Salmonid By-catch in Targeted Chum Salmon Fisheries of Puget Sound

Commissioned Report for the Puget Sound Salmon Commission
February 2012

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ABSTRACT

This report compares by-catch mortalities of chinook and coho salmon during the fall Puget Sound chum salmon season, for the two major gear types – gill nets and purse seines. Gill netters can legally retain their chinook and coho; therefore landed catch of these fish is an accurate measure of by-catch mortalities. Purse seiners are often required to release their by-catch. Thus to best estimate purse seine by-catch rates, the record of chinook and coho catches during the Apple Cove Point chum salmon run update test fishery, which uses chartered purse seiners, was reviewed in addition to the landed catch records. The rate of coho by-catch (number caught per 1,000 chums) was likely two or three times greater for purse seiners than for gill netters, over the recent time period under which a 6-1/4" minimum gill net mesh was required. Probably the majority of purse-seine-caught coho can be released unharmed, if careful handling rules are enforced; this should be confirmed with additional tests using on-board, trained observers.

For chinook salmon, it is evident that the purse seine by-catch rate is many times greater than that for gill netters. The smallest chinook taken by the 6-1/4" gill nets are about four pounds, yet the abundance in Puget Sound of (immature) chinook less than four pounds is much greater than for those four pounds or more. Many purse-seine-caught chinook are the smaller ones gilled in the net or descaled. Numerous literature citations of on-board observations confirm that some 50% of purse-seine-caught chinook would be dead or moribund, and others would die after release due to descalation or other capture stress.

Substantially improving the survival rates of purse seine by-catch of chinook could require extensive modifications in gear and/or fishing methods; the testing of a 6-1/4" top "escape" strip was one suggestion.

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Introduction

The two major non-Indian gear types that harvest chum salmon in Puget Sound are purse seines and gill nets. These two operate on quite different principles concerning physical deployment and fish behavior. While targeting chums in the fall, each may take other fish species, sea birds, shellfish or marine mammals as bycatch. It is, of course, desirable to minimize by-catch, for several obvious reasons: Other salmon species may be of low abundance; immature salmon of other species should be allowed to grow to maturity and not be wasted as by-catch mortality; other fish or shellfish may be contributing to valuable alternative sport or commercial fisheries; or by-catch fish, birds, or marine mammals may be ESA listed as threatened or endangered.

This report is directed to salmonid by-catch, i.e. what are the comparative by-catch mortalities of chinook and coho salmon (and steelhead) in the non-Indian purse seine and gill net fisheries for chum salmon?

The Fishery

Puget Sound chum salmon is a growing and valuable resource, primarily commercial (Figure 1). Both wild and hatchery segments are doing well in Hood Canal (primarily hatchery) and Inner Puget Sound (primarily wild). Not only has abundance increased over the recent three decades, but so has the economic value in real dollars per pound. The present ex-vessel price now exceeds \$1.00/lb. whereas just 8-10 years ago it was a fraction of this. Furthermore, a growing portion of the gill net catch, now about 20%, is marketed directly to consumers through farmer's markets and other channels, yielding to the fishermen perhaps higher market values, which includes high egg value for caviar. (Purse seine chum are not self marketed; the volume of the catch is probably too high to make this practical.) Thus catches in recent years of say half a million 9-10 pound fish translates to total fishermen values that are in excess of five million

dollars. With the decline of other commercial salmon fisheries in Washington, Puget Sound chum may be the most valuable non-Indian opportunity remaining.

Not only is the total value high, but the share by each boat has risen very substantially due to license reduction over the past 20 years. Limits were placed on the number of commercial licenses allowed and through attrition and Federally funded buy-back the numbers were reduced over time to the present stable levels of 195 gill netters (over 1500 at the maximum) and 75 purse seiners (maximum of over 300) (Table 1). Thus, seasonal catch values per gill net boat of \$10,000-\$20,000 (or more, depending on self marketing), and \$50,000 or more for a purse seiner, are significant add-ons to salmon fishing elsewhere, or to other species fisheries or other jobs. In summary, the Puget Sound chum fishery is healthy and understandably competitive – within and between gear types.

The total non-treaty catch, while growing over time, tended to go more and more to the purse seiners (Figure 2), reaching as high as about 90%. Recently, the proportion by seiners has decreased somewhat and is presently 75-80%. A purse seiner employs a crew of 4-5, whereas a Puget Sound gill netter may employ a crew of one. Purse seiners tend to do relatively better than gill netters on big runs (Figure 3), since they are less restricted in maximum catch per day. On average, gill netters even on a big year, could not pick and hold more than say 1,000 fish per daily period, whereas a modern seiner could catch and hold 10,000 or more per day. Southeast Alaska pink salmon is an analogous example. The bigger the run, the lesser the proportion that could or would be taken by gill netters.

Gear Description - Gill Nets

Gill nets are walls of large mesh, relatively fine but strong twine that are set perpendicularly to the strongly motivated, uni-directionally migrating mature salmon. In Puget Sound the gill nets are a legal maximum of 1,800 feet long, suspended from the top by a row of floats (corks) and weighted by a leaded rope at the bottom. The fine netting has diminished visibility to the fish, and their migratory proclivities cause them to attempt to swim through the net. If the perimeter of the mesh (which hangs in the water as an open parallelogram of four equal length sides) is less than the maximum girth of a fish, it can't get through. If it does get through beyond the gills it can't easily back out and will probably get caught – hence the term gill net. But a fish with a maximum girth less than the perimeter of the mesh will tend to swim right through. Big fish, which maybe could stick their head into a mesh but not up to the gills, would tend to bounce back and not get caught.

Thus, gill nets are well known the world over, in both commercial fisheries and research, to be potentially very size selective. (Pauley, 1984, pp 12-18; Murphy and Willis, 1996, chapter 7) For example, if you want to target big salmon like kings,

(mature chinook) but minimize by-catch of a smaller species like sockeye, you specify by law the minimum mesh size allowed. In Southeast Alaska when targeting spring running kings, which average about 20 lbs., while minimizing by-catch of sockeye (averaging about 6 lbs.), the Alaska Department of Fish and Game (ADFG) sets a 7" mesh size minimum. If they catch you with a smaller mesh net, they will confiscate your catch and charge a healthy fine. If they find you using a 7.5" net for kings, that's OK because the law said a minimum of 7" – and a sockeye is even less likely to be caught in a 7.5" net than a 7" net.

The mesh, being a parallelogram or open diamond when hanging in the water, can be stretched into a straight line by hand out of the water, pulling at the top and bottom points of the mesh. Hence the law usually reads "a 7 inch (or whatever size) stretched mesh" gill net minimum. To enforce mesh size is straightforward. You encounter a boat on the water as it is pulling the net, hang a 10 lb. weight on several meshes and measure between knots of a mesh, or even simpler, encounter the boat at the dock after a fishing opening. Since this "stretched out" diamond really has two sides of twine, the total perimeter of the 7" mesh as it hangs in the water is 14". If you took a piece of string and measured the girth of sockeye salmon at their thickest point closely behind the head and gills, you would find very few with a girth bigger than 14"; they swim easily through the 7" net.

In Puget Sound a 6-1/4" stretched mesh minimum for all chum salmon gill netting was enacted by 1995 after discussion between the Washington Department of Fish and Wildlife (WDFW) and the gill netters. Prior to that it had been a 6" minimum for the chum season (October-November). The larger mesh size was specifically enacted to minimize as much as possible the bycatch of coho, steelhead and immature chinook (blackmouth) which all tend to be smaller than adult chum. Gill net fishermen had to buy new gill nets at a cost of \$5,000-\$6,000 to comply with the new regulation.

There is no WDFW depth restriction on gill nets. In practicality about 200 meshes or approximately 100 feet is about as deep as these nets go. (Each "diamond" of a 6-1/4" stretch mesh net hangs in the water slightly less than 6").

The net is set straight, or maybe with a slight bow perpendicular to the direction from which the fish are coming, and it drifts with the tide. The time of the set varies, depending on tides, winds and patience of the fisherman. As long as it stays straight and perpendicular to the direction the fish are swimming it is effectively and passively fishing. When pulled back on an hydraulically operated drum (actually the boat is pulled to the net, not the other way around which would be impossible given the drag on the net), the fish are picked out one by one. Understandably most fish, both target and by-catch, are dead or would die from injuries and/or stress if released. So the WDFW allows by-catch of non chum salmon species to be retained

and sold (not steelhead, however, these have been given recreational status and can't legally be sold).

The boats range from about 24 to 40 feet long. The smaller ones tend to be faster bow pickers (net roller in the bow), with hold capacities as small as about 3-4,000 pounds. The bigger stern pickers can hold upwards of perhaps 10,000 pounds on average. Some of them carry ice during the chum season, particularly self-marketers.

Gear Description - Purse Seines

Salmon purse senies are walls of small-mesh, heavy-twine nets towed in a circle around a school of fish or set in a "U" shape with the opening to the oncoming direction of migrating fish, and held open for some time as the captain may desire. Two boats do the job, the seiner, a 40'-75' long boat (mostly about 58' to comply with Alaska's maximum allowable length, where most of the Puget Sound boats also fish) with a crew of 4 or 5 at one end of the net, and the seine skiff, a high powered 16-24' open boat, at the other end. The net is suspended by large, closely spaced floats at the top and a heavily leaded rope at the bottom. Attached to the bottom rope at short intervals are steel rings through which a strong rope (purse line) passes. As the net encircles the fish, the "U" is closed by running the main vessel and the skiff together. The skiff then casts off from its end of the net. Now both ends of the net are attached to the main vessel on the hauling side, and the net is still, hopefully, in more or less a circle. The skiff goes to the non-hauling side of the net, takes a fore- and aft-bridled tow line, and drives perpendicularly away from the main vessel trying to hold it sideways away from the very sizeable net. This is to try and keep the net in its essentially circular shape and keep the net away from the running gear of the main vessel as the back-hauling process begins. The first part of the haul-back is to draw in the purse line with a heavy-duty, deck mounted capstain. Drawing in the purse line bags up the bottom of the net, and now, presumably, you've got the fish with no escape holes. Then the net, including both the top cork line and bottom lead line is worked back aboard the seiner via an overhead, hydraulic, boom-mounted power block or a deck-mounted drum until only a small pocket (bunt-end; very heavy mesh) holding the payload is in the water. With the power block style used by most seiners (since the drum style is not allowed in Alaska), two or three men stand at the back deck stacking the net as it comes back down through the power block. This is hard work since the mess of corks, web, and leads is coming at you fast, maybe loaded with jelly fish or other debris, and must be stacked in orderly, separate piles of cork line, mesh, and lead line. It has to be stacked properly so as to go out smoothly on the next set. With a drum you don't need the stacking crew and can get by with a couple less crew.

Once down to the bunt, the fish are either rolled on deck with boom-mounted winch lines, or removed in successive "dips" with a large, winch operated dipnet called a brailer. The rolling-aboard process is quicker and thereby favored, but for large

catches which might roll the boat over if yanked too enthusiastically, smaller "bites" with the brailer, or "splits" (rolling bit by bit) could be needed. In any case, a big haul is a pretty busy process involving several hardworking people who have to know what they are doing.

The maximum legal length of a purse seine in Puget Sound is the same as for a gill net – 1,800 feet. Additionally, seiners are allowed a 400 foot lead net which is not supposed to be attached to the main net. This may be placed shoreside, in perpendicular fashion, to lead fish that are migrating close to the beach outward into the seine. There is no legal depth maximum for a purse seine – whatever can be practically handled. A depth of about 200 feet may be the norm, with a maximum of about 235 feet. The legal minimum mesh size for the main body of the net was 4" until recently changed to 3-1/2" to match SE Alaska's rule. Thus, Puget Sound purse seines are either 3-1/2" or 4" mesh size, with no practical difference between the two. They don't have to be of reduced visibility like gill nets, but do have to be strong enough, particularly in the bunt end, to hold catches into tens of thousands of pounds. The 3-1/2" to 4" mesh is a practical choice – small enough to hold all salmon of marketable size down to about two pounds for SE Alaska pinks, but big enough to pass fingerling salmon and bait fish.

An exception to the 3-1/2" to 4" mesh size is the "top strip", a "strip" of seine material being 100 meshes deep. Seiners for several decades have been required to build into their nets a strip of 5" minimum mesh at the payload end when fishing chum salmon in the fall. The required top-strip length is now 75 fallons (450 feet of the 1,800 foot total length). The history of the 5" strip is worth presenting, because this is one feature of a purse seine that is size selective. It is intended to allow immature salmon smaller than about three pounds a potential escape route as the net is hauled back.

In the 1960's, the Washington Dept. of Fisheries (WDF, now WDFW) became concerned about the number of immature chinook and coho (fish of roughly 15" to 20" in length) that were being gilled in the 4" seine mesh of the time. WDF was trying to rebuild the badly depleted Puget Sound winter sport fishery, which took fish at the minimum sport size limit then of 16" (it has since been raised to 22" for chinook). WDF estimated that several thousand (Cole, 1975) of these small fish were being killed in Puget Sound purse seines during the fall chum season and thrown back since there wasn't a market for such small fish particularly if damaged by the net. So WDF did controlled experiments with purse seine webb of 5" mesh on top versus 4" mesh throughout and concluded that about two-thirds of the fish in the 15" to 20" range, susceptible to gilling in a 4" mesh would swim through a 5" mesh (Fiscus, 1964). Chum salmon, being 9-10 pound fish would not fit through a 5" mesh, so here was a mechanism that could potentially save many small chinook and coho without loss of chum harvest capability.

The Fishery Management Regime

The main fall chum fishing areas for both purse seiners and gill netters are 10 and 11 of South Puget Sound and Area 12 for Hood Canal. Areas 10 and 11 include most waters south of a west-east line between Apple Cove Point (Kingston side) and a light on the Edmonds breakwater, and down to the lower ends of East and West Passages. Area 12 is Hood Canal south of the bridge and down to Misery Point. Historically upper Sound areas, Admiralty Inlet and Discovery Bay were also allowed. Fall chum fishing by both gears is also allowed at times in areas adjacent to Skagit and Snohomish Rivers, but such fishing activity is not considered in this report. Also, there are various sub-areas within Areas 10-12 for special fisheries or gears, but I have not considered these either.

WDFW has been historically consistent in its management approach. It attempts to forecast preseason run strength from standard tools such as sibling analysis, escapements, climate and hydrological analysis at early life, etc. Then it does run strength updates from catch analysis of weekly test fishing at Apple Cove Point during the season using chartered purse seiners. The tendency was to equalize allowed fishing periods each season (partial days) between the two gear types, and alternate weekly openings between the two, to try and give each gear some level of equality at "first crack" at the fish. The season runs roughly as a six week period starting around October 10 and running through mid to late November. Generally 1-3 fishing periods (days) each week would be allowed depending on run strength. The fishing periods for purse seiners are daylight hours - generally 9 to 11 hours per day as these change through the season, and for gill netters the night time hours, which with allowance for full change of light at dusk and dawn would give them several more actual hours per period than purse seiners. In Area 12, the gill netters now fish during the day light, not nighttime as in 10 and 11, but with more hours than purse seiners to get change of light at either end.

There was a substantial shift in this long term pattern of equal fishing periods in favor of the gillnetters in 2003, in recognition of an increasing catch share by the seiners (Figure 2), and a change in statute which directed WDFW to encourage "niche" marketing. Gill netters were also given "market openings" for Areas 10 and 11, beginning in 2008; these are half-night openers late in some weeks to promote gill netters' self marketing in weekend farmer's markets and the like. Another added opportunity for the gill netters occurred fortuitously toward the end of the 2011 season when there was such a small portion of the allowable harvest left that the WDFW didn't wish to risk overfishing by the more powerful seine fleet. So, gill netters were given three extra days above the preseason announcement. WDFW's caution in this regard may be due to overfishing and underescapement several years previously by the more powerful seine fleet.

In addition to concern with the economic well-being and stability of each of these historic gear types, the WDFW's responsibilities are to preserve the stocks through optimum spawning escapement and habitat maintenance, and to achieve full

harvest of target stocks with minimum by-catch of non-target salmonids and other fish, birds, shellfish, and marine mammals. My purpose is to address just the non-target salmonid by-catch of these two main gears during the fall chum season.

I need to point out that inner Puget Sound (Areas 10, 11) is ecologically different than Hood Canal (Area 12). Hood Canal is relatively simple in terms of shoreline and oceanography. It's a "straight-pipe" compared to inner Puget Sound, which is apparently more diverse and productive for bait fish and other food organisms. This simple comparison of obviously complex systems is most apparent in that inner Sound has a relatively rich winter population of immature, feeding chinook and coho compared to Hood Canal. Winter sport fishing is much more popular in inner Puget Sound than Hood Canal. This difference is also apparent in some of the incidental catch analysis presented below.

By-Catch of Mature Coho

Coho runs to Puget Sound and Hood Canal are of similar order of magnitude as chum runs, and a mix of hatchery and wild fish. The wild fish may need extensive protection in weak years. Inner Puget Sound (Areas 10 and 11) tends to have a mixture of ocean migrating and "resident" stocks, the latter being fish that spend their full lives within the Sound. Hatchery fish probably predominate in the resident component, due to several decades of WDF attempts at delayed release strategies designed to keep them home and augment the Puget Sound sport fishery. The resident coho will tend to be 2-3 pounds smaller at adulthood than returning ocean components. In addition to the adult (3-year old) components that are potential bycatch during the chum season, there are also immature (2-year old) resident coho present in Areas 10 and 12, which during the chum season would be fish of about 16" and two pounds. Area 12 does not appear to have many resident coho because it is less a winter feeding ground. This shows up in the larger size of coho in Area 12 compared to Areas 10 and 11 for both purse seines and gillnets (Table 2).

Coho runs in Puget Sound peak at least a month earlier than fall chum runs. By the beginning of the chum harvest season, most adult coho are gone. Thus the by-catch of coho is quite low, but still of concern in years of low wild coho runs. WDFW fish ticket landings of these two species for Oct-Nov are given by gear and area in Table 3 for years 1996-2011. (I start with 1996 because although the 6-1/4" gillnet minimum mesh restriction was enacted in 1995, it took perhaps a year before everyone complied.) Each ticket in this data base represents the daily catch in pounds and numbers by species – those sold, including self-marketed, plus any retained for home consumption.

In both inner Puget Sound and Hood Canal gill netters have been allowed to retain coho by-catch. However purse seiners on many occasions have been required to release their coho. Thus for Areas 10 and 11 there were only four purse seine retention years available for comparing purse seine and gill net coho by-catch rates directly from the fish ticket data – 1996, 1997, 1998, and 2001. For these years the

average by-catch rates (total coho divided by thousands of chums) were about one coho per thousand chums and 1.3 coho per thousand chums for gill nets and purse seines, respectively (Table 3). For Area 12 seiners were allowed to retain coho in all years since 1996 except 2002, 2008, and 2010. For the remaining 13 purse seine retention years the coho by-catch rates were about 6 coho per thousand chums and about 12 coho per thousand chums, for gill nets and purse seines, respectively.

There is another data series available for comparing coho by-catch rates for the two gears in Areas 10 and 11 that is less sparse than the fish ticket series. This is the Apple Cove Point (Kingston shore) test fishing series. Each year about 30 or more sets with chartered purse seiners are made over a six weeks period to up-date run strength. Biologists aboard record numbers of coho and chinook in addition to chums (Table 4). How representative these sets may be of the entire fishery is unknown. For example, the Edmonds shore may have relatively more coho than the Kingston shore, since Lake Washington and the Green River have strong coho runs. Conversely by the time you get to East or West passage, the above two coho runs are out of the fishery. Nonetheless this is the only consistent non-fishery data series available for which biologists or trained technicians were aboard. (A much larger WDFW data series of sampled sets is available but many of these are from observations off another boat, or skipper interviews ("hailings") and therefore inconsistent in methodology.)

For the purse seine non-retention years, 2002 - 2010, the purse seine coho by-catch rate from the Apple Cove Point test fishery was 22 coho per thousand chum. (Table 4). The Area 10 and 11 gill net rate from the fish tickets for these same years was about seven coho per 1,000 chums (Table 3).

The apparent reason why gill net coho by-catch rates were consistently less than such rates for purse seine is the size selectivity of the 6-1/4" minimum gill net mesh. The smaller ones are going through the net, as indicated by the fact that gill net coho average larger than seine coho for both inner Sound and Hood Canal (Table 2). The 6-1/4" mesh appears to be non-size selective for the chums (Table 5), but chums are bigger on average than coho.

By-Catch of Chinook

An insignificant number of mature chinook overlap in timing with the fall chum season. Fall chinook peak about a month earlier than coho, which are about a month earlier than fall chum. Spring chinook would be completely out of the picture. But, Puget Sound is a winter feeding area for resident immature chinook of all ages, moreso for Areas 10 and 11 than Area 12. Most of these are small fish less than the 22" (about four pounds) sport size limit. For example, of 313 immature chinook caught by sport gear during a 1992-1993 hooking mortality study, 234 were less than 22" and 79 were 22" or greater. (Natural Resource Consultants,

(NRC), 1993). Gill netters are allowed to retain their chinook during the chum season but not purse seiners. For Areas 10 and 11, gill netters landed 86 chinook and 634,306 chums since 1996 (Table 3), or 0.14 chinook per 1,000 chums. For Area 12, they landed just 13 chinook in taking 471,708 chums, or .03 chinook per 1,000 chums. The smaller chinook by-catch rate for Area 12 reflects my earlier conclusion that Hood Canal is not a productive feeding area for immature salmon. The size of gill net chinook in all of Areas 10, 11, and 12 for years 1996-2010 (catch weights were not available for 2011) ranged from 4-30 lbs., averaging about eight pounds. Chinook less than four pounds did not show up in the catch, yet it is well known that they outnumber chinook greater than four pounds in Puget Sound by about 3:1. It is clear that the 6-1/4" minimum mesh eliminated the by-catch of the abundant, smaller chinook; they swam through the nets.

Although purse seiners couldn't legally land chinook during 1996-2011, there is abundant data on their likely catch of these mostly small fish. Fiscus (opcit) reviewed data for eight years between 1948-1962 in which WDF observers were aboard. In a total of 756 observed sets made in Areas 4A, 5, 6, 10, 11, and 12 after Oct. 4 the average number of chinook per set by year ranged from 2.2 - 12.3. Fiscus (opcit) reported that most of these fish were 15"-20" in their second year of life that were gilled in the 4" top strip. Further, Fiscus (opcit) reported on the tests that concluded a 5" top strip could save about two-thirds of these small chinook.

Cole (opcit) reported on 442 observed sets made between 1965-1973 mostly after Oct. 4. He gives an average of 3.07 chinook per set and offers analysis that about 90% of these were less than the 26" minimum commercial size limit of the time. Cole additionally breaks the observations down by area. The worst areas for small chinook were Admiralty Inlet, Point No Point, and Port Gardner, outside presently allowed Areas 10, 11, and 12. Cole's (opcit) average for sets made within Areas 10, 11 and 12 was 1.75 chinook per set.

The 5" top strip rule went into effect in 1973. Therefore both the Fiscus (opcit) and Cole (opcit) data represent the situation prior to this by-catch reducing measure. For current years, the Apple Point Cove test fishery provides the most consistent data set for which professional observers were on board. Again it should be stressed that such sampling may not be representative for all of Area 10 and 11. For years 1996-2011, a total of 1,269 chinook and 119,193 chum were caught in 509 sets – about 11 chinook per 1,000 chums and 2.49 chinook per set (Table 4). The catch per set is on the same order of magnitude as with the historical data of Fiscus (opcit) and Cole (opcit).

How big are these Apple Point chinook? I had weight data for only two years, 1996 and 1997. The 204 chinook averaged 3.55 lbs. That size is pretty consistent with what one might expect from earlier reports and the use of the 5" top strip, which would eliminate many of the 15-20" chinook from the catch.

Purse Seine Non-Retention By-catch Mortality Rate - Immature Chinook

This is the percentage of the catch that is dead or moribund at capture or that dies after live release due to stress from capture. For example, if 100 chinook are caught of which 30 were dead or so badly injured as to be considered dead, and 30 of the remaining 70 which were released alive subsequently died from the stress, the by-catch mortality rate would be $(30 + 30) \div 100 = .60$, or 60%.

Immature chinook of the apparent average size presently caught by purse seines, of about 3.5 lbs., would be of optimial size to gill in a 5" top strip, and smaller ones could gill in the 3-1/2" to 4" main body webb. A gilled fish is probably dead. Also, immature chinook are quite prone to de-scaling, and a purse seine is pretty abrasive to a fish trying to escape in the water or being brought aboard in the folds of the net as it passes upward to the power block.

There is substantial evidence that the majority of small, immature chinook are dead or badly injured from their capture by a purse seine. The Chinook Technical Committee of the Pacific Salmon Commission (PSC) has summarized much of this evidence (PSC, 1997). This Committee of U.S., Canadian and Tribal scientists has the responsibility of developing and applying a coast-wide chinook salmon fishery model that includes all harvest groups, escapements, natural mortality rates, and gear specific non-retention by-catch mortality rates. The model is used to balance out complex treaty (U.S. vs. Canada and U.S. vs. Tribes) allocation requirements and escapement needs.

I have reproduced in Appendix 1 their Table 14 which summarizes immediate mortality rates from many observations in the SE Alaska purse seine fishery. This fishery targets pinks, chum and sockeye salmon; chinook by-catch is only about 1% of the catch. So just like the Puget Sound chum situation, the SE Alaska chinook would be compacted in the seine or brailer with a large mass of target fish, and the crew would have to search through a big pile to find and release them. For all sizes of fish the several studies referenced by PSC (opcit), indicated that on average 49% were dead on landing. How about the delayed mortality? I have reproduced the PSC (opcit) Table 15 in my Appendix 1. This summarizes the results of three potentially relevant studies. The NRC (1994b) study had only four chinook which were held in a tank for just three hours. The Ruggerone and June (1996) study was for large, mature chinook captured at Hidden Falls, SE Alaska. The study given most credence by the PSC scientist was the one by Candy, et al (1995) who captured with purse seine and sonic tagged 47 chinook (>55 cm) and tracked them for 2-33 hours. Nine of them died or 23%. The Chinook Technical Committee thus recommended using a rate of 72% for total chinook non-retention mortality for all sizes of fish combined. They arrived at this by simply summing immediate mortality of 49% and delayed mortality of 23%. However, this simple summation is mathematically incorrect, due to theories of competing mortalities. The correct mathematics can be simply shown

by referring back to my previous example. Assume you catch 100 chinook of which 30 are dead, and then released the 70 live ones with say, sonic tags and found that 30 of these 70 died ($30 \div 70 = 40\%$) You should not add 30% + 40% = 70% to get by-catch mortality. Correct would be (30 + 30) $\div 100 = 60\%$, Thus, the correct estimate of the percentage of chinook by-catch by purse seines that are dead or die after release due to the stress of capture, should be 61% not 72%, from the PSC (opcit) data.

There are other observations that point to the relatively high immediate mortality of purse seine caught immature chinook. The PSC Chinook Technical Committee reviewed the studies of Nagtegael, et al (1988; 1990; 1993a,b, 1994) and concluded that for such studies "most small chinook boarded were dead or severely injured, but the condition of large chinook was much more variable". I asked Bill Patton who is the South Puget Sound Regional Fisheries Biologist with the NW Indian Fisheries Commission, and who kindly sent me the file of the Apple Cove Point test fishery catches, if they used recovery tanks for the chinook and coho caught incidentally to the chums. He'd been aboard these cruises since 2003. He answered that, no, most were dead anyway.

The Chinook Technical Committee in a later report (PSC, 2004) confirmed their early (1997) recommendations, but stated additionally that the WDFW was by then using a non-retention by-catch rate of 45% for immature chinook. No data were given for the WDFW's downward departure from the (erroneous) 72% of PSC, (1997) and PSC (2004). I surmised that WDFW may have been giving some credit to their set of regulations intended to decrease non-retention mortality, such as brailing large catches, restricting the hauling of salmon through the power block, sorting on deck with hatches closed, and using recovery tanks. I have requested information from WDFW on their rationale or evidence for use of specific non-retention mortality rates, but to date have not received such.

Purse Seine Non-retention By-catch Mortality Rate - Mature Coho

Because mature coho would be larger on average than immature chinook and therefore less likely to gill in the 5" or the smaller sized meshes, and would be less prone to de-scaling, I would not expect as high a rate of non-retention mortality as for immature chinook. Purse seine capture has been used for a long time for salmon tagging research. I worked on two studies like this early in my career. When tagging mature Bristol Bay sockeye as a graduate student, we could typically account for about 75% of the tags in the catch and escapement with the other 25% an apparent combination of delayed stress-from-capture mortality, non-reporting of tags from the fishery, and natural mortality. Similarly high survival of purse seine caught and tagged Puget Sound chums was apparent in a 1960's WDF study I worked on. But in such studies the bulk of the catch is the target. You wrap them up in the bunt and dip them one or a few at a time into a holding tank; dope them with something to slow them down, tag them; recover them in the tank, and release them. In the Puget Sound chum fishery the by-catch is about 2% of the catch, so there is

considerable compaction stress from the target mass. Also it may take some time to sort through the target catch and find the by-catch.

But there is other evidence that purse seine capture of mature coho could be pretty benign if done with care, such as the WDFW slowdown/recovery box regulations are intended to do. It has been found that coho stressed by commercial capture, as measured by physiological parameters, will recover pretty quickly in recovery boxes (Farrel, et al, 2001a; 2001b). Ashbrook, et al. (2007) had virtually 100% survival of mature coho caught and tagged with a small experimental purse seine in Willipa Harbor. A recent WDFW news release (Dec. 10, 2010) reported that test fishing on the Columbia River with purse seines as alternatives to gill nets took 10,800 chinook, 8,100 coho, and 2,100 steelhead with only 25 direct mortalities.

The best scientific evidence I could find for estimating the non-retention mortality of mature coho in purse seine fishing for Puget Sound chums was a 1997 study by the Department of Fisheries and Oceans of Canada (DFO). They've got a problem in B.C. with wild coho, which are going down hill. Their summertime purse seine and gill net fisheries targeting on abundant mid to late summer sockeye and pink salmon in Juan de Fuca and Johnstone Straits take coho as by-catch. Coho make up about 1% of the target catches, so here was an analogous situation with the by-catch problem in the Puget Sound chum fishery (and the SE Alaska chinook salmon by-catch) i.e. - masses of target fish to sort through to find what you need to release, hopefully unharmed.

The Nanaimo lab of the DFO, a highly respected research outfit, put a lot of trained observers aboard a lot of commercial purse seiners to see how many coho were being caught and to what extent they could be released unharmed. They made efforts to find out how factors like total catch of target species in a set or ocean conditions during the haul would effect the variability of coho non-retention mortality. Some of the purse seined coho were put into live tanks for mortality observations (Kelly and Hop Wu, 1998). These experiments are summarized in Table 6. They estimated that between what actually died and what was likely to die ("lethargic"), the direct mortality rates from capture were 24% and 29% for Juan de Fuca and Johnstone Straits, respectively. All these experimental fish were from sets with relatively small catches of target species and calm ocean conditions. They then jacked the mortality factors upward to reflect the fact that most seine catches would be in less benign circumstances (details were not clear from the report, but it made sense to do so) and estimated that for the entire fishery, the direct mortalities would be 25% and 38% for Juan de Fuca and Johnstone Straits, respectively. Finally, they had to fairly recognize two additional unknowns in all of this: (1) purse seiners at the time could voluntarily retain their coho, so some unknown number came aboard dead and were sold, and (2) maybe some capture-stress-related mortality continued after release. Their final recommended range of non-retention mortality rate for mature, purse seine caught coho was 20-50%, which I think fairly speaks to the uncertainty in all of this, plus the variability in expected value for any individual haul due to ocean conditions, size of target catch, diligence of the crew, etc.

By-catch of Immature Coho

These would be two-year-old "resident" coho averaging about 16" long during the Puget Sound chum season. I would not expect many to be caught. Virtually all would go through a 6-1/4" gill net and most through a 5" top strip on a purse seine. I mention them primarily in relation to an unexpected size anomaly from the 1996-1997 Apple Cove Point test fishery data set. The 361 coho caught (Table 4) had an average weight of 3.55 pounds, yet the all fishery average purse seine and gill net combined weight is 7-8 pounds – three year old coho. If the Apple Cove Point weight data are correct, there must have been a substantial fraction of two year-olds in the test catch, which could also have been mature jacks. I asked Bill Patton (NWIFC) about this and he said that he remembered seeing some very small coho in the 2011 Apple Cove Point test catches, which in his opinion were pretty bright, i.e. not jacks. I don't think incidental catch of "resident" two year old coho should be of concern. But I do think that the Apple Cove Point test catches of all species should be carefully observed and measured in the future in this regard.

By-catch of Steelhead

The steelhead by-catch is virtually non-existent. In a WDFW file of several thousand observations of purse seine and gill net sets over the period 2000-2011 there were only six observed steelhead during the fall chum season. This file is a conglomerate of on-board observations, interviews ("hailings"), and observations from another vessel. Any steelhead taken at that time would probably be early winter run fish, which are mostly hatchery fish.

Summary and Discussion

The number of coho caught per thousand chum salmon appears to be at least twice as high for purse seiners as for gill netters. This is apparently due to gill net selectivity for larger coho. Gill net caught coho averaged substantially larger than purse seine caught coho, indicating escapement of the smaller ones through the 6-1/4" minimum mesh. The higher coho by-catch rate for purse seiners can be mitigated to the degree that coho can be released with good survival. If only 50% survive which is the low end of the range according to substantial research by Canadian scientists (20%-50% for mortality), then the two gears would have approximately equal effects in terms of number of coho killed per unit of chums landed.

However, it is fair to assume that the mortality rate of the released coho can be substantially lower than 50% perhaps nearer the 20% end of the DFO estimated range, if several of the restrictions on care and handling of live caught coho are followed. These rules include: (1) brailing of large seine catches; (2) no fish allowed to go through the power block; (3) hatch covers closed during sorting on deck, and (4) proper use of recovery tanks. They may seem onerous to a gung-ho fisherman, and time consuming to enforce, particularly the on-deck aspects which would seem to require some on-board enforcement personnel. But, according to recent physiological research, live held fish will recover from exhaustion, and it has long been observed that mature salmon caught in experimental purse seining are mostly alive at capture and apparently in good shape when released.

The WDFW is serious about enforcing these purse seine handling procedures, giving tickets for infractions, which have held up in court, (Jeff June, Natural Resource Consultants, personnel communication). Therefore, these rules are not just window dressing.

What is needed to make this work best and convince fishermen to take the time needed, other than just giving tickets for not following the rules, is further on-board research with actively fishing seiners to show how well the fish can survive and how best to improve survival. Commercial fishermen and sport fishermen are alike in their desire to conserve salmonids as best they can. Catch-and-release fishing should work just as well here as with trout fishermen in a stream. In the latter case, a great deal of research went into measuring non-retention survival and determining how best to improve it.

The solution for immature chinook salmon in purse seines is not as clear as for mature coho. Immature chinook of all ages and sizes are prevalent in inland waters from Puget Sound to SE Alaska. Their size-abundance relationship is like a pyramid with the largest, least abundant on top. And the way nets work – gill nets or purse seine – the smaller the mesh the more chinook you will catch – and many by gilling. These will be dead. The scales of the immature fish are deciduous – they rub off against abrasive purse seine webb or when the fish are thrashing in a filled seine bunt or brailer. If an immature chinook loses a large percentage of its scales it still has to go through months or years of life, avoiding diseases and other problems against which the scales protect. A mature coho with a similar scale loss only has to make it for a few more weeks.

The by-catch rate of chinook salmon by purse seines is many times greater than that by gill netters, if the Apple Cove Point test catches are representative, as previous observations of purse seining in Puget Sound confirm.

It is noteworthy that the <u>smallest</u> chinook in the gillnet catches were 4 pounds, whereas the <u>average</u> in the 1996-1997 Apple Cove Point purse seine test catches was 3.5 pounds. Remembering the size-abundance pyramid, it is pretty convincing

that the 6-1/4" gill nets will, under just about any circumstance where the two gears fish together, take far less immature chinook than purse seiners, even with a 5" top strip, which was shown to be effective in partially reducing the small chinook catch. Most of the purse seine total by-catch mortalities are chinook that were dead or close to it when brought aboard. Live recovery boxes won't help too much.

Thinking about this caused me to speculate, why not a 6-1/4" top strip for purse seiners, to potentially equalize the escapement rate for small chinook between the two gears? Any seiner reading this will probably scream at this idea, because of the likelihood of substantial gilling of the chums and larger coho in the 6-1/4" mesh. What a mess this would be, but maybe it could work. A heavy, visible 6-1/4" top strip could lead the chums along it until the bunt was reached. Or maybe as one friend with long experience on commercial salmon and herring boats suggested (Tom Crawford, Ellensburg, WA), the chums would tend to dive in the net down to the depth of the 3-1/2"-4" net. I'll let those with more seining experience decide if this is worth anything. If it worked, it might eliminate the need for some of the other rules.

Let's put some of these perhaps intractable by-catch problems in broader perspective. Overall, even counting the potentially unavoidable issues like by-catch fish being dead in gill nets, or small chinook gilling and descaling in purse seines, the total by-catch of these two species in the chum fishery is only 1 or 2% of the target catch in numbers and less in weight. It is pretty clear that there are plenty of other industries that kill orders of magnitude more chinook and coho as by-catch of their products - hydro-electricity, farm products, forest products, mining products, etc. etc. Most Puget Sound fishing boats fish as well in Alaska, or for crab or something else. This industry supports thousands of jobs on the boats and processing plants. If you talked to any ten college graduate professionals who grew up in the Pacific Northwest you'd find at least one who put himself through college on a seine boat crew or working in an Alaska cannery – or he or she would certainly know some folks that worked in the industry. Let's hope that relatively minor by-catch issues like this don't take anymore from this, clean-green-sustainable industry than what has already been lost.

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Table 1. Chum salmon catches and licenses in non-Indian commedial purse seine and gill net fisheries of south Puget Sound and Hood Canal, 1973-2010

Year	Year Purse seine catch	Purse seine licenses	Gill net catch	Gillnet licenses	Total catch	PS catch/license	GN catch/license	•
	000's of fish		000's of tish		000's of fish	000's of fish	000's of fish	by purse seines
1973	33.4	320	59.8	1303	93.2	0.104	0.046	35.8
1974	13.3	137	2	1990	15.3	0.097	0.001	86.9
1975	3.5	385	æ	1659	6.5	600'0	0.002	53.8
1976	54.4	376	65,4	1536	119.8	0.145	0.043	45.4
1977	32	393	114.4	1517	146.4	0.081	0.075	21.9
1978	125.3	402	166.4	1532	291.7	0,312	0,109	43
1979	6.2	402	6.9	1501	13.1	0.015	0.005	47.3
1980	113.1	398	79	1487	192.1	0.284	0.053	58.9
1981	60,3	396	63.4	1450	123.7	0.152	0.044	48.7
1982	129.4	390	70.8	1420	200.2	0.332	0.05	64.6
1983	82.9	383	46.1	1374	129	0.216	0.034	64.3
1984	172.2	367	94	1259	266.2	0.469	0.075	64.7
1985	131	349	53.8	1196	184.8	0.375	0.045	70.9
1986	205.2	534	71.6	1200	276.8	0.384	90.0	74.1
1987	360.6	341	105.7	1148	466.3	1.057	0.092	77.3
1988	317.8	342	153,8	1142	471.6	0,929	0.135	67.4
1989	178.9	341	95.9	1152	274.8	0.525	0.083	65.1
1990	172.6	337	89.2	1148	261.8	0.512	0.078	62.9
1991	230.1	330	77.8	1132	307.9	0.697	0.069	74.7
1992	. 355.7	327	173.8	1118	529.5	1.088	0.155	67.2
1993	276.8	318	125.2	1083	402	0.87	0.116	689
1994	322.5	306	64.5	1042	387	1.054	0.062	83.3
1995	233.4	297	55.2	996	288.6	0.786	0.057	80.9
1996	416	292	74.3	887	490.3	1.425	0.084	84.8
1997	190.3	290	19.5	872	209.8	0.656	0.022	90.7
1998	362.1	276	25	820	414.1	1.312	0.063	87.4
1999	71.7	262	18.8	682	90.5	0.274	0.028	79.2
2000	104.6	262	19.3	629	123.9	0.399	0.028	84.4
2001	630.7	. 122	48.5	329	679.2	5.17	0.135	92.9
2002	758.9	\$	29.5	215	788.4	9.035	0.137	96.3
2003	654.6	83	29	208	713.6	7.887	0.284	91.7
2004	933.3	81	113.8	204	1047.1	11.522	0.558	89.1
2002	223.8	81	94.9	202	318.7	2.763	0.47	70.2
2006	579.7	75	116.2	198	635.9	7.729	0.587	83.3
2007	428.4	75	169.9	198	598.3	5.712	0.858	71.6
2008	283.4	75	92,4	196	375.8	3.779	0.471	75.4
2009	199.4	7.5	78.7	196	278.1	2.659	0.402	71.7
2010	306.3	75	98.1	195	404.4	4.084	0.503	75.7
2011	317	75	84.7	195	401.7	4.227	0.434	78,9

Data source: Concise Explanatory Statement Puget Sound Commercial Salmon Regulations for 2011 pursuant to Rule-making Order CR-103P, WDFW

Table 2. Average round weights of coho salmon by purse seines and gill nets in inner Puget Sound and Hood Canal, 1996-2010

PS GN

Areas 10,11 5.63 lbs.* 8.22 lbs.

Area 12 7.59 lbs. 8.62 lbs

Data source: WDFW fish tickets that give catch in numbers and total pounds

^{*} May not be representative for the entire period since purse seine non-retention from 2002

Table 3. Non-Indian purse seine (PS) and gill net (GN) reported catches in number of chum, coho, and chinook salmon taken in Puget Sound areas 10,11, and 12, during Oct. and Nov. (chum season), 1996-2011

	GN chinook	2	æ	0	ന	0	0	0	0	0	m	0	7	0	0	0	0
	GN coho G	26	0	∞	9	14	8	6	82	256	332	97	517	125	482	152	431
	GN chum	33027	13238	17173	2986	6486	15555	2068	21777	29784	37548	29110	71602	50211	50651	39216	44395
Area 12	PS chinook	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
∢	PS coho	36	249	913	84	9	929	6	2644	11505	2547	923	3296	9	2820	10	1959
	PS chum	244652	176042	167865	25295	16901	187663	227125	278356	523272	62388	286284	150066	149786	93105	136173	156232
	N chinook	19	2	12	1	œ	2	0	1	80	7	2	1	15	2	4	4
	GN coho GN chinook	32	7	0	0	22	56	6	384	1517	732	201	337	26	106	51	104
	GN chum	29809	3270	29361	8726	12841	32950	26730	37266	73628	49758	87050	95880	28398	24239	54100	40300
4reas 10&11	PS chinook	4	Ħ	0	*0	**0	0	0	***0	0	0	0	0	0	0	0	0
	PS coho	244	154	09	0	0	547	6	0	9	0	10	40	0	0	0	11
	PS chum	154183	9291	165607	45891	87207	413303	472330	244829	401122	148892	255065	213553	99525	86488	155447	160782
Year		1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011

*The data list one chinook landing of 246 fish at 2219 pounds; probably an error and should be chum

The data list one cinook landing of 22 fish at 275 pounds; probably an error and should be chum *The data list one chinook landing of 92 fish at 790 pounds; probably an error and should be chum

Data sources:

1996-2010; WDFW electronic data file of fish ticket non-Indian PS & GN catches furnished by WDFW 12/12/2011 2011; Prelimonary Puget Sound salmon catch data generated from the Quick Reporting System on 12/5/2011

Table 4. Numbers of chum, chinook, and coho salmon in the Apple Cove Point purse seine test fishery, 1996-2011

Coho per 1000 chums	62.03	138.61	16.24	6.19	23.28	15.44	14.81	40.39	31.19	31.63	8.32	21.09	17.79	15.89	9.54	11.44	;	21.75
Chinook per 1000 chums 1	39.08	6.6	8.12	71.92	48.59	2.32	5.62	3.65	17.11	4.96	9.17	17.29	7.37	4.44	1.55	1.76	1	10.65
Coho/set	6.79	1.91	4.37	0.31	3.22	11.03	6.29	12.21	12.86	6.38	3.34	3.57	1.94	1.94	2.22	1.3	1	5.09
Chinook/set	4.28	0.14	2.18	3.58	6.72	1.66	2.39	1.1	7.06	Н	3.69	2.93	0.8	0.54	98'0	1.3	:	2.49
Total	319	42	118	œ	103	320	195	354	463	217	97	100	2	89	8	39	2593	
Total chinook	201	ന	59	93	215	48	74	32	254	34	107	82	29	19	13	9	1269	
Total chums	5143	303	7266	1293	4425	20719	13161	8764	14844	. 0989	11665	4742	3934	4280	8385	3409	119193	
No. of sets	47	22	27	26	32	29	31	29	36	34	29	28	36	35	36	30	509	
Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total	Wgt. Ave.

Data sources:

1996-1997, WDFW fish tickets where catches were categorized as TEST 1998-2011, data file furnished by Bill patton, Northwest Indian Fisheries Commission

Table 5. Average round weights (lbs.) of chum salmon in Inner Puget Sopund and Hood Canal, 1996-2010, by gear

Year	PS	GN
1996	8	8.43
1997	10.06	9.95
1998	8.89	8.88
1999	9.32	9.59
2000	9.99	9.96
2001	8.53	8.76
2002	9.48	9.5
2003	8.82	8.77
2004	8.44	8.73
2005	9.74	9.51
2006	9.28	9.11
2007	9.27	9.17
2008	9.39	9.12
2009	8.52	8.57
2010	8.45	8.51

Data source: WDFW fish tickets which give numbers caught and total weight of catch

Table 6. 1997 holding mortality results for mature coho caught by commercial purse seines in Juan de Fuca and Johnstone Straits (from Kelly and Hop Wu, 1998)

	No. placed alive in holding tanks	Average holding time, hrs	No. dead before release	No. lethargic at release	Estimated short term mortality %	Estimated total mortality
Juan de Fuca Strait	374	1.14	98	4	24%	25%
Johnstone Strait	164	1.06	23	25	79%	38%

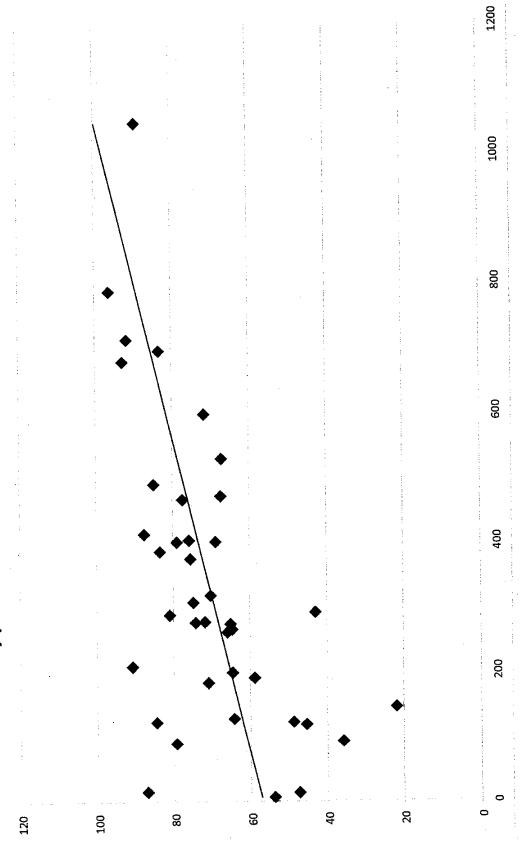
Table 7. Summary of chinook and coho by-catch rate estimates for purse seines and gill nets in inner Puget Sound and Hood Canal, in average number per one thousand chums

	PS	N B
Area 12 coho for all years but PS non- retention years 2002, 2008 and 2010, from fish tickets	11.69	6.02
Areas 10 and 11 coho for PS retention years 1996, 1997,1998 and 2001, from fish tickets	1.35	0.99
Areas 10 and 11 coho for PS non-retention years 2002-2011, from fish tickets		6.7
Areas 10 and 11 coho for PS non- renetion years 2002-2011, from Apple Cove Point Test sets	21.75	
Area 12 chinook for years 1996-2011, from fish tickets		0.03
Areas 10 and 11 chniook for years 1996-2011, from fish tickets		0.14
Areas 10 and 11 chinook for years 1996-2011, from Apple Cove Point Test sets	10.65	

Figure 1. Puget sound chum salmon catch by non-Indian gears over **(**> **⋄** ⋄ **(**> time, 1973-2011 Q. **(**> <> <>'

Figure 2. Percentage of non-Indian Puget Sound chum salmon catch taken by purse seiners, plotted against year

Figure 3. Percentage of non-Indian Puget Sound chum salmon catch taken by purse seiners, plotted against thousands of fish caught



Apendix 1. Tables 14 and 15 of Pacific Salmon Commision (1997) report on chinook salmon fishing mortality rates

Table 14. Number and percentage of chinook salmon dead at landing by purse seiners during non-retention periods for chinook salmon in Southeast Alaska. Chinook salmon were categorized by three size ranges (total length): small, ≤ 21 in (53 cm); medium, > 21 (53 cm) but < 28 in (71 cm); and large, ≥ 28 in (71 cm).

21 (32) VIII) VIII - 20 III (11 VIII), min		0.0						(7
		Š	Small	Medium	ium	Ľ	Large	Com	Combined
Study	Year	Landed	Landed % Dead	Landed	% Dead	Landed % Dead	% Dead	Landed % Dead	% Dead
Van Alen and Seibel (1986) 1985	1985	295	50.2	37	18.9	157	6.1	489	32.3
Van Alen and Seibel (1987)	9861	19	63.9	20	70.0	47	57.4	128	62.5
Rowse and Marshall (1989) 1987	1987	807	1.69	352	84.9	268	35.1	1,427	8.89
Rowse (1990)	1988	217	8.73	632	28.0	1,551	17.6	2,898	32.3
Annual Average			62.8		50.5		28.0		49.0

Table 15. Summary of results from studies conducted to estimate catch-and-release mortality of chinook salmon from purse seine

vessels.						
	Hours					
	Held or	Sample	Sample Number Number Mortality	Number	Mortanty	
Study	Tracked	Size	Survived	Died	(%)	Comments
NRC (1994b)	3.2	4	4	0	0	Held in live tank aboard seiner. Puget
						Sound.
Ruggerone and June (1996)	50	91	06		1.1	Transferred in shipboard tank and held in
						net pen. SE Alaska.
Candy of al (1996)	2-33	47	38	6	19.2	Tracked with ultrasonic telemetry.
Canaly of all (1999)) 				(23.0)	Johnstone Strait, B. C. Number in
					,	parantheses is adjusted 24-hr mortality,
						as reported by Candy et al. (1996).

RESUME OF STEPHEN B. MATHEWS - MARCH, 2012

The following summary of education and experience is offered as qualifying expertise for the report "Salmonid By-Catch in Targeted Chum Salmon Fisheries of Puget Sound".

- 1. Ph.D in Fishery Science from the University of Washington School of Fisheries (UWSOF); degree received, 1967.
- 2. Five years experience as a biometrician (i.e., biological statistician) with the Washington Department of Fisheries, 1967-1971.
- 3. Twenty five years as a Professor at the UWSOF teaching and conducting research on quantitative fisheries management of salmon and other Pacific Coast species of economic importance, 1972-1997. Currently retired Professor Emeritus.
- 4. Two years experience as a scientific consultant to a private, non-profit salmon conservation group (Long-Live-the-Kings), 1998-1999.
- 5. Author of 40 peer-reviewed scientific journal articles and 100 other gray literature reports and publications, primarily on Pacific Coast and Alaska fishery management issues and problems.
- 6. Considerable hands-on field research employing several types of research-scaled fishing gear types, including gill nets, purse seines, beach seines, long lines (multiple hook and line), traps, and electro-fishing.
- 7. Four years serving on the Statistical Committee of the Pacific Salmon Commission during the formative phase of the treaty, 1989-1992. This committee of U.S. and Canadian scientists was responsible for developing mutually acceptable protocols for collection and statistical analysis of data pertaining to abundance, migration, and exploitation of salmon stocks shared by the two countries.