2005). Menhaden stocks are also harvested well below their biological capacity and controls on the fishing are comprehensive (IFFO, 2007b).

There are several other significant sources of fish meal and fish oil in the Western Hemisphere associated with processing by-products from sustainably managed fisheries, specifically the Alaska pollock (*Theragra chalcogramma*) fisheries in the Bering Sea and Pacific salmon fisheries in Alaska (*Oncorhynchus* sp.). These fisheries have been certified as being sustainably managed by the Marine Stewardship Council (www.msc.org). The Alaska pollock fishery is considered the best managed fishery in the world and is second in landings only to the Peruvian anchovy in terms of rankings of capture fisheries in the world. NOAA Fisheries, formerly the National Marine Fisheries Service, is the federal agency responsible for managing the nation's living marine resources. NOAA Fisheries conducts annual trawl and hydro-acoustic surveys to assess Alaska pollock stock abundance and determine the Acceptable Biological Catch level. This value is used to calculate the Total Allowable Catch level which is then set at or below the Acceptable Biological Catch level (http://www.fakr.noaa.gov/npfmc/). In addition, each fishing vessel is assigned two NOAA Fisheries observers who sample the nets to record by-catch. Records indicated that by-catch is minimal, approximately 1% and most of the by-catch is retained and processed, making the discard rate approximately 0.5%, a fraction of the average discard rate of 25% for the world's fisheries. Total landings of Alaska pollock were 1,414,962 mt in 2005 (Table 1). Of this total, 66% was processing by-product, e.g., material remaining after filleting comprised of the head, viscera, backbone with retained muscle tissue, and skin (Table 2). Fish meal and fish oil are produced from by-product material in shore-based fish processing plants and onboard fishing vessels using conventional wet reduction processing methods. Since the material processed to make fish meal and oil is removed from human-grade pollock or salmon, the quality of pollock or salmon fish meal or oil is very high. Production in 2000 and 2005 is shown in Table 3; pollock meal and oil production is concentrated at ports in the Aleutian Islands, primarily Dutch Harbor, and on at-sea processing vessels, whereas salmon meal production is in Kodiak. It should also be considered that if the 66% of the harvest is not rendered and recycled into fishmeal then the only alternative is to dump this valuable waste material, which used to be a widespread practice.

Five species of Pacific salmon are native to Alaska, and collectively they represent the second largest fisheries in Alaska after pollock. Total salmon harvest in 2005 was 408,014 mt, resulting in 110,164 mt of by-product (Tables 1-3). Production of salmon meal and oil is a seasonal activity limited to one processing plant, Kodiak Reduction, located in Kodiak Alaska. The biggest consideration concerning the production of organic fish meal and oil in Alaska from fish processing by-products will be the necessity of having strict limits on inclusion of other species in batches of processing by-product. Very small numbers of non-targeted species, such as skates and rays, are always captured in the pollock fishery, and either discarded at sea, or added to processing by-product used to make fish meal and oil. Strict limitations on allowable amounts of by-catch in organically labeled fish meal and oil produced from fisheries processing by-products must be established. Salmon, in contrast, are harvested in targeted fisheries that do not result in capture of non-targeted species. The primary challenge to producing pure salmon meal is concurrent processing of non-salmonid fish during the salmon fishing season, and the necessity of keeping by-products from fish processing plants in Kodiak that are handling other species of fish from being combined with salmon processing by-products (D. James, personal communication).

TRACEABILITY OF FISH MEAL AND FISH OIL PRODUCED FROM WILD STOCKS

Traceability refers to product identification along the chain of custody from production to the end user, and is a critical element of concern with regard to the possibility of producing fish meal that is labeled organic from processing by-products or whole fish in the case of menhaden or anchovy meal. Conventional fish meal contains an added antioxidant, ethoxyquin, that is not allowed under organic rules. Hence, any fish meal or oil destined for organic certification must be made in a separate batch from conventional fish meal or oil to avoid contamination with ethoxyquin, and to allow addition of natural antioxidants permitted in organic production. Product traceability is essential to maintain product identification, but maintaining traceability is a minor issue for fish meal and fish oil producers, who routinely produce different grades of fish meal for different markets and therefore must maintain product identity in fish meal and oil production plants in Alaska.

Utilizing processing waste from organically-reared fish to produce fish meal and oil for organic aquafeeds is also feasible. The main priority in utilizing this potential resource will be to avoid recycling of fish pathogens. Therefore fishmeal and fish oil derived from processing by-products of organically-farmed fish must be subjected to appropriate thermal treatment and should ideally not be used in aquafeeds used to feed the same or closely related farmed species of fish. Unfortunately, fish meal and oil from organically-reared fish is not available in the USA because standards for producing organically-reared fish have not yet been adopted.

QUALITY OF FISH MEAL AND FISH OIL PRODUCED FROM WILD STOCKS

Quality of fish meal and fish oil refers to degree of freshness of the starting material, degree of lipid oxidation, and levels of environmental contaminants, primarily methyl mercury and organic compounds such as PCBs, PBBs, dioxin and related compounds, collectively known as persistent organic pollutants or POPs. Organic rules related to production of grains and oilseeds used to produce feed ingredients are concerned with exposure of crops to POPs, and rules are designed to ensure that crops are not exposed. In the case of fish, no such oversight can be made because wild-caught fish swim freely in the ocean and theoretically may be exposed to persistent organic pollutants (POPs) prior to being harvested. Nevertheless, the US Organic Food Production Act specifically allows organic labeling of wild products, as does the Final Rule. However, analytical testing can detect minute amounts of POPs in fish meal and oil, making it possible to test for the presence of POPs in fish meal and oil, and select products of consistently high quality for use in organic aquafeeds. Further, new processes to remove POPs from fish meal and oil have been adopted in the EU and in the menhaden fish meal and oil industry in the USA that lower POP levels to miniscule amounts ((http://www.999.dk/). These processes involved removal with activated carbon and can be done economically on large batches of fish meal and oil (Hardy, 2006). This is an important point because POP levels in farmed fish are directly related to POP levels in their feed, nearly all of which are associated with fish meal and fish oil in the feed. Farmed fish consuming feeds containing fish meal or oil with elevated POP levels would accumulate these in their tissues. Fortunately, fish meal and fish oil produced from Peruvian anchovies, menhaden or Alaska pollock/salmon processing by-products has very low POP contamination. Elevated POP levels in fish meal and fish oil have been noted in some products produced from Baltic or North Sea pelagic fish, but treatment with activated carbon reduces POP levels in fish meal and fish oil made from these sources to levels below EU regulated levels.

The level of POPs found in fishmeals and fish oils is very related to the location of the fishery. Concerning levels of methyl mercury in fish meal and fish oil, levels in relatively short-lived fish are orders of magnitude below levels found in long-lived fish at the top of the aquatic food chain, such as marlin, swordfish or large sharks. Levels of methyl mercury are very low in farmed fish, and have never been a concern because the ingredients used in aquafeeds, including fish meal and fish oil, contain negligible levels of methyl mercury.

In regard to degree of freshness and degree of oxidation of the raw material used to make fish meal and oil, and of the final products, fish meal and oil produced from Alaska pollock are very fresh and stable, in part because they are made from human-grade material and in part because they are caught in cold water and held prior to processing in refrigerated sea water. Menhaden and anchovy, in contrast, are captured in warm water and sometimes held without refrigeration prior to processing. Clearly, strict standards must be developed for menhaden and anchovy meals to ensure that they are produced from fresh starting material. Fortunately, degree of freshness is easy to monitor using chemical tests, as is degree of lipid oxidation. Standards for organic fish meal and oil from these species can be developed quickly as the knowledge base in this area is solid.

NEED FOR FISH OIL IN AQUAFEEDS TO ENSURE NUTRITIONAL QUALITY FOR THE CONSUMER

A final issue concerning the use of fish meal and oil in organic aquafeeds is the nutritional quality of farmed fish for the consumer, specifically their content of omega-3 fatty acids. As mentioned earlier, the fatty acid profiles of fish, livestock and even humans reflect dietary fatty acid intake. Farmed fish fed diets containing primarily plant oils have fatty acid profiles that are similar to plant oils (Hardy et al., 1987; Bell et al., 2001). Fillets from such fish are not nutritionally comparable to fillets from fish fed feeds containing fish oil, the primary source of long chain omega-3 fatty acids. The presence at slaughter of sufficient quantities of eicosapentanoic acid (EPA) and docosahexanoic acid (DHA) in fish fed diets containing fish meal and oil confers clear and well documented health advantages to the consumer (Mozaffarian and Rimm, 2006). There is no evidence that the presence of omega-6 or short chain omega-3 fatty acids, which would result using feed containing plant oils, confers such health advantages – rather the opposite. In the USA, the omega-6:omega-3 ratio in the average Western diet is 17:1, rather than 2:1 as recommended by health authorities (Eaton et al., 1998). The only way this ratio can be lowered is for consumers to reduce their intake of corn and soybean oil (and products containing them), both high in omega-6 fatty acids, and increase their intake of fish oil, either directly as a supplement or indirectly through consumption of high-fat fish fillets, such as salmon or trout. Consuming wild salmon is an ideal approach for consumers to increase their intake of HUFAs, but unfortunately, there is not enough wild salmon to provide the quantity in demand in USA markets. Total salmon harvest in Alaska was 408,014 mt in 2005. Assuming a recovery of fillets of approximately 50% of the round weight of salmon (Crapo et al., 2004), Alaska produced 204,000 mt, or 204,000,000 kg of edible salmon fillets but nearly 65% of Alaska harvest was pink salmon, nearly all of which is canned. Per capita consumption of salmon in the USA increased from 0.72 kg in 2000 to 1.105 kg in 2005, and at a current USA population of 350 million, total salmon consumption in the

USA is approximately 387 million kg, well above the quantity of Alaska's salmon harvest. Currently, farmed salmon production is approximately 2.5 times that of wild salmon harvest.

CONCLUSIONS

With the exception of grass carp, rabbitfish and a few other species of fish that consume vegetation, virtually all species of farmed fish are carnivorous during some stage of their life history, in contrast to livestock and poultry. This is likely the result of fundamental differences between the terrestrial and aquatic ecosystems, primarily in how energy from the sun is captured and converted to stored energy (starch) in seeds in terrestrial compared to aquatic plants, where energy is stored as fatty acids (lipid). Fish meal is a valuable and, in many cases, an essential ingredient in feeds for many farmed fish species, and limiting or forbidding its use in aquafeeds violates the organic principle of providing feeds that promote well-being and good health in farmed animals and fish. Although scientists have made significant progress in understanding the nutritional requirements of farmed fish, and are using this knowledge to formulate aquafeeds containing much lower levels of fish meal than was the case a decade ago, many species of farmed fish important to the aquaculture industry and to the consumer cannot be produced yet using feeds lacking fish meal. Fortunately, there are sustainable fisheries resources such as Peruvian anchovy and Gulf of Mexico menhaden that, with suitable standards in place, could supply fish meal to the organic aquafeed industry. Further, the Alaska pollock and salmon fisheries, already certified as sustainably managed by the MSC, are poised to produce fish meal and fish oil to organic standards from human-grade fish processing by-products. Given that this material is from sustainably managed fisheries and easily recovered and produced following organic standards for quality and traceability, and also conforms to organic principles of utilizing byproducts if possible, it is logical to utilise this high-quality resource as a source of fish meal and fish oil for organic aquafeeds. The US Organic Food Production Act specifically allows organic labeling of wild products, as does the Final Rule. Both the aquaculture industry and the consumer will benefit from such a practice.

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Table 1. Commercial fisheries harvest in Alaska[1]

	2000 MT	Data Source	2005 MT	Data Source
Marine Finfish				
Alaska Pollock	1067738	NMFS 2000[2]	1414962	NMFS 2005
Salmon	319472	ADF&G 2000[3]	408014	ADF&G 2005
Pacific Cod	226709	NMFS 2000	225341	NMFS 2005
Flatfish	141530	NMFS 2000	111357	NMFS 2005
Yellowfin Flat			87787	NMFS 2005
Atka Mackerel	39986	NMFS 2000	58423	NMFS 2005
Perch	17077	NMFS 2000	21002	NMFS 2005
Sablefish	13547	NMFS 2000	14944	NMFS 2006
Rockfish	10472	NMFS 2000	13447	NMFS 2005
Pacific Herring	32509	ADF&G 2000	37610	ADF&G 2005
Halibut[4]	32686	NMFS 2000	26016	NMFS 2006
Others	3523	NMFS 2000	29092	NMFS 2005
Total	**1905249**		**2447995**	
Marine Shell Fish				
Crab	22968	ADF&G 2000	24145	ADF&G 2004
Shell Fish	881	ADF&G 2000	1286	ADF&G 2004
Squid	333	NMFS 2000	1183	NMFS 2005
Total	24182		26614	
Marine Aquaculture Production				
Oyster[5]	93	ADF&G 1998	114	ADF&G 2004
Clams	12	ADF&G 1998	31	ADF&G 2004
Mussels	2	ADF&G 1998	1	ADF&G 2004
Total	107		146	

[1] Data compiled by P.J. Bechtel for presentation at AAAS 2006 Arctic Science Conference. In Fairbanks, AK.

[2] NMFS is National Marine Fisheries Service

[3] ADF&G is Alaska Department of Fish and Game

[4] NMFS report Halibut harvest with head and viscera removed; adjusted for 12% viscera 16% head.

[5] Assumes average oyster weight of 0.1kg

Table 2. Production of fish meal and oil in Alaska from pollock and cod[1, 2]

	2000 Meal	2000 Oil	2000 Meal+ Oil	2005 Meal	2005 Oil	2005 Meal + Oil
	MT	MT	MT	MT	MT	MT
Shore Side Plants						
Bering Aleutian Area	36785	12899	**49684**	47547	17196	**64743**
Gulf of Alaska Area[3]	15921	3268	**19189**	15525	3811	**19336**
Total	52706	16167	**68873**	63072	21007	**84079**
Catcher-Processors						
Bering Aleutian Area	12571	305	**12875**	15511	909	**16420 0**
Motherships						
Bering Aleutiuan Area	814	585	**1400**	5996		**5996**
Totals	**66091**	**17057**	**83148**	**84579**	**21916**	**106495**

[1] Data compiled by P.J. Bechtel for presentation at AAAS 2006 Arctic Science Conference. In Fairbanks, AK.

[2] Calculations from National Marine Fisheries Service 2000 & 2005 Statistics

[3] Assumed 13000 MT of Meal and 3000 MT oil for Kodiak Fishmeal Company

Table 3. **Estimated fish by-products produced In 2005 in Alaska**[1]

	% of Fish	**Total** MT
Alaskan Pollock		
Total Harvest	100	1414962
Total By-Product	66	933875
Salmon		
Total Harvest	100	408014
Total By-Product	27	110164
Pacific Cod		
Total Harvest	100	225341
Total By-Product	46	103657
Flat Fish		
Total Harvest	100	111357
Total By-Product	72	80177
Atka Mackerel		
Total Harvest	100	58423
Total By-Product	32	18695
Perch		
Total Harvest	100	21002
Total By-Product	38	7981
Sable Fish		
Total Harvest	100	14944
Total By-Product	32	4782
Yellowfin Sole		
Total Harvest	100	87787
Total By-Product	31	27214
Others		
Total Harvest	100	29092
Total By-Product	33	9600
Pacific Herring		
Total Harvest	100	37610
Halibut		
Total Harvest	100	26016
Total By-Product	28	7284
Rock Fish		
Total Harvest	100	13447
Total By-Product	43	5782
Total Harvest		**2447995**
Total By-Product		**1309212**

[1] Data compiled by P.J. Bechtel for presentation at AAAS 2006 Arctic Science Conference. In Fairbanks, AK.