Care and Handling of Salmon: The Key to Quality

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Care and Handling of Salmon: The Key to Quality

by

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This bulletin is dedicated in memory of A.K. Larssen, who worked tirelessly to increase the professionalism of North Pacific fishermen and to improve the quality of fish landed in North Pacific ports. A.K. was a fisherman and writer whose educational guidelines for commercial fishermen have been published in the United States and Norway. His works include *Safety Notes for the North Pacific Fisherman*, a Marine Advisory bulletin published in 1975 by the University of Alaska Sea Grant Program, and "Some ABC's of Fo'c'sle Living," which was co-authored by Sig Jaeger, appeared in the July 1974 edition of *Marine Fisheries Review*, and later was published as a handbook.

Contents

Preface

The purpose of this publication is to summarize available information on the major quality problems encountered by users of wild Pacific salmon and to make recommendations for the improvement of quality. Much information included in this bulletin has been developed since the most recent previous work of its kind, *Recommended Salmon Quality Guidelines for Fishing, Tendering and Processing Operations,* was published by the Alaska Seafood Marketing Institute (ASMI) in 1986. Kevin O'Sullivan, ASMI's Quality Program Manager, provided encouragement and support for the preparation and production of this bulletin. In addition, ASMI fully funded the second printing of the publication in August 1994 and the third printing in June 1995. Although it is directed primarily to fishermen, the general facts and information it contains are applicable to all persons who handle or transport raw salmon.

Fish quality education has been a priority of the Marine Advisory Program since its inception in 1963 as the Fisheries Extension Program at the University of Alaska. Captain Chuck Wells, who has fished commercially in Alaska for many years, is prominent among those who influenced the establishment of fish quality education and resource conservation as long-term objectives of the program. To him I extend my sincerest thanks.

ASMI, Icicle Seafoods, Inc., Kodiak Seafood Processors, and the University of Alaska cosponsored this publication. Many other organizations and individuals contributed to its development and production. Continual encouragement, sources of information, and many helpful comments on the manuscript were provided by Dr. Donald Kramer, Program Chairman, Marine Advisory Program (MAP), School of Fisheries and Ocean Sciences, University of Alaska Fairbanks. Others who reviewed the manuscript and made valuable suggestions are Chuck Crapo, Seafood Quality Specialist, MAP; Charles C.R. Campbell, Chief, Technical Services and Product Inspection, Department of Fisheries and Oceans, Government of Canada; and Kenneth Hilderbrand, Marine Advisory Program, Oregon State University.

Special thanks are due to Cliff Phillips of E.C. Phillips and Son and to Erling Nilson of Port Chatham Packing Company for information on seafood quality problems, and to Captain David Wilson, *F/V Lady JoAnne*, and Captain Art Bivan, *F/V Lady Nina*, for their extensive comments on the design and operation of upwelling RSW systems on purse seiners. Laurie McNicholas edited, designed, and supervised the production of this bulletin; Ellie Evans typed the manuscript; and Deborah Mercy produced the illustrations. Their efforts are greatly appreciated. ASMI contributed the cover photograph. One of the photos in this publication appears courtesy of the U.S. Food and Drug Administration, and two appear courtesy of G. Baker and G. Gibbard, as noted in captions; others were taken by the author at seafood processing plants.

Although many persons provided information for this publication, the author is entirely responsible for any erroneous facts, interpretations, or recommendations that may appear in it.

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I. Introduction

Salmon that are bruised in handling are a major economic drain on the fishing industry. They create an unfavorable market image, have higher weight loss, and are of lower grade and quality than salmon that are handled carefully. Bruised products have long plagued many segments of the food industry. For example, bruising of even the hardy potato is a serious economic problem in the industry it supports (Kline-Schmidt 1989). To compete effectively for the consumer's food dollar, all segments of the food industry must continually improve the quality of their products.

Quality is especially important in today's highly competitive salmon market. Unlike rice, potatoes, or pasta, salmon is not daily fare; it is a speciality food in North America, Asia, and Europe. Consumers must be attracted to salmon, and if they are to be repeat customers, the product must meet their expectations. To meet consumer expectations, the quality of net caught salmon must improve. The old ways of handling and taking care of fish are no longer acceptable.

Over the past 15 years, the following major changes in the salmon market have affected all aspects of the industry: (1) in the mid-1970s, the amount of salmon going to the frozen market increased at the expense of the canned volume, and (2) in the late 1980s, the production of farmed salmon expanded rapidly.

The industry did not react quickly to meet market needs for a better product as consumer demand shifted from canned to frozen salmon. The quantity of frozen salmon increased, but in general its quality still does not meet market expectations. Historically, most Pacific salmon destined for the frozen and mild cure markets were taken by trollers and gillnetters in Southeast Alaska, British Columbia, and the Pacific Northwest. These fishermen traditionally fished for the high value markets and took very good care of their catch, meeting the demand for kings, silvers, and bright Southeast Alaska chum salmon. In the mid-1970s, the demand for fresh and frozen fish, including frozen salmon, increased rapidly in the U.S. market. Later increases in demand were spurred by a devaluation of the dollar against European and Japanese currency. To meet the increased demand, salmon freezing expanded in Southcentral Alaska and Western Alaska. However, fishermen operating in these areas had little experience in producing fish for the frozen market, so the product quality did not meet market needs.

A second major source of pressure on Alaska's salmon markets is the recent rapid expansion in production of farmed salmon. From 1985 through 1990 the world supply of farmed salmon increased from 102 million pounds to 621 million pounds. In contrast, between 1982 and 1990 Alaska's production of fresh and frozen salmon has averaged 323 million pounds annually. (See figure 1 on page 3). Most farmed salmon are sold fresh, and limited amounts are frozen, so it is obvious that Alaska no longer controls the salmon market; instead, the market controls the Alaska salmon industry.

A very recent trend in salmon farming will put even greater pressure on wild salmon markets. In 1990 and 1991 Norway froze large amounts of salmon to ease the glut of fresh salmon on the world market. Salmon farmers in Chile freeze about half of their total production. In 1990 Chilean exports of frozen farmed salmon to Japan accounted for 7% of Japan's salmon imports, according to a forthcoming paper by J. L. Anderson and Y. Kusakabe.

A. The problem

Bad attitudes that persist among some members of the fishing sector are a major cause of poor product quality. Such attitudes stem from short seasons, fierce competition for fish, and limited vessel capacity for fish and machinery. These conditions produce a general feeling that the first and foremost job is to maximize the harvest and that care of the product is secondary. This feeling leads to rough handling; poor or no chilling; and in some cases, dirty, unsanitary holding conditions. These practices must change if the Alaska salmon industry is to regain control of the salmon market.

Despite bad attitudes among some in the fishing sector, during the past 25 years all segments of the Alaska salmon industry have made good progress in improving product quality. For example, fish pughs are no longer commonly used, dry scow tendering is almost a thing of the past, and a large percentage of the purse seine fleet uses

(Continued on page 4)

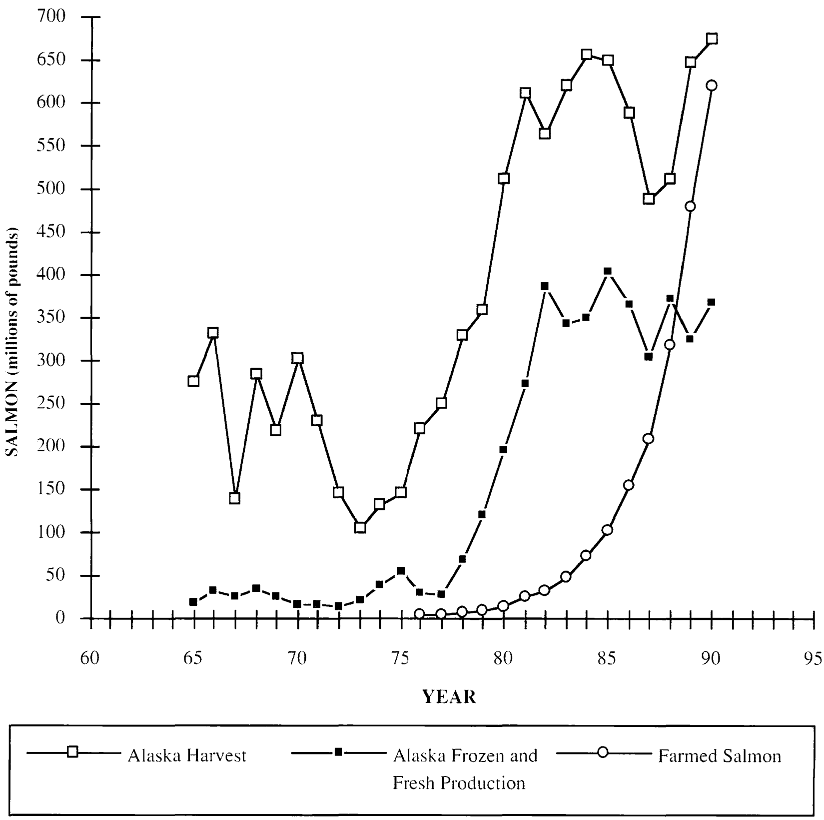

Figure 1. Comparison of total Alaska salmon harvest, world production of farmed salmon, and Alaska's fresh and frozen salmon production. Alaska's canned salmon production is the difference between the total Alaska salmon harvest and the total Alaska production of fresh and frozen salmon. All figures are in round weight. Sources: Alaska Department of Fish and Game statistical leaflets, Alaska Seafood Marketing Institute, National Food Processors Association, and Alaska Fisheries Entry Commission.

(Continued from page 2)

some form of chilling. Some in the gillnet fleet (even in remote areas) use ice or chilled sea water to cool their fish.

The problem facing the Alaskan salmon industry is that its competitors have advanced so rapidly in marketing a high-quality product. For example, handling of farm reared salmon is designed to produce the freshest, most defect-free product possible. Farm reared salmon, regardless of their source of origin, are usually in transit to market within four hours after they are slaughtered.

B. The opportunity

The world supply of salmon increased rapidly during the 1980s, and by 1990 farmed salmon amounted to 28 percent of the world production (Alaska Seafood Marketing Institute [ASMI] 1991). This indicates that the growth in farmed fish has increased the consumption of salmon. Currently, most farmed fish are marketed fresh, which reduces inventory costs. More importantly, freshness appeals to consumers. The 1991 ASMI report shows that quality, freshness, and consistency of supply are the *most important* factors in attracting users to farmed salmon. Until ocean ranching of chinook, sockeye, and coho becomes a major element in overall "wild" salmon production, Alaskan fish producers can control only quality, one attribute of which is freshness. Producers of farmed salmon can control supply as well as biological factors such as weight, flesh color, flesh firmness, and oil content.

C. The characteristics of quality

Each species of salmon has its own distinctive quality attributes. Quality is what buyers consider desirable in a product, a set of characteristics that makes eating the product an enjoyable experience. For salmon, these characteristics include appearance, flavor, odor, texture, and freshness. (As the word *freshness* is used here, it is a function of time and temperature and does not differentiate between frozen and unfrozen fish.) Freshness is given primary emphasis by marketers of farmed salmon. For the most part, harvesters and processors of wild salmon do not pay enough heed to freshness. Neither the U.S. Food and Drug Administration nor the Alaska

Department of Environmental Conservation inspects for freshness. Both agencies ensure only that minimum standards are met. Their main concerns are that the product is wholesome (free from decomposition, adulteration, and contamination) and was not handled and processed under conditions wherein it may have become contaminated or adulterated.

A voluntary seafood inspection program has been administered for many years by the National Marine Fisheries Service for the U.S. Department of Commerce (USDC). The USDC inspection certifies only that salmon is processed under sanitary conditions and meets a company's own definition of standards as stated on its packages. In the North American scientific community, most seafood technology research has been devoted to understanding bacterial spoilage, chemical measurements of spoilage, and methods of extending the shelf life of fish. No wonder we pay so little attention to the overall quality and freshness of our seafood. In contrast, much research in Japan and Europe is devoted to methods for measuring freshness, and both physical and chemical methods have been developed. In Japan the chemical score for freshness often is displayed on a product at the retail level. This chemical score is a measure of chemical changes in fish flesh which occur before significant bacterial growth takes place. These methods are little used in North America. Our lack of concern for freshness is an attitude which must change if Pacific wild salmon from North America are to compete successfully with farm reared fish.

II. Objective

The objective of this bulletin is to increase awareness of quality problems in the care and handling of wild salmon harvested by gillnet, purse seine, and troll gear in all areas of the northeast Pacific. This bulletin points out quality problem areas commonly encountered in the production and manufacturing of wild salmon and makes recommendations that, if followed, will reduce complaints encountered in the marketplace.

III. Biology

Several aspects of salmon life history affect the quality of the end product. Genetic controls determine flesh and skin color as well as oil content; however, degree of maturity also strongly affects these quality attributes. Factors associated with the method of harvest and killing also have an impact.

A. Intrinsic quality

Intrinsic quality refers to the set of characteristics unique to a species, to populations within species, and to individuals within populations.[1] These characteristics reflect the natural condition of a live fish. Intrinsic quality characteristics that are important market factors include size, color of skin and flesh, oil content, flesh texture, and degree of maturity. Intrinsic quality varies with stage of maturity, age, and season.

B. Extrinsic quality

Extrinsic quality refers to changes in fish flesh that take place during and after harvesting. These changes include preventable defects caused by bruising, poor workmanship during processing, contamination, or physical abuse. Extrinsic quality is influenced by the method of harvest and by every person who handles the fish (from the fisherman to the consumer). It also is affected by bacterial growth and chemical changes which cannot be stopped, but can be slowed by proper handling and storage. Fishermen can have their greatest impact on quality, and therefore the market, by controlling extrinsic quality.

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[1] Because there are so many genetically separate populations within a species of salmon, the intrinsic quality of fish of the same species varies greatly. All major buyers of Alaska salmon are well aware of that fact. For example, Yukon king salmon are renowned for their high oil content, bright flesh color, and thick belly walls. In 1991 Yukon fishermen received an average of $4.10 per pound for gillnet caught fish. Cook Inlet kings are large but do not enjoy a good reputation because they have low oil content, relatively poor skin color, and thin belly walls. The average price for Cook Inlet king salmon in 1991 was $1.15 per pound. Fish buyers also recognize the differences in handling practices and other extrinsic quality factors in salmon produced in different regions.

C. Maturity

Salmon go from the juvenile stage to sexual maturity, spawning, senility, and death in a short time. The timespan for the maturing process varies by species and is closely correlated to the distance from salt water to the spawning grounds. The onset of maturity coincides with rapid growth, increase in gonad size, firming of the flesh, and setting of the scales. Growth can be spectacular. For example, coho salmon in Southeast Alaska grow at a rate of 1 pound per week during the August through September period prior to spawning. An immature, 3-pound coho harvested at the end of June easily could have exceeded 12 pounds by the first week of September. An increase in gonad size and flesh oil content coincides with an increase in body weight. High oil content, roe weight, and maturity are important attributes of intrinsic quality.

As salmon mature, they migrate to their home stream or spawning system. Feeding stops with the onset of sexual maturity, and from that point on, intrinsic quality characteristics deteriorate. Stored oil and proteins are the only energy sources. Proteins are used as the primary energy sources during spawning migration. Oils are transferred to the gonads and are used as secondary energy sources during the maturation process and spawning migration. Pigments are metabolized along with the oils and protein. The carotenoid pigments (red color compounds) are transferred to the eggs and skin in females and to the skin in males (Ando 1986). As maturity progresses, skin color changes and the bright silver color is lost. Morphological changes in body conformation associated with maturity also have a negative effect on quality. In addition, odor and flavor compounds undergo chemical changes which result in a less desirable product as maturity progresses (Josephson, Lindsay, and Stuiber 1991). These important intrinsic quality properties which change with age are relevant to the selection of fishing locations and periods during the season. Therefore, salmon management has an important impact on the ultimate quality of Alaskan salmon. No buyer wants a salmon with a dull color and low oil, low protein, and high water contents.

D. Death and rigor mortis

The way a salmon is killed impacts its overall flesh quality. A quick, nonviolent death by stunning and bleeding causes the least damage. A violent, protracted struggle has a negative impact on quality. It causes a series of rapid chemical changes that directly control rigor mortis and affect freshness and storage life.

When a fish dies, its flesh and skin are bright and elastic and its body is limber. This immediate post-death period is called pre-rigor mortis. During pre-rigor, the chemical breakdown of high energy compounds and enzyme activity continue at a temperature-controlled rate in the same way as when a fish is alive. When a fish is alive, chemical breakdown and buildup are in balance, but upon death, all system repair stops. The resultant chemical changes bring about contractions of the skeletal muscle tissue. The stiffening of the body is called rigor mortis. Rigor is similar to a severe muscle cramp or charley horse. During pre-rigor and rigor, the breakdown of high energy compounds is accompanied by the oxidation of glycogen. Glycogen metabolism produces lactic acid. The buildup of lactic acid in the flesh lowers pH; that is, it raises its acidity. High acid content inhibits bacterial growth, so spoilage bacteria do not start to increase until after the fish comes out of rigor. The period after rigor is post-rigor mortis. During the immediate post-rigor period, the fish becomes flaccid. At that time bacteria build up and spoilage begins. The longer a fish stays in pre-rigor and rigor, the longer freshness is maintained.

The length of rigor varies from species to species and within species. Much depends on the condition of the individual fish. However, maximizing rigor time must be one of the handling objectives. The critical period for maintaining freshness begins at the time the fish first encounters the gear and extends through the rigor period. The longer a fish struggles before it is killed, the faster it will go into rigor and the shorter will be the rigor period. Struggling causes a rapid breakdown of high-energy compounds and the rapid oxidation of glycogen, leaving little to be consumed during the rigor process.

Temperature also controls the length of the pre-rigor and rigor periods, because it controls the chemical reaction rates. The higher the temperature, the faster the reaction rates, and the shorter the periods of pre-rigor and rigor. For cod the time in rigor at 0°C (32°F) is three times longer than at 11°C (51.8°F). Even gentle handling of fish during rigor shortens the rigor period (Jones 1964). The importance of extending the rigor period as long as possible cannot be overemphasized.

IV. Causes of Quality Problems

Once a fish loses freshness and general quality, no amount of processing or technology can reverse the process. Fishermen get first crack at the product because they are first in a long chain of handlers extending from the ocean to the consumer. Each time a fish is handled, irreversible damage takes place. The degree of damage depends on how gently or how roughly the fish is handled. There is no magic in the fish business; careful handling and attention to every detail of quality are the only ways to prevent quality problems.

A. Physical defects

Physical damage is the primary cause of quality loss in net caught salmon. Gaping flesh is the most common serious defect, followed by bruising and soft (mushy) flesh. Many of these defects cannot be detected in fresh or frozen dressed salmon until the fish are split, filleted, or steaked. Damage from net marks results in a loss of scales. Gillnet marks detract from the appearance of fish, but unless the marks are deep, damage is superficial and easily trimmed.

1. Gaping

Gaping is the separation of the muscle layers due to weakening of connective tissue that causes holes or slits to appear between the muscle layers (see photograph 1 on page 23). The severe gaping shown in photograph 1 is a serious defect that makes the side unsuitable for mild curing or a cold smoked product. It also detracts from the appearance of fillets and steaks. The chief causes of gaping are:

a. Allowing the fish to go into and through rigor at high temperature (Love and Haq 1970). This is directly correlated with the pH of the flesh (Love 1979). At a high temperature, the muscle tissue contracts so violently that it separates from the connective tissue. (The thin, white layers shown between the large, red muscles in photograph 6 on page 28 and photograph 11 on page 33 are connective tissue.) The connective tissue in fish is very weak compared to that of mammals, and is further weakened at high temperature.

b. The nutritional condition of the fish. A fish in good condition has higher stores of glycogen that provide for greater lactic acid buildup and more violent contraction of muscle tissue.

c. Physically bending the fish while it is in rigor. The muscles are very hard and rigid during rigor. Bending or straightening the fish will tear its connective tissues and lead to gaping.

d. Lifting or pulling the fish by its tail, particularly when removing salmon from a gillnet or lifting a heavy fish. This form of abuse causes gaping in the area of the caudal peduncle (tail section).

Gaping is insidious in that neither the external appearance nor the belly cavity of the fish may reveal any sign of poor handling. Gaping eliminates many fish of otherwise fine quality from the high price side of the market because they are not acceptable for manufacturing as smoked salmon or for use in the white tablecloth restaurant trade.

2. Bruising

As explained in the opening paragraph of this bulletin, internal bruises are the bane of the wild salmon industry. A large bruise not only prevents the fish from being manufactured as lox, it represents waste because the bruised area and the soft, mushy flesh adjacent to it must be cut away. The equivalent of several steaks or the entire caudal peduncle area may be wasted. Bruising just in front of the caudal peduncle, as shown in photograph 2 on page 24, may be caused by lifting a salmon by the tail, dropping it on the tail, or bending the tail when the fish is in rigor. Any action that breaks the backbone of the fish can cause a severe bruise.

Bruising can occur both when the fish is alive and after it is dead. The flesh of the salmon shown in photograph 3 on page 25 was bruised after the frozen fish was defrosted. Japanese research on gillnet caught chum salmon showed that the incidence of bruising increased from 21% in fresh, split fish to 40% after the fish had been frozen. Apparently, freezing of the soft flesh in the area of a bruise further damages the tissue, allowing blood to spread.

Most fish with external gillnet marks will have superficial bruises along the dorsal bones and near the dorsal fin (see photograph 4 on page 26). These bruises easily can be trimmed away when splitting the fish; they are not obvious in steaks. Deep gillnet marks that leave indentations in the skin and flesh can be accompanied by bad bruises (see photograph 5 on page 27). Such bruises generally result from leaving gear in the water too long in heavy seas. As the net surges in heavy seas, the fish again may be gilled by a section of net. This will cause the net to stretch and can result in serious damage to the fish, including breaking the back and cutting the skin. Towing a gillnet containing salmon also will damage the catch. Fish damaged as severely as the salmon shown in photograph 5 should be discarded but seldom are.

Other causes of bruising include heavy blows to the flesh, as when fish are hit with the back of a gaff, dropped from the brailer to the bottom of the hold, stepped on, gaffed or pughed in the body, or thrown into holds, onto the deck, or into totes. Bruises still occur in troll caught fish due to improper gaffing (see photograph 6 on page 28) and in gillnet caught fish due to puncturing with a picking hook, gaff, or pugh (see photograph 7 on page 29). Bruises appear more often and are larger in fish held at a high temperature (Jones 1964). Bruises appear in both canned and frozen products. They are unsightly and unappetizing, and they result in unhappy consumers. *Remember, when salmon bruises, everyone loses:* Handle with care.

3. Mushy flesh

Mushy or soft flesh is caused by physical damage or by chemical damage such as enzymatic breakdown and bacterial digestion. Physical damage will be emphasized in this section. Photograph 8 on page 30 shows physical damage in the caudal area of a gillnet caught sockeye salmon. The yellowing of the flesh just posterior to the belly cavity below the backbone shows that oxidation of the oil in that area has taken place much faster than in the undamaged dorsal muscle. Mushy flesh is caused by the same kinds of abuse that causes bruising, including stepping on fish, piling them too deep, and dropping them, but the damage is more general.

Mushiness is easily detected when a salmon is split, because the knife will stick to the flesh. Mushy flesh renders a side unsuitable for the manufacture of lox. It will give a fillet a poor, dull appearance. The cooked flesh will have a dry, mealy texture and may have an off flavor associated with rancidity. Preventing mushy flesh by handling salmon more carefully is a must.

B. Enzymatic breakdown of protein

Enzymes are chemical compounds responsible for speeding up reactions such as the breakdown of protein. They also are essential for building proteins. However, all maintenance stops when the fish dies. Enzyme activity is temperature controlled; it increases in proportion to increases in temperature.[2]

The most commonly seen effect of enzymatic degradation is belly burn (shown in photograph 9 on page 31). Belly burn is caused by digestive enzymes that break down the wall of the intestinal tract, leak into the belly cavity, and then begin to digest the body wall. In less severe cases the belly wall will have a deep red color, but no rib bones will be exposed. Other enzymes which control protein breakdown are present in the muscle cells. They are responsible for the general softening of flesh.

Other major factors that hasten enzymatic degradation of fish flesh are crushing and pressure. Experiments have shown that even relatively low pressure will significantly increase enzyme activity. Sockeye salmon that were held under 36 inches of fish for 24 hours had enzyme activity three times higher than that of sockeye held for the same time under only 12 inches of fish (Motohiro and Akazawa).

The degree of maturity affects enzyme activity in some fish. For example, immature silver salmon become very soft immediately post-rigor, even though they are firm and resilient before and during rigor. Salmon which have stopped feeding have lower stomach enzyme activity than do actively feeding fish.

C. Spoilage

The narrow definition of spoilage is decomposition and putrefaction caused by protein digesting bacteria. Bacterial spoilage is still a problem with salmon produced in Alaska. It can be found in fresh, frozen, and canned products. While incidents of decomposition are much less common than other defects, the loss of quality and freshness due to bacterial changes are problems encountered statewide.

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[2] This is generally true between 32°F (0°C) and 68°F (20°C); however, each enzyme has a specific temperature at which it is most active. Most enzymes which break down protein are denatured at high temperatures.

A live salmon has bacteria on the skin, gills, and in large numbers in the gut. The flesh of a live fish is sterile; however, when the skin is broken or punctured, bacteria enter the flesh. After the fish has been killed, bacteria populations remain relatively stable during pre-rigor and rigor. When the fish emerges from rigor, bacteria populations grow at a fairly predictable rate which is temperature dependent. As with enzyme reactions, the higher the temperature, the faster bacteria populations increase. Bacteria can be added to the product from anything that comes in contact with the fish, such as gloves, the boat deck, the beach, and the chilling system. The more bacteria on the fish, the faster they lose freshness and spoil. Cuts or punctures in the skin or belly wall expose flesh, and the things that make these cuts or punctures can inject bacteria into the flesh. This will greatly accelerate spoilage of the fish.

D. Other causes of quality problems

1. Rancidity

Rancidity in fish is caused by the oxidation of oils (lipids). The first sign of rancidity in salmon is yellowing of the exposed flesh of the belly cut and collar. In more advanced stages, further yellowing of flesh takes place, especially in the belly, and the flesh has a strong, unpleasant odor. In the most severe cases, the oils bleed to the surface of the belly wall and skin and develop a rusty color. Such fish are unfit for human consumption.

Rancidity usually doesn't show up in properly handled, fresh fish, because the reaction rate for lipid oxidation is slower than it is for bacterial spoilage or enzymatic breakdown. The chain reaction of lipid oxidation starts soon after the fish is killed but proceeds more slowly. Sunlight and certain ions (such as iron and copper ions) are catalysts for lipid oxidation reactions. The ultraviolet (UV) in sunlight is a particularly strong catalyst. Exposure of flesh to direct sunlight for as little as one hour can cause oils to oxidize to the point that rancid odors become obvious. Once the oxidation reaction starts, it cannot be stopped at frozen storage temperatures of 0°F (-17.78°C) to -15°F (-26.11°C), even if air is sealed off by glazing or impermeable vacuum packaging.

2. Sunburn

Sunburn can be a serious problem in the setnet and skiff fisheries. In mild cases sunburn appears as a slight blushing during freezing. After freezing a deeper blush will appear. In severe cases the skin will be dry and wrinkled, as shown in photograph 10 on page 32. Such fish have mushy flesh from enzymatic breakdown and are unfit for human consumption. Direct sunlight is not necessary either for sunburning or for catalyzing oxidation reactions. The UV in sunlight will penetrate cloud layers and cause the same problems as will direct sunlight.

3. Dirt

Dirt is a problem with many fish caught in setnets. In Cook Inlet and Bristol Bay, which have high tidal ranges, fast currents make it difficult to pick fish from the nets except during high and low tide slack periods. Wide tidal flats ensure that the nets will go dry at low tide, allowing fish to lie in mud. This adds large quantities of bacteria to the surface of the fish. Sand and mud are difficult to wash off fish because they lodge in the slime and especially in the gill cavity. There is the potential for dirt to end up in the finished product. Dirty decks, checkers, and holds add to the bacteria load. Pets present special sanitation problems, so they should *not* be permitted on vessels that catch or transport salmon.

V. Improving Handling Techniques

The quality of Alaskan salmon can be greatly improved by better care and handling of the fish at every step from harvesting through processing. The temperature and manual handling of the product are under the control of the fishermen. Facts and recommendations that must be considered in any attempt to improve product quality and regain lost markets include the following.

A. Temperature

Shelf life is defined as the maximum length of time a food is desirable for human consumption. Shelf life is a direct function of product temperature. When all else is equal, the rate of loss of freshness will increase with increases in temperature (Doyle 1989).

The shelf life of fresh sockeye salmon handled under ideal conditions generally is considered to be 12 days, assuming that the fish is held at 32°F (0°C) from the time of death. In a 24-hour period, when a fish is held at 32°F (0°C), 1 day of shelf life is used; at 39°F (3.89°C), 2 days of shelf life are used; and at 50°F (10°C), 4 days of shelf life are used. In other words, when a sockeye salmon is held at 50°F (10°C) for 1 day, only 8 days are left to get the product to the consumer (see table 1 on page 18). The shelf life of a fish varies with its intrinsic quality at the time it is harvested. The expected shelf life for various species of high-quality, commercially caught and processed salmon is as follows: kings, 10 days; silvers, 10 to 12 days; chums, 13 days; and pinks, 6 days.[3]

Many fishermen believe that holding salmon from 12 to 24 hours at ambient temperature does little damage. *This is sheer nonsense.* As pointed out above, the first few hours after death are critical in determining the duration of the pre-rigor and rigor periods. Extending rigor as long as possible is a primary objective of chilling fish. Crapo, Kramer, and Doyle (1988) have shown that mature silver

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[3] Because laboratory experiments usually are conducted under ideal handling conditions in which the fish receive little abuse, published shelf life times usually are longer than those listed here. Laboratory experiments usually do not reflect the "real world" in which a large quantity of product must be handled in a short time.

salmon caught in a purse seine and bled, gutted, and layer iced were in excellent to good condition after 8 days. In the same experiment, silvers held at 50°F (10°C) for 12 hours and then iced were in fair to good condition after 8 days, while delaying chilling for 24 hours prior to icing resulted in a product that was unacceptable on the fresh or frozen market 8 days after harvesting. Immediate chilling of the catch is the only acceptable holding method if wild salmon are to compete at the top end of the market.

Another marketing disadvantage in unchilled fish is shrinkage. Research by Tomlinson et al. (1969a) showed that sockeye salmon stored in boxes 12 inches deep and held at 60°F (15.56°C) for 12 hours lost 0.7% of their body weight, while those held 24 hours lost 1.2% of body weight. Sockeye salmon held in the hold of a vessel will lose much more weight than the fish held in a box only 12 inches

Table 1. Relative rates of spoilage and loss of equivalent days on ice for different temperatures and times*

Temperature		Relative rate of spoilage	Equivalent days on ice with time	
°C	**°F**		**12 hrs.**	**24 hrs.**
-2.00	28.40	0.64	0.32	0.64
0.00	32.00	1.00	0.50	1.00
2.00	35.60	1.44	0.72	1.44
4.00	39.20	1.96	0.98	1.96
6.00	42.80	2.56	1.28	2.56
8.00	46.40	3.24	1.62	3.24
10.00	50.00	4.00	2.00	4.00
12.00	53.60	4.84	2.42	4.84
15.00	59.00	6.25	3.12	6.25

* Equivalent days on ice computations were carried out to three places for mathematical accuracy only. Because of biological variablility within a species, numbers are meaningful only to one place past the decimal point. For example, if a fish is held a 50°F (10°C) for 24 hours, r = 4 means 4 days of shelf life are used in 24 hours; 2 days are used in 12 hours.

deep, because the greater physical pressure on them will squeeze out more body fluid and slime.

The old saying, Colder is better, is true to a point: a low temperature inhibits bacterial growth. However, at 28.4°F (-2°C), where fish flesh is partially frozen, ice crystals form in the cells and some enzymes become more active. Salmon roe turns dark and is of low value when partially frozen. An ideal holding temperature for salmon is 31°F (-0.56°C) to 32°F (0°C).

B. Chilling methods

The three acceptable options available to a fisherman for cooling his fish on a vessel are ice; chilled sea water (CSW), which is sea water chilled with ice and mixed using air; and refrigerated sea water (RSW). CSW is also known as "champagne ice." Of the three choices, properly applied ice is best, followed by CSW, and then RSW (Tomlinson et al. 1974; Crapo et al. 1990). Laboratory experiments show that pink salmon held in ice are acceptable to taste panels up to 10 days, while pinks held in CSW at 31°F (-0.56°C) are unacceptable after 6 days (Crapo et al. 1990).

Each of the chill storage methods has the following advantages and disadvantages.

1. Advantages of ice

a. Keeps salmon fresh longer.
b. Results in a better appearing product when properly applied.

2. Disadvantages of ice

a. Requires more labor and time than do other methods.
b. Requires horizontal shelving in holds more than 4 feet deep.
c. Is unavailable in some locations.

3. Advantages of CSW

a. Low labor input needed for fish stowage.
b. Has a simple mechanical system.
c. Fish are maintained at a constant temperature of 31°F (-0.56°C) in properly designed systems.
d. Is cheaper to install and operate than RSW.

e. Can absorb heat from large loads of fish more rapidly than ice or RSW.

4. Disadvantages of CSW

a. Maximum storage time is shorter than that of ice because fish spoil faster.
b. Scale loss can be severe in heavy weather.
c. Requires more ice than does the ice storage method alone, because after ice is used to lower the temperature of sea water in the hold to 31°F (-0.56°C), ample quantities of ice must be left to refrigerate the added fish.

5. Advantages of RSW

a. Low labor input needed for fish stowage.
b. Requires no ice and can operate anywhere clean sea water is available.
c. Cools fish more rapidly than ice.
d. Can obtain lower temperature than ice or CSW.

6. Disadvantages of RSW

a. Maximum storage time is shorter than that of ice because fish spoil faster.
b. Has high initial costs and operating costs.
c. Requires skilled operators.
d. Has no backup if system breaks down.
e. Temperature fluctuation is greater than that of CSW or ice.

Despite the fact that RSW and CSW systems can be colder than ice, salmon keep better in ice for several reasons. Fish held in RSW or CSW gain weight and absorb salt. For example, research by Crapo et al. (1990) has shown that the salt content of pink salmon held in CSW doubled in 24 hours and was 4 times higher than the original content in 4 days. The water uptake of a pink salmon stored in CSW reached 3.5% of the body weight in 4 days. Water absorption makes salmon more susceptible to handling damage. Salt and water uptake affect both the texture and flavor of frozen salmon, and salt uptake promotes rancidity. Salmon keep better in fresh water ice because the salt content of the flesh will not change significantly during storage. Salmon iced in layers less than 12 inches deep absorb about 0.5 percent of their body weight in 4 days (Tomlinson et al. 1969a). (Additional information about the effects of deep stowage is provided on page 22.)

Another factor that shortens the shelf life of salmon held in CSW or RSW is the difference in the kinds of bacteria which grow on the skin of the fish (Crapo et al. 1990). *Pseudomonas* bacteria are potent spoilers of protein foods and cause objectionable odors and flavor. In CSW systems this group of bacteria, which always is present in sea water and in fish slime, quickly becomes the dominant bacterial group. In contrast, the *Pseudomonas* populations gradually drop to zero in salmon held in ice (Crapo et al. 1990).

Any oxygen in an RSW system is rapidly used by aerobic bacteria, which produces anoxic conditions. Anaerobic bacteria (a type of bacteria which grows only in the absence of air) quickly dominate the system. Many anaerobic bacteria take their oxygen from sulfur compounds present in the slime, skin, and flesh. This produces hydrogen sulfide, which is the source of the strong, objectionable odor found in most RSW systems after several days of operation. This odor is readily absorbed by the fish and affects its flavor.

7. Changing from ice to RSW or CSW and vice versa

It is common practice to switch fish held in ice to CSW or RSW or the opposite when the fish are transferred from one part of the harvesting chain to another. Some fish handlers believe that fish transferred from RSW or CSW to ice or vice versa lose their quality faster than fish held in ice. This has been verified in work by Crapo et al. (1990), who found that pink salmon which were changed from one system to the other had quality scores intermediate between pink salmon held in ice and those held in CSW. When iced fish were switched to CSW, the results were closer to those of the fish stored in CSW. When fish held in CSW were switched to ice, the quality scores were closer to those of the iced fish. Crapo et al. (1990) concluded that it is less detrimental to fish quality to change fish from CSW to ice than vice versa.

The bulk of salmon produced in Alaska are frozen or canned. Therefore, the storage period for fresh fish before processing must be short enough to allow for shelf life after processing. The maximum preprocessing storage times for salmon in ice and RSW or CSW are:

	Ice	RSW or CSW
pink	4 days	3 days
sockeye	8 days	4 days
chum	8 days	4 days
king	8 days	3 days*
silver	8 days	3 days*

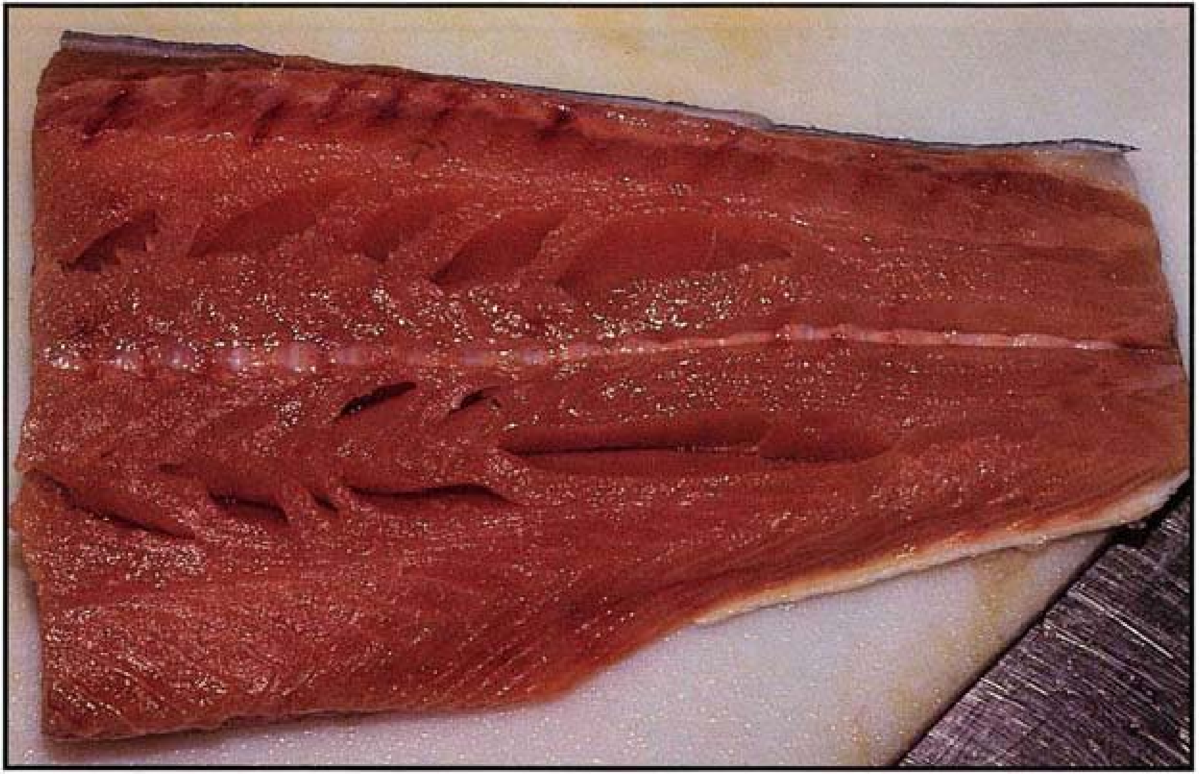
*Recommendations for storage of king and silver salmon are based on anecdotal evidence. Frozen king salmon previously stored in RSW or CSW can be soft and mushy when thawed. Because king salmon taken by seine and gillnet often are pumped or brailed and subsequently are held in RSW or CSW, rough handling may be the cause of or a contributing factor to the poor texture.

8. Special problems with chilling systems

a. Ice: The weight of iced fish puts pressure on fish stowed at lower levels in deep holds. Well-iced sockeye stored 40 inches deep lost about 2.5% of their body weight in 4 days at sea (Tomlinson et al. 1969b). Enzyme activity in fish increases as pressure from the weight of fish stored above them increases, as was pointed out on page 14.

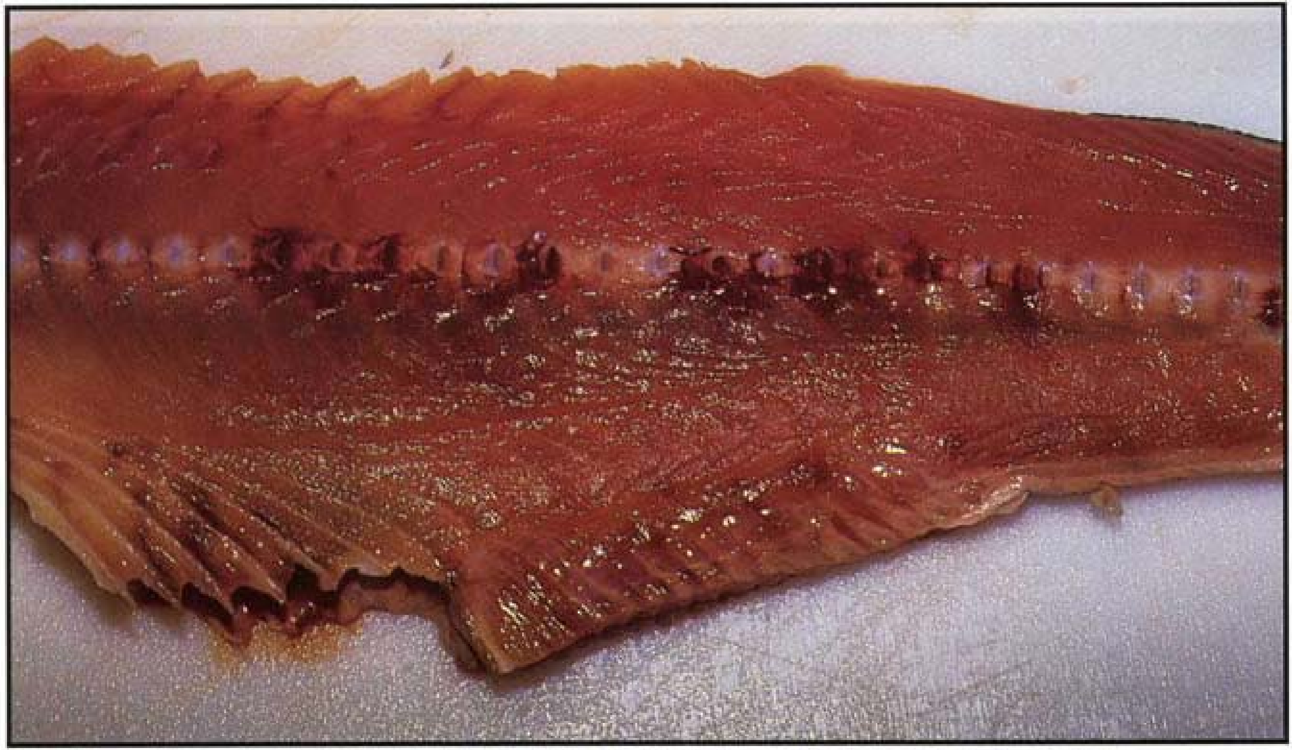
The use of horizontal shelving reduces pressure on fish stored beneath other fish. Shelving in pens of iced fish should be about 24 inches apart and never more than 36 inches apart. Enough ice to absorb incoming heat and cool the fish must be applied in the right places. Sources of incoming heat must be considered in estimating adequate amounts of ice. Major heat sources are the engine room bulkhead, sides of the hold, and shaft alley. The deck head will absorb heat on warm days. If the hold is well-insulated (with the equivalent of 6 inches of urethane foam on the engine room bulkhead and 4 inches on other surfaces), 4 inches of ice on the bottom, sides, and engine room bulkhead should be adequate for a 2-day or 3-day fishing period. Each layer of fish should be only 1 fish deep, with enough ice to just cover each layer. When shelving is used, leave enough room for 2 inches of ice between fish and shelving boards. When the pen is full, 3 inches of top ice are plenty if fish are delivered to dock or tender winthin 24 to 72 hours after harvesting. Keep

(Continued on page 39)

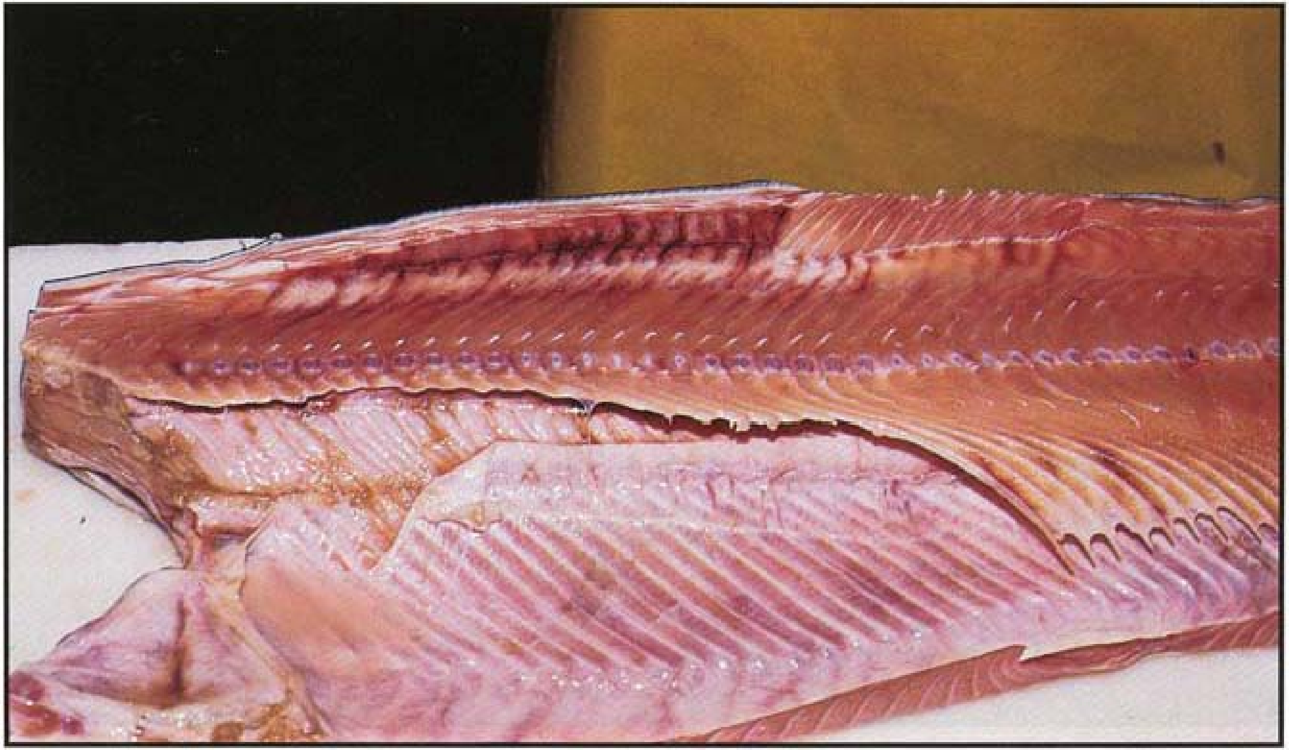


Photograph 1. Severe gaping is shown in the caudal peduncle area of a gillnet caught chum salmon. In this case, the gaping extended up the back of the collar region. This was a silver bright fish with no external sign of abuse. The belly cavity was clean with no marks, bruises, or damage.

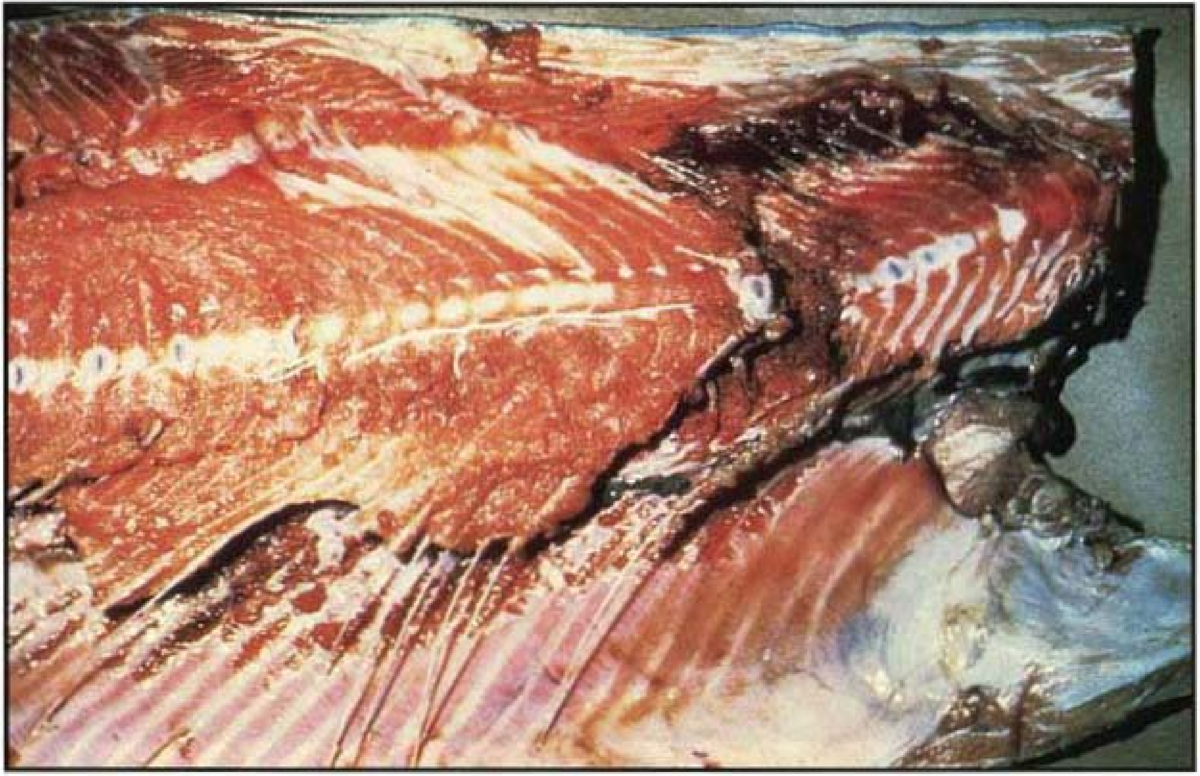
Photograph 2. The bruise in this area is typical for a broken backbone and probably was caused by handling the fish by the tail. Note the dark blood between the vertebrae.



Photograph 3. No blood was obvious at the time this previously frozen sockeye salmon was split. The backbone was broken intentionally, and this photo was taken ten minutes later.

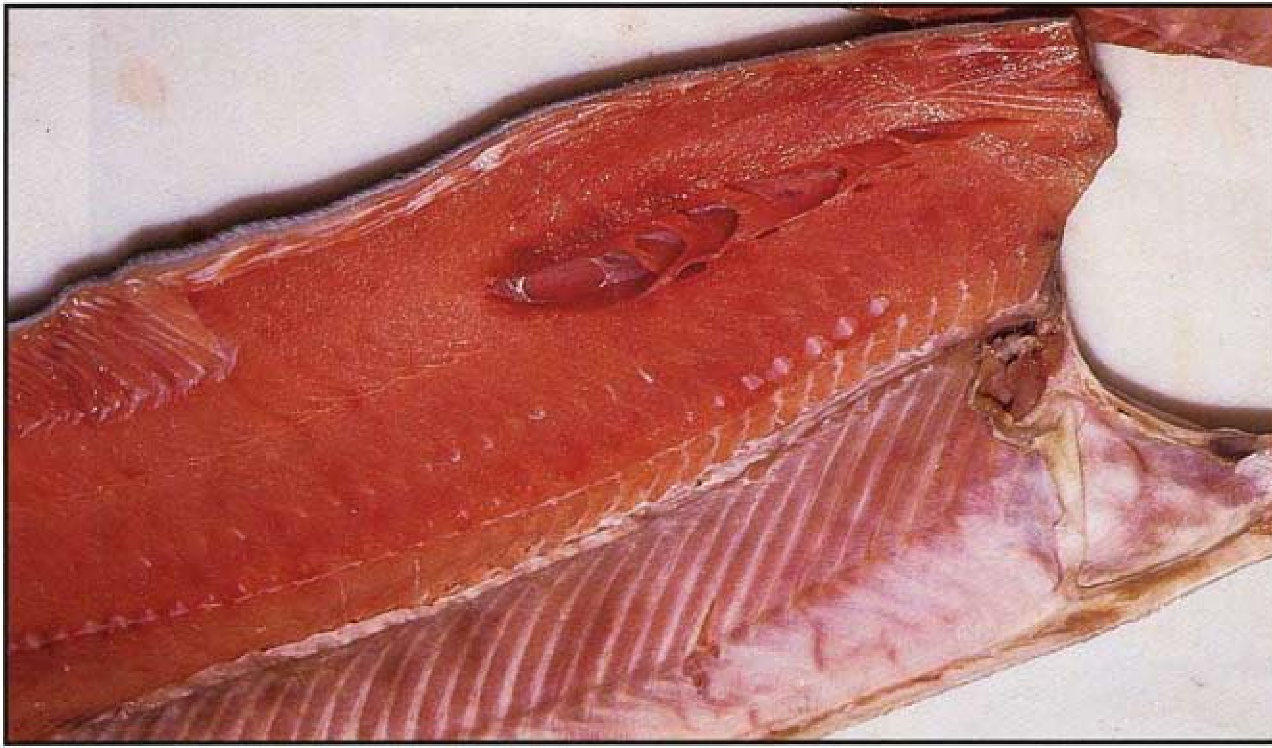


Photograph 4. Bruising by a gillnet along the dorsal vertebrae is shown in this photo. Most of these bruises are removed by minor trimming at the time the fish is split. The bruises do increase trim loss.

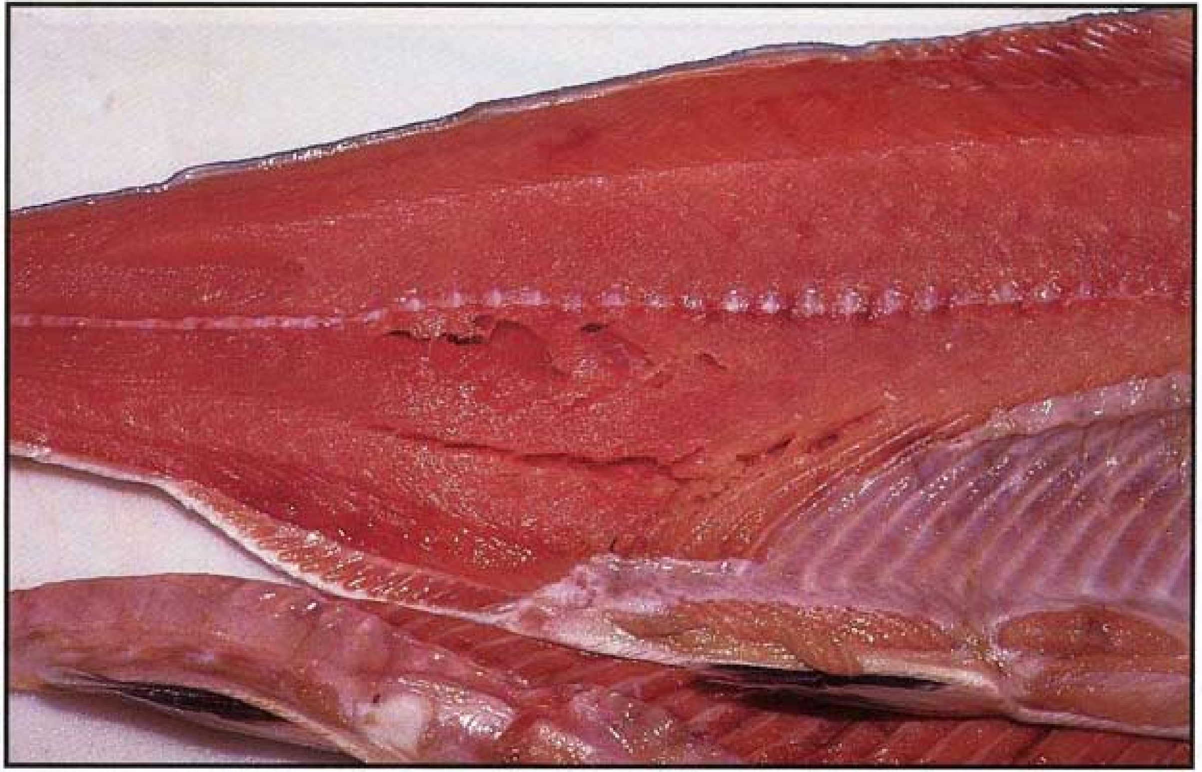


Photograph 5. A gillnet caused the bruise and broken back shown above. This fish has no market value.

Photograph 6. The deep puncture wound in this troll caught king salmon was caused by gaffing the fish in the back. The bruise spread from the gaff wound.



Photograph 7. The puncture wound in this sockeye salmon taken by gillnet in Cook Inlet during the 1990 season was made by a picking hook, pugh, or gaff.

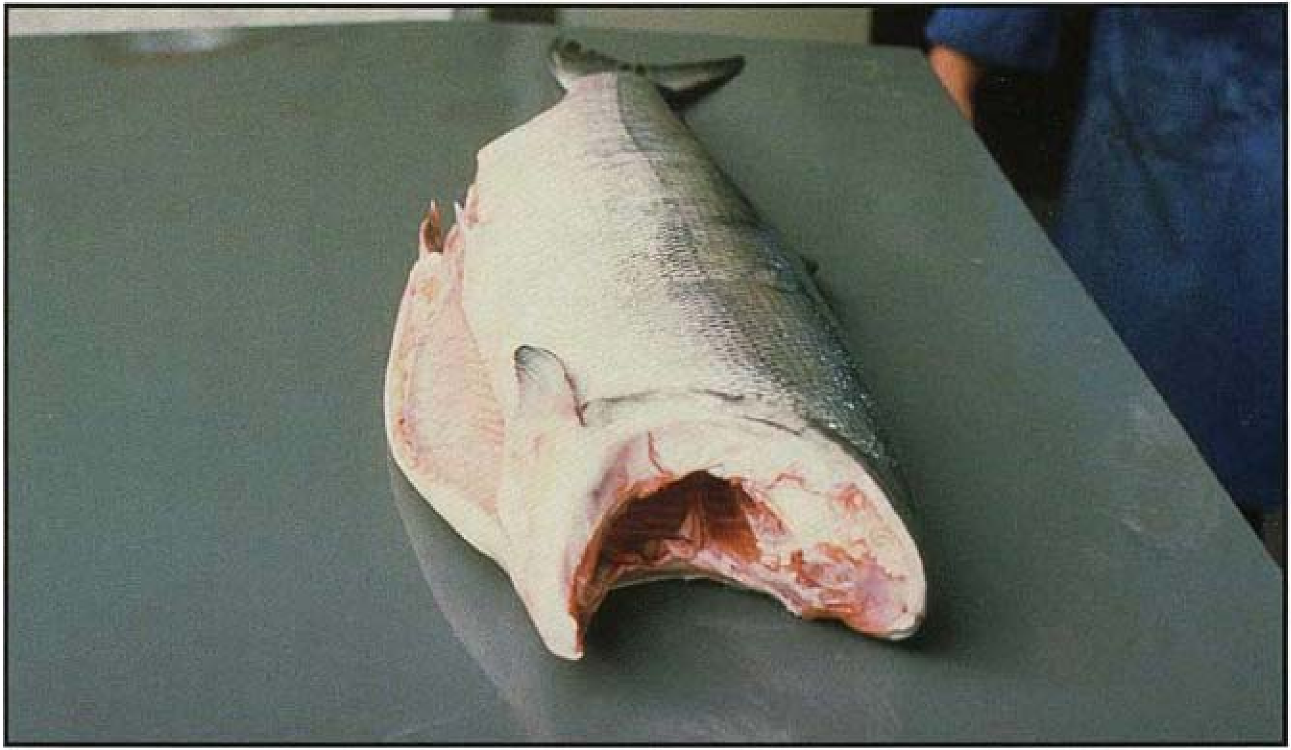


Photograph 8. Gaping, mushy flesh is shown in this sockeye salmon. The soft flesh hastened oxidation of the flesh posterior to the body cavity.

Photograph 9. Moderate belly burn is shown in a gillnet caught sockeye salmon. Note the evidence of poor workmanship in dressing the salmon.

Photograph 10. The dry skin of these sunburned sockeye salmon will turn much darker on freezing. The tag on the fish indicates that they were embargoed by the U.S. Food and Drug Aministration (FDA) and condemned by the State of Alaska. Photo courtesy of the FDA.

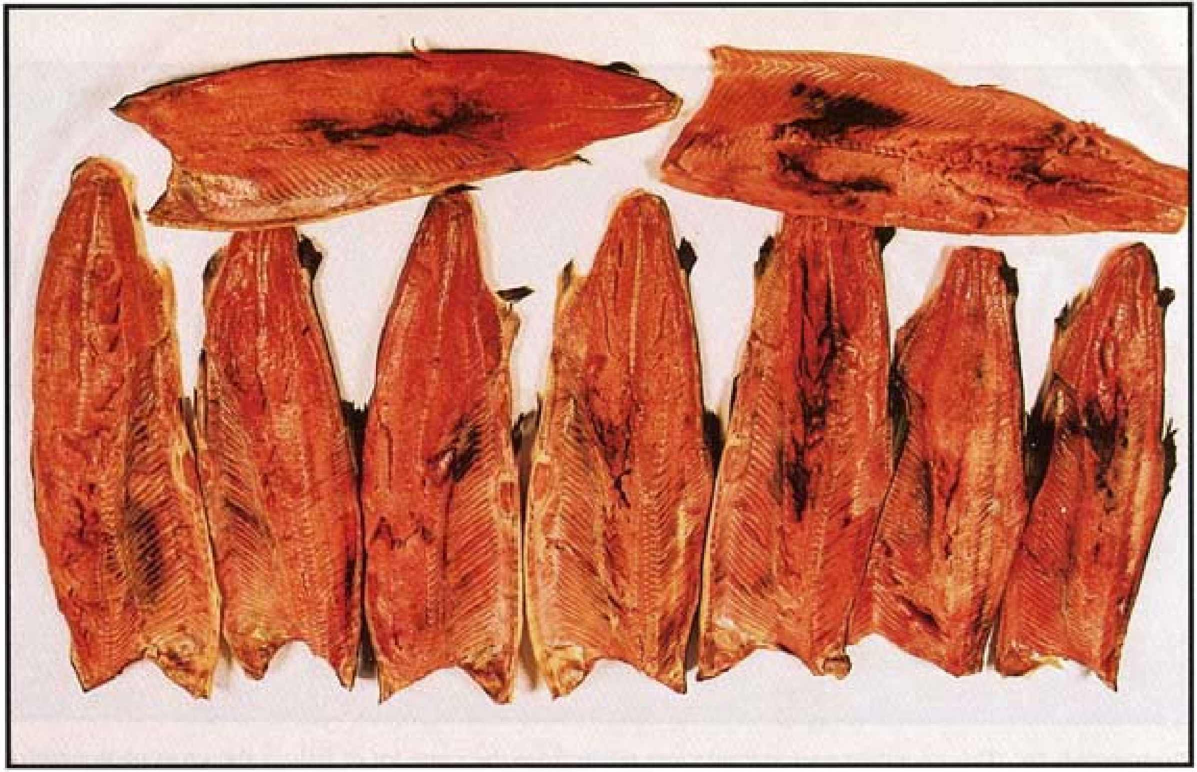
Photograph 11. The bruise on this troll caught king salmon was caused by a blow from a gaff when the fish was stunned.



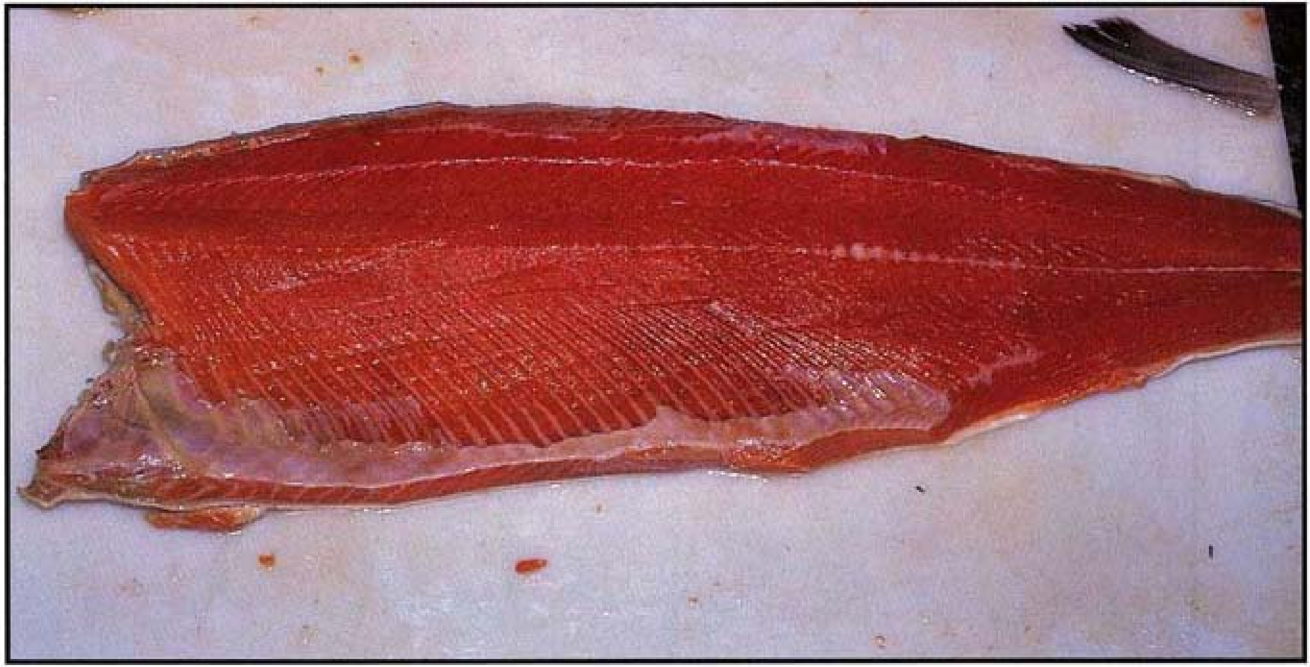
Photograph 12. This is a proper head cut of a frozen, troll caught king salmon. Photo courtesy of G. Baker and G. Gibbard.

Photograph 13. This is a poor head cut of a troll caught king salmon. The flesh exposed at the nape will increase the possibility of freezer burn. Photo courtesy of G. Baker and G. Gibbard.

Photograph 14. The bad body bruise on this sockeye salmon, harvested in a setnet in 1991, probably was caused by throwing or dropping it against a sharp surface. Note the gaping flesh, which is another indication of poor handling.



Photograph 15. Rough, multiple handling and pumping badly damaged these chum salmon harvested by purse seine off the west coast of Prince of Wales Island in 1990. Externally, the fish appeared to be of good quality. The entire lot of fish had to be destroyed.



Photograph 16. This excellent sockeye side was taken from the same lot of fish as shown in photograph 14. With proper handling procedures, 80% to 90% of net caught sockeye could look like this example.

(Continued from page 22)

in mind that it takes at least 24 hours of storage in ice to lower the temperature of a 5-pound to 6-pound sockeye from 55°F (12.78°C) to 35°F (1.67°C).

b. CSW: The maximum salmon loading rate for either a CSW or an RSW system is 45 pounds per cubic foot of hold space. Denser loading will prevent proper circulation of sea water. The successful operation of a good CSW system requires sufficient ice and proper mixing of the ice, sea water, and fish. The amount of ice needed can be calculated on the bases of the hold size, amount of fish expected, amount of insulation, outside air and water temperatures, length of trip, and several other minor factors. Apply this simple formula to obtain a useful estimate of ice needed:

$$\text{Tons of ice} = \frac{W+F+D}{6}$$

where W = weight of water in tons
F = tons of fish to be chilled
D = trip length in days

The amount of ice needed per trip to cool the water and a maximum load of fish for each 1,000 cubic feet of hold space can be computed using the following figures and formula. One thousand cubic feet of hold space will contain 31 tons of water and accommodate 22.5 tons of salmon, so to estimate the amount of ice needed for a 4-day trip, use the formula: $\frac{31+22.5+4}{6} = 9.6$ tons. The assumptions are that the hold is filled with sea water which is cooled to 31°F (-0.56°C) before any fish are loaded and that the hold has 3 to 4 inches of polyurethane insulation on deck heads and sides and 6 inches on the engine room bulkhead. A short period of experimentation will help in refining estimates of the amount of ice needed to take care of most situations. Every measure should be taken to avoid running out of ice. Without ice, the hold will quickly reach the temperature of the outside water and air, resulting in warm water, warm fish, or in the worst case, a lost load.

Some method must be used to mix the sea water, ice, and fish to prevent warm spots and stratification. The best and most efficient way to mix sea water, ice, and fish is to force compressed air through holes in a grid of pipes at the bottom of the hold. (See figure 2).

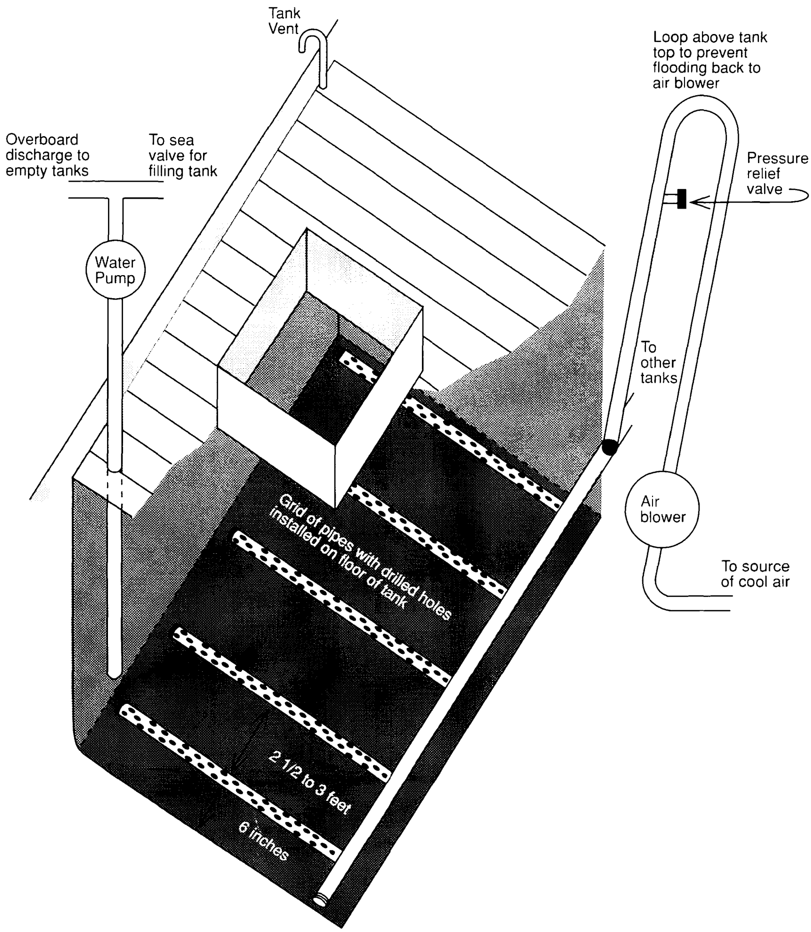


Figure 2. Diagram of a chilled sea water system. Air is bubbled through the holes in the grid of pipes on the floor of the tank to agitate the ice-fish-sea water mixture. Adapted from Kramer (1980).

Because the air that is pumped through the sea water and ice produces bubbles, CSW often is called the "champagne system." Correct spacing of the pipe grid is a must. With a proper system, the temperature of a load of fish can be brought from 56°F (13.33°C) to 31°F (-0.56°C) in less than 6 hours. When the temperature reaches 31°F (-0.56°C), the air can be turned off and then operated intermittently until the next haul is brought onboard. The greatest variation in the temperature of fish landed in CSW systems is caused by inadequate mixing of sea water, ice, and fish.

c. RSW: RSW is the method most commonly used to chill and hold salmon. Purse seiners, tenders, and a few gillnetters have adopted this system. A major problem with many RSW installations is inadequate refrigeration capacity. Many RSW systems require 14 to 16 hours to bring a tank of sea water from 52°F (11.11°C) to 32°F (0°C). That is far too long considering the short running time to the fishing grounds and the high loading rates in some salmon fisheries. A preferred system will bring the temperature of sea water in an RSW tank down to 32°F (0°C) in 6 hours. Observations of and conversations with some purse seine vessel operators who use RSW systems indicate that once they unload on the fishing grounds, take on new sea water, and add fish, they do not get the system temperature down to 35°F (1.67°C) by the end of a fishing period. The internal temperature of the fish is even higher. One observer who checked tenders using RSW systems reports they could not lower the temperature of the fish and sea water mixture to 32°F (0°C) in 24 hours after loading was complete (Chuck Crapo, Marine Advisory Program, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, personal communication, July 1991). This points out the need to chill the RSW system to 32°F (0°C) before adding fish.

Two factors that must be considered in RSW systems on fishing boats and tenders are the refrigeration capacity (measured in tons) and the amount of evaporator surface in the heat exchanger. One ton of refrigeration (equal to 12,000 Btu/hr) is the amount of heat removed in freezing 1 ton of water, and capacity usually is given in tons per 24 hours. As a rule of thumb, for a well-insulated hold, 17 to 18 tons of refrigeration capacity are needed for each 1,000 cubic feet of hold space in order to be able to lower the temperature from 52°F (11.11°C) to 32°F (0°C) in 6 hours.

The evaporator (chiller) surface area is important when the sea water temperature has been lowered to within a few degrees of the evaporator temperature. The rate of heat removal is proportional to the temperature difference between the refrigerant and the sea water. When the sea water temperature is 52°F (11.11°C) and the heat exchanger temperature is 30°F (-1.11°C), the rate of chilling will be fast. When the sea water reaches 33°F (0.56°C), the difference in temperature between it and the evaporator is only 3 degrees, and the rate of heat exchange will be slow. An evaporator with a large surface area allows more contact between the sea water and the evaporator, which results in faster cooling if the system has adequate horsepower.

The minimum safe operating temperature to prevent freeze-up of the heat exchanger is 30°F (-1.11°C) for RSW systems with sea water of normal salinity. The freezing point of sea water is directly proportional to its salinity. At a salinity of 30 parts per thousand (ppt), sea water will freeze at 29°F (-1.67°C). The surface salinity on the continental shelf of the Gulf of Alaska is about 30 ppt in August. The salinity inshore and in bays, sounds, and inlets is lower. For example, in the bays of Prince William Sound, Kodiak Island, and Southeast Alaska, it is common to find surface salinities of 24 to 25 ppt. Waters with that salinity freeze at about 29.7°F (-1.28°C). Inner bay salinity can be significantly lower. For example, Port Valdez commonly has salinities of less than 1 ppt during heavy rains in July and August. Therefore, to take on sea water, fishing vessels and tenders should move as far out to open water as is practical and safe. Another reason for doing so is that high bacteria loads commonly are found in the water in and near harbors.

Operators of RSW systems sometimes add salt to the systems to lower the freezing point. This is often done haphazardly, with little attention paid to the amount of salt needed or to ensuring that it is dissolved and well-mixed. Although complete mixing is a must, it is seldom achieved. Dumping salt or even brine into sea water in the hold will not do the job because salt or brine immediately will sink to the bottom of the tank and stay there until the entire tank is physically mixed. Sea water will float on brine like kerosene on water, and no amount of pitching and rolling of the boat will mix the two. The only practical way to mix brine and sea water is to have a circulation pump with the system intake in a sump at the lowest point in the tank. Continual pumping will gradually mix the brine and sea water. It is important to note that rock salt will take much longer to dissolve and mix. When the salinity is above 26 ppt, it is probably better to operate the system at a little higher temperature than to add salt.

Table 2 on page 44 gives close approximate values for the amount of salt needed per 1,000 cubic feet of hold space to bring the salt content to 3.4% (an amount approximately equal to 35 ppt salinity, which is equal to standard sea water).

The proper design of RSW systems is absolutely necessary to ensure complete circulation of the refrigerated sea water through the fish. S.W. Roach points out the inherent disadvantages of a system in which the flow is from top to bottom (that is, a system in which cold water is pumped in at the top and the intake suction is located at the bottom). Most systems now in use are of that design.

The recommended system of circulation is to force cold sea water into the tank from a high-pressure pump through manifolds running lengthwise in the hold. Holes in the manifold allow the cold sea water to be forced up through the fish. Adequate screening at the forward or sump end of the tank is necessary to ensure that fish are not pressured against the screens, blocking waterflow. The up-welling water will tend to hold the fish in suspension, allowing circulation throughout the load that will help to eliminate warm spots. For a more thorough discussion of the technical aspects of RSW systems, see "Operating Instructions for RSW Systems on B.C. Salmon Packers," by S.W. Roach. A design for an efficient upwelling RSW system is shown in figure 3 on page 45.

In Bristol Bay and Cook Inlet, high silt loads and low salinity present special problems for RSW operators. They should take on sea water well away from river systems in green water about one hour before high tide to obtain the cleanest water with the highest salinity in those regions.

Remember, an internal temperature of 31°F (-0.56°C) to 32°F (0°C) is ideal for holding Pacific salmon. The ideal is seldom realized. More often salmon are landed with an internal temperature

(Continued on page 46)

Table 2. Salinity conversions to degrees salometer, specific gravity, and approximate values for the amount of salt needed per 1,000 cubic feet of hold space to obtain the listed freezing point of 35 ppt salinity sea water*

Salometer Degrees**	Specific Gravity***	Approximate salt content by % of weight	Approximate Salinity in ppt***	Freezing point	Approximate lbs. salt to be added to reach 35 ppt
0	1.000	0.0	0.0	32.0	2,220
2	1.004	0.53	5.3	31.5	1,890
4	1.007	1.06	10.6	31.1	1,555
6	1.011	1.56	16.0	30.5	1,220
8	1.015	2.11	21.4	30.0	880
9	1.017	2.33	24.1	29.7	720
10	1.019	2.64	26.8	29.3	540
11	1.021	2.85	29.6	29.1	360
12	1.023	3.17	32.3	28.8	180
13	1.0245	3.38	35.1	28.5	

* Adapted from Roach (N.d.) and Hilderbrand (1979).

** A salometer is a special hydrometer used to measure the strength of a brine solution. Standard readings are at 60°F (15.56°C), because cold water is denser than warm water. Subtract 1 degree salometer for each 10 degrees F below 60°F. When using a standard hydrometer, be sure it has a range of 1.000 to 1.050.

*** Any difference of specific gravity of .002 or a salinity of 1 ppt will cause strong stratification in the hold.

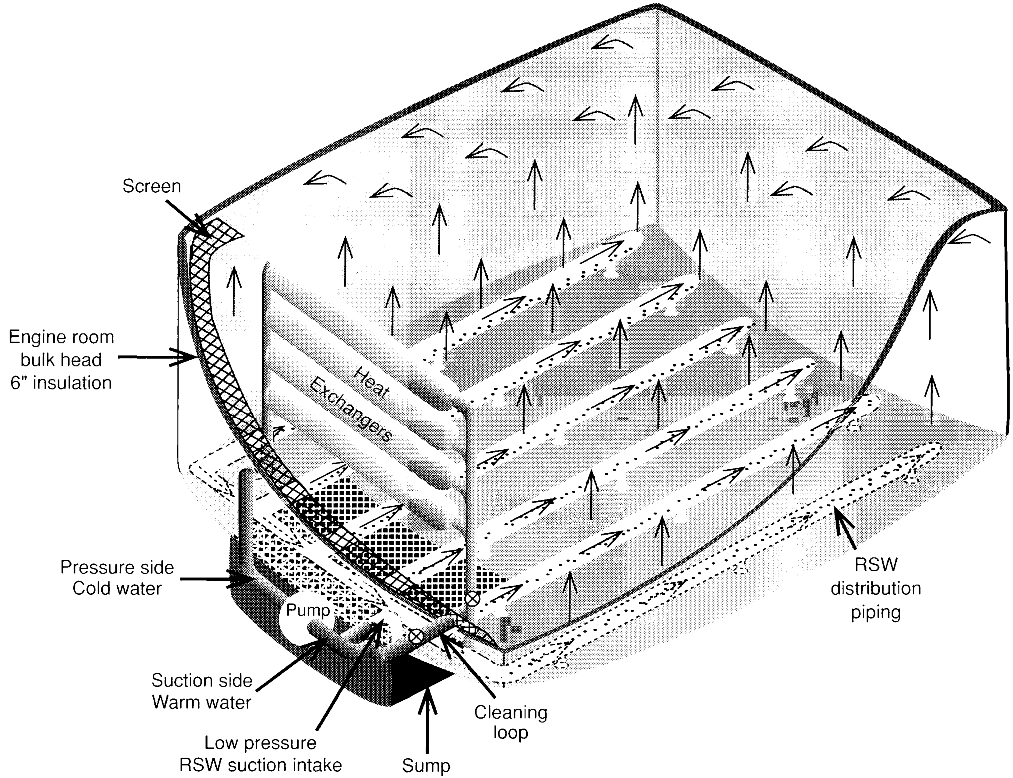


Figure 3. Schematic of an upwelling refrigerated sea water (RSW) system. This RSW system will force cold water through the mass of fish, which will provide an even temperature throughout the hold.

(Continued from page 43)

of 35°F (1.67°C). Bringing the temperature of fish down as close as possible to 32°F (0°C) is very important. Experiments have demonstrated that pink salmon held at 31°F (-0.56°C) for 2 days are much superior to pink salmon from the same lot held at 35°F (1.67°C) and 37°F (2.78°C) (Crapo and Elliott 1987). In the same experiments, when fish were held for 4 days at 31°F (-0.56°C), 20% graded excellent and 80% graded good; of those held at 37°F (2.78°C), 20% graded good and 80% fair. While these findings are particularly important to tender operations, they also point out to the fisherman the importance of getting the product temperature down as soon as possible and keeping it down.

All RSW systems should have a temperature measuring device in the hold to monitor sea water temperature and record fluctuations. Rugged thermistors, electric temperature sensing instruments which accurately measure temperature, should be placed close to the suction intake of the pump. The thermistor should be connected to a temperature readout on the bridge, and a record should be kept of temperature and fluctuations. Continual recording devices are available that will provide a temperature record for each trip.

A thermistor inserted into an RSW tank gives the temperature of the RSW, not of the fish. Unless the fish are held several days, their internal temperature will be several degrees higher than that of the surrounding sea water. In addition, a thermistor will give the temperature in one place and may not indicate warm spots. To detect warm spots, an array of several thermistors are required in corners of the hold, at the center, and in a position well away from the pressure side of the inflow manifolds. When the temperature of a full load of fish drops faster than is normal, be suspicious: that is a good sign of overloading, and hot spots will develop.

If a product of good quality is an objective, the use of ice, RSW, or CSW is a must for chilling salmon.

VI. Harvest Methods–Problems and Recommendations

Each catching method has its own set of problems and opportunities for producing high-quality salmon. If the salmon fishermen of the northeast Pacific are to maintain their market share, it has become necessary for them to take advantage of every opportunity to maintain high quality.

A. Trolling problems

Trollers have the best opportunity to produce premium grade fish because they take fish alive, one at a time. They can gill and bleed fish immediately and then quickly place them on ice or in a freezer. There is no reason for an intrinsically high-quality salmon to come off a troll boat as anything but premium grade. However, all too often major defects are found in troll caught fish. Bruises caused by stunning (shown in photograph 11 on page 33) and gaff puncture wounds (shown in photograph 6 on page 28) are often found in troll caught salmon.

B. Recommendations for trollers

1. Gaffing salmon

Fish should be gaffed only in the head. If gaffed in the body, a salmon should be separated from premium grade fish and iced with fish that have visible defects such as seal bites.

2. Stunning salmon

Gaping commonly occurs in troll caught fish. To prevent gaping, all salmon must be stunned when first brought onboard. The failure to stun salmon is a major reason for scale loss and bruising that can be caused by the fish thrashing on deck. Small fish, in particular, are often hauled onboard without being stunned. Troll caught fish are active feeders and are in especially good nutritional condition. If these fish are not stunned, their struggling increases the buildup of lactic acid in the muscle tissue and promotes severe muscle contractions that can cause gaping.

3. Bleeding Salmon

Bleeding is best accomplished by gilling or by a deep throat cut when the fish is landed. Bleeding is more complete if fish are placed in sea water. For example, Valdimarsson, Matthiasson, and Steffansson (1984) have shown that bleeding salmon in sea water removed twice as much blood from the flesh as bleeding them in air. Bleeding salmon in sea water slows clotting, prevents the temperature of fish from rising, and provides better flesh color. It has been shown that bleeding and gutting Atlantic cod in one step gives results very similar to bleeding and then gutting the fish 20 minutes later (Valdimarsson, Matthiasson, and Steffanson 1984). Because belly burn can happen very rapidly in actively feeding fish, it is recommended that bleeding and gutting be done immediately as a single step. When fish are in the checker for bleeding, continually pump fresh sea water into the bottom of the checker to wash away blood and slime.

4. Dressing salmon

Care must be taken when dressing salmon. In the proposed new Canadian grade standards for fresh and frozen fish, any cut in the belly wall in excess of 1 inch (2.4 cm) will reduce a fish from Grade A to Standard Grade, according to an unpublished document prepared by the Department of Fisheries and Oceans in 1991. Splitting the throat too far forward causes the collars and belly flap to be separated during the heading or when the fish is handled. When frozen, the collars of those fish are often bent out of shape and/or the belly flaps are distorted. This results in a second grade fish. To dress fish for icing, remove the kidney (blood line) with a dull spoon, then wash the fish and remove any bits of viscera next to the backbone, especially in the collar area.

Dress salmon for freezing in the same way as for icing, with the addition of these three steps: (1) when washing the fish, use the back of a spoon to gently press the remaining blood from the veins along the ribs; (2) wash slime off the skin because slime will prevent the skin from taking a good glaze; and (3) head the fish. The head is removed by cutting well forward of the throat latch and slicing to the top of the head by following the curve of the collar, then exiting at the top of the head above the eye. The knife should pass through the back part of the brain case as shown in photograph 12 on page 34. A cut too far back will expose flesh at the nape to bacteria and dehydration (see photograph 13 on page 35).

5. Icing salmon

After the fish have bled for 10 to 20 minutes, they must be lowered, not dropped, into the slaughterhouse. Icing must take place as soon as possible. Putting fish in the slaughterhouse will prevent further warming of them, but will not cool them. Plenty of ice is a must; enough should be used on the bottom, sides, and bulkheads to prevent fish from touching hold surfaces until the end of the trip. On boats with holds deeper than 36 inches, horizontal shelving should be placed every 24 inches. Do not overfill spaces between shelves. To do so will crush fish and negate the use of shelves.

Using chilling coils in ice can be beneficial in several ways (Crapo 1986). Refrigeration coils cut down heat gain from outside sources, which slows ice melt. This makes the ice easier to work, and that translates to better chilling. Refrigeration coils also can eliminate hot spots such as the deck heads, engine room bulkhead, and shaft alley areas.

Trip length must be limited to eight days for king and silver salmon and to fewer days when sockeye and pinks are taken. Technological advances should be used to improve the quality of the product landed, *NOT* to increase trip length.

6. Freezing salmon

The numbers of freezer trollers (and of freezer gillnetters in Canada) are increasing. Some fishermen have achieved success in direct marketing of their frozen product because they have developed a reputation for producing salmon of very good quality. However, common complaints about salmon frozen at sea are that they are not properly glazed (have no glaze, little glaze, or an inconsistent amount of glaze); show poor workmanship in dressing; and were frozen slowly or incompletely.

It is beyond the scope of this paper to discuss freezer equipment requirements. For a discussion of freezer options, see Gibbard (1978) and Kolbe (1981). A well-engineered freezing system will produce the best results. Needless to say, a transport truck refrigeration system installed in the fish hold will not produce good results. When considering a freezing operation, space requirements are of prime importance. To be satisfactory, a system should be capable of freezing a 25-pound fish to a core (center of the maximum thickness) temperature of -20°F (-28.89°C) and of maintaining a storage temperature of -15°F (-26.11°C). Slow freezing results in increased drip loss on thawing and greater cooking loss, giving dry, tough flesh (Bilinski 1977; Jones 1964; Love 1979). The freezer vessel operator should strive to maintain a constant hold temperature. A constant hold temperature of -10°F (-23.33°C) is better for holding frozen salmon than a temperature that fluctuates between -10°F (-23.33°C) and -15°F (-26.11°C). There must be enough freezer space and refrigeration capacity to handle the largest anticipated daily catch.

Salmon should be frozen pre-rigor or post-rigor but never during rigor. Freezing during rigor distorts the frozen fish (as shown in photograph 13 on page 35); increases gaping; and results in a dry, tough, cooked product. Freezing during pre-rigor is preferable. If that is impossible, the fish must be chilled until the resolution of rigor. Do not hasten rigor by allowing the fish to become warm.

When the core temperature reaches -15°F (-26.11°C) to -25°F (-31.67°C), the fish should be glazed. The core temperature can be measured by punching a hole in the thick part of the back with an awl and inserting a dial-type thermometer. A good glaze can be obtained using clean sea water. It is important that the glaze water be as close as possible to freezing to prevent warming of the fish. Keeping glaze water cold will allow the fish to take on a good, even glaze. If the amount of glaze on each lot of fish is to be the same from one batch to another, the temperature of the fish and the temperature of the glaze water must be consistent from one batch to another.

After glazing, the fish should be placed in boxes lined with 4-mil polyethylene bags to prevent loss of glaze and dehydration of the fish flesh, and then stored in the side pens. For further information on freezing salmon at sea, see Davis (1980).

C. Drift gillnet problems

The size of gillnet vessels, fishing conditions, fish handling practices, and attitudes of gillnet fishermen differ widely over the range of the salmon harvest. These factors lead to a great variation in the quality of gillnet caught salmon.

As I pointed out in previous paper (Doyle 1978), variations in the quality of net caught salmon from different regions around the northeast Pacific are related to handling practices onboard the fishing vessel. There is a direct relationship between the attitude of the fishermen of a given region toward quality and handling and the quality of gillnet salmon produced in that region. Prior to the early 1970s, most net caught salmon which were frozen came from Southeast Alaska. Many of the gillnet fishermen in that region also trolled and had a good understanding of the quality requirements of the frozen market. For a long time, Southeast Alaska gillnetters have had enclosed, insulated holds and have used ice or a CSW system to cool fish immediately after catching them. Fishermen from other areas of the state traditionally have fished for the canned market. These different traditions are the sources of different attitudes that exist among fishermen as to the importance of the care and handling of salmon in relation to the quality of the product.

Gillnet boats tend to be larger in the Pacific Northwest, Canada, and Southeast Alaska than in the rest of Alaska. Because the larger boats in Southeast Alaska have fewer space constraints than the smaller boats in use in the rest of the state, they allow for better handling of the catch. Another constraint on gillnet fishermen in Prince William Sound, Cook Inlet, and Bristol Bay is that the catch rate per day during the peak run is much higher than it is to the south where runs extend over a longer period. When catch rates are high, time is spent harvesting with little thought or effort given to careful handling of salmon.

Many gillnet boats have unlined, uninsulated holds that connect directly to the bilge. In some cases the engine partially extends into the hold and is covered with an uninsulated box. These conditions are totally unacceptable because they make it impossible to land a quality product. Fish held in such conditions are bruised by exposed frames and reach high temperatures, especially those which lie against the engine room bulkhead.

D. Recommendations for drift gillnetters

1. Handle fish gently because that is the key to reduced bruising.

2. Hold drifts to one hour; fewer fish will die in the net, and net marks and dropouts will be fewer.

3. Pick fish by holding the head, not the tail; fewer broken backs and bad bruises will result.

4. *DO NOT* wind fish onto the reel; crushing of fish and net cuts will be reduced.

5. Place fish in checkers rather than dropping them on the net cockpit deck, and transfer them to the hold by a chute; this will reduce the bruising and crushing which result in mushy flesh.

6. Keep fish cool; dry boats should deliver to tenders as often as possible.

7. When using a brailer on the boat, use horizontal shelving every 24 inches and do not overfill. Use fine mesh, knotless web for brailers.

8. Load only 200 sockeye per brailer (and fewer silvers and chums per brailer) to prevent crushing.

9. Dress salmon as described above in "Recommendations for trollers."

E. Set gillnet problems

Setnetters face more difficult problems and have more difficulty delivering a quality product than do other salmon fishermen. Most setnetters operate in areas of high tides, broad tidal flats, and strong currents. These problems are particularly acute in upper Cook Inlet and Bristol Bay. When nets go dry, the catch is exposed to sun and wind and will lie in sand or mud until picked from the net. Setnet skiffs are, of necessity, small and cannot carry large amounts of fish. These constraints make it very difficult for upper Cook Inlet and Bristol Bay setnetters to produce a high-quality product.

Setnet fishermen have exhibited ingenuity in increasing their productivity. Many of them put their gear on running lines so they can pull their nets offshore as the tide recedes or pull nets loaded with fish onshore using a tractor. The result of such rough treatment is shown in photograph 5 on page 27.

In some areas where ice is available, setnet fishermen ice their catch in totes, and small tenders come by frequently to transport the iced catch to the processor. This operation results in a higher percentage of good-quality salmon. It has become extremely important that setnet fishermen adopt innovative operations and procedures to improve product quality. In locations where water and electricity are available, setnet fishermen, either individually or as a group, could install ice machines close to their operations to ensure a constant supply of ice for their catch.

F. Recommendations for set gillnetters

Because setnet fishing takes place under a wide range of physical conditions, it is hard to form definitive guidelines, but these recommendations should be followed as closely as possible:

1. Pick fish from the net as often as physically possible, especially at slack tide.

2. Always handle salmon by the head.

3. Carry white plastic totes in the picking skiff and place all fish in them. This will ensure that the fish do not get contaminated with fuel, oil, and gurry which may accumulate in the bottom of a skiff. Cover totes with white covers because white does not absorb heat as fast as dark colors.

4. Handle fish gently. Do not throw them. Photograph 14 on page 36 shows the damage caused by rough handling of a sockeye salmon taken in a setnet.

5. Unload totes by boom directly to a delivery truck or tender. Do not throw fish into a truck.

6. Wash the fish which have lain on tide flats immediately after picking them from the net.

7. Do not drag a net loaded with fish onto the beach with a tractor, because dirt will be ground into the flesh, and the strain on the net will cause severe damage.

G. Purse seine problems

Because salmon taken by purse seine are brought onboard alive, logic indicates that purse seiners should land fish of consistently high quality, but that is not the case. Their quality varies greatly both within regions and between regions. In general, king salmon and sometimes silvers taken by purse seine are soft and mushy.

The many reasons for the wide range in quality of seine caught salmon include large variations in the intrinsic quality of fish. For example, pink salmon change in color, shape, and fat content within a short time and a short migrating distance. King, sockeye, and silver salmon taken by purse seine often are migrating fish which are actively feeding. This makes them prone to belly burn, other enzymatic breakdown, and gaping. Kings, silvers, and sockeye, all of which are referred to as "money fish," may be handled several times before they are delivered to the plant. The more often fish are handled, the greater the incidence of bruising, according to D.E. Kramer, Marine Advisory Program, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks (personal communication, July 1991). Photograph 15 on page 37 provides graphic evidence of the effect of multiple pumping and rough handling of chum salmon taken in a purse seine. From a practical viewpoint, taking large amounts of fish in a single set makes rapid chilling and careful handling difficult.

Among several suspected causes of bruising and mushiness in seine caught salmon is the common practice of hauling a seine bunt loaded with salmon over the gunnel and onto the deck. Pressure from the weight of fish and knots in the seine web can result in extensive damage to the load. The same is true of the growing practice of sewing a codend into the bunt and hauling the codend over the side of the boat. Pumping, brailing, or splitting the load would cause less harm. Multiple handling of fish destined for freezing also damages them. At the time fish are pumped from seiner to tender, it is common practice to separate the sockeye, kings, chum, and coho destined for freezing from pinks destined for the cannery. The fish are separated after they are pumped onto the dewatering line, and then the sockeye, kings, chum, and coho are dropped into totes. Instead of dropping the fish, sliding them into totes along a chute would lessen damage. Often the fish are returned directly to the hold of the seiner, only to be pumped to a tender for transport to a freezer plant. A better practice would be to transfer the "money fish" directly to the tender in totes.

The great variation in the quality of fish landed by different purse seine vessels which fish the same areas is due in part to attitude and in part to the characteristics of the vessels. Some dry purse seiners in the fleet still have unlined holds and exposed frames and use no refrigeration. Many RSW systems vary in their chilling capacity and uniformity of temperature within the hold. Some vessels using CSW have poor mixing systems and are prone to warm spots.

H. Recommendations for purse seiners

1. Handle fish gently and as few times as possible. When "money fish" are separated from pinks on the tender, place them in totes as gently as possible. *DO NOT* drop them from the dewatering line to the bottom of the tote. If possible, hold "money fish" on ice or stow them separately.

2. When practical, large sets should be pumped directly from the seine to the tender.

3. Do not pull large loads into the bunt of the seine directly over the gunnel.

4. All holds must be lined, watertight, designed with a sump, and equipped with a sump pump.

5. All CSW systems should use compressed air forced through a manifold system (as shown in figure 2 on page 40) to properly mix the fish, ice, and sea water.

6. All RSW systems should have a refrigeration capacity sufficient to reduce the ambient summer sea water temperature to 32°F (0°C) in 6 hours.

7. When possible, prechill RSW systems to 32°F (0°C) before taking on fish.

8. All new or replaced RSW systems should be designed so that the chilled sea water is forced in at the bottom of the hold through a manifold system and the warmer water is taken off the top.

9. Load CSW and RSW systems to a maximum of 45 pounds per cubic foot of hold space.

10. Encourage fishery management agencies to allow fishing as far away from the home stream area as possible in keeping with sound fishery management practices.

11. Dress salmon as described above in "Recommendations for trollers."

VII. Cleaning and Sanitation

Good housekeeping on a fishing boat is essential to provide a clean environment for both fish and crew. Bacteria will grow on any surface where there are food and moisture. On a boat, this means that bacteria and mold can be found almost everywhere except the engine exhaust manifold and exhaust stack. Fish gurry and slime build up on all surfaces touched by fish.

The rate of spoilage or decomposition is directly related to the number of bacteria on the skin and in the flesh. Blood, slime, and bits of fish provide bacteria with excellent food and a good place to live. Fish generally spoil faster than other protein foods. Therefore, to hold down the bacteria population, it is necessary to practice good housekeeping by frequently cleaning decks, equipment, tools, and clothes. Special attention should be given to cleaning the hold. Cleaning and sanitation are two separate operations, and cleaning must be done first. After all dirt and gurry have been removed, surfaces should be sanitized to kill the remaining bacteria. Manufacturers of a number of cleaners on the market claim that they both clean and sanitize. However, the sanitizers in many of these compounds are not effective killers of pseudomonad bacteria, the potent spoilers mentioned on page 21. In other sanitizers the alkalinity of the solution is too high for chlorine compounds to be effective. Therefore, it is strongly recommended that cleaning and sanitizing be done in two steps.

A. Cleaning

Cleaning is a continual operation in a fish plant, and on a boat it should be the same. Decks should be hosed down after each set. At the end of the day, decks should be scrubbed with a strong detergent and then flushed. Checkers should be flushed out, hosed down, and scrubbed each time they are emptied. On trollers, all surfaces where the fish are dressed should be rinsed continuously to reduce the number of bacteria that can enter the cut flesh of the salmon.

The holds, including pen boards, shelves, and stanchions of all salmon boats and tenders, must be washed after every delivery. Operators of gillnet vessels that use brailers in the holds need to keep their brailers clean. Slime-soaked twine and knots are perfect growing places for bacteria. Wash brailers in a tote of sea water with a strong detergent and rinse them in sea water containing household bleach.

The easiest and best way to clean a hold is to use a pressure spray system. All large processing plants have such systems, so when delivering fish for processing, use the plant's pressure cleaning system. Small, inexpensive, portable units are adequate for vessel cleaning. All processors should be able to provide the vessel operator with excellent cleaning agents. When pressure systems or special cleaning agents are not available, a stiff brush, deck bucket, laundry detergent, and plenty of elbow grease will work wonders on a dirty boat and hold.

Use a half-cup of strong laundry detergent per 5-gallon bucket of water. Add a half-cup of household bleach to help break down the protein. In this case the bleach is not a sanitizer, but it is a great help in removing slime and blood. Start cleaning at the top and work down. Material that is hard to remove, such as partially dried slime, will require extra effort. Pay special attention to cleaning corners and areas that are hard to reach. Remember that bacteria will multiply rapidly when food is available and the temperature is high. Rinse away all cleaning agents after scrubbing has been completed.

B. Sanitation

After cleaning the deck area and hold, it is necessary to kill the bacteria on surfaces with which fish have come in contact. Sanitizers are effective for this purpose if they are applied to clean surfaces. If chlorine-based sanitizing agents come in contact with gurry or dirt, they will react with them and will not reach the bacteria.

Chlorine is the best and most readily available sanitizer to use on a fishing boat. If you are at a fish plant, ask the dock foreman to increase the chlorine content in the plant's fresh water supply from 10 parts per million (ppm) to 25 ppm, and if that is possible, thoroughly wash down all areas. Do not rinse them off.[4] Often the

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[4] Some fishermen don't want to use chlorine, because they believe it will cause corrosion. However, it has been demonstrated in food plants that the regular use of chlorine on equipment will reduce corrosion by killing bacteria that produce acid to break down protein.

plant cannot provide high levels of chlorine in its fresh water system; in that case, use household bleach. A half-cup of bleach per 5 gallons of water will provide from 25 ppm to 50 ppm of chlorine. *DO NOT USE A STRONGER SOLUTION.* The recommended concentration will provide the optimum killing power (Doyle 1970). The powdered form of chlorine (calcium hypochlorite) sometimes is distributed by seafood processors. Do not use powdered forms of chlorine-producing compounds, because they have a very high chlorine content which is difficult to dilute to a proper level. Never mix together chlorine and ammonia compounds, because the mixture gives off toxic chlorine gas. Never use phenolic compounds on a fishing boat for any reason. They will impart a strong, unpleasant, and persistent odor to the fish.

It is impossible to properly sanitize unprotected wooden surfaces because bacteria will invade pores in the wood and will be protected by cracks. This means that wooden holds should be lined with fiberglass, or the wood must be coated with a suitable paint.

Use the same concentration of detergent and bleach as recommended above to wash oilskins and gloves at the end of the day. Wash gloves in soapy water, rinse them, and leave them overnight in a deck bucket containing 25 ppm to 50 ppm chlorine (a half-cup bleach per 5 gallons of water). This will provide clean, sweet-smelling gloves, which will be more comfortable to wear as well as bacteria free. Wash brailers and then soak them in a tote in a solution of 25 ppm to 50 ppm chlorine.

C. Special cleaning problems

The piping in CSW systems and the piping, pumps, and heat exchangers in RSW systems present special problems.

1. CSW systems

When the air is off, water pressure will cause the pipes to flood, carrying in bacteria, slime, and blood. The slime and blood will stick to the inside, providing the bacteria with food and a place to grow. These pipes must be cleaned, or the next load of fish will be contaminated with bacteria.

The air piping system should be constructed so that it is easy to take apart. After unloading fish, take the pipe apart and lay it on the bottom of the hold. While the hold is being scrubbed, wash water will accumulate in the pipes and soften the gurry attached to the pipe walls. After pumping the wash water out of the hold, add enough water and a strong cleaning mixture (1 cup cleaner per 5 gallons of water) to cover the piping. Allow it to soak for 30 minutes. Pump out the cleaning mixture and cover the piping with a standard solution of bleach or chlorinated water. Leave the pipes in the solution until they must be reassembled.

2. RSW systems

Because the heat exchanger is completely enclosed, it presents the greatest problem in adequately cleaning and sanitizing an RSW system. The heat exchanger often is located in the engine room. When a heat exchanger in that location is not operating, its temperature will rise to that of the engine room, and when the hold is pumped down during unloading, the heat exchanger will contain sea water, blood, and slime. The result is a perfect environment for anaerobic bacteria (bacteria that grow without oxygen). Anaerobes are stinkers–that is, in breaking down protein they produce hydrogen sulfide, the source of the foul odor in many RSW systems after a short period of operation.

Proper cleaning of the heat exchanger, pump, and piping is a must. Figure 4 on page 61 is a diagram of an RSW system showing a cleaning loop that isolates the pump and heat exchanger from the hold. A cleaning loop is essential; without it, cleaning would require that the hold be partially filled with a cleaning solution before the pump could pick it up and circulate it.

Clean the hold in the same way as recommended for dry holds and CSW systems, and then clean the pump and heat exchangers. Fill the cleaning loop with a strong cleaning agent and circulate it for 15 to 20 minutes. Then flush the system into the hold and continue to flush with fresh sea water until no cleaning agent remains in the system. The final step is to kill remaining bacteria with a sanitizing agent. Chlorine at a concentration of 25 ppm to 50 ppm will suffice, but a better agent is an "iodophor," an iodine containing compound often used as a hand dip in processing plants. Iodophors are noncorrosive, long-lasting, and safe in contact with food. Fill the cleaning loop with an a 25 ppm iodophor solution, circulate if for 20 to 30 minutes, then pump it out, and flush the system with clean water. This will kill most spoilage bacteria. When filling the hold and starting the refrigeration system, pump the iodine or chlorine based sanitizer directly into the hold. If an iodophor solution is used, the concentration of iodine in the hold will be undetectably small. Use of the procedure outlined above will reduce corrosion in the system and provide a better quality of fish.

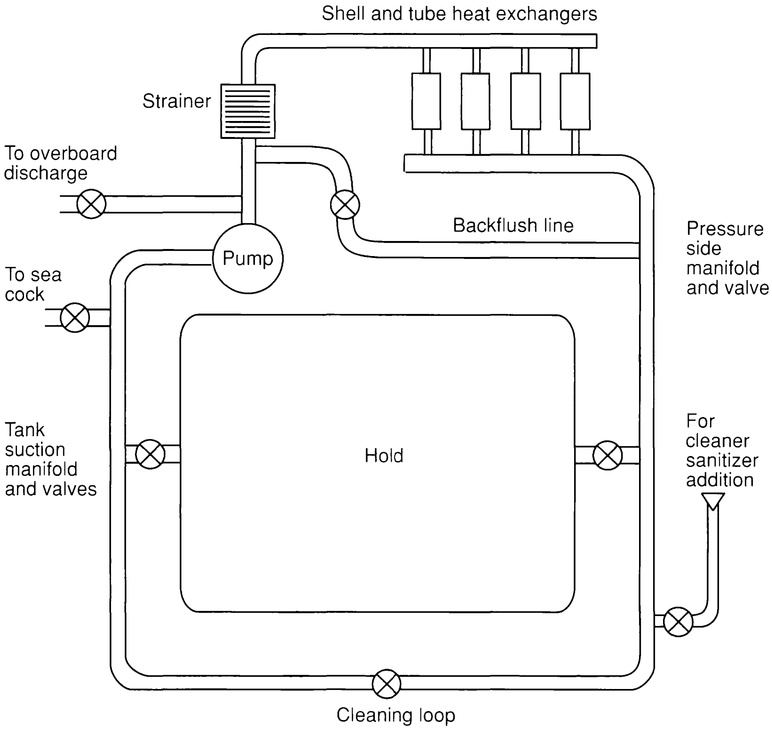

Figure 4. Diagram of a refrigerated sea water system showing the cleaning loop. Adapted from Kramer (1980).

VIII. General Recommendations

The following recommendations apply to all vessels harvesting and/or transporting fresh salmon.

A. Holds

1. All vessels must have watertight holds that prevent any contamination from the engine room, bilges, and shaft alley.

2. Holds must be lined with a nonporous material such as glass-reinforced plastic (fiberglass); aluminum; or coated steel.

3. Holds must be adequately insulated to reduce incoming heat. The engine room bulkhead should have an "R" factor of 50, and other surfaces, including the shaft alley, should have an "R" factor of 33.

4. All angles and corners must be faired because the hold cannot have sharp obstructions.

5. There must be a sump and a sump pump at the lowest part of the hold.

6. Fuel lines and hydraulic lines that pass through the hold must be shielded to prevent heat loss and contamination from spillage.

7. Hatch combings and covers must be adequate to prevent leakage of water and contaminants from the deck into the hold.

8. Setnet and other skiff fisheries must hold and transport fish in light-colored totes.

B. Chilling

1. All fishing vessels must chill their fish at the time of catch, using ice, chilled sea water, refrigerated sea water, or its equivalent.

2. Salmon must be chilled to a core temperature of at least 35°F (1.67°C) within 24 hours of harvest.

IX. Conclusions

The Alaska fishing industry faces a difficult struggle to regain lost markets. Neither its competitors nor the marketplace will be swayed by advertising or promotion. Consumers must see a significant improvement in the quality of wild salmon from Alaska and, to a lesser extent, from Canada and the Pacific Northwest before they will return to the use of wild salmon for top-of-the-market items.

The most important change needed is *a change in attitude* in the industry; firstly, a recognition of the need for improved quality, and secondly, a willingness to move away from the concept that the most important job is to maximize production and to accept the idea that the job is to produce a high-quality food. If these changes take place, the industry will be well on its way to better serving the consumer.

With proper care and handling, up to 90% of net caught sockeye and coho salmon should provide sides of the quality shown in photograph 16 on page 38.[5]

The State of Alaska has a responsibility for and a vested interest in promoting salmon quality, in a broad sense to protect Alaska's economy, and in a narrower sense to maximize income to the State treasury.

Salmon products from Alaska often will be judged by the product of lowest quality–that is, by the lowest common denominator. Therefore, the State should implement as regulations either the general recommendations given on page 62 or similar requirements. The hold recommendations should be enforced no later than the 1993 fishing season, and the chilling recommendations should be enforced no later than the 1995 season.

Remember, salmon is a fine food:
Handle with care.
Keep it cold,
keep it clean,
keep it moving to the consumer.

[5] Prince William Sound fishermen instituted a voluntary quality and education program in 1980 and 1981. As a result, the quantity of exported number one sockeye salmon suitable for the manufacture of lox increased from a previous level of 70% to between 80% and 90%. (Sources: Interviews by the author with the president and staff of Sanyo Food Co., Hokkaido, Japan, 1984 and 1986).

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