Can Quality Revitalize the Alaskan Salmon Industry?

Bruce A. Babcock and Quinn Weninger

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Center for Agricultural and Rural Development
Iowa State University
Ames, Iowa 50011-1070
www.card.iastate.edu

Bruce Babcock is a professor of economics and director of the Center for Agricultural and Rural Development, Iowa State University. Quinn Weninger is an associate professor in the Department of Economics, Iowa State University.

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For questions or comments about the contents of this paper, please contact Bruce Babcock, 578F Heady Hall, Iowa State University, Ames, IA 50011-1070; Ph: 515-294-6785; Fax: 515-294-6336; E-mail: babcock@iastate.edu.

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Abstract

Declining salmon prices, due primarily to expansion of farmed salmon production, have reduced revenues for Alaska's wild salmon fisheries by roughly 62 percent over the past 10 years. One possibility for reversing this trend is to differentiate wild and farmed salmon in consumer markets through quality improvements and marketing. We use a simple conceptual model to highlight the challenges that Alaska's wild salmon industry must overcome before the industry is likely to see significant revenue gains from increased quality. Our tentative conclusion is that product differentiation could increase profits for wild salmon. However, implementation may require significant departures from traditional production and management practices and possibly an amendment to the Alaska state constitution.

Keywords: product differentiation, salmon, quality assurance.

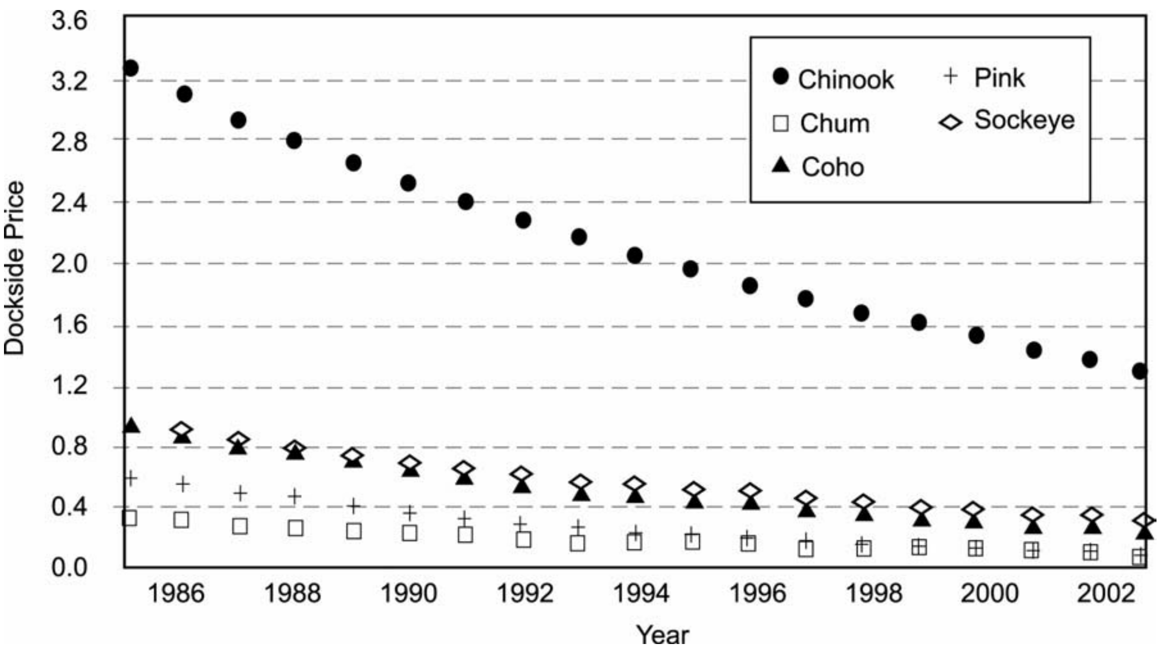
CAN QUALITY REVITALIZE THE ALASKAN SALMON INDUSTRY?

I. Introduction

In 1980, 1 percent of the world salmon supply was farm raised. The share of farm-raised salmon produced worldwide rose to 32 percent by 1992 and exceeded 60 percent in 2002. Wild salmon production during this period remained relatively constant because of limitations imposed by the carrying capacity of the ocean environment. Consequently, the share of world salmon production from wild Alaskan fisheries has declined considerably over the last 20 years. From 1985 to 2001, world salmon production increased from 8.5 million metric tons to 16.9 million metric tons while the Alaskan market share declined from roughly 35 percent to 19 percent.

The dramatic increase in world salmon supply has been accompanied by significant price declines. As shown in Figure 1, dockside prices in Alaska dropped 0.86 percent per year from 1985 to 2000. Industry revenues in 2002 were $141 million, roughly 38 percent of the average revenues received in the 1990-1995 period. Not unexpectedly, industry changes, particularly reduced fishing income, have raised serious concerns in the state.

State and local governments, industry, and Alaskan residents accept the presence of farmed salmon in world markets. Lingering hope that pressure from environmental groups would lead consumers away from the farmed product has all but disappeared. Regulators and industry must decide whether to accept the decline in the Alaskan wild salmon industry or to devise strategies to revitalize it. One strategy under consideration is to differentiate wild salmon from farmed salmon and to devise new plans for production, marketing, and promotion to deliver a superior-quality product to consumers. If consumers perceive a difference between wild and farmed salmon, perhaps they could be induced to pay a price premium for wild salmon that could increase industry revenues and revitalize the industry.



The natural logarithm of annual average dockside price is regressed against total harvest quantity (which is fixed by regulators) and a linear trend. A system of five equations was specified using data from 1984 to 2002. Iterated seemingly unrelated regression is used for estimation. Fitted price trends are evaluated at the average harvest quantity.

FIGURE 1. Average annual dockside prices for Alaskan salmon

In the remainder of the paper, we discuss the challenges facing the salmon industry and regulators in carrying out a strategy to differentiate wild from farmed salmon. In Section II we describe quality considerations in salmon, including intrinsic and extrinsic characteristics. In Section III we present a conceptual model of decision making in the salmon industry to demonstrate the problems that must be overcome by the wild salmon industry as it tries to compete with farmed salmon. Wild Alaskan salmon are harvested from remote waters, often in dangerous weather conditions, under strict regulatory controls, and during a shortened pre-spawning period when salmon congregate at the mouths of the rivers of their birth. In sharp contrast, farmed salmon are harvested year round, or in response to consumer demand, from enclosures that have been strategically located near transportation routes.

In Section IV, we discuss proposed solutions to the problem of the difficulties of creating required incentives to increase quality, followed in Section V by a discussion of whether consumers really will pay more for wild salmon. Salmon are highly perishable, and price premiums are unlikely if consumers do not see and taste a superior quality product. Despite less-than-ideal conditions, steps to improve the quality of the wild salmon product are available and are being implemented in some segments of the industry. Remaining challenges, highlighted in Section VI, concern the regulatory environment and, more fundamentally, the historical, cultural, and constitutional nature of the Alaskan salmon industry. The industry continues to struggle with regulations designed to address overexploitation and overcapitalization that plagues common property resources such as fisheries. Alaskan regulations unnecessarily raise harvesting costs and exacerbate uncertainty. The constitutional requirement that Alaskan fisheries resources be accessible to all Alaskans further magnifies these problems.

Conclusions and recommendations are given in Section VII. Despite the many challenges facing the industry, quality improvement, marketing, and regulatory changes could pay dividends for the Alaskan salmon industry.

II. The Determinants of Salmon Quality

Intrinsic Quality

Intrinsic salmon quality refers to characteristics that are unique to the salmon species, unique to a population within the species, or unique to individuals within a population. Intrinsic characteristics refer to the natural condition of a live fish such as size, color of skin and flesh, oil content, flesh texture, and degree of maturity. These conditions vary across the five species of pacific salmon, across runs[1] of the same species, and within individual fish from the same run and species. The five Pacific salmon species are (1) king or chinook (*Oncorhynchus tshawytcha*), (2) sockeye or red (*Oncorhynchus nerka*), (3) coho or silver (*Oncorhynchus kisutch*), (4) chum or keta (*Oncorhynchus keta*), and (5) pink or humpback (*Oncorhynchus gorbuscha*).

Important characteristics that vary across salmon species include the amount of health-enhancing Omega-3 fatty acid contained in their flesh, size and coloring of the flesh and skin, and average timing of spawning, among other factors. Table 1 summarizes key characteristics that determine the intrinsic quality of each salmon species. For comparison purposes, the characteristics of the main farmed species, Atlantic salmon and coho salmon, are also reported.

TABLE 1. Intrinsic characteristics of wild and farmed salmon

Species	Size (lbs.) Average [low, high]	Total fat (grams/100 g)	Omega-3 (grams/100 g)	Primary Product Form	Harvest Season
King	19 [4, 40]	11.5	1.8	Fresh/frozen	May-Sept.
Sockeye	6 [4, 10]	7.5	1.1	Fresh/frozen/canned	May-Sept.
Coho	10 [4, 18]	5.7	1.2	Fresh/frozen	July-Sept.
Chum	8 [2, 12]	5.3	0.8	Canned	June-Oct.
Pink	3 [2, 6]	5.3	1.7	Canned	July-Aug.
Farmed Atlantic	4-6[a]	10.9	1.8	Fresh/frozen	Jan.-Dec.
Farmed Coho	4-6[a]	7.7	1.2	Fresh/frozen	Jan.-Dec.

Source: USDA nutrient database; Alaska Manufacturers Association.
[a] Note that farmed salmon is harvested at the size preferred by customers, usually between 4 and 6 lbs.

Sockeye salmon tend to be visually appealing, with a rich red-colored flesh. King salmon have a high fat content and tend to be visually appealing, with firm flesh and a rich pink-red color. Coho have an appealing color but tend to soften more quickly than other species after harvest.

Fat content also varies across runs within each species. A determinant of the total fat content is the distance that the salmon must travel to reach their spawning ground. For instance, salmon that spawn in the Copper River must swim farther upstream to reach the spawning beds on which they were born than do salmon that spawn in most other rivers along the western Alaskan coastline. The genetic makeup of this particular run has programmed the fish to prepare for the long upstream journey by accumulating extraordinary amounts of fat. Varying traits across and within salmon species have been compared to variation in wines that are unique to a particular soil or weather pattern.

Intrinsic quality varies with the stage of maturity of salmon. Most significantly, in the final stage of the salmon life cycle, hormonal changes cause proteins, oils, and flesh color to change in ways that decrease quality. Skin color is transformed from bright silver to mottled blacks, grays, and greens or, in the case of sockeye, to bright red. Farmed salmon are harvested prior to the onset of discoloration.

Extrinsic Quality

Extrinsic quality refers to the changes in fish flesh that take place during and after harvest. Fish handling, from the time of harvest to the time of consumption, is the primary determinant of extrinsic quality. Natural biological deterioration processes begin at the time of death. The nature of death itself can influence the duration of rigor mortis and the rate at which natural chemical processes begin to break down flesh. A violent or prolonged death expedites the deterioration process, whereas a quick, non-violent death by stunning and bleeding causes the least damage.

The harvest method can also significantly affect extrinsic quality. The three primary capture methods used in the state of Alaska are gillnet, purse seine, and trolling. A gillnet is a vertical net anchored on shore or to buoys. When a salmon swims into the net, its gills become entangled. The net is then retrieved using a hydraulic drum or pulled up by hand, and the fish are removed from the net and placed into a fish hold. A purse seine is a net set around a school of fish. A draw line closes the bottom of the net, forming a purse-shaped enclosure. The salmon are then retrieved either with a hand brailer (hand-held net) or with a water vacuum tube. Trolling vessels drag baited or artificial lures through the water at varying depths. Once a number of salmon are hooked, the troll line is retrieved with a powered winch. The salmon are then retrieved from the lure.

A violent death, which might occur if a fish trapped in a gillnet is left to thrash against the rough netting for a prolonged period, can accelerate natural biological deterioration. On the other hand, purse seine and trolling methods are well-suited for maintaining extrinsic salmon quality. Individual troll-caught fish are typically recovered individually allowing careful handling and immediate bleeding, gutting, and icing. Purse-seine-caught salmon may be brought on board alive with a vacuum system, immediately bled, and flash frozen within hours of the time of death. Some fishermen have recently begun to transport live salmon to processing plants in large holding tanks. The suction retrieval system reduces handling and thus bruising, and bleeding and immediate freezing significantly slows natural biological deterioration.

Gaping, bruising, and chemical damage can also reduce extrinsic quality. Gaping is the separation of muscle layers due to weakening of connective tissue, which causes holes or splits to appear between the muscle layers. Gaping damage can cause the fish to be unsuitable for particular processing uses such as curing and cold smoking. Gaping also affects the quality of fillets and steaks. The chief causes of gaping are allowing the fish to go through rigor mortis at high temperatures, bending the fish while it is in rigor, and lifting and pulling the fish by its tail.

Internal bruising creates soft, mushy flesh that is unsightly and unappetizing. Bruising can preclude certain processed forms, such as lox and steaks, and is the most serious deterrent to the overall quality of the product. Bruising can occur at various stages in the handling process and can be caused by lifting the salmon by the tail, dropping it on the tail, bending it by the tail when the fish is in rigor, or breaking the backbone. Bruising can also be caused by leaving gear in the water too long in heavy seas, or by towing gillnets laden with salmon. Other causes include stepping on the fish, dropping the fish into the hold or onto the deck, or improper gaffing of the troll-caught salmon.

Other causes of quality decline are spoilage from bacteria, rancidity caused by the oxidation of oils, burn caused by careless freezing, and contamination from dirt or materials that are introduced on board the vessel (e.g., engine lubricants or cleaning materials) or during the transportation and processing process. The rate of enzymatic activity increases in proportion to temperature but is also affected by the intrinsic quality and species of the salmon. Salmon that have stopped feeding—a stage in the maturity process—have lower stomach enzyme activity than do actively feeding fish and thus are less susceptible. Immature coho salmon become very soft post rigor due to enzymatic activity.

Temperature Is Key

Salmon are endowed with a given level of intrinsic quality at the time of death. The goal of post-death handling practices is to minimize further reductions in intrinsic quality and to control the activities that contribute to extrinsic quality decline. The most effective way to control the natural decaying process is to reduce the body temperature and slow bacterial growth. The shelf life (maximum time a food is desirable for human consumption) of fresh sockeye salmon is roughly 12 days if the body temperature is maintained at freezing temperature immediately following death. The rate of shelf-life decline is proportional to the degrees above freezing at which the salmon is stored and to the exposure time to higher temperatures. Shelf life also varies with the intrinsic quality of the fish at the time of harvest.

Enzymatic activity is also proportionally related to temperature. Enzymatic breakdown may cause a condition referred to as belly burn. This occurs when stomach enzymes break down and begin to digest the stomach wall, causing discoloration and tissue damage. In less severe cases, the belly wall takes on a deep red color. Severe belly burn includes exposed rib bones.

To limit extrinsic quality decline, harvesters must handle the salmon gently at all times: they should avoid handling the fish by the tail, avoid throwing, kicking or stepping on fish, and protect the fish from damage caused by contact with vessel machinery. The killing method should be swift, preferably before the fish is removed from the water or soon after it is brought on board. Coho and king salmon that are still feeding should be eviscerated and washed soon after harvest. Containers used for moving and storing the harvested fish should not be so large that fish are weight compressed (800 pounds is the recommended maximum weight). All storage facilities should be sanitary. Gillnet set time should not exceed two hours, and nets should not be wound onto reels until all fish have been picked from the net.

Tendering vessels are sometimes used to transport salmon from or near the point of harvest to the processing plant. The care and handling of the salmon during this segment of the vertical production process can have similar effects on extrinsic fish quality. Thus, gentle handling, attention to temperature, and sanitary and uncontaminated storage facilities are essential.

Processing is the final stage in the vertical production process. The Alaska Department of Environmental Conservation and the U.S. Food and Drug Administration regulate many aspects of fish processing. Recommended guidelines for handling, chilling, and storing salmon to maintain extrinsic quality are similar to those for harvesters and tenders. In addition to the aforementioned general guidelines, specific procedures must be followed depending on the type of processing operation that is chosen. For example, freezer type, operating temperature, product type, product thickness, and contact between the product and the freezing surface affect quality in freezing plants. Glazing can protect the fish from quality loss due to dehydration but these procedures may become ineffective if not applied properly. Maintaining quality in cold storage plants requires careful temperature control to reduce temperature fluctuations and to ensure consistently low temperatures in all storage areas.

III. Producing a Quality Product: The Conceptual Problem

Delivering high-quality wild salmon from the sea to the plate is complicated by several factors. First, the production process involves distinct production stages that are often controlled by separate agents. Fishermen harvest the catch and sell to processors who sell salmon to fish movers who transport the product to distributors for sale in retail consumer outlets or restaurants. Because salmon is highly perishable, coordination among subsequent stages along the vertical chain is critical. An additional complicating factor is that intrinsic salmon quality characteristics are difficult to observe and extrinsic quality characteristics are only marginally more observable. With a few exceptions, only when the final product is consumed is the true quality revealed. Unobservable quality attributes complicate the exchange of governance mechanisms that are used to transfer salmon ownership along the vertical production chain. In addition to being largely unobservable, the intrinsic quality of wild salmon is quite variable because of natural variations in size, color, and sexual maturity. This contrasts with farmed salmon, which has minimal variability.

Our approach in understanding the challenges facing the wild salmon industry in their competition with farmed salmon is to examine how industry structure influences the optimal level of quality-control efforts taken by processors and fishermen. We also examine quality provisions for a farmed-salmon producer.

The Fisherman's Problem

To begin, consider the problem of an independent fisherman who can take actions to increase quality. Let a_1 denote the level of effort by the fisherman to limit damage (i.e., further quality decline) from the time the fish are caught and killed to the time the fish are delivered to a processor. The per unit price the fisherman receives for the fish from the processor is a non-decreasing function of quality, $P_1 = P_1[q_1]; P_1' \geq 0.$ Assume that the intrinsic quality of delivered fish is a random variable. Denote intrinsic quality as $\theta \in \Re$ with cumulative distribution function $G(\theta)$. Then $G(\theta) = \int_0^\theta g(x)dx$ is the proportion of delivered fish with intrinsic quality no greater than θ. Conditional on a given level of intrinsic quality θ, the quality of salmon that is delivered to the processor is assumed given by $q_1 = \theta(1-d_1)$, where $d_1 = d(a_1)$; $0 < d_1 < 1$, and $d'(a_1) < 0$ (primes will denote derivation with respect the function's argument. Denote the unit costs of quality-control effort as w_1.

Suppose the fisherman does not alter quality control efforts for fish of different intrinsic quality. Expected or average profits from fishing are given by

$$E\pi_1 = E_\theta P_1(q_1)Q - a_1 w_1 - C_1(Q) = E_\theta P_1[\theta(1-d(a_1)]Q - a_1 w_1 - C_1[Q], \tag{1}$$

where Q is the quantity of fish delivered and $C_1(Q)$ is the cost of catching fish. For now, assume that this quantity and its associated cost are exogenously determined. The average price received for fish is

$$E_\theta P_1(q_1) = \int_\theta P_1[\theta(1-d_1(a_1)]dG(\theta)$$

The necessary condition for expected profit maximization is

$$\frac{\partial E\pi_1}{\partial a_1} = -\int_\theta P_1'\theta d'(a_1)QdG(\theta) - w_1 \leq 0. \tag{2}$$

And, when equation (2) holds with equality, $a_1 = 0$. Equation (2) states simply that the fisherman will only invest in quality control efforts if for some level of effort the marginal value of the effort exceeds its cost. Again, if the fisherman does not receive a higher price for fish, then the profit-maximizing effort will be zero.

Before proceeding to the processor's problem, note that we have not explicitly considered how quality is observed at dockside. For now, all we are saying is that there is an expected price function that relates actual quality to price. Later we will return to the problem of observability.

The Processor's Problem

An independent processor buys loads of fish from fishermen and sells to consumers, incurring processing and shipping costs. The processor, too, can take quality-control actions that limit quality damage. Denote the processor's quality-control efforts by a_2 and the resulting quality level as q_2. The price function for the processor's product (output) is denoted by $P_2[q_2]$, where $q_2 = \theta(1-d_1)(1-d_2)$. As with the fisherman, $d_2 = d(a_2)$, with $0 < d(a_2) < 1$, and $d'(a_2) < 0$.

In general, if the cost of quality-control effort is low and the amount of variability of delivered quality is high, then one would assume that the processor would increase quality-control efforts for high-quality fish. For now, we restrict the processor to a single level of quality-control effort based on the distribution of incoming quality.

The processor's problem is to maximize

$$E_{\theta}\pi_2 = E_{\theta}P_2[q_2]Q - P_1[q_1]Q - w_2 a_2 - C_2(Q) = \int_{\theta} P_2[\theta(1-d_1)(1-d_2)]QdG(\theta) - P_1 Q - w_2 a_2 - C_2(Q), \tag{3}$$

where $C_2(Q)$ is the cost of processing and shipping processed fish to a wholesale market. This treatment of the processor's problem assumes that the quantity shipped is predetermined by the fisherman. Note that under this specification, the maximum quality that can be obtained following the processing stage cannot exceed the intrinsic quality of the fish and can only decline as a result of the actions of the fisherman.

The necessary condition for expected (processor's) profit maximization is

$$\frac{dE\pi_2}{da_2} = -\int_{\theta} P_2{}'\theta(1-d_1)d_2{}'QdG(\theta) - w_2 \leq 0. \tag{4}$$

If equation (4) holds with equality, it must be true that $a_2 = 0$. The optimal quality-control effort for the processor is such that the benefit of a price increase in the consumer market due to quality increases is exactly offset by the cost of the effort.

Processing Farmed Fish

The problem facing the processor who processes farmed fish has two differences compared with that of the processor who farms wild salmon. First, the salmon are harvested from enclosed pens. Second, the intrinsic quality is much less variable with farmed salmon than with wild salmon. As an approximation, we set intrinsic quality equal to a constant, $\theta = \theta_F$, and let $d_F = d(a_F)$ denote the quality damage of farmed fish, with a_F denoting the quality efforts of the farmed-fish producer. Profits can be written as

$$\pi_F = P_F[\theta_F(1-d_F)]Q - a_F w_F - C_F(Q), \tag{5}$$

where w_F is the unit price of quality efforts, and $C_F(Q)$ is the cost of raising farmed salmon, other than quality effort costs. The optimization condition is

$$\frac{\partial \pi_F}{\partial a_F} = -P_F{}'\theta_F{}'Q - w_F \leq 0. \tag{6}$$

As in equation (4), if equation (6) holds with equality, then $a_F = 0$.

A Comparison of Quality-Control Efforts

We first examine the effects of variable intrinsic quality on the degree of effort by wild salmon processors. For this purpose, the concept of a mean-preserving spread in variability will be useful. If $P_2{}'\theta$ is convex (concave) in θ, then a mean-preserving spread in θ increases (reduces) optimal quality-control efforts of processors. This is a general result of Rothschild and Stiglitz 1971.

Consider if consumers' marginal willingness to pay for higher-quality salmon (P_2') increases at an increasing rate. This will occur perhaps when the highest-quality salmon is a rare luxury good. In this case, processors know that most revenue is generated by the highest-quality salmon, which they will more likely obtain under greater quality variability. Thus, an increase in quality variability will induce greater quality-control efforts. This result assumes that effort cannot be conditioned on intrinsic quality.

If consumer marginal willingness to pay for quality is positive but declining, then an increase in quality variability increases both the quantity of high-quality and low-quality salmon. This reduces the return from investing in quality control effort, so effort is reduced.

Extending this marginal analysis to a comparison of optimal quality investment by farmed salmon versus wild salmon producers, note that there are two important differences. The first difference is that the marginal value of quality control by the wild salmon processor is affected by the amount of fish damage caused by fishermen.

The second difference is that intrinsic quality is variable for the wild salmon processor. For exposition purposes, suppose for a moment that $d_1 = 0$. Then, if we assume that θ_F is a constant, wild salmon producers will tend to invest more (less) in quality-control efforts than will processors of farmed salmon if the marginal willingness to pay increases (decreases) at an increasing rate. That is, the more that consumers of salmon view high-quality salmon as a luxury item, the greater will be the incentive for wild salmon processors to invest in quality-control efforts.

Now consider the effects of the mean level of intrinsic quality. If there is a perception among consumers that the attribute of "wildness" in wild salmon implies a superior product, then the mean quality level of wild salmon may exceed the quality of the farmed product. In this case, the payoffs from quality-control efforts by processors of wild salmon might be greater than those from the efforts by processors of farmed salmon.

Now consider the quality-effort decision of the fisherman. For a moment, assume that $d_2 > 0$. Then marginal benefits of care taken by the fisherman to preserve quality are affected since $P'(.)$ depends on d_2. Suppose for example that the consumer price function is a strictly increasing and concave function of overall quality. Then $d_2 > 0$ will increase the marginal benefits of quality efforts by the fisherman. On the other hand, if $P'(.)$ is increasing and strictly convex, $d_2 > 0$ will tend to lower the marginal value of quality efforts by the fisherman.

Anecdotal evidence suggests that quality problems of Alaska wild salmon are caused by lack of investment in quality control by fishermen, not overinvestment. The reason for this lack of investment is that fishermen are paid a per-pound dockside price for salmon delivered to processors that is constant across all salmon delivered from all boats. That is, quality incentives simply do not exist. And because the payoff from quality-control efforts by the processor and shipper depend on the quality of delivered salmon, there is also likely to be underinvestment in quality at later stages. For example, the marginal benefit—in terms of the additional price premium from quality—of having a clean and speedy processing line is likely to be small and possibly zero if the core temperature of a harvested fish rises on the fishing boat causing deterioration of the flesh.

The model suggests that wild salmon producers face a complicated joint investment problem. Independent fishermen must be given a direct financial incentive to invest in quality-control efforts. Missing such investments, the level of on-board damage to fish will be determined entirely by chance or by the degree of effort needed to meet any minimum quality thresholds that will allow a load of fish to be accepted by an independent processor. Likewise, if the salmon that is delivered to processors is of low quality, the payoff to processors from their own quality-control efforts is likely to be low.

Farmed salmon are often delivered live to processors. Thus, there is little (no) harvesting damage. And because initial quality is higher, it is likely that the payoffs from quality-control efforts at the processing stage are large. Thus one can expect that the quality of delivered farmed salmon will be greater than the quality of wild salmon.

What can be done to increase the quality of wild salmon? First, it is important to recognize that the value of effort to maintain quality at any stage of handling depends on the actions that are taken at all other stages. Providing the proper incentives to implement the optimal action at each stage is critical. And, of course, an important first step is to give fishermen an incentive to reduce on-board quality damage to their fish. One possibility is to vertically integrate fishermen with processors. This is being done, for example, in Chignik, Alaska. Vertical integration can reduce the transaction costs that arise when designing incentive contracts. For example, a profit-sharing agreement between fishermen and processors could increase the incentive to invest in quality efforts at both the harvesting and processing stages.

Could increased marketing of Alaska wild salmon as a differentiated product help? As discussed earlier, if the wild attribute of Alaska wild salmon can be successfully used to turn high-quality wild salmon into a luxury good, then this would increase the incentive for processors of wild salmon to invest in quality-control efforts. However, such efforts will likely be futile without creating a new method for ensuring that fishermen view the fish they catch as a luxury food item and take the corresponding efforts required to increase on-board fish quality. We now consider alternative schemes that could be used to increase quality efforts by fishermen and how the cost of observing intrinsic quality affects the feasibility of each scheme.

IV. Alternative Schemes to Increase Salmon Quality

We consider three types of efforts or programs that either are being implemented or have been proposed to increase salmon quality. The first is a broad-based effort designed to induce groups of fishermen to increase quality-control actions and then to market these fishermen's catch as being of higher quality through a certification program, thereby increasing the average price received. The second type of effort is to estimate the quality of each fisherman's delivered fish and then pay accordingly. The third effort is vertical integration of processors and fishermen. Before considering these alternative schemes, a discussion about the cost of discerning quality will be helpful.

In the preceding analysis we assumed that the intrinsic quality of salmon can be observed without cost. But salmon quality is ultimately revealed only when it is consumed. Signals that are correlated with quality can be observed on board, at dockside, when the fish is processed, and when it is purchased by the consumer. These signals include size, color, and signs of damage on external flesh. More information, such as internal flesh color, texture, and aroma, is revealed after the fish is processed.

Adoption of Improved Fish-Handling Standards

The Alaska Manufacturers Association has begun a new program to raise the quality of Alaska wild salmon. The Alaska Quality Seafood Program has many aspects to it, but for our purposes its essence is that it enlists fishermen and processors who are willing to adopt practices to improve fish quality. This higher-quality fish is then graded and marketed as quality-certified Alaska wild salmon. Certification is granted only when harvesters, processors, and logistics agents follow strict handling guidelines. The hope is that, over time, buyers will be willing to pay a higher price for consistently high-quality Alaska wild salmon, with the price premiums returning to the fishermen who participate in the program.

This program is an attempt to get fishermen to recognize that their actions affect quality and to provide some incentive for them to adopt new practices. The incentive is a higher price for their fish if the certified salmon sold in the program actually commands a price increase. One difficulty that this type of program must overcome is the free-rider problem.

Processing firms that participate in the program buy salmon from many participating fishermen. The link between the fish and a particular fisherman is broken when the fish are off-loaded and pooled with the catch of other fishermen. Only pooled fish are graded, packed, and sold by processors. Even if fishermen are paid additional amounts for quality, the payment will depend on the average quality from the sale of the pooled fish. To see how this program may lead to free riding, suppose two fishermen deliver to a single processor. The fishermen know that part of the investment in quality that increases price will end up in the pocket of the other fisherman. The two fishermen get roughly a half-share of the benefits of quality-control efforts, yet they both bear the full cost of those efforts. Under this arrangement, both fishermen will take less care with quality.

Proper monitoring and enforcement may overcome the free-rider problem. Icing fish as soon as they are caught is perhaps the most effective action that fishermen can take to maintain quality. Spot inspections of fishing vessels should prove quite effective at reducing free-rider problems. In addition, rejecting loads of fish transported with inadequate ice could also help. And finally, if significant premiums are available for certified fish, then care must be taken to prevent non-certified fish from being pooled with the certified fish. Again, enforcement and monitoring efforts must accompany this type of broad-based program.

Paying for Each Vessel's Quality

An obvious solution to the free-riding problem is to maintain an identification link between a fisherman and his or her catch. Implementation of this solution however requires that a link between fish and fisherman be maintained until meaningful quality measurements are made. Full traceability from fisherman to consumer would be required if quality is revealed only by the final consumer. Recently, British Columbia salmon trollers adopted an experimental tagging system that allows traceability back to individual vessels. Under this system, each fish is uniquely identified, which enables easy detection of substandard quality. Those who do not maintain high-quality standards risk losing membership in the program and thus risk forfeiting the price premiums that are expected to emerge as consumers gain confidence that the salmon they are purchasing is of consistently high quality (*Pacific Fishing Magazine* 2003). The costs of implementing the tagging system are not known. But it is reasonable to expect that the cost is greater for fisheries that have limited openings that force fishermen and processors to handle a large volume of fish in a short time. If costs of traceability increase with volume and time, then implementation of a tagging system is most practical for large, troll-caught fish, such as the chinook fisheries on the West Coast of North America.

But full traceability might not be required. As discussed in Section 2, a critical on-board action that fishermen can take to maintain quality is to immediately ice fish and to keep the internal temperature of salmon at just above freezing. It is not enough to measure the temperature of fish at the dockside because variations in temperature will degrade quality. What is needed is a means to monitor on-board fish temperature continually. If such monitoring demonstrates that fish temperature has been maintained at the proper level, then that fish could be sold at a higher price.

Such monitoring is now feasible with temperature tags. The tags are sturdy, waterproof temperature recorders that can be attached to an individual fish in a vessel's fish hold or to a transport container during shipping. The device takes and records periodic temperature readings. The information that is gathered can then be used to locate problems, for example, lack of effort by fishermen to cool harvested fish or an incident where salmon are left to warm on an airport tarmac.

Vertical Integration

The complications and cost of providing fishermen and processors with proper incentives for their quality-control efforts may be lessened if fishermen and processors are employees of a single firm. For example, if transfer of ownership of fish at the dockside is avoided, free-riding problems may be reduced. Also, it may be easier for the vertically integrated firm to implement and monitor how fish are caught and handled on board and while being processed. Of course, a vertically integrated firm still faces the problem of offering the proper incentives for its workers to provide the optimal amount of quality-control efforts (a comprehensive discussion is available in Milgrom and Roberts 1992). Given that wild salmon are often caught in remote areas by fishermen on small vessels working in dangerous conditions, a vertically integrated salmon company may still find it difficult to compete with a vertically integrated salmon farm, with its much more closely controlled work environment.

V. Will Increased Quality Pay?

Efforts to trace salmon, monitor temperature, and improve quality will raise profits in the Alaska wild salmon industry only if consumers are willing to pay a price premium for higher-quality Alaskan salmon. In the context of the simple model, $P_2'(q_2)$ must be strictly positive. Furthermore, the price premium must be paid across nontrivial quantities to achieve nontrivial revenue increases. A serious concern is that the magnitude of quality price premiums and their responsiveness to supply increases is uncertain. In fact, there is reason to question whether consumers will be willing to pay any price premium for quality wild salmon. A 1993 survey of 1,500 northeastern and mid-Atlantic seafood consumers found that, all else equal, consumers prefer farmed salmon to the wild product (Holland and Wessels 1998). It is difficult to know the underlying reasons for the preference or if preferences have changed during the 10 years since the study was conducted. Some seafood consumers may have concerns about the safety of wild salmon, or about resource depletion and management problems that have plagued ocean fisheries.

There is evidence that some consumers do place higher values on wild salmon. The price paid for the spring run of Copper River salmon is typically four to five times higher than the average salmon prices received throughout the rest of the summer harvest season. Investigations reveal that the success of the Copper River fishery can be attributed to two key factors: salmon returning to the Copper River have above-average Omega-3 fatty acid content, a valued health attribute, and the Copper River run is the first of the summer harvest season. Consumer excitement accompanying the season's first fresh wild salmon in the (salmon savvy) Pacific Northwest markets drives prices up. As excitement dissipates, and substitute salmon supplies from other early summer runs appear on the market, prices decline. Copper River Kings and Copper River Reds have brand recognition, which is essential for product differentiation and a price premium.

It is clear that Alaskan wild salmon must be differentiated from mass-produced farm-raised salmon before it can realize a price increase. Less clear are the steps that Alaskan managers and industry must take to differentiate their product. Currently, state and federal contributions, plus 1 percent of salmon revenues contributed by the industry, are being spent on generic advertising of Alaskan seafood, which of course includes salmon. The Alaska Seafood Marketing Institute (ASMI) promotes all types of Alaska seafood in markets throughout the world. It is difficult to know what effect these marketing efforts have because salmon prices in the absence of generic marketing are unknown.

Generic advertising, however, has limitations. Traceability and free riding are often significant problems when ownership of the brand is spread across all producers in the state. With literally thousands of salmon industry participants, it is impossible to link the actions of any one individual to consumer perceptions about salmon quality. Yet, the actions of any one of these individuals do contribute, albeit a small amount, to salmon quality and thus to consumer willingness to pay for Alaskan wild salmon. The incentive to free ride on the quality efforts of others suggests that generic marketing is not likely to lead to significant increases in average quality and thus is unlikely to lead to significant price premiums.

An alternative approach is to develop privately owned brands. The recently formed Chignik Seafood Producers Alliance, a fishermen's cooperative permitted under the American Fisheries Act, is selling their share of the Chignik sockeye run under the brand name Castle Cape Reds. The group has adopted strict quality standards, wherein live salmon caught in purse seines are transported, live, in circulating seawater tanks to holding tanks at a processing facility. The fish are held in pens at the plant, processed, and shipped, fresh or frozen, to consumers on demand. The company boasts "the highest grade of Alaskan salmon available on the market today." The co-op owns the brand name and has sharp incentives to protect it (i.e., to ensure all salmon sold as Castle Cape Reds is of high quality).

Determining the optimal number of brands is an interesting problem. One can imagine supermarket shelves displaying several cuts of salmon distinguished by species, run, harvest method, and brand to signal a reputation for quality, for example, Oregon Troll-Caught Kings, Copper River Kings, or Copper River Reds. In fact, this is precisely how chefs and experienced fish buyers in the Seattle area talk about the salmon that they buy and sell. Because the advertising required to differentiate wild salmon detracts from the total economic benefits in the industry, it is possible to have too many brands, and costly efforts to differentiate wild brands in consumer markets may be better spent on differentiating wild from farmed salmon.

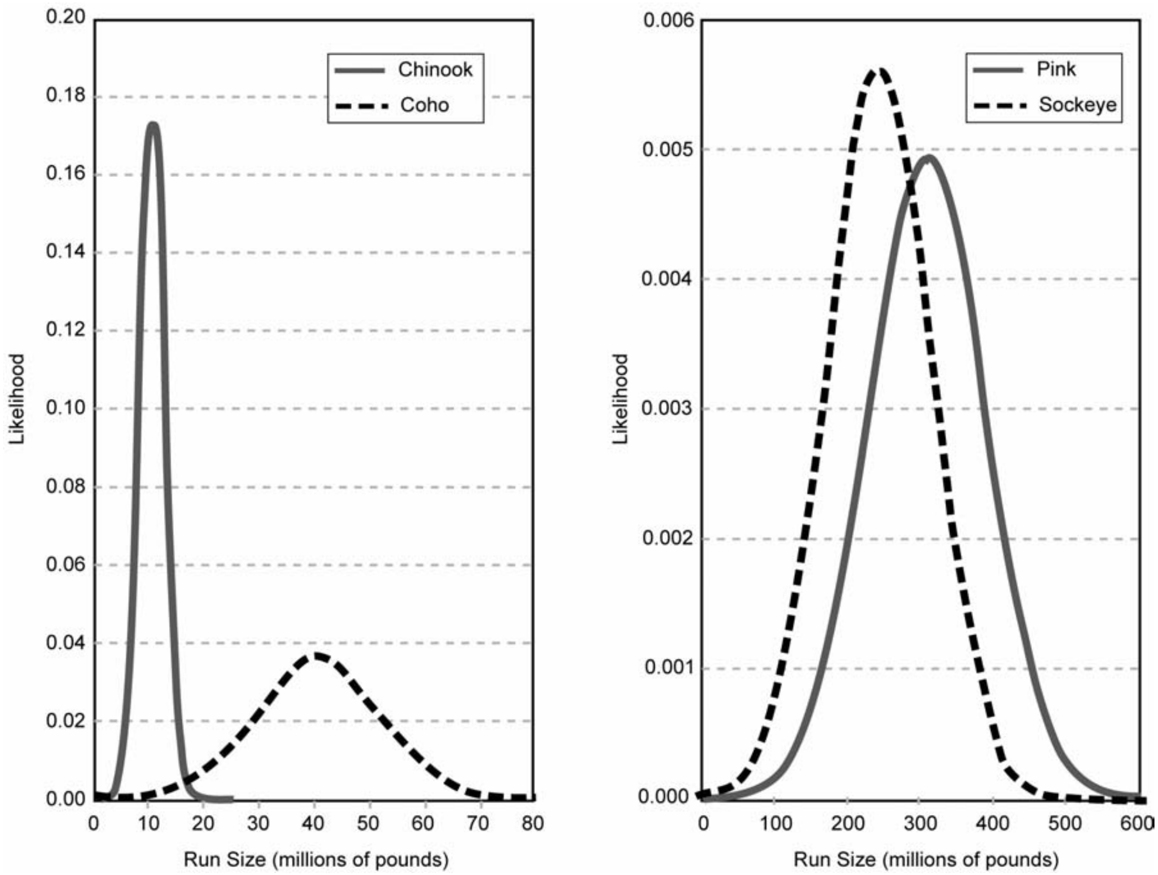
The Alaska Manufacturers Association (AKMA) is currently pursuing a strategy to develop brand recognition for quality certified Alaskan salmon. Certification is granted only when harvesters, processors, and logistics agents follow strict handling guidelines. The hope is that over time, developing a recognizable brand with a reputation for a consistently high-quality product will be rewarded with price premiums. To date, the strategy has been modestly successful. AKMA's Alaska Quality Seafood Program certified and sold 115,000 lbs. of salmon in 2001, 73,742 lbs. in 2002, and over 200,000 lbs. in 2003. Processors from around the state participate. Unofficial reports suggest price premiums in the range of 5¢-50¢/lb. in 2001-02. The range of price premiums is large, and the quantity of product being sold under the AKMA brand remains small. Whether consumer markets are capable of absorbing larger quantities of salmon without price declines remains to be determined.

Another important issue is how to differentiate wild and farmed salmon. Recent attacks against the salmon farming industry, primarily by environmental groups, may scare consumers away from farmed and toward wild salmon. However, if scare tactics are based on misinformation, it is unlikely they will have lasting impacts. False claims that farmed salmon has less Omega-3 fatty acid and unsubstantiated claims that farmed salmon contain dangerous levels of PCBs are unlikely to alter consumer buying patterns (see Hardy 2003 for additional discussion).

VI. Other Challenges

Uncertain environmental conditions during the period that salmon spend feeding in the Pacific Ocean create large fluctuations in the size of returning salmon stocks. Salmon fisheries are managed by controlling escapement, that is, by controlling the number of salmon that are allowed to reach upstream spawning grounds. If too many salmon return to spawn, competition for nest sites in the stream gravel beds and competition for food among salmon fry lower numbers of young recruited into the fishery. Having too few salmon returning to spawn also lowers recruitment. Fisheries managers monitor the fish that swim upstream, leaving the surplus to be harvested by industry. The result is high variability in run size as shown in Figure 2. The figure shows fitted probability distributions for the run size of chinook, coho, pink, and sockeye salmon. For each species, the estimate of variance relative to the mean run size is quite large, particularly for coho, pink, and sockeye salmon.

Having a highly variable run size means that harvest fleets, processing plants, and transportation channels are taxed to their limits in years when runs are large and are underutilized in years when runs are small. Marketing a quality product on a large scale is also complicated by variability in supply. National grocery chains are capable of moving large volumes of fish but prefer stable supply channels, which is an important attribute of farmed salmon. Wild salmon supplies are, on the contrary, seasonal and highly variable from year to year.



The fitted probability distributions are assumed normal. Data used to estimate distribution moments are from 1984-2002.

FIGURE 2. Distributions of salmon run size

Alaska is remote. There are two highways leading in and out of the state and only a few roads linking cities and fisheries within the state. There are no roads leading to western Alaska where the Bristol Bay sockeye salmon fishery is located, or to prime salmon fisheries along the Alaska panhandle. Salmon harvested from the Copper River must be moved by boat across Prince William Sound, where it can be trucked to Anchorage to be loaded onto airplanes before being shipped to markets in the contiguous U.S. states. The flights that carry salmon from Anchorage are passenger flights that exist only because of the state's popular tourism industry. Logistics agents indicate that salmon shipping costs would rise considerably without tourism. It is likely that expanding the scale of quality salmon production, in particular into midwestern and eastern U.S. markets, may require investments in transportation infrastructure in the state.

A successful effort to differentiate Alaskan salmon and raise revenues will require convergence of industry objectives and the objectives of fisheries managers. The regulations under which harvesting and processing take place remain driven by the common-pool nature of ocean fisheries, which are designed to prevent overexploitation of the resource. These regulations raise harvesting and processing costs, as well as the cost of quality care (see also Link et al. 2003; Knapp 2001). The Copper River salmon gillnet fishery provides just one example. In this fishery, invisible and very effective monofilament gillnets are prohibited. Fishing vessels are prohibited from fishing more than one net at a time. Gillnet size is restricted. The fishery typically is open for an eight-hour period and then is closed for a few days to allow additional escapement. Fishermen and processors are notified of an upcoming opening only hours in advance. These regulations are in place to prevent overfishing. They raise costs by increasing the quantity of fuel, labor, and capital services required to land each pound of salmon. Randomly announced and short openings create a frantic on-and-off production environment under which harvesting and processing plant capacity varies from being completely unutilized to being fully utilized. Supply pulses cause periods of frantic effort to move salmon through transportation channels to markets, only to be followed by periods of inactivity.

Regulations that limit individual vessel catch levels are in place because in many Alaskan salmon fisheries there are too many boats chasing too few fish. The extent of the overcapitalization varies across fisheries; however, evidence suggests that some harvesting fleets may be four or five times larger than required. Recent developments in the Chignik purse seine sockeye salmon fishery provide an indication of the extent of the problem. This fishery has been managed with a system of vessel entry permits that limits the number of boats, and other input controls to prevent overfishing. In 2001, 77 vessels organized a cooperative and were granted an exclusive right to harvest 69.3 percent of the Chignik salmon run. The cooperative paid 22 of its members to harvest its share of salmon. The 55 vessels that did not fish shared in the economic benefits arising from the cost savings.

Changing the rules of capture to facilitate quality improvements and differentiation from farmed salmon may require fundamental shifts in attitudes toward fisheries management. It may also require changes to Alaska’s constitution (see Knapp 2001). The right to share Alaska's bountiful natural resources is a valued privilege that is shared by all residents. Article VIII of the Alaskan Constitution on fisheries resources establishes that "Wherever occurring in their natural state, fish, wildlife, and waters are reserved to the people for common use" (Section 3); and "No exclusive right or special privilege of fishery shall be created or authorized in the natural waters of the State" (Section 15). While culture and state law favor shared fisheries resources, quality marketing and product differentiation may require additional private control over resource management, as well as private ownership of brand names.

VII. Conclusions

Expansion of the salmon aquaculture industry has significantly reduced world salmon prices. Revenues in the Alaska salmon industry declined almost 70 percent from 1985 to 2001. Quality improvements and product differentiation have the potential to reverse this trend. However, several challenges must be overcome by industry, regulators, and the residents of Alaska before price premiums for wild salmon can be realized.

Producing high-quality salmon requires that careful steps be taken at several vertical stages of production to maintain quality. Salmon are highly perishable. Carelessness at any one stage can significantly reduce the quality of the final consumer product. The extent to which price premiums for high-quality wild salmon can emerge in consumer markets is not fully known. Anecdotal evidence suggests that consumers could be willing to pay more for Alaskan wild salmon, although it appears that considerable effort will be required to develop a reputation for delivering a consistently high-quality product before these premiums can be realized.

Developing and promoting quality salmon may require fundamental changes in the way that fisheries are managed. Privatizing what have historically been publicly owned fisheries resources may be required in order to reduce the costs of harvesting and maintaining quality and to allow the formation of privately owned salmon brands.

Endnote

1. A “run” refers to the cohort of salmon that return to a particular inland stream to spawn. For instance, “Copper River reds” are sockeye salmon that return to spawn in the Copper River, which is located on the eastern side of Prince William Sound in South-Central Alaska.

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