Estimating the Size of Historical Oregon Salmon Runs

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Abstract

Increasing the abundance of salmon in Oregon's rivers and streams is a high priority public policy objective. Salmon runs have been reduced from pre-development conditions (typically defined as prior to 1850), but it is unclear by how much. Considerable public and private resources have been devoted to restoring salmon runs, but it is uncertain what the current recovery potential is because much of the freshwater and estuarine habitat for salmon has been altered and there is no expectation that it will be returned to a pre-development condition. The goals of all salmon recovery efforts are based on assumptions about the size of the runs prior to significant habitat alteration, coupled with an estimate of the amount and quality of freshwater and estuarine habitat currently available. We estimated the historical aggregate salmon run size in rivers along the Oregon coast (excluding the Columbia River) using two methods: (1) Converting estimated aboriginal population levels into numbers of salmon; (2) Extrapolating cannery pack into numbers of salmon. Annual aboriginal harvest of all salmon species is estimated to have been approximately 10 million pounds per year (4,500,000 kg) or 1.75-5.36 million salmon, a harvest level similar to that occurring during the height of commercial fishing on Oregon's coastal rivers in the late 1800s and early 1900s. Extrapolating cannery pack data, the estimated size of the late 1800s aggregate runs of coho salmon (*Oncorhynchus kisutch*) was 1.5-2.5 million. The estimated size of aggregate runs of chinook salmon (*Oncorhynchus tshawytscha*) runs was 290,000-517,000. Compared to our estimates of mid-1800s coho salmon levels, early 2000 runs (during favorable ocean conditions), were 11-19% of the historical level. During poor ocean conditions (1990s), current coho salmon runs were 3-6% of the historical size.

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[1]*The views and opinions presented are those of the authors and do not necessarily represent those of any organization.*

Introduction

Naturally spawning populations of coho salmon (*Oncorhynchus kisutch*) on the Oregon coast were listed under the U.S. Endangered Species Act (ESA) on August 10, 1998. Court and policy arguments over the legality of this listing continue, but this, and other ESA salmon listings in the western United States have already cost billions of dollars with mixed results in recovering wild salmon (Lewallen and Brooks, 2002).

One of the policy and technical challenges in salmon recovery is establishing realistic goals for run size. In other words, what level of recovery should society realistically expect for a given set of actions and expenditures? Scientists have yet to either reliably determine the number of salmon the Oregon coastal watersheds can currently support without supplementation from hatcheries or what type of habitat improvement would be the most effective in increasing recovery potential.

To calculate the maximum current recovery potential, it is essential to estimate how many salmon the Oregon coastal streams supported prior to significant habitat alteration (~1850), and then adjust this estimate to reflect the habitat currently available. Oregon's coastal watersheds considered in this study encompass the area of the coast south of the Columbia River and extend to the California border (Figure 1). The Columbia River and its tributaries are not included.

Insert Figure 1 (Map) Near Here

We used a four step process to estimate recovery potential for Oregon coastal rivers. First, historical salmon run size was reconstructed by analyzing anthropological research that estimated the extent of salmon consumption by aboriginal inhabitants of the Oregon coast. Salmon abundance has been shown to be a good predictor of aboriginal populations (Baunhoff, 1963; Sneed, 1972; Donald and Mitchell, 1975; Hunn, 1982). With an estimate of the size of the aboriginal population, coupled with likely aboriginal salmon consumption and harvest rates, a rough estimate of the size of the salmon runs can be calculated.

Second, historical runs were also reconstructed by analyzing early (1800s) written records and Oregon's coastal salmon cannery pack. Cannery records are the longest continuous record of salmon harvest on the Oregon Coast. Using cannery data, it is possible to extrapolate salmon runs by converting the salmon cannery pack to numbers of salmon and then applying a catch-efficiency rate. Mullen (1981b) and Lichatowich (1989) have estimated historical run size along the Oregon coast by using cannery pack; however, we modified some of their procedures and correction factors to reflect more recent research results.

Third, the overall changes in coastal salmon habitat from the mid-1800s to the present were estimated. Habitat alteration on the Oregon coast and elsewhere has potentially reduced the quantity and quality of salmon habitat a great deal. Because available freshwater and estuarine habitat likely constrains the long-term abundance of wild salmon, it is essential to determine the quantity of habitat that is currently available.

Fourth, using results from the first three steps, the maximum realistic recovery potential of wild salmon for the Oregon coast was estimated by adjusting historical estimates of abundance to reflect current habitat conditions. Such an estimate of recovery potential provides an approximate upper limit on long-term sustainable runs.

Estimated Aboriginal Population Levels

For the last 10,000 years aboriginal peoples have populated the entire U.S. and Canadian Pacific Northwest coastal area (the coastal area from Alaska to California) (Cressman, 1977). In 1774, as many as 200,000 aboriginal peoples lived in the region, making it one of the most densely populated nonagricultural areas in the world. These coastal inhabitants were hunters and gatherers who specialized in harvesting salmon. Along the Pacific Northwest coast, the abundant salmon runs allowed aboriginal human populations to prosper (Boyd, 1990). Not only were salmon abundant, they were also seasonally predictable and could be dried for storage and easy transport. Aboriginals could return to a particular site at a known time of the year and capture large quantities of fish. Overlapping runs, coupled with salmon curing for storing, provided coastal aboriginals with a nearly year-round supply of animal protein (Schalk, 1986).

Because of their close nutritional tie to salmon (and therefore salmon runs loosely regulated aboriginal population size), it is possible to roughly extrapolate salmon run size using the estimated aboriginal population size and likely consumption rate. The extent of aboriginal dependence on salmon is well documented (Craig and Hacker, 1940).

Extent of Salmon Harvest

Aboriginal harvest of salmon was comparable to the harvest rates of the industrial fishery at its peak from 1883 to 1919 on the Columbia River and in California's Central Valley (Craig and Hacker, 1940; Yoshiyama, 1999). Effective gear and techniques were used to achieve high catch levels. The most prolific harvest sites usually included a riffle or waterfall, places where salmon tended to congregate. From natural rock ledges or wood platforms over the stream, they were able to spear, harpoon, or net salmon in large numbers. Aboriginals would return to productive sites year after year, generation after generation (Barnett, 1937; Hewes, 1973).

In areas of slow water, such as estuaries, aboriginals used gillnets, seines, and weirs. They also created impenetrable barriers on smaller streams, and occasionally used poisons to capture salmon (Barnett, 1937). Aboriginal fishing techniques were comparable to modern commercial fishing practices and, arguably, could have been even more efficient (Hewes, 1973). Because aboriginal technology was effective, it likely permitted more fish to be caught than were actually needed (Craig and Hacker, 1940).

In hunting and gathering societies, human population levels are usually constrained roughly by food resources during the "lean season" (Baunhoff, 1963). Thus, the size of salmon runs probably constrained the size of the aboriginal population along the Oregon coast. Consistent with this hypothesis, historical records show that famine occurred periodically during early spring immediately before the first salmon of the season were caught (Smith, 1983). In other areas where large salmon runs have occurred (e.g., the lower Klamath and Fraser rivers and the coastal rivers of southern British Columbia), salmon productivity has been shown to be a good predictor of aboriginal population level (Baunhoff, 1963; Sneed, 1972; Donald and Mitchell, 1975; Hunn 1982).

Aboriginal Salmon Consumption Rate

Until the 1930s, most analysts estimated that the aboriginal population in the Columbia River basin was 50,000. Using such an estimate, Craig and Hacker (1940) assumed that aboriginals each consumed one pound (.45 kg) of salmon per day, and subsequently calculated that aboriginals in the Columbia River basin harvested 18,000,000 pounds (8,100,000 kg) of salmon per year. Swindell (1942) suggested that Oregon coastal aboriginal populations may have been even more dependent on salmon, and most likely consumed more than one pound per day (the consumption rate is currently being debated, the outcome will increase or decease the total number of salmon harvested by aboriginals on the Oregon coast). Hewes (1973) used revised population estimates for the Columbia River basin of 61,500, recalculated aboriginal harvest to include fish that were wasted, and estimated the historical Columbia River catch to be 22,274,500 pounds (10,023,525 kg) and the Oregon coastal catch to be 5,600,000 pounds (2,520,000 kg).

Using newer and more refined archaeological, ethnohistoric, and ethnographic data, Schalk (1986) estimated aboriginal harvest to be 41,754,800 pounds (18,789,660 kg) for the Columbia River, an estimate that puts aboriginal harvest in the same range as the modern commercial harvest at its height (Craig and Hacker, 1940).

Calculating Salmon Run Size

We followed the general analytical approach used by Schalk (1986) to estimate historical salmon run sizes for the Columbia River. The first step is to determine how many pounds of salmon individual aboriginals likely consumed per year. The second step is to adjust upward the estimated individual consumption rate for the fact that salmon lose calories as they make their way upriver on their spawning migration (Hunn, 1981). The "caloric loss factor" is computed as a ratio of the distance from the mouth of the individual river to the middle of each tribe's territory to the entire length of that river. This ratio is then multiplied by the average value for calorie loss during salmon migration, 0.75, and the product is subtracted from one.

The third step involves dividing the per capita consumption estimate by a waste loss factor of 0.8 which yields an estimate of the weight of the fish utilized by aboriginal people (Table 1). Hunn (1982) suggested that 80% of the total salmon was edible.

Insert Table 1 Near Here

To convert the weight of fish consumed into numbers of fish consumed, an average size needs to be estimated. We assumed that the aboriginal catch had the same species proportions as the commercial catch from 1880 to 1920. The Northwest Power Planning Council (NWPPC) (1986) determined that an average weight for all of the species of salmon for the Columbia River was 6.62-9.27 pounds (2.98-4.17 kg). Using NWPPC (1986) estimates to convert the total catch in pounds to numbers of individual salmon caught, we estimate that aboriginals harvested between 1-1.5 million salmon from Oregon's coastal rivers.

To estimate the total historical run size from estimated catch, Craig and Hacker (1940) assumed that the aboriginal population harvested 28-57% of a run (depending on the run size). Using Craig and Hacker's harvest rates, we estimate the total salmon run along the Oregon coast was 1.75-5.36 million.

Decline of Aboriginal Populations

The rate at which aboriginal populations declined and Euro-American populations moved into the Pacific Northwest was dramatic. By 1900, the aboriginal population in Oregon had decreased by 95%, while the immigrant population increased from less than 800 in 1840 to more than 1.1 million in 1900. Overall, from 1774 to 1900 the aboriginal population along the Northwest coast dropped from 200,000 to 10,000, largely as a result of introduced infectious diseases (Boyd, 1985, 1990). As aboriginal populations declined throughout the mid-1800s, Euro-American populations were increasing (Figure 2).

Insert Figure 2 (human populations) Near Here

The precipitous decline in the aboriginal population likely affected the size of salmon runs. Salmon runs may have been larger in the 1850s than just about any other time in post-glacial history because the aboriginals were no longer harvesting large quantities of fish (Craig and Hacker, 1940; Hewes, 1947). Another hypotheses, however, is that salmon runs would briefly increase, but then fall to a new equilibrium due to the increased intraspecific competition on the spawning grounds (Van Hyning, 1973; Chapman et al. 1982).

Changing Oregon Landscape of the 1800s

Both aboriginals and early Euro-Americans relied on natural resources for their existence. Euro-Americans, however, exported natural resources much more aggressively, especially furs, salmon, wheat, and logs. The fur trade was probably the first Euro-American influence on salmon abundance. Traders eliminated many of the once substantial beaver populations, which reduced the structural diversity of streams, which decreased the quantity and quality of habitat for juvenile salmon.

Overall however, the anthropogenic effects on salmon in coastal Oregon were, not obvious until 1851 when prospectors discovered gold in the Illinois River. Soon, mining towns developed throughout southern Oregon (Dicken and Dicken, 1979). The effects of mining on salmon were often substantial and widespread.

Placer mining, the earliest type of gold mining, consisted of excavating large quantities of sand and sediment by hand, then panning by hand. This type of mining probably only had minimal impacts on salmon and most effects were local. In 1856, hydraulic mining began in Oregon. This type of mining was much more devastating to salmon (Dicken and Dicken, 1979). Gravity fed ditches diverted large quantities of water into pipes that supplied miners with pressurized water. Miners then used the pressurized water to blast away gold bearing hillsides to wash excess sediment into streams and rivers. Entire hillsides were washed into streams, suffocating adult salmon and smothering redds. For example, early mining dumped enough material into the Rogue River that the entire river turned reddish-yellow (Ward, 1938). Mercury and other chemicals leached from gold mines drastically changed water quality. Diversion dams, built for collecting water to support hydraulic mining, often blocked the passage of spawning salmon. Massive numbers of juvenile salmon were killed as they were sucked into the intake pipes that supplied the water cannons. During the summer months diversions often severely reduced river levels. Because of the geology of Oregon, most mining took place in southwestern and eastern Oregon.

The rapid rise of Oregon's population in response to the discovery of gold stimulated demand for agricultural products, which in turn lowered affected salmon runs. For example, farming started in the Tillamook River basin in the 1850s and 1860s (Swift, 1909). To keep up with the rising demand for agricultural products, farmers converted unplowed land into agricultural land in the lower reaches of many Oregon coastal watersheds.

Logging also affected salmon runs by altering salmon habitat. Early logging activities were focused around the Willamette Valley and the lower Columbia, Tillamook, Yaquina, Coos, and Umpqua river basins. As early as 1863, three sawmills opened near Tillamook Bay (Levesque, 1985). In Coos Bay, by 1872, 16 vessels arrived for lumber each week (Dicken and Dicken, 1979). Initially, loggers would harvest trees in easily accessible areas, often not more than a mile from river transport (Holbrock, 1956). As a consequence, riparian zones were the first areas to be harvested. Reducing streamside cover often elevated water temperature, eroded banks, and increased sediment loads (Chapman, 1962).

Transporting logs also adversely affected salmon. During the mid-1880s, 11 Western Oregon streams had logjams from 100 to 1500 feet (30-450 meters) in length, often making it very difficult or impossible for adult salmon to pass. In smaller streams and rivers, splash dams were a common practice starting in the early 1870s. They would let the water build up behind the dams until there was enough to flush the logs down to the mills, at times almost completely blocking the water flow. By 1910, there were 160 splash dams on coastal rivers and lower Columbia River tributaries in Oregon (Sedell and Luchessa, 1982).

Splash dams not only obstructed stream flow, they also damaged salmon habitat when breached. The high-stream flows eroded banks and filled in deep pools, which might have been the last refuge for juvenile salmon given the low water levels (Chapman, 1962; Sedell and Luchessa, 1982). Sawmills also dumped tons of sawdust into streams and bays, further smothering fish, redds, and other aquatic life (Chapman, 1962). By the 1860s, prior to the construction of the first salmon canneries on the Oregon coast, trappers, farmers, irrigators, and loggers had already significantly altered the spawning and rearing habitat of salmon along Oregon's coast (Craig and Hacker, 1940).

Development of Oregon Salmon Canneries

Pacific Northwest aboriginal peoples traded salmon with visiting ships as early as 1792 (Howay, 1990). Trade became more substantial in the early 1800s when permanent forts were established in Oregon (Merk, 1968). In 1823, the Hudsons Bay Company started developing additional markets for salmon, and in 1824, tried sending barrels of salted salmon to London, but they spoiled during the long trips (Merk, 1968). This small-scale salting practice continued until 1865 when Andrew Hapgood along with William, George, and R.D. Hume established the first cannery on the Columbia at Eagle Point (Deloach, 1939; Smith, 1979).

By the late 1870s, Columbia River salmon runs had decreased. In 1876, R.D. Hume started building a cannery on the Rogue River after hearing rumors of large salmon runs. His brother, George W. Hume, also saw potential on the Oregon coast and built a cannery on the Umpqua River in 1878. By 1887, there were canneries on the Nehalem River, Tillamook Bay, Nestucca River, Yaquina Bay, Alsea Bay, Siuslaw River, Coos Bay, Rogue River, Umpqua River, and Coquille River. In 1896, a cannery was opened on the Siletz River making it the 11^{th} river basin to have a cannery on the Oregon coast.

In 1877, R.D. Hume's cannery on the Rogue River processed less than 8,000 cases of salmon. Just 10 years later, when 14 canneries were running on the Oregon coast, the pack was over 70,000 cases. From 1888 to 1920, the salmon pack fluctuated greatly from approximately 25,000 cases in 1891 to nearly 140,000 cases in 1911 (Cobb, 1930). The large variation appears to be caused by natural as well as anthropogenic factors (Dodds 1959).

In 1930, Cobb summarized cannery production for the Oregon coast dating back to 1877 and created the longest continuous record of salmon abundance on the Oregon coast. Using this data, several scientists have estimated past salmon runs for the Columbia River basin and the Oregon coast (Mullen, 1981a; Chapman, 1986; Lichatowich, 1989; Gresh et al., 2000). Although each used slightly different methods, each employed three common components to estimate the historical run size:

(1) Convert salmon pack data from cases of salmon to numbers of salmon;

(2) Select a time period to represent typical run size. For example, Chapman used the five consecutive years that yielded the highest average, whereas Lichatowich used the highest yielding years and averaged them; and

(3) Estimate what fraction of the total run was caught and canned by applying a catch efficiency rate.

Analysis of Cannery Data

Not all of an individual salmon was canned; the head, fins, and organs were discarded or processed in a different manner. To account for this unpacked part of the catch, Craig and Hacker (1940) and Mullen (1981a) converted each 48 pound (21.6 kg) case of salmon to 68 pounds (30.6 kg) of total salmon biomass. Thus, by multiplying the number of cases packed by 68, it is possible to convert cases of salmon into pounds of salmon caught.

To determine the number of salmon, an average weight must be assumed. Depending on the assumed weight for an individual salmon, there will be dramatically different estimates. Chapman (1982) used estimates of 22.99 pounds (10.35 kg) for chinook and 6.99 pounds (3.15 kg) for coho. Lichatowich (1989) used Bigler et al.'s (1996) estimates of 19.8 pounds (8.91 kg) for chinook and 9.9 pounds (4.46 kg) for coho. We used Mullen's (1981a) estimate of 10.49 pounds (4.72 kg) for coho, and Craig and Hacker's (1940) estimate of 23.25 pounds (10.46 kg) for chinook, because they were working with Oregon coastal runs.

Cannery data must also be adjusted for waste. Often more fish were caught than could be canned. Further, with limited cooling technology, captured salmon often spoiled and had to be discarded prior to canning. Gresh at el.(2000) assumed the waste of uncanned fish was 25% of the cannery pack for the entire Pacific Northwest (Gresh et al., 2000), but waste in cannery operations was not evenly distributed throughout the Pacific Northwest. It typically increased when salmon prices were low and when multiple canneries were located on a river system. Fisherman would often catch salmon, then save only the size and species that would yield the best price at the canneries. When competition was high between canneries, salmon would be caught, killed, and discarded trying to prevent other canneries from reaching their quota (Marchak, 1988). This type of fierce competition was not as prevalent on the Oregon coast as it was on the Columbia River and other locations in the Pacific Northwest where numerous canneries were located on one river system. Individual river systems on the Oregon Coast often only had one cannery in operation at a time.

Some cannery operators on the Oregon coast made the connection between their own long-term viability and the need to allow at least some salmon to spawn (Dodds, 1959). Also, because of stricter regulations on the Oregon coast during the late 1800s, we used a waste estimate that is less than half of Gresh's et al.(2000) waste estimate (10% vs. 25%) for the entire Pacific Northwest.

Cannery data must also be adjusted for those salmon caught and sold without being canned. Salmon that were harvested were often sold fresh, salted, smoked, and pickled, and were not accounted for in the cannery pack. In 1901, 94% of the total Oregon coastal catch was canned, but by 1923 only 32% of the salmon harvested were being canned (Mullen, 1981b). Reliable records were not kept for all of the years in between so an exact correction factor cannot be calculated. As Oregon coastal fisheries developed, however, a greater percentage of the harvest was sold fresh (Gharrett and Hodges, 1950). We assumed that 10% of the catch was processed in ways other than canning.

The final correction factor that must be made to Cobb's (1930) data set is to account for all of the other rivers and lakes on the Oregon coast that were not included in the original data set. The bay and river systems that had canneries, and therefore were included in Cobb's data set, were the Nehalem River, Tillamook Bay, Nestucca River, Yaquina Bay, Alsea Bay, Siuslaw River, Coos Bay, Rogue River, Umpqua River, Siletz River, and Coquille River. Cobb states that fish caught in the Chetco and Windchuck rivers were either pickled or sold to the California canneries, therefore, fish from these systems did not show up in Oregon's cannery records. The Necanicum River, being only 10 miles south of the Columbia River, most likely showed up in the Columbia River pack, and not the coastal rivers' pack (Cobb, 1930). Cobb only mentions two other rivers in his data set, the Sixes and the Elk rivers. Fish caught in these two systems were either salted or sold to canneries on the Coquille River (Cobb, 1930).

Fish were being brought from other rivers to the 11 cannery rivers, however this exchange was most likely very small until 1915 when non-motorized vessels were being converted into gas engines (Smith, 1979), and until roads and railroads were built to connect coastal communities (Cobb, 1930). Before 1920, the cannery pack probably closely reflected the actual catches for the river system that the canneries were located on (Mullen, 1981a). To minimize the influence of outside systems, we only used Cobb's (1930) case pack until 1915.

Many of the rivers without canneries were extremely productive, and must be accounted for in Oregon's coastal salmon populations as a whole. According to Chenoweth (1972), "With the coming of the railroad to Tenmile Lake, Columbia River gill-netters used to ship their boats by train to Tenmile Lake and it is said in November 1920 these boats caught 500 tons (or 95,000 fish) of salmon."

The Oregon Department of Fish and Wildlife has compiled estimates of salmon stock size on Tenmile Lake since 1955. In 1955, they estimated that 41,500 adults and 36,000 jacks spawned in the Tenmile Lake area. This does not include lake or ocean harvest, nor does it take into account years of over-harvest and habitat alteration. Tenmile, Talkenitch, and Siltcoos lakes were all extremely productive coho salmon lakes in the 1950s even though lake habitat had already been significantly altered (Al Magie, personal communication, 2003).

Using estimates (from Oregon Department of Fish and Wildlife field surveys) of coho salmon spawning miles, we partitioned the Oregon coast into rivers with and without canneries. The river systems with canneries accounted for 4,814 coho spawning miles (7,751 km); those without canneries accounted for 588 spawning miles (947 km). We then extrapolated to obtain an estimate of the percent of miles of coho spawning habitat that were not included in the cannery records. We estimate 10.9% of the overall coho spawning habitat was not being accounted for in the cannery records.

Using the various correction factors described above, we used Cobb's (1930) cannery pack to calculate the number of fish harvested. Mullen's (1981a) estimates were taken at five year intervals. Chapman (1982) used the average harvest for the five consecutive years that yielded the highest combined harvest. Five year averaging minimizes the effects of unusually good or bad years skewing the results. Conversely, Lichatowich (1989) used the peak catch years rather than five consecutive years to avoid including years when the catch may have been reduced by market conditions (Johnson, 1983). We used both methods.

Individual canneries did not always report their harvest for a certain year. For example, in 1911, the largest coho run reported in Cobb's records was missing all of the data for the Rogue River (Cobb, 1930). To adjust for the missing years, we used a third method, one similar to that used by Lichatowich (1989). Missing years probably represent large catches, therefore we averaged the five largest peak catch years for each river system which had data, calculated an average, and then substituted this average value for the missing data which allowed us to estimate the average pack for that year.

Estimating Harvest Rates

Harvest rates of salmon in Oregon's coastal rivers were not measured until the 1950s. Tag and recapture methods were used in the Alsea River, Tillamook Bay, Nehalem River, and Siletz River. The estimated harvest rates in 1954 ranged from 12-32% (Cleaver, 1951; Willis, 1954; Henry, 1955, 1964). Based on the above harvest statistics, Mullen (1981b) and Lichatowich (1989) estimated an average harvest rate of 40% because fishing was more severely restricted during the 1950s. In Chapman's (1986) salmon study on the Columbia River, he used the optimal harvest rate of 67% for pre-development production of salmon on the Columbia River. This higher harvest rate for the Columbia River is justified because there was far less fishing pressure on the Oregon coast during the late 1800s. By the time the fishery was well established in coastal watersheds, strict laws limiting harvest were already in place. In 1880, the Columbia had 29 canneries employing 4,000 people, and the Oregon coastal rivers only had two canneries employing 95 people. By 1900, the Oregon coast was a productive fishery; however restrictions had long been limiting the harvest rate. As early as 1878, a law was enacted prohibiting commercial fishing between sunset Saturday and sunset Sunday. In 1881, the commercial season was shortened to April 1 through November 15, and fixed gear such as traps, setnets, and weirs were restricted to only one-third the width of the river. In 1901, the only fixed-gear allowed on Oregon's coastal streams were setnets. Some of these regulations would change from year to year depending on the river and the species that were being harvested, however, as a whole, these rules put more and more constraints on the fisheries (Gharrett and Hodges, 1950).

Using the above analytical methods, we estimate that the late 1800s coho run size was most likely 1.5-2.5 million, and chinook run size was most likely 290,000-517,000 (Table 2). Because of the number of assumptions that must be used in the calculations, these estimates should be regarded as approximations.

Insert Table 2 Near Here

Recovery Potential

An important use of estimates of historical salmon runs is to provide a baseline from which to estimate *current* recovery potential. The recovery potential of Oregon coastal runs is generally assumed to be constrained by the quantity and quality of available salmon habitat.

Analysis of early descriptions in technical reports, diaries, and government surveys, provides compelling evidence that Oregon's coastal river habitat has changed considerably over the last 150 years. Because of the paucity of consistent long-term data, expert opinion is arguably the best method for estimating the extent and quality of past versus currently available salmon habitat. To provide a rough estimate of the quality and quantity of existing salmon habitat, 5 fisheries biologists with extensive experience in Oregon coastal watersheds were consulted. Each were asked (independently and confidentially) to estimate the net change of Oregon coastal salmon habitat. These biologists estimated the loss in habitat for chinook at 30-45% and 45-70% for coho habitat.

In aboriginal times (pre-1800), we assumed that no significant salmon habitat alteration had taken place. Based on our analysis of aboriginal and cannery data, we estimated that Oregon coastal coho run size was (pre-1850) between 1.5-2.5 million and chinook run size ranged from 290,000-517,000. Reducing the pre-habitat alteration population estimate by the 30-45% reduction for chinook habitat and a 45-70% reduction for coho habitat, we estimated the recovery potential given *present-day* habitat conditions. In the absence of other controlling factors, present-day run size for coho on the Oregon coast could be 760,000-1.4 million. For chinook, the run size could be 284,000-361,000. Current runs are, however, substantially below these predicted levels (Table 3). Our recovery potential estimates are, however, highly sensitive to assumptions about the amount of salmon habitat lost.

Insert Table 3 Near Here

If freshwater and estuarine habitat is the limiting factor, if our historical run size estimates are accurate, and if coho habitat has been reduced by 45-70%, then the potential run size for coho salmon on the Oregon coast could be 760,000-1.4 million. During “poor” ocean years, the current run size is 6-11% of the potential run size: in “good” ocean years it is 20-37% of the potential run size (Table 4).

Insert Table 4 Near Here

There are many reasons why there is such a large discrepancy between the predicted present estimate and the current estimate. First, our estimates of historical run size may be wrong. Second, there may be substantial error in the predicted estimate of present habitat quality and quantity. The current productive salmon habitat estimate may be lower than 30% of the historical capacity. Other explanations for the discrepancy include cyclical, but deteriorating (from a salmon perspective) ocean conditions, competition with introduced exotic fish species, predation (especially by birds and marine mammals), increased pollution (from agricultural and urban sources), effects of hatchery-supplemented runs, consequences of past or current fishing levels and practices, and many others.

The status of the ocean is a key determinant of the condition of Oregon coastal runs. In “poor” ocean years the current run size is estimated to be 3-6% of the historical level; during “good” ocean years it is estimated to be 11-19% of the historical level (these figures include hatchery produced coho) (Table 4). Depending on ocean conditions, overall along the coast of Oregon, coho runs have been reduced by 80-95% since the 1850s.

Given that in 2001, 2002, and 2003 the Oregon coast has experienced the highest run sizes in 30 years (Table 3), and that salmon habitat has declined, this leaves ocean conditions as the dominant factor affecting fluctuations in run size. Assuming that ocean conditions are at a cyclical peak (“good” conditions), current run sizes are at the upper end of the coho population (~282,000) that can be supported by currently available habitat. Under “poor” ocean conditions (and with the current available habitat), the expected number of coho would be ~84,000 (Figure 3). Consequently, given that current ocean conditions are likely optimal, current runs are arguably as large as will occur without major improvements in salmon freshwater and estuarine habitat.

Insert Figure 3 (oscillating run size) Near Here

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Figure Captions:

Figure 1. Oregon coastal watersheds considered in this study.

Figure 2. Changes in Oregon aboriginal and Euro-American population levels over the past three centuries.

Figure 3. Hypothesized effects of decreasing salmon habitat and fluctuating ocean conditions on salmon runs along the Oregon coast (modified from Lawson, 1993).

Table 1. Estimated salmon harvest by aboriginals inhabiting the Oregon coast in the 1700s.

Aboriginal Group	Pop. Size[a]	Per Capital salmon meat consumed[b]	Caloric loss factor[c]	Per Capita salmon meat consumed converted for caloric loss[d]	Per Capita salmon meat consumed converted for caloric loss and waste[e]	Annual harvest[f] (lbs)
Tlatskanai	1,600	365	.97	376	470	752,000
Tillamook	4,320	365	1	365	456	1,970,000
Alseans	3,060	365	1	365	456	1,395,000
Siuslawans	2,100	365	1	365	456	958,000
Coosans	2,250	365	1	365	456	1,026,000
Coastal Athapascans	4,500	365	1	365	456	2,052,000
(Takilma) Interior Athapscans	4,500	300	.90	333	416	1,872,000
TOTAL						10,025,000

Note: *The data are calculated as follows: First, divide per capita consumption estimate in lbs (b) by the migration calorie loss factor (c) to obtain an estimate of salmon consumption (d). Second, divide the weight estimate (d) by 0.8 to obtain the per capita annual consumption weight estimate (e). Third, multiply the annual consumption weight (e) by the estimated number in each population group (a) to estimate the salmon harvest. Finally, sum the harvest levels to estimate the total annual harvest (in pounds) of salmon along the Oregon coast (f).*

Table 2. Estimated salmon run sizes (late 1800s) for Oregon coastal rivers based on extrapolations from cannery pack.

Coho salmon	
Top Five Consecutive Years	1,501,000
Top Yielding Years	1,992,000
Average of Individual Streams Systems Top Yielding Years	2,529,000

Chinook salmon	
Top Five Consecutive Years	290,000
Top Yielding Years	378,000
Average of Individual Streams Systems Top Yielding Years	517,000

Individual river systems			
Nehalem River	236,000 coho	Siuslaw River	547,000 coho
	44,000 chinook		23,000 chinook
Tillamook Bay	234,000 coho	Umpqua River	199,000 coho
	51,000 chinook		21,000 chinook
Nestucca River	107,000 coho	Coos Bay	161,000 coho
	29,000 chinook		55,000 chinook
Siletz River	122,000 coho	Coquille River	342,000 coho
	30,000 chinook		14,000 chinook
Yaquina Bay	65,000 coho	Rogue River	114,000 coho
	7,000 chinook		154,000 chinook
Alsea Bay	153,000 coho		
	38,000 chinook		

[a] *Entries listed as "Bay" represent all streams and rivers entering into that bay.*

Table 3. Recent coho runs for Oregon coastal rivers (data from Oregon Department of Fish and Wildlife).

	coho run size (numbers of individuals)								
	1995	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Nehalem River									
Wild	1,689	1,283	1,305	1,293	3,757	14,638	22,528	19,082	32,352
Hatchery	5,695	7,362	3,476	2,665	1,533	686	8,357	5,671	1,631
Total	7,384	8,645	4,781	3,958	5,290	15,324	30,885	24,753	33,983
Tillamook Bay and River									
Wild	290	662	389	272	2,175	1,983	1,893	15,270	13,246
Hatchery	7,414	1,036	803	1,484	3,979	4,673	17,270	12,641	5,014
Total	5,004	1,698	1,430	1,756	6,154	6,656	19,163	27,911	18,260
Nestucca River									
Wild	1,811	519	271	169	2,201	1,171	3,941	13,068	8,648
Hatchery	0	0	0	0	8	57	187	3	122
Total	1,811	519	271	169	2,209	1,228	4,128	13,071	8,770
Siletz River									
Wild	607	763	336	394	706	3,553	1,437	2,700	10,010
Hatchery	984	438	9	57	19	16	688	89	0
Total	1,591	1,201	345	451	725	3,569	2,125	2,789	10,010
Yaquina Bay and River									
Wild	5,668	5,127	384	365	2,588	647	3,039	24,415	13,074
Hatchery	0	4,367	2,297	3,155	7	52	268	0	21
Total	5,668	9,494	2,681	3,520	2,595	699	3,307	24,415	13,095
Alsea Bay and River									
Wild	724	1,687	718	270	2,082	2,465	3,339	6,260	8,661
Hatchery	3,241	4,170	4,278	7,688	1,008	60	772	72	2
Total	3,965	5,857	4,996	7,958	3,090	2,525	4,111	6,332	8,663
Siuslaw River									
Wild	6,089	7,625	668	1,089	2,724	6,767	11,024	56,971	29,397
Hatchery	0	2,708	44	161	216	75	56	171	11
Total	6.089	10,333	712	1,250	2,940	6,842	11,080	57,142	29,408
Umpqua River									
Wild	11,673	10,333	2,233	8,589	6,631	10,605	33,880	35,720	28,888
Hatchery	1,686	9,417	1,388	2,628	1,877	3,081	22,027	3,061	2,641
Total	13,359	19,750	3,621	11,217	8,508	13,686	55,907	38,781	31,529
Coos Bay and River									
Wild	10,374	12,156	1,136	3,189	4,967	5,406	43,391	35,453	31,688
Hatchery	1,085	475	224	314	282	532	1,821	2,291	3,058
Total	11,459	12,631	1,360	3,503	5,249	5,938	45,212	37,744	34,746
Coquille River									
Wild	2,117	16,186	5,723	2,467	3,038	6,130	13,322	8,553	27,045
Hatchery	22	568	133	98	263	613	2,956	259	744
Total	2,139	16,754	5,856	2,565	3,301	6,743	16,278	8,812	27,789
Rogue River									
Wild	3,761	4,622	8,282	2,316	1,438	10,966	12,213	7,800	6,754
Hatchery	9,550	8,699	8,710	3,131	4,755	10,177	13,166	12,759	7,296
Total	13,311	13,321	16,992	5,447	6,193	34,373	21,143	20,559	14,050
Totals for listed rivers									
Wild	44,803	60,963	20,727	20,413	32,307	64,331	150,007	225,292	209,763
Hatchery	22,296	39,240	21,362	24,901	12,939	20,022	67,568	37,017	20,540
Total	67,099	100,203	42,089	45,314	45,246	84,353	217,575	262,309	230,303
% wild	67%	61%	49%	45%	71%	76%	69%	86%	91%
Total coast wide	**92,624**	**128,354**	**56,176**	**63,575**	**71,239**	**113,161**	**277,752**	**315,674**	**251,782**

Table 4. Comparison of average coho runs size for “good” and “poor” ocean years with historical and average predicted current estimates in Oregon coastal rivers.

Historical Estimated Total Run	Predicted Current Estimated Total Run	Average Run for “Good” Ocean Years	Average Run for “Poor” Ocean Years
1.5-2.5 million	759,000 - 1,391,000	281,736	84,188
% of historical		11 - 19	3 - 6
%of predicted		20 - 37	6 – 11

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