West Coast Pinniped Program Investigations on California Sea Lion and Pacific Harbor Seal Impacts on Salmonids and Other Fishery Resources

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EXECUTIVE SUMMARY

This report provides the results of the West Coast Pinniped Program established in 1997 by the National Marine Fisheries Service (NMFS) and Pacific States Marine Fisheries Commission (PSMFC) to investigate the impacts of expanding pinniped populations on salmonids (especially ESA-listed salmon) and other fishery resources. The Program was primarily funded with Congressionally designated line-item funding of about $750,000 per year for "*a study of the impacts of California sea lions and harbor seals on salmonids and the West Coast ecosystem*." Over 150 projects were completed through 2008 and are described in this report. The accomplishments of the West Coast Pinniped Program relative to the recommendations in the 1999 "*Report to Congress: Impacts of California Sea Lions and Pacific Harbor Seals on Salmonids and West Coast Ecosystems*" is presented in the conclusion.

Investigations on pinniped predation on salmonids were conducted in west coast rivers and estuaries including rivers draining into Hood Canal, Ozette River, Columbia River, Alsea River, Rogue River, Klamath River, Mad River, and San Lorenzo River; and at Bonneville Dam, Willamette Falls, San Juan Islands, Año Nuevo Island, and Monterey Bay. The field studies used observations of pinniped surface-feeding events to estimate salmonid predation and/or analyses of pinniped fecal material (scat) to determine overall diet, as well as tracking of pinniped movements to infer foraging behavior. Captive feeding studies were conducted to assess prey digestion variables that affect pinniped consumption estimates derived from scats. Genetic identification techniques were developed and applied to identify salmonid species from the bones in scats. The pinniped predation studies documented that salmonids are a common prey species for Pacific harbor seals and California sea lions in many west coast rivers/estuaries and even in open marine waters (e.g., Monterey Bay), and pinnipeds can adversely affect the recovery of ESA-listed salmonid populations.

The population growth and status of California sea lion and Pacific harbor seal populations were investigated, and assessments indicated the Washington and Oregon harbor seal populations were at their optimum sustainable population (OSP) levels. Population assessments initially demonstrated that California sea lions had reached OSP, but continued exponential growth indicated from the 2006 to 2008 pup counts suggest the population is not yet at OSP. Additional surveys are needed to affirm California harbor seal status.

Pinniped interactions with commercial and recreational fisheries in California were investigated. California sea lions were documented interacting with hook-and line fisheries for salmon, Pacific barracuda, yellowtail, and other important fishery species. The removal of catch or bait from fishing gear was the principal interaction problem; the severity of loss varied by area, target species, and year.

Pinniped deterrence efforts to deter or remove pinnipeds from resource conflicts including hazing, pyrotechnics, acoustic deterrence, underwater shock waves (pulsed power), taste aversion, rubber projectiles, electric barriers, and physical barriers are described and evaluated. The evaluation indicated that the non-lethal deterrence measures have limited effectiveness; while some measures appeared to be initially effective, they became ineffective over time as pinnipeds "learned" to either tolerate or avoid the deterrence measure.

The West Coast Pinniped Program made significant progress in developing and applying methodologies to determine pinniped impacts on salmonids; however, further research is needed to better estimate pinniped impacts on ESA-listed salmonids.

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INTRODUCTION

In the 1994 Amendments to the Marine Mammal Protection Act of 1972 (MMPA), Congress directed that a scientific investigation be conducted to "*determine whether California sea lions and Pacific harbor seals a) are having a significant negative impact on the recovery of salmonid fishery stocks which have been listed as endangered or threatened under the Endangered Species Act (ESA), or which the Secretary finds are approaching such status, or b) are having broader impacts on the coastal ecosystems of Washington, Oregon, or California*." The responsible federal agency, the National Marine Fisheries Service (NMFS), determined it did not have the resources nor sufficient time to conduct a thorough field investigation on the issues identified by Congress, so NMFS convened a state/federal working group that prepared a report in 1997 titled "Investigation of Scientific Information on the Impacts of California Sea Lions and Pacific Harbor Seals on Salmonids and on the Coastal Ecosystems of Washington, Oregon, and California" (NMFS 1997). This "Investigations Report" was essentially a review of information from past field studies and made recommendations for specific, targeted studies that should be designed to address pinniped impacts on salmonids and other fishery resources (NMFS 1997). After completing the 1997 Investigations Report, NMFS in consultation with the Pacific States Marine Fisheries Commission (PSMFC) developed a "Report to Congress: Impacts of California Sea Lions and Pacific Harbor Seals on Salmonids and West Coast Ecosystems" that provided agency findings on west coast pinniped issues, recommendations for amendments to the MMPA and recommendations for additional research (NMFS 1999a).

In 1997, Congress identified dedicated funding for NMFS and PSMFC (on the behalf of the state fish and wildlife agencies in Washington, Oregon, and California) for "*a study of the impacts of California sea lions and harbor seals on salmonids and the West Coast ecosystem*" (House Report 105-405). This dedicated Congressional funding, ranging from $500,000 in fiscal year 1998 to $750,000 in fiscal years 2000 through 2005, allowed NMFS and PSMFC to establish a "West Coast Pinniped Program" to design, plan and implement studies to evaluate the impacts of expanding pinniped populations on salmonids and west coast fishery resources. The resulting West Coast Pinniped Program studies, which are described in this report, were designed to follow-up on the 1997 Investigation Report (NMFS 1997), and address the recommendations and findings in the 1999 Report to Congress (NMFS 1999a).

The formation of the West Coast Pinniped Program coincided with the listing of many west coast salmonid populations under the Endangered Species Act (ESA). Thus, a program priority was to obtain better information on potential impacts of expanding pinniped populations on ESA-listed salmonid populations. Studies were structured to investigate pinniped food habits in areas of overlap with ESA-listed salmonids (e.g., at river mouths and estuaries) with emphasis on conducting surface observations of pinniped predation on salmonids as well as scat analysis.

This report provides the results of the investigations by the West Coast Pinniped Program and other relevant expanding pinniped population studies through 2008. Funding for the investigations was primarily from the dedicated Congressional funding (1998 to 2005); other funding sources included MMPA implementation funds, Saltonstall-Kennedy Grants, NMFS Regional Office funds, state and tribal funding, and private and foundation funding.

WEST COAST PINNIPED PROGRAM

The West Coast Pinniped Program was established in 1997 as a cooperative state/federal program for designing and implementing a coastwide program to study and monitor the effects of expanding populations of Pacific harbor seals and California sea lions. The program investigations focused on five areas:

- Pinniped affects on ESA-listed or declining stocks of salmonids
- Pinniped conflicts with commercial and recreational fisheries
- Non-lethal methods to mitigate pinniped conflicts with people and other resources
- Pinniped population assessments
- Other coastal ecosystem pinniped impacts.

Under the direction of the NMFS Northwest Regional Office in Seattle, WA, a West Coast Pinniped Program Work Group was formed consisting of state/federal/tribal/academic resource managers, biologists and researchers on the west coast. The Work Group included the researchers who conducted the field studies described herein. The Work Group members, shown in Appendix A, were from the NMFS Northwest Regional Office (NWR), NMFS Southwest Regional Office (SWR), the NMFS Southwest Fisheries Science Center (SWFSC), NMFS Northwest Fisheries Science Center (NWFSC), NMFS Alaska Science Fisheries Center - National Marine Mammal Laboratory (NMML), NMFS Headquarters Office of Protected Resources, Pacific States Marine Fisheries Commission (PSMFC), Washington Department of Fish and Wildlife (WDFW), Oregon Department of Fish and Wildlife (ODFW), California Department of Fish and Game (CDFG), California State University - Moss Landing Marine Laboratories (MLML), California State University - Humboldt State University (HSU), and the Yurok Indian Tribe Fisheries Program (YTFP). Pinniped researchers from the Canada Department of Fisheries and Oceans, University of Washington, Oregon State University, and other federal/state researchers also participated in Work Group meetings and workshops.

The West Coast Pinniped Program identified the key studies needed to address expanding pinniped population issues, collectively developed study plans, critiqued methods and techniques, discussed and reviewed field work, provided recommendations and input to researchers, convened workshops, held annual meetings to review progress and findings of pinniped studies, reviewed proposals for new and continuing studies, and implemented appropriate studies. NMFS, PSMFC and State fish and wildlife agency members of the Work Group provided recommendations and priorities for allocation of the Congressionally-directed pinniped funds to necessary studies. Workshops and symposia convened or sponsored by the West Coast Pinniped Program included:

- Workshop - Pinniped Predation on Salmonids: Study Design, Field Methods, Data Analysis and Evaluation - May 1997, Corvallis, OR.
- Washington Harbor Seal OSP Workshop - May 1998, Seattle, WA. (Huber and Laake 1998)

- Workshop on Sampling Methodologies to Assess Pinniped Predation on Salmonids - July 1998, Portland, OR.
- Workshop on Field and Analytical Methodologies for Assessing Pinniped Predation on Salmonids - April 1999, Newport, OR. (Didier and Scordino 1999)
- Pinniped Prey Identification and Quantitative Analysis Workshop - December 2000, Seattle, WA. (Riemer and Lance 2001)
- Marine Mammal/Fisheries Conflicts Workshop - January 2000, Moss Landing, CA.
- Pinniped Prey Identification and Quantitative Analysis Workshop - November 2001, Vancouver, B.C.
- Interactions of Pinnipeds and Fisheries in the North Pacific - Symposium at the 14th Biennial Conference on the Biology of Marine Mammals - Dec 2001, Vancouver, B.C. (Harvey and Scordino 2001)
- California Harbor Seal Abundance Workshop - March 2002, La Jolla, CA. (Barlow 2002)
- Fisheries Interaction Roundtable with Commercial and Recreational Fishermen - May 2003, Monterey, CA.
- Non-Lethal Deterrence Workshop - December 2005, La Jolla, CA.

The West Coast Pinniped Program studies assessed pinniped food habits and their impacts on salmonids, population status and trends of California sea lions and Pacific harbor seals, severity and impacts of pinniped interactions with fisheries, and deterrence methodologies. A listing of the studies funded under the West Coast Pinniped Program with the Congressionally directed and NMFS funds is shown in Appendix B. Summaries of the results of the studies are provided in the following sections of this report.

PINNIPED PREY AND PREDATION ON SALMONIDS

The West Coast Pinniped Program prioritized the allocation of funds to food habit studies that assessed the impacts of pinniped predation on ESA-listed salmonids. Study plans, which provided sampling approach and frequency and analytical design, were prepared by principal investigators and reviewed by the West Coast Pinniped Program Working Group before funds were allocated. Surface observations of pinniped predation at river mouths and upriver where pinnipeds and salmonids co-occurred was the preferred approach for estimating salmonid predation, with the collection and analysis of pinniped scats to assess overall food habits. In most cases, funding was not sufficient for comprehensive sampling, and field observation study designs had to be structured to optimize the probability of observing predation events. Study sites and designs were adjusted between years in some investigations to optimize sampling and ensure statistically reliable results. A brief description of each study and a summary of the primary results are provided below in a north to south order.

HOOD CANAL

WDFW researchers conducted pinniped predation studies in Hood Canal, Washington to evaluate the effects of harbor seal predation on the recovery of the ESA-listed summer chum salmon runs in the Quilcene, Dosewallips, Duckabush, Hamma Hamma and Skokomish River systems. Hood Canal was the focus of the predation studies by WDFW because of the isolated nature of the Hood Canal system and the year-round presence of about 1,500 harbor seals co-occurring with runs of summer chum salmon, fall chum salmon, coho salmon, pink salmon and Chinook salmon. The sources of information on the Hood Canal harbor seal study are Jeffries et al. (2000a, 2001, 2004), London (2006), London et al. (2002, 2003), Lance and Jeffries (2009a, 2009b), Lance et al. (2005), and Lance pers. comm. (2009).

Methods - Hood Canal

WDFW investigated harbor seal food habits and predation on salmon runs in Hood Canal from 1998 through 2003 using surface predation observation techniques, scat analysis, and through capture, tagging, and tracking of seals. Daylight surface observations of harbor seals foraging on salmon were conducted from shore within the intertidal regions of the Quilcene, Dosewallips, Duckabush, Hamma Hamma Rivers from September to November in 1998-2001 and 2003. The Skokomish River was observed only in 1998 and 1999. Observations were conducted from one site in each river except for the Duckabush which had a second upriver observation site in 1999 to 2001 and in 2003. After a preliminary night observation feasibility evaluation in 1999, night observations were conducted from the two observation sites in the Duckabush River in the fall of 2000, 2001 and 2003. Harbor seal scats were collected at haul-out sites near the mouths of all five rivers in 1998-2001 and 2003-2005; all hard parts of prey remains in the scats were identified to species when possible. In 2002, WDFW focused its studies on applying radio transmitters to harbor seals and tracking their movements between haul-out sites and foraging areas. Studies in 2003 and 2005 addressed the potential effects of transient killer whale foraging on harbor seals in Hood Canal. The WDFW Genetics Laboratory applied molecular genetic techniques to salmonid bones in scat to identify species.

Surface Predation Observations - Hood Canal

WDFW conducted surface observations during five years (1998 through 2001, and 2003). Harbor seals were responsible for all observed predation events except for two observations in 1998 of California sea lions consuming salmon at the Hamma Hamma River. Harbor seals were observed feeding on Chinook, coho, pink, summer chum and fall chum salmon. The number of seals observed foraging for salmon at the river mouths averaged from two to seven seals each day which represented less than 5% of the total population of seals that used nearby haul-outs.

In 1998, WDFW conducted 817 hours of observations at the mouths of the Quilcene, Dosewallips, Duckabush, Hamma Hamma and Skokomish River systems from September 5 to November 20, 1998. WDFW observed 82 harbor seal predation events on chum and coho salmon. Harbor seal predation on salmon was observed at all five river mouths. At Quilcene, 73% of the predation events identified to species were chum and 27% were coho indicating a potential selection for chum over coho by foraging harbor seals. Based on the surface predation observations, WDFW estimated 1,230 salmon were taken by harbor seals in 1998.

In 1999, WDFW conducted 1,212 hours of observations at the mouths of the Quilcene, Dosewallips, Duckabush, Hamma Hamma and Skokomish River systems from August 15 to November 11, 1999. WDFW observed 135 harbor seal predation events on chum, coho, pink and Chinook salmon. The observation data collected by WDFW in 1998 and 1999 indicated that 70% of the predation events were occurring during the incoming tides. WDFW estimated 1,282 salmon were consumed by harbor seals in 1999.

In 2000, WDFW conducted 696 hours of observation (592 hours during daytime and 104 hours at night) at the mouths of the Quilcene, Dosewallips, Duckabush, and Hamma Hamma river systems from August 20 to October 29, 2000. Night observations were conducted for six weeks at the mouth and about 0.5 kilometers upriver in the Duckabush River, and salmon predation was observed. WDFW observed a total of 104 harbor seal predation events on salmon at all four rivers. WDFW estimated 666 salmon were consumed by harbor seals in 2000.

In 2001, WDFW conducted 528 hours of observation (320 hours during daytime and 208 hours at night) at the mouths of the Duckabush and the Dosewallips River systems from August 12 to November 1, 2001. Night observations were conducted on 12 nights at the two sites in the Duckabush River, and predation was observed. WDFW observed a total of 233 harbor seal predation events on salmon in both rivers. WDFW found that there was a difference between day and night salmon consumption. The mean number of seals and predation events observed at night was 4.04 and 1.88 respectively, compared with 7.70 and 5.04 during daytime. The extent though to which the difference might be caused by the inherent reduced visibility at night was not determined. WDFW estimated 2,065 salmon were consumed by harbor seals in 2001.

In 2003, WDFW reinitiated fall observations to determine if killer whale predation on harbor seals (see description below) had changed the dynamics of the Hood Canal harbor seal population and foraging on salmon. WDFW conducted 540 hours of observation (436 hours during daytime and 104 hours at night) at the mouths of the Duckabush and the Dosewallips River systems from August 11 to October 18, 2003. Night observations were conducted on 12 nights at the two sites at the Duckabush River. At least six individual seals in the Dosewallips and eight seals in the Duckabush were observed repeatedly, indicating individual animal preference for foraging on salmon in these rivers. WDFW observed 294 harbor seal predation events on salmon, and estimated 2,421salmon were consumed in 2003.

Scat Collections and Analyses - Hood Canal

In 1998, WDFW collected 601 harbor seal scats during 16 collection trips from haul-out sites near the mouths of the Dosewallips (243 scats), Duckabush (7 scats), Hamma Hamma (68 scats), Quilcene (156 scats) and Skokomish (127 scats) from August 14 to November 13, 1998. WDFW found an average of 1.8 different prey per scat and 19 different prey taxa in 581 scats with identifiable remains. The most frequently occurring prey were Pacific whiting - 85% (ranging from 79% to 100% of scats at each river), Pacific herring - 44% (ranging from 39% to 47% of scats at each river), and salmonid - 26%. The occurrence of salmonids in scat from each river system was: 36% at the Skokomish, 25% at Quilcene, 21% at Hamma Hamma, 21% at Dosewallips, and 14% at Duckabush.

In 1999, WDFW collected 608 harbor seal scats near the mouths of the Hood Canal rivers during 29 collection trips in the spring and fall. WDFW identified 23 different prey taxa in 598 scats with identifiable remains. The average number of different prey per scat was 2.2 in the spring and 1.9 in the fall. WDFW collected 197 harbor seal scats in the spring at the Dosewallips (170 scats), Quilcene (10 scats), and Skokomish (17 scats) from March 17 to June 3, 1999. In the fall, WDFW collected 411 scats at the Dosewallips (199 scats), Duckabush (9 scats), Hamma Hamma (40 scats), Quilcene (115 scats), and Skokomish (48 scats) from July 15 to December 3, 1999. The most frequently occurring prey in the spring scat samples were: Pacific whiting - 81%, Pacific herring - 40%, northern anchovy - 27%, and salmonid - 16%. The most frequently occurring prey in the fall scat samples were: Pacific whiting - 72%, Pacific herring - 41%, and salmonid - 29%. The frequency of occurrence of salmonids in the fall in each river system was: 40% at Skokomish, 36% at Quilcene, 36% at Hamma Hamma, 21% at Dosewallips, and none at the Duckabush.

In 2000, WDFW collected 608 harbor seal scats during 25 collection trips from July 18 to November 15, 2000 at Dosewallips (156 scats), Quilcene (245 scats), Duckabush (127 scats), and Hamma Hamma (80 scats). WDFW found an average of 2.1 different prey per scat and 23 different prey taxa in the 596 scats with identifiable remains from the fall collection. The most frequently occurring prey in the scat samples were: Pacific whiting - 79%, herring spp. - 49%, and salmonid - 27%. The occurrence of salmonids by river was: 35% at Hamma Hamma, 23% at Quilcene, 18% at Dosewallips, and 16% at Duckabush River.

In 2001, WDFW collected 424 harbor seal scats from haul-out sites near the mouths of the Dosewallips (175 scats), Duckabush (102 scats), and Quilcene (147 scats) during 20 collection trips from August 31 to November 7, 2001. WDFW found an average of 2.0 different prey per scat and 18 different prey taxa in 417 scats with identifiable remains. The most frequently occurring prey in the three river systems were Pacific whiting - 58% (ranging from 29% to 72% of scats at each site), salmonid - 35% (with 45% occurrence at Duckabush, 41% at Quilcene, and 19% at Dosewallips), and Pacific herring - 33% (ranging from 19% to 44% of scats at each site).

In 2003, WDFW collected 120 harbor seal scats from haul-out sites near the mouths of the Dosewallips (93 scats), Duckabush (24 scats), and Quilcene (3 scats) during ten collection trips from August 15 to October 15, 2003. WDFW found an average of 1.8 different prey in each scat and 13 different prey taxa in 119 scats with identifiable remains. The most frequently occurring prey in the scat samples were: Pacific whiting - 51%, Pacific herring - 52%, and salmonid - 24%. The salmonid occurrence by river was: Dosewallips - 23%, Duckabush - 17%, and Quilcene - zero.

In 2004, WDFW collected 170 scats at harbor seal haul-out sites near the mouth of the Dosewallips (129 scats) and Skokomish (41 scats) during six collection trips in the fall from September 2 to November 9, 2004. WDFW found an average of 2.0 different prey per scat and 18 different prey taxa in 170 scats with identifiable remains. The most frequently occurring prey in the scat samples were: Pacific whiting - 39%, Pacific herring - 37%, and salmonid - 34%. The salmonid occurrence by river was 40% at Dosewallips and 10% at the Skokomish.

In 2005, WDFW collected 449 harbor seal scats at haul-out sites near the mouths of the Hood Canal rivers during 23 sampling trips in the spring and fall. WDFW identified 15 prey taxa in 447 scats with identifiable remains. The average number of different prey in each scat was 2.2 in the spring and 1.8 in the fall. WDFW collected 205 harbor seal scats in the spring at the Dosewallips (82 scats), Duckabush (5 scats), Hamma Hamma (13 scats), and Skokomish (105 scats) from April 5 to June 13, 2005. In the fall, WDFW collected 244 scats at the Dosewallips (86 scats), Duckabush (2 scats), Hamma Hamma (40 scats), Quilcene (66 scats), and Skokomish (50 scats) from July 18 to September 9, 2005. The most frequently occurring prey in the spring scat samples were: Pacific whiting - 53%, northern anchovy - 43%, shiner perch - 27%, herring spp. - 20%, and salmonid - 13%. The most frequently occurring prey in the fall scat samples were: Pacific whiting - 59%, Pacific herring - 19%, and salmonid - 21%. The occurrence of salmonids for each river system in the fall was: 39% at Skokomish, 17% at Quilcene, 10% at Hamma Hamma, 17% at Dosewallips, and none at the Duckabush River.

Genetic Analysis of Salmon Bones in Scat - Hood Canal

The WDFW Genetics Laboratory used single nucleotide polymorphisms (SNPs) DNA analysis for salmonid species identification on 393 salmon bones from 339 different scat samples collected from 1999 to 2001. Eighty-five of the 393 samples analyzed (22%) failed to yield detectable PCR products. Another 16 samples (4% of all samples analyzed) yielded PCR products that had electropherogram patterns on the DNA sequencer that could not be reliably interpreted. The remaining 292 bones (74%) were successfully identified to species.

Chum salmon was the single most common species identified in all years, ranging from 37% (2001) to 62% (1999) of all bones identified to species. Overall, the salmonid remains were identified as chum salmon - 51%, coho salmon - 22%, Chinook salmon - 16%, pink salmon - 5%, and cutthroat trout - 6%.

Two or more salmonid bones were analyzed from 32 scat samples. There were 17 cases where two bones were analyzed and determined to be from the same species, 14 cases where two bones were analyzed and found to be from different species, and one case where three bones were analyzed and each bone was from a different species.

Comparison of Occurrence of Salmon in Scat and from Surface Predation Observations

WDFW used the split-sample frequency of occurrence (SSFO) model on the scat data to estimate numbers of salmon consumed during the Hood Canal fall observation periods in 1998 and 1999. Using SSFO, WDFW estimated the salmon biomass consumed at 14,079 kg in 1998 and 16,391 kg in 1999, representing 2,830 and 2,802 individual salmon consumed each year, respectively. These estimates based on scat were over double the estimated 1,230 and 1,282 individual salmon consumed in 1998 and 1999, respectively based on surface observations. This analysis indicated that either the model was overestimating salmon consumption or additional salmon predation was occurring away from river mouths and was not observed.

Capture, Tagging and Tracking Harbor Seals - Hood Canal

WDFW captured harbor seals and applied satellite tags, sonic tags, VHF radio transmitters, and time depth recorders (TDR) to track seal movements and foraging. WDFW found that individual seals appeared to habitually return to forage in the same specific areas. Satellite and radio tag data indicated that seals haul out at consistent locations and forage in distinct areas approximately 10 kilometers from their haul-out site. Examination of telemetry data from seals tagged with VHF and sonic tags also showed the same seals were present in the river during both day and night.

Estimating Predation on Summer Chum Salmon - Hood Canal

To estimate predation on summer chum salmon using surface observations, WDFW had to make assumptions on allocating observations of “unidentified salmon” predation events to a particular species and on the extrapolation of observed predation rates across day and night periods. After multiple analyses, WDFW calculated harbor seal consumption of summer chum salmon with an assumption that 1) night predation rates were equal to those observed during daylight hours, and 2) harbor seals consumed salmon species in proportion to their relative abundance. WDFW compared day and night predations in 2000, 2001 and 2003 in a paired analysis. Results of the paired analysis showed a significant difference in the number of predations observed. On average, approximately three times as many predations were observed during the day, than at night. However, the number of seals in the river and the behaviors observed were considered the same. WDFW determined that the paired analysis likely said more about how difficult it was for observers to confirm predations at night compared with day than any indication of actual difference in predation rates, and thus used a 24-hour constant predation rate. In regard to the assumption of equal allocation (i.e., seals consume salmon species in relationship to their abundance), WDFW compared those predations identified to species by observers with the relative abundance of salmon species in the study areas and found that the assumption of equal allocation was reasonable. However, WDFW did find that in some years there were dramatic differences between relative abundance and observed predations.

WDFW estimated that harbor seals consumed an average of 8% of the returning adult summer chum salmon across all sites and all years. The greatest proportion of returning summer chum salmon consumed was 28% in the Dosewallips in 1998 and 27% in the Duckabush in 2000; all other rivers/years were 1% to 11% of the run consumed. The highest and lowest estimate (28% and 1%) of summer chum run consumed occurred at the Dosewallips in 1998 and 2001 respectively. The difference could have been due to the effect an abundant alternate salmonid species (i.e., pink salmon which returned only in odd years) can have as a potential buffer to predation on summer chum salmon.

Transient Killer Whale Impacts on Hood Canal Harbor Seals

In 2003 and 2005, transient (mammal-eating) killer whales foraged in Hood Canal for 59 and 172 days respectively. Prior to 2003, killer whales were considered a rare occurrence in Hood Canal. Harbor seals were likely the principal prey of these killer whales, and whales were observed consuming seals on several occasions. Bioenergetic models and boat-based observations were used by WDFW to estimate total harbor seal consumption by killer whales. The estimated consumption was approximately 950 seals for both years. However, aerial surveys conducted by WDFW following the killer whale foraging periods each year did not detect a significant decline in the harbor seal population.

Impact of Pinniped Predation on Salmonids - Hood Canal

Although the observed predation on salmon and frequency of salmon in harbor seal scat were among the greatest recorded on the west coast, the summer chum salmon populations in the study area increased over the time of the study to near historical highs due to a large supplementation program. Because of this increase, the levels of harbor seal predation observed were likely not significantly impacting the recovery of summer chum salmon in Hood Canal. If the summer chum population declines after cessation of the supplementation program, harbor seal predation may become a factor limiting recovery.

DUWAMISH RIVER

WDFW conducted a pilot study in 1999 and 2000 in the lower Duwamish River, which enters Puget Sound at Harbor Island in Seattle, Washington, to obtain a preliminary assessment of California sea lion foraging on free-swimming and gillnet-caught winter steelhead and other salmonids. This site was selected because of fishermen reports of California sea lions foraging on gillnet caught salmonids and free-swimming steelhead. The sources of information on the Duwamish River pinniped predation study are Walker (1999, 2001a).

Methods - Duwamish River

Surface observations were conducted primarily from a boat at the Duwamish River mouth and upstream. WDFW monitored for both free-swimming predation on salmonids and for sea lion removal of salmonids from the gillnet fishery for chum salmon and steelhead. Boat observations were conducted two to three days per week.

Surface Predation Observations - Duwamish River

In 1998/1999, WDFW conducted 307 hours of observations from December 15, 1998 to June 8, 1999. California sea lions were observed on 54% of the 52 days of observations. A maximum of five sea lions was observed at the same time on two days. Gillnet fishing occurred on five of the observation days and sea lion interactions with gillnets (i.e., sea lion approaches or contacts the gillnet) were observed on one day when a single sea lion interacted with a net twice. WDFW observed 12 steelhead killed by sea lions, all during days when gillnets were not present (i.e., free-swimming fish were taken), and estimated 61 adult steelhead were taken by sea lions during the observation period. California sea lions were also observed consuming salmonid smolts on several occasions, but no estimates of numbers were possible. Harbor seals were observed on 13 days. One gillnet interaction was observed, but no salmonid predation was observed.

In 1999/2000, WDFW conducted 297 hours of surface observations from November 15, 1999 to May 19, 2000. California sea lions were observed on 61% of the 56 days of observations. Gillnet fishing occurred on 13 of the observation days and sea lion interactions with gillnets (i.e., sea lion approached or contacted the gillnet or catch) were observed on two days; one of which involved a steelhead removal from a net. A maximum of four sea lions was observed at the same time on four days. WDFW observed 24 salmonids killed by sea lions (16 chum salmon, one coho salmon, three steelhead and four unidentified salmonids); all were free-swimming kills by sea lions except one steelhead removed from a net. WDFW estimated 172 adult salmonids were taken by sea lions during the observation period. California sea lions were also observed consuming salmonid smolts on several occasions, but no estimates of numbers were possible. Harbor seals were observed on 13 days, but no salmon predation or gillnet interactions were observed.

Impact of Pinniped Predation on Salmonids - Duwamish River

The potential impact of California sea lions on salmonids was not assessed in this pilot study. Although the numbers of salmonids taken appears minimal, further studies under a broader sampling plan that includes obtaining concurrent salmonid run abundance data would be needed before a definitive determination can be made on pinniped impacts.

SNOHOMISH RIVER

WDFW conducted a pilot study in 2001 in the lower Snohomish River, which enters Puget Sound at Everett, Washington, to obtain a preliminary assessment of California sea lion and/or harbor seal foraging on winter steelhead. California sea lions haul out in the Everett area each year from September to May. In the late 1980s, a peak count of 1,000 sea lions was reported in the Everett area, while counts in the 2000s have ranged from 100 to 300 sea lions at the log booms in the Everett Naval Base. Harbor seals occur year-round in the Snohomish River with

20 to 40 at a haul-out site at Smith Island in the lower Snohomish River area and 40 to 100 seals hauling out on log booms at the Everett Naval Base. The source of information on the Snohomish River pinniped predation study is Walker (2001).

Methods - Snohomish River

Surface observations were conducted primarily from a boat at the Snohomish River mouth and upstream including sloughs off the mainstem to the Interstate Highway bridge. Shore observations were conducted infrequently at several sites to focus observations on harbor seal activity. Boat observations were conducted two to three consecutive days per week.

Surface Predation Observations - Snohomish River

WDFW conducted 270 hours of observations from late February to early June 2001. Only one California sea lion was observed in the mainstem lower Snohomish River; no sea lions were observed in the sloughs. Harbor seals were observed in the mainstem Snohomish and the sloughs during each observation period, usually consisting of single seal sightings. No predation was observed.

Impact of Pinniped Predation on Salmonids - Snohomish River

Although the absence of any predation observations in this pilot study would suggest pinnipeds are not impacting salmonids in the Snohomish River, further studies under a broader sampling plan should be undertaken before reaching such conclusion on pinniped impacts.

SAN JUAN ISLANDS

WDFW investigated harbor seal food habits in the San Juan Islands, Washington to assess seasonal and temporal diet, and examine the dependence of harbor seals on forage fish and rockfish communities. Approximately 4,000 to 7,000 harbor seals occur on over 150 rocky and estuarine haul-out sites in the San Juan Islands area. The sources of information on the San Juan Islands harbor seal food habits studies are Lance and Jeffries (2006, 2007, 2009a).

Methods - San Juan Islands

WDFW investigated harbor seal food habits in the San Juan Islands by collecting scat from haul-out sites from 2005 through 2007 and identifying all hard parts of prey remains in the scat to species when possible.

Scat Collections and Analyses - San Juan Islands

In 2005/2006, WDFW collected 509 harbor seal scats during 11 collection trips at 18 haul-out sites from April 1, 2005 to February 17, 2006. WDFW found 35 different prey taxa in 507 scats with identifiable remains. Individual samples typically contained one to three (mean = 1.95) different prey species, but occasionally contained as many as eleven. The most frequently occurring prey in the scat samples were: Pacific herring - 57%, salmonids - 26%, gadids - 24%, Pacific sand lance - 20%, and northern anchovy - 19%. Diet differed among seasons with gadids, Pacific herring and Pacific sand lance important during spring, adult salmonids and Pacific herring during summer/fall, and Pacific herring, northern anchovy, gadids, Pacific sand lance and spiny dogfish during winter. Mean number of different prey species differed among seasons with winter diet the most diverse, with 3.59 different prey species, and summer/fall and spring less so with 1.72 and 2.14 different prey species, respectively. In general, species composition in harbor seal diet was comparable to fish abundance based on bottom trawl data and salmon return abundance timing in the San Juan Islands.

In 2006/2007, WDFW collected 398 harbor seal scats during 12 collection trips at 17 haul-out sites from April 13, 2006 to February 23, 2007. WDFW found 32 different prey taxa in 392 scats with identifiable remains. Individual samples typically contained one to three (mean 2.23) different prey species, but occasionally contained as many as nine. The most frequently occurring prey in the scat samples were: Pacific herring - 57%, salmonid - 19%, walleye pollock - 15%, rockfish - 12%, threespine stickleback - 12%, cephalopods - 11%, shiner perch - 11%, and Pacific sand lance - 10%. Diet differed among seasons with Pacific herring and northern anchovy important during spring, adult salmonids and Pacific herring important during summer/fall and Pacific herring, walleye pollock, shiner perch, rockfish species, and sculpins important during winter. The mean number of different prey species differed among seasons with winter diet the most diverse (2.79 prey species) and summer/fall more diverse (2.20 prey species) than spring (1.98 prey species). In general, species composition in harbor seal diet was similar to fish abundance based on bottom trawl data and the timing and abundance of salmon returns through the San Juan Islands.

Impact of Pinniped Predation on Salmonids - San Juan Islands

Although the potential impact of harbor seals on salmonid populations was not assessed in this study, the finding that salmonids were the second most frequently occurring prey in the scat in both years indicates the relative importance of salmonids as a prey species for harbor seals in the San Juan Islands. The high percentage of scats with salmon remains suggests salmonids were a principal prey species in this area. Thus, pinnipeds may adversely affect salmonid populations that occur or migrate through the San Juan Island area.

SOUTHERN PUGET SOUND

WDFW investigated harbor seal food habits in southern Puget Sound, Washington to assess seasonal and temporal diet. Approximately 1,200 harbor seals occur on five primary haul-out sites in southern Puget Sound. The source of information on the south Puget Sound harbor seal food habits study is Lance and Jeffries (2009a).

Methods - Southern Puget Sound

WDFW investigated harbor seal food habits in south Puget Sound by collecting scats from haul-out sites at Gertrude Island and Eagle Island in 1995, 1997 and 2004, and identifying all hard parts of prey remains in the scat to species when possible.

Scat Collections and Analyses - Southern Puget Sound

WDFW collected 314 harbor seal scats in October 1995, April to May 1997, June to August 1997, October to December 1997, and September 2004. WDFW found 41 different prey taxa in 311 scats with identifiable remains. The most frequently occurring prey in the scat samples were: Gadidae (Pacific whiting, Pacific tomcod) - 99%, Clupeidae (herring) - 69%, plainfin midshipman - 47%, flatfish - 33%, cephalopods - 19%, shiner surfperch - 14%, salmonids - 13%, and rockfish - 9%. WDFW did not find large seasonal fluctuations in diet; however, minor seasonal fluctuations in occurrence were observed for cephalopods, shiner surfperch, juvenile salmonids and rockfish. Prey assemblages in south Puget Sound seal diet were likely due to differences in habitat and the predominance of relatively shallow and calm inlets and bays.

Impact of Pinniped Predation on Salmonids - Southern Puget Sound

The potential impact of harbor seal foraging on salmonids was not assessed in this study. The occurrence of salmonids in scats exceeded 10% indicating salmonids were a common prey species for harbor seals in this area, and thus warrants further investigation.

OZETTE RIVER / LAKE OZETTE

NMML, in cooperation with the Makah Indian Tribe, investigated pinniped predation on ESA-listed sockeye salmon at the Ozette River and Lake Ozette, located in northwest Washington, from 1998 to 2001. Although there were no pinniped haul-out sites in or adjacent to the Ozette River, this site was chosen for predation studies because harbor seals had been reported upriver and pinniped scars had been observed on ESA-listed sockeye salmon that averaged 900 fish in the 1990s. The sources of information on the Ozette River / Lake Ozette harbor seal predation study are Gearin et al. (1999, 2000, 2002), and Gearin pers. comm. (2009).

Methods - Ozette River / Lake Ozette

NMML conducted surface observations in daytime and at night from shore at the mouth of the Ozette River in 1998 and 1999 to enumerate pinniped predation events and foraging. Vessel, diver and shore surveys were also conducted by NMML in Lake Ozette from 1998 to 2001. Scats were collected in 1998 from harbor seal, California sea lion and Steller sea lion haul-out sites on offshore rocks and islands within about six kilometers of the mouth of the Ozette River. There were no pinniped haul-out sites in or adjacent to the Ozette River, the closest harbor seal haul-out site was at East Bodelteh Island which is 3.6 kilometers from the Ozette River. All hard parts of prey remains in the scats were identified to species when possible. An underwater camera at an upriver weir located near Lake Ozette used to determine sockeye run size by the Makah Tribe also provided information on pinniped scarred fish, predation on sockeye by harbor seals and river otters, and movements of seals in and out of Lake Ozette. To assess pinniped scarring, NMML captured and marked sockeye in the lower river in 2000 and then recaptured the fish at the upriver weir to assess occurrence of new predator marks. NMML also collected data on river otter foraging because otters had been observed preying on sockeye at the upper river weir.

Surface Predation Observations - Ozette River / Lake Ozette

In 1998, NMML conducted 38 hours of surface observations at two shore sites in the lower Ozette River from June 3 to July 22, 1998. Up to three seals at a time were observed inriver during six of twelve daytime observation periods conducted over nine days. Although harbor seals were present and exhibiting foraging behavior, no predation events were observed. The upriver area of the Ozette River, from the mouth to the upriver weir (near the entrance to Lake Ozette), was also observed by NMML in May and June during four surveys by raft and swimmers. No harbor seals were sighted during these surveys.

Boat surveys were also conducted in Lake Ozette in 1998. One boat survey was conducted in June and two boat surveys in December at sockeye spawning grounds. No harbor seals were sighted during these surveys. Divers conducting spawning ground surveys in Lake Ozette on December 8 and 9, 1998 also saw no harbor seals.

In 1999, surface observations were conducted every day from June 8 to June 29, 1999 in the lower river and mouth of the Ozette River. NMML conducted 278 hours of observations, of which 62 hours were paired day-night observations. Harbor seals were observed on twelve of the daytime observation days, and were observed chasing sockeye in a pool just inside the mouth of the river on two days. No seals were observed at night. No predation events were observed.

Boat surveys were conducted by NMML on Lake Ozette on 10 days between June 24, 1999 and January 31, 2000. The surveys resulted in two sightings of harbor seals in Lake Ozette: one on January 13, 2000 and the other on January 31, 2000. Divers conducting spawning ground surveys in Lake Ozette from mid-November 1999 to mid-January 2000 observed harbor seals on six different days at the lake-side spawning beaches. On one survey, divers found portions of sockeye carcasses on the lake bottom that appeared to have been eaten by predators.

In 2000, NMML shifted the surface observation effort to focus on Lake Ozette during the sockeye salmon spawning period. NMML conducted 188 hours of daytime surface observations at four shore sites in Lake Ozette from November 2, 2000 to January 10, 2001. Harbor seals were sighted on nine of the 20 observation days in the lake. Based on concurrent sightings at different locations, there were at least two seals in the lake during the observation period. Harbor seals were observed foraging and chasing sockeye, and one harbor seal predation on a sockeye was observed. Divers conducting spawning ground surveys in Lake Ozette from November 2000 to mid-January 2001 found portions of sockeye carcasses on the bottom that appeared to have been eaten by predators. Divers collected 36 sockeye heads with evidence of mammalian bite and chew marks from depths greater than five meters indicating the predation was likely by a harbor seal or a river otter (and not by a terrestrial mammal). NMML examined 30 carcasses collected by divers that had bite and chew marks and determined that 28 of the carcasses had bites from a river otter (based on inter canine distances) and two had bite marks from a harbor seal.

Scat Collections and Analyses - Ozette River / Lake Ozette

Harbor seal scats were collected by NMML from May 6 to July 30, 1998 at haul-out sites on East Bodelteh Island, Ozette Reefs, Father and Son Rock, and Cooke Rock. All prey hard part remains in the scats were identified to species when possible in the 347 scats collected. NMML found 37 different prey (identified to species or family) in the 340 scats with identifiable remains and the most frequently occurring prey in these scat samples were: Pacific tomcod - 41%, smelt - 31%, and Pacific whiting - 29%. Salmonid remains were found in 1.5% of the scats, and the salmonid bones were identified as coho salmon and Chinook salmon by the NWFSC utilizing genetic identification techniques.

Steller sea lion were collected by NMML from May 6 to July 29, 1998 at haul-out sites on West Bodelteh Island, Sea Lion Rock, Carroll Island and Tatoosh Island. All prey hard part remains in the scats were identified to species when possible in the 124 scats collected. NMML identified 22 different prey in the 124 scats with identifiable remains and the most frequently occurring prey in these scat samples were: Pacific whiting - 88%, spiny dogfish shark - 24%, and starry flounder - 16%. Salmonid remains were found in 2% of the scats, and the one salmonid otolith in the remains was identified as a Chinook salmon.

California sea lion scats were collected by NMML on May 6, 1998 at a haul-out site on Sea Lion Rock. All prey hard part remains in the scats were identified to species when possible in the 21 scats collected. NMML identified 11 different prey in the 17 scats that had identifiable remains and the most frequently occurring prey in these scat samples were: Pacific whiting - 82%, spiny dogfish shark - 24%, and Pacific mackerel - 24%. Salmonid remains were found in 12% of the scats.

"Mixed" sea lion scats (scats from sites that had both Steller and California sea lions mixed together) were collected by NMML from May 6 to May 19, 1998 at haul-out sites on East Bodelteh Island. All prey hard part remains in the scats were identified to species when possible in the 21 scats collected. NMML identified 22 different prey in the 46 scats that had identifiable remains and the most frequently occurring prey in these scat samples were: Pacific herring - 57%, Pacific whiting - 57%, salmonids - 30%, and Pacific sardine - 22%. Salmonid remains were found in 30% of the scats, and the one salmonid otolith in the remains was identified as a Chinook salmon.

Underwater Video Camera Footage of Predations, Scarred Sockeye and Pinniped Movements

In 1998, harbor seals were documented on underwater camera footage passing through the weir at least eight times and on one occasion with a sockeye in its mouth. River otters were documented 82 times passing through the opening in the weir and at least eight times with sockeye in their grasp. The video tapes also indicated that upwards of 15-20% of the fish passing through the weir had predator scars indicative of pinniped predation activities.

In 1999, the underwater footage showed river otters carrying sockeye in their mouths ten times and harbor seals twice during the 1999 season. The underwater video tapes showed that at least 10% of the sockeye passing through the weir had predator scars. Makah Tribe observers at the weir observed an additional seven occasions when river otters were observed preying on adult sockeye in the upper Ozette River.

Sockeye Capture/Release and Re-capture to Assess Bites and Marks in Ozette River

In 2000, 82 sockeye salmon were captured in the lower Ozette River. The fish were tagged, photographed, and their predator scars were evaluated and counted. The predator scarring rate for the 82 fish was 33% at capture in the lower river and increased to 44% when they were re-captured at the upper river weir. The mean transit time for sockeye to travel from the lower to the upper river, a distance of about seven kilometers was 65 hours. This relatively long passage duration makes fish susceptible to predators in the river. The intercanine distances of the predator scars were used to determine that the scars on the sockeye at the time of capture were attributable to harbor seals (60%), California or Steller sea lions (25%), and river otters (15%).

Impact of Pinniped Predation on Salmonids - Ozette River / Lake Ozette

The studies documented that harbor seals prey on sockeye salmon in this area, but the extent and potential impact of such predation was not determined. Although predation events were not observed inriver, the observed foraging activity and the high incidence of scars on sockeye salmon indicated adverse effects of predation may have occurred. Sockeye salmon spawning in Lake Ozette also may be adversely affected by the presence of harbor seals at spawning sites.

LOWER COLUMBIA RIVER

NMML investigated harbor seal food habits in the lower Columbia River from 1994 to 2002 to assess potential pinniped impacts on ESA-listed salmonids. Both harbor seals and California sea lions co-occur in the river with spring and fall runs of twelve ESA-listed salmonid populations (Chinook, chum, sockeye, and coho salmon and steelhead). Harbor seals reside year-round in the Columbia River with as many as 1,500 seals on a tidal sandbar (Desdemona Sands) near Astoria, Oregon. California sea lions occur seasonally in the river from September through May with 200 to 300 hauling out in the east mooring basin in Astoria. Although California sea lion scats have been collected at Astoria by ODFW, the food habits study described below focuses on harbor seals because the California sea lion haul-out was adjacent to a fish processing plant and the prey composition in the sea lion scats may have been biased by sea lions feeding on processing plant discharges. The sources of information on the lower Columbia River harbor seal food habits study are Browne et al. (2002), Laake et al. (2002a), Rhydderch et al. (2003, 2004), and Huber pers. comm. (2009).

Methods - Lower Columbia River

NMML conducted pilot studies in 1994 to assess the feasibility of conducting surface observations of predation events in the lower river. Surface observations proved infeasible due to the large size of the lower river (6.5 km width), so the focus of the NMML investigation was on harbor seal scat collection and analysis. To determine food habits, NMML collected harbor seal scats from Desdemona Sands, the largest haul-out site in the lower Columbia River located about 26 kilometers upriver from the Columbia River mouth. Scats were collected at extreme low tides from early March to mid-October. All prey hard part remains in the scats were identified to lowest possible taxon. Fish mass was estimated from regressions of otolith length to fish mass. NMML developed a biomass reconstruction model to estimate annual consumption of salmonids and other prey, and compared the results to a split frequency of occurrence model. The NMFS Northwest Fisheries Science Center (NWFSC) applied molecular genetic techniques to identify the salmonid bones in the scat to species and ESU.

Scat Collections and Analyses - Lower Columbia River

NMML collected 4,298 harbor seal scats with identifiable remains at the Desdemona Sands haul-out site in the Columbia River from 1994 to 2002. Effort, sample sizes, seasonal collections (not all seasons were sampled in all years), and scat analyses differed among years. Prey species were identified in all of the 1,610 scats from 1994 to 1997. For the scats collected in 1998 to 2002, prey identification was completed on 601 of the 2,688 scats collected (only those scats with salmonid remains were analyzed for prey identification).

In the scats collected from 1994 to 1997, NMML identified 52 prey taxa and the most frequently occurring prey in the scat samples by family/order were: Clupeidae (herring, shad) - 48%, Pleuronectiformes (flatfish) - 30%, Gadidae (Pacific whiting, Pacific tomcod) - 28%, Cottidae (sculpins) - 26%, Osmeridae (smelt) - 26%, Petromyzontidae (lamprey) - 17%, Embiotocidae (surfperch) - 12%, and Salmonidae - 11%. Dividing the scat collections into spring (March 1 to May 14), summer (May 15 to July 15) and fall (July 16 to October 15) seasons resulted in differing primary species in the scat. In the spring, Pleuronectiformes were the most frequently occurring in 41% of the scats followed by Clupeidae - 40%, Cottidae - 37%, Osmeridae - 27%, Petromyzontidae - 24%, Gadidae - 23%, and Salmonidae - 21%. In the fall, Gadidae were the most frequently occurring in 47% of the scat followed by Clupeidae and Osmeridae at 35%, Pleuronectiformes - 29%, Cottidae - 25%, Engraulidae (northern anchovy) - 18%, and Salmonidae - 12%. In the summer, Clupeidae occurred in 62% of the scats followed by Pleuronectiformes - 26%, Petromyzontidae - 21%, Embiotocidae - 19%, Osmeridae - 17%, and Gadidae - 16%.

NMML identified salmonid remains in 425 (16%) of the 2,688 scat collected in 1998 to 2002. Salmonid occurrence ranged from 2% of the scats in summer 2002 to 25% of the scats in fall 2000.

NMML conducted a thorough analysis of 1,385 scats with identifiable remains collected from 1995 through 1997 and estimated biomass consumed. NMML compared the frequency and number of individual prey identified using otoliths as compared to using all bones and hard parts in the scat. Examination and identification of all hard parts, as compared to just identifying otoliths, increased the minimum number of individuals (MNI) detected and at least doubled the frequency of occurrence of most taxa. Identification of all hard parts (the “all structures” technique) greatly improved the estimates of particular taxa that were underestimated by otolith identifications including salmonids, Pacific tomcod, Pacific whiting, American shad, and hexagrammids (greenlings and lingcod). The occurrence of some prey varied greatly between seasons. Pacific tomcod occurred in 39% of the scats in the fall, but only 9% in the summer. Pacific herring occurred in 57% of the scats in the summer and 22% in the fall. Northern anchovy occurred in 19% of scats in fall and only 1% in the spring. Pacific lamprey occurred in about 25% of the scats in summer and spring, but only 6% in the fall. Salmonid remains were greatest in the spring with a 25% frequency of occurrence in scats consisting mostly of juvenile Chinook salmon. NMML surmised that the differences in frequency and number of all harbor seal prey in the lower Columbia River probably reflected temporal availability of prey rather than prey selection.

Biomass Reconstruction of Prey Consumed - Lower Columbia River

NMML used a simple model (Biomass Reconstruction Model) to estimate consumption of salmonids in the Columbia River by harbor seals during spring (March 1 to May 14), summer (May 15 - July 15) and fall (July 16 - October 15) in 1995 through 1997. Harbor seal daily biomass requirements from an energetics model were used by NMML along with expected sex and age structure and measured abundance of the seal population to predict total metric tons of biomass consumption. Using the estimated age and sex structure and biomass requirements of harbor seals in the river, NMML estimated that the seals would consume 704 mt of biomass during the 7.5 month period. From 1,384 scats collected, NMML reconstructed 1.15 mt of biomass predicted to have been consumed during the same period which was only 0.16% of the required biomass consumption.

In the spring, sculpin constituted the largest portion of biomass consumed at 16% of biomass, followed by flatfish - 11%, adult Chinook salmon - 8%, shad - 7%, greenling/lingcod - 7%, herring - 6%, shark/skate/ray - 4%, and juvenile Chinook salmon - 4%.

In the summer, shad constituted the largest portion of biomass consumed at 17% of biomass, followed by herring - 16%, adult Chinook salmon - 10%, Pacific whiting - 9%, flatfish - 8%, sculpin - 8%, adult coho salmon - 4%, and greenling/lingcod - 4%.

In the fall, adult Chinook salmon predominated the portion of biomass consumed at 47% of biomass, followed by Pacific tomcod - 9%, shad - 8%, Pacific whiting - 8%, flatfish - 5%, adult coho salmon - 4%, sculpin - 4%, and greenling/lingcod - 4%.

Comparison of Biomass Reconstruction Model to Spilt Frequency Occurrence Model

NMML demonstrated the influence of the assumptions in the biomass reconstruction (BR) model, which assumes each scat represents a variable amount consumed, by comparing it with an alternative approach used by Olesiuk et al. (1990) called split-sample frequency of occurrence (SSFO), which assumes each scat represented a fixed amount consumed. An advantage of the SSFO method was that it did not require enumeration or size estimation of prey (as does the BR model). However, the method was potentially limited by assuming that hard remains in a scat represent each species eaten in the previous 24 hours of feeding, and that the prey species contained within each scat were consumed in equal quantities. It also assumes that meals of different prey species were equally represented in subsequent scats.

NMML reported that different models used to estimate diet composition yielded prey size-specific differences in consumption estimates that were as large as ten-fold for the smallest and largest prey. The difference between SSFO and BR estimates of consumption was size-specific with smaller prey items being increased and larger prey items decreased by SSFO relative to BR. This was expected because SSFO assumes that each prey represents an equal volume and each scat represents an equal-sized meal consumed. For large prey such as salmon, the BR method may overestimate biomass while the SSFO method underestimates biomass consumed.

Genetic Analysis of Salmon Bones in Scat - Lower Columbia River

The NWFSC conducted genetic analysis on at least one salmonid bone from all scat samples (471) containing salmonid bones from 1994 to 1999. Using molecular genetics techniques, NWFSC identified salmonids to species in 95% (586 of 620) of the scat containing salmonid bones: Chinook salmon occurred in 55% of the scats with salmonid remains, coho salmon in 29%, steelhead in 16%, chum salmon in 0.6%, and sockeye salmon in 0.2%. Two bones from one scat sample collected in fall 1998 were identified as Atlantic salmon. The genetic analysis also revealed that 25 bones from 24 scat samples were misidentified morphologically and were not salmonid structures. For the most part, these were degraded or fragmented structures. Examining the data further by age class, most juveniles were found in the spring and summer and most adults in the fall. Four samples contained both adult and juvenile Chinook and two samples contained adult and juvenile steelhead. Chinook salmon were primarily juveniles in the spring, fairly evenly distributed between adults and juveniles in the summer, and predominantly adults in the fall. Coho salmon in the spring and summer were predominantly juvenile fish and in fall were mainly adult. Steelhead were found mainly in spring and summer and individuals were mainly juveniles. To determine whether these scat samples contained different salmon species, 79 scats were screened for multiple observations (from two to eight bones). Twenty scat samples processed had more than one salmon species and all were juvenile fish.

A comparison of the 38 scat samples with both genetic and otolith identification had some differences. For scat samples that contained only Chinook or coho salmon, otolith and genetic identification agreed. However, where otolith identification was cutthroat, the genetic identification was usually steelhead or coho salmon. The discrepancy between otolith and genetic identification mostly involved juveniles.

The NWFSC also experimented with assigning the ESU for the Chinook salmon bones. For

71 Chinook bone samples with high strength of assignment, 60% were assigned to the Lower Columbia River ESU, 10% to the Upper Willamette River ESU, 12% to the Interior spring group (consisting of Middle Columbia River spring, Upper Columbia River spring, and Snake River spring/summer ESUs), and 19% to the Interior fall group (consisting of Upper Columbia River summer/fall, Snake River fall and Deschutes River summer/fall Chinook ESUs). Bones were attributed to the Lower Columbia River ESU in scats collected in the spring and fall season but not in the summer. Also, in the spring Lower Columbia ESU samples, only juveniles and unknown age were identified whereas both juveniles and adults were found in the fall. Bones assigned to the Upper Willamette ESU and Interior spring group occurred more frequently in the spring than in the summer or fall. No adult individuals were identified in the Interior spring group, all were juveniles and unknowns. All of the samples assigned to the Interior fall RG occurred in the fall, except one in the summer.

Impact of Pinniped Predation on Salmonids - Lower Columbia River

Adult Chinook salmon predominated the biomass consumed by harbor seals in the fall indicating returning adult Chinook salmon were a principal prey for harbor seals seasonally when adult salmonids migrate into the river. Harbor seal predation likely adversely affects the recovery of one or more of the five ESA-listed Chinook salmon ESUs especially in years of low returns.

BONNEVILLE DAM

Bonneville Dam is located 235 kilometers upriver from the mouth of the Columbia River. The presence of California sea lions in the tailrace of Bonneville Dam in the spring has been documented in fishway inspection reports since the early 1980s. Typically, the reports were about sporadic sightings of one to two sea lions in the tailrace of Bonneville Dam with a few instances of a salmonid predation observation. However, during the 2001 migration of one of the largest runs of spring Chinook salmon to pass Bonneville Dam, the sightings increased to six sea lions in the tailrace at the same time and all of them taking salmonids. Due to concerns about the effects of potentially increasing pinniped predation on ESA-listed salmonids, the U.S. Army Corps of Engineers (USACE) began monitoring pinniped predation in 2002 and subsequently began a cooperative deterrence program with ODFW, WDFW and the Columbia River Inter-Tribal Fisheries Commission (CRITFC). In December 2006, Oregon, Washington and Idaho applied for authorization under Section 120 of the MMPA for the lethal taking of California sea lions that were having a significant negative impact on the recovery of ESA-listed salmonids. After convening and receiving recommendations from a Pinniped-Fishery Interaction Task Force, NMFS provided a five-year authorization on March 18, 2008 for the permanent removal of individually identifiable California sea lions that repeatedly forage on salmonids at Bonneville Dam. The sources of information on the Bonneville Dam pinniped predation study and predation reduction program are Stansell (2004), Tackley et al. (2008a, 2008b), Norberg et al. (2005), Wright et al. (2007b), Brown et al. (2007, 2008), NMFS (2008), and Stansell pers. comm. (2009).

Methods - Bonneville Dam

USACE used surface observations to evaluate the seasonal presence, abundance, and occurrence of salmonid predation by California sea lions, Steller sea lions and harbor seals at the Bonneville Dam tailrace. Observation sites were located at each of the three major tailrace areas of the dam. Initially, observations began each year when California sea lions were first seen at the dam on consecutive days, and ceased when the last sea lions departed. However, because sea lions were arriving earlier each year, the study year was basically January 1 to May 31. Sea lion deterrence efforts began in 2005 with the hazing of sea lions that entered the fish ladder, placement of exclusion barriers at ladder entrances, and deterrence of sea lions near the fish ladder entrances. Boat-based pinniped hazing by ODFW, WDFW and CRITFC began in 2006 in areas just below Bonneville Dam (primarily in the Boat Restricted Zone at the dam) and up to 14.5 kilometers downriver. Sea lion scats were collected by ODFW and WDFW in the vicinity of Bonneville Dam and all prey hard part remains in the scats were identified to species when possible. Pinniped scarred salmonids were documented in the Bonneville Dam fish ladder.

Surface Predation Observations - Bonneville Dam

In 2001, after several sea lions had been reported almost daily for a month in the Bonneville Dam tailrace, USACE began collecting data on sea lion presence. Observations began on April 11, 2001 and continued on an irregular basis until the last pinniped was observed on May 13, 2001. The maximum number of sea lions observed at one time was six. Seventy sea lion observations and 15 predation events were documented on 24 days that sea lions were present.

In 2002, USACE began a daily pinniped monitoring program and conducted 662 hours of surface observations from the dam from March 21 to May 24, 2002. USACE identified 30 different individual California sea lions and observed 463 predation events consisting of 430 salmonids (79 Chinook salmon, two steelhead and 344 unidentified salmonids), 26 lamprey and four unidentified fish. The expanded estimate of salmon taken by pinnipeds was 1,010 salmonids (0.4% of the run) in 2002.

In 2003, USACE conducted 1,356 hours of surface observations from the dam from March 3 to June 2, 2003. USACE identified 111 different individual pinnipeds: 106 California sea lions, three Steller sea lions, and two harbor seals. The maximum number of California sea lions observed in one day was 32 sea lions. USACE observed 1,810 predation events consisting of 1,538 salmonids (1,475 Chinook salmon, 10 steelhead, and 53 unidentified salmonids), 205 lamprey, 63 shad and one unidentified centrarchid (sunfish or bass). Based on the predation observations, USACE estimated that 2,329 adult salmonids (1.1% of the run) were consumed by pinnipeds in the tailrace of Bonneville Dam during the period of January 1 to May 31, 2003.

In 2004, USACE conducted 516 hours of surface observations from the dam from February 24 to May 30, 2004. During 73 days of observations, USACE identified different individual pinnipeds: 101 California sea lions, two Steller sea lions, and two harbor seals. A California sea lion branded #C404 was observed in the fish ladder on seven days. The maximum number of California sea lions observed in one day was 37 sea lions. USACE observed 989 predation events consisting of 838 salmonids (483 spring Chinook salmon, 25 steelhead and 330 unidentified salmonids), 127 lamprey, 20 shad and two other fish. Based on the predation observations, USACE estimated that 3,533 adult salmonids (1.9% of the run) were consumed by pinnipeds in the tailrace of Bonneville Dam during the period of January 1 to May 31, 2004.

In 2005, USACE conducted 1,109 hours of surface observations from April 11 to May 31, 2005. USACE identified 85 different individual pinnipeds: 80 California sea lions, four Steller sea lions, and one harbor seal. At least eight California sea lions were observed entering the fish ladder from March 11 to May 20, 2005, and were observed in the viewing window area every day but one from March 11 to March 31. The mean number of California sea lions observed per day was 19 with a maximum on one day of 43 sea lions. USACE observed 2,444 predation events consisting of 1,653 salmonids (973 spring Chinook salmon, 31 steelhead and 649 unidentified salmonids), 613 lamprey, one sturgeon, 69 shad and three other fish. USACE estimated that 2,920 adult salmonids (3.4% of the run) were consumed by pinnipeds in the tailrace of Bonneville Dam during the period of January 1 to May 31, 2005.

In 2006, USACE conducted 3,650 hours of surface observations from February 10, 2006 to May 31, 2006. USACE identified 85 different individual pinnipeds: 72 California sea lions, ten Steller sea lions, and three harbor seals. Sea lion #C404 was observed in the fish ladder on 33 days (in spite of the exclusion barriers that prevented other pinniped from entering the fish ladder). The mean number of California sea lions observed per day was 20 with a maximum on one day of 46 sea lions. USACE observed 3,797 predation events consisting of 2,711 salmonids (1,704 spring Chinook salmon, 295 steelhead and 712 unidentified salmonids), 372 lamprey, 262 sturgeon, 32 shad, five other fish and 414 unidentified fish. An additional 83 salmonids (3.1% of total observed salmonid catch) were observed caught by pinnipeds, but escaped and swam away with unknown levels of injuries. USACE estimated that 3,023 adult salmonids (2.8% of the run) were consumed by pinnipeds in the tailrace of Bonneville Dam during the period of January 1 to May 31, 2006.

In 2007, USACE conducted 4,433 hours of surface observations from January 8 to May 26, 2007. USACE identified 80 different individual pinnipeds: 69 California sea lions, nine Steller sea lions, and two harbor seals. One California sea lion, brand #C404, was observed inside the fish ladder on ten days. The mean number of California sea lions observed per day was 16 with a maximum on one day of 54 sea lions. USACE observed 4,594 predation events consisting of 3,569 salmonids (2,274 spring Chinook salmon, 311 steelhead and 984 unidentified salmonids), 119 lamprey, 360 sturgeon, nine shad and 534 unidentified fish. USACE estimated that 3,859 adult salmonids (4.2% of the run) were consumed in 2007.

In 2008, USACE conducted 5,131 hours of surface observations at the three tailrace areas from January 11 to May 31, 2008. Salmonid predation was documented both inside and outside the tailraces, as far downriver as Skamania Island (approximately 14.5 kilometers below the dam). USACE identified 103 individual pinnipeds: 84 California sea lions, 17 Steller sea lions, and two harbor seals. The mean number of California sea lions observed per day was 21 with a maximum on one day of 63 sea lions. USACE observed 5,621 predation events consisting of 4,243 salmonids (3,955 spring Chinook salmon and 288 steelhead), 111 lamprey, 606 sturgeon, 14 shad, 12 other fish, and 698 unidentified fish. USACE estimated that 4,466 adult salmonids (2.9% of the run) were consumed by sea lions at Bonneville Dam from January 1 through May 31, 2008. An additional 75 salmonid predation events were observed by Portland State University students during 303 hours of observations downstream of the dam.

Predation Control - Bonneville Dam

USACE and cooperating agencies (ODFW, WDFW and CRITFC) began efforts to deter sea lions from preying on salmonids at Bonneville Dam in 2005. Initial deterrence efforts in April 2005 consisted of hazing sea lions that entered the fish ladder with pyrotechnics such as bottle rockets. A test of non-lethal deterrence "tools" that could be dispatched from the dam or boats to deter sea lions from the tailrace at Bonneville Dam was conducted by ODFW, WDFW, USACE and NMFS in May 2005. The tests indicated that deterrence may be effective in temporarily moving sea lions away from fish passage entrances, and an annual deterrence program was implemented each year after 2005.

To prevent sea lions from entering the fish ladders at Bonneville Dam, USACE designed removable "sea lion exclusion devices" (SLEDs) in 2005 for installation at the entrances to the fish ladders. The SLEDs consisted of vertical bars with 40 centimeter spacing to allow fish to pass but not sea lions. The first SLEDs built were installed at four fish ladder entrances late in the season on May 30, 2005, about a week before sea lions otherwise departed the area. In 2006 and beyond, the SLEDs were installed at all of the main fish ladder entrances by early February. Once the SLEDs were installed in 2005, only one sea lion, branded #C404, was observed in the fish ladder. Sea lion #C404 was observed in the fish ladder in 2006 and 2007, while all other sea lions appeared to have been excluded by the SLEDs.

In April 2005, USACE also placed acoustic deterrence devices (ADDs) that emitted 205db at 10-15 kHz at the base of the fish ladder entrances. The ADDs were placed in March or earlier each year after 2005 and operated daily until about May 31 each year from 2005 to 2008.

From 2006 through 2008, pyrotechnic screamers and poppers, cracker shells and rubber bullets/batons were used opportunistically from dam structures and land each year between March and May by USDA wildlife agents to deter sea lions within 30 meters of fish ladder entrances and sea lions hauled out at the dam.

In 2006, WDFW, ODFW and CRITFC conducted boat-based deterrence from April 2 to May 27, 2006 in the tailrace of Bonneville Dam and downstream several kilometers. These personnel used above water pyrotechnics (cracker shells and screamer/poppers), rubber batons or buckshot, and underwater pyrotechnics (underwater firecrackers called "seal bombs"). An estimated 1,000 deterrent actions were taken with sea lions. Approximately 6,000 seal bombs, 8,000 cracker shell rounds, 1,500 rubber buckshot or baton rounds, and 1,000 screamers/poppers were used to deter sea lions over the course of the season.

In 2007, ODFW, WDFW, and CRITFC conducted 1,603 deterrent actions (involving one or more sea lions) from boats using seal bombs, cracker shells, rubber buckshot, and vessel chase. From February 1 to February 28, 2007, boat-based deterrence was conducted on 15 days in the sturgeon spawning area below the Boat Restricted Zone (BRZ) out to Marker 85. A total of 109 deterrent actions occurred involving 137 sea lions (135 Steller sea lions and two California sea lions). The deterrence actions involved 636 cracker shells and 10 rubber buckshot rounds. From February 28 to May 24, 2007, boat-based deterrence was conducted seven days/week primarily in the BRZ, but also extended down to Marker 85. During this period, a total of 1,494 deterrent actions occurred involving 2,495 sea lions (2,432 California sea lions and 63 Steller sea lions). The deterrence actions involved 13,511 cracker shells, 1,040 rubber buckshot rounds and 2,694 seal bombs.

In 2008, ODFW, WDFW, and CRITFC conducted deterrent actions from boats using seal bombs, cracker shells, rubber buckshot, and vessel chase from December 11, 2007 to May 15, 2008. During this period, 749 deterrent actions occurred over 89 days involving 1,353 sea lions (830 California sea lions and 523 Steller sea lions). The deterrence actions involved 9,225 cracker shells, 3,148 seal bombs, and 590 rubber buckshot rounds.

Sea Lion Captures - Bonneville Dam

In 2007, ODFW, WDFW, and NMFS constructed a portable sea lion trap that was placed at

Bonneville Dam in the tailrace of Powerhouse Two on February 21, 2007 and remained there until May 23, 2007. From April 4 to May 17, 2007, three Steller sea lions and 16 California sea lions were captured, branded (only California sea lions were branded with unique identifying numbers), and relocated or released. These sea lions were relocated to Astoria, OR (12 sea lions), Newport, OR (one) and to Seaside, OR (one). Five were released at Bonneville Dam. All but one of the 19 sea lions returned to Bonneville Dam within days (the one that did not return was released in Astoria in mid-May when sea lions normally start departing the river). Satellite transmitters were applied to eight of the relocated California sea lions to track their movements.

In 2008, four traps were deployed at Bonneville Dam in the Powerhouse Two tailrace: one on February 21 and three newly constructed traps on April 21-22, 2008. Sea lion captures on the traps occurred on April 24 and April 28, 2008, and during an unplanned capture on May 4, 2008 when trap doors on two of the traps closed under unknown circumstances with six sea lions inside. Trapping activities in 2008 ceased after the May 4 incident, and an enforcement investigation on the circumstances did not reveal how the trap doors had closed. Fifteen California sea lions were captured: six were transferred into permanent captivity at Sea World, four were branded and released, one died while under anesthesia, and four died on the traps during the unplanned capture on May 4, 2008. Four Steller sea lions were captured: two were released on site and two died on the traps during the May 4 event.

Scat Collections and Analyses - Bonneville Dam

In 2006, a total of 20 California sea lion scats were collected from haul-out sites at Bonneville Dam near Powerhouse Two. Adult salmonids were found in 95-100% of the scat samples followed by lamprey (40%) and juvenile salmonid (25%).

In 2007, a total of 49 California sea lion scats and 29 mixed sea lions scats (likely California sea lion, but some may have been from Steller sea lions using same haul-out) were collected from haul-out sites at Bonneville Dam in March (2 scats), April (64 scats) and May (4 scats). The most frequently occurring prey in the California sea lion scat samples were: salmonids - 95%, Pacific lamprey - 5%, American shad - 2%, and suckers - 2%. Salmonids were found in 97% of the mixed sea lion scat and lamprey in 10%.

In 2007, a total of 12 Steller sea lion scats were collected primarily at Dodson (River Mile 140) in February and March. The most frequently occurring identifiable prey in the Steller sea lion scat samples were: sturgeon - 50%, American shad - 25%, adult salmonids - 25%, and Pacific lamprey - 8%.

Pinniped Scarred Salmonids - Bonneville Dam

Fish passage monitors at the Bonneville Dam salmon viewing windows documented scars on salmonids attributable to pinnipeds on 11% to 37% of the returning spring Chinook salmon and steelhead passing the dam from 1999 to 2005.

Impact of Pinniped Predation on Salmonids - Bonneville Dam

NMFS determined that California sea lions were having a significant negative effect on ESA-listed salmonid populations that migrate through Bonneville Dam. USACE observations from 2002 to 2008 indicated that increasing numbers of California sea lions were foraging on salmon at Bonneville Dam each year, salmon predation rates increased, and the deterrence efforts were having little effect on preventing predation. Observations of individual branded California sea lions indicated that many of the same sea lions were returning year after year and some were spending more time each year foraging at Bonneville Dam.

Steller sea lions, which were relatively easy to deter in early years, became bolder and less responsive to deterrence. Steller sea lions were also taking increasing numbers of white sturgeon each year at a sturgeon spawning site just below Bonneville Dam, and were likely adversely affecting the sturgeon population.

WILLAMETTE FALLS

Willamette Falls is located 206 kilometers upriver from the mouth of the Columbia River at Oregon City, Oregon. The earliest known report of California sea lions at this site was from April 1975 when two sea lions were reported taking salmon and hindering fish passage at the fish ladder. Other than the 1975 sighting, there were no reports of sea lions at Willamette Falls until the late 1980s when personnel at the fish ladder reported California sea lion sightings below the falls. Sea lions were sighted sporadically near the falls until 1995 when California sea lions began occurring almost daily from February through late May. The year 1995 also marked the first year that a California sea lion was reported repeatedly entering one of the fish ladders and consuming spring Chinook salmon. ODFW initiated a monitoring program in 1995 to assess the occurrence and significance of sea lion predation on ESA-listed spring Chinook salmon and winter steelhead. In December 1997, NMFS and ODFW completed an Environmental Assessment (EA) on actions for preventing sea lion foraging and predation on salmonids at Willamette Falls. Notice of the final EA was published in the Federal Register (63 FR 55, January 2, 1998). The NMFS approved preferred alternative was for ODFW to non-lethally remove the “nuisance animals” (California sea lions) under the authority of Section 109(h) of the MMPA because the sea lions foraging at Willamette Falls were adversely affecting fish passage and salmonids were vulnerable to excessive predation. The sources of information on the Willamette Falls sea lion predation study and predation reduction program are Boatner (1999, 2000, 2003), Brown et al. (1998, 2004), NMFS and ODFW (1997), and Wright pers. comm. (2009).

Methods - Willamette Falls

ODFW undertook a preliminary pinniped predation monitoring program in 1995 after receiving repeated reports of a California sea lion preying on salmonids near and in the fish ladders at Willamette Falls. In 1996, a joint ODFW-NMFS monitoring plan was developed, and NMFS provided funding to ODFW to initiate a daily monitoring program during the spring Chinook salmon and winter steelhead migration up the Willamette River. In most years, the monitoring effort commenced soon after reports of sea lion sightings were received. ODFW observers conducted surface observations from the top of the fish ladder structure where they could observe the area in front of the entrances to the fish ladder and the base of the falls. A night-vision scope was used in 2001 for pre-dawn and dusk observations. ODFW also undertook deterrence measures in an attempt to reduce sea lion predation on salmonids.

Surface Predation Observations - Willamette Falls

In 1995, ODFW initiated observations well after the first California sea lion was reported in February. Due to the short period for initiating an observation program, ODFW conducted only

58 hours of daylight surface observations on ten days between May 1 and May 28, 1995. ODFW observed four different California sea lions (identified by unique markings and size) foraging in the area until May 24 when the last sea lion was observed. Fifteen predation events were observed (nine spring Chinook, two winter steelhead and four unidentified salmonids). Since the observations did not commence until late in the season, no extrapolations of the observed takes were made by ODFW.

In 1996, ODFW conducted 210 hours of daylight surface observation from April 2 to May 31, 1996. Seven different California sea lions were observed on 26 of the 46 days of observation (sea lions were observed from April 2 to May 4). Up to four sea lions were observed in the area at the same time. The late arrival of sea lions (in April as compared with February and early March in other years) may have been caused by the flood situation in the Willamette River in February 1996. ODFW observed 115 predation events by at least seven different California sea lions consuming 89 salmonids (42 spring Chinook salmon, 27 steelhead and 20 unidentified salmonids) and 26 Pacific lamprey. Based on the predation observations, ODFW estimated that sea lions consumed 391 salmonids (238 spring Chinook and 153 steelhead) during the time that sea lions were present at the falls. ODFW estimated the total predation at about 1% of the spring Chinook run and about 9% of the winter steelhead run in 1996.

In 1997, ODFW conducted 563 hours of daylight surface observation from April 1 to May 23, 1997. At least four different California sea lions were observed on 33 of the 48 days of observation (sea lions were observed from April 9 to May 15). Up to four sea lions were observed in the area at the same time. ODFW observed 165 predation events by California sea lions consisting of 164 salmonids (65 Chinook salmon, 39 steelhead and 60 unidentified salmonids) and one Pacific lamprey. ODFW estimated 234 salmonids (146 spring Chinook and 88 steelhead) were taken during the period that sea lions were present. The estimated take was about 1% of the 1997 spring Chinook run and about 2% of the winter steelhead run.

In 1998, ODFW conducted 567 hours of daylight surface observations from March 26 to June 4, 1998. California sea lions were observed on 40 of the 62 days of observation. At least four different California sea lions were observed from March 25 (the day before daily observations began) until May 15. Up to three sea lions were observed in the area at the same time. ODFW observed 167 predation events by California sea lions consisting of 144 salmonids (30 spring Chinook, 49 steelhead, and 65 unidentified salmonids) and 23 Pacific lamprey. ODFW estimated 275 salmonids (104 Chinook salmon and 171 steelhead) were taken during the time sea lions were present. The estimated percent of the runs taken by sea lions was 0.3% of the spring Chinook run and about 5% of the winter steelhead run in 1998.

In 1999, ODFW conducted 487 hours of daylight surface observations from March 16 to May 28, 1999. California sea lions were first observed at the falls on March 2 (prior to when the observation effort began) and the last sea lion was observed May 19. A minimum of ten different California sea lions were observed on 37 of the 56 days of observation. Three of the sea lions (#C-117, #C-122 and #C11?) were animals that had been branded by ODFW at Astoria, OR as part of ODFW's sea lion distribution and movements program. ODFW observed 170 predation events by California sea lions consisting of 164 salmonids (39 Chinook salmon, 58 steelhead and 67 unidentified salmonids) and six Pacific lamprey. The estimated total predation during the period of sea lion presence was 370 salmonids (149 spring Chinook salmon and 221 steelhead). The estimated percent of the runs taken by sea lions was 0.4% of the spring Chinook run and about 3% of the winter steelhead run in 1999.

In 2000, ODFW conducted 699 hours of daylight surface observations from February 7 to June 9, 2000. At least five different California sea lions (including one branded #C-122) were observed from February 3 (prior to initiation of the daily observation effort) to June 1. Sea lions were observed on 41 of 87 days of observation. ODFW observed 152 predation events by California sea lions consisting of 141 salmonids (31 Chinook salmon, 34 steelhead and 76 unidentified salmonids) and 11 lamprey. Sea lion #C-122 (which was also observed at Willamette Falls in 1999) was observed from February 7 to February 29 consuming 12 steelhead (35% of the observed steelhead takes) and one lamprey. ODFW estimated the total predation during the period of sea lion presence was 355 salmonids (169 spring Chinook salmon and 186 steelhead). The estimated percent of the runs taken by sea lions was about 1% of the spring Chinook run and about 4% of the winter steelhead run in 2000.

In 2001, ODFW conducted 600 hours of surface observations from March 27 to June 2, 2001. Observations included use of a night-vision scope for pre-dawn and dusk observations. California sea lions were observed on 21 of the 50 days of observation. At least five different California sea lions (including one branded #C-172) were observed from March 22 (prior to the daily observation effort) to May 18. ODFW observed 38 predation events by California sea lions consisting of 34 salmonids (13 Chinook salmon, eight steelhead and 13 unidentified salmonids) and four Pacific lamprey. The estimated total predation during the period of sea lion presence was 59 salmonids (37 spring Chinook salmon and 22 steelhead). The estimated percent of the runs taken by sea lions was 0.1% of the spring Chinook run and 0.2% of the winter steelhead run in 2001.

In 2002, ODFW conducted 390 hours of daylight surface observations from March 18 to May 24, 2002. California sea lions were observed on 22 of the 49 days of observation. At least eight different California sea lions (including three branded #C-199, #C-235 and #C-257) were observed from April 4 to May 15. Up to four sea lions were observed in the area at the same time. ODFW observed 104 predation events by California sea lions consisting of 98 salmonids (61 Chinook salmon, 18 steelhead and 19 unidentified salmonids) and six Pacific lamprey. The estimated total predation during the period of sea lion presence was 173 salmonids (134 spring Chinook salmon and 39 steelhead). The estimated percent of the runs taken by sea lions was 0.2% of the spring Chinook run and 0.2% of the winter steelhead run in 2002.

In 2003, ODFW utilized an all-volunteer observation program. The volunteer observers conducted 477 hours of daylight surface observations from February 26 to June 13, 2003. California sea lions were observed on 37 of the 74 days of observation. At least five different California sea lions (including one branded #C-199 that was also present in 2002) were observed from February 19 (prior to initiation of the daily observation effort) to June 4, 2003. Up to four sea lions were observed in the area at the same time. ODFW observed 58 predation events by California sea lions consisting of 48 salmonids (six Chinook salmon, eight steelhead, 34 unidentified salmonids) and ten Pacific lamprey. ODFW estimated the total predation during the period of sea lion presence was 160 salmonids (69 spring Chinook salmon and 91 steelhead). The estimated percent of the runs taken by sea lions was 0.1% of the spring Chinook run and about 1% of the winter steelhead run in 2003.

Predation Control - Willamette Falls

In 1996, ODFW installed a barrier gate at fish ladder entrance #1 which was where a sea lion had been observed entering the fish ladder in 1995. The barrier was constructed of 2.5

centimeter aluminum bar stock, with three-meter vertical bars spaced at 38 centimeter intervals placed at the bottom of the fish ladder with a stop-log gate lowered down on top of it. The removable barrier was designed to allow unrestricted access by adult salmonids and prevent access by sea lions. Observations by ODFW in 1996 indicated the barrier was effective in preventing sea lions from entering the fish ladder.

In 1996, ODFW tested the use of rubber projectiles (rubber buckshot and batons) shot from a shotgun to deter the California sea lions observed to repeatedly forage near the fish ladders. Sea lions were identified by natural markings or by temporary streamer dart tags that were applied using a CO_2 pistol. Over a four day period, four individually recognizable sea lions were shot with rubber buckshot and batons. The smaller and less commonly occurring sea lions reacted more to being shot than the larger, bolder sea lions. The smaller animals immediately left the area and did not return, while the larger animals returned to the immediate area in less than 24 hours. On return, the larger sea lions were more wary, moving from area to area, surfacing in less predictable ways and spending more time underwater thus preventing dispatch of another rubber projectile.

From 1997 to 1999, ODFW used underwater firecrackers (called "seal bombs") and rubber projectiles shot from a shotgun to deter sea lions from areas near the fish ladder entrances. These deterrents caused sea lions to temporarily move away from the immediate area and changed their pattern of approach, but the deterrence did not prevent continued foraging.

In 2000, paint balls dispatched from a CO_2 pistol were used to deter and temporarily mark sea lions. The effects were similar to the other deterrents in that the struck sea lions would move from the immediate area but continued foraging.

In 1998 and 1999, a floating baited trap was placed near one of the fish ladder entrances in attempt to capture the offending California sea lions. The trap was baited and operational from April 2 to May 5, 1998 and in April 1999. The trap was baited with tethered live hatchery steelhead inside the trap that would trigger the door on the trap to close when taken. Sea lions were observed swimming around the trap (where they presumably could see the steelhead), but they did not enter the trap.

Impact of Pinniped Predation on Salmonids - Willamette Falls

The percentage of the returning ESA-listed spring Chinook salmon runs consumed by California sea lions at Willamette Falls was low (0.2% to about 1%). Predation likely was not a major factor affecting Chinook salmon recovery, although there were unobserved predation events occurring downstream of the falls that were not included in the estimate. California sea lion predation rates on ESA-listed winter steelhead were greater (0.2% to about 9%) and may be a factor affecting steelhead recovery in years of small returns. Sea lion foraging near the fish ladder entrances also may have indirect effects from disrupting, delaying or impeding salmonid passage into the fish ladder.

NEHALEM BAY

ODFW investigated harbor seal food habits in Nehalem Bay to determine prey species. About 100 to 150 harbor seals haul out in Nehalem Bay throughout the year. The source of information for this food habits study is Riemer pers. comm. (2009).

Methods - Nehalem Bay

ODFW investigated harbor seal food habits in Nehalem Bay by collecting scat from the Nehalem Bay haul-out site from January 29 through December 19, 2003. Scats were collected on nine of 17 collection trips. ODFW collected 110 scats and 103 were processed. All hard parts of prey remains in the scats were identified to species when possible.

Scat Collections and Analyses - Nehalem Bay

ODFW found 35 different prey taxa in 87 scats with identifiable remains. The most frequently occurring prey in the scat samples were: Dover sole - 37%, rex sole - 36%, Pacific sand lance - 17%, hagfish - 17%, English sole - 17%, and Pacific whiting - 17%. Salmonids were identified in 6% of the scats.

Impact of Pinniped Predation on Salmonids - Nehalem Bay

This was only a one year study to determine harbor seal food habits from scats. Salmonids occurred in less than 10% of the scats collected suggesting that harbor seals were not impacting salmonids. However, at least three years of scat data should be collected and possibly combined with surface observations before any conclusions are reached on pinniped impacts on salmonids in this system.

ALSEA RIVER/BAY

ODFW conducted pinniped predation studies at the Alsea River/Bay, Oregon to assess and estimate the consumption of coho salmon by harbor seals. About 300 to 600 harbor seals are in Alsea Bay year-round and co-occur with an ESA-listed run of wild coho salmon, as well as with more robust runs of fall Chinook and winter steelhead. The sources of information on the Alsea River harbor seal predation study are Riemer et al. (1999a, 1999b, 2001), Wright et al. (2002, 2003a, 2003b, 2007a), Kvitrud et al. (2005), and Wright pers. comm. (2009).

Methods - Alsea River/Bay

ODFW investigated pinniped predation in the Alsea River from September through November in 1997 through 2000 and in 2002 by conducting surface feeding observations from shore and boats to estimate total adult salmonid predation by seals and collecting harbor seal scats to determine diet. All hard parts of prey remains in the scats were identified to species when possible. In 2001, scat collections continued, but no surface observations were conducted. Night observations were conducted in 2000 and 2002. ODFW also captured and marked harbor seals in 2000 and 2002 to track individual seal movements and foraging behaviors. Oregon State University (OSU), in collaboration with ODFW, applied molecular genetic techniques to identify the salmonid bones in the scat to species.

Surface Predation Observations - Alsea River/Bay

In 1997, ODFW conducted 552 hours of observations from shore at nine sites in the Alsea River/Bay from September 2 to November 30, 1997. One predation event was recorded during shore observations (two off-effort predation events also were recorded). Based on the surface predation observations, ODFW estimated a total of four salmonid predations in 1997 during the study period (daylight hours only). An undetermined portion of the four predations were likely coho salmon. The Alsea River system had an estimated 680 spawning wild coho in 1997.

In 1998, ODFW conducted 885 hours of observations at 28 sites in the Alsea River/Bay from September 6 to November 30, 1998. Shore observations totaled 617 hours and boat observations, which were added during this second year of study, totaled 268 hours. Fifteen predation events were recorded during boat observations in the river and 14 were recorded during shore observations in the estuary, all by harbor seals. The addition of boat observations at the Alsea River resulted in an increase in observed predation. Based on the surface predation observations of 24 salmonids (23 by harbor seals and one by a California sea lion), ODFW estimated a total of 177 salmonid predations in 1998 during the study period (daylight hours only). An undetermined portion of the 177 predations were likely coho salmon. The Alsea River system had an estimated 213 spawning wild coho in 1998.

In 1999, ODFW conducted 519 hours of surface feeding observations at 31 sites from September to November 1999. ODFW observed 23 predation events during surface feeding observations, of which 13 were identified as salmonids (five Chinook salmon and eight unidentified salmonids). Based on the surface predation observations, ODFW estimated a total of 106 salmonid predations in 1999 during the study period (daylight hours only). An undetermined portion of the 106 predations were likely coho salmon. The Alsea River system had an estimated 1,996 spawning wild coho in 1999.

In 2000, ODFW conducted 1,518 hours of daytime surface feeding observations at 29 sites (shore and boat-based) from September 13 to November 29, 2000. ODFW observed 55 predation events, of which 41 were identified as salmonids, four as non-salmonids, and ten were unidentified. An additional five salmonid predations were observed while conducting other activities, resulting in a total of 60 events. Fifty-nine of the predation events were by harbor seals and one was by a California sea lion. Of the 46 salmonid predations, 11% were identified as coho salmon, 24% as fall Chinook salmon, 2% as winter steelhead, and 63% could not be identified to the species level. All but two (96%) of the observed salmonid predations were in the river above the bay. ODFW found no evidence to suggest that the occurrence of a salmonid predation event was dependent on tidal stage, time of day, or river discharge. ODFW estimated that, at a minimum, pinnipeds (primarily harbor seals) consumed 418 adult salmonids, of which 120 were coho salmon. This was a minimum estimate because it was limited to only those hours and sites that were actually available for sampling (which was approximately 22% of all possible daylight hours and sites within the estuary). If the minimum estimate was inflated to include all possible hours and sites (i.e., assume the sample was representative), the estimated total predation was 1,887 adult salmonids of which 539 were coho salmon. The estimated wild coho spawner abundance for the Alsea Basin in 2000 was 2,414. The minimum and expanded coho salmon consumption estimates therefore represent 5% and 18% of the estimated coho salmon run in 2000, respectively.

Also in 2000, ODFW conducted 17 hours of observations at night over four days at one site in the river. Although seals were observed actively foraging in the river at night, no predation events were observed.

In 2002, ODFW conducted 760 hours of daytime surface feeding observations at 63 sites in the estuary from September 1 to November 23, 2002. ODFW had 17 observations of harbor seals consuming adult salmonids, of which 76% were in the river. ODFW also conducted 78 hours of nighttime surface feeding observations at two sites. During these nighttime observation periods, ODFW observed four salmonid predation events, three by harbor seals, and one by a

California sea lion. From the daytime surface observations, ODFW estimated that seals consumed 1,161 adult salmonids in the 18.9 km study area during daylight hours during the 84-day study period. Based on seal movement data (see below), the daytime estimate was believed to represent only 27% of the total salmonid predation (i.e., nocturnal predation accounted for 73% of the total). Furthermore, based on genetic analysis of salmonid remains found in scat (see below), coho salmon were believed to represent 54% of total salmonid predation. Given an estimated coho spawner estimate of 9,073 fish, total adjusted coho predation was believed to account for 21% of the total run size. However, uncertainty in nocturnal and coho-specific predation rates, and daylight predation and spawner abundance estimates, resulted in a wide 95% confidence interval of 3-63% of run size consumed. ODFW speculated that the majority of this predation occurred upriver, at night, by a relatively small proportion of the local seal population.

Scat Collections and Analyses - Alsea River/Bay

In 1997, ODFW collected 506 harbor seal scats from four haul-out sites in the Alsea River estuary from September 3 to November 26, 1997. ODFW identified 41 prey taxa and the most frequently occurring prey in 439 scats with identifiable remains were: English sole - 36%, flatfish (unidentified) - 26%, rex sole - 25%, sanddab spp. - 13%, Pacific staghorn sculpin - 12%, and Pacific herring - 11%. Salmonid remains were in 4% of the scats. The occurrence of salmonids in scats was different between 23 scats from the upper estuary haul-out sites which had 35% salmonid occurrence, and 416 scats from the lower estuary scats which had 6% salmonid occurrence.

In 1998, ODFW collected 392 harbor seal scats from four haul-out sites in the Alsea River estuary from September 9 to November 3, 1998. ODFW identified 36 prey taxa and the most frequently occurring prey in 353 scats with identifiable remains were: flatfish (unidentified) - 39%, English sole - 29%, rex sole - 28%, Pacific herring - 16%, and Pacific whiting - 15%. Salmonid remains were found in 7% of the scats. The occurrence of salmonids was different between 13 scats from the upper estuary haul-out sites which had 23% salmonid occurrence, and 343 scats from the lower estuary scats which had 6% salmonid occurrence.

In 1999, ODFW collected 244 harbor seal scats from four haul-out sites in the Alsea River estuary from September to November 1999. ODFW identified 36 prey taxa and the most frequently occurring prey in 216 scats with identifiable remains were: English sole - 63%, rex sole - 38%, sanddab spp. - 25%, Pacific staghorn sculpin - 17%, Pacific herring - 15%, and flatfish (unidentified) - 13%. Salmonid remains were found in 7% of the scats.

In 2000, ODFW collected 139 harbor seal scats from four haul-out sites in the Alsea River estuary from September to November 2000. ODFW identified 37 prey taxa in the scats. The most frequently occurring prey in 124 scats with identifiable remains were: Pacific sand lance - 36%, Pacific tomcod - 18%, English sole - 18%, unidentified Pleuronectidae (righteye flounders) - 17%, Pacific herring - 15%, sanddab spp. - 13%, and rex sole - 11%. Salmonids were found in 9% of the scat.

In 2002, ODFW collected 131 harbor seal scats in the Alsea River estuary from September 6 to November 15, 2002. ODFW identified 30 prey taxa in the scats. The most frequently occurring prey in 117 scats with identifiable remains were: Pacific herring - 42%, English sole - 37%, unidentified flatfish - 24%, rex sole - 20%, Dover sole - 15%, Pacific sand lance - 13.7%, and Pacific tomcod - 14%. Salmonids were found in 9% of the scat.

Genetic Analysis of Scat for Salmon Identification - Alsea River/Bay

OSU used a PCR-based species test and microsatellite genotyping to determine salmonid species of 745 bones recovered from 71 scats with salmonid bone remains collected in 1997. Of the 745 bones, 421 (56%) were genetically identified to species using the PCR tests. Salmonid species was identified in 94% of the scat samples with 39% of the scats containing exclusively coho salmon bones, 46% had exclusively Chinook salmon bones, 13% had both coho and Chinook salmon bones, and one scat had Chinook bones and bones identified to be either steelhead or cutthroat trout. Of the 41 scats that contained Chinook bones, 26 scats had multiple Chinook bones and 13 had bones from more than one individual Chinook salmon. Among the 13 scats containing multiple Chinook salmon bones, eight scats had remains from two salmon, three had remains from three salmon, and two contained remains from four individual salmon.

Pinniped Scarred Salmonids - Alsea River

ODFW examined 1,121 coho salmon in 1997 and 1,530 in 1998 at the Fall Creek Hatchery in the Alsea River, and found that 2.1% and 2.2%, respectively, had scars (bites, arches, scratches) attributable to pinnipeds. This was much less than scarring rates from previous years of 31%, 23% and 20% in 1996, 1995, and 1994, respectively, recorded by hatchery staff.

Pinniped Movements - Alsea River/Bay

In 2000, ODFW marked 62 harbor seals in July, August and September with uniquely identifiable head patches, and attached radio transmitters to 25 of them. During surface feeding observations, 23% of the marked seals were sighted at least once in the river, 40% were only observed in the bay and 37% were never resighted. Marked seals were involved in 23% of all observed predation events. A single individual was responsible for at least 10% and possibly as much as 17% of all observed predation events.

In 2002, ODFW captured and marked 59 harbor seals in August and September 2002. Seals were outfitted with acoustic transmitters and tracked using an array of 15 automated data-logging hydrophones. ODFW logged over 375,000 detections from 56 seals over the 12-week study period. Twenty-three seals were detected in the riverine portion of the study area at least once. Collectively, these 23 seals made 593 trips upriver totaling 5,067 hours; however, just seven of the seals accounted for 94% of the total hours. Seventy-three percent of the total hours spent upriver occurred at night. The tracking study indicated that a small proportion of marked seals (13%) exhibited behavior that was consistent with specialized foraging on salmonids. These seals spent the majority of their time in the riverine portion of the study area and did so disproportionately more at night than day.

Impact of Pinniped Predation on Salmonids - Alsea River/Bay

Harbor seal predation appears to have exceeded 10-20% of the returning ESA-listed coho in three of the four years observed. The surface observations and tagging results indicated that a small number of harbor seals appeared to be consistently foraging upriver on salmonids in the fall. During years of low returns, such predation may adversely affect the recovery of the Alsea River coho salmon population.

SILTCOOS RIVER

NMML conducted a pilot study in the Siltcoos River, Oregon in 1997 to assess the occurrence of pinniped predation on coho salmon (Mellman 1998). Thirty-seven hours of daylight surface observations were conducted by NMML at the mouth of the Siltcoos River on a weekly basis from October 2 to November 25, 1997. No predation events were observed.

The data collected from this pilot study suggested that pinniped predation on salmonids was not occurring; however, the study was limited. Multiple years data should be collected before conclusions are made on pinniped predation in this river.

UMPQUA RIVER

NMML investigated harbor seal predation on salmonids in the Umpqua River in 1997 and 1998 to assess potential impacts on a cutthroat trout population that was proposed for ESA listing. About 300 to 400 harbor seals haul out year-round in the Umpqua River and co-occur with cutthroat and other salmonids. The sources of information on the Umpqua River pinniped predation study are Mellman (1998), Orr et al. (2004), and Purcell et al. (2004).

Methods - Umpqua River

NMML conducted daytime surface observations from shore at two sites near the mouth of the Umpqua River in the fall of 1997. Upriver boat and shore surveys also were conducted weekly by NMML in fall 1997 to determine harbor seal distribution and assess if predation was occurring upriver. The shore surveys consisted of 15-minute observation periods at nine sites along the river from Reedsport up to River Mile 20. Harbor seal scats were collected by NMML in the fall of 1997 and in the spring and fall of 1998 at two haul-out sites located about five kilometers upriver from the mouth of the river. All prey hard parts remains in the scats were identified to species when possible. The Northwest Fisheries Science Center (NWFSC) conducted genetic analysis of salmonid bones in the scat to determine salmonid species.

Surface Predation Observations - Umpqua River

NMML conducted 23 hours of surface observations at Half Moon Bay and Windy Cove, located about 1.5 kilometers upriver from the mouth of the Umpqua River, from September 15 to December 1, 1997. No predation events were observed. However, a harbor seal predation event was observed off-effort at Half Moon Bay on September 17, 1997 when a harbor seal was observed for thirty minutes diving and surfacing repeatedly while consuming a coho salmon.

NMML also conducted 51 hours of upriver shore surveys from September 15 to December 1, 1997. Harbor seals were observed at all upriver sites with at least one seal observed per hour at the upriver sites at River Mile 14, 16 and 18. One harbor seal predation event was observed at Brady Bar (River Mile 14) on October 2, 1997. Two seals were observed diving and surfacing repeatedly during the observation period and one of the seals had a small salmonid in its mouth.

During five boat surveys totaling 11 hours of observations, NMML observed 11 harbor seals at eight locations, but no predation events were observed.

Scat Collections and Analyses - Umpqua River

NMML collected 728 harbor seal scats from the two inriver haul-out sites in the fall of 1997

(September 16 to November 25, 1997), the spring of 1998 (March 24 to June 12, 1998), and the fall of 1998 (August 5 to October 8, 1998). Of the total collected, 651 scats had identifiable remains: 119 scats of 148 collected in fall 1997, 219 of 254 in spring 1998, and 313 of 326 in fall 1998). NMML identified 40 different prey (identified to species or family) and the most frequently occurring prey in the scat samples were: unidentified Pleuronectids (righteye flounders) - 39%, Pacific whiting - 28%, rex sole - 27%, Pacific staghorn sculpin - 24%, English sole - 22%, and smelt - 21%. A majority of the scats with identifiable remains had one to three prey taxa present and less than 4% contained more than ten taxa. NMML found that the majority (76%) of prey were fish that inhabit marine and estuarine areas suggesting that the majority of the seals at the inriver haul-out sites forage in the ocean and estuary.

Genetic Analysis of Scat for Salmon Identification - Umpqua River

Salmonid remains were found in 6% of the 651 scat samples. Two of these scat contained otoliths (which allowed identification to species), and the remaining 37 were analyzed by the NWFSC using molecular genetic techniques to identify salmonid bones to species. Chinook salmon occurred in 49% of these scats containing salmonids, coho salmon occurred in 36%, steelhead occurred in 13%, and 10% remained as unidentified salmonids. No cutthroat trout remains were identified.

Impact of Pinniped Predation on Salmonids - Umpqua River

This study was designed to assess harbor seal impacts on cutthroat trout which were proposed for ESA listing at the initiation of this study. The lack of cutthroat trout remains in harbor seal scats and lack of any observed predation events suggests it was unlikely that harbor seals were negatively affecting Umpqua River cutthroat trout. However, the observations were limited to one year. Multi-year observational studies under a broader sampling plan that addresses all fall run salmonids (including ESA-listed coho salmon) should be conducted before conclusions are made on pinniped impacts on Umpqua River salmonids.

ROGUE RIVER

ODFW conducted pinniped predation studies at the Rogue River in southern Oregon to evaluate California sea lion, Steller sea lion and harbor seal predation on salmonids, and determine harbor seal food habits. Although multiple species of salmonids occur in the river during fall months including coho salmon, fall Chinook salmon, and steelhead, the fall studies focused on potential pinniped impacts to ESA-listed coho salmon. About 200 to 500 harbor seals occurred year-round in the Rogue River area at inriver and nearshore haul-out sites. California sea lions occurred in the river seasonally from fall through spring. A Steller sea lion rookery is located at Rogue Reef (located about four kilometers from the mouth of the Rogue River) and Steller sea lions occurred in the Rogue River in the spring, summer and fall. The sources of information on the Rogue River pinniped predation study are Riemer and Brown (1996), Riemer et al. (1999a, 1999b, 2000, 2001), and Riemer pers. comm. (2009).

Methods - Rogue River

ODFW conducted surface observations in the fall from September through November in 1997 through 1999 at eleven pre-selected shore sites in the lower sixteen kilometers of the Rogue

River. ODFW also conducted pilot studies in the spring of 1996 and limited observations at night in 2000 to determine the feasibility of night observations. In 1996, surface observations were conducted by ODFW at the mouth of the river (between the jetties) in the spring (April to June) as a preliminary assessment of potential pinniped impacts on spring Chinook salmon. In May of 2000, ODFW conducted limited daytime and night observations from shore primarily at the mouth of the river to evaluate night predation. Harbor seal scats were collected from the two inriver haul-out sites near the mouth of the river from 1996 to 1999 and all prey hard part remains in the scats were identified to species when possible. Occasional boat surveys were also conducted in 1997 to 1999 to document pinniped presence in the lower 16 kilometers of the Rogue River. Two upriver surveys were conducted in 1997 starting at RM 35 and ending at the mouth with the majority of the pinnipeds documented in the lower 16 kilometers of the river, except for a single harbor seal at River Mile 24 on one occasion. ODFW hatchery staff collected data on pinniped scarred coho returning to the Coles Rivers Hatchery.

Surface Predation Observations - Rogue River

In 1996, ODFW conducted surface observations in the Rogue River two-days per week from April 3 to June 10, 1996 for a total of 55 hours. California sea lions, harbor seals and Steller sea lions were observed foraging in the Rogue River. ODFW observed 63 predation events consisting of 15 Chinook, one steelhead, five unidentified salmonids, 23 lamprey and 19 unidentified species. California sea lions were responsible for 19 predation events, of which 13 were salmonids. California sea lions tended to be more aggressive and obvious while killing and consuming adult salmonids, while harbor seals were noticeably more secretive while preying on salmon, bringing the fish to the surface only briefly to breathe and then submerging again to consume pieces of the fish. Harbor seals were responsible for 34 of the predation events consuming the most lamprey (19 of 23), the most unidentified species (12 of 19) and only three salmonids. Steller sea lions were responsible for ten predation events of which five were salmonids. The 21 observed salmonid predation events extrapolated to an estimated 349 salmonids taken by pinnipeds (1.4% of the spring Chinook salmon and steelhead runs).

In 1997, ODFW conducted 814 hours of observations over 490 observation periods from September 2 to November 30, 1997. ODFW observed 40 predation events consisting of three coho, four Chinook, three steelhead half-pounders, 22 unidentified salmonids, and eight other prey. Harbor seals were responsible for most (33 of 40) of the foraging events and most of the salmonids (24 of 32). California sea lions had seven predation events, all of which were salmonids. One Steller sea lion predation of a Chinook salmon was observed. The 32 salmonids observed consumed were extrapolated by ODFW to an estimate of 249 salmonids consumed by pinnipeds. An undetermined portion of the 249 predations may have been ESA-listed coho salmon. The Rogue River system had an estimated 8,282 spawning wild coho in 1997.

In 1998, ODFW conducted 925 hours of observation over 555 observation periods from September 6 to November 30, 1998. ODFW observed 60 predation events (49 by harbor seals, ten by California sea lions, and one by a Steller sea lion) consisting of four coho, five Chinook, one steelhead half-pounder, 28 unidentified salmonids, and 22 other prey. Most of the predation events were in the lower three kilometers of river. The 38 salmonids observed extrapolated to an estimated 218 salmonids consumed by pinnipeds. An undetermined portion of the 218 predations may have been ESA-listed coho salmon. The Rogue River system had an estimated 2,249 spawning wild coho in 1998.

In 1999, ODFW conducted 961 hours of observations over 577 observation periods from September to November 1999. ODFW observed 80 predation events (65 by harbor seals and 15 by Steller sea lions; no California sea lion predation was observed) consisting of two coho, eleven Chinook, one steelhead, 25 unidentified salmonids, and 41 other prey. The 39 salmonids observed extrapolated to an estimate of 227 salmonids. An undetermined portion of the 227 predations may have been ESA-listed coho salmon. The Rogue River system had an estimated 2,370 spawning wild coho in 1999.

In 2000, ODFW conducted 58 hours of observations from May 15 to May 26, 2000 with 26.7 hours at night and 31.7 hours during daylight. The night observations were made only at the mouth of the Rogue River, whereas daylight observations were at the mouth and at an upriver site. During the two week study, there were five observed predation events all during the daytime observation periods consisting of one salmonid, one perch, one lamprey, and two unidentified fish. Two predation events were by California sea lions and three by harbor seals Harbor seal activity was observed at night, but due to poor night visibility at the site, predation events could not be observed. An average 2.9 seals were observed per 100 minute interval during the night compared with 4.1 during the day. Sea lions were observed only once at night and averaged less than 0.2 sea lions per 100 minute interval at night as compared with 2.7 during the day. ODFW found that the river mouth site was not conducive to night observations.

Scat Collections and Analyses - Rogue River

In 1995/1996, ODFW processed 384 scats from 25 collection trips at the two harbor seal haul-out sites in the Rogue River from April 1995 to May 1996. The most frequently occurring prey in the scat samples were: Pacific lamprey - 26%, rex sole - 23%, rockfish - 22%, and Pacific tomcod - 20%. Salmonid remains were found in 13% of the scats. The month with the greatest frequency of occurrence of salmonids in the scat samples was October 1995 with 43% of the scat containing salmonids.

In 1997, ODFW collected 331 scats at the two harbor seal haul-out sites in the Rogue River from September 15 to November 24, 1997. ODFW identified 45 prey taxa in the scats. The most frequently occurring prey in 331 scat samples with identifiable remains were: rockfish - 39%, rex sole - 33%, slender sole - 17%, salmonids - 15%, Pacific whiting - 14%, and English sole - 14%. Salmonid occurrence in the samples ranged from 10% in September to 30% in October to 4% in November.

In 1998, ODFW collected 245 scats at the two harbor seal haul-out sites in the Rogue River from September 21 to November 9, 1998. ODFW identified 35 prey taxa in the scats. The most frequently occurring prey in 223 scat samples with identifiable remains were: flatfish - 30%, rex sole - 28%, Pacific lamprey - 25%, Pacific whiting - 17%, and Pacific hagfish - 15%. Salmonid remains occurred in 10% of samples. Salmonid occurrence in the samples ranged from 14% in September to 8% in October to 10% in November.

In 1999, ODFW collected 270 scats at the two harbor seal haul-out sites in the Rogue River from September to November 1999. The most frequently occurring prey in 233 scat samples with identifiable remains were: rex sole - 42%, Dover sole - 34%, English sole - 30%, slender sole - 29%, flatfish - 24%, Pacific hagfish - 21%, and rockfish - 18%. Salmonid remains occurred in 11% of samples.

Pinniped Scarred Salmonids - Rogue River

ODFW hatchery staff at the Coles River Hatchery in the Rogue River examined 3,809 coho in 1998 and 5,417 coho in 1999 and found that 1.7% and 1.3% respectively had scars (bites, arches, scratches) attributable to pinnipeds. This compared to prior year scarring rates of 1%, 2% and 3% in 1994, 1995, and 1996, respectively. No scarring information was recorded for 1997 when 8,742 coho returned to the hatchery.

Impact of Pinniped Predation on Salmonids - Rogue River

The potential impact of pinniped predation on ESA-listed coho salmon was not assessed. If most of the estimated predation in 1998 and 1999 was on ESA-listed coho, it could have had an adverse effect. The high occurrence of salmonids in harbor seal scat samples in some years/seasons (e.g., 30% in September 1997 and 43% in October 1995) are of concern, especially if ESA-listed coho salmon were the primary salmonid consumed.

SMITH RIVER

HSU conducted pinniped predation studies at the Smith River in northern California to assess potential harbor seal impacts on ESA-listed winter steelhead and fall Chinook salmon. An average of about 25 harbor seals haul out at the river mouth. A maximum of 80 harbor seals were counted by HSU during aerial and shore based surveys. The sources of information on the Smith River harbor seal predation study are Goley and Gemmer (2000) and Goley et al. (2002).

Methods - Smith River

HSU conducted surface observations in the fall of 1999 to assess harbor seal predation on fall Chinook salmon and in the winter of 2001 to assess harbor seal predation on winter steelhead. Harbor seal scats were collected by HSU at two inriver haul-out sites in 1999 and 2001. All prey hard part remains in the scats were identified to species when possible.

Surface Predation Observations - Smith River

In 1999, HSU conducted 287 hours of observations at eight observation sites in the lower 1.5 kilometers of the Smith River during a twice-a-week observation effort from August 31 to December 15, 1999. All sites were observed on 24 days, and harbor seal foraging behavior was observed on 18 of those days. Seven predation events were observed and three were salmonids. Three predation events involved a single harbor seal foraging independently, while the other four predation events involved cooperative foraging by two to six seals. HSU estimated 112 salmonids were consumed during the 16 week observation period. The percent of the fall Chinook salmon run consumed could not be estimated because escapement data was not available.

In 2001, HSU conducted 473 hours of observations at ten observation sites in the lower one kilometer of the Smith River during a two to three days a week observation effort from January 1 to April 14, 2001. Harbor seal foraging behavior was observed on 62 of the 87 observation days. HSU observed a total of 26 predation events, of which ten were salmonids. About half of the predation events involved single harbor seals foraging independently, while the remaining predation events involved cooperative foraging by two to five seals. HSU estimated 126 salmonids (2% of the winter steelhead escapement) were consumed by seals during the 15 week observation period.

Scat Collections and Analyses - Smith River

In 1999, HSU collected 47 harbor seal scats on nine days between August 31 and December 15, 1999 from the two haul-out sites in the Smith River. The most frequently occurring prey in the 47 scats with identifiable remains were: Pacific staghorn sculpin - 34%, Pacific sanddab - 32%, rex sole - 32%, surf smelt - 23%, sand sole - 23%, Dover sole - 21%, English sole - 19%, and skate/ray - 19%. Salmonid remains were found in 2.1% of the scats.

In 2001, HSU collected 78 harbor seal scats on nine days between January 1 and April 14, 2001 from the two haul-out sites in the Smith River. A total of 47 prey taxa were identified. The most frequently occurring prey in the 74 scats with identifiable remains were: longfin smelt - 51%, Pacific staghorn sculpin - 37%, Pacific tomcod - 37%, butter sole - 30%, slender sole - 28%, skates - 28%, Pacific sanddab - 23%, and Pacific whiting - 18%. Salmonid remains were found in 10% of the scats.

Pinniped Scarred Steelhead - Smith River

CDFG reported that 40% of the 145 steelhead returning to the Rowdy Creek Fish Hatchery in 2001 had been scarred by predators.

Impact of Pinniped Predation on Salmonids - Smith River

The potential impact of harbor seals on ESA-listed Smith River salmonids was not assessed due to limited scope of the studies. The first year of the study focused on fall Chinook salmon and run data was not available. The focus of the study switched to winter steelhead in 2001 and an estimated 2% of the run was taken by seals. The scat analyses indicate that salmonids are a common prey species and the steelhead scarring rate raise concerns about potential adverse effects of predation on ESA-listed steelhead. Further studies over at least three consecutive years are needed before conclusions can be made on impacts of pinniped predation in this river system.

KLAMATH RIVER

The Yurok Tribal Fisheries Program (YTFP) conducted investigations on pinniped predation on fall-run Chinook salmon in the lower Klamath River from 1997 to 1999. About 400-500 harbor seals haul out year-round in the Klamath River, while small numbers (less than 10 to 20) California sea lions and Steller sea lions commonly enter the river in the spring and fall overlapping returning adult runs of salmonids (fall Chinook salmon, coho salmon, spring Chinook salmon and steelhead). The sources of information on the Klamath River pinniped predation study are Hillemeier (1999) and Williamson and Hillemeier (2001a, 2001b).

Methods - Klamath River

YTFP conducted surface observations in the lower three kilometers of the Klamath River from shore from August through October in 1997 and from August through November in 1998 and 1999. Harbor seal scats were collected at the inriver haul-out site from April 1998 to March 1999 and from September to November 1999. “Mixed” sea lion scats were collected from a coastal sea lion haul-out site (used by both California and Steller sea lions) at Klamath Cove located about 1.5 kilometers north of the mouth of the Klamath River.

Surface Predation Observations - Klamath River

YTFP conducted 2,813 hours of surface observations of pinniped foraging in the Klamath River over three years. YTFP observed a total of 1,366 salmonid predation events.

In 1997, YTFP conducted observations of surface feeding events by pinnipeds from August 3 to October 26, 1997. YTFP observed 555 salmonid predation events during 472 hours of observations. Predation events were distributed throughout the lower three kilometers of the estuary, with most predation events (22%) observed at the river's confluence with the ocean. California sea lions were the primary pinniped predator, accounting for 87% of the predation events. Harbor seals and Steller sea lions were also observed feeding on salmonids, accounting for approximately 9% and 4% of the predation events respectively. YTFP estimated that approximately 10,105 adult salmonids were consumed. Fall-run Chinook salmon was the primary species consumed, with an estimated 8,809 Chinook salmon consumed (9% of the fall Chinook salmon run). An estimated 900 spring-run Chinook salmon were consumed during the first three weeks of the study, and an estimated 223 coho salmon and 173 steelhead were consumed during the entire study period.

In 1998, YTFP conducted observations of surface feeding events by pinnipeds from August 4 to November 14, 1998. YTFP observed 483 salmonid predation events during 1,358 hours of observations. California sea lions were responsible for 90% of the predation events. Harbor seals and Steller sea lions were also observed consuming salmonids, accounting for approximately 5% and 1% respectively of the predation events. YTFP found increased frequency of predation events at the river mouth during late morning and during low tide. YTFP estimated that approximately 3,077 adult salmonids were consumed. Fall-run Chinook salmon was the primary prey species, with an estimated 2,559 Chinook salmon consumed (3% of the fall Chinook salmon run). An estimated 438 spring-run Chinook salmon were consumed during the first three weeks of observations, and an estimated 20 coho salmon and 60 steelhead were consumed by pinnipeds during the entire study period.

In 1999, YTFP conducted observations of surface feeding events by pinnipeds at six sites in the lower three kilometers of the Klamath River from August 8 to November 15, 1999. YTFP observed 328 salmonid predation events during 1,259 hours of observations. California sea lions accounted for 94% of the predation events on salmonids. Harbor seals and Steller sea lions accounted for approximately 5% and 1% of the predation respectively. The majority of salmonids taken by pinnipeds (94%) were determined to be free-swimming fish that were not taken from recreational or tribal fishers. YTFP estimated that approximately 1,804 adult salmonids were consumed. By applying the proportionate catch of fall Chinook, coho and steelhead in the tribal and sport fisheries to the salmonids consumed by pinnipeds, the YTFP determined that fall-run Chinook salmon was the primary prey species, and estimated that 1,630 fall Chinook salmon (2.3% of the fall Chinook salmon run) were consumed by pinnipeds in 1999. YTFP estimated that 63 coho salmon (1.2% of the coho salmon run) also were consumed by pinnipeds. An additional 110 steelhead were estimated consumed by pinnipeds.

In 1999, YTFP also conducted night observations two to three times a week from August 20 to September 23, 1999 primarily at one site just inside the mouth of the river. During 55 hours of night observations, no predation events were observed. One potential sea lion foraging event was reported, but the actual predation could not be confirmed with the night vision equipment.

Scat Collections and Analyses - Klamath River

YTFP collected 399 harbor seal scats from the south spit at the mouth of the Klamath River from April 1998 to March 1999. The identifiable prey remains in 390 scats were divided into three timeframes for analysis: 1) autumn - from August to November to coincide with the fall Chinook and coho runs; 2) spring - from April through July to coincide with spring Chinook run; and 3) winter - from December through March to coincide with winter-run steelhead.

In the autumn 1998 scat collections, 47 prey taxa were identified from 252 scats with identifiable remains. The most frequently occurring prey in the scat samples were: smelt - 56%, unidentified Pleuronectids (righteye flounders) - 34%, lamprey spp. - 17%, and sanddab spp. - 15%. Salmonid remains were found in 14% of the scats.

In the spring 1998 scat collections, 38 prey taxa were identified from 105 scats with identifiable remains. The most frequently occurring prey in the scat samples were: Pacific whiting - 56.2%, unidentified Pleuronectids (righteye flounders) - 22%, lamprey spp. - 19%, and smelt - 19%. Salmonid remains were found in 4% of the scats.

In the winter 1998/99 scat collections, 26 prey taxa were identified in 33 scats with identifiable remains. The most frequently occurring prey in the scat samples were: unidentified Pleuronectids (righteye flounders) - 30%, smelt - 30%, poacher - 24%, sculpin - 24%, snailfish - 24%, and skate - 15%. Salmonid remains were not found in any of these scats.

In the fall of 1999, YTFP collected 91 harbor seal scats from the south spit at the Klamath River mouth from September 7 to November 9, 1999. A total of 29 prey taxa were identified. The most frequently occurring prey in the 90 scats with identifiable remains were: unidentified Pleuronectids (righteye flounders) - 54%, smelt - 39%, Pacific lamprey - 33%, and sanddab spp. - 21%. Salmonid remains were found in 12% of the scats.

YTFP also collected California sea lion and Steller sea lion "mixed" scat on September 23 and October 7, 1999 from a sea lion haul-out site located approximately 1.6 kilometers north of the Klamath River mouth. YTFP collected 29 mixed sea lion scat, all of which had identifiable remains. A total of 24 prey taxa were identified. The most frequently occurring prey in the scat samples were: salmonids - 45%, Pacific whiting - 24%, Pacific saury - 24%, rockfish - 24%, and smelt - 24%.

Pinniped Interactions with Recreational Fishery - Klamath River

In 1997, California Department of Fish and Game personnel asked angler questions about catch lost to pinnipeds while monitoring the recreational fishery. The survey indicated that 23% of the recreational catch was taken by pinnipeds.

Impact of Pinniped Predation on Salmonids - Klamath River

The study confirmed that salmonids were common prey of both harbor seals and California sea lions in the Klamath River. The levels of California sea lion predation observed could have an adverse effect when returns of Klamath River fall Chinook salmon are small. Potential upriver predation by harbor seals was not investigated. Potential pinniped impact on ESA-listed coho salmon was not assessed.

MAD RIVER

HSU conducted pinniped predation studies at the Mad River, California to assess potential harbor seal impacts on ESA-listed winter steelhead and fall Chinook salmon. An average of about 15 harbor seals haul out at the river mouth daily. A maximum of 113 seals were counted by HSU during aerial and shore based surveys. The sources of information on the Mad River harbor seal predation study are Goley and Gemmer (2000), Goley (2003), Goley et al. (2002, 2003), and Goley pers. comm. (2009).

Methods - Mad River

HSU conducted surface observations in the fall of 1999 to assess harbor seal predation on fall Chinook salmon and in the winter of 2001 and 2003 to assess harbor seal predation on winter steelhead. Harbor seal scats were collected by HSU at two inriver haul-out sites in 1999, 2001 and 2003. All prey hard part remains in the scats were identified to species when possible. CDFG provided data on pinniped scars on salmonids.

Surface Predation Observations - Mad River

In 1999, HSU conducted 287 hours of observations at six observation sites in the lower Mad River during a twice-a-week observation effort from August 31 to December 15, 1999. All sites were observed on 26 days, and harbor seal foraging behavior was observed on 22 of those days. Four predation events were observed just upriver from the river mouth consisting of one Chinook and three unidentified salmonids. One predation event involved a single harbor seal foraging independently, while the other three predation events involved cooperative foraging by two seals. HSU estimated 114 salmonids were consumed during the 16 week observation period. The percent of the fall Chinook salmon run consumed could not be estimated because escapement data was not available.

In 2001, HSU conducted 1,127 hours of observations at 10 observation sites in the lower one kilometer of the Mad River during a five to six days a week observation effort from January 1 to April 14, 2001. Harbor seal foraging behavior was observed on 62 of the 87 observation days. HSU observed 33 predation events, of which 26 were salmonids. About half of the predation events involved single harbor seals foraging independently, while the remaining predation events involved cooperative foraging by two to five seals. HSU estimated 149 salmonids (1.4% of the winter steelhead escapement) were consumed by seals during the 15 week observation period.

In 2003, HSU conducted 1,156 hours of daytime surface observations in the lower Mad River during a six day per week observation effort from December 15, 2002 to March 29, 2003. HSU observed 17 predation events, of which ten were salmonids. HSU estimated that 70 salmonids (1.4% of the winter steelhead escapement) were consumed by seals during the 15 week observation period.

HSU also conducted a pilot study in 2003 to assess nighttime harbor seal foraging and the upriver habitat use and behavior of harbor seals in the Mad River. Between December 15, 2002 and March 29, 2003, HSU conducted 61 hours of nighttime observations at the Mad River mouth and had 78 harbor seal sightings and no observed predation events. During 30 hours of daylight upriver observations, HSU had 15 seal sightings and no observed predation events.

Scat Collections and Analyses - Mad River

In 1999, HSU collected 37 harbor seal scats on eight days between August 31 and December 15, 1999 from the harbor seal haul-out sites on the north and south spits near the mouth of the Mad River. The most frequently occurring prey in 37 scats with identifiable remains were: Pacific sanddab - 41%, Dover sole - 35%, rockfish - 24%, slender sole - 22%, and rex sole - 19%. Salmonid remains were found in 11% of the scats.

In 2001, HSU collected 104 harbor seal scats on 12 days between January 1 and April 14, 2001 from the harbor seal haul-out sites on the north and south spits near the mouth of the Mad River. A total of 43 prey taxa were identified. The most frequently occurring prey in 100 scats with identifiable remains were: sanddab spp. - 25%, salmonids - 25%, Pacific tomcod - 22%, rex sole - 20%, Pacific whiting - 19%, Dover sole - 18%, Pacific lamprey - 18%, and Pacific staghorn sculpin - 17%.

In 2003, HSU collected 92 harbor seal scats on 18 days between December 15, 2002 and March 29, 2003 from the harbor seal haul-out site on the south spit near the mouth of the Mad River. A total of 32 prey taxa were identified. The most frequently occurring prey in 76 scat with identifiable remains were: rex sole - 36%, Dover sole - 32%, hagfish spp. - 29%, eelpout spp. - 28%, and sanddab spp. - 25%. Salmonid remains were found in 5% of the scats.

Pinniped Scars on Salmonids - Mad River

In 2001, CDFG reported that 20% of the 6,743 steelhead returning to the hatchery had predator scars. In 2003, CDFG documented that 38% and 28% respectively of the 4,281 steelhead hatchery returns and 526 angler caught steelhead (from creel census) had predator scars.

Impact of Pinniped Predation on Salmonids - Mad River

The potential impact of harbor seals on ESA-listed Mad River salmonids was not assessed. Although the numbers of salmonids observed taken appeared low, the proportion of scats with salmonid remains was high. Further studies under broader sampling plans with concurrent data on salmonid populations are needed before any conclusions can be reached on pinniped impacts in the Mad River.

EEL RIVER

HSU conducted pinniped predation studies at the Eel River, California to assess potential harbor seal impacts on fall Chinook salmon. An average of about 64 harbor seals haul out at the river mouth. A maximum of 250 seals were counted by HSU during aerial and shore based surveys. The sources of information on the Eel River harbor seal predation study are Goley and Gemmer (2000) and Goley pers. comm. (2009).

Methods - Eel River

HSU conducted surface observations in the fall of 1999 to assess harbor seal predation on fall Chinook. Harbor seal scats were collected by HSU at the haul-out sites on the spits at the river mouth and at estuary haul-outs in 1999. All hard parts of prey remains in the scat were identified to species when possible.

Surface Predation Observations - Eel River

HSU conducted 378 hours of observations at eight observation sites in the lower 1.5 kilometers of the Eel River during a twice-a-week observation effort from August 31 to December 15, 1999. All sites were observed on 21 days, and harbor seal foraging behavior was observed on 11 of those days. Two California sea lions were observed in the estuary, but no predation events were observed. Eleven harbor seal predation events were observed and two were salmonids. Seven predation events involved a single harbor seal foraging independently, while the other four predation events involved cooperative foraging by two to three seals. HSU estimated 50 salmonids were consumed during the 16 week observation period. The percent of the fall Chinook salmon run consumed could not be estimated because escapement data was not available.

Scat Collections and Analyses - Eel River

HSU collected 62 harbor seal scats on 11 days between August 31 and December 15, 1999 from the harbor seal haul-out sites on the spits near the river mouth and at three upriver haul-out sites. The most frequently occurring prey in 55 scats with identifiable remains were: Pacific sanddab - 44%, Dover sole - 40%, rex sole - 38%, English sole - 35%, Pacific lamprey - 27%, rockfish - 27%, Pacific tomcod - 24%, hagfish - 20%, and slender sole - 18%. Salmonid remains were found in 2% of the scats.

Impact of Pinniped Predation on Salmonids - Eel River

The potential impact of harbor seals on ESA-listed Eel River salmonids was not assessed due to lack of data on the salmonid runs. More than one year of data should be collected under structured sampling plans with concurrent data on salmonid populations before an assessment of pinniped impacts can be made.

AÑO NUEVO ISLAND

MLML conducted California sea lion food habit studies at Año Nuevo Island from 2001 to 2006 to assess foraging ecology and effects of environmental changes on California sea lion diet and foraging. In addition, since more than 16,000 California sea lions occur on Año Nuevo Island, the study provided an assessment of California sea lion consumption of salmonids in the central California area. The sources of information on the Año Nuevo sea lion food habits study are Weise and Harvey (2003a, 2005b, 2005c, 2008b), Weise (2006), and Weise pers. comm. (2009).

Methods - Año Nuevo Island

MLML collected California sea lion scat on Año Nuevo Island on a monthly basis from November 2001 to December 2006. Scats were analyzed and prey species were determined by identifying prey hard parts recovered from fecal samples, such as fish otoliths, skeletal fish bones, cartilaginous parts, eye lenses, teeth, and cephalopod beaks to the lowest taxon possible. To estimate prey consumption using a biomass reconstruction model, prey hard parts were measured to estimate standard length and mass of prey consumed by sea lions. Species-specific correction factors were applied to lengths of otoliths to compensate for degradation during digestion. A numerical correction factor (0.35) was used for salmon based on the MLML captive feeding study that indicated adult salmon pass through an animal in multiple fecal samples. An average correction factor of 43% was applied to species not reported in the literature. Cephalopod beaks and teeth of hagfish and lamprey do not appreciably reduce in size during digestion, so no correction factor was applied. Standard length and mass of prey consumed by sea lions were estimated using species-specific linear regressions of otolith length, and upper rostral beak length of squid. For adult-sized salmon skeletal material, a conservative average mass of gutted salmon landed in the fishery was used (2.0 kg).

Scat Collections and Analyses - Año Nuevo Island

MLML collected a total of 1,542 scats at California sea lion haul-out sites on Año Nuevo Island from 2001 to 2006. Of those collected, 1,382 scats contained identifiable prey hard parts with 13,302 individual prey occurrences (MNI). Schooling prey were the predominant prey species based on reconstructed biomass, including rockfish - 31%, Pacific sardine - 16%, Pacific whiting - 15%, northern anchovy - 12%, and salmon - 8%. The most frequently occurring of the prey identified were: northern anchovy - 24%, Pacific whiting - 22%, rockfish - 17%, Pacific sardine - 15%, and market squid - 7%. Salmonid remains were found in 2% of the scat samples collected from 2001 to 2006.

Salmon Consumption - Año Nuevo Island

MLML analyzed the scat collected in 2001 through 2002 and found that salmon occurred in the sea lion diet year-round, with the greatest frequency of occurrence, percentage reconstructed biomass, and relative importance in the diet during the spring and summer. Because spring and summer correspond with the commercial and recreational salmon fisheries seasons in central California, MLML presumed that hooked salmon from the fisheries likely contributed to the occurrence of salmon in the diet. Overall, frequency of occurrence of salmon was relatively small and total numbers of fish consumed were small, but the relative importance of salmon in the diet was consistently in the top ten for all prey species in all seasons as a result of the greater percentage of reconstructed biomass. The MLML consumption models indicated that the number of salmon consumed by sea lions in central California ranged between 19,664 and 54,942 salmon in the spring, 25,931 to 88,142 salmon in the summer, and 28,700 to 104,971 salmon in the fall. Thus, MLML estimated that sea lions consumed between 9% and 30% of the Central Valley fall Chinook salmon population.

Impact of Pinniped Predation on Salmonids - Año Nuevo Island

Although the occurrence of salmonids in the scat was small, the extrapolated estimate (based on biomass consumption estimate) of proportion of the Central Valley fall Chinook run consumed was high. Sea lion predation of 30% of the Chinook salmon run may have had an adverse effect on the Central Valley fall Chinook salmon population.

SCOTT CREEK

MLML conducted surface observations at Scott Creek, California to assess potential pinniped predation on ESA-listed coho salmon and winter steelhead. Although there were no harbor seal haul-out sites in Scott Creek, this site was chosen for predation studies because of reports of high levels of pinniped scars on the small runs of salmonids returning to Scott Creek (less than 500 coho salmon and 500 winter steelhead returning each year). The Monterey Bay Salmon and

Trout Project reported a high percentage of pinniped tooth and claw marks on salmonids with 50% of the steelhead and 40% of the coho salmon marked in 1994/1995, and 32% of the steelhead and 28% of the coho salmon marked in 1995/1996. The sources of information on the Scott Creek pinniped predation study are Harvey and Weise (1997), Weise and Harvey (1999), and Weise pers. comm. (2009).

Methods - Scott Creek

MLML conducted surface predation observations at Scott Creek in March 1997 and from November 1998 through mid-April 1999. Daylight and night surface observations for pinniped foraging were conducted from a bluff overlooking the surf zone, river mouth, and river lagoon. The two harbor seal haul-out sites near Scott Creek (one was just south and the other was about two kilometers north) were inaccessible for scat collection, so no scat analysis was possible. Coho salmon and winter steelhead abundance and pinniped scarring data were collected by the Monterey Bay Salmon and Trout Project at a fish weir on Scott Creek from 1994 to 1996, but not during the course of this study.

Surface Predation Observations - Scott Creek

MLML conducted 127 hours of daytime and night observations at the mouth of Scott Creek and the surf zone in 1997 and 1998/1999. Thirteen harbor seals, one elephant seal, and one California sea lion were sighted in the surf zone during 46 hours of observations in March of 1997, but no predation events or foraging behavior were detected. In 1998/1999, Scott Creek was monitored for 78 hours in daytime from November 1998 through April 1999, and for three hours at night on March 18, 1999 with night viewing equipment. No pinnipeds, foraging behaviors or predation events were observed in 1998/1999.

Impact of Pinniped Predation on Salmonids - Scott Creek

The lack of predation observations would suggest that pinniped predation on salmonids in Scott Creek was insignificant. However, the high level of pinniped scarred salmonids that has been observed would suggest otherwise. The high level of pinniped scarring in 1994 to 1996 may have been due to differing situations with the river breaching the sand bars and creating pools where salmonids may have been more vulnerable to predation, or predation was occurring at areas and times that were not observed in 1998 and 1999. Further predation observations would need to be made concurrent with observations for pinniped scarred salmonids before any determination can be made on the effects of pinnipeds on Scott Creek salmonids.

SAN LORENZO RIVER

MLML investigated pinniped predation on ESA-listed winter-run steelhead in the San Lorenzo River, California from 1997 to 2001. The San Lorenzo River, which enters the ocean at Santa Cruz, California, has a run of less than 1,000 winter steelhead that co-occurs with several hundred harbor seals in the vicinity of the river year-round. The San Lorenzo was selected for predation studies because a year-round harbor seal haul-out was located just inside the mouth of the San Lorenzo River, and reports of high levels of pinniped scars on winter steelhead returning to San Lorenzo River. The Monterey Bay Salmon and Trout Project (MBSTP) had reported that 40%, 52%, 47% and 54% of the winter steelhead examined in San Lorenzo River in the winter of

1992/93, 1993/94, 1994/95, and 1995/96, respectively had pinniped tooth and claw marks. The sources of information on the San Lorenzo River harbor seal predation study are Harvey and Weise (1997), Weise and Harvey (1999, 2002), and Weise pers. comm. (2009).

Methods - San Lorenzo

The MLML conducted daylight and night surface observations for harbor seal predation between early November and mid-April at the mouth of the river from 1997 to 2001. MLML also analyzed scat samples collected at three haul-out sites in the vicinity of the San Lorenzo River from November through April of 1997/1998, 1998/1999 and 1999/2000. MLML identified prey from otoliths, beaks, diagnostic salmonid bones, cartilaginous parts and teeth in the scats. Winter steelhead abundance and pinniped scarring data was collected by the Monterey Bay Salmon and Trout Project (MBSTP) at a fish trap at the Felton diversion dam located about 15 kilometers upstream.

Surface Predation Observations - San Lorenzo

MLML conducted 851 hours of daylight observations in March 1997, January to March 1998, and November 1998 to April 1999, at the mouth of the San Lorenzo River. Observations in 1999 also occurred about one kilometer upriver. No predation events were observed in 1997 or 1998, but harbor seals were observed exhibiting foraging behavior. In 1999, harbor seals were observed foraging and six predation events were observed consisting of one unidentified salmonid, one unidentified fish and four lamprey.

Night observations were conducted in mid-March in 1999 to assess if night-vision equipment could be used to determine if harbor seal foraging activity and predation may be occurring. During 31 hours of night observations, harbor seals were observed at the mouth of the river but no foraging behavior was observed. Night observations conducted upstream of the mouth of the river (about one kilometer upriver) resulted in multiple observations of harbor seals exhibiting foraging behavior, but no predation events were observed.

In 2000, MLML shifted the observation program to focus on night observations at the river mouth and upstream. From January 17 to April 13, 2000, MLML conducted 258 hours of night observations and 42 hours of daytime observations. MLML observed 57 predation events (18 of which were salmonids): 53 were at night and four during daylight. Harbor seals were responsible for 55 of the predation events with 44 predation events observed at the river mouth and 11 observed upstream (about one kilometer from the mouth). California sea lions were responsible for two predation events in the ocean area just beyond the surf zone. Based on the predation observations, MLML estimated that harbor seals consumed approximately 111 steelhead (15% of the 1999/2000 winter steelhead run).

In 2001, MLML conducted 276 hours of night observations and 138 hours of daytime observations from January 2 to April 14, 2001. MLML observed 53 harbor seal predation events, all occurring at the river mouth: 31 were at night and 22 during daylight. The 53 predation events consisted of 17 adult steelhead, three steelhead smolt, 25 lamprey, and eight unidentified fish. Based on the predation observations, MLML estimated that harbor seals consumed approximately 85 steelhead (11% of the 2000/2001 winter steelhead run).

In 2002, MLML conducted 288 hours of night observations and 142 hours of daytime observations from January 5 to April 10, 2002. MLML observed 35 harbor seal predation events, all occurring at the river mouth: 34 were at night and one during daylight. The 35 predation events consisted of six adult steelhead, 27 lamprey, and two unidentified fish. Based on the predation observations, MLML estimated that harbor seals consumed approximately 28 steelhead (2% of the 2001/2002 winter steelhead run).

Scat Collections and Analyses - San Lorenzo

MLML collected 194 harbor seal scats from October to April in 1998 to 2000 at harbor seal haul-out sites at the San Lorenzo River mouth, Elkhorn Slough, and a concrete ship at Seacliff State Park. Identifiable prey remains were found in 173 scat samples, consisting of 41 prey taxa. The most frequently occurring of the prey identified were: Dover sole - 26%, rockfish - 25%, northern anchovy - 25%, octopus - 23%, and English sole - 22%. Salmon hard parts occurred in 2% of the scat samples over the three year period. Two of the three samples with salmon remains were collected inside the mouth of the San Lorenzo River, yet only 17 samples were collected at this harbor seal haul-out site over three years (i.e., 12% of inriver scat samples contained salmonid remains). Scat collection inriver was limited due to tidal and river flow washing over the haul-out site multiple times per day.

Pinniped Scars on Steelhead - San Lorenzo

The MBSTP examined steelhead at an upriver trap in the San Lorenzo River and found pinniped tooth and claw marks on steelhead in each year from 1998 to 2001. In 1998, 28% of the 170 winter steelhead passing the trap had predator scars. In 1999, 33% of 531 winter steelhead in the trap had predator scars. In 2000, 37% of the 560 steelhead in the trap had predator marks. In 2001, 37% of the 553 steelhead in the trap had predator marks.

Capture and Marking - San Lorenzo

MLML captured four harbor seals in the San Lorenzo River on January 30 and February 14, 2001, and tagged animals with head-mounted VHF tags and color markings for individual identification. Seals were tracked for more than 60 hours using hand-held antennae during night and daytime hours over the next two months. Individually tagged seals were only heard and observed in the river mouth in close proximity to the haul-out site or heard directly offshore from river mouth. No tagged individuals were heard or seen on haul-out sites outside of the river mouth during the steelhead season. These findings indicated a degree of seasonal site fidelity among tagged harbor seals that haul out in the San Lorenzo River.

Impact of Pinniped Predation on Salmonids - San Lorenzo

The observed predation of 2% to 15% of the winter steelhead run each year was likely a low estimate since the data indicate that most of the salmonid predation was occurring at night when observations were difficult. Predation rates of 11-15% combined with the high level of pinniped scarring (28% to 36%) observed upriver on such a small run of winter steelhead is likely adversely affecting the recovery of this winter steelhead population. The tracking data combined with scat data suggest that the small population of harbor seals that haul out inriver may be responsible for much of the winter steelhead predation occurring in the San Lorenzo River.

MONTEREY BAY

MLML investigated California sea lion food habits in Monterey Bay, California to assess their impacts on salmonids. California sea lions haul out in several areas in Monterey Bay and significant loss of salmon resulting from their interactions with salmon troll fisheries in Monterey Bay have been reported. The study consisted of California sea lion scat collection and analysis. MLML also studied California sea lion interactions with fisheries in Monterey Bay and that study is described in the fishery interaction section of this report. The sources of information on the Monterey Bay sea lion food habits study are Weise (2000), Harvey and Weise (1997), Weise and Harvey (2003b, 2008a), and Weise pers. comm. (2009).

Methods - Monterey

MLML investigated California sea lion predation on salmonids in Monterey Bay by collecting and analyzing scat from the two main California sea lion haul-out sites (the Monterey Coast Guard jetty and the Santa Cruz wharf) in Monterey Bay from 1997 to 1999. MLML identified prey from otoliths, beaks, diagnostic salmonid bones, cartilaginous parts and teeth in the scats. The biomass of prey consumed was estimated using a "biomass reconstruction" and a "mean percentage mass" model.

Scat Collections and Analyses - Monterey

MLML conducted 79 scat collections from April 1997 to November 1999 at the two California sea lion haul-out sites in Monterey Bay. MLML collected 621 scat samples, of which 573 contained identifiable prey, and identified 32 prey taxa. Scats contained a mean of 1.75 prey per scat. The most frequently occurring of the prey identified were: Pacific sardine - 49%, market squid - 34%, northern anchovy - 29%, Pacific whiting - 23%, rockfish - 13%, and salmon - 7%. The greatest occurrence of salmon (18%) was in the summer of 1998 (May-July).

Although the occurrence of salmon was relatively low (less than 7%) over all seasons, MLML found that salmon represented a significant portion of biomass consumed by sea lions during some seasons. Based on estimated biomass consumed using a biomass reconstruction model, salmon were the primary prey species in fall (August to October) 1997 and summer (May to July) 1998 with an estimated 671,300 and 403,400 kilograms respectively of salmon consumed. The greatest relative importance of salmon in the sea lion diet was during summer 1998, which coincided with the greatest sea lion depredation rates in the commercial and recreational salmon fisheries. MLML found that the estimated depredation of hooked fish in salmon fisheries accounted for approximately 51% of sea lion consumption estimates in 1998 and 37% in 1999. Therefore, contrary to initial MLML impressions reported in Weise and Harvey (2005a), MLML found that California sea lions were also taking quantities of free-swimming salmon.

MLML found that the short-term seasonal changes in diet corresponded with prey movement and life history patterns, whereas long-term annual changes corresponded with large-scale ocean climate shifts, namely the large 1997-98 El Niño and 1999 La Niña. MLML found the impact of ocean basin-level regime shifts on sea lion diet was apparent with a significant and relatively stable change in diet from a cold "anchovy regime" to a warm "sardine regime."

Impact of Pinniped Predation on Salmonids - Monterey

The Monterey Bay food habit studies by MLML demonstrate that larger prey species such as salmon can constitute a significant portion (i.e., biomass) of the diet of California sea lions while having a low occurrence relative to the numbers of individual prey species consumed. The quantities of salmon consumed by California sea lions during the summer and fall seasons may adversely effect salmon populations in Monterey Bay especially in years of low salmon returns.

CARMEL RIVER

MLML conducted a pilot study at Carmel River, California to assess potential pinniped predation on steelhead in March 1997 (Harvey and Weise 1997). A total of 44 hours of surface observations were conducted by MLML at the Carmel River mouth and in the surf zone. Sightings of one harbor seal and four California sea lions were reported, but no foraging behaviors or predation events were observed.

The data collected from this pilot study suggested that pinniped predation on salmonids was not occurring; however, the study was limited. Multiple years data should be collected before conclusions are made on pinniped predation in this river.

CAPTIVE FEEDING STUDIES

Captive feeding studies were funded by the West Coast Pinniped Program to assess prey digestion variables that affect pinniped consumption estimates derived from scats. The identification of prey species from undigested hard parts remains in scats is the primary method used in food habit studies to calculate prey frequency of occurrence or biomass of prey consumed. Thus, it was important to attempt to validate some of the consumption assumptions used in harbor seal and sea lion food habits studies and estimates of prey consumption.

MLML conducted captive feeding studies with harbor seals and California sea lions. Objectives of the captive studies were to: 1) determine the proportion of hard parts recovered in scats after prey consumption and develop correction factors; 2) determine single meal and mixed meal passage rates; 3) determine the length of time before hard parts appear in scats, and duration they continue to pass; 4) determine reduction in estimated prey lengths due to otolith erosion and develop correction factors; 5) correlate size of prey with hard parts recovered; and 6) correlate meal frequency with hard parts recovered.

Harbor Seal Captive Feeding Study

MLML conducted captive feeding studies with seven male harbor seals (five adults and two sub-adults) during 256 days (62 day average captive testing per seal). Harbor seals were fed Pacific sanddab, Pacific sardine, market squid, shortbelly rockfish, pink salmon, steelhead smolt, and Pacific whiting in 177 experimental meals (total prey fed exceeded 2,700 fish). The results of the harbor seal feeding study reported herein are from a Masters Thesis by Phillips (2005) and Phillips and Harvey (2009).

A total of 619 scats (no spewing) were collected, of which 589 had identifiable remains that were analyzed. An average of 2.4 scats per seal per day was collected. Hard parts were passed in four to 161 hours after ingestion (average minimum was 17 hours and average maximum was 76 hours with 73% of hard parts passed within 48 hours of ingestion). Hard parts from a single meal were recovered in one to ten scats (average 3.8 scats), confirming that a single scat does not represent a single meal, but rather a series of foraging events throughout the previous 24 to 48 hours. Hard parts representing up to five prey species (meals) were found in one scat.

Overall, 58% of otoliths and 89% of squid beaks were recovered. Recovery rates varied with prey having smaller, fragile otoliths recovered in lesser quantities than prey with larger, robust otoliths. Otoliths of pink salmon, steelhead smolts, and Pacific sardines had significantly lower recovery rates than Pacific sanddab and Pacific whiting. Recovery rates were greatest for prey with large otoliths such as Pacific whiting, shortbelly rockfish, and Pacific sanddab. Recovery of all prey except pink salmon was improved by 32% when all diagnostic skeletal structures were used, indicating that the all-structure technique will improve recovery biases due to complete otolith erosion. The percent increase in MNI using the all structures method was 50% for Pacific whiting, 46% for steelhead smolt, 31% for Pacific sardine, 21% for rockfish, and 13% for sanddab. The "all structure" technique overestimated the number of fish eaten for shortbelly rockfish, Pacific whiting, and pink salmon. The pink salmon recovery rate increased from 28.3% to 310.0% when the all-structure technique was used, highlighting the issue of fragmentation of a single meal across a series of scats.

Mean length reduction of recovered otoliths was 20%. Correction factors calculated from average length reduction improved length estimates for all fish species. Grade-specific length correction factors reduced variability in all of the estimates and significantly improved estimates of prey with highly eroded otoliths including Pacific whiting and shortbelly rockfish.

MLML compared consumption estimates from the Split-Sample Frequency of Occurrence (SSFO) model and the Reconstructed Biomass (RB) model. The SSFO overestimated the proportion of Pacific whiting and pink salmon in the diet, and underestimated the proportion of shortbelly rockfish, Pacific sardines, and market squid. Excluding pink salmon, the mean difference between the SSFO estimate and known consumption quantities was 55.2%. The RB model underestimated the biomass of Pacific sardine and Pacific whiting in the diet, and overestimated the amount of Pacific sanddab, pink salmon, and steelhead smolts. The mean difference between the RB estimate and known consumption quantities was 18.6%.

California Sea Lion Captive Feeding Study

MLML conducted 255 captive feeding experiments with five male (two adult, three subadult) and four female (two adult, two subadult) California sea lions. The sea lions were fed eleven different meal compositions, equating to 5-10% of their body weight per day, consisting of natural prey species: northern anchovy, Pacific sardine, Pacific mackerel, jack mackerel, Pacific whiting, shortbelly rockfish, market squid, steelhead smolts and adult pink salmon. MLML collected a total of 778 scat and spew samples. Sea lions produced a mean 3.2 scats per day. This captive feeding study was the topic for a Masters Thesis by Sweeney (2008) and the information reported herein is from the thesis.

Hard parts from a single meal were distributed in a mean of six scats, and passed between a minimum of 1.8 hours (Pacific whiting) and a maximum of 387.8 hours (squid beaks). Otoliths appeared in scats from 5.4 to 169.3 hours after ingestion. Final defecation time was 8-258 hours for all structures, excluding squid beaks. A mean of 16% of all skeletal structures passed 20 hours after ingestion, 28% in 40 hours, and 46% in 60 hours. All prey species fed to sea lions had between 40% (steelhead smolt) and 57% (northern anchovy) recovery after 40 hours of ingestion, except for adult pink salmon. Of the adult pink salmon hard parts, 86% were recovered within 20 hours and 97% by 40 hours. Passage rates did not differ between small and large meals.

The recovery rate differed significantly among prey species using otoliths and improved for adult salmon and sardine using the all structure method. The mean recovery rate was 57% for otoliths, 39% for other bones, and 89% for squid beaks. Mean recovery rate increased to 68% using the all-structure method. Adult pink salmon had a significantly greater recovery rate (100%) when using the all structure method compared with 74% when counting only otoliths. Larger and more robust otoliths of Pacific whiting had greater recovery rates (78%) than smaller, more fragile otoliths of Pacific sardines (32%).

The mean otolith reduction was 14%. Otolith erosion increased with meal size of Pacific mackerel. Based on the observed otolith reductions, Sweeney (2008) developed otolith length correction factors that better estimated length of prey consumed than the length estimates calculated with uncorrected otolith ventral lengths and widths. Average length correction factors (LCF) better estimated prey size and biomass than estimates using the partially digested otolith length. Graded LCFs better estimated original prey size than a LCF, with decreasing error values.

MLML found that the all structure method and VBR model, in conjunction with numerical and graded length correction factors, most accurately estimated diet of California sea lions. Tests with the Modified and the Split-Sample Frequency of Occurrence models indicated they misrepresented the amount of prey consumed. MLML found that prey consumed in lesser numbers, usually large prey with greater recovery rates, will be overestimated and prey consumed in greater numbers, usually small prey with lesser recovery rates, will be underestimated. Also, smaller prey with fragile otoliths, such as Pacific sardine, have lesser recovery rates, and their relative importance was underestimated by MNI (minimum number of individuals).

GENETIC IDENTIFICATION OF SALMONIDS IN PINNIPED SCATS

The West Coast Pinniped Program supported the development and implementation of genetic techniques to identify salmonid species from their skeletal remains in scat samples. In many cases, salmon bones, but not otoliths (which can be morphologically identified to species) were found in scats and the species of salmon could not be determined (i.e., reported as unidentified salmonid). Genetic identification provided identification of specific salmon species of concern such as distinguishing the occurrence of ESA-listed coho salmon from fall-run Chinook salmon in scat samples when both species occurred in a river at the same time. Genetic studies were conducted by NMFS Northwest Fisheries Science Center (NWFSC) on harbor seal scat samples from the Umpqua and Columbia Rivers (Purcell et al. 2004, Rhydderch et al. 2003), Oregon State University on harbor seal scat samples collected by ODFW in Alsea Bay (Kvitrud et al. 2005), and WDFW Genetics Laboratory on harbor seal scat samples collected in Hood Canal (Lance and Jeffries 2009b, Lance et al. 2005).

NWFSC developed a DNA isolation procedure for salmonid bones found in seal scat and species-specific diagnostic mitochondrial DNA markers to uniquely identify each of the seven Pacific salmonids (Chinook salmon, coho salmon, pink salmon, chum salmon, sockeye salmon, steelhead, and cutthroat trout) found in North America (Purcell et al. 2004). These molecular genetics techniques were applied to 116 salmonid bones found in harbor seal scats collected by NMML in the Umpqua River. At least one salmonid bone or bone fragment from each scat sample with salmonid bones was processed for genetic identification. Salmonid bones to be analyzed genetically were selected by number or size (or both) to represent different species or individuals present in each scat. For example, if a scat had 95 approximately equal-size vertebrae (a salmonid has approximately 65 vertebrae), then at least two vertebrae (potentially representing at least two individuals) were used for genetic identification. Also, if a sample had a very large gillraker and three small vertebrae, then the gillraker and one vertebra were analyzed for genetic identification. The size of diagnostic structures was also used to categorize salmon remains as juvenile or adult, when possible. Of the 116 salmonid bones, 67% were amplified by PCR. But, because most of the sampled scats contained multiple salmonid bones, Purcell et al. (2004) was successful in amplifying bones in 90% of the 39 scats. There was no relationship between bone size and DNA extraction success. The smallest bone successfully amplified was a 0.2 mg tooth and the largest was a 21.8 mg vertebra. Direct sequencing of mitochondrial DNA was the main technique used for bone identification, but 23 bones were identified using a restriction fragment length polymorphism (RFLP) technique. Fourteen of these 23 bones were additionally confirmed by sequencing and the two techniques gave matching results. Purcell et al. (2004) concluded that sequencing or RFLP analyses were both viable methods of identifying salmonid species. The resulting salmonid identifications are provided in the Umpqua River section of this report.

Oregon State University used genetic techniques to identify salmonid remains in harbor seal scats collected by ODFW in Alsea Bay. Kvitrud et al. (2005) used a PCR-based species test and microsatellite genotyping to determine salmonid species composition. Samples identified as Chinook salmon were subsequently analyzed to determine if individual scat samples contained bones from more than one fish or if an individual salmon could be detected in more than one scat. All 745 of the salmonid bones in the scat samples were processed (rather than a sample from each scat). DNA extraction and species identification was successful for 56% of the bone samples, and 93% of all scat samples had bones that were identified to species. Kvitrud et al. (2004) found 13% of the scat contained bones from more than one species of salmonid indicating that all salmonid bones in a scat should be genetically analyzed (rather than just a sample of the bones in a scat). Of the scat samples that contained Chinook salmon bones, 32% had bones from more than one individual Chinook salmon. The remains from one individual Chinook salmon was found in three different scat samples collected on the same day indicating either prey sharing between more than one seal or multiple defecations by the same animal. The resulting salmonid identifications are provided in the Alsea Bay/River section of this report.

The WDFW Genetics Laboratory used genetic techniques to identify salmonid remains in harbor seal scats collected by WDFW in Hood Canal. A total of 393 salmon bones from 339 different scat samples were subjected to single nucleotide polymorphisms (SNPs) DNA analysis for species identification (Lance and Jeffries 2009b, Lance et al. 2005). Of the 393 samples analyzed, 22% failed to yield detectable PCR products. Another 4% of the samples yielded PCR products that had electropherogram patterns on the DNA sequencer that could not be reliably interpreted. The remaining 292 bones (74%) were successfully identified to species. The success rate for species identification varied by bone type: over 90% of all radials and vertebrae were successfully identified to species and 80% of all teeth were successfully identified to species. In contrast, only 55% of gill rakers were successfully identified to species. Although sample sizes were very small, all hypurals, parasphenoids, fin rays, and unidentified "bits" were successfully identified to species, whereas only 75% of ribs and 67% of quadrates were successfully identified to species. Two or more salmonid bones from the same scat sample were analyzed for 32 scats, and 44% of these scats had salmon bones from different species. In one case where three bones were analyzed, each bone was from a different species. The resulting salmonid identifications are provided in the Hood Canal section of this report.

The NWFSC also used genetic techniques to identify salmonid remains in harbor seal scats collected by NMML in the lower Columbia River. Rhydderch et al. (2003) had an improved salmonid identification success rate of 93% of all bones processed. Two methodological changes may have accounted for this improvement. First, when the PCR failed to yield product on an agarose gel, a reamplification PCR using the initial PCR product as template was conducted. In a subset of 27 samples, which failed to yield PCR product after the first PCR, six samples were successfully reamplified and screened using RFLP (proportionally increasing the success rate by 22%). Due to this improvement and as a time saving measure, all subsequent samples were PCR amplified and then reamplified. Second, the DNA extraction was initially conducted by soaking the bones in 10% bleach for 10 minutes before decalcifying. After 89 bones were processed with lesser success in identification, the use of bleach was stopped because bleach, even in trace amounts, was an inhibitor to PCR. Rhydderch et al. (2003) recommended that future DNA isolation remove the bleaching step and that PCR reamplification be conducted for all samples. The resulting salmonid identifications are provided in the Columbia River section of this report.

The NWFSC also experimented with assigning the ESU to the Chinook salmon bones found in the Columbia River harbor seal scats. Rhydderch et al. (2004) used the Chinook salmon microsatellite baseline to assign the stock of origin (i.e., ESU) to Chinook salmon bones from harbor seal scat using individual multi-locus genotypes. They found that the baseline could resolve the eight Columbia River ESUs only with moderate success. However, after pooling some of the ESUs into regional reporting groups, the baseline was more successful. The pooled reporting groups (RGs) were the Interior Spring (consisting of Middle Columbia River spring, Upper Columbia River spring, and Snake River spring/summer ESUs) and Interior fall (consisting of Upper Columbia River summer/fall, Snake River fall and Deschutes River summer/fall Chinook ESUs). The ESA-listed Lower Columbia River ESU and the Upper Willamette River ESU remained unpooled. Of the 279 Chinook salmon bones processed, 63% were successfully amplified and scored at seven or eight loci, and the ESU or RG was assigned for 71 bones with high strength of assignment. The resulting ESU or RG assignments are provided in the Columbia River section of this report.

In summary, the extraction of DNA from salmonid bones in scats can be done with a commercially available kit with minor modifications. Both sequencing and RFLP analyses were viable methods of identifying the seven common salmonid species. Further work is needed to find quicker species assay and to further investigate use of microsatellites from nuclear DNA to identify salmonid stocks or ESUs.

FISHERY INTERACTIONS

Harbor seals and California sea lions have interacted with almost all commercial and recreational fisheries on the west coast. Because pinniped mortalities due to entanglement in fishing gear do not appear to have had any negative effects on the increase in seal or sea lion populations, the principal concern over pinniped fishery interactions is pinniped removal of fish caught on fishing gear and potential indirect impacts on the fishery stocks.

NMFS (1997) identified salmon fisheries and the California commercial passenger fishing vessel (CPFV) fishery (also called charterboat or partyboat fishery) as having the most severe interactions with pinnipeds. Follow-up studies conducted by the west Coast Pinniped Program as a result of the findings in the NMFS (1997) report are described in this section.

San Diego Commercial Fishing Passenger Vessel (CPFV) Fishery

CDFG conducted at-sea observations of pinniped interactions with CPFVs in San Diego County in 2000-2001 to assess the severity of pinniped removals of fish catch and bait. The source of information on San Diego County CPFV pinniped interactions is Read and Sweetnam (2003b).

Methods - San Diego CPFV Fishery

CDFG placed observers onboard randomly selected CPFV vessels departing from Oceanside, Mission Bay, and San Diego Bay. Observed trips were regularly scheduled weekday and weekend trips for one-half day, three-quarter day and overnight trips. The targeted fishing grounds were the near-shore waters off San Diego County and the Coronado Islands off Mexico. Data collected by observers included port of departure/return, fishing locations, time fished and number anglers fishing at each fishing location, number and species of fish caught, number and species of pinnipeds at each fishing location, and number and species of fish (including bait) removed by pinnipeds from fishing lines.

Fishery Observations - San Diego CPFV Fishery

In 2000, CDFG conducted onboard observations on 176 CPFV trips representing 3% of the 5,438 CPFV trips in San Diego County from mid-April to the end of August 2000. CDFG observers documented pinniped occurrence (where a pinniped approaches within 100 meters of the vessel when anglers were actively fishing) on 80% of the CPFV trips observed. Depredation of catch or bait (where the pinniped takes part or all of the fish on a hook) occurred on 58% of the observed trips. California sea lions were observed on all trips except one which only involved a harbor seal, and both pinnipeds were observed on seven trips.

In 2001, CDFG conducted onboard observations on 120 CPFV trips representing 2% of the 5,838 CPFV trips in San Diego County from mid-April to the end of August 2001. CDFG observers documented pinniped occurrence during fishing on 75% of the trips observed, and depredation of catch or bait on 53% of the observed trips. California sea lions were the only pinniped observed on 114 trips, harbor seals were the only pinniped observed on two trips, and both pinnipeds were observed on four trips.

Fishery Interactions - San Diego CPFV Fishery

California sea lions were the primary pinniped involved in the observed CPFV interactions. Sea lions took catch or bait off hooks on 56% of the observed CPFV trips in 2000 and 2001. Baitfish (anchovy or sardine) were the most frequently observed fish removed from hooks by sea lions. Of the targeted catch, Pacific barracuda was the most frequently removed catch (71% of observed fish removals), followed by yellowtail - 9%, Pacific mackerel - 6%, kelp bass - 5%, and ocean whitefish - 3%. Sea lions took 6% of the observed Pacific barracuda caught on CPFVs followed by 3% of the yellowtail caught. A review of 11,274 CPFV logbook reported trips out of San Diego in 2000 and 2001 also indicated that Pacific barracuda was the principal catch species removed by sea lions accounting for 54% of the fish removals, followed by yellowtail - 19%, kelp bass - 9%, ocean whitefish - 6% and Pacific mackerel - 4%.

About 25% of observed CPFV trips had to relocate their fishing location because of sea lion interactions. The average lost fishing time was greater than 30 minutes per trip due to fishing site relocation. The loss of bait to sea lions also resulted in an undetermined amount of lost fishing time for re-baiting the hook and getting the baited-hook back down to the proper fishing depth. CDFG found that lost fishing time can be up to 50% of typical CPFV half day time allotment.

California Commercial Fishing Passenger Vessel (CPFV) Fishery Logbook Program

SWFSC analyzed the pinniped interaction data reported by California CPFV operators in their logbooks. The SWFSC obtained the CPFV logbook data from CDFG for 1994 through 2001 covering 265,217 trips by over 250 vessels, and provided the following information (Thomson and Castrence 2005).

California CPFV Pinniped Interactions - Logbook Program

From 1994 to 2001, 12% of the CPFV trips were negatively effected by pinnipeds (where fish caught were lost to pinnipeds) ranging from a low of 8% of the CPFV trips in 2000 to a high of 18% in 1998. About 2% of the catch was lost to pinnipeds ranging from 1% in 2000 to 2% in 1998. CPFVs fishing in southern California lost more fish to pinnipeds than trips in central and northern California.

The Pacific barracuda was the species most frequently taken by pinnipeds accounting for 39% of all caught fish removed, followed by Pacific mackerel - 18%, yellowtail - 11%, Chinook salmon - 8%, Pacific bonito - 6%, kelp bass - 5%, rockfish - 3% and ocean whitefish - 3%. Sea lions took 6% of the Pacific barracuda caught on CPFVs followed by Pacific bonito - 5%, Chinook salmon - 5%, Pacific mackerel - 4%, yellowtail - 4%, white seabass - 4%, and California halibut - 3%.

The fishing strategy most affected by pinnipeds was mooching, followed by trolling, anchored and drifting.

California Salmon Troll Fishery

CDFG augmented their ocean salmon fishery monitoring program from 2000 to 2002 to collect at-sea data on pinniped interactions with the commercial salmon troll fishery along with their standard fishery data collection. The source of information on the California salmon troll fishery interactions is Palmer-Zwahlen (2003).

Methods - California Salmon Troll Fishery

CDFG placed observers onboard commercial salmon troll vessels to document sea lion depredation rates and calibrate dockside data collection as well as to collect “standard” fishery monitoring data. CDFG also continued collecting dockside information from salmon troll vessel operators on pinniped interactions during their port sampling program (CDFG had collected information on sea lion depredations on salmon during their dockside sampling program since 1995). The dockside sampling occurred in Crescent City, Eureka, Fort Bragg, San Francisco and Monterey in 2000 to 2002, and Morro Bay in 2002 only.

At-sea Fishery Observations - California Salmon Troll Fishery

In 2000, CDFG staff spent 31 days at-sea collecting data onboard commercial salmon trollers from June through September. All observations occurred in the San Francisco and Monterey areas where most fishing activity occurred. Sea lion depredations were observed on three of the 12 days at-sea in the San Francisco area, and on two of the 19 days at-sea in the Monterey area. The greatest depredation rates observed were in June in the Monterey area (5% of catch) and in September in the San Francisco area (5% of catch). Overall, CDFG observed 2.4% of the 709 hooked salmon taken by sea lions.

In 2001, CDFG staff spent 16 days at-sea collecting salmon troll data in May, June and September. The May and June observations occurred in the Monterey area and the September observations occurred in the San Francisco area. Sea lion interactions were observed on one of 12 days at-sea in the Monterey area, and on one of four days at-sea in the San Francisco area. The greatest depredation rate observed (13% of catch) was in May in the Monterey area. Overall, CDFG observed 8% of the 321 hooked salmon taken by sea lions.

In 2002, CDFG staff spent 11 days at-sea collecting salmon troll data from June through August. All observations occurred in the Monterey and Fort Bragg areas. No sea lion interactions were observed in the Monterey area at-sea trips. In the Fort Bragg area, sea lion interactions occurred on three out of nine trips. The greatest depredation rate observed (4% of catch) was in August in the Fort Bragg area. Overall, CDFG observed 0.4% of the 989 hooked salmon taken by sea lions.

Dockside Interviews - California Salmon Troll Fishery

In 2000, CDFG sampled 144,089 Chinook salmon landed commercially in California. The salmon troll vessels making these deliveries reported 15,802 salmon taken (8% of catch) by sea lions. The greatest depredation rates were in August in the San Francisco area (21% of catch) and the Monterey area (17% of catch).

In 2001, CDFG sampled 50,036 Chinook salmon landed commercially in California. The salmon troll vessels making these deliveries reported 3,926 salmon taken (5% of catch) by sea lions. The greatest depredation rates were in June in the Monterey area (18%), August in the San Francisco area (17% of catch) and September in the Eureka area (17% of catch).

In 2002, CDFG sampled 114,975 Chinook salmon landed commercially in California. The 1,616 salmon troll vessels making these deliveries reported 5,952 salmon taken (4% of catch) by sea lions. The greatest depredation rates were in August in the Monterey area (19% of catch), in May in the Monterey area (13% of catch), and in September in the Eureka area (12% of catch). Depredations coastwide were greatest during May, declined during June and July, and increased again during August and September.

Assessing How Sea Lions Detect Hooked Fish

MLML conducted a "cues study" to determine if California sea lions used visual and acoustic cues to detect fish caught on fishing lines. The study was based on the hypothesis that pinnipeds may partially determine that a fish has been caught by hearing the caught fish (e.g., specific movements of a caught fish and vibrations of the fishing line or the hydraulic noise of retrieving the line on commercial troll vessels). If the hypothesis was found to be true, then it may be possible to mask the sound of a caught fish, by placing white noise in the water near the fishing gear, as means of reducing sea lion conflicts with fishing operations. The sources of information on this cues study are Woolery and Harvey (2005), and Harvey (2003).

Methods - Cues Study

To determine the viability of a "sound masking" approach, MLML undertook field tests to visually record the capture of salmon off fishing lines by California sea lions. An underwater "fish-like appearance" camera was designed in 2002 (called a "Robofish") that was towed behind trolled fishing gear from a salmon troll vessel during the commercial salmon season in 2003 and 2004 in Monterey Bay.

MLML hypothesized that California sea lions were using acoustic cues produced by the hooked fish and by the hydraulics to determine when a fish was hooked. That implied that the mean frequency and duration of sea lion encounters with fishing gear (i.e., sea lions actively approaching fishing gear) would be greater when hydraulics were activated than when hydraulics were not activated, and that the mean time lapse between when a live fish was hooked and a sea lion takes it will be less than when a dead fish was on the line. MLML also hypothesized that sea lions were possibly using visual cues to determine the presence of a hooked fish (in essence visually detecting that a fish was caught) and tested changes in the frequency and duration of sea lion encounters when the towed camera system was fish-like in appearance (i.e., the "Robofish") as compared with a plain housing (i.e., normal camera sled). MLML also hypothesized that the mean encounter rate would be greater with a fish on the line than if there was no fish and greater if the fish was struggling as compared with a dead fish.

Cues Study Results

MLML spent twelve days in the field conducting the study with 47 hours of video recorded. Fourteen fish were hooked (13 salmon and one incidentally caught rockfish). MLML found no effect from hydraulics; there were no encounters recorded during trials when hydraulics were turned on and off at set periods, nor when the gear was retrieved. Five trials with hooked salmon were recorded while sea lions were present and MLML found no significant difference between mean encounter rate when a salmon was on the line and when it was not, nor when the salmon was alive or dead. MLML compared encounter rates with the fish-like camera casing and the plain camera housing and determined there was no evidence that sea lions used a visual cue associated with sighting a fish on the line.

Cues Study Conclusions

Although the sample size was small, MLML found no evidence that sea lions were using auditory or visual cues. The frequency of encounter rates indicated it was more likely that sea lions were checking the gear on a regular basis regardless of whether a salmon was hooked or not. Thus, the only approach for addressing this type of fishery interaction may be eliminating the sea lions that have learned this foraging strategy, designing some method to prevent sea lions from removing fish off hooks (which is likely not feasible), or decreasing the time required to land a caught fish.

Monterey Bay Salmon Fisheries

MLML investigated California sea lion interactions with the commercial salmon troll fishery and the recreational hook-and-line salmon fisheries in Monterey Bay, California to assess sea lion impacts on the fisheries. The sources of information on the Monterey Bay salmon fishery interactions are Weise and Harvey (2003b, 2005a) and Weise (2000).

Methods - Monterey Bay Salmon Fisheries

MLML conducted onboard observations and dockside interviews to assess sea lion interactions with the commercial salmon troll fishery and the recreational salmon fishery in and near Monterey Bay. Dockside interviews were conducted with commercial and recreational fishermen after their return to the ports of Santa Cruz, Moss Landing, and Monterey. The recreational fishery consisted of the commercial passenger fishing vessels (CPFVs) and private skiffs. Data collected included port of call, number of fish landed, number of fish taken by pinnipeds at or below the surface, species and number of pinnipeds involved, number of fish released, number of released fish taken by pinnipeds, and type and amount of gear loss. Data from the three ports were pooled because the vessels often fish in the same areas. MLML found no significant differences in mean percentages of fish taken by sea lions between onboard and dockside surveys in the commercial and skiff fisheries, and therefore assumed that dockside surveys provided a representative measure of pinniped takes in the salmon fisheries and onboard survey data were pooled with dockside interview data for subsequent analysis.

Fishery Observations and Interviews - Monterey Bay Salmon Fisheries

From 1997 to 1999, MLML conducted 1,745 hours of onboard surveys (101 vessels) and dockside interviews (2,780 vessels) in Monterey Bay. From April 20 to September 30, 1997, 337 hours of onboard and dockside surveys were conducted: 144 hours in the commercial fishery, 103 hours in the CPFV fishery, and 90 hours in the skiff fishery. From March 15 to September 30, 1998, 704 hours of onboard and dockside surveys were conducted: 370 hours in the commercial fishery, 270 hours in the CPFV fishery, and 64 hours in the skiff fishery. From March 15 to September 30, 1999, 704 hours of onboard and dockside surveys were conducted, 410 hours in the commercial fishery, 258 hours in the CPFV fishery, and 36 hours in the skiff fishery.

Fishery Interactions - Monterey Bay Salmon Fisheries

MLML found that adult male California sea lions were almost exclusively responsible for the depredation of hooked salmon in the commercial and recreational fisheries in Monterey Bay, taking 98% of the observed hooked salmon taken by pinnipeds from 1997 to 1999 (harbor seals were responsible for the remainder of the observed takes). Overall from 1997 to 1999, sea lions removed 15% of the total salmon catch (16% of catch in the commercial troll fishery, 13% in the CPFV fishery, and 26% in the private skiff fishery). Estimated mean annual percentages of legal-sized salmon taken by sea lions ranged from 11% to 71% in the commercial troll fishery, 3% to 26% in the CPFV fishery, and 5% to 31% in the skiff fishery. Depredation levels in the commercial and recreational salmon fisheries were greatest in 1998 (likely a result of the large El Niño event that occurred from 1997 to 1998). MLML estimated that 38,834, 50,453, and 9,049 salmon were taken from fishermen by sea lions in 1997, 1998 and 1999 respectively representing 4%, 9% and 1% of the California Central Valley salmon populations in those years.

Commercial salmon troll fishermen lost an estimated $18,031 to $60,570 of gear and $225,833 to $498,076 worth of salmon as a result of interactions with sea lions. The recreational fisheries lost between $172 and $18,533 worth of gear as a result of sea lion interactions from 1997 to 1999. Total revenue losses as a result of fish taken by sea lions in the commercial fishery were equivalent to 14%, 84% and 26% of the total salmon fishery revenues in 1997, 1998, and

1999 respectively.

California Recreational Salmon Fisheries

CDFG augmented their ocean salmon fishery monitoring program from 2000 to 2002 to collect at-sea data on pinniped interactions along with standard fishery data collection on CPFVs and to maintain a 20% dockside sampling of recreational fishing vessels (private skiffs and CPFVs) that included collection of pinniped information. The source of information on California recreational salmon fishery interactions is Palmer-Zwahlen (2003).

Methods - California Recreational Salmon Fisheries

CDFG placed observers onboard CPFVs to document sea lion depredation rates to calibrate dockside data as well as to collect "standard" fishery monitoring data. CDFG also continued collecting dockside information from recreational salmon fishing vessels on pinniped interactions (CDFG had collected information on sea lion depredations on salmon during their dockside sampling program since 1995). The ports sampled were Crescent City, Eureka, Fort Bragg, San Francisco and Monterey from 2000 to 2002, and Santa Barbara in 2002 only.

At-Sea Fishery Observations - CPFV Salmon Fishery

In 2000, CDFG staff conducted 81 at-sea observer trips on CPFVs in the Monterey and San Francisco areas from April 7 to September 11, 2000. Observers documented 43 out of 1,693 hooked salmon (2.5%) were taken by sea lions from angler lines before the fish could be landed. The greatest depredation rates observed were in late-May in the Monterey area (16% of catch) and in late-July in the San Francisco area (11% of catch). The greatest depredation observed on one trip was 90% of the catch (9 of 10 salmon) on July 23, 2000 in the San Francisco area.

In 2001, CDFG staff conducted 71 at-sea observer trips on CPFVs in the Monterey, San Francisco and Fort Bragg areas from April 3 to November 2, 2001. Observers documented 23 out of 1,165 hooked salmon (2%) were taken by sea lions. The greatest depredation rates observed were in early April in the Monterey port area (8.5% of catch) and during the latter half of August in the Fort Bragg port area (6% of catch). The greatest depredation observed on one trip was 33% of the catch on September 5, 2001 in the Fort Bragg area.

In 2002, CDFG staff conducted 53 at-sea observer trips on CPFVs in the Monterey, San Francisco and Fort Bragg areas from April 24 to October 17, 2002. Observers documented five out of 1,245 hooked salmon (0.4%) were taken by sea lions. The greatest depredation observed on one trip was 9% of the catch on May 24, 2002 in the San Francisco area.

CDFG collected data on 888 and 223 CPFV trips in southern California (SoCA) and northern/central California (No/CenCA) respectively from 1999 to 2002. Pinniped interactions were higher in southern California in all years. Bait loss to pinnipeds occurred on 11% of the SoCA trips and 7% of the No/CenCA trips. Pinniped removal of catch occurred on 10% of the SoCA trips and 10% of the No/CenCA trips. Lost fishing time caused by pinniped interactions occurred on 4% of the SoCA trips and 2% of the No/CenCA trips.

Dockside Interviews - California Recreational Salmon Fisheries

In 2000, CDFG interviewed 56,029 anglers that landed 49,156 Chinook salmon from April through November. Anglers reported 1,136 salmon (2% of catch including shakers) were taken by sea lions. Most of these interactions occurred in the Monterey (53%) and San Francisco (34%) areas. The greatest depredation rates were in May in the Monterey CPFV fishery (8%) and private skiff fishery (6%), and in April in the Monterey private skiff fishery (8%). No sea lion depredations were reported in the Crescent City and Eureka CPFV fisheries.

In 2001, CDFG interviewed 43,493 sport anglers that landed 26,178 Chinook salmon from April through November. Anglers reported 733 salmon (2% of catch including shakers) were taken by sea lions. The greatest occurrence of sea lion interactions were the Monterey (47%) and San Francisco (28%) areas. The greatest depredation rates reported were: 22% of catch in the Monterey private skiff fishery in September, 17% in Fort Bragg CPFV fishery in August, 15% in Monterey CPFV fishery in May, 12% in Monterey CPFV fishery in April, and 13% in Fort Bragg private skiff fishery in May. Sea lion depredations were lowest in the Crescent City area (0.3% of catch in all months).

In 2002, CDFG interviewed 51,886 anglers that landed 45,806 Chinook salmon from March through November. These anglers reported 1,104 salmon (2% of catch including shakers) were taken by sea lions. Most of these interactions occurred in the Monterey (59%) and San Francisco (22%) areas. The greatest depredation rates reported were: 8% in Monterey CPFV fishery in April, 8% in Santa Barbara private skiff fishery in May, 7% in private skiff fishery in April, and 7% in Fort Bragg CPFV fishery in August. There were no reported sea lion depredations in the Eureka CPFV fishery.

California Bait Receivers (Baitfish Storage Pens)

The NMFS Southwest Regional Office investigated reports of increasing California sea lion attacks on baitfish storage pens (bait receivers) through a contracted study. Bait receivers are floating pens or containers where small schooling fish (Pacific sardine and northern anchovy) and squid are kept alive for sale as sportfishing bait. The receivers were anchored or secured to shore in bays and harbors where the live bait was sold to charterboats (CPFVs) and fishermen on private boats. The study purpose was to assess the impacts of California sea lions interacting with bait receivers in California harbors. The source of information on baitfish receiver interactions with California sea lions is Hanan (2002).

Methods - Bait Receivers

Nineteen of 22 bait receiver operators who maintain 279 bait wells of varying sizes from San Francisco Bay to San Diego Bay were interviewed in 2001 to identify bait receiver designs, determine the extent of California sea lion interactions and operator efforts to minimize interactions, and estimate the economic impacts of the interactions. Observations were made of sea lions interacting with bait receivers in San Diego. California sea lions were captured on the bait receivers in April/May 2002 and sea lion movements were tracked with radio transmitters applied to seven sea lions.

Interactions - Bait Receivers

The study found that California sea lions were attracted to the receivers by the availability of live/dead bait as a food source and as a haul-out site. California sea lions exhibited numerous behaviors at bait receivers: they climbed onto them, swam near and under them, ate baitfish that escaped or were lost during bait transfer operations, ate dead baitfish that dropped out bottoms of pens, and broke into or tore the bait receiver pens attempting to consume the baitfish. Bait receiver structures and receiver lids were damaged by sea lions hauling out on them. If the receiver lid on a bait pen was open, sea lions would jump into the pen. The sea lions also would blow bubbles up through the bottom of the bait pens agitating the baitfish causing mortality, descaling and loss of the bait through pen openings.

To prevent sea lions from attacking the baitfish in the pens, most net pen facilities installed predator nets around the inner net wall to prevent sea lions from biting bait through a single-walled net. Facilities with side boards reported sea lions causing damage by attempting to break through the boards.

Economic Impacts - Bait Receivers

Estimates of lost revenue include damage to bait receivers, repair costs, increased construction costs and maintenance, value or volume of bait killed or consumed, and cost of replacing bait destroyed by California sea lions. The study projected individual operator loss estimates over the six-month peak period of interactions, and estimated California sea lions caused a $2.3 million annual loss in 2002. By region the estimate was: San Francisco ($130,000), Santa Cruz ($160,000), Morro Bay, Avila, and Santa Barbara ($70,000), Ventura and Oxnard ($0), Redondo ($0), Marina Del Rey ($32,000), Los Angeles/Long Beach ($286,000), Newport Beach ($270,000), Dana Point and Oceanside ($405,000), Mission Bay and San Diego ($937,000). The retail value of the baitfish in this industry was estimated at about $30 million, and the loss to sea lions was about 8% of the retail value.

West Coast Recreational Fishery Survey

SWFSC analyzed the recreational fishery-pinniped interaction data collected off Washington, Oregon and California by the Marine Recreational Fisheries Statistical Survey (MRFSS) program (Thomson and Castrence 2005). The MRFSS program, which collects nationwide recreational angler data on catch/effort for all fish species, has been conducted by the PSMFC on the west coast through funding from NMFS since 1989. The MRFSS program was asked in 1989 by the NMFS-NWR to collect pinniped interaction data in conjunction with sport catch/effort data that was collected under a statistically designed sampling program. The MRFSS program intercepts anglers at docks as they disembark private fishing vessels or charter boats or at beaches or piers, and conduct interviews on the fishing effort and sample the catch.

Methods - West Coast Recreational Fishery

In 1989 and again in 1999, MRFSS samplers were asked to add several pinniped questions to their interviews of anglers. Specifically, they asked 1) were pinnipeds in the fishing area; 2) did pinnipeds approach the fishing operation (come within 100 meters); and 3) did the pinnipeds come in contact with gear or catch (i.e., did they remove or attempt to remove bait or catch from the anglers hook while fishing).

West Coast Recreational Fishery Interactions

In 1989, MRFSS intercept samplers interviewed 22,982 recreational anglers about their fishing and pinniped interactions. Anglers fishing off boats in southern California had the greatest incidence of fish loss; about 2% of the anglers reported fish loss from CPFVs and private boats. In

Washington/Oregon, 19% of the anglers fishing on private boats reported pinniped interactions (where pinniped approached their catch/gear), but only 1% reported loss of catch.

In 1999, MRFSS intercept samplers interviewed 45,505 recreational anglers about their fishing and pinniped interactions. Anglers fishing off boats in southern California had the greatest incidence of interactions and fish loss; 6% and 5% of the anglers reported fish loss from CPFVs and private boats respectively. In Washington and Oregon, only 1% of the anglers fishing on private boats reported fish loss.

PINNIPED DETERRENCE

A variety of measures have been considered, tested and/or implemented to deter or remove pinnipeds from areas where their presence 1) creates conflicts with other resources, 2) results in interactions with human activities (including fishing), or 3) threatens human safety and/or damages property. The following is a description and evaluation of the effectiveness of measures that have been attempted by state and federal fishery/wildlife officials to control pinnipeds in several problem situations (e.g., California sea lions killing salmonids at the Ballard Locks and Bonneville Dam), by fishermen to protect their catch and gear from pinnipeds, and by others to protect public safety or property. Guidelines for non-lethal measures that the public may use to deter pinnipeds as authorized under Section 101(a) of the MMPA can be found at the NMFS Northwest and Southwest Regional Office web-sites.

Firecrackers

Underwater firecrackers (called "seal bombs") are pyrotechnic devices that have been used to deter pinnipeds and disperse fish in a number of situations. Firecrackers used by state and federal wildlife managers were trade named “Seal Control Devices” that are manufactured in the U.S. and regulated by the U.S. Department of Transportation (49 CFR Subtitle B). The Seal Control Devices, which were commercially available for use as wildlife deterrents in agriculture and fishing applications, consisted of a spiral-wound cardboard tube containing 36 grains of potassium perchlorate and pyro-aluminum flash powder with an 8-second waterproof fuse and were weighted with sand so as to sink and explode underwater. They produced light and sound pressures on the order of 190 dB re 1 μPa at one meter (Aubrey and Thomas 1984). Most of the sound energy was focused below one kHz which is below the range of maximum hearing sensitivity for sea lions.

Firecrackers were used successfully in 1986 to reduce sea lion predation on steelhead at the Ballard Locks. However, in subsequent years firecrackers became relatively ineffective on several sea lions that habituated to preying on steelhead at the Locks (Pfeifer et al. 1989). Although these sea lions were initially frightened by the firecrackers, they soon began to either return in a few hours or resumed preying on steelhead in a different area. Some sea lions, which had been observed over several seasons, appeared to have learned to ignore or tolerate the noise. They also appeared to learn to evade close exposure to firecrackers by diving and surfacing in unpredictable patterns (Pfeifer et al. 1989). Similar tolerance of firecrackers has been observed in fisheries interaction situations with harbor seals (Geiger and Jeffries 1986). Use of firecrackers to deter California sea lions at Bonneville Dam also have had limited effectiveness in keeping sea lions away from salmon forage areas near the dam (Brown et al. 2007).

No visible injuries to sea lions from firecrackers were observed during their use at the Ballard

Locks (NMFS and WDFW 1985). Sea lions that were exposed to repeated use of firecrackers at the Locks from 1986 to 1988 were observed in subsequent years and showed no ill effects from the exposure. These same sea lions continued to react to noise stimuli indicating they had not been deafened by their exposure to firecrackers.

The advantage of firecracker use as a deterrence measure was that they were small, easily transported, inexpensive, and caused short-duration startle response in pinnipeds without harm if used properly. The disadvantage was that the deterrence effects were short-term and lost effectiveness when used repeatedly on the same pinnipeds.

Cracker Shells

Cracker shells are pyrotechnic devices discharged from a 12 gauge shotgun. The shells contain a flash explosive charge (same as a firecracker) that is designed to explode in air or on the surface of the water at a distance of 75 to 100 meters from the point of discharge. The impulsive noise from the shotgun firing is comparable to firing a regular round of ammunition, and the noise from the cracker shell explosion is similar to a firecracker. Noise from the cracker shell explosion is intended to startle the target animal and cause it to flee. There is no injury to the pinnipeds involved since the explosion is in the air or on the water's surface.

Cracker shells were used to deter California sea lions at Bonneville Dam with limited effectiveness in keeping sea lions away from salmon forage areas near the dam (Brown et al. 2007). Cracker shells also have been used in fishery interaction situations with harbor seals with limited effectiveness because the seals learned to avoid or ignore the noise (Beach et al. 1985).

The advantages and disadvantages of cracker shells were similar to firecrackers. They were favored over firecrackers when longer distance dispatch was necessary. However, their use was restricted or precluded in some areas because they required the use of a firearm.

Aerial Pyrotechnics

Aerial pyrotechnics (screamer rockets, poppers, banger rockets, bottle rockets) have been used to scare birds away from crops, to scare pinnipeds off docks, and to deter birds and sea lions at Bonneville Dam. The units were ignited using a hand held launcher (similar to a .22 short caliber starter pistol) and flew through the air, emitting a loud whistling sound (screamers) that ended with "bang" similar to a firecracker. Noise from screamer and banger rockets was less intense than cracker shells but still was intended to startle the target pinniped and cause it to flee. The units were used at Bonneville Dam to reduce avian predation on juvenile salmonids, and their use was extended to keep sea lions away from the fish ladder at Bonneville (NMFS 2008).

Acoustic Deterrents

Acoustic devices were developed in the 1980s to produce underwater noises at specific frequencies and with sufficient power to deter pinnipeds. Acoustic harassment devices (AHDs) were designed to produce high amplitude, pulsed but irregular "white noise" underwater in the 12 to 17 kHz range that is intended to cause physical discomfort and to irritate pinnipeds, thereby repelling them from the area of the sound. The output of AHDs is designed to vary randomly to reduce habituation. AHDs produce bursts of short, upswept tones at 160dB to 185dB.

One of the initial AHDs called a "Sealchaser" was developed by Oregon State University specifically for repelling pinnipeds in fishery conflict and other situations where there was a need to non-lethally remove pinnipeds (Mate et al. 1987). Initial testing of the Sealchaser with harbor seals indicated it could be effective in repelling seals from certain areas (Mate and Harvey 1987). A description of the Sealchaser and field tests is presented in a workshop report on "Acoustic Deterrents in Marine Mammal/Fishery Conflicts" (Mate and Harvey 1987). Norberg and Bain (1994) measured the output of the Sealchaser and found that it produced source sound pressure levels of 188 dBRMS re 1 μPa at one meter. The individual tones lasted approximately 0.1 seconds, and swept up in frequency from about 11.5 kHz to 15 kHz while increasing gradually in intensity. The bursts lasted four to five seconds, and consisted of approximately 20 to 25 tones.

AHDs were initially effective in some situations, but their effectiveness diminished in most situations apparently as pinnipeds learned to tolerate the noise. An AHD was used to attempt to control sea lion predation at the Ballard Locks, but was found to be ineffective (NMFS and WDFW 1995). Geiger and Jeffries (1986) reported that the use of an AHD on commercial fishing nets resulted in the devices appearing to act as a "dinner bell" attracting pinnipeds to the fishing gear because fishermen would turn the devices on when they had fish in their nets. The principal problem encountered with AHDs was that pinnipeds appeared to “learn” to tolerate the noise. Sound pressures from these AHDs were probably not great enough to cause sufficient pain to overcome the ability of pinnipeds to learn that the negative stimulus could be tolerated.

Due to the inconsistent effectiveness of the AHDs, more powerful acoustic devices were created by the Airmar Corporation and tested at the Ballard Locks. These more powerful devices called “acoustic deterrent devices” (ADDs) were designed to cause pain to pinnipeds (rather than be just a physical discomfort or irritation as caused by AHDs). [Note: The term ‘ADD’ used herein should not be confused with pingers that also have been called ‘ADDs.’ Pingers are much lower dB acoustic devices used on nets to alert marine mammals of the nets presence.] The more powerful ADDs had omni-directional and unidirectional arrays which produced periodic sound emissions at higher decibel levels than the AHDs. The omni-directional ADDs produced periodic sound emissions at a frequency centered at 10 kHz with source levels that were measured to be between 190-196 dBRMS re 1 μPa at one meter (Norberg and Bain 1994). Sound pressure levels produced by the directional ADD array were designed to be at or above the 200-220 dB estimated pain threshold for California sea lions (Aubrey and Thomas 1984). However, because of spreading losses on the order of 20 dB re 1 μPa for each ten fold increase in distance, sea lions would not be exposed to sound pressures of this intensity unless they approach within about three meters of an operating directional transducer.

An “acoustic barrier” was created at the Ballard Locks in 1994 by placing arrays of the directional and omni-directional ADDs in the area below the spillway dam to create an ensonified zone (NMFS 1996). The array cycled through four transducers in a period of 17-17.6 seconds. Each transducer fired individually in sequence during a cycle and produced a chirp lasting 2.3-2.5 seconds. Each chirp was composed of about 60 pulses lasting from 0.5-2.5 milliseconds each. A pause, lasting about two seconds occurred between chirps as the transmitter signal advanced from one transducer to the next. The directional ADD array produced sound pressures of about 206 dBRMS re 1 μPa at one meter with a duration of approximately one millisecond, with the frequency centering at 15 kHz rather than 10 kHz (Norberg and Bain 1994). The “ensonified zone” created near the dam by the omni-directional arrays had sound pressures of approximately 170 dBRMS re 1 μPa. These sound pressures were significantly decreased in the presence of turbulence caused by spill over the dam (Norberg and Bain 1994). Measured sound levels at distances greater than one meter ranged from 185.6 dBRMS for the directional array at 10 meters down to 139.7 dBRMS for the omni-directional array at 1000 meters (Norberg and Bain 1994).

The array signal levels declined by about 17.8 dB for each 10-fold increase in distance.

Although sound pressure levels on the order of 200-220 dBRMS re 1 µPa (for a constant tone of more than one second) could present some potential for causing temporary or permanent hearing loss for sea lions, field measurements showed that the duration of a pulse in the directional array was approximately one millisecond. In addition, because of spreading losses and boundary effects (i.e., reflection from surface and bottom, and absorption by entrained air), the area where sound pressures of this magnitude would be encountered by sea lions was quite small (within three meters of transducer). It was unlikely that sea lions would be in the immediate vicinity of an operating transducer for sufficient time to sustain permanent hearing damage. Subsequent observations of sea lions that had been exposed to the ADD array (i.e., entered the ensonified zone at the Ballard Locks) indicated these sea lions had not been deafened as they still reacted to noise stimuli.

In regard to effects on fish, AHD tests conducted by Mate et al. (1987) indicated that sound pressure levels of 185 dB/µPa at one meter and frequency ranges from 8-12 kHz within an enclosed tank had no effect on adult salmonids or spawn viability. Frequencies above one kHz were beyond the normal "hearing" range of the fish.

The ADDs appeared to be effective in deterring new sea lions from the Ballard Locks area, but had less effect on California sea lions that repeatedly foraged at this site (NMFS 1996). However, even the “repeat” sea lions demonstrated altered behavior in the area of the ADDs. The “repeat” sea lions approaching the ADD array at the Ballard Locks did not frequently enter the ensonified area adjacent to the fish ladder, and on the few occasions when they did, they were there for very short periods of time. Their foraging behavior in the zone also was altered with more time at the surface and a tendency to stay in areas of turbulence where the ADD signal would have been reduced. The propagation of the signal from the acoustic devices was strongly influenced by turbulence and entrained air caused by water spilling over the dam. Air bubbles in the water column absorb the acoustic signal and sound levels decreased as spill increased (Norberg and Bain 1994).

ADDs also were used at Bonneville Dam. Directional transducers were placed on the bottom at the entrances to the fish ladders during the spring Chinook run. Observers did not report any obvious effects to the California sea lions foraging in the area (Tackley et al. 2008b).

Overall, although acoustic devices (AHDs and ADDs) had been successfully used to deter pinnipeds in some areas, there was concern that over time (perhaps months for harbor seals, days for California sea lions) pinnipeds would become tolerant of the sound and ignore it or change their behavior to limit the acoustic noise effects. Advantages were they could be effective for short-term, did not affect fish, and were easily controlled. Disadvantages were they were expensive and sometimes large (transmitter and batteries), and the transducers needed to be placed near the target animals away of turbulence. Some studies have indicated that acoustic devices placed in open marine areas (e.g., at salmon net pens) can affect harbor porpoise distribution and movements (Olesiuk et al. 2002).

Pulsed Power

Pulsed power is an electrical power (arc gap) discharge system that generates an electrical spark that creates a concussive pressure wave that turns into a sound wave. An arc-gap transducer to generate underwater shock waves was first tested on pinnipeds by Shaughnessy et al. (1981) to deter Cape fur seals from fishing nets and appeared effective at close range (2–10 m) but was ineffective at greater distances. An arc-gap system initially designed to remove fouling organisms from boat hulls was field tested on California sea lions in 1995 and had potential as a deterrent; however, the unit was large and its weight of over 136 kilograms made it infeasible for use on fishing boats. In 1997, NMFS awarded a Saltonstall-Kennedy grant to PSMFC to develop a practical pulsed power system that could be used on charter fishing boats. A prototype pulsed power device (PPD) was built by Pulsed Power Technology Inc. in 1998 for testing in open water to obtain actual signal output from the device and develop safe protocols for testing the device on California sea lions involved in fishery interactions.

The prototype PPD was an advancement of the arc-gap transducer concept (NMFS 1999b). As with the arc-gap transducer, the PPD pulsed electrical power discharge system was a compressed wave (shock-wave) generator that also produced an acoustical component. The primary difference between the PPD system and the arc-gap transducer used by Shaughnessy et al. (1981) was the stored energy available to create the arc. The PPD was capable of storing from one to three kilojoules (kJ) of energy as compared with 520 joules (0.52 kJ) in the device used by Shaughnessy et al. (1981). In both systems, energy was transferred from a charged capacitor bank into an underwater "arc-gap." The electrical discharge from PPD created a dense, highly ionized plasma (ionized gas) channel across the gap in the underwater projector unit. The plasma channel was created within a few microseconds (μsec), and a compression wave was produced by the expansion of the bubble surrounding the plasma channel. Within a millisecond, the plasma channel dissipated and the bubble collapsed. The two events (expansion and collapse of the bubble) produced a compression wave followed by an acoustic wave.

The prototype PPD generator consisted of two parts, a deck transmitter unit and an underwater transducer unit (NMFS 1999b). The deck unit, consisting of a rectangular box with a cable storage reel, was 71 centimeters (cm) high, 61 cm long, and 46 cm deep. It weighed 27 kilograms (kg) without cables. The underwater unit was 20 cm in diameter, and 224 cm long, with a lifting eye hook. With a stainless steel housing, the underwater unit weighed 98 kg. The pulse rate and output energy level could be adjusted by the operator either manually or cycled automatically. The pulse signal was generated by discharging an electric arc between two electrodes immersed in the water column. The transducer unit was capable of a minimum energy output of approximately one kJ and a maximum output of three kJ; however, consistent firing was more difficult to obtain at the one kJ setting and required a special setting of the output spark gap electrodes. Although the PPD was capable of outputting three kJ of energy, NMFS-SWR did not want the device used at this energy level due to potential effects on other wildlife. Field measurements of the PPD indicated that the sound pressure levels decreased to 180 dBRMS re 1 μPa at a distance of 200 meters for a source energy of 1.34 kJ and at a distance of 262 meters for a source energy of 1.8 kJ. Source sound pressure levels on the order of 240 dBpeak re 1 μPa at one meter were calculated based on received levels of 209 dBpeak at 44 meters for output of 1.8 kJ. The pulse duration was less than 500 microseconds (μs).

The prototype PPD was tested on California sea lions in captivity (Finneman et al. 2003) and found to be effective in safely deterring sea lions without causing permanent hearing damage to the involved sea lions.

The field effectiveness of the prototype PPD has yet to be evaluated under a rigorous monitoring program. There was uncertainty on whether it would be feasible for use on fishing vessels to deter sea lions because of the size of the device (transducer was over two meters long and weighed 98 kg.).

Taste Aversion

Taste aversion is a form of aversive conditioning that involves putting an emetic agent (e.g., lithium chloride) into a prey species to induce vomiting when the prey is consumed. This technique has been used on coyotes and was successfully tested on a prey specific basis with captive California sea lions (Kuljis 1986). Kuljis (1986) conditioned captive sea lions to avoid one of three prey species without affecting the sea lions' desire to eat the other two species using lithium chloride treated fish. Taste aversion using lithium chloride was attempted on California sea lions at the Ballard Locks, but the effort was not successful (NMFS and WDFW 1995). A variation on this method, which has not been tested, would be to dart (inject) an emetic such as apomorphine or ethylestridiol directly into a pinniped when it consumes a fish or enters an area. The same theory applies, if the pinniped associates becoming sick with entering an area or consuming fish in that area, it would develop an aversion.

The potential advantage of taste aversion is conditioning pinnipeds to avoid specific fish (e.g., salmon). A disadvantage is that the treatment must be applied at least twice to achieve results. NMFS found that taste aversion is not a feasible deterrence approach in most cases due to the difficulty in repeated field application and uncertain results along with the possibility that treated fish might be lost and consumed by other wildlife (NMFS and WDFW 1995).

Predator Sounds

The underwater broadcast of killer whale sounds has been attempted with marine mammals to move them away from an area. The effectiveness of predator vocalizations to frighten sea lions has not been consistent (NMFS and WDFW 1995). Pinnipeds sometimes have shown immediate avoidance responses to the projection of killer whale sound recordings, but generally they have habituated quickly. In one study, sea lions were actually attracted to a researcher's broadcast of predator vocalizations in the Baja California area. NMFS found that this approach was not practical for pinniped deterrence and does not warrant further consideration (NMFS and WDFW 1995).

Predator Models

Placement of predator models (such as fiberglass models of killer whales or great white sharks) to deter pinnipeds has been suggested, but has not been used on the west coast due to its likely ineffectiveness. There were media reports on the effective use of a killer whale model in repelling seals from net-pens in Scotland; however, use of the same predator model at net-pens in Maine had no effect in repelling harbor or gray seals (NMFS and WDFW 1995). NMFS dismissed testing of a three-meter killer whale model (secured by a local radio station) at the Ballard Locks because it was highly unlikely that sea lions would react to the model predator and NMFS did not want to be involved in a "media show." Past field observations of pinnipeds in proximity to natural predators, and the problems and limitations with maneuvering predator models led NMFS to conclude that the predator model approach was not practical and does not warrant further consideration (NMFS and WDFW 1995).

Chasing or Hazing

Boats have been used to attempt to scare or chase pinnipeds at the Ballard Locks, at Bonneville Dam, and in gillnet fisheries. This method was not totally effective as pinnipeds in many cases simply swam under the boat and resisted leaving the area. Aggressive boat maneuvering combined with use of underwater firecrackers was initially effective at the Ballard Locks, but became less effective as California sea lions learned to avoid the boat or temporarily move downstream and then immediately return to the Locks (Pfeifer et al. 1989). Fishermen have used their vessels to chase seals and sea lions from their operation, but such efforts were usually unsuccessful (Beach et al. 1985).

Rubber Projectiles

Shotgun-fired rubber buckshot and slugs designed to non-lethally repel bears have been used on California sea lions at Willamette Falls and at Bonneville Dam. Rubber-tipped arrows shot from a crossbow were used on California sea lions at the Ballard Locks. The discharge of rubber projectiles were intended to deliver a non-lethal impact causing potential bruising but not penetrating the skin. The rubber projectiles were directed at the exposed part of the target animal's body, avoiding the head and eyes, to achieve the deterrent effect.

During rubber-tipped arrow use at the Ballard Locks, California sea lions showed avoidance behavior after being hit while others did not. One sea lion that accounted for the majority of the steelhead kills entered the target zone 70 times and was hit six times (Pfeifer et al. 1989). This animal appeared to avoid the area near the shooter, but still preyed on steelhead.

At Willamette Falls, ODFW tested the use of rubber projectiles (rubber buckshot and batons) shot from a shotgun over a four day period. Four individually recognizable sea lions were shot with rubber buckshot and batons in 1986. The smaller and less commonly occurring sea lions immediately left the area when shot and did not return. Larger animals returned to the immediate area in less than 24 hours and were more wary on return, moving from area to area, surfacing in less predictable ways and spending more time underwater thus preventing dispatch of another rubber projectile (NMFS and ODFW 1997). In subsequent attempts by ODFW, the sea lions appeared to learn to avoid the fish ladder area where the shooter was located and foraged out of range near the falls (Boatner 2000). The use of paint balls dispatched from a CO_2 pistol at Willamette Falls had effects similar to the other deterrents in that the struck sea lions would move from the immediate area but continued foraging (Boatner 2000).

At Bonneville Dam, shotgun dispatched rubber buckshot and batons were used on California sea lions in 2006 through 2008. Over 3,000 rubber buckshot/baton rounds were used from boats during the three years with limited effectiveness in deterring sea lions (Brown et al. 2008).

The advantage of shotgun fired rubber projectiles was that they delivered a non-lethal blow concurrent with the noise of the shotgun blast. In most cases, they did cause an initial flight response by the targeted pinniped. Disadvantages were that they needed to be used in close proximity to the targeted pinniped and shooting was difficult because only a small portion of the pinniped typically showed for a only a short amount of time. Although most individual pinnipeds temporarily reacted when hit, they did not always leave the foraging area and in many instances immediately returned. Use of rubber projectiles also posed safety hazards to people in the immediate area due to potential ricochet, and thus could only be used in restricted areas.

Physical Barriers or Exclusion Devices

Where feasible, physical structures have been placed to exclude or prevent pinnipeds from accessing areas such as fish ladders. At Bonneville Dam, sea lion exclusion devices were installed at the entrance to each fish ladder to prevent sea lions from entering the fish ladder (Tackley et al.

2008a). The welded aluminum grate structures, consisting of a series of evenly spaced vertical bars, were installed in the eight fish ladder entrances just prior to the spring Chinook salmon migration each year. The bars provided sufficient spacing for migrating salmon to pass, but the spacing was too narrow for sea lions to easily enter. A similar grate structure was installed at the fish ladder entrance at Willamette Falls to prevent sea lions from entering the fish ladder (NMFS and ODFW 1997). Prior to installation of these structures, California sea lions were frequently entering the fish ladders at Bonneville Dam and Willamette Falls. At Bonneville Dam, one sea lion was still able to enter the fish ladder. Lack of access to the fish ladder did not deter sea lions from feeding on salmonids near the ladder entrance.

A physical barrier was tested at the Ballard Locks to prevent sea lion access to a prime forage area near the entrance to the fish ladder (sea lions were not entering the fish ladder, but foraged effectively on steelhead as they approached the ladder entrance). The experimental barrier at the Ballard Locks (a large-mesh net strung underwater) was ineffective because fish passage may have been hampered by the barrier and because sea lions quickly learned to effectively forage on steelhead at the face of the barrier (NMFS and WDFW 1995).

At the Dosewallips River, a barrier was placed across the river mouth to prevent harbor seals from entering a channel in the river where harbor seal presence was causing high fecal coliform counts in shellfish beds. The fence type barrier at the Dosewallips River was effective in excluding harbor seals from a haul-out site and resulted in lowered fecal coliform counts at the shellfish beds. Flood conditions subsequently washed out the fence and it was not replaced because fecal coliform levels did not exceed acceptable levels.

Railings and fences have been used to prevent sea lions from hauling out on docks and buoys in a number of areas. The barriers had to be designed to allow people access to docks from their boats while preventing access by pinnipeds.

At some salmon net-pen facilities, a larger mesh “predator” net has been installed outside the inner net pens as a barrier to prevent sea lions from biting salmon inside the pens. These predator nets have had mixed success because, unless the net is very taunt, sea lions can push the predator net against the inside net and still bite and damage salmon in the pen.

Electric Barrier

Electrical fields have been used in fresh water to create underwater barriers that limit fish movements (such as carp and lamprey in the Great Lakes), and in 2007 were tested as a potential pinniped deterrent. An electrical barrier functions by establishing an underwater graduated electric field of low-voltage DC between an anode and cathode placed up to several meters apart in the water. Forrest et al. (2009) found that an electrical barrier could be established that would repel seals and sea lions, without affecting the fish on which they were feeding. An electric gradient was tested in a tank on two captive harbor seals, and found to cause an avoidance response at voltage gradients and pulse width settings much less than typically required for freshwater fish (Forrest et al. 2009).

In April 2007, the electric voltage gradient was tested on harbor seals in the field on four days at the Puntledge River in Courtenay, B.C. This site was chosen because studies by Olesiuk et al. (2001) had documented harbor seals in the Puntledge River using the light-shadow boundary from the lights on the 5th Street Bridge to forage on out-migrating juvenile salmon. The Puntledge River at the 5th Street Bridge was considered to be an ideal location to field test deterring seals from feeding on juvenile salmon using an electrical gradient system because the system could be fixed on the river bottom, and the effects on harbor seals easily observed. Forrest et al. (2009) found that harbor seals avoided the electrical field and did not pass through the area when the system was on. Seals returned to their normal feeding behavior in the electrical array area shortly after the power was turned off and in subsequent days.

In August 2007, an experimental salmon gillnet with a built-in electrical gradient system was constructed to test the effectiveness of the electric barrier in reducing harbor seal predation on gillnet caught salmon in the Fraser River (Forrest et al. 2009). The net was divided into two 50 fathom sections: a control section receiving no treatment and a treated electric section. A portable 3.5 KW AC generator, attached to a DC Pulse Generator unit, located onboard the fishing vessel, supplied the electrical power to the system. Forrest et al. (2009) found that harbor seals appeared to be deterred from the electric section of the net. The total salmon catches and cumulative catch-per-unit-effort (CPUE) were substantially greater for the electric section of the net (1,108 salmon, 298.9 CPUE) as compared to the control section (272 salmon, 50.7 CPUE).

This technology has been proposed for testing at Bonneville Dam to deter California sea lions. Such testing, if conducted on a longer term basis (i.e., through the entire 3-4 month period that sea lions forage in the area) should provide data needed to adequately evaluate the field effectiveness of this technology. It also would be useful to have the concept tested for the entire period that juvenile salmon migrate out of the Puntledge River to determine if the application has continuing effectiveness or if the seals "learn" to forage either in the electrified zone or in adjacent or nearby areas. A measure of success for this technology in the Puntledge would be cessation of harbor seal predation at the site during the juvenile salmon out-migration period.

Capture and Removal

Capture and relocation efforts with California sea lions at the Ballard Locks indicated that transporting captured sea lions relatively short distances (from Ballard to the outer Washington coast) was not an effective approach because the sea lions quickly returned. Similar results occurred with California sea lions relocated from Bonneville Dam to the outer Oregon coast. Longer distance relocation of California sea lions from Ballard to the southern California breeding area also resulted in sea lions returning. This costly and labor intensive long-distance relocation did provide a means of delaying sea lion return for at least 30 days, thereby providing a window of safe passage for migrating salmonids that season (NMFS and WDFW 1995). However, the disadvantage was that some of the "targeted" sea lions (those had been captured/removed previously and returned to forage at the Ballard Locks) could not be recaptured (NMFS 1996). A harbor seal also was captured and relocated a relatively short distance (Ballard Locks to Hood Canal), and the seal also soon returned to the problem area.

One of the California sea lions captured at the Ballard Locks was placed in temporary captivity and released after the steelhead run. Temporary holding was found to be ineffective in the long-term because this sea lion returned the following season and could not be recaptured before it had preyed on salmonids (NMFS 1996).

California sea lions from the Ballard Locks and Bonneville Dam also have been captured and placed in captivity permanently as a means to eliminate the conflicts they caused. Although permanent captivity does eliminate the "problem" sea lions without having to kill them, the method is costly, labor intensive, and limited by the availability and interests of display facilities that are willing to keep the sea lions permanently.

Population Control

An overall reduction of the pinniped populations has been speculated as a means to reduce coastwide pinniped interactions and conflicts. However, because many of the conflict situations involve individual pinnipeds that are repeatedly involved in interactions and problem situations, it is unclear how a population control program would be effective unless these individual animals were specifically targeted as part of the population reduction effort. Pinniped population reduction programs such as controlling grey seals in Scotland were not successful or did not have the rigorous monitoring necessary to scientifically document the effects (Bonner 1982).

There have been public suggestions to reduce the numbers of California sea lions through birth control. Reducing the number of sea lions through this approach though would not reduce current pinniped conflicts because it would only affect pup production and not the current number of sea lions that cause fishery interactions or other conflicts. Over the long term, such an approach would not be effective unless "new" sea lions did not learn the problem behaviors.

Reducing pinniped numbers as a means to control conflict situations is unlikely to be successful. NMFS (1999a) determined that population control was not a feasible approach to resolving pinniped conflicts, but that targeted lethal removal of the problem animals was a reasonable approach and the MMPA should be amended to allow such removal by state and federal wildlife officials.

Selective Lethal Removal of "Problem Animals"

NMFS (1999a) determined that lethally removing the individual "problem" pinnipeds may be the only efficient and cost-effective method to reduce or eliminate pinniped conflicts in many situations. NMFS (1999a) found that non-lethal methods have limited effectiveness and that lethal removal of the individual offending pinnipeds was warranted when such pinnipeds from healthy, robust populations were having negative effects on ESA-listed salmonid populations.

Deterrence Summary

In most cases, non-lethal deterrence measures were found to have limited or short-term effectiveness because pinnipeds appeared to learn to avoid or ignore the measure applied. The use of noise or other stimuli that cause a startle and flight response in pinnipeds were found to cause initial fright reactions and short-term avoidance, but the measures were eventually ignored or avoided by pinnipeds that had prior exposure. During many years of attempting to deter California sea lions from foraging on steelhead at the Ballard Locks (Scordino and Pfeifer 1993), NMFS and WDFW found that non-lethal deterrence measures had to inflict physical pain to the pinniped in order to effectively deter the pinniped beyond the initial startle response especially when the pinniped had previously foraged on salmonids at the site (NMFS 1996). Otherwise, the only effective measure was removal of the pinniped. ODFW and WDFW had the same results in attempting to deter California sea lions from Bonneville Dam (Brown et al. 2008).

CALIFORNIA SEA LION SURVEYS, ASSESSMENTS AND LIFE HISTORY

Population assessment studies that monitored status and trends and provided the data necessary to determine the status of California sea lions relative to their optimum sustainable population (OSP) level were a priority for West Coast Pinniped Program funds. This included annual aerial photographic surveys of California sea lions in California, coastal distribution surveys, and life history studies on San Miguel Island. The branding of California sea lions at Shilshole Bay in Puget Sound, Washington and at Astoria, Oregon (near the mouth of the Columbia River) were also supported to allow identification of "problem" sea lions at the Ballard Locks, Willamette Falls, and Bonneville Dam and to monitor individual sea lion movements coastwide.

California Sea Lion Surveys

The U.S. stock of California sea lions has been monitored since 1975 through ground counts of pups at rookeries and aerial surveys (Lowry 2001, Lowry 2004, Carretta et al. 2007). In 1987, SWFSC began an experimental evaluation of counting California sea lions using large format aerial photographic surveys in lieu of the traditional ground count method (Lowry 1999). After successfully demonstrating that a sea lion census could be accurately performed using a large format aerial photographic survey, SWFSC began statewide California sea lion surveys in 1998. The surveys were conducted at the end of the breeding season in July when the United States stock of California sea lions was expected to be distributed mostly within California. The surveys covered the four rookeries in southern California (Santa Barbara Island, San Clemente Island, San Miguel Island, and San Nicolas Island) and the shoreline and offshore rocks and islands off central and northern California from Point Conception to the California/Oregon border. A twin-engine, high-winged Partenavia PN68-observer model aircraft was flown at airspeed of 185 km/h and at an altitude of 183 to 213 m (typically 213 m) during surveys. The low altitude ensured that California sea lions could be detected on rocky substrates (especially when animals were wet), aided in identification of different pinniped species, and enabled accurate counts from aerial photographs. During the central and northern California coast survey, the aircraft was flown over the coastline or slightly offshore to locate sea lions onshore. Surveys were made without regard to tidal conditions or time of day and all areas inhabited by sea lions were photographed. Sea lions were counted in the photographs through a 7-70X zoom binocular microscope as the photographs were illuminated by a light table. The resulting pup counts from these surveys were reported in the NMFS annual stock assessment reports (e.g., Caretta et al. 2007). Pup counts increased each year since 1975 except during the 1983, 1992/1993, 1998 and 2003 El Niño events, when above average water temperatures were present and when productivity levels were low due to decreased upwelling in the region.

In 1998 and 1999, the SWFSC expanded the coastal California survey of haul-out sites to include an at-sea survey of California sea lions using a strip transect method from a fixed-wing aircraft with a belly viewing port (Lowry and Forney 2005). The sum of these two surveys was used to estimate total sea lion abundance for central and northern California. The greatest number of sea lions occurred near Monterey Bay and San Francisco Bay for all surveys. Abundance was high in central and northern California in 1998 when warm water from the 1997/1998 El Niño affected the region and was low in July 1999 when cold water La Niña conditions were prevalent. At-sea abundance estimates in central and northern California ranged from 12,232 to 40,161 sea lions, and haul-out abundance was 13,559 to 36,576 sea lions. Total abundance of California sea lions in central and northern California was estimated as 64,916 in May/June 1998, 75,673 in September 1998, 56,775 in December 1998, and 25,791 in July 1999. The proportion of total abundance to animals hauled out on land for the four complete surveys ranged from 1.77 to 2.13, and the mean of 1.89 was used to estimate a total abundance of 49,697 for July 1998. This multiplier may be applicable in the future to estimate total abundance of California sea lions off central and northern California from haul-out counts.

Aerial surveys of hauled-out California sea lions were also conducted in coastal and inland waters by WDFW and ODFW in Washington and Oregon respectively to determine seasonal sea lion abundance and distribution.

Branding California Sea Lions at Shilshole Bay (Seattle, Washington)

NMML began trapping and branding California sea lions at Shilshole Bay (near the Ballard Locks) in 1988 to identify individual California sea lions that were preying on salmonids at the Ballard Locks and to track the movements and occurrence of individual sea lions that migrated into Northwest waters each year. Initially, a cage trap was built on a dock and then on a mooring buoy to capture sea lions. In 1994, NMML designed a floating trap that was anchored in Shilshole Bay and used each year until 2007 to capture/mark sea lions. The weight, length, and unique markings on each captured sea lion were recorded and records of subsequent recaptures (including weight/length) and sighting locations were maintained. Radio transmitters and satellite tags were applied to some sea lions to track movements more directly. NMML branded 1,058 California sea lions between 1988 and 2007, with an additional 685 recaptures of previously branded sea lions. The greatest number of sea lions branded in one year was 210 sea lions in 1994 (Gearin et al. 1996, Gearin et al. 2001, Gearin pers. comm. 2009).

Resights of branded sea lions and radio/satellite tracking provided information on movements of sea lions between Puget Sound, inland waters of British Columbia, coastal areas, and the Channel Islands. Satellite tracking of one sea lion showed a southward migration time of 17 days from release on June 8, 1995 in the Straits of Juan de Fuca in Washington to San Miguel Island (Gearin et al. 1996). The maximum distance traveled by this sea lion in one day was 177 km. Of six sea lions relocated to the Channel Islands on March 21, 1990 as part of a predation control effort at the Ballard Locks, three returned to Puget Sound in 30 to 45 days. However, of three sea lions relocated to the Channel Islands later in the season in a later year (April 27, 1994), none were resighted until the following year. In another relocation effort to control sea lion predation at the Ballard Locks, 37 sea lions that were relocated to the outer Washington coast between mid-February and mid-April 1989 and 29 returned in an average of 14 days (range 6-30 days). The brand resights also indicated movements of sea lions between Puget Sound and interior waters of British Columbia between November and April were common.

Branding California Sea Lions at Astoria, Oregon

ODFW began trapping and branding California sea lions in the East Mooring Basin in Astoria, OR in 1997 (Brown et al. 2005a, Tennis pers. comm. 2009). The purpose was to allow for identification of individual sea lions that were preying on salmonids at Willamette Falls (and subsequently at Bonneville Dam) and to track the movements and occurrence of individual sea lions that migrated into Columbia River each year. A floating trap similar to the Shilshole trap was placed near a jetty where sea lions were hauling out in the East Mooring Basin. The weight, length, and unique markings on each captured sea lion were recorded and records of subsequent recaptures (including weight/length) and sighting locations were maintained. ODFW branded 879 California sea lions between 1997 and 2008, with an additional 537 recaptures of previously branded sea lions. An average of 73 sea lions was branded each year, with the greatest number (136) in 2008.

Satellite Tracking California Sea Lions Captured at the Columbia River

ODFW studied the migration of male California sea lions during the non-breeding season by satellite-tracking 26 sea lions captured in the lower Columbia River over the course of three non-breeding seasons between November and May in 2003/2004, 2004/2005, and 2006/2007. Fourteen of the sea lions had previously been observed in the Columbia River ("river type") and 12 animals were "unknown" types. Wright et al. (2010) found there was considerable within and between individual variation in spatial and temporal movements, which presumably reflected variation in foraging behavior. Many sea lions repeatedly alternated between several haul-out sites throughout the non-breeding season.

Twenty of the 26 satellite-tagged sea lions remained within the waters of Oregon and Washington during the time they were monitored; the remainder made forays north to British Columbia or south to California. All 14 of the previously known "river" sea lions were later documented upriver (either by tracking or direct observation); none of the 12 "unknown" animals were detected upriver. Only one sea lion traveled past the continental slope (off central California) out to 250 km from shore and over water 4,400 m deep. Southward departure dates from the Columbia River ranged from May 7 to June 17. Travel time to the breeding grounds ranged from 12 to 21 days. Only one animal was tracked back to the Columbia River; it returned on 18 August after a 21-day trip from San Miguel Island (Wright et al. 2010).

Movement of sea lions to the base of Bonneville Dam to forage on salmonids was documented in only a fraction of the sea lions tracked. This suggests that the problem of pinniped predation on Columbia River salmonid stocks should be addressed primarily at upriver sites such as Bonneville Dam rather than in the estuary where sea lions of many behavioral types co-occur (Wright et al. 2010).

California Sea Lion Life History Studies

NMML initiated a long-term mark/resight study of California sea lions on San Miguel Island, CA in 1987 to obtain estimates of the survival and reproductive parameters of the population for use in a species-specific population growth model, and to monitor changes in vital parameters in response to environmental and population trends. The study, which consisted of onshore observations during the breeding season and branding of about 500 California sea lion pups each year, was supported by funding each year from the West Coast Pinniped Program starting in 1998. As the branded sea lions got older and matured, survival and natality rates and other vital parameters were estimated from the annual observations. From these observations, Melin et al. (2004) determined that the mean age-specific natality rate of California sea lions was 0.767 for the post-recruiting ages 6-12. Laake et al. (2002b) estimated sex and age specific survival rates from the resight data. Other studies have included at-sea distribution and diving behavior of lactating California sea lions at San Miguel Island (Melin and DeLong 2000), and hookworms as a population regulator (DeLong et al. 2005).

California Sea Lion Status, Trends and OSP Determination

Using the counts from the SWFSC aerial surveys, NMFS estimated the U.S. population of California sea lions at 238,000 in 2005 (Caretta et al. 2007). A generalized logistic growth model indicated that the maximum population growth rate was 6.52 percent per year from 1975 to 2005 when pup counts from El Niño years (1983, 1984, 1992, 1993, 1998, and 2003) were removed. A generalized logistic growth model of pup counts obtained from 1975 to 2005 (excluding El Niño years) indicated that the population reached its maximum net productivity level (MNPL) of 39,800 pups in 1997 and had reached carrying capacity at 46,800 pups per year (Caretta et al. 2007). However, that assessment cautioned that the OSP determination should be taken with caution until more years of data were collected to verify whether the flattening of the generalized logistic curve persists in future years. Pup counts obtained in subsequent years (2006 to 2008) showed that the population was continuing to exhibit exponential growth and thus was not at carrying capacity (Lowry pers. comm. 2009).

PACIFIC HARBOR SEAL SURVEYS, ASSESSMENTS AND LIFE HISTORY

Population assessment studies that monitored status and trends and provided the data necessary to determine the status of harbor seals relative to their optimum sustainable population (OSP) level were a priority for West Coast Pinniped Program funds. This included harbor seal surveys in all three states, tagging harbor seals to develop onshore/offshore correction factors needed for population estimates, and life history studies at Gertrude Island, WA.

Washington Harbor Seal Surveys

Two stocks of harbor seals were monitored in Washington, a coastal stock and an inland stock. The coastal stock, which is part of the Oregon/Washington harbor seal stock, includes over 150 haul-out sites along the outer Washington coast from the Columbia River to Tatoosh Island. The inland stock includes over 200 haul-out sites in the Strait of Juan de Fuca, San Juan Islands, Puget Sound and Hood Canal. Recent studies by Huber et al. (in press) indicate there is further genetic distinction that suggests additional stocks in Puget Sound.

WDFW has conducted annual aerial photographic surveys for harbor seals since 1978 (Jeffries et al. 2003). Aerial surveys were flown at low tide during the pupping season when maximum numbers were onshore. All known haul-out sites were surveyed and potential new sites were examined on each census. An atlas describing all of the harbor seal haul-out sites surveyed in Washington was developed by Jeffries et al. (2000b). Because of differences in timing of pupping, surveys were flown in late May to mid-June for the coastal stock and August through September for the inland stock. Surveys were scheduled as closely as possible (tides permitting) to the time when peak numbers of pups were expected to be present. Surveys were scheduled to occur within a week of the peak of pupping for each region. Surveys were typically flown between two hours before low tide to two hours after low tide in a single engine plane at 213 to 244 meter altitude at 80 knots. The total number of seals (including pups) present at each site was counted from photographic slides. In the 22 years from 1978 to 1999, counts of harbor seals in Washington State increased nearly threefold from 6,786 to 19,379. An onshore/offshore correction factor developed by Huber et al. (2001b) was applied to the survey counts to generate a population estimate. The survey results and trends in abundance were to determine the status of Washington harbor seals relative to OSP as described below (Jeffries et al. 2003).

Oregon Harbor Seal Surveys

ODFW has conducted annual aerial photographic surveys for harbor seals since 1978. Harbor seals onshore were counted each year during the mid-May to mid-June reproductive period (Brown et al. 2005b). The coast was divided into two survey regions, each of which could be flown during a four hour survey. Surveys were conducted from a single-engine, high-wing aircraft at altitudes of between 180 and 300 meters. Surveys were flown within two hours of the predicted morning low tide under good visibility and weather conditions (no fog, little or no precipitation, 300 meter minimum ceiling). Photographs of seals were taken obliquely through a side window of the aircraft using a hand-held 35-mm SLR camera, with a 70–210 mm zoom lens. The photographs were projected onto a white surface for counting. A digital SLR camera was used in conjunction with a GIS system starting in 2002 to obtain harbor seal counts and locations. Seals in the water were not counted. An onshore/offshore correction factor developed by Huber et al. (2001b) was applied to the survey counts to generate a population estimate. The survey results and trends in abundance were used to determine the status of Oregon harbor seals relative to OSP as described below (Brown et al. 2005b).

California Harbor Seal Surveys

CDFG conducted annual surveys for harbor seals from 1982 until 1995 when they ceased due to budgetary constraints. The West Coast Pinniped Program provided the support needed to reinitiate the annual aerial surveys of harbor seals conducted in California from May to July to document the number of seals hauled out during the molt period. These data were critical for population assessments and OSP status determinations.

In 1999 and 2000, surveys were conducted by CDFG but were incomplete due to camera problems and/or weather conditions (Hanan and Read 1999, Read and Roberts 2000). The data from these surveys could not be used in population assessments.

In 2001, surveys conducted by CDFG resulted in extraordinarily low counts (Read and Reynolds 2001) likely due to improper timing of the survey, and the use of these data for population assessments was questionable. Thus, a workshop was held in 2002 at the SWFSC to review survey methodology, data gaps, and further data needed for harbor seal population assessments (Barlow 2002). The workshop resulted in specific recommendations for aerial survey timing, overlapping surveys by CDFG and SWFSC in 2002 to compare results, and other data needs including a compilation of ground counts, a review/recalculation of the onshore/offshore correction factors used for past population estimates, and the development of new correction factors. The workshop recommended that to compensate for latitudinal differences in the timing of harbor seal molt, California should be divided into three strata with surveys beginning in the southernmost stratum in May of each year and progressing north in June and July. Workshop recommendations for compiling all California ground count data (Lee et al. 2005), adjusting past correction factors (Hanan 2005), and obtaining new correction factors (Harvey 2004, Harvey 2008) were funded by the West Coast Pinniped Program.

In 2002, aerial surveys were flown by CDFG and SWFSC. These surveys had to be conducted during low tide levels during the peak molt period which was difficult to schedule due to fog and cloudy conditions that occur during that period in California. The CDFG surveys, conducted from May 19 to July 19, were incomplete due to camera problems and weather conditions (Sweetnam and Read 2002). The 2002 surveys conducted by the SWFSC from May 22 to July 1, were complete and resulted in a statewide count of 21,433 harbor seals at 467 haul-out sites (Lowry et al. 2008). SWFSC applied a coastwide onshore/offshore correction factor of 1.3 to the count resulting in an estimate of 27,862 harbor seals.

In 2003, the aerial surveys were conducted solely by CDFG. CDFG completed two coastwide surveys. The first survey was from May 25 to 28 in the southern segment of the state and June 9 to 12 in the northern segment. The second survey was from June 17 to 19 in the south and July 18-20 in the north. The results were a count of 17,567 in the first survey and 18,031 in the second survey (Read and Sweetnam 2003).

In 2004, the survey was conducted solely by SWFSC. The 2004 surveys completed by the SWFSC from May 18 to July 19 resulted in a statewide count of 26,333 harbor seals at 567 haul-out sites (Lowry et al. 2008). SWFSC applied a coastwide 1.3 onshore/offshore correction factor to the count resulting in an estimate of 34,232 harbor seals. Concurrent with the SWFSC aerial survey, MLML and HSU captured and tagged harbor seals in northern and central California in May and June 2004 and developed an onshore/offshore correction factor of 1.65 for northern and central California harbor seal estimates (Harvey 2004).

No surveys were flown in 2005 or 2006. The West Coast Pinniped Program determined that surveys could be flown every other year and still provide reliable data for population assessments (and save on costs and logistics of annual surveys). Since successful surveys had been conducted by SWFSC in 2002 and 2004, the next survey was scheduled for 2006. However, the contractor scheduled to provide the plane/pilot for the SWFSC 2006 survey was unable to provide twin-engine, high-wing Partenavia aircraft that had been used in past surveys and a suitable alternative was not available.

In 2007, the harbor seal survey was conducted by SWFSC, but counts were obtained only for southern California due to camera malfunction in central and northern California. Concurrent with the aerial survey, MLML captured and tagged 68 harbor seals in southern California in April and May 2007 and developed an onshore/offshore correction factor of 2.86 for adjusting counts of harbor seal obtained in southern California (Harvey 2008).

Harbor Seal Life History Studies

Life history parameters for harbor seals in Washington State were determined from studies on Gertrude Island in southern Puget Sound (Huber et al. 2001a, Huber et al. 2004). The Gertrude Island harbor seal haul-out site was chosen because it was readily accessible, easy to observe, protected from human disturbance due to its proximity to a prison, and was the largest haul-out site in Washington with these qualities. Harbor seals at Gertrude Island have been well studied since the mid 1970s and seals have been tagged there since 1983. Because of unequal resighting effort, tag loss, and the difficulty of reading worn tags, it was not possible to determine life history parameters from a tagging study alone. For this reason, a branding study was begun at Gertrude Island in 1993. Resighting effort was standardized and concentrated during the breeding season. A total of 523 harbor seals of all age classes were captured and branded in south Puget Sound, WA between 1993 and 2003. About 40% were known-age animals: the oldest female was 16, the oldest male was ten. Age specific natality increased from 0.03 at age three to 0.3 at age four, to 0.44 at age five and then leveled off to about 0.7 at age six and older. The age of first reproduction for known-age females ranged from three to seven years of age. The mean age of first reproduction was 5.1 years. Annual natality ranged from 0.4 to 0.63. Harbor seal resighting data from 1993 to 2003 were analyzed using the program MARK to determine the probability of survival and the probability of resighting. The probability of survival to the next year was lowest for pups: 0.25 for males and 0.39 for females. For yearlings, the probability of survival was higher: 0.59 for males and 0.83 for females, survival was higher still for seals over two years (0.86 for males and 0.92 for females).

Harbor Seal Status, Trends and OSP Determination

For harbor seals in Washington, Jeffries et al. (2003) applied exponential and generalized logistic models to the aerial survey counts to examine population trends and size relative to maximum net productivity level (MNPL) and carrying capacity (K). Harbor seal counts had increased 3-fold since 1978, and estimated abundance had increased seven to ten fold since 1970. The observed population size for 1999 was similar to the predicted K for both the inland and coastal stocks. These results provided overwhelming evidence that both stocks in Washington were above MNPL and thus in their OSP range. These stocks could decline or be reduced by 20% and they would still be above MNPL with a high degree of certainty (Jeffries et al. 2003).

For harbor seals in Oregon, Brown et al. (2005b) used mean annual counts of non-pups (adults and subadults) as an index of population size and the trend in the counts was modeled using exponential (density-independent) and generalized logistic (density-dependent) growth models. The population dynamics of harbor seals in Oregon were best described by the generalized logistic model; the population grew during the 1970s and 1980s and stabilized in the early 1990s. These results provided clear evidence that harbor seals in Oregon were above the estimated maximum net productivity level (MNPL) and thus in their OSP range.

The harbor seals in Oregon and the coast of Washington are considered to be one stock - the Oregon/Washington coast stock, which extends from the California-Oregon border north to Cape Flattery, Washington. The Oregon/Washington coast harbor seal stock increased at an annual rate of 7% from 1983 to 1992 and at 4% from 1983 to 1996 (Caretta et al. 2007). The trend analysis by Brown et al. (2005b), when considered with those of Jeffries et al. (2003), provided evidence that the Oregon/Washington coast harbor seal population was above its MNPL and within its OSP range. It appears that both the Washington and Oregon portions of this stock have reached carrying capacity (i.e., upper end of the OSP range) and are no longer increasing.

Counts of harbor seals in California showed a rapid increase from the early 1970s to 1990. Net production rates appeared to be decreasing from 1982 to 1994 (Caretta et al. 2007). Although there has been no peer-reviewed analysis published in the literature (as there is with Washington and Oregon harbor seals) on status relative to OSP, the NMFS population assessment report (Caretta et al. 2007) states that the decrease in population growth rate has occurred at the same time as a decrease in human-caused mortality and may indicate that the population is approaching its environmental carrying capacity (i.e., upper end of the OSP level).

DISCUSSION

The West Coast Pinniped Program supported over 150 projects with the eight years of dedicated Congressional funding of $500K to $750K each year (see Appendix B). The program made significant progress in implementing cooperative investigations on pinniped food habits. The program ensured pinniped studies were designed to answer specific questions (e.g., what is the impact of harbor seal predation on ESA-listed coho salmon in the Alsea River system) so that applicable methodologies and statistical analyses could be applied in a comprehensive and focused manner. Many of the past problems with pinniped food habit studies as described in the Investigation Report (NMFS 1997) were resolved through the coordinated approach taken by the West Coast Pinniped Program.

Pinniped Predation on Salmonids

The primary approach to assessing pinniped predation on salmonids was to undertake direct observations of pinniped predation on salmonids in areas of known pinniped-salmonid co-occurrence. This proved to be an effective study approach to assess pinniped predation on adult salmonids for most rivers/estuaries, albeit there were a number of challenges to researchers in extrapolating the observations to proportions of a specific salmonid species/run taken by pinnipeds in a given year. Adult salmonid predation could be observed because both harbor seals and California sea lions would bring these larger prey items to the surface and break them up for consumption, whereas salmonid smolt predation was not observable as the smaller salmon smolts were likely swallowed whole underwater. Although observers could distinguish salmonid predation events from other fish species in most cases, they had difficulty in determining the salmonid species (e.g., coho salmon verses Chinook or chum salmon or steelhead) at a distance. During night observations, observers were not able to identify species because of the limitations of the night scope. Since several salmonid species may co-occur in an area, assessments of impacts to species required the apportionment of unidentified salmonids to species using 1) run size of each salmon population, 2) observed predation events where species identification was possible, or 3) relative proportion of each salmonid species in scat samples collected in the study area.

The salmon predation study sites were rivers/estuaries that had spatial and temporal overlap of pinnipeds and salmonids (areas of co-occurrence). However, the presence of pinnipeds in areas of salmonid occurrence or migration did not necessarily indicate exclusive or predominate feeding on salmonids. Studies in the Alsea River demonstrated that the “pinch point” at the river mouth near a large harbor seal haul-out site was not the principal area of salmonid predation, but rather most salmonid predations occurred upstream and the study design had to be adapted to observe upriver areas using vessels. In contrast, at the Klamath River, California sea lion predation occurred at the river mouth and could be observed from shore. In the Umpqua River where harbor seals and cutthroat trout co-occur possibly year-round, no evidence was found of harbor seal foraging on cutthroat trout. In large river systems such as the Columbia River, observational studies were found to be infeasible due to the large area involved, although observations were possible at upriver terminal areas such as Bonneville Dam and Willamette Falls.

The studies showed that a minimum of three to five years of observations at a site (river/estuary) is necessary to begin to assess salmonid predation, and that field methodologies and sampling approach likely need to be adjusted each year based on the observed conditions at the study site. For example, in the San Lorenzo River observation study by MLML, no predation events were observed in the first two years of daytime observations. In the third year, only a few predation events were observed during daylight hours, but pilot studies at night revealed multiple seals exhibiting foraging behavior. In the fourth through sixth years of study, MLML adjusted their sampling approach to conduct observations at night at the river mouth and upstream resulting in multiple observations of predation events. Had MLML only conducted the first three years of daytime observations, they likely would have concluded that harbor seal predation on steelhead was minimal; however, after conducting daytime and night observations in subsequent years, MLML concluded that pinniped predation may be a factor limiting the recovery of ESA-listed steelhead in the San Lorenzo River (Weise and Harvey 2002).

Salmonid predation was affected by tidal stage at several sites. At each site in Hood Canal, the majority of salmon predations by harbor seals occurred on an incoming tide and within a few hours of high tide (London 2006). In the San Lorenzo River, MLML found that harbor seal foraging changed with changing tidal levels, river flow, and shifting river depths (Weise and Harvey 2002). Tidal effects on salmonid predation were also noted in the Klamath, Mad and Rogue River studies, but they were not in the Alsea River study.

Night predation on salmonids by harbor seals was found to occur at the San Lorenzo River, Alsea River and the Hood Canal rivers. In the San Lorenzo River, over 80% of the observed predation events were observed at night during the last three years of study. In the Alsea River, harbor seal tracking studies indicated certain harbor seals were foraging extensively at night. In Hood Canal, WDFW estimated that night predation on salmonids by harbor seals was equal to daytime. The use of night-vision equipment necessary for nighttime observations was found to be useable only at certain sites due to ambient light and observations were limited in most situations. Night vision equipment was tested at mouth of the Rogue River and found to not be feasible for observations. In the Ozette River, no predation events were observed at night, but they were not observed during daytime either although other evidence (pinniped scarred sockeye) indicated predation was occurring.

Multiple harbor seals foraging on the same salmonid were observed at several sites. The observations included more than one seal (two to four) either herding a salmonid into shallow water and then consuming it in a group, or multiple seals sharing a salmonid caught by one of them. In the Alsea River, multiple seals were involved in 49% of the observed salmonid predation events in 1997-99 (Riemer et al. 2001) and 15% of the observed salmonid predation events in 2000 (Wright et al. 2002). In the Rogue River, multiple seals participated in 54% of the salmonid predation events observed in 1997 to 1999 (Riemer et al. 2001). Cooperative feeding by multiple harbor seals (2-6) was also observed in the Smith, Mad and Eel Rivers. Groups of two California sea lions were observed sharing prey in 13% of the salmonid predation events observed in the Rogue River (Riemer et al. 2001). Multiple pinnipeds involved with a single salmonid can affect estimates derived from scat analyses since the remains of one salmonid could be recovered in multiple scats. These observations necessitate the use of genetic identification of salmonid remains in scats to distinguish individual salmonids among different scat that otherwise are assumed to be different individual fish.

Several studies found that a small number of individual harbor seals that appear to have developed a specialized feeding behavior may have been responsible for most of the salmonid predations observed. ODFW marked and tracked 56 seals in the Alsea River and found that only seven of them exhibited behavior that was consistent with specialization on salmonids. These seals spent the majority of their time in the riverine portion of the study area and did so disproportionately more at night than day (Wright et al. 2007a). Some marked seals consumed a disproportionately higher number of salmonids than others. In Hood Canal, WDFW noted that the number of individual harbor seals actively foraging for salmon in the lower reaches of the Duckabush and Dosewallips Rivers at any one time represented less than five percent of the total population of seals that used nearby haul-out sites (London 2006). WDFW found that a small subset of the Hood Canal harbor seal population had adapted to focus almost exclusively on salmon within the lower reaches of these small rivers (London 2006). At Bonneville Dam and Willamette Falls, observations of individually marked California sea lions have demonstrated that certain individual sea lions have developed a preference for foraging on salmonids at these sites as evidenced by the same animals returning each year. At the Rogue River and the Klamath River, the salmonid predations observed were by relatively few California sea lions that enter the rivers (no inriver haul-out sites) and it is unknown if the same sea lions are involved each year.

The individual harbor seals that selectively forage on salmonids may preferentially utilize upriver haul-out sites rather than lower river/estuary haul-out sites in those rivers/estuaries that have multiple haul-out sites. ODFW's tracking study of harbor seals in Alsea Bay/River found that seals captured at the haul-out site located at the mouth of the bay tended to spend most of their time in the ocean and bay, while seals captured at the haul-out site located further inland in the bay tended to spend most of their time in the bay and river (Wright et al. 2003b). The movement data further indicated that the "river seals" (those that preyed inriver on salmonids) did not utilize the lower haul-out site at the mouth of the bay (Wright et al. 2007a). The scats collected at the upper bay haul-out site also had a higher incidence of salmonids though sample sizes were small. In 2003, 50% of the scat collected at the upper Alsea haul-out had salmonid remains while only 7% of the scat contained salmonids in the lower bay haul-out site (Wright et al. 2003b). The same was found in the 1997 and 1998 Alsea Bay scat samples with 35% and 23% of scats with salmonids in the upper estuary haul-out sites and 2% and 6% respectively at the lower estuary haul-out site (Riemer et al. 1999a, Riemer at al. 1999b). These results suggest preferential hauling out behavior by harbor seals that forage on salmon and raise concerns on a potential bias on occurrence of salmonids in scats dependent on where the majority of the scat samples are collected.

Studies in Hood Canal demonstrated that estimates of salmonid predation derived from predation observation efforts may not compare directly with estimates derived from scat analysis (Jeffries et al. 2001), and more work is needed to address this issue.

Use of the "all structures" method of identifying prey in scat demonstrated that salmonids are a common prey species (occurring in 10% or more of the scat samples) for harbor seals and California sea lions in many west coast rivers/estuaries and even in open waters (i.e., California sea lions in Monterey Bay). The studies provided evidence that some individual pinnipeds do preferentially or selectively forage on salmonids at certain areas and times. It appears that as adult salmon begin migrating into a river system, some of the pinnipeds in that area will alter their foraging patterns to target migrating salmonids.

Assessing the role of pinniped predation on salmonid populations remains a difficult task. Researchers found numerous problems associated with observational sampling of predation behaviors that could have affected predation estimates including the temporal scale of sampling efforts because of the sporadic nature of upstream fish passage. Four to five randomly selected sampling days within a tidal stratum may have missed the conditions that facilitate fish passage, and presumably miss the times when there was a greater probability of predation. Nightly observations covered only a small portion of the areas where salmonids and pinnipeds co-occur, so observed predations may be underestimated. Several studies concluded that pinnipeds may not be impacting salmonid runs because the affected salmonid population was increasing; however, salmonid numbers do vary so such conclusions may change. The indirect effects of seals foraging on salmonids directly on spawning sites, such as at Ozette Lake and several Hood Canal rivers, need to be assessed.

Pinniped Food Habits

Significant progress was made in advancing the analysis of pinniped scats to determine food habits. Scat sampling and analysis was a topic in numerous meetings of the West Coast Pinniped Program. Researchers conducting food habit investigations participated in several workshops hosted by the West Coast Pinniped Program (Didier and Scordino 1999, Riemer and Lance 2001), and a pinniped food habits and prey identification techniques protocol was published (Lance et al. 2001). If all researchers conducting pinniped food habit investigations adhere to the protocol when conducing and reporting results of scat analyses, many of the potential problems and biases in the research outcomes should be minimal. Scat collection and analysis studies should not be conducted without first preparing sampling plans that prescribe the number of scats needed to be collected by timeframe and location. Studies in the Alsea River/Bay showed that prey composition in scats may be different among haul-out sites in a study area (i.e., the upper bay site had proportionately greater salmonid remains than the lower bay haul-out sites where most scats were collected) (Wright et al. 2003a, Riemer et al. 1999a); thus, scat sampling plans should ensure that all haul-out sites are adequately sampled to ensure that prey composition estimates are not biased. Concurrent movement studies to determine where seals on a particular haul-out site are foraging may be necessary to complement scat analyses. In Alsea Bay, researchers found that some harbor seals may have preferentially foraged offshore while others appeared to forage only inriver (Wright et al. 2007a).

Common prey species for harbor seals at all study sites (defined as taxa that occurred in at least 10% of the scats at one or more of the study sites) were: Clupeidae (herrings - including Pacific herring, Pacific sardine and American shad), Gadidae (codfish - including Pacific whiting, Pacific tomcod and walleye pollock), Salmonidae (salmon and trout), Order Pleuronectiformes (flatfish - including English sole, Dover sole, Pacific sanddab, slender sole, starry flounder, rex sole, sand sole and butter sole), Engraulidae (anchovies), Ammodytidae (sand lance), Osmeridae (smelts), Cottidae (sculpins), Embiotocidae (surfperch), Scorpaenidae (rockfish), Petromyzontidae (lamprey), Myxinidae (hagfish), Rajidae (skates), Batrachoididae (toadfish - including plainfin midshipman), Order Octopoda (octopus), Pholidae (gunnels), Ophidiidae (cusk-eels), Agonidae (poachers), Cyclopteridae (snailfish), Zoarcidae (eelpouts), Sciaenidae (drums - including croaker), Cyprinidae (minnows - including peamouth), and Gasterosteidae (sticklebacks). Salmonids were a common prey item at eight of the fourteen study sites where harbor seal scats were collected. The frequency of occurrence of salmonids in harbor seal scats was 25% or greater in Hood Canal, San Juan Islands, lower Columbia River, and Mad River. The greatest frequency of occurrence of salmonids in harbor seal scats was 35% in 2001 in Hood Canal.

The food habits studies confirmed the necessity of identifying all prey hard part remains in scats (the “all structures” technique), especially to determine the frequency of occurrence of salmonids. Many past studies only used fish otoliths and cephalopod beaks to determine prey species, and this has been demonstrated to greatly underestimate the frequency of occurrence of some prey species in the scats. For example, in the scats collected in Alsea Bay from 1997 to 1999, Riemer et al. (2001) found salmonid remains in 59 scat samples, but only two of them contained salmonid otoliths. In Hood Canal fall scat collections, otoliths were present in only 5% to 20% of the scats with salmonid remains analyzed each year from 1998 to 2005 (Lance pers. comm. 2009). Browne et al. (2002) found that the minimum number of individuals (MNI) and percent frequency of occurrence (FO) both increased when all structures were used, particularly for taxa such as Pacific tomcod, Pacific whiting, American shad, and salmonids. In captive feeding studies on harbor seals, Phillips (2005) found that recovery of all prey except pink salmon was improved by 32% when all diagnostic skeletal structures were used, indicating that the all-structure technique will improve recovery biases due to complete otolith erosion. However, the use of all structures does complicate development of consumption estimates as it may bias the estimate of MNI upwards. In captive studies with harbor seals, Phillips (2005) found that the all structure technique overestimated the number of fish eaten for three species: shortbelly rockfish, Pacific whiting, and pink salmon. The use of all structures also may misrepresent species composition. In captive studies on California sea lions, Sweeney (2008) found that Pacific whiting found in scat samples were detected more frequently than sardine and anchovy because the skeletal structures of Pacific whiting resisted digestion and were easier to identify in a scat than the atlas, axis, and prootics of sardine and anchovy which were small and difficult to pick out of a group of vertebrae. Phillips (2005) found the pink salmon recovery rate in captive harbor seals increased from 28% to 310% when the all-structure technique was used due to fragmentation of a salmonid's remains in multiple scats. However, field scat collections are conducted with less frequency (e.g., weekly) than the daily scat collection in captive studies and the potential problems with fragmentation of a single fish in multiple scats causing over-estimates is likely minimal. The identification of all structures is also more time consuming and requires more experienced personnel in determining species identifications. Nonetheless, the use of several prey structures (in addition to otoliths) will minimize the likelihood of failing to identify a prey type in a scat sample. A workshop should be convened to further discuss the implications of the results of the captive feeding studies on the use of the "all structures" technique, as well as developing standards for use of the correction factors derived from the captive feeding studies.

The captive feeding studies with California sea lions and harbor seals provided detailed information about biases associated with scat analysis and developed correction factors that will be useful for consumption estimates. For example, hard parts from a single meal were recovered in a mean of 3.8 scats confirming that a single scat does not represent a single meal, but rather a series of foraging events throughout the previous 24-48 hours (Phillips 2005). With the incorporation of regularly recovered diagnostic bones such as prootics, gill rakers, and vertebrae, in combination with numerical correction factors developed in the captive studies, estimates can be made that more accurately reflect what was consumed. Also, as a result of the captive studies, the use of various consumption models can now be critically evaluated. A workshop should be convened that involves all west coast researchers that use scat analyses in food habit studies to discuss the application of these and other recent captive feeding study results (e.g., Tollit et al. 2007) to the development of pinniped consumption estimates.

Pinniped Population Assessments

Aerial surveys of California sea lion and harbor seal haul-out sites were conducted to track and estimate population size. The status of west coast pinniped populations relative to their OSP level was determined for Washington and Oregon harbor seals. Additional surveys are needed to affirm that California harbor seals are at OSP. Although California sea lions appeared to be at OSP (Caretta et al. 2007), more recent counts from 2006 to 2008 indicate continued exponential growth and OSP status will need to be re-evaluated in the future. In all cases, it was not possible to determine that the pinnipeds had reached MNPL (the lower bound of OSP level) until almost ten years after the fact. This highlights the importance of long-term systematic monitoring to understand and track pinniped population dynamics.

Fishery Interactions

Fishery interactions were documented in recreational and commercial hook-and-line fisheries off California. Loss of catch to California sea lions was documented in all fisheries sampled and the severity of the loss and interactions varied by year, locality, and type of fishing. The most severe interactions appeared to occur in the Monterey Bay commercial salmon fishery where MLML estimated that total revenue losses as a result of fish taken by sea lions in the commercial salmon fishery were equivalent to 84% of the total salmon fishery revenues in 1998 (during large El Niño event). California sea lion interactions with bait pens in California also were studied with findings in 2002 of $2.3 million annual loss to sea lions.

MLML conducted at-sea experiments to assess whether sea lions were using caught fish or gear sounds to locate hooked salmon (to determine if masking sounds could be developed to prevent the interactions), but found no evidence that sea lions were using auditory or visual cues. The frequency of encounter rates indicated it was more likely that sea lions were checking the gear on a regular basis regardless of whether a salmon was hooked or not.

Estimates of coastwide economic losses caused by pinniped-fishery interactions were not developed. Economists did not complete socio-economic survey/interview approaches that would screen out responses biased by when the fisherman actually had an interaction and the severity of the interaction, and whether in the case of sport fisherman they would not pay for another charterboat trip or fish again from a specific port (thus resulting in indirect economic losses to that port area).

Pinniped Deterrence

Pinniped deterrence methods were reviewed and some were tested or utilized in the field by federal and state fisheries/wildlife authorities. To date, an effective, long-term non-lethal approach to eliminating pinniped conflicts has not been found other than removal of the "problem" pinniped. Different methods must be combined and used repeatedly to have temporary effects (deterring animal from area). Over the long term, the "problem" pinnipeds appear to avoid the deterrence measures or work around them, or in some cases totally ignore them. For example, at Willamette Falls, California sea lions "learned" to avoid the area where deterrence measures were dispatched and continued preying on salmonids near the falls (which was inaccessible for deterrence measures) (Boatner 2000). Some non-lethal deterrence measures appear to be initially effective or effective on "new" animals, but become ineffective over time or when used on "new" animals in the presence of "repeat" animals that do not react to deterrence. This was the case at the Ballard Locks where the "repeat" sea lions (those that had habituated to feeding on steelhead regardless of deterrence measures) would sometimes be accompanied by "new" sea lions (those that had not foraged previously at the Locks and could otherwise be easily deterred) and neither sea lion could be easily deterred (NMFS and WDFW 1995). Removal, either lethally or permanently to captivity, of known problem pinnipeds may be the only means of fully resolving conflicts in some areas of severe conflicts. This was the case at the Ballard Locks conflict of California sea lions preying on steelhead; the permanent removal of the experienced/habitual predator sea lions was the only method that worked in eliminating the conflict (NMFS 2001). In situations where non-lethal measures are successful on "new" pinnipeds, permanent removal (lethal or to captivity) of the experienced/habitual predators combined with continued non-lethal deterrence of "new" animals may be an effective means of controlling pinniped conflicts (NMFS 2001).

Although deterrence measures are unlikely to have a long term effect, those that evoke an initial startle or flight response should be attempted when problems first occur. Even though the deterrence measures may need to be repeated often, they may result in the desired effect of removing the pinniped from the problem situation at least temporarily. Initial deterrence may also prevent pinnipeds from habituating to the site where the conflict occurs. Lack of action will likely result in the problem getting worse as the pinniped(s) will likely continue the offensive behavior if nothing is done. This especially applies to sea lions hauling out on docks and boats, where they may create safety problems or cause damage. Immediate and repeated deterrence efforts should be applied as they may eventually result in the sea lions moving to other "non-conflicting" areas; but, taking no action will likely result in the sea lions becoming accustomed to the site thus making it even harder to deter them when necessary (e.g., to access a boat or get to other end of dock).

At Bonneville Dam, an extensive harassment effort using firecrackers, cracker shells and rubber bullets to deter California sea lions from preying on salmon has not been effective in eliminating the problem (Brown et al. 2008). However, ODFW, WDFW and USACE have continued the harassment effort, in combination with a capture/removal effort, in accordance with their Letter of Authorization and in an attempt to prevent the problem from getting worse.

In Gold Beach, Oregon, an apparently successful deterrence program was implemented in 2006 to prevent sea lions from taking caught salmon off fishing lines at the mouth of the Rogue River (Lottis et al. 2007a, Lottis et al. 2007b, Lottis et al. 2009). The sea lion harassment (hazing) program, funded by the port and community, consisted of a clearly marked "sea lion hazing" vessel that would harass any sea lions that entered the mouth of the river or occurred in the area of fishing during the hours of peak sport fishing effort. Before initiation, the program was approved by ODFW and NMFS. The harassment program included use of seal bombs, cracker shells, rubber buckshot, and active pursuit of sea lions using the hazing boat. When a sea lion was encountered, the hazing vessel discharged firecrackers nearby and then actively pursued the sea lion toward the bay entrance and beyond the entrance bar. Once the sea lion was out of the fishing area or outside the entrance bar at the mouth of the bay, cracker shells and/or rubber buckshot were used to drive sea lions beyond the harbor jetties. The operator of the hazing vessel also maintained radio and visual contact with sport fishermen to locate and harass any sea lions that returned or were not sighted by the hazing vessel. The hazing program was complemented by port activities to prevent sea lions from hauling out on docks and eliminating the disposal of salmon carcass into the water at docks (which had provided a feeding attraction to sea lions in the past). This program appears to have been effective in 2006, 2007 and 2008 because the sea lion hazing vessel was active every day during the fishery in a relatively small area and any observed sea lion was immediately targeted for harassment. Although a few angler-caught salmon were lost to sea lions during the vessel hazing efforts, the numbers were minimal when compared to prior years. Sea lions were not marked, so the occurrence of "repeat" sea lions is unknown.

In order to evaluate deterrence, there is a need to individually mark pinnipeds (i.e., apply brands) in conflict areas so that individual pinnipeds can be easily recognized. The permanent marking of California sea lions in Puget Sound and the Columbia River allowed federal/state authorities to better assess and undertake necessary actions to address conflicts at the Ballard Locks, Willamette Falls and Bonneville Dam. Without marking individual pinnipeds, it is not possible to determine the severity of the conflict (how many different pinnipeds are involved), whether the same pinnipeds are repeatedly involved, and how frequently individual pinnipeds return to sites of conflict after deterrence. Individual marks would also allow the application of differing and possibly combined deterrence techniques that may be necessary to remove "repeat offenders" from conflict areas.

Section 101(a)(4) of the MMPA does allow people to deter sea lions to protect their property. However, based on news articles, there seems to be an impression in the public that they cannot do anything that might harass a "problem" pinniped (i.e., a sea lion that has hauled out on their boat or dock). A Non-Lethal Deterrence Workshop in 2005 in San Diego resulted in guidelines that the NMFS Southwest and Northwest Regions have published on their websites. The websites provide examples of what people can do, and clearly they do allow people to legally harass seals and sea lions. An outreach program is needed to educate the public on what they should do when "problem" sea lions occur especially in marinas that have problems with sea lions hauling out on vessels causing damage and in some cases sinking small boats. Such outreach should encourage port officials to take aggressive and active action to non-lethally remove the sea lions, rather than a passive approach that may create an even greater problem. When a sea lion gets onto a dock or boat, authorities need to immediately scare it away rather than just closing the area to people.

Further Studies

Further studies are needed to better assess pinniped impacts on salmonids. Although significant progress was made in developing and applying appropriate methodologies, many of the studies had limitations in the data collected or data made available (e.g., salmonid run data) that may have affected the results of the analyses on salmonid impacts. Some of the pinniped predation observation and food habit studies were limited in scope and timeframe (e.g., extent of area observed, diurnal/nocturnal observations, frequency of sampling haul-out sites for scats, numbers of scats collected, and number of seasons/years sampled). Target numbers of scats (based on a sampling plan) needed to be collected in all months of the year for at least three years at all haul-out sites in each study area. Genetic identification of salmonids in scats was not completed for all scats collected and should be applied to all future scat collections. New genetic prey identification techniques need to be applied such the work by Tollit et al. (2009) that revealed additional prey species by applying genetic identification to the non-bony material in scat. Prey consumption (biomass by species) was not estimated for most study sites due to uncertainty on models and pending results from captive feeding studies. The captive studies have now been completed, and a workshop needs to be convened to discuss and refine appropriate biomass reconstruction models and applicable correction factors (derived from captive feeding studies).

There is a need to individually mark pinnipeds (i.e., apply brands) in areas of repeated conflicts so that individual pinnipeds can be easily recognized. The Alsea Bay/River study demonstrated the importance of marking and tracking pinnipeds to determine individual foraging patterns. The permanent marking of California sea lions in Puget Sound and the Columbia River allowed federal/state authorities to better assess the severity of the conflicts at the Ballard Locks, Willamette Falls and Bonneville Dam. Permanently marking pinnipeds at study sites would allow determinations to be made on whether the same individual pinnipeds are repeatedly involved in salmonid predation events or interaction conflicts, and how frequently individual pinnipeds return to sites of conflict after deterrence. California sea lions that occur in conflict areas such as the Rogue River, Klamath River, Monterey Bay, San Diego harbor (at bait receivers), and marinas such as Newport Beach should be permanently marked so that individual sea lions movements and behaviors during interactions and deterrence can be identified. The permanent marking of harbor seals that occur in salmon predation sites such as San Lorenzo River, Mad River, Alsea River and Hood Canal would also be beneficial for tracking movements of seals in rivers where salmonids are vulnerable to predation. The capture, marking and tracking of individual pinnipeds should be an integral component of all future salmonid predation studies and deterrence programs. Ideally, pinniped marking efforts would be coordinated, overseen and funded by a West Coast Pinniped Program if Congressional funding was reinstated.

Future pinniped-salmonid predation studies need to be multi-year investigations that combine comprehensive direct observations (observations on shore and vessels from river mouth to upriver extent of pinniped occurrence through entire period of adult salmonid migrations), marking and tracking of individual pinnipeds, collection and analysis of scat using standardized protocols for identifying all hard part remains and using genetic identification on all salmonid remains in the scats to identify salmon species/ESU. Analyses conducted should include extrapolating all observed predation events by salmonid species and comparing that to the run-size of the affected salmonid species. Salmonid predation observations should be examined in conjunction with the movement patterns of marked pinnipeds occurring in the area. Salmonid consumption estimates should be calculated from scat analysis and compared to the direct observation estimates.

CONCLUSION

The West Coast Pinniped Program was successful in bringing together a coastwide cohesive state/federal/academic effort to obtain information on expanding pinniped population issues. The program was effective in identifying issues as they arose and implementing coordinated investigations. The program fostered development of rigorous study designs and applicable methodologies for investigations. With termination of Congressional funding, the program and its efforts to resolve west coast pinniped issues have ceased. There is still much work to be done on pinniped conflicts on the west coast. Congress and NOAA should reinstate the budget line-item annual funding of $750,000 that supported the efforts of the West Coast Pinniped Program.

The investigations confirmed that pinnipeds can have negative impacts on salmonids in certain situations. Although pinnipeds and salmonids may have coexisted for centuries, Pacific harbor seal and California sea lions have increased dramatically since the 1970s, while salmonid populations have declined and their freshwater habitat deteriorated. Pinniped predation on salmonids needs to be taken into consideration in recovery measures for ESA-listed salmonids.

Although the West Coast Pinniped Program made significant progress in developing and applying methodologies to assess pinniped impacts on salmonids, further research is needed to better estimate pinniped consumption of ESA-listed salmonids. Additional direct observation studies need to be conducted in those areas where studies were limited in observer coverage (time or area) and in other areas of pinniped/salmonid spatial overlap. Analytical methodologies for extrapolating observed predation events and estimating potential impacts on specific salmonid species need to be reviewed and refined. Additional scat collection and analysis is needed for sites where sampling was limited or sample sizes were small as well as other sites of temporal and spatial overlap of pinnipeds and salmonids. Biomass consumption estimates need to be made from scat collections utilizing correction factors derived from captive feeding studies. Genetic identification techniques need to be improved and expanded including techniques to identify individual pinnipeds associated with scats, to distinguish scats between California sea lions and Steller sea lions (since these sea lions haul out together at some sites, the scat can only be attributed to “mixed” sea lions), and to more accurately identify all material (bony and soft material) in scats for prey identification. Capture/marking and tracking of pinnipeds is needed in all of the areas where pinnipeds were observed foraging on salmonids to develop better understanding of the movements (including extent of upstream travel) and behaviors of pinnipeds that may preferentially forage on salmonids.

Report to Congress: Impacts of California Sea Lions and Pacific Harbor Seals on Salmonids and West Coast Ecosystems

The West Coast Pinniped Program was structured to address the key information needs and legislative recommendations in the 1999 Report to Congress (NMFS 1999a) using the Congressionally designated federal funds appropriated from 1998 to 2005. The bullets below are the "information needs" identified in the Report to Congress followed by program research accomplishments relative to that information need. The three legislative recommendations (denoted with solid bullets below) also are evaluated based upon the results of the program and other state/federal activities conducted since the 1999 Report to Congress was concluded.

- Conduct site-specific investigation on pinniped predation impacts on various salmonids populations.

The studies documented that salmonids are a common prey species for harbor seals and California sea lions in many west coast rivers/estuaries and even in open waters (i.e., California sea lions in Monterey Bay), and pinnipeds can adversely affect the recovery of ESA-listed salmonid populations. The studies provided evidence that some individual pinnipeds do preferentially or selectively forage on salmonids at certain areas and times. The research also confirmed that harbor seals do forage on salmonids at night. In most areas, it appears that as adult salmon migrate into an area, some of the pinnipeds in that area will alter their foraging behavior to target salmonids. Although precise estimates of pinniped predation could not be developed for some of the study sites due to sampling and estimation complications, the data from the studies are sufficient to demonstrate potential adverse effects of pinniped predation on ESA-listed salmonids. The role of pinniped predation as a limiting factor in the recovery of ESA-listed salmonids was difficult to address at all of the study sites, but there are inherent difficulties in quantifying the role of any of the potential factors that may limit salmonid productivity, including habitat. Nonetheless, the pinniped studies provide valuable information that will need to be considered in salmonid recovery efforts.

- Conduct state-by-state and river-by-river investigations on salmonid populations that are vulnerable to pinniped predation.

Pinniped food habits and/or foraging on salmonids was documented/determined in a number of river systems where salmonids were considered vulnerable to pinniped predation including Hood Canal (London 2006, Jeffries et al. 2004, London et al. 2002), San Juan Islands (Lance and Jeffries 2009a), Ozette River/Lake (Gearin et al. 2002), lower Columbia River (Browne et al. 2002, Laake et al. 2002a), Willamette Falls (Brown et al. 2004, Boatner 2000), Alsea Bay/River (Wright et al. 2003a, 2007a), Umpqua River (Orr et al. 2004), Rogue River (Riemer et al. 1999b, 2001), Klamath River (Williamson and Hillemeier 2001), Mad River (Goley et al. 2003), Año Nuevo Island (Weise and Harvey 2005c), San Lorenzo River (Weise and Harvey 2002), and Monterey Bay (Weise and Harvey 2008a). Studies specific to the salmonids in these and other river systems were the subject of other NMFS and State programs outside the West Coast Pinniped Program.

- Conduct studies of comparative skeletal anatomies of different salmonids species so that specific prey species may be identified

Genetic identification techniques were developed to identify specific salmonid species and ESUs from their hard part (bones) remains in pinniped scats (Purcell et al. 2004, Kvitrud et al. 2005, Rhydderch et al. 2003). Protocols for analyzing scat for food habits studies and identifying prey based on characteristic bony structures were developed (Riemer and Lance 2001) and standardized food habit study protocols were published for broad use (Lance et al. 2001). Biomass consumption estimation models were critiqued and refined (Laake et al. 2002a). Captive feeding studies provided data on prey passage rates, otolith erosion from digestion, and correction factors for prey estimation from harbor seal and California sea lion scats (Phillips 2005, Sweeney 2008).

- Conduct research on site-specific seasonal abundance and distribution of California sea lions and Pacific harbor seals north of Point Conception

The West Coast Pinniped Program funded surveys in Washington, Oregon and California that resulted in determinations that harbor seals in Washington and Oregon reached OSP in the mid-1990s (Brown et al. 2005b, Jeffries et al. 2003). They also initially demonstrated that California sea lions were at OSP (Caretta et al. 2007), but continued exponential growth indicated from 2006 to 2008 pup counts suggests the population is not yet at OSP. Although harbor seals in California are likely also at OSP, additional surveys are needed to affirm their status. Additional directed studies on site-specific seasonal abundance were not conducted due to funding constraints; however, research activities on pinnipeds and their predation on salmonids did include site-specific information on pinniped abundance. Continued surveys are needed to update these assessments and determine population stability as they fluctuate around their carrying capacity.

- Conduct research to assess and evaluate potential impacts of pinnipeds on specific fisheries and fishing areas

Pinniped interactions with hook-and line fisheries for salmon, Pacific barracuda, yellowtail, Pacific bonito, Pacific mackerel, kelp bass, ocean whitefish and rockfish were documented in California. California sea lions were the principal pinniped species involved in all of the interactions. The primary issue was the removal of hooked catch by sea lions, but sea lion removal of bait from fishing gear was also a major problem for CPFV (commercial passenger fishing vessel or charterboat) operators. Interactions varied by area, target species, and year. Onboard observations of the southern California CPFV fishery documented sea lions removing catch on over half of the observed trips, with Pacific barracuda taken most frequently. The salmon fishery interactions with California sea lions were most severe in Monterey Bay in 1998 likely because of a large El Niño event.

- Conduct socioeconomic studies on impacts of pinnipeds on various commercial and recreational fisheries

A coastwide systematic estimate of socioeconomic impact of pinniped interactions with fisheries was not accomplished due to the limited funding that was directed primarily to pinniped impacts on salmonids. Initial efforts to frame a socioeconomic survey were confounded by access to confidential fishing vessel data and inherent biases in survey questions that might be used to derive pinniped impact information. The fishery interaction studies that were accomplished documented loss of catch in recreational and commercial hook-and-line fisheries off California. The severity of the losses and interactions was influenced by locality and type of fishing. Loss of fishing bait to California sea lions in the San Diego CPFV fishery was documented by CDFG as well as the frequency of charterboats having to move to other fishing areas away from interacting pinnipeds (causing increased fuel and time costs). Another issue for charterboats, that was not assessed, was foregone future revenue caused by fishermen potentially not taking future fishing trips due to negative interactions with pinnipeds. The most severe economic loss documented was an estimated 84% loss in potential total revenue due to California sea lions interactions with commercial salmon fishermen in Monterey Bay in 1998 (Weise and Harvey 2005a). Another study on California bait receivers (baitfish storage pens) by Hanan (2002) estimated a $2.3 million annual loss to California sea lions in 2002 (8% of the retail value).

- ○ Conduct ecosystem research where the impacts of pinniped predation on non-salmonid resources can be addressed

Although food habit studies were conducted at many major pinniped haul-out sites, a systematic coastwide study on pinniped consumption of non-salmonid resources was not conducted due to the limiting funding that was directed primarily to pinniped impacts on salmonids. The studies did show that many commercially important fish species such as Pacific whiting and flatfish (e.g., Dover sole) are also principal prey species for pinnipeds. Biomass consumption estimates for all prey species were not calculated from the scats collected due to uncertainty on models and pending results from captive feeding studies. The captive studies have now been completed, and if funding is reinstated for the West Coast Pinniped Program, one of the first actions should be to convene a workshop to discuss and refine appropriate biomass reconstruction models and applicable correction factors (derived from captive feeding studies) so that new biomass consumption estimates can be generated.

- ○ Collect unbiased samples for food habit studies

Through development of standardized protocols including the “all structures” method for analyzing scat and development of correction factors from captive feeding studies, many of the concerns over biases inherent to using scats for food habit studies have been addressed. The program did not attempt direct lethal collection of pinnipeds for analysis of stomach contents due to inherent research permit issuance problems that likely would have ensued.

- Implement site-specific management for California sea lions and Pacific harbor seals

The direct observational studies, combined with the marking and tracking of individual pinnipeds, demonstrated that relatively few individual pinnipeds may be responsible for much of the salmonid predation at specific sites. These individual pinnipeds may be specialists in their foraging behavior rather than generalists and are likely targeting specific prey species (i.e., salmonids). These research results confirm the findings in the Report to Congress and support the rationale for the need for site-specific pinniped management. Also, state/federal experience related to the use of non-lethal deterrence and existing authority under the MMPA for lethal removal of pinnipeds demonstrates that this recommendation remains valid.

Non-lethal methods have not been effective in reducing predation and are expensive to maintain. The existing provisions within the MMPA to remove predatory pinnipeds are limited to specific individuals after it has been ascertained that their predation is having a significant impact on the affected salmonids runs. Such constraints result in an ineffective strategy to protect salmonids, in part because predatory pinnipeds are allowed to continue their exploitation at sites where salmonids are particularly vulnerable until such time that determinations can be made on the significance of the predation. This approach is inconsistent with sound principles of wildlife management, in which uncertainty should be interpreted to favor the species most at risk. The strategy also maximizes learning opportunity for pinnipeds; therefore, it increases the number of pinnipeds that must be removed to effect adequate protection of salmonids populations. The 1999 Report to Congress recommendation for site-specific pinniped management addresses these concerns and is supported by the recent studies; thus, it continues to be a valid recommendation.

- Develop safe, effective non-lethal deterrents

Many of the problem situations with California sea lions and harbor seals involve only a relatively few pinnipeds, and in some cases are individual animals that have learned to engage in actions that negatively affect other resources, fisheries, property or people. Studies have shown that these individual animals need to be dealt with quickly to prevent the conflict from escalating. The use of deterrence measures can prevent the severity of the conflict from increasing, but in most cases will not eliminate the conflict. Although most deterrence actions have limited effectiveness, this should not preclude them from being used when and where necessary, and in combination with other measures whenever possible to address pinniped conflicts.

Studies at the Ballard Locks in Seattle, Willamette Falls in Oregon, and Bonneville Dam on the Columbia River have documented that deterrents are not effective in providing long-term, effective reduction of pinniped predation on salmonids. Deterrence efforts on fishing vessels have had similar ineffective results with deterring pinniped from fish caught on fishing gear. A review of pinniped deterrence provided in this report demonstrates this lack of reliable effect; therefore, a large-scale investment in non-lethal deterrence is not likely to result in successful alternatives. Accordingly, this recommendation may no longer be necessary. A better recommendation would be to provide long-term funding for re-establishment of the West Coast Pinniped Program since it can provide a more holistic comprehensive approach to assessing pinniped conflicts and developing site-specific deterrence or other measures as appropriate dependent on the circumstances of the specific conflict.

- Selectively reinstate authority for intentional lethal taking of California sea lions and Pacific harbor seals by commercial fishers

The West Coast Pinniped Program did demonstrate that pinnipeds continue to cause damage to fishing gear and catch, and the losses and damage from pinnipeds may be locally severe seasonally. However, the directed, intentional lethal taking by commercial fishermen was not evaluated relative to its effectiveness in eliminating pinniped interactions with fisheries. Lacking some certainty on the need for and benefits of directed lethal taking by fishermen, as well as humane taking concerns, this recommendation may be invalid until such time that confirming studies are conducted.

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APPENDIX A: WEST COAST PINNIPED PROGRAM - WORKING GROUP

PACIFIC STATES MARINE FISHERIES COMMISSION (PSMFC)
Dave Colpo, Randy Fisher, Al Didier, Dave Hanson

NOAA - NATIONAL MARINE FISHERIES SERVICE (NMFS)
Northwest Regional Office - Joe Scordino, Garth Griffin
Headquarters Office of Protected Resources - Tom Eagle
Southwest Regional Office - Monica DeAngelis, Christina Fahy, Tim Price
National Marine Mammal Laboratory - Bob DeLong, Jeff Laake, Harriet Huber, Pat Gearin
Southwest Fisheries Science Center - Mark Lowry, Jay Barlow, Cindy Thomson
Northwest Fisheries Science Center - Linda Park, Linda Jones

WASHINGTON DEPARTMENT OF FISH AND WILDLIFE (WDFW)
Steve Jeffries, Monique Lance, Josh London

OREGON DEPARTMENT OF FISH AND WILDLIFE (ODFW)
Robin Brown, Bryan Wright, Sue Riemer

CALIFORNIA DEPARTMENT OF FISH AND GAME (CDFG)
Dale Sweetnam, Robert Read, Melodie Palmer-Zwahlen, Doyle Hanan

MOSS LANDING MARINE LABORATORIES (MLML)
Jim Harvey, Michael Weise

HUMBOLDT STATE UNIVERSITY (HSU)
Dawn Goley

YUROK TRIBE FISHERIES PROGRAM (YTFP)
Dave Hillemeier, Kathleen Williamson

APPENDIX B: LIST OF FUNDED PROJECTS (dollars in thousands)

Entity	PROJECT TITLE	1998	1999	2000	2001	2002	2003	2004	2005	2006
NMML	Pinniped Predation on ESA-listed Salmonids in Columbia River Basin	$105.0	$104.4	$34.5	$82.2	$30.0	-------	$29.0	-------	-------
NMML	Pinniped Predation on Sockeye in Ozette River and Lake	$0.0	$0.0	$49.3	$0.0	-------	-------	-------	-------	-------
NMML	Pinniped Predation in Umpqua	$0.0	$0.0	-------	-------	-------	-------	-------	-------	-------
NMML	Assessing the Food Habits of California Sea Lions in the Lower Columbia River	-------	-------	-------	-------	-------	$14.0	-------	-------	-------
NMML	California Sea Lions Life History Parameters	$29.0	$38.4	$37.4	$10.0	$30.0	$86.0	$65.0	-------	-------
NMML	Demography of California sea lions	-------	-------	-------	-------	-------	-------	-------	$80.0	-------
NMML	California sea lion OSP paper	-------	-------	-------	-------	-------	-------	-------	$2.0	-------
NMML	Branding Zalophus at Ballard Locks	-------	-------	-------	-------	-------	$9.8	-------	-------	-------
NMML	Harbor Seal Life History Parameters	$37.0	$38.5	$39.4	$23.0	$30.0	$44.5	$32.0	-------	-------
NMML	Harbor seal stock substructure genetics	-------	-------	-------	-------	-------	$0.0	$0.0	$0.0	-------
NMML	Assessment of Harbor seal stock boundary in Washington	-------	-------	-------	-------	-------	-------	$7.0	$10.0	-------
NMML	WA Harbor Seal OSP - Correction Factor	-------	-------	$19.7	-------	-------	-------	-------	-------	-------
NMML	Harbor Seal and Sea Lion Food Habits in Puget Sound	$35.0	-------	-------	-------	-------	-------	-------	-------	-------
NMML	California sea lion food habits (scat samples from San Miguel)	-------	-------	-------	-------	-------	-------	-------	$30.0	-------
NMML	Hookworm disease in California sea lions and northern fur seals	-------	-------	-------	-------	-------	-------	-------	$20.0	-------
NWC	Genetic Identification of Salmonid Remains in Scats	$30.0	$69.6	$74.0	$54.5	$75.0	$54.5	$74.0	$0.0	-------
NWR-F/PR	Evaluation of Non-Lethal Deterrence Measures	$25.0	-------	($25.0)	-------	-------	-------	-------	-------	-------
SWC	Socio-Economic Impacts of Pinniped-Fisheries Interactions	$55.0	$0.0	$0.0	$0.0	$0.0	$50.4	$22.0	$25.0	-------
SWC	California Sea Lion Census	$14.0	$32.3	$24.7	$25.0	$27.0	$32.0	$27.0	$31.0	-------
SWC	Status determination of California sea lions from diversity in their diet	-------	-------	-------	-------	-------	-------	$7.0	-------	-------

Entity	PROJECT TITLE	1998	1999	2000	2001	2002	2003	2004	2005	2006
SWC	California Sea Lion Abundance and Distribution in Central/Northern CA	$75.0	$30.3	$0.0	-------	-------	-------	-------	-------	-------
SWC	California sea lion stock structure (genetics)	-------	-------	-------	$7.0	-------	-------	-------	-------	-------
SWC	Diet of California sea lions and counts of northern elephant seals	-------	-------	-------	-------	-------	-------	-------	$41.0	-------
SWC	California harbor seal survey	-------	-------	-------	-------	$18.0	$0.0	$35.0	$35.0	$0.0
Yurok	Pinniped Predation on Salmonids in Klamath	$50.0	$90.0	$0.0	-------	-------	-------	-------	-------	-------
MLML	Pinniped Predation on Salmonids in San Lorenzo River	$40.0	$50.0	$49.4	$40.0	$0.0	-------	-------	-------	-------
MLML	Sea lion abundance in Monterey	-------	-------	-------	$3.0	-------	-------	-------	-------	-------
MLML	Assessing cues	-------	-------	-------	$15.0	$10.0	-------	$18.0	-------	-------
MLML	Captive Feeding Studies	-------	-------	$93.0	$20.0	$20.0	-------	-------	-------	-------
MLML	Salmonids in California sea lion scats at Año Nuevo	-------	-------	$0.0	$39.0	$39.0	$39.1	$15.1	$14.7	-------
MLML	Genetic techniques to identify prey in captive sea lion fecal samples	-------	-------	-------	-------	$20.0	[-$20.0]	-------	-------	-------
MLML	Capture/Tagging of Harbor Seals in Central California (Correction Factor)	-------	-------	-------	-------	$40.0	$0.0	-------	-------	-------
MLML	Capture and Tagging of Harbor Seals in Southern California	-------	-------	-------	-------	-------	-------	-------	$73.5	$0.0
MLML	Implant tags for log term tracking	-------	-------	-------	-------	-------	-------	[$10.0]	-------	-------
MLML	Capture and tagging of Harbor Seals in Northern California	-------	-------	-------	-------	-------	$52.1	$15.1	-------	-------
HSU	Capture and tagging of Harbor Seals in Northern California	-------	-------	-------	-------	-------	-------	[$12.8]	-------	-------
HSU	Tracking tagged harbor seals in Northern California	-------	-------	-------	-------	-------	$2.3	-------	-------	-------
HSU	Pinniped Predation on Salmonids in CA (Mad, Eel, Smith Rivers)	-------	$64.5	$27.5	$40.4	$0.4	$0.0	-------	-------	-------
CDFG	Pinniped Feeding Ecology, Salmon Depredation, and Deterrent Testing at Selected California Rivers	$88.3	($63.2)	-------	-------	-------	-------	-------	-------	-------
CDFG	Pinniped Interactions with Market Squid Fishing Vessels in CA	$29.4	($29.4)	-------	-------	-------	-------	-------	-------	-------

Entity	PROJECT TITLE	1998	1999	2000	2001	2002	2003	2004	2005	2006
CDFG	Sea Lion Interactions with Salmon Troll and Sport Fisheries in CA	$39.2	$20.0	$41.2	$50.0	$0.0	-------	-------	-------	-------
CDFG	Alternative tagging methods for CPFV interactions	-------	-------	-------	-------	$10.0	($10.0)	-------	-------	-------
CDFG	Pinniped Interactions with Commercial Passenger Fishing Vessels in CA	$29.4	$8.7	$49.0	$0.0	$0.0	-------	-------	-------	-------
CDFG	Harbor Seal Survey/Census in California	$49.0	($10.6)	$34.3	$29.0	$35.0	[-$35.0]	-------	-------	-------
Contractor	Compilation of existing harbor seal ground count data in California	-------	-------	-------	-------	$20.0	[$20.0]	-------	-------	-------
Contractor	Harbor Seal Correction Factor Adjustment	-------	-------	-------	-------	$10.0	[$10.0]	-------	-------	-------
ODFW	Pinniped Predation on Smolt in Alsea Bay	$24.5	$19.8	$0.0	$0.0	-------	-------	-------	-------	-------
ODFW	Abundance, Distribution, and Movements of California sea lions in the Columbia River	$40.0	-------	-------	-------	-------	-------	-------	-------	-------
ODFW	California Sea Lion Abundance, Movements and Foraging Behaviors in the Columbia and Willamette Rivers	-------	-------	$74.3	$53.8	$106.3	-------	-------	-------	-------
ODFW	Monitor Predation at Willamette Falls	-------	$24.8	$0.0	$0.0	$0.0	$0.0	-------	-------	-------
ODFW	Columbia-Willamette Rivers Area Pinniped-Salmonid Interactions	-------	-------	-------	-------	-------	$102.0	$121.1	$121.1	-------
ODFW	Seasonal distribution and abundance surveys for pinnipeds in Oregon	-------	$47.3	$0.0	-------	-------	-------	$0.0	$0.0	-------
ODFW	Seasonal Distribution and Abundance Surveys for California sea lions in Oregon	$19.6	-------	-------	-------	-------	-------	-------	-------	-------
ODFW	Seasonal Distribution and Abundance Surveys, and Annual Population Assessment for Pacific Harbor Seals in Oregon	$19.6	-------	-------	-------	-------	-------	-------	-------	-------
ODFW	Oregon Coastal Area Pinniped-Salmonid Interactions	-------	-------	-------	-------	-------	$67.1	$69.0	$67.0	-------
ODFW	Monitoring Pinniped Predation on Adult Salmonids in Alsea River	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	-------	-------	-------

Entity	PROJECT TITLE	1998	1999	2000	2001	2002	2003	2004	2005	2006
ODFW	Monitoring Pinniped predation and salmonid Abundance in Selected Coastal River Systems in Oregon	$132.4	$153.2	$98.0	$117.8	$59.6	-------	-------	-------	-------
ODFW	Reducing and Evaluating Pinniped Predation on Threatened and Endangered Salmonids in the Columbia River Below Bonneville Dam	-------	-------	-------	-------	-------	-------	-------	-------	$60.0
WDFW	Monitoring Pinniped Predation on Summer-Run Chum Salmon in Hood Canal, Washington	$132.3	$170.0	$157.4	$165.0	$163.2	$163.3	$69.1	-------	-------
WDFW	Assessment of Seasonal Abundance and Distribution of Harbor Seals in Washington	$63.1	$49.7	-------	$0.0	-------	$19.2	-------	-------	-------
WDFW	Assessment of Seasonal Abundance and Distribution of California and Steller Sea Lions in Washington	$39.9	$25.4	-------	-------	-------	-------	-------	-------	-------
WDFW	Aerial Surveys for Assessment of Harbor Seals and Sea Lion Abundance in Washington State Waters	-------	-------	-------	-------	-------	-------	$26.1	$0.0	-------
WDFW	Investigation of seal and sea lion abundance and harbor seal diet in Washington	-------	-------	-------	-------	-------	-------	-------	$166.7	-------
WDFW	Conduct Scat Collections from Harbor Seals in San Juan Islands, Hood Canal, and Southern Puget Sound to Characterize Diet.	-------	-------	-------	-------	-------	-------	$70.0	$0.0	-------
WDFW	Reducing and Evaluating Pinniped Predation on Threatened and Endangered Salmonids in the Columbia River Below Bonneville Dam	-------	-------	-------	-------	-------	-------	-------	-------	$58.8
PSMFC	Pinniped Interaction Documentary	-------	$10.0	-------	-------	-------	-------	-------	-------	-------
PSMFC	Coordination, Travel, Workshops	$0.0	$0.0	$0.0	$14.5	$0.0	$47.1	$8.9	$15.6	$10.0
PSMFC	Indirect	$13.3	$9.8	$8.4	$9.5	$6.5	$6.9	$5.6	$6.4	$1.2
	TOTAL	$1,215.0	$953.5	$886.4	$798.7	$750.0	$865.3	$738.8	$739.0	$130.0