

The weather affects surface temperature and wind patterns, which in turn affect current. In the North Pacific the maximum area of possible upwelling occurs in January and the minimum area in July. See Figure 8. Once the 43-degree surface temperature contour moves north of the Aleutian ridge in May, the North Pacific nutrient pool is inaccessible until November.

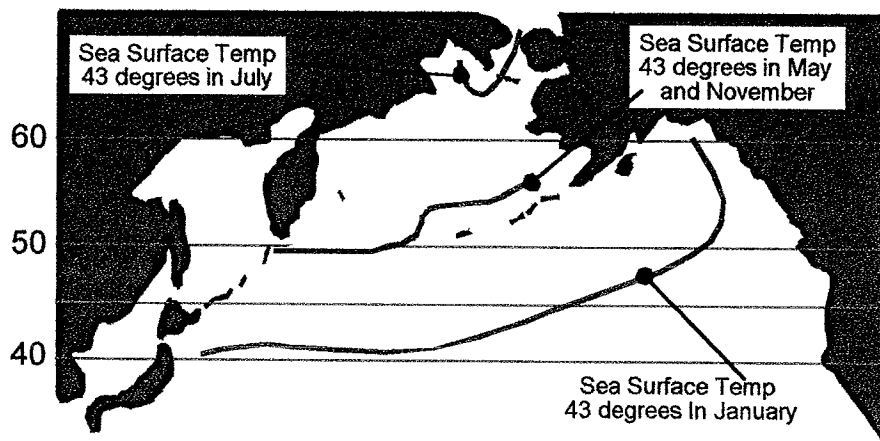


Figure 8 Limits of Sea Surface Temperatures

Ocean Currents

Once on the surface, the distribution of the nutrients depends on current to carry the nutrient laden water south to climates that are more temperate. These currents are generated by wind and weather patterns, and the rotation of the earth. In the northern Pacific, the flow is counter clockwise roughly around the center of the ocean.

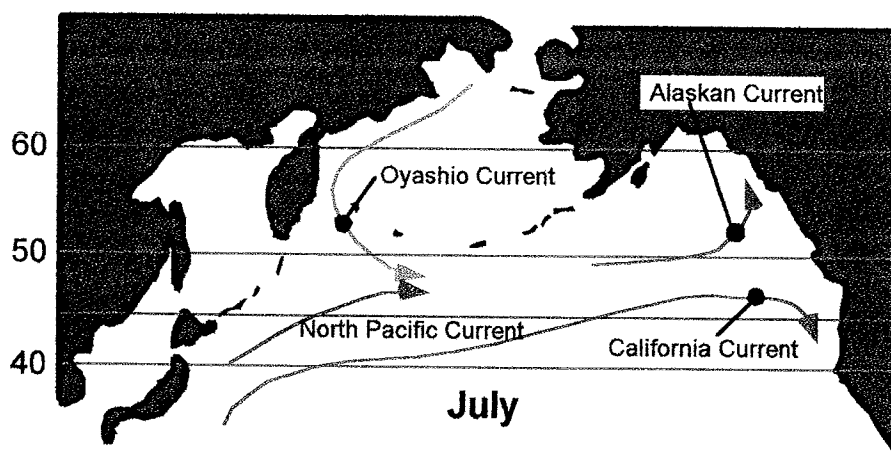


Figure 9. Current patterns in the North Pacific in July

Pacific Coast salmon are strongly influenced by the North Pacific, California and the Oyashio surface currents. The North Pacific current has its origins around Honshu Island in Japan and flows northeast between 40 and 50 degrees north latitude. This current strikes the North American continent in July somewhere around northern Vancouver Island depending on weather patterns. The part of the North Pacific Current

that turns south is called the California Current. The part that turns north is called the Alaskan Current. See Figure 9.

The Oyashio Current flows out of the western Bering Sea striking the North Pacific Current and turns eastward. Since the 43-degree F. temperature line is now north of the Aleutian Ridge, the only nutrients reaching the North Pacific Current are those carried out of the Bering Sea by the weak Oyashio Current.

In the winter, the North Pacific current moves south with the northern edge of the current south of the 43-degree temperature line, and now strikes the North American Continent opposite the Columbia River. See Figure 10. However now the Oyashio Current is stronger and as it flows through the area where upwelling can occur it can carry nutrients from the deep ocean pool back to the surface. Thus through this process, for a short period during the winter deep ocean nutrients are available to surface life.

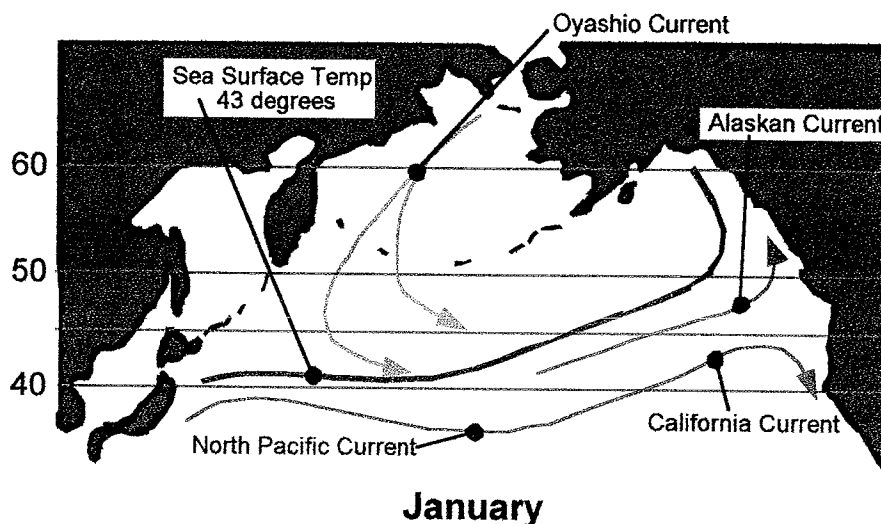


Figure 10. Current in the North Pacific in January

If the cold nutrients rich water is slowly warmed as it journeys south, the nutrients will stay accessible. However, where the cold Oysahio current meets the warm North Pacific current, the warmer lighter water over rides the colder water, forcing some of the colder nutrient rich denser water down beyond the reach of surface life once again. As the current moves east some temperature adjustment of the surface water due to mixing and convection occurs and some nutrients rise again. Finally, when the current reaches the coast of North America some of these mid level nutrients can be recovered by upwelling caused by onshore winds and local weather patterns.

The onshore wind patterns can set up relatively shallow vertical currents by driving the water downward near the shore and upward further off shore. These vertical currents can bring the midlevel cooler nutrient rich water back to the surface. Rich blooms of phytoplankton are observed after these episodic upwelling events. Between 1960 and 1981, a strong correlation existed between the intensity of the coastal upwelling and the smolt to adult survival of Coho salmon.³⁰

³⁰ Nickelson, T. E. , 1986, Influence of Upwelling, Ocean Temperatures and Smolt Abundance on Marine Survival of Coho Salmon in the Oregon Production Area. *Can J. Fish. Sci.* **49**: 783-789

The location and angle that the North Pacific current strikes the North American Continent effects the amount of flow turning north or south, which in turn effects the amount of nutrients flowing north or south. Ten or fifteen years prior to the early 1970s, much of the nutrient rich water was flowing south along the Pacific Coast.³¹ The result was the salmon thrived for a short time and their numbers increased along the south coast and decreased in Alaska. In the early 1970s, the California Current changed course and most of the flow was deflected north into the Gulf of Alaska.³² The result was a weaker, warmer, less nutrient rich current flowing south along the pacific coast. Thus, the wind driven upwelling found no depressed nutrient rich waters.

As a result of these changes in current and weather patterns, nitrate became undetectable in the California Current during the summer months in the 1990s.³³ During this same 30-year period, the lack of food caused the average weight of the salmon caught to decrease by 25 percent.³⁴ Another study places the blame for the decline of British Columbia salmon on the warming of the North Pacific waters off Vancouver Island and the accompanying loss in food productivity. The study concludes that over the next 50 years the expectation is that good salmon waters will shrink to relatively small patches in the Bering Sea. As seen earlier the Bering Sea is not a major source of deep nutrients.³⁵

The cause of the shrinking supply of cold fertile waters is attributed to the warming of the atmosphere. Whereas, there is evidence that the oceans and atmosphere are warming, it is yet unclear as to the cause. However, the production of greenhouse gas and the quality of our atmosphere is contributing to this warming trend. Any increase in burning of fossil fuels to replace the power generated by Snake River dams is a step in the wrong direction.

Ironically, the environmentally driven decision 30 years ago to rely on fossil fuels rather than other less polluting power sources may be related to the loss of Pacific Salmon. For example, it can be shown that the decision to stop building hydro and nuclear power plants caused the burning of 135 million billion BTUs more fossil fuel than would have been burned had dams and nuclear power plants been allowed to be constructed. Certainly, it should be evident that removal of dams would increase the use of fossil fuels and would aggravate the atmosphere, energy and thus the salmon problems.

It is pointed out by the author of the paper on ocean conditions off Vancouver Island, that the Snake River salmon use the same area off Vancouver Island to mature. Thus, the decline of the Snake River fisheries is also connected to changing ocean habitat. By comparison, the abundant Hanford Reach salmon in the Columbia River, feed farther to the north in colder waters where the food is adequate. These two facts seem to minimize the effects of river habitat compared to effects of ocean habitat. It is

³¹ Kaczynski, V.C. 1994, Comments on the Potentially Critical Habitat, Personnel Communication.

³² Percy, W.G., Fisher, J., Brodeur, R. and HJJohnson, S., 1985, Effects of the 1983 El Nino on Costal Nekton off Oregon and Washington. El Nino effects in the Eastern Sub Arctic Pacific Ocean. Washington Sea Grant Program. Univ. of Washington, Seattle, Pages 188-204

³³ Hobson, L.A., 1980, Primary Productivity of the North Pacific Ocean, a review, Salmonid Ecosystems of the North Pacific, Pages 231 -246

³⁴ Kaczynski, V.C. 1994, Comments on the Potentially Critical Habitat, Personnel Communication.

³⁵ Welch, D. W. Ishida, Y. Nagasawa, K. 1998, Thermal Limits and Ocean Migrations of Sockeye Salmon, Can. J. Aquat. Sci. 55:937-948

also apparent that ocean habitat is a very complex and sensitive environment. A few degrees of surface temperature warming or cooling can radically influence the food supply. Without food in the ocean, improving river habitat is of little value.

Ocean Survival Rates

Management of salmon over the past century has concentrated on the hatcheries and harvest while considering the ocean habitat to be an inexhaustible pasture. The current approach of concentrating on the river habitat makes a similar erroneous assumption. Another common belief about the ocean habitat is that nothing can be done to change it. Both of these commonly held opinions are questionable.

Ocean-estuary survival rates can be measured by comparing the number of salmon leaving the rivers to those returning. It has long been known that ocean survival rates must remain above 2.7 percent to provide sufficient Coho salmon in order to maintain a population without any harvest.³⁶ If we look at ocean survival rates for the Oregon Coast Coho over the 30 years from 1965 to 1995 as shown in Figure 11, we can see a steady decline.³⁷

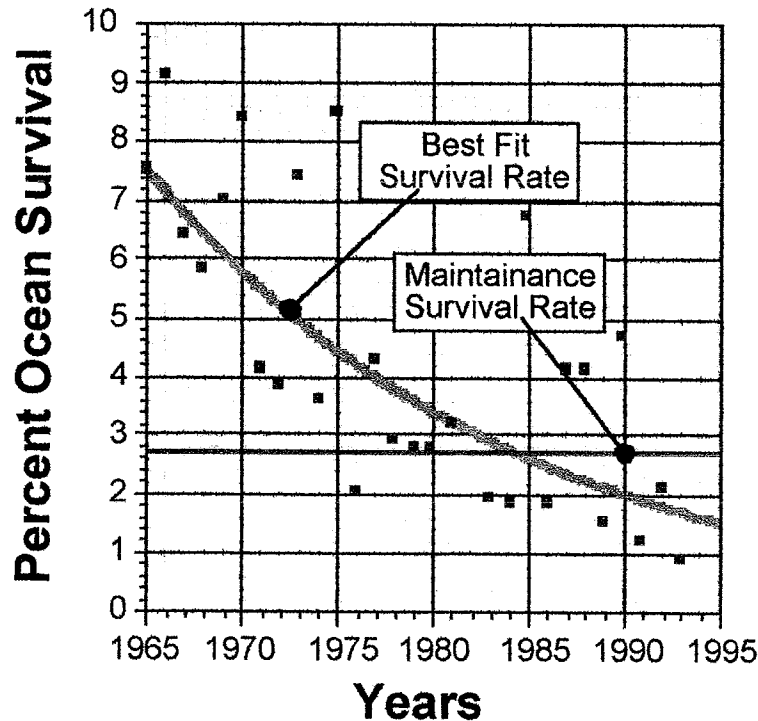


Figure 11. Ocean Survival rates for Oregon Coastal Salmon

The best-fit survival rate curve crosses the minimum survival rate curve somewhere around 1984. Thus, since 1984 the ocean conditions have been adverse (through lack of food and abundance of predators) to salmon survival.

³⁶ Caughley, G., 1967, Parameters for Seasonally Breeding Populations, Ecology. Vol 48:834-839

³⁷ Kaczynski, V.C. 1994, Comments on the Potentially Critical Habitat, Personnel Communication.

While the southern salmon (Oregon, Washington and California) have been steadily declining over the past 35 years, the salmonid populations in British Columbia have been mixed, falling in the south and rising in the north. The changes in BC were primarily shaped by marine, not river, habitat and gradually moved northward.³⁸ By 1990 onward, the return of spawning fish at the north end of Vancouver Island dropped abruptly from 15 to 4 percent, while in Alaska the salmon return has nearly doubled during the same period. However, as the salmon population has increased in Alaska, there has been a corresponding decrease in the average adult size at return.^{39,40} This inverse relationship indicates a limitation to the salmon-sustaining resources of the ocean.⁴¹

Reduction in body size is a factor in reproductive success.⁴² Life history theory predicts that large body size is a premium among salmon populations that migrate over long distances to spawn and enter the ocean as smolt. Small body size reduces egg size, which produce smaller alevin and fry that in turn inherit a diminished probability of survival.⁴³ For example, small body size also decreases the salmon's ability to allude predators.

Historic Food Supply

It should be obvious by now that with such a complex and variable nutrient supply that the salmon food supply must be variable as well. If the salmon food supply is variable then the salmon population will also vary. If we are going to predict the salmon population, it is necessary to be able to predict the salmon's food supply. To be able to predict the future it is necessary to understand the past. We have only a few studies that provide an insight into historic salmon's food sources.

Anchovies and herring are known food sources for salmon. Historic data on the abundance of anchovies, herring, saury, hake and mackerel have been obtained by examining data from core samples taking from the ocean bottom off the NW Coast.

By counting the relative abundance of sardine, anchovy, hake, saury, and mackerel scales at different depths in these ocean sediments and comparing them to present stocks, estimates of past abundance of these five fish can be determined over the last 200 years.⁴⁴ It is interesting to compare this data with the historic Columbia River salmon catch data.⁴⁵ The red curve dots are the fish scale abundance estimates and the blue dots are the Columbia River Salmon catch data. See Figure 12.

³⁸ Welch, D. W. Ward, B.R. Smith, B.D., and Everson, J.P.,

³⁹ Rogers, D.E., 1980, Density-dependent growth of Bristol Bay Sockeye Salmon, *Salmonids Ecosystems of the North Pacific*. Pages 267-283

⁴⁰ Peterman, R. M. , 1984 Density Dependent Growth in early Ocean Life of Sockeye Salmon, *Can. J. Fish. Aquat. Sci.* **41**:1825-1829

⁴¹ Bigler, Brian S., Welch, David W. and Helle, John H., 1996, A review of Size Trends Among North Pacific Salmon. *Can. J. Fish. Aquat. Sci.* **53**:445

⁴² Forbes, L.S. and Peterman, R.M., 1994, Simple Size-structured Models of Recruitment and Harvest in Pacific Salmon. *Can. J. Fish. Aquat. Sci.* **51**:51-60

⁴³ Beacham, T.D. and Murray, C.B., 1987, Adaptive, Variation in Body Size, Age, Morphology, Egg Size, and Development Biology of Chum Salmon in British Columbia, *Can. J. Fish. Aquat. Sci.* **44**:244-261

⁴⁴ Smith, P., 1978, Biological Effects of Ocean Variability: Time and Space Scales of Biological Response, *Rapp. P-V. Reun. Cons. Int. Explor. Mer.* **173**:177-127

⁴⁵ Kaczynski, V. Palmisano, 1992, Oregon Wild Salmon and Steelhead Trout, A Review of the Impact of Management and Environmental Factors, Oregon Forest Industries, Page 232

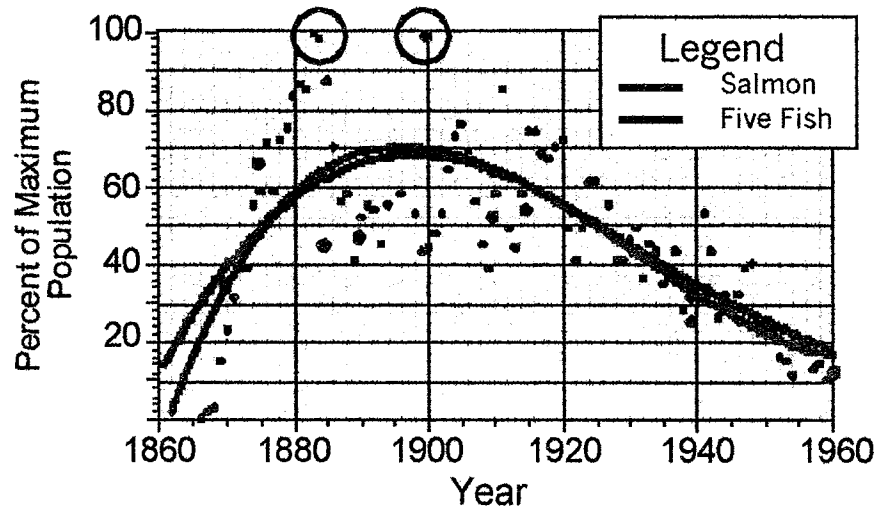


Figure 12. Comparison of Best-Fit Curves

Notice that peak populations occur just a few years apart and the red and blue dots follow the same general trend. The quality of the correlation of the data can best be seen by generating the polynomial best-fit curves to these data over the 100-year period. The two best fit curves track each other remarkably well. The duration and similarity of the population trends exclude coincidence as a possible explanation. They are definitely linked and what caused the decline in one most likely caused the decline in the other. It should be emphasized that this striking correlation is not meant to imply that the lack of anchovies, sardines, saury, mackerel, and hake is the reason for the decline in salmon. This correlation by itself is not proof, it is an indicator that studies need to address this issue and determine the link. Possible links might be that:

- The six species have a common food source that was declining,
- There has been a decline in basic nutrients,
- There has been a decline in plankton,
- The six species have a common predator that is on the increase,
- All of the above.

Important River Disconnect

The correlation in Figure 12 also indicates that there are some important disconnects between the river habitat and the decline in salmon. It is apparent that all six species declined similarly. Since five of these species never enter the river, river habitat cannot be a factor in their decline. Since these fish only live in the ocean, their decline had to be due to ocean conditions. Since the salmon live partly in the ocean, the ocean condition decline would also influence the salmon. Now, if the river habitat strongly influenced the decline of the salmon, the salmon would be taking a double hit; one in the ocean and one in the rivers. In that case, the salmon curve (blue) would be below the red curve and pull away from it as the river conditions worsened. Notice that from about 1930 on, the salmon numbers are greater than the other five fish. Admittedly, the amount is

not large, but even if the performance was equal or worse, the conclusion must be that, the probability of the river habitat being an important factor in salmon decline is remote.

Predators

It is hard to understand why the role of predators has been ignored in the process of restoring salmon. Considering that a partial list of salmon predators would include at least 137 different vertebrate, the impact of predator populations has a major effect on the salmon population.⁴⁶ The list in this reference contains at least 53 birds, 20 mammals, 4 amphibians, 3 reptiles and 57 other species that prey on salmon on rare occasions. Missing from this list are at least seven mammals including man and all the fish predators.

Fish species that are known to prey on salmon are walleye, catfish, carp, small-mouth bass, large-mouth bass, shad, sculpin, bull trout, rainbow trout, cutthroat trout, white sturgeon, tuna, pacific hake, bullet mackerel, chub mackerel, wahoo, ling cod, pacific perch, pacific barracudas, Coho salmon, sockeye salmon, Chinook salmon, chum salmon, steelhead, whitefish, and squawfish.

Bird predators include, rhinoceros auklet, Brandt's cormorant, double crested cormorant, olivaceous cormorant, pelagic cormorant, American crow, northwestern crow, American dipper, harlequin duck, bald eagle, golden eagle, great egret, northern gannet, common goldeneye, burrow's goldeneye, pigeon guillemot, Clark's grebe, pied-billed grebe, western grebe, Bonaparte's gull, Heermann's gull, California gull, glaucous gull, glaucous-winged gull, herring gull, ring-billed gull, Thayer's gull, western gull, black-crowned-night heron, great blue heron, belted kingfisher, blacklegged kittiwake, common loon, pacific loon, red-throated loon, black-billed magpie, common merganser, red breasted merganser, common murre, ancient murrelet, marbled murrelet, osprey, American white pelican, brown pelican, tufted puffin, common raven, sooty shearwater, artic tern, Caspian terns, common tern, elegant tern, Forster's tern.

Mammals include harbor seals, northern fur seals, Guadeloupe fur seal, elephant seal, California sea lions, Stellar sea lions, river otter, Pacific striped dolphin, White-sided dolphin, harbor porpoise, Dall's porpoise, killer whales, fin whales, humpback whales, Baird's beaked whale, Cuvier's beak whales, sperm whales, pilot whales, gray wolf, black bear, grizzly bear, mink, mountain lion, bobcat, raccoon, water shrew, and man to name a few. The above list brings the known number of salmon predators to 160 different species. Without a doubt, the populations of these various predators have a profound effect on the number of salmon in our rivers. Many of these species are on the endangered list, which forces us into the realization that endangered species are causing the extinction of other endangered species.

Estimating the Kill

At this point, it is constructive to estimate the magnitude of salmon being killed by these predators. The number of salmon being killed depends on, the number of predators (N_p), total intake of food (I), the percentage of the intake that consists of salmon (D_s), and the amount of the salmon ingested.

⁴⁶ Cederholm, C. J. et al, 2000, Pacific Salmon and Wildlife Ecological Contexts, Relationships and Implications for Management, Wildlife-Habitat Relationships in Oregon and Washington, Page 35

$$\text{Kill} = (\text{Np}) (\text{I}) (\text{Ds}) / (\text{A})$$

Each of these factors has varying amounts of uncertainty, which leaves considerable room for maneuvering. The truth lies somewhere in between. Obviously, this is an enormous task if applied to the 160 plus predators. Much of the needed data for those 160 predators is not known. However, we can get an idea of the magnitude of this number by estimating the kill by pinnipeds, Caspian terns, cormorants and gulls in the Columbia River.

Pinniped Kill

To arrive at the pinniped kill first, it is necessary to determine the total number of pinnipeds (Np). As you can see from table 1, the total numbers of seals and sea lions depends on the geographical area you consider. If you want to minimize the number, you can do so by considering only a small area like say the Columbia River, or from Netarts Bay to Grays Harbor. Current estimates by Fish and Wildlife tend to look only at the pinnipeds in the Oregon estuaries.

This assumption minimizes the number of salmon killed. The killing of salmon in confined waters is easier to observe and is better documented. Taking salmon in the open ocean is more difficult for the seals and sea lions, and is not often observed, but that does not mean that it doesn't happen. Now, we know that the salmon do not stay in the area of the Columbia River, but migrate long distances along the continental shelf spending considerable time in near-shore water and migrate extensively into the North Pacific.⁴⁷ We also know that sea lions migrate considerable distances up and down the coast during the year. Seals and sea lions are attracted to large concentrations of salmon. By nature, salmon travel in schools and are therefore always concentrated. Therefore, this migration exposes salmon to larger numbers of predators. How many Oregon salmon are killed by Alaskan seals and sea lions is unknown. How many northern fur seals exist is unknown.

⁴⁷ Brannon, Ernest L., 1999, The ESA listing of Puget Sound Chinook and the NMFS Status Review, Center for Salmonid and Freshwater Species at Risk. Haggerman Fish Culture Experiment Station, Univ. of Idaho, page 4.

Table 1. Estimated Selected Pinniped Populations

Species & Location	Estimated Population	Annual Increase	Total Population
California Sea Lions			
Oregon	10,500	5%	
Washington & California	235,000	5%	
British Columbia ⁴⁸	11,000	5%	
SE Alaska	Unknown		
Total			300,000
Northern Sea Lions			
Oregon	800	5%	
Washington	Unknown	5%	
British Columbia	38,000	5%	
SE Alaska	200,000	5%	
Total			250,000
Northern Fur Seals			
Harbor Seals			
Oregon	15,000	7%	
Washington	57,000	8%	
California	43,000	6%	
British Columbia ⁴⁹	177,000	6%	
SE Alaska	Unknown		
Total			310,000
Netarts to Grays Harbor	28,000	11%	

The numbers in Table 1 come from various sources. Actual numbers of northern sea lions are as yet unavailable, but current estimates of the numbers are around 238,000.⁵⁰ It is unlikely that northern sea lions make it to California, but the fact that they exist in Oregon indicates that they must also be in Washington.⁵¹

The amount of total food consumed (I) by a seal or sea lion depends on the sex, body weight and species. Using data from Federal Fish and Wildlife fact sheets and other published reports; the present daily biomass required by each of the species to maintain body weight can be estimated. See Table 2. The Fish and Wildlife Commission assumes that California sea lions consume 15 lbs. of biomass per day, a very conservative approach, which leads to a significant underestimate of the salmon killed.⁵² For example, pinnipeds in the middle of a school of salmon would be prone to gorging and may consume more than three times the biomass required to maintain body weight, increasing

⁴⁸ Biggs, M., 1985, Status of Stellar Sea Lion and California Sea Lion in British Columbia, Can. Spec. Publ. Fish. Aquat. Sci 77

⁴⁹ Olesiuk P. et al., Recent Trends in the Abundance of Harbor Seals in the Straits of Georgia, based on Scat Analysis. Can. Tech. Rep. of Fish and Aquat. Sci., no. 1730.

⁵⁰ Olesiuk, P. and Biggs, M., 1988, Seals and Sea Lions on the British Columbia Coast, Pacific Biological Station, Nanaimo, B.C., Department of Fisheries and Oceans.

⁵¹ Beach, R., et al., 1985, Marine Mammals and their Interaction with Fisheries of the Columbia River and Adjacent Waters, Third Annual Report, Washington Department of Wildlife.

⁵² _____, NOAA-NWFSC Tech Memo 28: Impact of Sea Lions and Seals on Pacific Coast Salmonids.

their capacity to as much as 130 lbs. of biomass per day. For the calculations done here we will assume a slightly higher but still conservative daily biomass consumption.

Table 2: Pinniped Required Biomass

Species	Biomass Range in lbs.	Gorging Biomass in lbs.	Biomass Assumed in lbs.	Annual Biomass in lbs
California Sea Lion ⁵³	10 to 25	75 to 30	20	7,300
Northern Sea Lion	11 to 45	130 to 33	40	14,600
Harbor Seal ⁵⁴	6	18	6	2,200
Northern Fur Seal				

The next factor required for the estimate is the percentage of the sea lion's diet that is salmon (Ds). This of course depends, to a great extent, on the amount of salmon available. All of the studies to determine the percentage of the diet comprised of salmon were made after the 1970's when the salmon population was severely depressed. Obviously, the pinnipeds are not going to eat salmon if they are not available. This is shown by the variance in the diet for harbor seals from 4 to 60 %. This large difference can be only explained by preference or by availability. It is unlikely that a seal would turn down a salmon meal if it were available. "When salmon are available, seals consume them in quantity."⁵⁵

Further, the methods used for food habit studies tend to under estimate consumption of large fish such as salmon. For example, one method used to determine the percent of salmon in the diet consists of counting the number of salmon ear bones in the skat and stomach contents of predators. Other methods using gill rakers and teeth began in 1996 to help get a more realistic count and increased the estimates by 25 percent.⁵⁶ Note however, that gill rakers and teeth are still a part of the head. Many times, the head of the salmon is not eaten; thus, the true percentage of salmon in the diet may be considerably higher.

Table 3 lists the maximum and minimum percent of salmon in the diet for the common varieties of seals and sea lions using current practice. Again, Fish and Wildlife studies select low values for the percent of salmon in the diet.

⁵³ Olesiuk, P. and Biggs, M., 1988, Seals and Sea Lions on the British Columbia Coast, Pacific Biological Station, Nanaimo, B.C., Department of Fisheries and Oceans.

⁵⁴ Kaczynski, V. Palmisano, 1992, Oregon Wild Salmon and Steelhead Trout, A Review of the Impact of Management and Environmental Factors, Oregon Forest Industries,

⁵⁵ Parks, D. L., 1993, Effects of Marine Mammals on Columbia River Salmon Listed under the Endangered Species Act, Tech Rep. 3 of 11, BPA page 4

⁵⁶ _____, NOAA-NWFSC Tech Memo 28: Impact of Sea Lions and Seals on Pacific Coast Salmonids.

Table 3. Pinniped Salmon Diet as a Percent

Species	Max Percentage	Min Percentage
California Sea Lion ⁵⁷	29	6
Northern Sea Lion ⁵⁸	10	10
Harbor Seal ⁵⁹	60	4
Northern Fur Seal		

The last variable is the amount of salmon that is consumed or wasted by the pinniped. A hungry seal or sea lion will consume almost all of a salmon, but as their need for food lessens, the animals eat only the choice parts such as the egg sack. The egg sack of the salmon is the most nutrient rich part of the fish and requires only a couple of bites of salmon or less than a pound. Fish and Wildlife estimates of pinniped kill assume the entire salmon is eaten.

Thus, we find the Fish and Wildlife used conservative estimates on each of the variables, which will obviously produce a number considerably below the actual number of fish eaten let alone destroyed by attacks where the fish is damaged but not eaten. It would be difficult to defend this conservative approach on a scientific basis.

It should be apparent by now that there exists a high level of uncertainty involved in estimating the number of salmon destroyed by predators. It is not in anyone's best interest to overestimate or underestimate these numbers. However, if we make reasonable but still conservative assumptions we might be able to better estimate the extent of the problem.

Table 5. Pinniped kill in millions of Salmon

Species	Population (Dp)	Annual Intake 365(I) in lbs	Salmon in Diet (Ds)	Amount Ingested (A) in lbs	Total Kill In millions
California Sea Lions	300,000	7,300	0.2	7	60
Northern Sea Lions	250,000	14,600	0.10	10	40
Northern Fur Seals					25 ⁶⁰
Harbor Seals	310,000	6,570	0.20	5	80
Total					190

If the numbers in table 5 seem large, consider that 60 million fish consumed by 300 thousand California sea lions is 200 fish per year by each animal. Two 75-day

⁵⁷ _____, NOAA-NWFSC Tech Memo 28: Impact of Sea Lions and Seals on Pacific Coast Salmonids.

⁵⁸ Olesiuk, P. and Biggs, M., 1988, Seals and Sea Lions on the British Columbia Coast, Pacific Biological Station, Nanaimo, B.C., Department of Fisheries and Oceans.

⁵⁹ Kaczynski, V. Palmisano, 1992, Oregon Wild Salmon and Steelhead Trout, A Review of the Impact of Management and Environmental Factors, Oregon Forest Industries,

⁶⁰ In 1984, Northern Fur Seals were responsible of killing about 10.5 million young salmon off the coast of Oregon. Considering a six percent per year increase in population over the last 16 years would produce a total kill today around 25 million.

salmon runs per year means that each sea lion needs to consume a little more than one fish per day. The larger male sea lions can consume 2.5 fish per day without gorging. Consider also that the half fish is left to scavengers, which results in three fish per day killed. Other Fish and Wildlife documents report that sea lions have been observed killing as many as 4.1 salmon per hour.⁶¹ Since sea lions are not restricted to an 8 hour day, that could be as many as 40 per day.

Thus, these numbers are well within the realm of possibility and these four species alone could easily be responsible for the loss of 190 million salmon per year. Compounding this problem is that these four species of predators are also responsible for a substantial reduction in the salmon's food supply because they also prey on anchovies, herring, and other food sources common to the salmon and are protected by the Marine Mammal Protection Act. The purpose for this protection is unclear because the population of California sea lions is at a historic high.

Terns, Cormorants and Gulls

The National Marine Fisheries Service indicates that terns, cormorants and gulls in the Columbia estuary have increased from a few hundred nesting pairs to well over 30,000.⁶² These three bird species are credited with killing over 40 million juvenile salmon in 1997 in the Columbia Basin alone. The blame for this killing was placed on the Corps of Engineers for piling spoil near the channel, which provided the nesting sites. While the problem may be the nesting site, it may also be too many terns. The Audubon Society successfully defeated the Corps of Engineers plan to harass the terns by showing that forcing the protected terns to Sand Island would not solve the problem and that their special interest in birds outweighs their social obligation to save another endangered species.

According to a three year study conducted by Daniel Roby, Larry Davies, and Carl Schreck of Oregon State University, 8,000 nesting pairs of Caspian terns consumed as many as 20 million smolt per year.⁶³ This is about 1250 salmon smolt per bird. To put the tern kill into perspective, we know that between 0 and 10 percent of the smolts that pass through turbines are killed.⁶⁴ Therefore, if we pass 50,000 smolts through a turbine, 5,000 will die, thus one turbine causes the same number of deaths as four terns. Caspian terns are not native to the Oregon Coast, but are protected by federal law - the Migratory Bird Act, which was passed in 1918 and amended in 1936, 1960, 1967, 1974, 1978, 1986, 1989 and 1998. Cormorants, gulls and many other birds that prey on salmon are also protected. Cormorants are at historic highs.

Other Predator kills

The numbers of other salmon predators, like bears, eagles and terns, have increased significantly in the last century. The Alaskan Fish and Game Service estimates that a single bear eats between 10 and 20 salmon per day during salmon runs. Eagles

⁶¹ _____, NOAA-NWFSC Tech Memo 28: Impact of Sea Lions and Seals on Pacific Coast Salmonids.

⁶² Collis, Ken and, Adamany, Stephanie, Robe, Daniel, D., Craig, David P., Lyons, Donald E., 1998, Avian Predation on Juvenile Salmonids in the Lower Columbia River.

⁶³ Collis, Ken and, Adamany, Stephanie, Robe, Daniel, D., Craig, David P., Lyons, Donald E., 1998, Avian Predation on Juvenile Salmonids in the Lower Columbia River.

⁶⁴ Espenson, Barry, 2000, Test Show Turbine Bennisfits, Columbia Basin Bulletin, March 10, 2000 NWPPC, Page 5

have recently been taken off the endangered species list. In 1963, only 800 eagles existed in the lower 48 states; presently there are over 11,000 birds, an increase of over 1300 percent. Salmon is a major food source for eagles. The common murre population in Oregon alone has been estimated at 40,000 birds. Studies indicate that each murre can consume 100 smolts per month.⁶⁵ Thus, the murre could easily account for 10 million smolts.

Total Kill

Thus, as shown in the above pages, the seven predators that have verifiable numbers of kill are responsible for killing close to 230 million salmon per year. Compare this with the optimum yearly catch in the Columbia River in 1883 of 2.3 million salmon.⁶⁶ Although one can argue with the predator kill numbers somewhat, and maybe it would be possible to eliminate 100 million, but then you will have to add the kill from the other 153 predators. The potential kill is enormous; 500 million salmon could easily be killed each year by predators.

Another way to approach the number of salmon killed by predators is to look at the entire ecosystem as a black box. The long time rule of thumb for hatchery efficiency is a 2.7 % return, which indicates a 97.3% loss.⁶⁷ Rules of thumb often have safety factors built into them. This rule of thumb can be examined by concentrating on a single pair of salmon. Thus, the number of salmon going into the system is just the number of eggs carried by a single female salmon and the percent of fertilization. The number of eggs varies according to species and size. Table 6 lists the average number of eggs for each species and their variability.

Table 6. Egg Count per Species

Species	Average Number of Roe	Variability
Pink	1700	±300
Coho	3000	±1500
Chum	3000	±1500
Chinook	5000	3000 to 12000
Sockeye	3500	±1500
Steelhead	3500	±1500

It can be seen that the data varies to such a degree that the percent of fertilization drops out of the equation. It is not necessary to know what goes on in the box. All we need to know is the number of salmon going in and the number coming out, the difference is the number of salmon that perish inside the system. For example, consider that a pair of chinook produces about 5000 fertilized eggs. In a balanced system, where

⁶⁵ Mathews, D. R., 1983, Feeding Ecology of the Common Murre, *Uria Aalge*, off the Oregon Coast, MS Thesis Univ. Of OR., Eugene OR.

⁶⁶ Lichatowich, James A., Morbrand, Lars. E., 1995, Analysis of Chinook Salmon in the Columbia River from an Ecosystem Perspective, page ix

⁶⁷ Kaczynski, V. W., 1998, Marine Survival of OPIA Hatchery Coho Salmon related to Marine Temperatures, Proc. Of the 49th Annual Pacific Northwest Culture Conference. Pages 131-147

the chinook population is going neither up nor down, those 5000 eggs must return to the river a single pair of salmon. See figure 13.

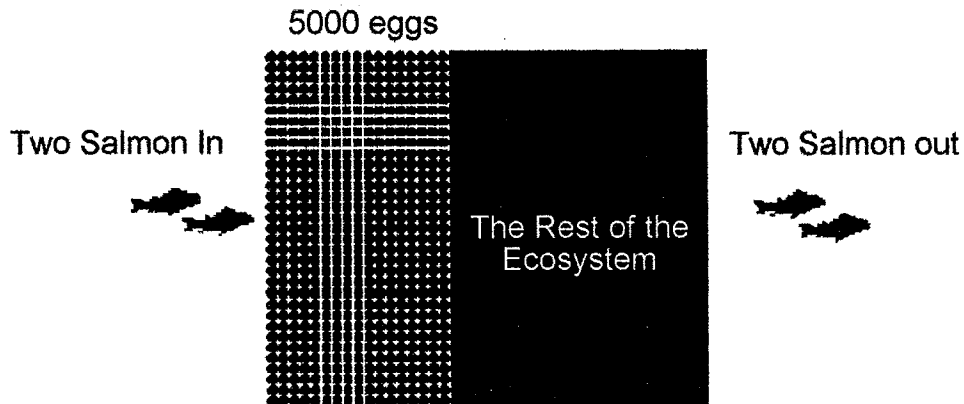


Figure 13. Black Box Approach

Thus, 4998 out of 5000 salmon do not survive for one reason or another or the break-even point is 99.94 percent, fairly close to the rule of thumb. The difference is the safety factor. To ignore the role of salmon predators in the reduction of salmon population is a major oversight in the current science. Predators are what keep prey in check. Prey and predators are tightly connected in a structure, which used to be called the Balance of Nature.

Balance of Nature

Even though the concept, "Balance of Nature," has been replaced with the more complex ecosystem, it is still useful to understand the interaction between prey and predator. See Figure 14. In this figure, there is a balance beam and three colored boxes. The green box contains all of the salmon and is larger than the red box, which contains all of the salmon predators including man. That is because the salmon rely on a survival strategy that is based on the school or herd concept. In other words, if we can't fight them or we can't out run them, we will out-produce them. This strategy relies on producing large numbers of off spring. However, salmon do little in the way of parenting. One reason hatcheries are effective, is they provide this missing parenting to the young salmon, nurturing and protecting them during the first months of their existence.

The predators in the red box rely on the green box for part of their diet. The salmon in the blue box are the ones that escape the predators and live to produce more salmon. When nature is in balance, there are enough salmon in the blue box to produce enough salmon to fill both the blue and green boxes. Thus, the numbers of predators in the red box are fed, the black balance beam is level and nature is in balance, this condition occurs rarely, and is sometimes referred to as, "a baseline." A baseline is a set of conditions that can be used for comparing trends in a phenomenon or interpreting the operation of a model. Later we will take a closer look at the salmon baseline.

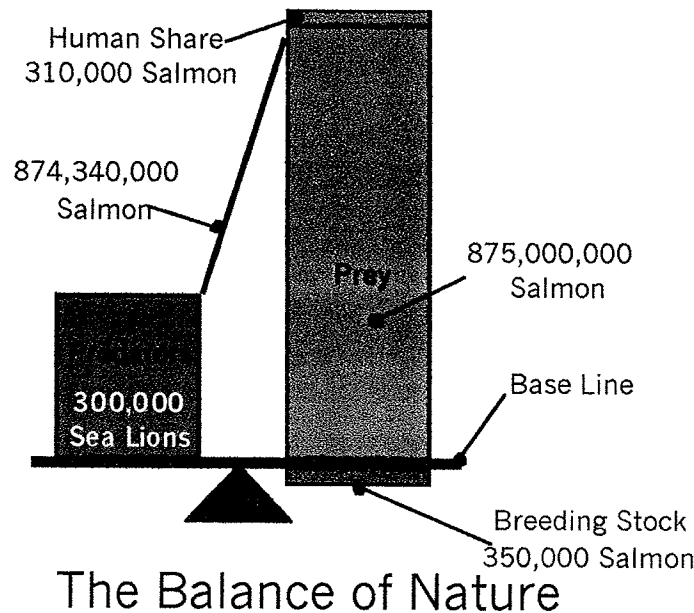


Figure 14. Concepts involved in the Balance of Nature

By using the average return of 350,000 salmon in the Columbia over the last 50 years as the number of spawners in the blue box and assuming half are female, that would produce 875 million eggs in the green box. Since the average Oregon catch over those same years was about 310,000 salmon and 350,000 must escape to the blue box again to keep the system in balance, 660,000 salmon are accounted for. This results in 874,340,000 salmon that were taken by some form of predator or 99.92 percent. Comparing these calculations with the one in the preceding section, human's are taking about 0.02 percent of the salmon.

Now, let's see what happens if we manipulate the balance by improving the habitat in the Columbia River and add 50,000 fish to the green box. Then we will have the condition shown in Figure 15. In this situation, all predators except sea lions and are allowed to eat only the same amount of salmon they ate last year, then the 50,000 new salmon would increase the present sea lion population by 250 individuals or less than 0.1 percent. That is one new sea lion pup in every 1000 breeding pairs. An increase of this magnitude would be well within the normal 6% population increase. It would only take forty Caspian Terns to consume the 50,000 extra smolt. In reality all predator numbers will rise as well and the sea lion and tern population will only increase by a few. This shows the futility of increasing the salmon in the green box, without controlling predator population.

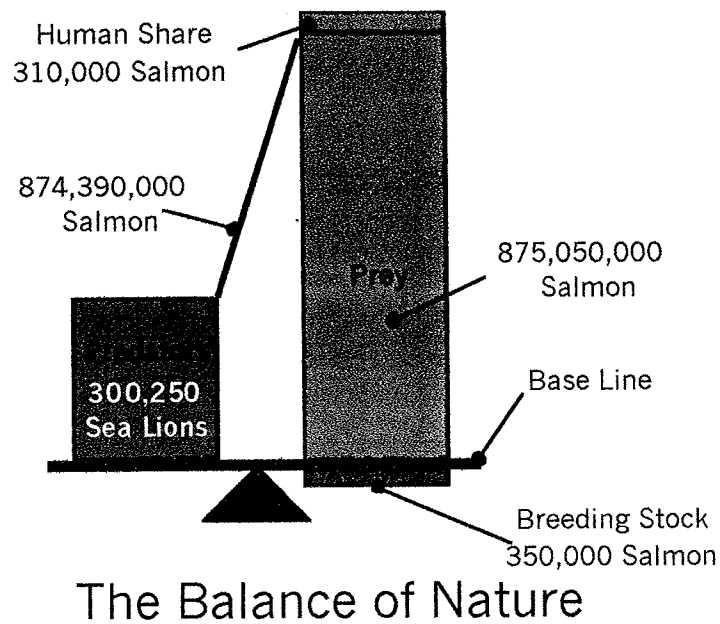


Figure 15. Adding to the Green Box.

Now lets turn to the red box. Suppose we reduce the number of sea lions in the red box by 250. Since the sea lions prey on salmon just before they spawn, the 50,000 salmon escaping would end up in the blue box. This condition is represented by figure 16.

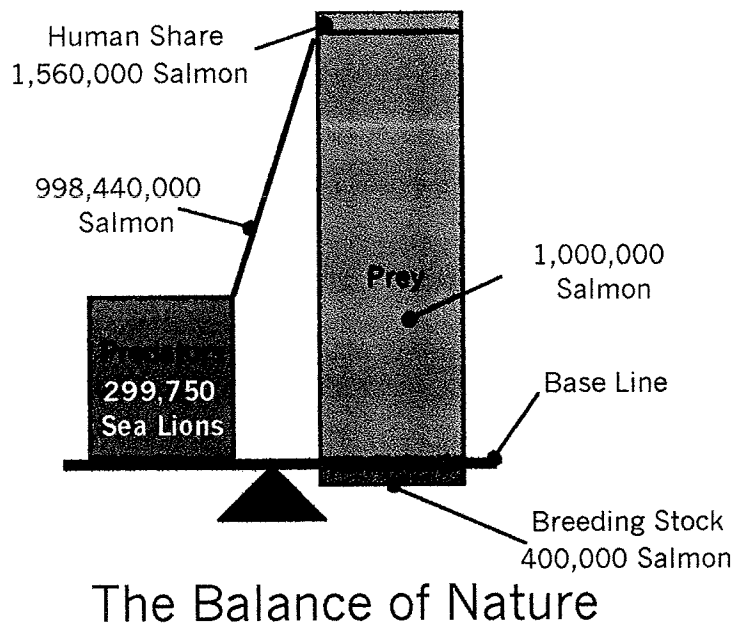


Figure 16: Reducing the Numbers in the Red Box

Now the green box is filled with a billion salmon. If man is allowed only one out of every hundred of those extra 125 million salmon the human harvest would jump to 1.56 million fish, and the rest of the predators would get the remaining 123.5 million salmon. This is more salmon than we harvested from the Columbia River in 1890. This of course assumes we could feed 125 million extra salmon, but it does show the leverage of working in the red box.

The actual salmon model will be considerably more complex than this simple model. Each of the boxes contains other boxes. For example, the red box might look like Figure 17 and the green box like Figure 18.

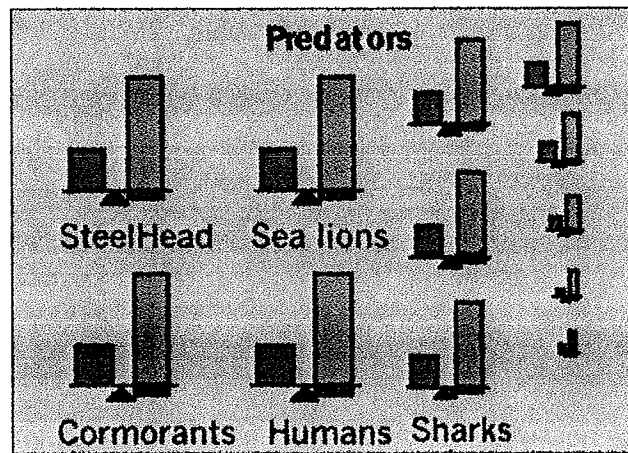


Figure 17. Inside the Red Box

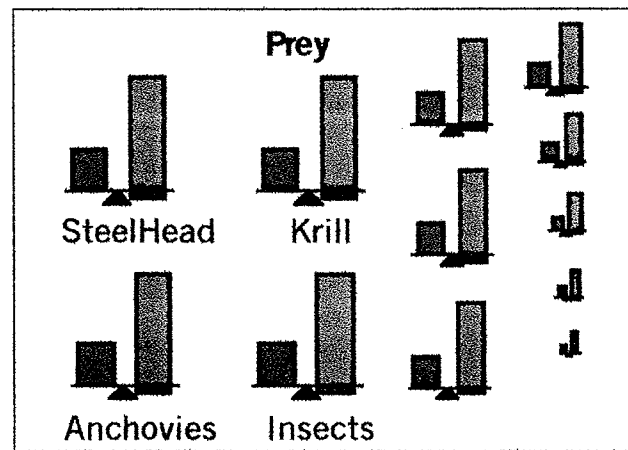


Figure 18. Inside the Green Box

Notice that there are other balances in each of these boxes representing each of the species in that box and each has its own set of balances with blue, red and green boxes filled with other boxes. There are also interconnections. For example, the seal has the shark as a predator in common with the salmon, and the salmon both eats and is eaten by steelhead.

Further, we must add to each box all of the environmental effects for each of the habitats, like turbidity, water temperature, ocean currents, dam operation, etc. There is little doubt that this model would be complex. However, if humans are to take over the responsibility of salmon survival from Mother Nature, humans must know how the system operates. The result of this model may well show that the well-meaning decisions 80 years ago to protect pinnipeds and sea birds may well be a major factor in the decline of the salmon.

Salmon Baseline

As we have seen above, the salmon baseline is the number that is used to compare performance over time. The current peer reviewed baseline for Columbia River salmon is estimated at 10 to 16 million salmon. This estimate is based on the number of Chinook salmon caught in 1883 and some rather esoteric assumptions on escape ratio and ratios between the chinook runs and the other salmon runs.⁶⁸ How this statement could be contained in a supposedly peer reviewed document is difficult to comprehend. None of the above assumptions stand up to critical examination. The pre 1800 levels of salmon can also be estimated by calculating the maximum breeding capacity and looking at historic data. See Figure 19.

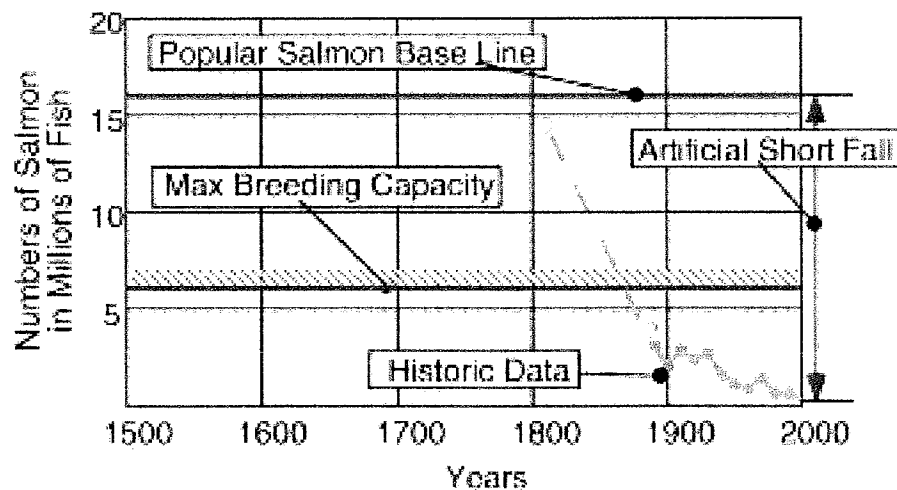


Figure 19. Columbia River Salmon Base Line

The maximum breeding capacity of the pre 1800 Columbia River system was calculated in the same report by assuming a return rate and that all available breeding space is fully utilized by salmon.⁶⁹ These calculations show the Columbia River is capable of producing about 6.2 million returning fish. Even though these calculations followed each other in the document, no attempt has been made to explain where the

⁶⁸ _____, 1986, NWPPC, Appendix D, Compilation of Information on Salmon and Steelhead Losses in the Columbia River Basin, Page 9

⁶⁹ _____, 1986, NWPPC, Appendix D, Compilation of Information on Salmon and Steelhead Losses in the Columbia River Basin, Page 8

extra 4 to 10 million fish needed for the popular baseline were bred. The maximum breeding return is like a barrier. It would be very difficult for any river to support a return that surpassed this number significantly.

The plot of the historic data is based on the total number of salmon caught in the Columbia and the total number of salmon passing up the fish ladders at Bonneville Dam. This assumes that the number of fish caught above Bonneville was not a major portion of the total catch and represents the fish that escaped. Thus, the total fish returning to the river can be calculated. The historic data curve is a reasonably accurate estimate of the total fish returning to the river up to 1940. Before 1938, the number of fish that escaped was estimated based on the average escapement ratio calculated from the first 12 years of Bonneville data. Since catch restrictions were enforced in the early 1900s and were increased every few years thereafter, fish that actually escaped prior to 1938 would be less than this assumption. Therefore, the actual population would be less than calculated. Even using this conservative approach, the maximum fish return would be a little less than 4 million fish.

It seems highly unlikely that the total number of returning salmon in the river would ever quadruple its historic highs in ninety years. Further, the concept of a constant fish return is inconsistent with nature. Most natural phenomenon varies over time. It is entirely possible that the population pre 1800 was less than it was in 1890. In any case, it is obvious that the 10 to 16 million number for the historic salmon population is a major over estimate, which produces false expectations. This obvious error leaves two issues unanswered, first, how did such a obvious error persist through so many peer reviews and second what was the fish population prior to the introduction of complex culture. We will discuss the subject of peer review later. To get a more accurate indication of the fish runs before 1890, we can look at eyewitness accounts, Native American ritual and evaluate core sample data.

Eye witness Accounts of Early Historical Runs

We have the accounts of two exceptionally accurate and thorough individuals who were instructed by the President of the United States to record natural wonders and resources. Lewis and Clark arrived at the Clearwater River on September 21, 1805, near what should have been the peak of the fall salmon run.⁷⁰ The question here isn't, "did they see salmon?" – the question is, "did they see a fall run as large as 8-10 million salmon?" A run of salmon that large would surely have been noted in the journals of these men, particularly because they were near starvation. When they reached the Clearwater River, they were reduced to eating dried salmon, roots, and horse and dog meat. Some of the men were so weak they had to be drug behind the horses on litters. When they reached the Clearwater, did the men gorge on the abundant salmon? If they did it is not recorded in the diaries.

Lewis and Clark journals clearly talk about salmon 44 times during the four to five week trip down the Clearwater and Snake rivers. The journal entries also complain about stomach trouble from their diet of salmon. However, almost all of those 44 times they obtained the salmon from the Indians. It is hard to believe that backwoodsmen would trade for salmon if they could catch salmon from the river. Certainly, they had the

⁷⁰ Moulton, Gary E., 1989, *The Journals of the Lewis and Clark Expedition*, Univ. of Neb. Press. Vol 5, page 227.

skills, especially in a river that was boiling with salmon as we have been led to believe. There is only one notation in the journal where they caught fresh salmon. That event occurred four days after they reached the Clearwater and they only managed to catch six fish.⁷¹ If the rivers were indeed teeming with millions of fish, why did these experienced backwoodsman not catch more salmon?

On the last day of September, they noted a great number of small ducks passing down the river. It is curious that they should mention a few hundred ducks, and not mention the millions of salmon presumed by popular notion to be in the river. The salmon that they ate on the Clearwater and Snake was dried salmon. The men did not like dried salmon. The dried salmon was made using spent salmon.⁷² Spent salmon are those salmon that have died naturally from exhaustion and starvation. The fat content of these salmon was therefore lower and the natives found that dried spent salmon kept better than fresh salmon.

Nowhere on the Snake or the Clearwater did Lewis and Clark come across any natives harvesting salmon. One entry in the journal mentions natives fishing, but fishing and harvesting are two different matters.

On October 10, after being on the river for 3 days and passing 30 rapids they came to an Indian village. They discussed the lives of the natives living on the river as the pursuit of summer and fall salmon fishing.⁷³ However, there was no notation about any ongoing salmon harvest, which should have been a big event for the village. In addition, some salmon at least should have been noted leaping in some of the rapids, as well as references to dead and dying spent salmon.

On the 13th of October, they came to Monumental Rock in Walla Walla County and noted that this was obviously a great fishing place. They noted, "a number wholes of fish." The spelling is so bad, that one is not sure whether Clark meant fishing holes or whole salmon. However, they neither noted large numbers of fish, alive or dead, nor Indians harvesting fish.⁷⁴ Thus, on the entire trip down the Clearwater and Snake Rivers this starving party of backwoodsmen dutifully recorded when they ate duck, dog or deer, but recorded eating only six fresh salmon. This from two rivers that the biologists would have us believe were teeming with fish, "Historically the Snake River fall component of this ESU (salmon) was the predominant source of production."⁷⁵

Finally, on October 17, 1805, Lewis and Clark reached the Columbia and made their first notation about observing great numbers of dead salmon.⁷⁶ They spend a day exploring up stream near Pasco and found the Indians apparently near the middle of the fish harvest. They reported salmon drying on racks and dried salmon stored in baskets. Thus, the salmon run must have been going on for some time. Why were there so few

⁷¹ Moulton, Gary E., 1989, *The Journals of the Lewis and Clark Expedition*, Univ. of Neb. Press. Vol 5, page 233.

⁷² Wilkes, Captain, 1841, *Wilkes' Narrative*, Vol .IV

⁷³ Moulton, Gary E., 1989, *The Journals of the Lewis and Clark Expedition*, Univ. of Neb. Press. Vol 5, page 259.

⁷⁴ Moulton, Gary E., 1989, *The Journals of the Lewis and Clark Expedition*, Univ. of Neb. Press. Vol 5, page 268.

⁷⁵ _____, 1996, *Status Review of Chinook Salmon from Washington, Idaho, Oregon and California*, NOAA Tech. Mem. NMFS-MWFSC-35, page xxiv

⁷⁶ Moulton, Gary E., 1989, *The Journals of the Lewis and Clark Expedition*, Univ. of Neb. Press. Vol 5, page 286.