Status and Future of
Salmon of Western Oregon
and Northern California:

FINDINGS AND OPTIONS SECTION OF THE REPORT ON SEA LIONS AND SALMON

REPORT # 8

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P R E F A C E

The Center for the Study of the Environment (CSE) was established in 1992 as a private, non-profit organization to conduct research directed toward finding constructive solutions to environmental problems. The Center seeks to provide an objective basis from which research and education can be used to determine environmental policy options and facilitate sound environmental decision-making.

This CSE report is the eighth in a series produced by the Center as part of a study of the salmon of western Oregon and northern California conducted by the Center in accordance with a contract from Oregon State University. In 1991, the Oregon Legislature charged the Oregon Board of Forestry to commission a study to "assign the relative importance of forest practices" to the decline in anadromous fish [salmon] and to "make recommendations as to how forest practices can assist in recovery of anadromous fish populations." CSE is conducting the study through funds provided by Oregon Senate Bill 1125 Section 25 (Oregon Legislative Assembly 1991); additional funds have been made available from the State of California Department of Forestry and Fire Protection (CDFFP).

This report is not a policy document and not contracted to be; it is a distillation and analysis of existing scientific information. It is not a prescription of specific policy, but is intended to provide an important foundation both for policy actions given the current state of knowledge, and to identify the key areas where additional research and monitoring are needed. This report is written for the state of Oregon and concerns only the issues and charges of Oregon Senate Bill 1125. A separate report is being prepared for the state of California, with a focus on specific issues and questions raised in their request to CSE.

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The Study Area

The study area was defined by the Oregon Department of Forestry to exclude the Columbia River, to be bounded to the north by that river's watershed but not include it; to be bounded on the east by the Willamette River and its watershed, and to extend west to the Pacific and south to the California border. Once the project was underway, the California Department of Forestry and Fire Protection contributed additional funds to it so that the southern boundary of the study could extend to include the Klamath and Trinity Rivers in northern California and thereby create an ecological and geological unity for the study area

SECTION ON SEA LIONS AND SALMON

From an historical perspective, concern with the possible take of salmon by marine mammals is not new. In 1901, C. Hart Merriam (an eminent scientist, then-Director of the Biological Survey, which became the U.S. Fish and Wildlife Service) wrote in *Science* Magazine (Merriam 1901) that the California State Board of Fish Commissioners had taken steps during the previous two years to "kill off a very large number of sea lions on the California coast, on the grounds that these animals are highly destructive to the salmon fishery." The president of the board stated that the goal was "merely to kill 10,000 of the 30,000 that now infest our harbor entrances and contiguous territory." Merriam went on to write that "the local fishermen, the State Fish Commission and others assert without qualification that the sea lions feed extensively on salmon." A few years before, when fur seals had been similarly accused, Merriam had examined the stomach contents of "a large number of these animals" and found to his "surprise" that "the great bulk of their food consisted of squids, hundreds of whose beaks and pens were found in the stomachs, while in only a few instances were any traces of fish discovered" (Merriam 1901).

Merriam also reviewed the experiences of Professor L.L. Dyche of the University of Kansas who, in the summer and early fall of 1899, had examined the stomachs of 25 sea lions killed on the California coast for the same reason -- they were believed to be feeding heavily on salmon (Merriam 1901). He examined eight of these in the presence of the fishermen who had shot them "because they were feeding on salmon." Professor Dyche made a detailed record of the stomach contents of the sea lions which contained only squid and octopus (including some pieces of the giant octopus). He found no fish scales or bones in any of the stomachs, in spite of the fact that the sea lions were killed in an area where fishermen were catching salmon. "You can hardly imagine the surprised look on these fishermen's face," he wrote, when he cut open a dead sea lion and found "masses of squid meat." Seventeen of the sea lions were examined off Point Carmel where rock cod were being caught. Professor Dyche also examined rocky islands where there was sea lion excrement a foot thick, which he searched and found not a single fish bone or scale. Merriam acknowledged that sea lions in captivity would eat fish rather than starve, and that they sometimes bit and ate salmon in nets, but available evidence from careful examination of stomach contents and excrement showed no sign of salmon as food for sea lions (Merriam 1901).

Jameson and Kenyon (1977) much later observed sea lions on the Rogue River with results similar to Merriam and Dyche. They state that "local fisherman complain that sea lions are feeding on anadromous salmonids."   They spent only 14.25 hours watching sea lions on the Rogue River, and observed 93 occurrences of feeding. Of these, the sea lions took or attempted to take sea lamprey in 76 cases (82 percent) and salmonids in only 2 cases (2 percent). However, no accurate estimate of biomass of salmon taken by sea lions is possible from these casual observations.

Conflicting Findings: In contrast to the panel's analysis, Kaczynski and

Palmisano (1993) estimated that pinnipeds were responsible for consuming 301,200 salmon in Oregon waters in 1990, or an amount equivalent to 85 percent of the commercial ocean harvest. The ODFW estimated that seals took an equivalent of 20 percent of the 1980 commercial harvest of salmon in Oregon (ODFW 1982). The doctoral thesis by Harvey in 1988 referred to earlier concluded that harbor seals consumed 1.3 million pounds of salmon off the Oregon coast in 1980; this is 30 percent of the 4.4 million pounds of ocean commercial salmon landed in 1980.

How can we account for these great differences between the observations reported by Merriam and Dyche in 1901 and 1899, and modern estimates of a large take of salmon by sea lions and seals? The first step is to examine the methods used to make the more recent estimates.

Simple estimates are made by assuming that the biomass ingested by a species of marine mammal is equal to the total population size multiplied by an individual's total food consumption in a year multiplied by the percent of total food consumed that is salmon, or

$$B = N*F*S*D \qquad \text{(Equation M)}$$

where B is biomass in kilograms of salmon eaten by a population of seals or sea lions; N is population size; F is daily food intake of an individual in kilograms; S is the percentage of intake that is salmon; and D is the number of days in a year an individual spent feeding on salmon.

We have reviewed the scientific literature in which the stomach contents of sea lions and seals have been analyzed and found none that provided a scientifically sound estimate for each of the factors in the above equation. For example, Pitcher (1980) examined the stomach contents of 548 stomachs of harbor seals in the Gulf of Alaska. He found food in only 269 of the stomachs. In those 269, salmon was found in 9 and Pitcher (1980) calculated that based on food volume, salmon made up 4.4 percent of the total volume of food found in all stomachs averaged for an entire year. This is an incorrect calculation, because among other problems, he did not take into account those stomachs sampled and found without food, and the potential seasonality of the feeding. Instead, he extrapolated to all marine mammals from only those with salmon in their stomachs, and he extrapolated feeding for an entire year when in fact salmon were only available for a short period.

The following paragraphs explain more of the problems with Pitcher's (1980) analysis. The primary food found in the stomachs of these Alaskan harbor seals was octopus and walleye pike. Salmon were found in the diet of harbor seals but only during the summer from Prince William Sound and Kodiak Island. In Prince William sound, salmon was found in four harbor seal stomachs; at a percentage of 28.6 percent +/- 25.9 percent (95 percent confidence intervals, this means that the percentage in those four could be anywhere from 2.7 percent to 54.8 percent). In the Kodiak Island area, salmon was also found in four individuals, and the mean percent volume was 10.0 +/-10.5 (the 95 percent confidence interval includes the value of 0, which means that 0 is a legitimate part of the range). When zero is part of a range of the estimate, the estimate is usually abandoned as meaningless.

Pitcher collected data over a five-year period and salmon were consistently found in the seal's stomachs only during July, August, and September. Since the data were not collected over a full year, it is difficult to use them to make an annual estimate. Based on the confidence intervals provided by Pitcher, and his estimates of feeding behavior, a range of salmon consumption for Oregon can be calculated to be from near zero up to as much as 600 MT, which makes his results essentially useless for the purposes of this study.

As noted before, Pitcher calculated an estimate of 4.4 percent, but he did not take into account those stomachs sampled and found to be without food, and the potential seasonality of the feeding. We must take into account all the stomachs sampled that had no food in them. Therefore, we multiply the calculated percentage of salmon of 4.4 by the ratio of full stomachs to empty stomachs: (4.4%)*(269/548) = 2.2%. Using these feeding rates for Oregon, assuming 9,000 harbor seals along the coast of Oregon, and an average intake of 4 kg/day per seal (recent estimates from ODFW marine mammologist, S. Riemer 1994), then the take based on Pitcher's data would be (0.022*4kg/harbor seal/day *365days*9000) = 289,080 kg (about 290 MT). This is likely an overestimate since salmon consumption would not occur 365 days a year, rather only during that portion of time when salmon were present. Differences in feeding behavior in Alaska as founded by Pitcher may also differ from that in Oregon.

Many point to the occurrence of bite marks on salmon as indirect evidence of pinniped predation. Chapman et al. (1991) and Harmon and Matthews (1990) report that during 1990 and 1991 bite marks, scratches, and scars on salmon "attributable to pinnipeds" were observed on 19 percent to 50 percent of upstream-migrating salmon in the Columbia River. Based on visual evidence, Chapman et al. (1991) estimated that over the years 1991 to 1993, 15 percent to 20 percent of Snake River spring/summer chinook salmon had been wounded by pinniped attack and many died as a result of the wounding.

Beach et al. (1981) report on marine mammal fishery interactions on the Columbia River, noting that less than one percent of harbor seals in the river were observed to be interacting with the ODFW test fishery off Woody Island on the day an aerial survey was conducted. They also state that harbor seals seemed to be affecting salmon more than sea lions. It is necessary to distinguish among salmon eaten by pinnipeds, salmon damaged by pinnipeds, and made either less saleable or unsaleable by pinnipeds, and damage to fishing gear, but generally these distinctions are not noted. Beach et al. (1981) report damage rates to be highest during summer, prior to fall salmon spawning runs. They reported 121 damaged salmon out of 1,759 sampled, or 7 percent, and estimate total damage that resulted in unsaleable salmon of $95,000. This is for an area and time when fishermen and pinnipeds were most likely to overlap and interact; therefore it would represent an upper limit if it were a statistically valid sample. Because the study was done over a short time and does not appear to have been developed around a statistically-valid sampling scheme with appropriate number of samples and distribution of samples, the data do not seem to have statistical validity. Simply said, the data from Beach et al. (1981) are also unusable.

Roffe and Mate (1984) studied the abundance and feeding habits of pinnipeds in the Rogue River and therefore in direct contact with migrating salmon. They examined stomach contents of 28 California sea lions and 14 harbor seals killed 1.6 km or more up the Rogue River. Unfortunately, they did not record their observations as weight of stomach contents or percentage by weight, again making estimation of total take impossible. As with the previously discussed report, simply said, the data from Roffe and Mate (1984) are also unusable. They found lampreys to be the principal food, but 15 sea lion stomachs contained salmon, with three containing one salmon each and the rest containing 1 to 12 steelhead. Based on this extremely limited sample, they assumed that the diet of sea lions within the Rogue River was 19 percent steelhead and 3 percent chinook; the diet of harbor seals was 4.4 percent steelhead and 5.6 percent chinook. Because weight was not taken, there is little basis for these statements. Even if we are to accept these comparatively high takes, which we do not, they estimate that the total pinniped take on the salmon run of the Rogue was 0.4 percent of spring chinook in 1977 and 0.6 percent in 1978, and 6.1 percent of the summer steelhead population in 1977 and 0.3 percent in 1978. These results again suggest that the pinnipeds take of salmon is low, even in situations where there is abundant salmon and the pinnipeds are in the river with them. Even if these were a statistically-adequate sample for the Rogue River, it would be impossible to make a valid extrapolation to other areas without having sampled other rivers for pinniped activities for comparison. Thus this study on the Rogue cannot be used as a basis for any quantitative estimate of marine mammal take of salmon, either for that river or for other rivers.

A review conducted by Kaczynski and Palmisano (1993) uses data and results from other studies to estimate the impact of marine mammals on Oregon's salmon. This report cites work by Harvey (1988) which we referred to earlier, along with reports by the Pacific Fisheries Management council and the Oregon Department of Fish and Wildlife. From these, Kaczynski and Palmisano (1993) conclude that harbor seals have recently had a very high impact and now are almost as detrimental to salmon populations as are humans. This is not a valid conclusion, as we will explain here.

Harvey (1988) calculated the weight and number of four salmon species (chinook, coho, sockeye and steelhead) that the Oregon population of harbor seals ate in 1980. Harvey estimated the population size of harbor seals on the Oregon coast, conducted feeding experiments with captive seals, and examined scats and intestinal tracts of wild seals. Based on his estimates of fish consumption by harbor seals, he found that in 1980, 10.8 percent of the seals' diet was from the salmon family. There is no range or confidence limits associated with this estimate, so there can be no assessment of its accuracy. The study Harvey conducted, however, was thorough and was one of the best we have reviewed directed at obtaining an accurate estimate of harbor seal population and dietary consumption. However, there are obvious inadequacies with scat analysis as acknowledged by Harvey. He reported a total of 604.5 MT consumed, but his total did not include sockeye; adding sockeye the total would be 613.3 MT.

Kaczynski and Palmisano (1993) used Harvey's 604.5 MT figure to calculate the total number of salmon eaten by harbor seals. In addition, Kaczynski and Palmisano (1993) made an error in calculating the average weight per fish from Harvey's data. They calculated a mean that was not proportioned by the number of fish of each species. Harvey calculated that harbor seals consumed 48,700 chinook (average weight 6.34 kg), 40,200 coho (avg. wt. 5.55 kg) and 560,300 steelhead (avg. wt. 0.13 kg, meaning that these were smolts swimming down to the ocean) in 1980. Kaczynski and Palmisano (1993) calculated and used an average weight per salmon of (6.34 + 5.55 + 0.13) / 3 = 4.01 kg) independent of the number of salmon. The weight of the smolts is therefore greatly exaggerated. If the more accurate weighted averages are used, then the result is [6.34 kg (48,700 chinook) + 5.55 kg (40,200 coho) + 0.13 kg (560,300 steelhead)] /3 = 0.93 kg or 2.1 lbs. average weight per fish. Kaczynski and Palmisano (1993) divided 604.5 MT by the incorrect average weight (4.01 kg) resulting in an estimate of 150,00 fish eaten. Harvey's table already provided the number of fish for each species; it is not explained why Harvey's calculations were not used. The correct method would be to use the number and weight of fish directly from Harvey (1988).

The number of fish consumed as calculated by Kaczynski and Palmisano (1993) was then compared to the commercial ocean harvest data from Pacific Fisheries Management Council's reports. There are problems with this comparison. The PFMC data are for coho and chinook only, but the data from Harvey, as used by Kaczynski and Palmisano (1993), include steelhead, a noncommercial species. Furthermore, the data from Harvey also include the Columbia River population of harbor seals, which are not included in the ocean harvest data used by Kaczynski and Palmisano (1993). If the Columbia population of harbor seals is excluded and Harvey's estimates of fish numbers is used, then the number of chinook and coho eaten by seals on the Oregon coast totals 79,800 fish or the equivalent of 13 percent of the ocean commercial catch of coho and chinook for 1980 (592,000 fish).

To assess the impact of harbor seals on the salmon population, all forms of mortality must be considered and it is inappropriate to compare the seal take only with commercial take, as most previous estimates have done. If the total of commercial harvest, sport catch (ocean and fresh water) and seal predation is compared to seal predation alone, then the relative impact of seals can be more accurately assessed. However, in addition to the problems with their methods given above, Kaczynski and Palmisano (1993) also made some arithmetic errors and omitted some essential data. These problems and mistakes are shown in Table 9. In this table, we reanalyzed Harvey's data to correct for arithmetic errors for harbor seal take. In addition we added ocean sport catch and fresh water sport catch, so that the harbor seal take can be seen as a percentage of total human harvest. This table merely illustrates the mathematical errors in their calculations. As we have discussed, one can question the validity of the original data and therefore the conclusions, even when the calculations are corrected.

The corrected figure of total salmon mortality (1,057,700 fish) see Table 1) does not include estimates of mortality from bycatch, noncatch mortality, illegal catch, or other sources of mortality attributable to humans, which would result in an even smaller percentage attributable to seals.

Kaczynski and Palmisano (1993) also attempt to estimate the impact of marine mammal predation in 1990 by extrapolating the values used in the 1980 estimate, even though the commercial catch was significantly lower in 1990, and fewer fish would be assumed available for consumption. They estimated that individual seals and sea lions were eating the same number of fish as in 1980 when salmon were more abundant. However, seals and sea lions are selective and opportunistic feeders, which means that they prefer certain prey but will take food as the opportunity arises, including less desirable foods. Such selectivity and opportunism is well known for land mammals, as discussed in the next section, whose above-water food habitats are easier to observe. Therefore it is unreasonable to assume that they would expend the extra effort necessary to obtain scarcer salmon when other prey species were available.

TABLE 1

TABLE 9: Correction of Kaczynski and Palmisano calculation of percent salmon taken by harbor seals. The column labeled "CSE" corrects mathematical errors in the estimation of harbor seal catch, and adds sport catch, which was omitted by the authors in their calculations. Units are numbers of fish.

Catch Source	CSE	Kaczynski and Palmisano
Commercial Ocean	592,000	592,000
Ocean Sport	345,000	N/A
Fresh Water Sport	40,900	N/A
Harbor Seals	79,800	150,000
Total	1,057,700	592,000
Percent Taken by Seals	7.5	25

Another problem with the type of estimates made by Kaczynski and Palmisano and others is that these estimates assumes the entire seal or sea lion population feed identically, that the annual food intake can be represented by a single constant, and that salmon are available to each pinniped throughout the year. These are completely unrealistic assumptions. If a particular pinniped consumed only salmon during salmon runs, salmon would account for only a small portion of the animal's annual food.

In summary, giving credence to the existing data, but correcting for mathematical errors, it is clear *that marine mammals are a minor factor in the harvest of salmon.* Moreover, *we have found serious problems with the existing data and analyses. Few of the data have been obtained by statistically-legitimate methods. This is particularly unfortunate because the topic has been the subject of debate for almost a century and the statistical methods required for appropriate sampling are well known; this issue is one of the most soluble of all those that surround the debate about salmon.*

Opportunistic Feeding : Early studies by Merriam and Dyche (Merriam 1901) indicated that sea lions prefer squid, but will feed on fish if nothing else is available (as in captivity), and feed on salmon in particular when it is easy to take (as when they are in traps). It is to be expected that the daily intake of salmon by sea lions and seals will depend on the relative abundance of salmon of an appropriate size compared to other prey species. This relative abundance varies with distance from river mouths where the salmon spawn, time of year, and other factors. A more complete model of the biomass of salmon consumed annually by a sea lion or seal population is described by Harvey (1988) with modifications for time and location strata for feeding, and correction factors for scat analyses based on the recovery of prey structures used by Olesiuk et al. (1990). These models take into account the different metabolic rates of different sex and age classes, variation in feeding by location and time of year, and inaccuracies associated with scat analyses for prey remnants, for which there are correction factors.

Parallels with Terrestrial Predators: Predators have always been an emotional subject, particularly to resource users who perceive predators as competitors. The history of terrestrial predators and both livestock grazing and hunting is remarkably parallel to that of marine mammals and fisheries. Many hunters and livestock raisers have considered predators to be their enemy and therefore it is instructive to discuss the comparison and some examples from terrestrial situations. Part of the livestock industry and populations of game animals have experienced declines, often, in the case of game animals, due to environmental variables including habitat degradation, frequently combined with past over-hunting, and in the case of livestock, due to social and economic factors. Where these factors are beyond the control of the ranchers or hunters, they often focus on predation, the factor that they feel they can control, particularly where populations of predators are believed to have increased. Often the demand is that the predators be reduced or eliminated, just has been the case for marine mammals assumed to feed on salmon. Where research is available it usually shows that the predators are not the cause of the resource users' problems. However, *in a few cases predation is significant and most often the result of only a few individual animals, and what is needed is not a program aimed at overall elimination or reduction of the predators but rather one that effectively targets the problem animals.* What is also needed is recognition of the real role that predators play. As President Nixon stated, "the old notion that the only good predator is a dead one is no longer acceptable as we understand that even the animals and birds which sometimes prey on domesticated animals have their own value in maintaining the balance of nature" (Nixon 1972).

It appears that lessons from the terrestrial predator situation may directly apply to the marine mammal/salmon situation. For example, marine mammal numbers have increased while salmon catch has decreased and some concerned people perceive a cause-and-effect relationship, as we have noted earlier and just as Dr. Merriam noted and refuted over 90 years ago. A current study of sea lion predation on steelhead notes the apparent widespread decline of the fish, but concludes that, "While marine mammal predation may be important locally ... it does not appear to be great enough to explain the general decline" (Fraker 1994), a conclusion similar to the terrestrial predation situation.

In addition, the state of knowledge of pinnipeds' food habits has not improved significantly since 1901. We know that like terrestrial predators, marine mammals have a highly variable diet and some of their predation may have important implications within their ecosystem. In the case of coyotes, rabbits and other rodents are their main food item, so coyotes' predation on rodents actually benefits sheep by reducing the direct competition for food between sheep and rodents. Similarly, it is known that sea lampreys are a main food item for some marine mammals, and since lampreys are parasites of salmon, it may be that marine mammals predation on lampreys also benefits salmon.

To return to the main subject at hand, it is clear that some sea lions do eat salmon, and there are problem animals, as there are with terrestrial predators. Perhaps the most widely publicized are the sea lions at the Chittenden Locks in Seattle. But even here the problem is apparently restricted to a few animals. Fraker (1994) notes, "Clearly, the majority of sea lions near the locks must be getting most of their food by eating something other than steelhead." In this situation the salmon are particularly vulnerable to predation because they are crowded and restricted by the locks. In more open situations, however, it is questionable that marine mammals are in fact effective predators of salmon. Consider the observed bite marks and other scars on salmon migrating upstream, scars that are attributed to seals and sea lion attacks that have been used to justify the conclusion of heavy predation. If predation were highly effective and only a few fish escaped, then a high percentage of scarred fish might indicate very heavy predation loss. If seals and sea lions are not highly effective salmon predators (except in the limited situation noted above), then a high percentage of scarred fish could also indicate a high percentage of unsuccessful attacks and would lead to the conclusion that marine mammals are not effect predators of salmon. *Thus the presence of scarred fish is not a reliable indication of how many salmon are killed by marine mammals.*

Statistical Sampling of Food Consumption: The major unknown in determining the total take of salmon by sea lions and seals is the percentage of salmon in their diet (variable *S* in equation M). The panel is amazed that after 96 years of discussion, argument, and measurement, no study has been conducted to obtain a statistically valid estimate of this percentage. While it may take decades or centuries to observe complete effects of changes in forest practices, a statistically-valid sample of sea lions and seals could be obtained in only a few years. Survey sampling methods, such as those used to sample bycatch referred to earlier, would allow a stratified random sample that would require sparse sampling. Only a small number of animals would be sampled using current state-of-the-art sampling techniques. Stomach contents could be analyzed as a function of season and geographic location. Using this information, an estimate with a mean and variance could be calculated to resolve if sea lions and seals are taking enough salmon to affect population growth and persistence.

In order to agree on what would be a reasonable estimate of the annual pinniped take of salmon, people must be informed on what amount of marine mammal take would constitute a problem to the salmon population. *No one appears to have discussed how much salmon, or what percentage of the population size, would have to be taken to have an important impact.* The answer to this would be obtained by developing a realistic, valid model of salmon populations that could calculate net population growth. Then one could calculate the number of salmon that, when removed, would change the growth rate from positive to negative. With a realistic estimate of the actual take by marine mammals, citizens would be in a position to consider tradeoffs that accommodate commercial and sport fisheries, salmon populations, and marine mammals.

A More Realistic Model of Marine Mammal Predation on Salmon : A plausible model of the biomass of salmon consumed annually by a sea lion or seal population would include the following parameters:

- the time of the year when salmon are high in density in areas subject to marine mammal predations (estuaries, river mouths, and lower river reaches);
- the actual salmon density during that portion of the year when density is high;
- the mean and variance of the biomass per salmon during the high density portion of the year;
- the density of salmon during the low-density portion of the year;
- the mean and variance of the biomass per salmon during the low-salmon-density portion of the year;

- the density of other prey during the portion of the year when salmon density is high;
- the mean and variance of the biomass of other prey during the high-salmon-density portion of the year;
- the density of other prey during the portion of the year of low-salmon-density;
- the mean and variance of the biomass of other prey during the low-salmon-density portion of the year; and

Development of this model would allow estimating marine mammal predation on salmon and forecasting future marine mammal effects.