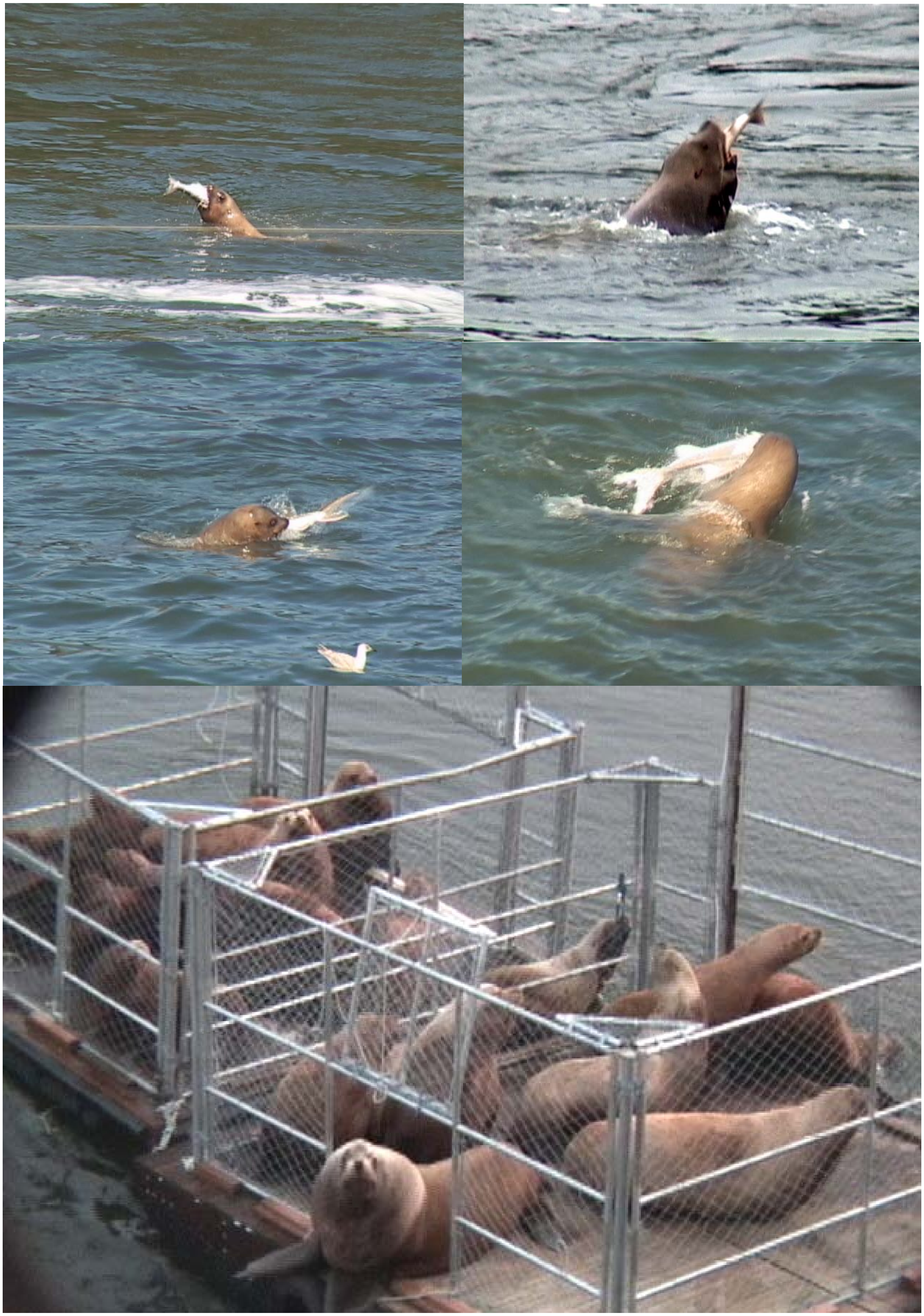
EVALUATION OF PINNIPED PREDATION ON ADULT SALMONIDS AND OTHER FISH IN THE BONNEVILLE DAM TAILRACE, 2008-2010

Robert J. Stansell, Karrie M. Gibbons, and William T. Nagy

U.S. Army Corps of Engineers
Portland District, Fisheries Field Unit
Bonneville Lock and Dam
Cascade Locks, OR 97014
(541) 374-8801

October 14, 2010



EXECUTIVE SUMMARY

The U.S. Army Corps of Engineers Fisheries Field Unit (FFU) has conducted surface observations to evaluate the seasonal presence, abundance, and predation activities of pinnipeds, including California sea lions (*Zalophus californianus*), Steller's sea lions (*Eumetopias jubatus*), and harbor seals (*Phoca vitulina*) in the Bonneville Dam tailrace each year since 2002. This monitoring program was initiated in response to concerns over the potential impact of California sea lion (CSL) predation on adult salmonids passing Bonneville Dam in the spring, including spring Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*O. mykiss*). This report summarizes observations from 2008 through 2010.

Observers stationed at each of the three major tailrace areas of the dam (Powerhouse 1, Powerhouse 2, and the spillway) recorded pinniped presence, recorded and identified fish catches, and identified individual CSL when possible. Individual pinnipeds were identified by cataloging unique physical characteristics and (for previously trapped and tagged animals) unique brand numbers. Individual identification was used to generate abundance estimates and to track individual predation and use patterns, both within and among years. Observations generally began in early January and continued through the last week of May. This study period included the fish passage season from 1 January to 31 May as few pinniped sightings occurred outside this timeframe. Special attention was paid to the spring Chinook salmon passage season at Bonneville Dam (15 March through 15 June). Observations were generally made from just prior to sunrise to just after sunset, 5 days per week (7 days per week in 2008). Observations made from 2002 to 2004 suggested that pinniped activity was minimal at night, and based on 30 hours of night observation in 2009, it is estimated that night predation was no more than 3.5% of total predation.

Total estimated salmonid catch has ranged from about 4,000 to 6,000 per year since 2008. The relative impact on the 1 January to 31 May run has varied with the number of fish passing each spring, which has risen each year from 2008 to 267,194 in 2010. An estimated 4,466 adult salmonids (2.9% of the run) were consumed by pinnipeds in the tailrace of Bonneville Dam during the 2008 1 January to 31 May period. An estimated 4,489 adult salmonids (2.4% of the run) were consumed in 2009, and an estimated 6,081 adult salmonids (2.2% of the run) were consumed in 2010. Presence and predation by CSL was first observed in the fall of 2008 and has been noted each fall since. Additional salmonids were caught by pinnipeds but escaped and swam away with unknown injuries (3.3%, 2.3%, and 2.6% of total salmonid catch escaped in 2008, 2009, and 2010, respectively). Prior to 2006, Powerhouse 2 (PH2) consistently showed the highest level of predation on salmonids, averaging 52.7% of the catch, with Powerhouse 1 (PH1) averaging 34.3% and the spillway averaging 13.0%. However, from 2006 to present predation activity has become more evenly distributed, with PH2 averaging only 35.8% while PH1 averaged 42.0% and the spillway averaged 22.2%. This is likely in response to full time hazing activity that began in 2006 and tends to chase pinnipeds from one tailrace location to another.

Pacific lamprey (*Lampetra tridentata*), white sturgeon (*Acipenser transmontanus*), and other fish were also consumed by pinnipeds on the surface. Lamprey comprised 1.4% of the total observed

catch from 2008 to 2010, although lamprey catch is probably underestimated. Estimated lamprey catch has declined each year since it peaked in 2005. Lamprey comprised 11.2% of the total catch between 2002 and 2007. White sturgeon predation, primarily by Steller's sea lions (SSL), has increased every year since 2006, averaging 2.5% of observed catch before 2008 and 16.0% the last three years. The estimated sturgeon catch increased each year from 315 in 2006 to 1,879 in 2010, so there is growing concern about the potential impacts of SSL on sturgeon at Bonneville Dam. SSL have also increased their consumption of salmonids. They averaged an estimated 19.7 salmonids each year between 2002 and 2007, but averaged an estimated 545.7 salmonids for 2008 and 2010.

The number of individual sea lions observed at Bonneville Dam has increased from an average of 83.0 per year between 2002 and 2007 to 123.7 per year for the last three years. This is primarily due to an increase in the presence of SSL (averaging 5.0 per year before 2008 and 46.7 from 2008 to 2010). Although the number of CSL dropped from 82 in 2008 to 54 in 2009, it rose in 2010 to 89. Overall they averaged 76.2 per year before 2008 and 75.0 the last three years. Harbor seals are seen only occasionally at the dam and never more than three in one year. The highest number of individual pinnipeds observed at the project on any one day increased every year except 2009, with a maximum daily count of 69 in 2010. However, the highest number of CSL seen dropped every year since the peak of 52 in 2007 to 26 the past two years. The mean number of pinnipeds observed per day during our study period was higher each of the last three years, but again this is primarily due to an increase in the daily presence of larger numbers of SSL, as mean daily CSL figures dropped the last two years.

The Corps and other federal, state, and tribal agencies implemented a variety of sea lion deterrents at Bonneville Dam from 2008 to 2010. Physical barriers called sea lion exclusion devices (SLEDs) installed at all primary fishway entrances, and floating orifice gate (FOG) barriers continue to be effective in preventing sea lions from entering fishways. Harassment efforts continued each year both from land and boats and continue to show limited local, short term benefits in chasing some sea lions away from fishways and tailrace areas. Acoustic deterrents have shown no impact at all to the presence of sea lions near the fishway entrances. In 2008, the Oregon Department of Fish and Wildlife (ODFW) and Washington Department of Fish and Wildlife (WDFW) began to capture and permanently remove specific returning CSL at Bonneville Dam. Over the past three years 40 known Bonneville CSL were removed (including 3 non-targeted CSL that died inadvertently on May 4, 2008). This is likely the cause of the decline in CSL mean daily presence and maximum numbers seen on any given day, as most of the removed individuals had returned many years and remained at Bonneville Dam for long periods of time.

Despite the increasing level of predation on salmonids, there does appear to be some reduction in the presence of CSL at Bonneville Dam over the past three years. This monitoring effort should continue, particularly in light of the CSL removal program and increased presence of SSL. The Corps should work with partnering agencies to evaluate impacts of pinniped predation in areas farther downstream of the dam. The Corps should also continue to evaluate potential non-lethal sea lion deterrent technologies as part of a long-term strategy to reduce sea lion predation on salmonids, sturgeon, and lamprey in the Bonneville Dam tailrace.

TABLE OF CONTENTS

TABLE OF CONTENTS cont.

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Since 2002, the U.S. Army Corps of Engineers (USACE) has used surface observations to evaluate the seasonal presence, abundance, and predation activities of pinnipeds, including California sea lions (*Zalophus californianus*), Steller's sea lions (*Eumetopias jubatus*), and Pacific harbor seals (*Phoca vitulina richardsi*) in the Bonneville Dam tailrace (Stansell, 2004; Tackley, et al., 2008a; Tackley et al., 2008b, Stansell, et al., 2009). This monitoring program is part of an ongoing effort to understand and appropriately manage pinniped predation on salmonids, particularly Endangered Species Act (ESA) listed Columbia River wild spring Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead trout (*O. mykiss*) in the tailrace of the dam. The USACE and partnering agencies have utilized a variety of deterrents and barriers to prevent predation in or around fishways and to deter predation on salmonids and other fish in the tailrace. This report is intended as a summary of monitoring and deterrence efforts implemented by or coordinated with the USACE. Agency partners included the Oregon Department of Fish and Wildlife (ODFW), the Washington Department of Fish and Wildlife (WDFW), the Columbia River Inter-Tribal Fish Commission (CRITFC), the National Oceanic and Atmospheric Administration, Fisheries (NOAA Fisheries), the U.S. Department of Agriculture (USDA) Wildlife Services, and Portland State University (PSU). Although primarily covering 2008 through 2010, data from 2002 to the present are also presented for comparative purposes.

OBJECTIVES:

1. Estimate the number of adult salmonids, white sturgeon (*Acipenser transmontanus*), Pacific lamprey (*Lampetra tridentata*), and other fish consumed by pinnipeds in the Bonneville Dam tailrace and estimate the proportion of the adult salmonid run impacted.
2. Determine the seasonal timing and abundance of pinnipeds present at the Bonneville Dam tailrace, documenting individual California sea lion (CSL) and Steller's sea lion (SSL) presence and predation activity when possible.
3. Evaluate the effectiveness of pinniped deterrents and barriers used at Bonneville Dam.
4. Evaluate the impact and effectiveness of the removal program of specific CSL by ODFW and WDFW on the numbers of pinnipeds present and predation rates at Bonneville Dam.

The Pinniped/Fishery Interaction Task Force, established to provide guidance to the National Oceanic and Atmospheric Administration (NOAA) for determining a course of action to reduce pinniped predation on ESA listed salmonids at Bonneville Dam, requires a check-in after three years to determine if the actions (particularly removal of select CSL) are having the desired effect. 2010 is the third year CSL removals have occurred, and we address this objective by summarizing relevant data from our monitoring efforts.

METHODS

STUDY SITE

Bonneville Dam is the first dam upstream from the mouth of the Columbia River at river kilometer (rkm) 235 (Figure 1). Construction of Powerhouse 1 (PH1), the spillway (main dam), and navigation lock was completed by 1938. Powerhouse 2 (PH2) was added in 1982, and a new navigation lock was completed in 1993. This created a tailrace that is broken up into three main areas separated by islands (Figure 2). Our primary study area included the tailraces of PH1, the spillway, and PH2.

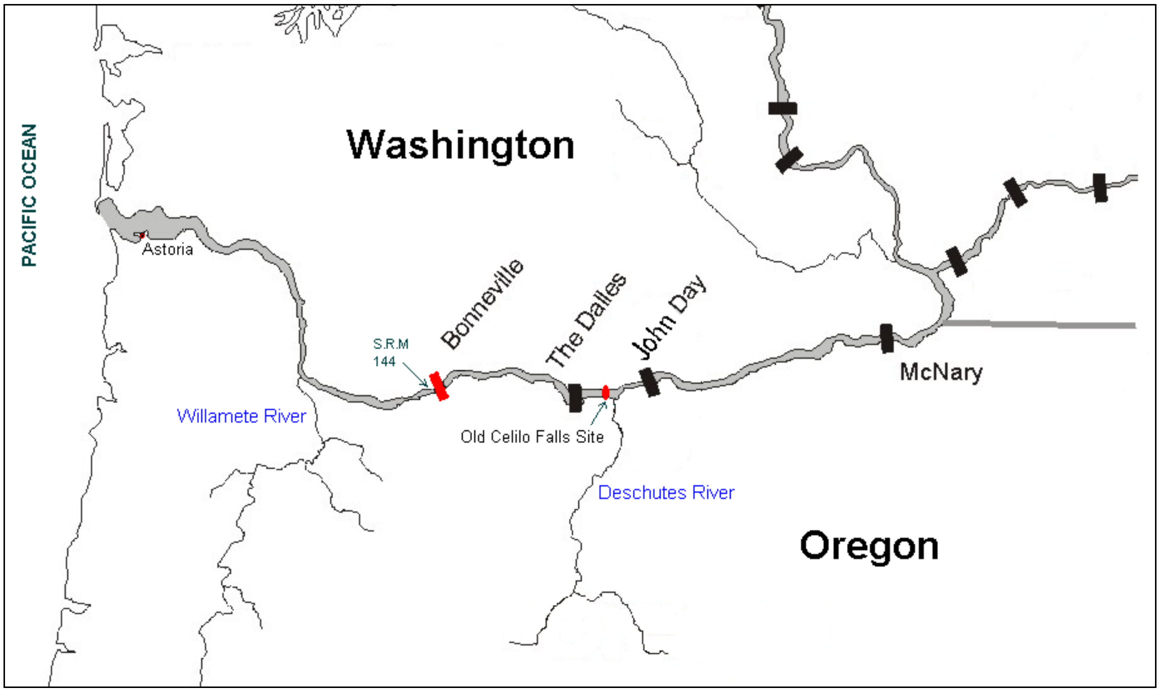


Figure 1. Overview of the Columbia River and location of Bonneville Dam.

SURFACE OBSERVATIONS

Pinnipeds, including CSL and SSL, typically bring large prey items, such as salmon and sturgeon (*Acipenser transmontanus*), to the surface to ease handling and dismemberment (London et al., 2002). In near-shore environments in which the target prey species are large-bodied, terrestrial observations can be used effectively to evaluate pinniped diet (Brown and Mate, 1983; Roffe and Mate, 1984). Previous scatological studies confirmed that CSL at Bonneville Dam are primarily targeting adult salmonids (Wright et al., 2007) and that SSL scat collected at Bonneville Dam and Phoca Rock (rkm 212) largely contained remains of white sturgeon (Susan Riemer, ODFW, personal comm.). While surface observations are a useful tool for assessing sea lion diet at Bonneville Dam, all consumption estimates and associated impacts outlined in this report should be considered minimum estimates. Assumptions made regarding this evaluation are listed in Appendix E.

Observers were stationed at each of the three major tailrace areas of Bonneville Dam (PH1, PH2, and the spillway). They used binoculars to record pinniped presence, record and identify fish catches, and identify individual CSL and SSL when possible. Other locations were observed briefly when time and resources allowed. Beginning in 2008 observers were instructed to assign a confidence rating of 1 (least confident) to 5 (most confident) to each identified fish catch. The category of "unidentified salmonid" was eliminated in 2008 from observation forms, and observers were instructed to identify all salmonid catches as either Chinook or steelhead, which are the only two salmonids likely to be observed during this study period at Bonneville. Individual pinnipeds were identified by cataloging unique physical characteristics and/or unique brand numbers. Individual identification was used to generate abundance estimates and to track individual predation and other behavioral patterns both within and among years. In 2008, observations began roughly one hour before sunrise and ended one hour after sunset. For 2009 and 2010, regular observations began roughly the hour of sunrise and ended the hour of sunset with one hour breaks in the morning and afternoon with the break hour changing each day. Observations were occasionally conducted at night or at other locations as time allowed but were not factored into the equation for determining expanded estimates. A night vision monocular, thermal imaging scopes, and spotlights were used to assist in sea lion detection, counting (at haul out locations), and predation events at night. Methods used in surface observations are described in more detail in Stansell (2004) and Tackley et al. (2008a). In 2010, for the first time, the location of predation events was recorded with more precision. Each tailrace was broken up into seven zones, 3 across (south, middle, north sides), near dam (from the face of the dam downstream about 100m), mid-tailrace, and beyond the tips of the islands (Figure 2).

This study included the period from January 1 to May 31, with special attention paid to the spring Chinook salmon passage season at Bonneville Dam. Few pinniped sightings occurred outside this timeframe, although a few CSL have now been observed between September and December since 2008, and one CSL was in the Bonneville Dam forebay above Bonneville Dam and several locations up to The Dalles Dam all summer and winter until trapped on January 25, 2010 and released at Clatsop Spit near the mouth of the Columbia River. SSL have also been observed catching and consuming white sturgeon in the Bonneville Dam tailrace and farther downstream as early as September during the last few years. In 2008, regular observations began January 11 and ended May 31 and covered seven days per week. In 2009, regular observations began January 14 and continued through May 29, Mondays through Fridays (and some weekends in April). In 2010, regular observations began on January 8 and ceased on May 28, Mondays through Fridays. Data were interpolated for days not observed and limited observations were conducted in early January and sometimes into June if pinnipeds were present.

Figure 2. Primary study area and location of zones (where predation events are first observed and recorded) at Bonneville Dam, 2010.

PREDATION ESTIMATES

Expanded Consumption Estimates

Surface observations were used to estimate total consumption of Chinook salmon, steelhead, Pacific lamprey (*Lampetra tridentata*) and white sturgeon. Since observers were not present at all times we used interpolation and expansion at each of the tailrace areas (PH1, PH2, and spillway) to estimate adult salmonid, sturgeon, and lamprey consumption. Estimates for all three tailrace sub-areas were combined to calculate total daily estimated consumption for the Bonneville Dam tailrace. For days on which no observations were made, we used linear interpolation to fill in the gaps. All daily estimated consumption totals were added to get the total *expanded consumption estimate* for the year. The *minimum estimated impact* on salmonids passing during the observation period (expressed as percent of run) was calculated by dividing the expanded salmonid consumption estimate by the expanded salmonid consumption estimate plus the total salmonid passage count from Bonneville Dam for the January 1 through May 31 time period:

$$I_m = \frac{C_e}{(C_e + P)}$$

where

C_e is the expanded adult salmonid consumption estimate,

P is the salmonid passage count at Bonneville from January 1 through May 31, and

I_m is the minimum estimated impact on adult salmonids passing Bonneville from January 1 through May 31.

Expanded Chinook Consumption Estimates

We estimated Chinook salmon consumption and the minimum estimated impact on the Columbia River spring Chinook salmon run at Bonneville Dam from 2002 to 2010. For 2002 through 2007 data, we multiplied daily expanded salmonid consumption estimates by the percentage of identified salmonid catches recorded as Chinooks to estimate expanded Chinook consumption. Daily estimates were combined to calculate the total expanded Chinook consumption estimate for each year. In 2008 through 2010, observers were instructed to identify all salmonid catches as either Chinook or steelhead and assign a confidence rating to their identification. After reviewing the confidence rating distribution for these years, we determined that the vast majority were identified confidently enough that it would be acceptable to assume that all catches identified as Chinook were indeed Chinook. Therefore, for 2008 through 2010 data, we used the standard expanded estimate to generate the expanded Chinook consumption estimate. For all years, the estimated impact on Chinook passing during the observation period (expressed as percent of run from January 1 through June 15) was calculated similar to overall salmonid impact estimates.

Adjusted Consumption Estimates

With additional information gained over the years, we can now make further adjustments to the estimates. For a variety of reasons, observers were sometimes unable to identify the fish caught during a predation event. To provide more comprehensive adult salmonid and sturgeon consumption estimates, we used daily observed catch distributions, unique to each predator species, to proportionally divide unidentified catch (Appendix B, Equation 1). The daily observed catch distributions included adult salmonids, sturgeon, American shad (*Alosa sapidissima*), northern pikeminnow (*Ptychocheilus oregonensis*), and bass (Centrarchidae). Lamprey and smolt (juvenile salmonids) were excluded from this proportional allocation, as we determined that their distinctive sizes and shapes made them extremely unlikely to be recorded as unidentified fish. The proportionally split consumption totals for CSL and SSL were added to the expanded consumption estimates to calculate the adjusted consumption estimate (Appendix B, Equation 2). We estimated night-time consumption to add approximately 3.5% to the daily estimates based on our work in 2009 (Stansell, et al., 2009) after noting that day-time hazing may be causing more predation at night than seen from 2002 to 2005. And finally, we can attribute catch to pinniped species and adjust for clepto-parasitism events (the stealing of prey from one predator species, CSL, by another predator species, SSL) to better estimate actual consumption impacts by species (Appendix B).

INDIVIDUAL IDENTIFICATION

Identification of individual CSL and SSL was used to determine the number of sea lions present (daily and seasonally), and to track individual presence and predation activity. We used video and photos from digital video recorders equipped with either 12 or 24X optical zoom lenses, 35mm cameras, field sketches, and observer notes to identify unique marks for individual CSL and SSL, and to confirm identities of individuals seen by multiple observers. We identified individual pinnipeds by noting a combination of physical characteristics such as brands, cuts, scars, lumps, color patterns, size, maturity, and also behavior. Since harbor seal presence was relatively minor at the dam, we did not attempt to identify and track individual harbor seals. Previously reported seasonal estimates of SSL and harbor seal abundance, which should be considered minimum abundance estimates, were derived from simultaneous multiple sightings across the study area, and from sightings of individual animals that were sufficiently different in appearance (size, coat color, coat pattern) to allow at least within-day identification. However, we now record individual SSL, using video and photos from prior years when possible.

Several behavioral and physical factors aided observers in the identification process. The longer an individual animal was present, the more time it spent above the water surface, and the more closely it approached observation positions, the easier it was for us to detect enough characteristics to identify it. Hazing activities altered the behavior of some individuals, sometimes with negative impacts on the individual identification process. Hazing activity prompted some animals to stay farther away from dam structures (and our observers) and to spend more time below the surface of the water, thereby reducing the risk of being hazed. Individual identification efforts were also hindered when sea lions left haul-out locations (due to capture events and other disturbances) before observers had an opportunity to identify the animals. Variation in physical characteristics also made some individuals more difficult to identify than others. Some had obvious markings that were readily visible; others had subtle markings or scars that were rarely seen, or that were not visible in subsequent years.

Due to variation in physical appearance and behavior, identified individuals were assigned to categories of certainty. The first category included “highly identifiable”, which included animals that were branded and those with marks or features that made them unique and likely to be identified in subsequent years (e.g. circle scars, major deformities, major scars or wounds). The second category included “likely identifiable” animals, which were animals that had unique marks or features, but were more difficult to observe. These animals had characteristics which allowed us to identify the individual within a particular year, but the marks or features were probably not good enough to identify the individual in subsequent years (e.g. small fresh cuts or wounds, subtle color patterns, missing patches of fur). The third category included “not likely identifiable” individuals, which included animals that lacked unique distinguishing marks or features, but displayed enough physical or behavioral nuances that within a day or short period of time, we could distinguish individuals from the others in our study area. However, there would be no chance of identifying particular animals again in subsequent years or outside of our study area, and if an animal left for some time and returned, we could not be certain it was the same individual. Additionally, some animals had virtually no identifying marks or features, never came in close enough for identification, did not stay long enough, or did not spend enough time above water for observers to note any characteristics that would distinguish them from other animals. These additional animals could be counted in daily tallies to determine how many pinnipeds were present, but it was possible we could see them the next day and have no idea if they were the same animal or a different one, so they were not used for annual tallies.

Animals in the "highly identifiable" category were used to determine number and percent of individuals returning each year. Animals in the "high" and "likely" categories were added to determine the minimum number of individuals seen for each entire season or year. The "not likely identifiable" category was used for daily tallies to determine the minimum number of pinnipeds seen per day.

Unique individual pinnipeds identified in the field were video-taped (when possible), and/or sketched to document the characteristics that made it unique from others seen at Bonneville Dam. The sketches were made available to all observers and the individual animals were typically given temporary names in the field for consistency in identification across observers. When an individual was documented by multiple observers and/or video-taped, it was considered a unique individual for that year and it was given a "B" code (for CSL) or "S" code (for SSL) for recordkeeping. "B" or "S" coded animals that were later branded were subsequently referred to by their brand number. Often, animals branded in Astoria by ODFW would show up at Bonneville Dam and subsequently be identified as being a previously known "B" code animal, and we would link up the database for those animals. Some animals captured and branded at Bonneville Dam were known before branding to be a specific individual "B" code and again, the data were linked.

DETERRENTS AND MANAGEMENT ACTIVITIES

We used and evaluated a variety of sea lion deterrents, from physical barriers and Acoustic Deterrent Devices (ADDs) to non-lethal harassment (hazing) techniques, as well as the CSL removal program (2008 - 2010). Sea lion exclusion devices (SLEDs) are large, barred, grate-like physical barriers that were installed at Bonneville Dam's twelve primary fishway entrances to prevent sea lions from entering the fishways. The SLEDs feature 15.38-in (39.05 cm) gaps that are designed to allow fish passage. SLEDs and floating orifice gates barriers (FOG's) were installed at all operating main fishway entrances typically by the end of January (late February in 2008). SLEDs were removed in early to mid-June each year. Floating orifice gates (FOGs) were equipped with bars with similar gap sizes as the SLEDs to prevent sea lions from entering the fishway collection channel running below the tailrace deck of PH2. These FOG barriers were installed the last week in January.

Airmar dB Plus II* (Airmar Technology Corporation, Milford, NH) acoustic deterrent devices (ADDs), which emit a 205 decibel sound in the 15 kHz range, were installed at most main fishway entrances by the end of January. These had been left on continuously in 2008 and turned on or off according to a randomized block design test in 2009. They were more or less randomly turned on and off for two to four day periods to look for any change in pinniped presence or behavior in 2010.

* Does not imply endorsement by the U.S. Army Corps of Engineers

Hazing involved a combination of acoustic, visual, and tactile non-lethal deterrents, including boat chasing, above-water pyrotechnics (cracker shells, screamer shells or rockets), rubber bullets, rubber buckshot, and beanbags fired from shotguns. Boat-based crews also used underwater percussive devices known as "seal bombs". Dam-based and boat-based crews coordinated with USACE personnel, including our observers, to ensure safety and to increase the effectiveness of hazing efforts. Dam-based hazing by USDA Wildlife Service agents began on the first week in March and continued seven days per week through the end of May each year.

Boat-based hazing was conducted by personnel from ODFW, WDFW, and CRITFC from the first week in January through mid-May each year. Boats operated from the Bonneville Dam tailrace downstream to Navigation Marker 85 (rkm 224). Boats could not operate within 30 m of dam structures or within 50 m of fishway entrances. The use of "seal bombs" was prohibited within 100 m of fishways, collection channels, or fish outfalls for the PH2 corner collector and smolt monitoring facility, and ceased after adult salmonid passage exceeded 1,000 fish per day. More on boat hazing activities can be seen in Wright et al., 2007, Brown et al., 2008, 2009, and 2010.

Personnel from ODFW and WDFW operated three to four floating sea lion traps (for details see Brown et al., 2008) along the PH2 Cascades Island north shore west end from mid-February through late May and elsewhere briefly (for example, during 2010 one trap was placed in the forebay on two different occasions). In accordance with the Marine Mammal Protecion Act (MMPA) Section 120 authority, animals captured were either selected for transfer to holding facilities or euthanized. CSL that meet four conditions established by the Pinniped/Fisheries Interaction Task Force are placed on the list for removal. The conditions are: 1) the CSL can be individually identified, 2) it has been observed in the Bonneville Dam tailrace on at least five days, 3) it has been observed to take at least one salmonid, and 4) it was present during active hazing conditions. Captured CSL that were unbranded and not on the list for removal were branded. In addition, 11 CSL were fixed with acoustic tags, and released. Twelve SSL were captured, eight given brands and satellite tags, six were given acoustic, and released on-site.

IMPACT OF REMOVAL PROGRAM

We evaluated the impact of selected CSL removal in three ways:

1) Compared the annual salmonid consumption estimates and minimum estimated impact on salmonids of pre- and post-removal years (excluding SSL contributions);
2) Compared estimated total CSL abundance of pre- and post-removal years;
3) Compared the pre-removal predation rates, daily presence, and other metrics of the removed animals with the "Bonneville" CSL population at large to assess the relative contribution of removed animals to salmonid consumption estimates.

Brown et al. (2009, 2010) used both a bioenergetics and a bootstrap method to estimate potential salmonids 'saved' as a result of the removal of selected CSL in 2008 and 2009. We continue to work with ODFW and WDFW to develop the methodology and assumptions for their estimates.

RESULTS AND DISCUSSION

PREDATION ACTIVITY

In 2010 (January 1 through May 31), observers completed 3,609 hours of observations. During this period, observers saw pinnipeds catch and consume 5,446 fish of several species. Adult salmonids were the primary prey item, comprising 71.8% (n=3,910) of observed catches. White sturgeon and Pacific lamprey were the second and third most commonly identified prey types, comprising 19.8% (n=1,100) and 0.7% (n=39) of total observed catch respectively. Observers were unable to identify 5.9% (n=323) of the fish caught and consumed by pinnipeds during this period. In 2009, observers completed 3,455 hours of observation, saw 4,434 fish caught by pinnipeds (2,980 or 67.2% of those being adult salmonids). White sturgeon made up 17.1% (n=758) of the catch, and lamprey comprised 1.4% (n=64) of the catch. In 2008, observers completed 5,131 hours (including weekends) and saw at least 5,621 fish caught (4,243 or 74.6% of those being adult salmonids). White sturgeon made up 10.8% (n=606) of the catch, while lamprey comprised 2.0% (n=111) of the catch. As in previous years, all consumption estimates should be treated as minimum estimates.

One CSL was observed feeding on salmonids at Bonneville Dam between September and November 2009. Since observations were opportunistic and intermittent, expansions were not made for these catches. The individual branded as C805 was seen on at least five days between September 22 and November 5. Observers noted at least one coho salmon (*Oncorhynchus kisutch*) caught by C805 during this period. This was the second year CSL were reported at Bonneville Dam in the fall. C805 was observed in the fall of 2008 and 2009, whereas C265 and C657 were both removed in the spring of 2009 after being seen in the fall of 2008 (Stansell et. al, 2009). C697 was observed many times in the forebay of Bonneville Dam feeding on salmonids throughout his time there (from May 16, 2009 to January 25, 2010) but these catches were not recorded.

Predation on Adult Salmonids

In 2010, the expanded adult salmonid consumption estimate for the Bonneville Dam tailrace observation area was 6,081 or 2.2% of the adult salmonid run at Bonneville Dam from January 1 through May 31. Accounting for unidentified fish, the adjusted estimated consumption was 6,321 (or 2.4% of the run) (Table 1). A progressive series of tables, broken out for CSL and SSL, showing estimated salmonid consumption (extrapolated for hours and days not observed), adjusted salmonid consumption (including unidentified fish caught), adding a 3.5% night-time consumption factor after hazing began (in 2006), and finally adjusting for clepto-parasitism events can be seen in Appendix D. Although the estimated number of adult salmonids consumed has increased each year since 2005 (Figure 3), the estimated percent of the run taken has declined each year since a high of 4.2% in 2007, reflecting an increase in the run size each year since 2007 (Figure 4). CSL were the primary salmonid predator, accounting for 83.8% (n=3,276) of the 3,910 observed catches in 2010 (Table 2). This percentage is lower than was seen in previous years, as observed salmonid catch by SSL increased from 0.3% (n=12) in 2007, 3.8% (n=162) in 2008, and 10.1% (n=300) in 2009 to 16.2% (n=634) in 2010.

Table 1. Consumption of salmonids by CSL, SSL, and harbor seals at Bonneville Dam tailrace, from surface observations conducted between 2002 and 2010. Total salmonid passage counts include all adult salmonids that passed Bonneville Dam from January 1 through May 31.

Year	Bonneville Dam salmonid passage (Jan. 1-May 31)	Expanded salmonid consumption estimate*		Adjusted salmonid consumption estimate*	
		Estimated consumption	% of run (Jan. 1 to May 31)	Estimated consumption	% of run (Jan. 1 to May 31)
2002	284,733	1,010	0.4 %	N/A	N/A
2003	217,185	2,329	1.1 %	N/A	N/A
2004	186,804	3,533	1.9 %	N/A	N/A
2005	82,006	2,920	3.4 %	N/A	N/A
2006	105,063	3,023	2.8 %	3,401	3.1 %
2007	88,474	3,859	4.2 %	4,355	4.7 %
2008	147,543	4,466	2.9 %	4,927	3.2 %
2009	186,060	4,489	2.4 %	4,960	2.7 %
2010	267,194	6,081	2.2 %	6,321	2.4 %

***** *The observed catch is expanded to adjust for missed observation time during daylight hours (mid-day break and weekends). This gives the expanded estimate. The expanded estimate is then adjusted for observations classed as "unknown catch" to give the adjusted estimate.*

Table 2. CSL and SSL predation on adult salmonids at Bonneville Dam, from January 1 through May 31, 2010. (See Table 1 for definition of expanded and adjusted estimates).

Predator	Observed Salmonid Catch	Expanded Salmonid Consumption estimate		Adjusted Salmonid Consumption estimate	
	Observed Catch	Estimated consumption	% of Run (1/1 to 5/31)	Estimated consumption	% of Run (1/1 to 5/31)
CSL	3,276	5,095	1.9 %	5,296	2.0 %
SSL	634	986	0.4 %	1,025	0.4 %

The 2010 spring Chinook salmon run was earlier than the previous six years and much larger (Figure 4). Chinook salmon that arrived early in the run were heavily targeted (proportionally) by sea lions (Figures 5 and 6). Chinook salmon were the most commonly identified prey species, comprising 94.0% (n=3,675) of observed adult salmonid catch in 2010 (89.0% in 2009 and 93.2% in 2008). The expanded Chinook salmon consumption estimate for the Bonneville Dam tailrace in 2010 was 5,757 or 2.0% of the Chinook salmon run (including jacks) at Bonneville Dam from January 1 through June 15, 3,997 or 1.7% in 2009, and 4,115 or 2.3% in 2008 (Table 3). Note that this time period includes the defined Columbia River spring Chinook salmon passage season at Bonneville Dam, which extends beyond the period during which sea lions are normally present. Steelhead comprised about 6.0% (n=235) of observed adult salmonid catch during the same period in 2010 (11.0% in 2009 and 6.8% in 2008). Steelhead, which are present in the Bonneville Dam tailrace throughout the winter and spring months, comprised the majority of salmonid catches prior to the onset of the spring Chinook salmon run. This year and last, SSL were often observed swallowing steelhead whole, suggesting that they could consume steelhead and jack Chinook salmon entirely below the surface. All consumption estimates provided are minimum estimates, but SSL predation may be significantly underestimated by surface observation techniques.

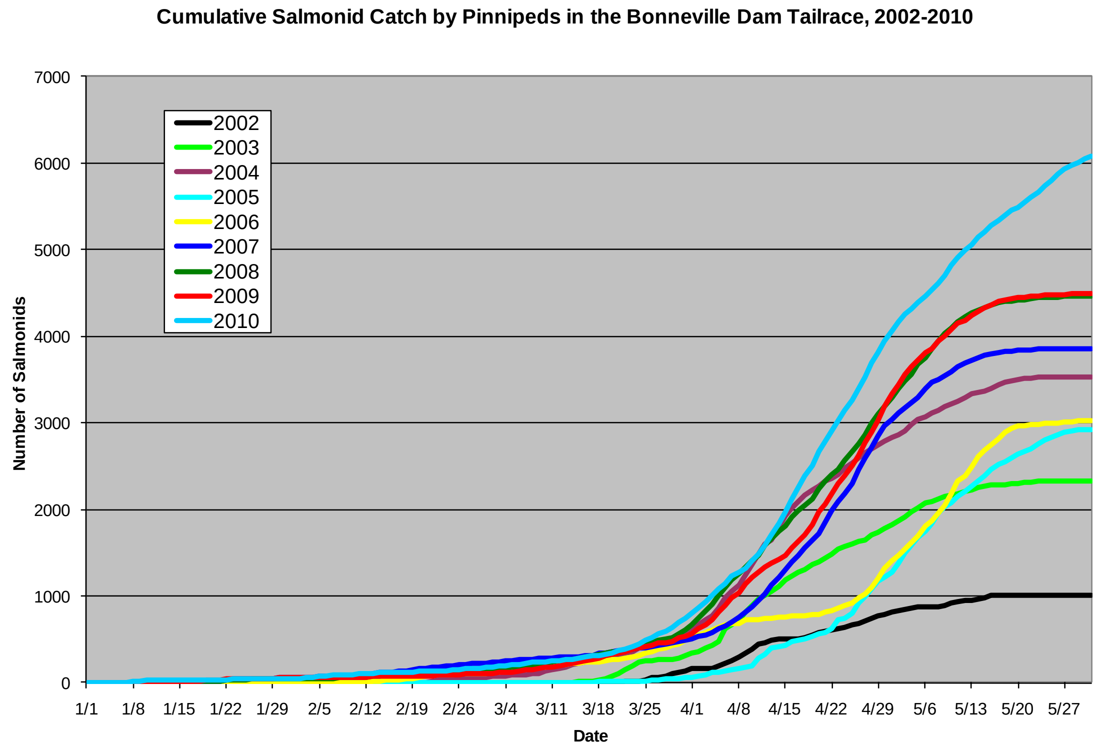


Figure 3. Cumulative salmonid catch by pinnipeds at Bonneville Dam, 2002 to 2010.

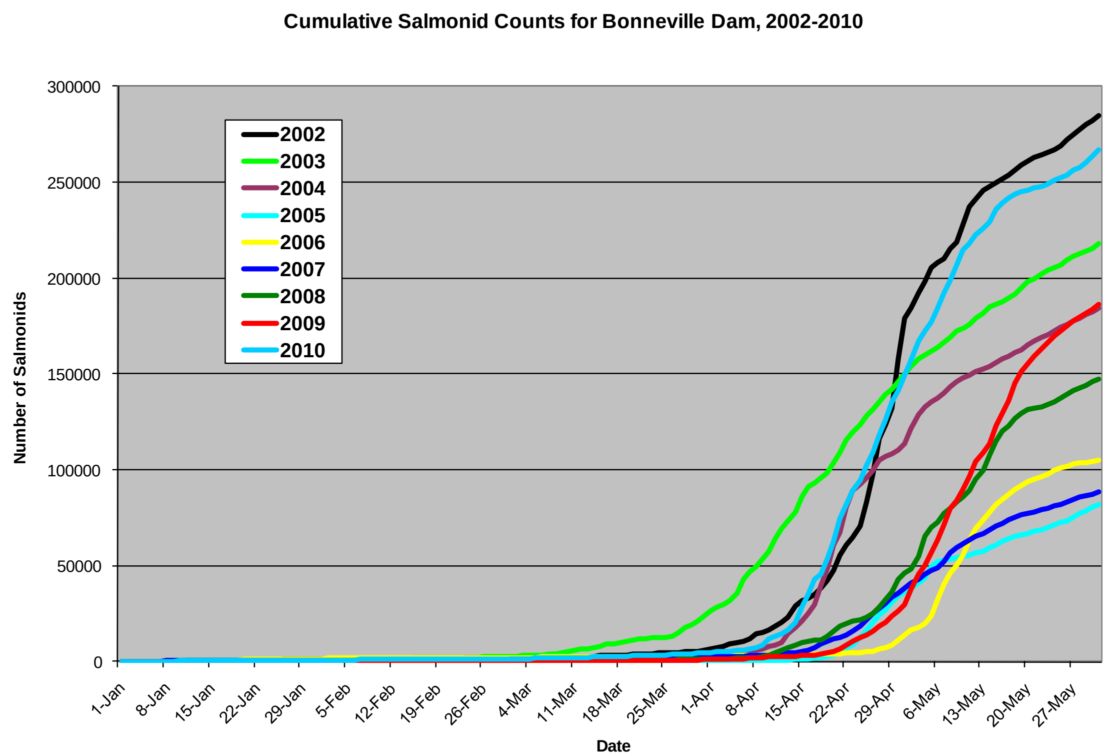


Figure 4. Cumulative daily counts of adult (including jacks) Chinook salmon and steelhead passing Bonneville Dam from January 1 through May 31, 2002 to 2010.

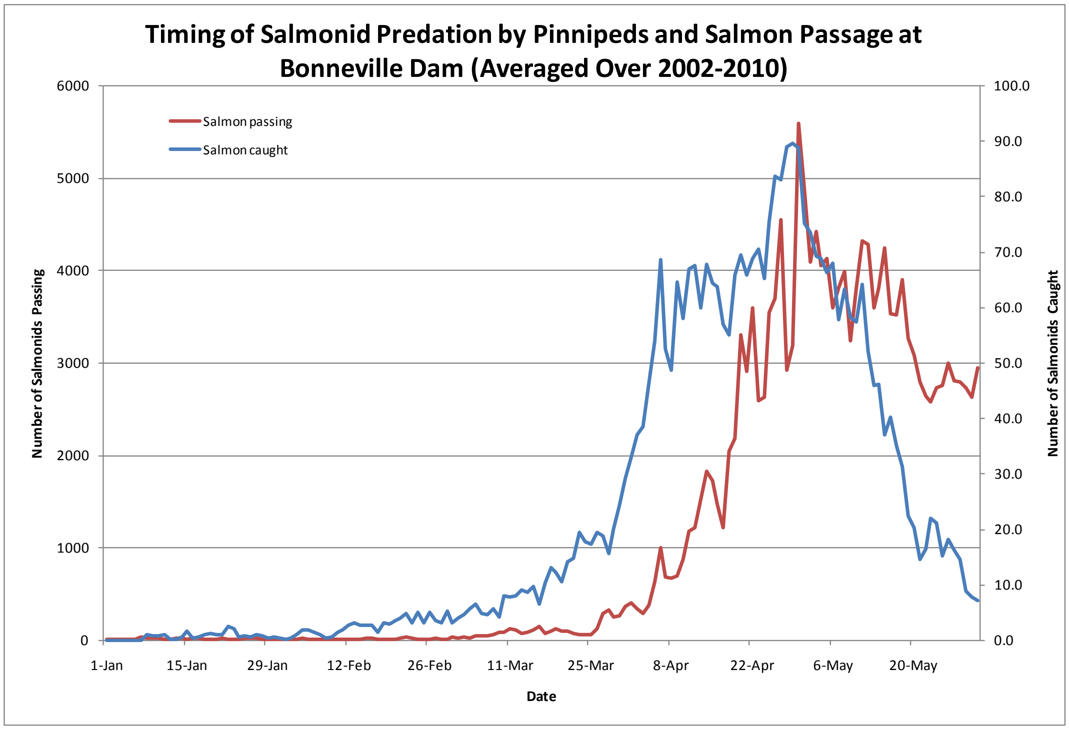


Figure 5. Daily salmonid passage and expanded consumption estimates by pinnipeds at Bonneville Dam, averaged for 2002-2010.

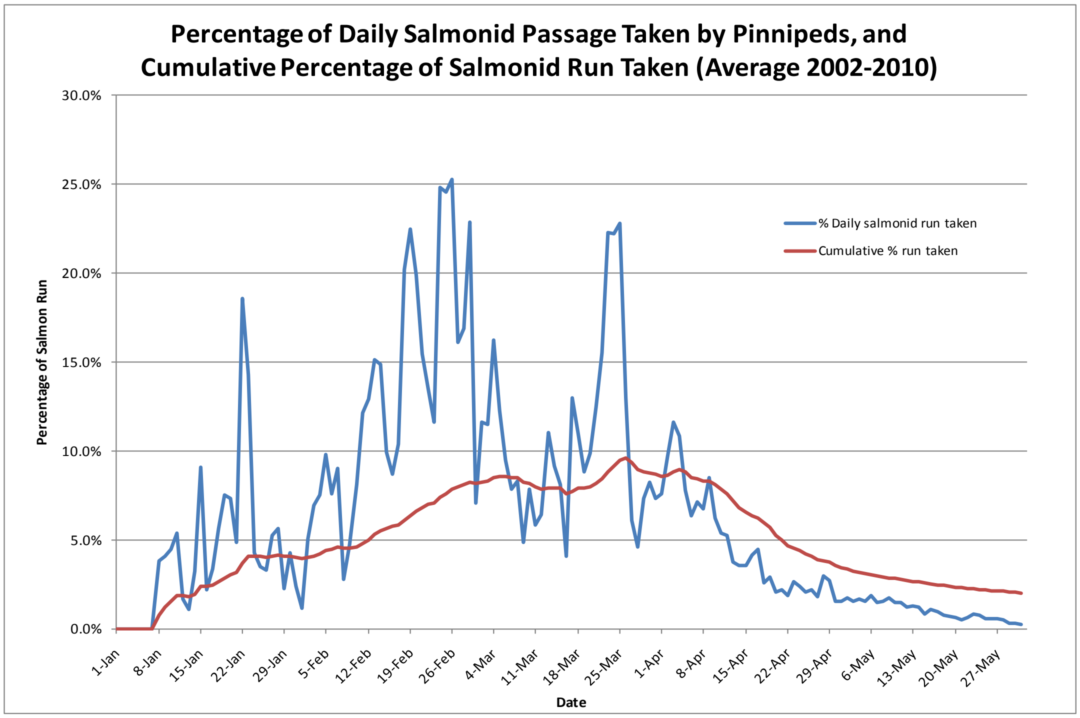


Figure 6. Percentage of daily salmonid passage caught by pinnipeds, and cumulative percentage of salmonid run caught at Bonnevlle Dam tailrace, averaged for 2002-2010.

Table 3. Consumption of Chinook salmon by pinnipeds at Bonneville Dam between 2002 and 2010. Regular observations were not made at the spillway in 2004.

Year	Chinook salmon passage (Jan. 1 – June 15)	Expanded Chinook consumption estimate	Percent of Chinook run (Jan. 1 – June 15)
2002	316,468*	880‡	0.3 %
2003	247,059	2,313	0.9 %
2004	210,569	3,307	1.5 %
2005	102,741	2,742†	2.6 %
2006	130,014	2,580	1.9 %
2007	101,068	3,403	3.3 %
2008	174,247	4,115	2.3 %
2009	229,271	3,997	1.7 %
2010	293,662	5,757	2.0 %

* Fish counts did not start until March 15 in 2002. Chinook passage from January 1 through March 15 was minimal in all other years.

‡ From March 15 through April 25, used fish passage count split between Chinook salmon and steelhead to estimate Chinook proportion of unidentified salmonid catch. Thereafter, used observed catch distribution to divide unidentified salmonid consumption.

† In 2005, regular observations did not start until March 18.

Predation on White Sturgeon

In 2010, the expanded white sturgeon consumption estimate for our study area was 1,879, continuing the upward trend in predation on sturgeon in the Bonneville Dam tailrace (Table 4). When unidentified catch was divided proportionally according to daily catch distributions and added to the expanded sturgeon consumption estimate, the adjusted consumption estimate was 2,172. White sturgeon were the most commonly observed prey for SSL, which made 99.5% (n=1,094) of the 1,100 observed sturgeon catches in 2010. SSL were known to be catching and consuming sturgeon in the vicinity of Bonneville Dam as early as October 2009, so observed and expanded catches represent minimum catch and do not include the predation outside the normal observation period. CSL took less sturgeon this year (6 observed) than the last two years (37 and 9). Predation on sturgeon dropped off dramatically after the first week of April when spring Chinook salmon began to show up and became the preferred prey of both SSL and CSL (Figure 7).

When possible, observers estimated the total lengths of sturgeon caught by pinnipeds. The estimated total lengths of sturgeon caught between 2006 and 2010 ranged from less than 2 ft (0.6 m) to over 7 ft (2.7 m), but 79.9% of sturgeon lengths (n=2,262) were 4 ft (1.2 m) or shorter (Figure 8).

Table 4. Consumption of white sturgeon by pinnipeds at Bonneville Dam from 1 January through 31 May, 2005 to 2010.

Year	Total Hours Observed	Observed Sturgeon Catch	Expanded Sturgeon Consumption estimate	Adjusted Sturgeon Consumption estimate
2005	1,108	1	N/A	N/A
2006	3,647	265	315	413
2007	4,433	360	467	664
2008	5,131	606	792	1,139
2009	3,455	758	1,241	1,710
2010	3,609	1,100	1,879	2,172

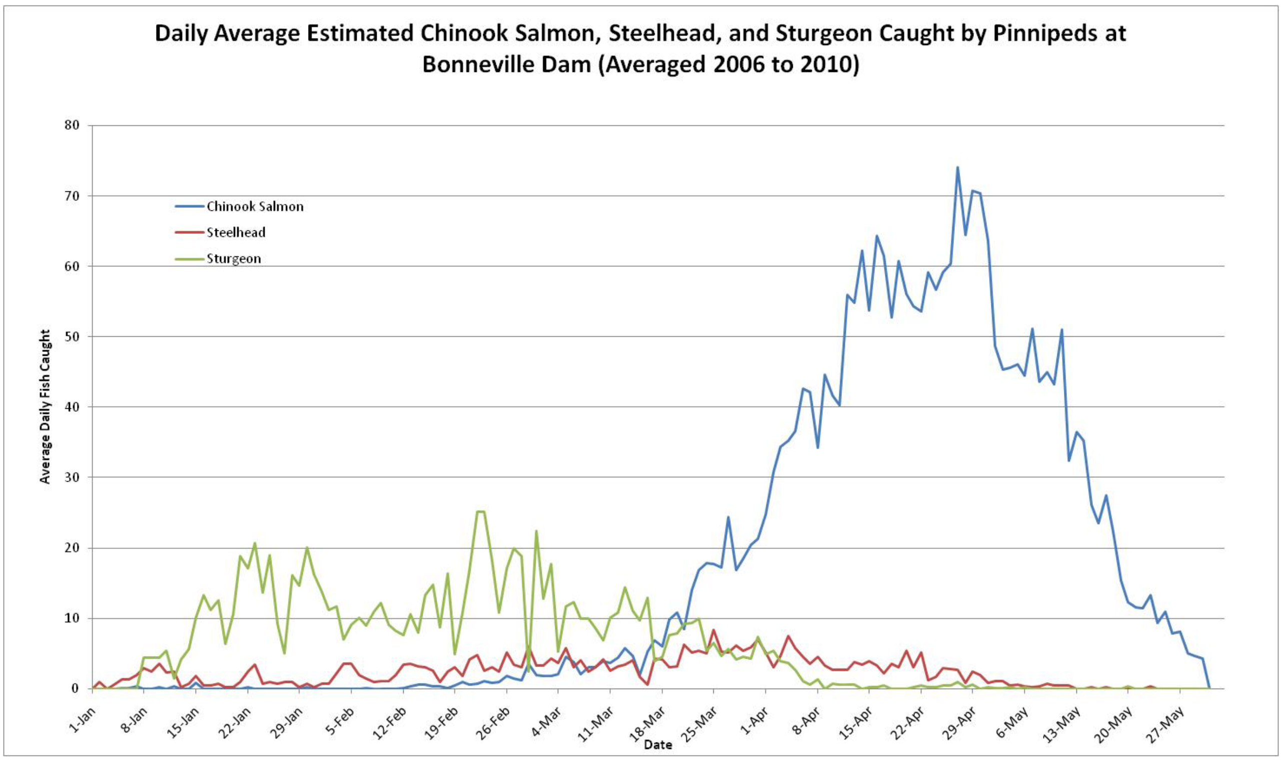


Figure 7. Daily average estimated Chinook salmon, steelhead, and white sturgeon caught by both SSL and CSL at Bonneville Dam from January 1 through May 31, 2006 to 2010.

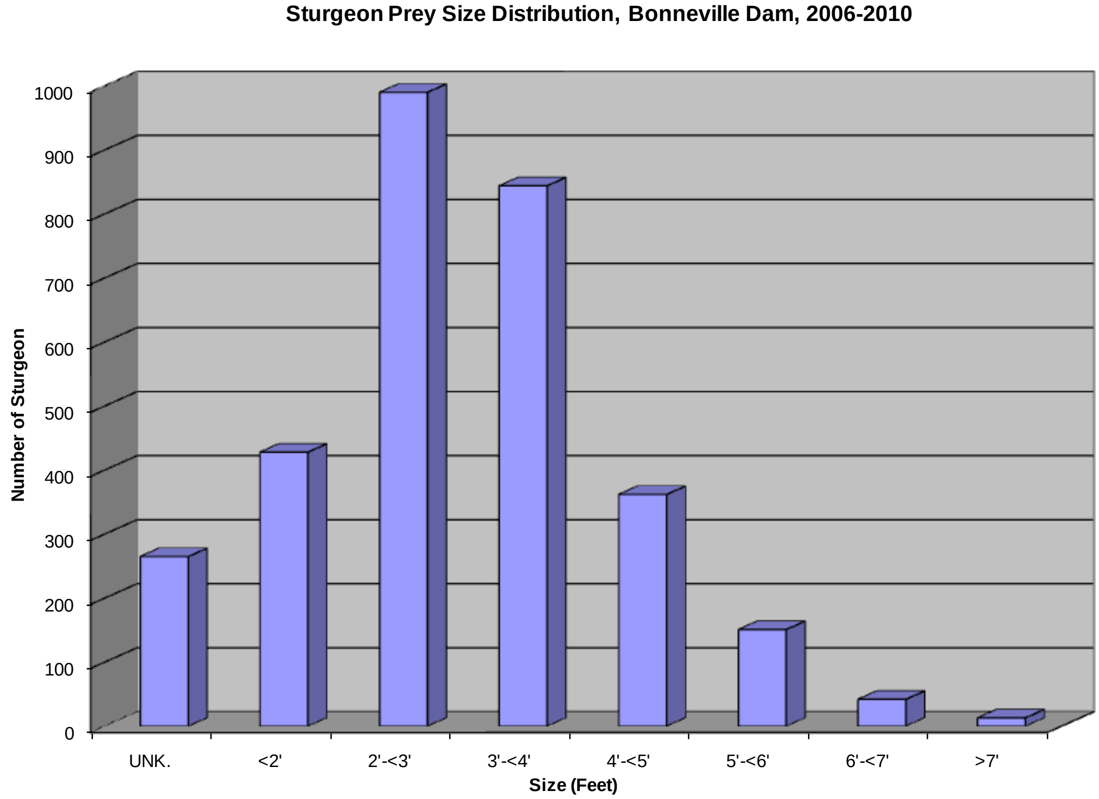


Figure 8. Estimated total lengths of white sturgeon consumed by SSL and CSL at Bonneville Dam, from January 1 through May 31, 2006 to 2010.

Predation on Pacific Lamprey

In 2010, the expanded Pacific lamprey consumption estimate was 77, fewer than the estimated 143, 145, and 102 caught in 2007, 2008, and 2009, respectively (Table 5). Lamprey were once again the second most commonly observed prey caught by CSL, which made 37 of the 39 observed lamprey catches in the Bonneville Dam observation area. However, lamprey catch comprised the lowest proportion of total observed catch (0.7%) since 2002. Due to the small body size, and presumed vulnerability of lamprey to predation, our surface observation approach may significantly underestimate actual predation impacts on lamprey.

Location of Predation Events

Figures in Appendix A confirm what we have suspected for years, that CSL seem to be taking salmonids primarily near the dam (Appendix Figure A-1), somewhat favoring one or both main fishway entrance areas along the corners of the shorelines. SSL predation on Chinook salmon occurs more mid-tailrace (Appendix Figure A-2) and for sturgeon mid-tailrace and farther downstream (Appendix Figure A-3). This indicates we are likely underestimating sturgeon take, as many of those activities are occurring at the extreme edge of our viewing area. Smaller sturgeon consumed in zone 7 of PH2 could likely be consumed unseen (typically sturgeon less than 4 feet were completely consumed in 1-5 minutes), whereas larger sturgeon can be seen being consumed as the SSL drift downstream into zone 7 of the spillway tailrace (we have noted larger sturgeon being fed upon by multiple individuals for as long as an hour or more). As always, this is simply the location the predator is first seen with the fish, and it is entirely possible the fish was caught farther upstream and dragged downstream underwater into other zones before being seen.

Predation on salmonids primarily occurred in the PH2 tailrace before 2006, but has alternated between PH1 and PH2 since 2006, likely due to hazing activities (Table 6). Sturgeon were primarily observed being consumed at the spillway from 2006-2008, however, more have been seen taken at PH2 the past two years.

Table 5. Consumption of Pacific lamprey by pinnipeds at Bonneville Dam from January 1 through May 31, 2002 to 2010.

Year	Total Hours Observed	Observed Pacific Lamprey Catch	Expanded Pacific Lamprey Consumption estimate	Percent of Total Observed Fish Catch
2002	662	34	47	5.6%
2003	1,356	283	317	11.3%
2004	553	120	816	12.8%
2005	1,108	613	810	25.1%
2006	3,647	374	424	9.8%
2007	4,433	119	143	2.6%
2008	5,131	111	145	2.0%
2009	3,455	64	102	1.4%
2010	3,609	39	77	0.7%

Table 6. Percentage of predation of salmonids and sturgeon for each tailrace location.

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010
					Salmon				
PH2	55.0%	57.4%	55.0%	43.4%	34.7%	26.4%	37.7%	32.4%	47.8%
PH1	30.5%	34.9%	39.2%	32.6%	56.7%	40.6%	34.9%	51.6%	26.3%
Spillway	14.5%	7.7%	5.8%	24.1%	8.6%	33.0%	27.4%	16.0%	25.9%
					Sturgeon				
PH2	0.0%	0.0%	0.0%	0.0%	14.4%	29.7%	33.5%	44.8%	56.1%
PH1	0.0%	0.0%	0.0%	100.0%	7.2%	5.3%	2.8%	20.3%	13.1%
Spillway	0.0%	0.0%	0.0%	0.0%	78.4%	65.0%	63.7%	34.9%	30.8%

Night Observations

No night time observations were made in 2010. Data for previous years (Stansell, et al., 2009) suggest an additional 3.5% of predation events could occur after dark during the season, but this generally would amount to only a couple hundred additional salmonids taken, increasing the percentage of the run taken by 0.1% at most.

PINNIPED ABUNDANCE, RESIDENCE TIMES, AND RECURRENCE

At 166 animals, the estimated number of individual pinnipeds observed at Bonneville Dam in 2010 was the highest since observations began in 2002 (Table 7). SSL numbers jumped upward in 2010 to 75 after dropping to 26 in 2009. The 53 SSL observed on one day in 2010 was more than double that seen in any previous year. CSL numbers also jumped upward in 2010 to 89 after dropping to 54 in 2009. Over the past two years, unusually large numbers of CSL have moved north of California after the summer breeding season. In 2009 this was likely the result of a significant warm water event related to El Nino that caused many CSL to move northward in search of cooler waters and abundant prey. In 2009 and 2010, increasing numbers of young, sub-adult sea lions have been observed at many locations in Oregon and Washington (Robin Brown, ODFW, Steve Jeffries, WDFW, pers. comm.). The increase in CSL abundance at Bonneville Dam in 2010, many which were not seen at the dam before, could be the result of this large group of young males exploring new areas, such as the Columbia River, to prey on fish. As in previous years, hazing activity typically resulted in changes in behavior (more time below the water surface, less time with backs and unique markings exposed, etc) that made identification of individuals challenging. These abundance figures should be considered minimum estimates. Also, it should be noted that the numbers presented for SSL now are comparable with those for CSL as we identified as many individuals as possible (going back through video tapes and photos) rather than previously just mentioning the highest number of SSL seen at any one time. SSL had not been a priority in the past, but with rising numbers, rising sturgeon take, and rising take and clepto-parasitism of salmon taken from CSL we are now making the same effort to identify individual SSL as we have with CSL. It is more difficult to identify individual SSL primarily because they tend to prey on sturgeon farther from the face of the dam, as opposed to CSL taking salmon near the fishways and our observers.

Table 7. Minimum estimated total number of individual pinnipeds observed at Bonneville Dam from 2002 to 2010.

	CSL	SSL	Harbor seals	Total pinnipeds
2002	30	0	1	31
2003	104	3	2	109
2004	99	3	2	104
2005*	81	4	1	86
2006	72	11	3	86
2007	71	9	2	82
2008	82	39	2	123
2009	54	26	2	82
2010	89	75	2	166

* Regular observations did not begin until March 18 in 2005.

Daily pinniped abundance peaked in April 2010 (Figure 9), primarily due to SSL numbers. The highest number of pinnipeds counted on any one day in 2010 was 69 (April 19), which was the highest seen since the program began in 2002 (Figure 10). This follows 2009 in which we saw the first reduction in peak numbers since we began monitoring. Mean daily number of pinnipeds present was 21.5 in 2010, slightly higher than the last two years and much higher than other previous years (Figure 10). The CSL component shows far fewer animals present daily on average than we have seen since 2004 and the maximum seen on any one day (26) was the same as last year and fewer than any other year since 2002 (Figure 11). However, the SSL were present in greater numbers in 2010 than previous years and averaged 12.6 per day (Figure 12).

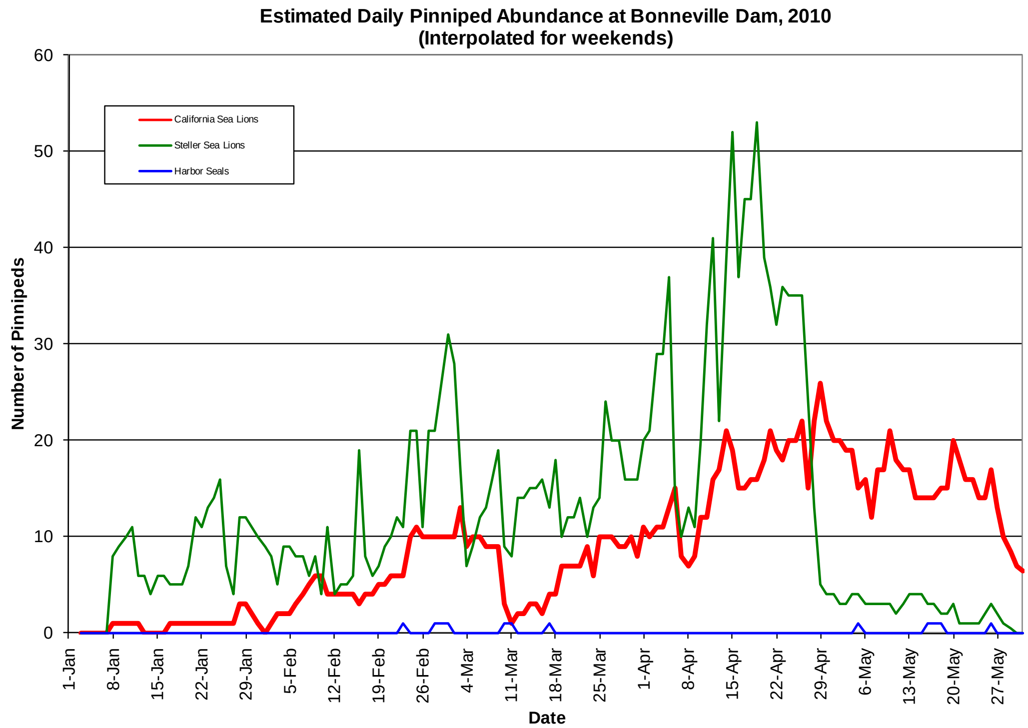


Figure 9. Daily abundance estimates for CSL, SSL, and harbor seals at Bonneville Dam from January 1 through May 31, 2010.

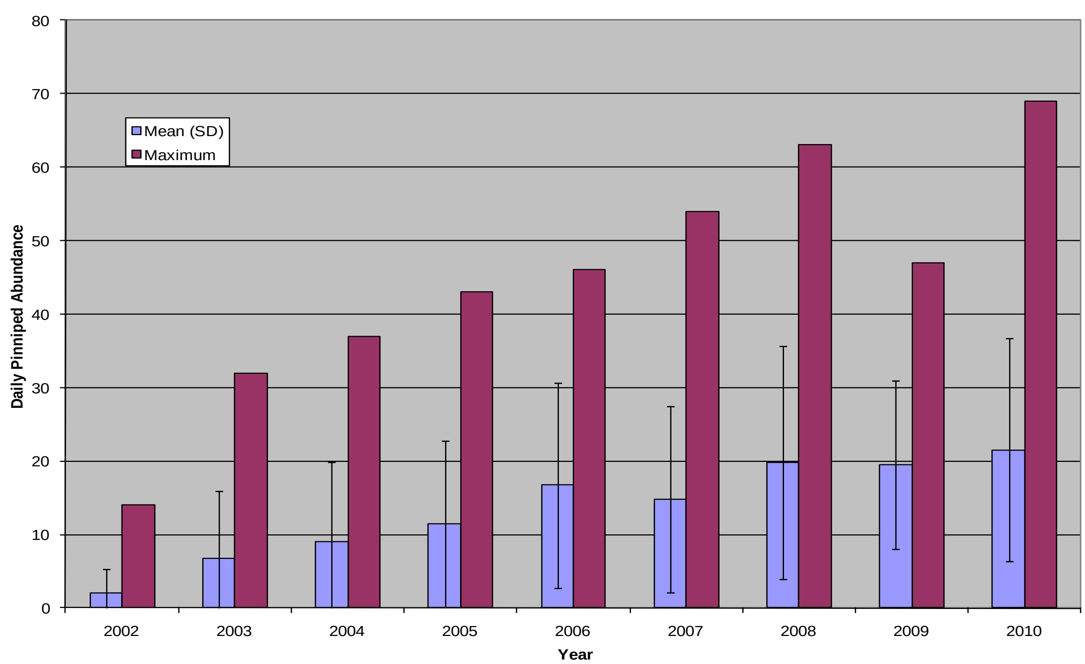


Figure 10. Mean, standard deviation, and maximum daily estimated number of pinnipeds present at Bonneville Dam between January 1 and May 31, 2002 to 2010.

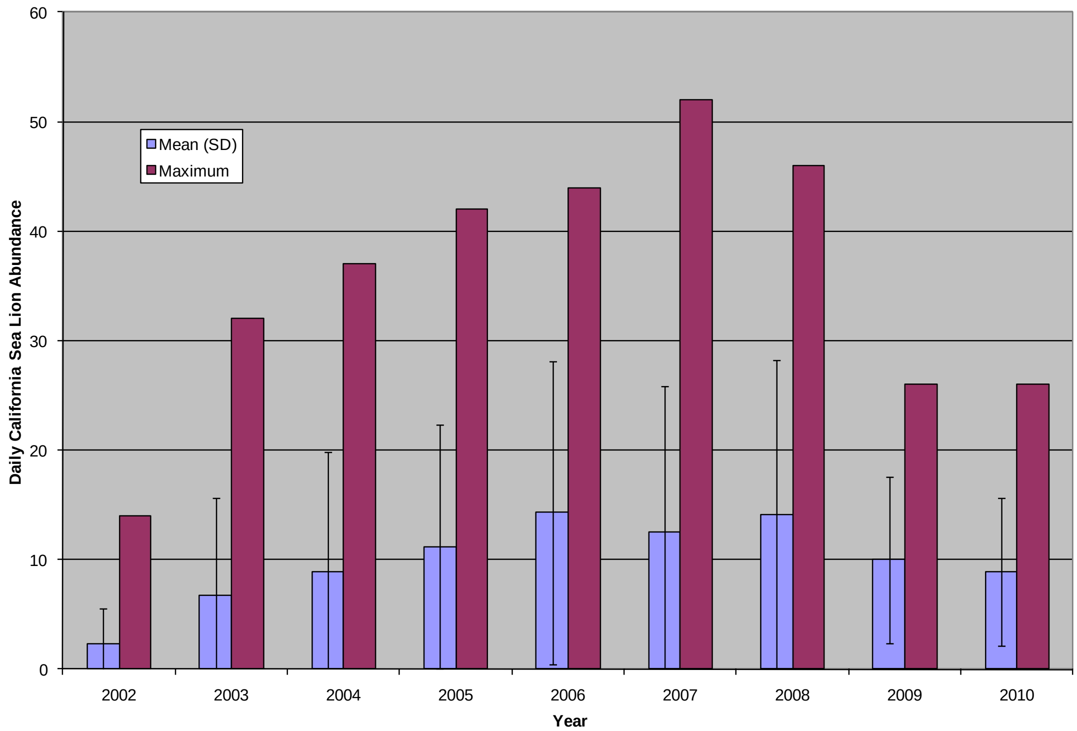


Figure 11. Mean (and standard deviation) and maximum daily estimated number of CSL present at Bonneville Dam between January 1 and May 31, 2002 to 2010.

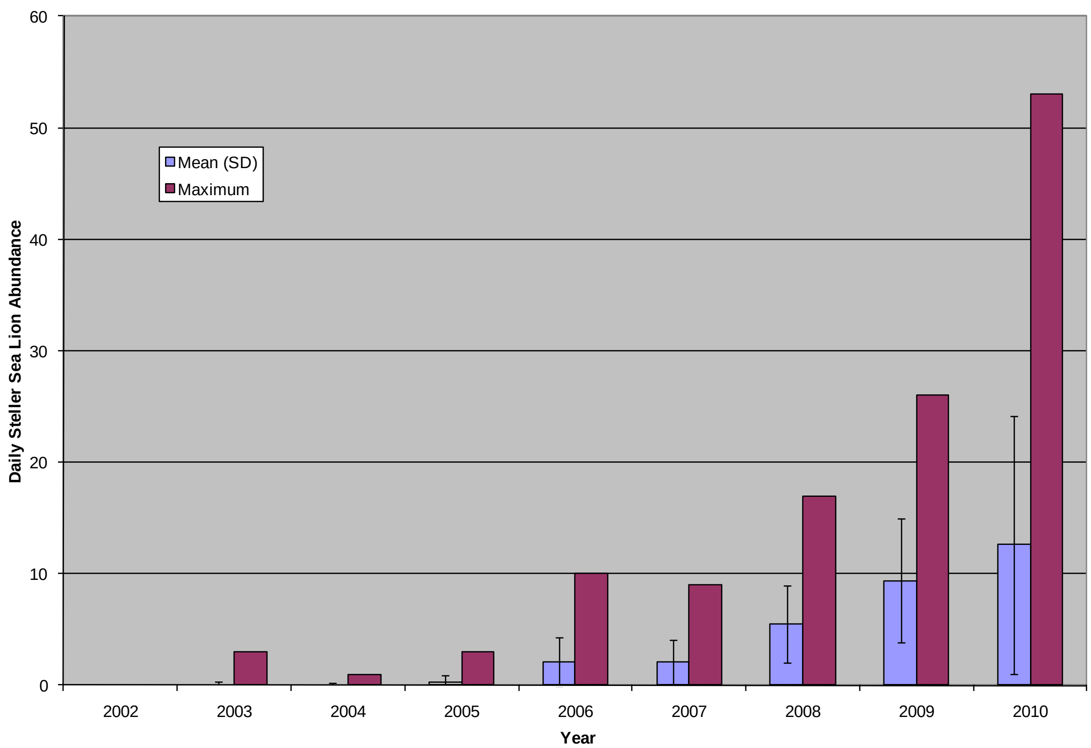


Figure 12. Mean, standard deviation, and maximum daily estimated number of SSL present at Bonneville Dam between January 1 and May 31, 2002 to 2010.

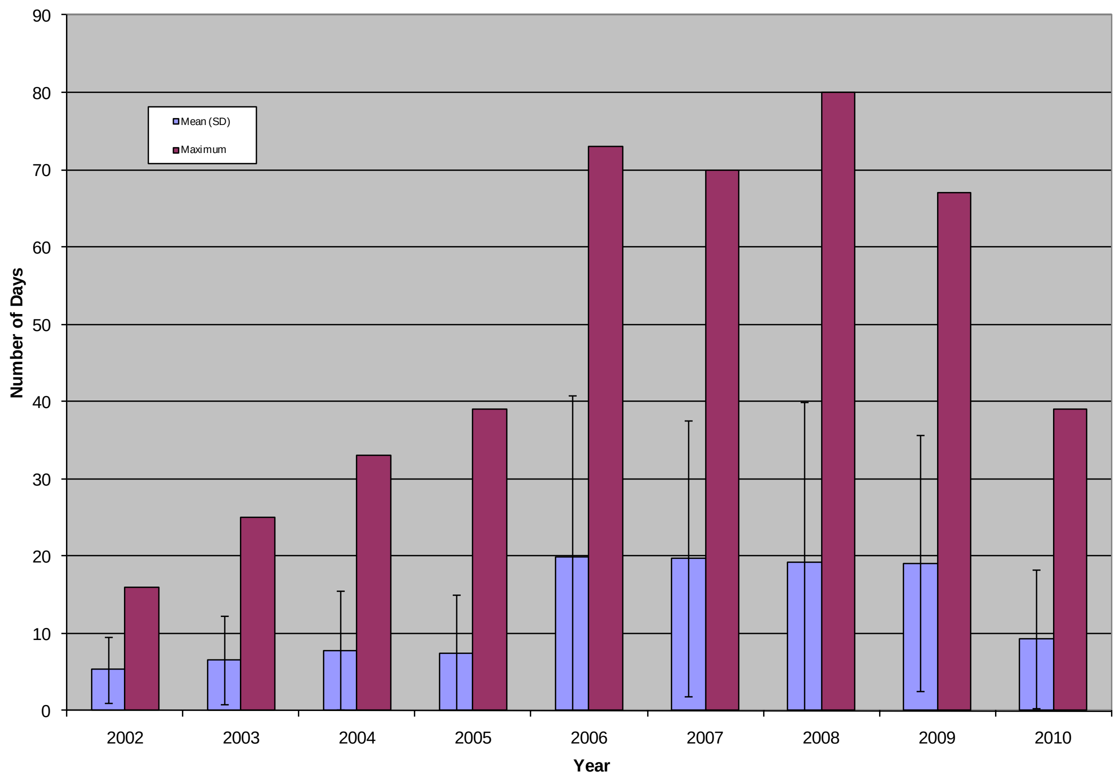


Figure 13. Mean, standard deviation),and maximum number of days individually identified CSL were observed at Bonneville Dam between January 1 and May 31, 2002 to 2010.

The most number of days an individual CSL was observed at Bonneville Dam was 39 days in 2010, much fewer than any of the previous four years (Figure 13). This could be due to the many new individuals seen staying only for a short period of time, unlike most of the returning older individuals, which have learned where the best haul out locations are and have become comfortable staying at the dam for longer periods. Many of the returning older individuals have been removed over the past three years. However, individuals spent less time at Bonneville Dam this year which may also be due to the concrete blocks placed on the favorite haul out for pinnipeds along the PH2 tailrace Cascades Island west end shoreline, forcing the animals to either haul out on rip-rap, traps, rest in the water, or go back to Astoria or some other location to get out of the water.

CSL not previously identified continue to show up each year. Of the 78 highly identifiable animals observed in 2010, 51 (65.4%) were new additions to that category (including 14 branded and 8 more given brands while at Bonneville). The percentage of CSL returning each year was at least 19.2%, 51.2%, 77.1%, 62.3%, 65.6%, 66.2%, 69.8%, and 34.6% for 2003 through 2010, respectively. This year had the fewest returning individuals since 2003. We have observed at least 128 individual CSL that have returned for one or more years to Bonneville Dam (Table 8).

Individual SSL are more difficult to identify to individual than CSL, mostly because they generally stay farther away from the dams than CSL. However, we have been able to confirm that at least 25 individual SSL have returned for one or more years (12 for a second year, nine for three years, three for four years, and one for six years).

Table 8. Number of years that individually identified CSL were present at Bonneville Dam between 2002 and 2010 and the number that have been removed. Individuals present for less than one year (<1) were animals identified in 2010.

Number of years present	All identified CSL	Removal list CSL	Removed CSL
8	5	5	3
7	4	4	2
6	2	2	0
5	17	17	7
4	18	14	4
3	34	17	7
2	48	23	8
1	226	11	4
<1	65	24	3

DETERRENTS AND MANAGEMENT ACTIVITIES

Physical Barriers

In 2010, SLEDs and FOGs were installed at all operating main fishway entrances by January 29. The PH1 and "B" branch entrances were not installed until after January 29 as this fishway was out of service for maintanence until March. There were no sea lions observed inside the fishways, nor did any observers note any sea lions attempting to get through the SLEDs or FOG barriers in 2010 despite significant predation activity near dam structures. C265 was observed entering the PH2 fishway entrances on January 14, 2009. In response, the project crane crew installed the SLEDs on January 15, about 2 weeks earlier than normally required. SLEDs were installed at PH1 on January 30. On January 31 it was reported that there was a sea lion inside the fishway at PH1. C635, who had been observed present in the tailrace days earlier, had apparently entered the fishway before the SLEDs were placed and became trapped. The project crane crew was called in on the weekend to raise the SLED at the downstream-most entrance. C635 was then hazed with cracker shells to move him downstream toward the open fishway entrance and out into the tailrace. The SLED was replaced, and C635 was subsequently observed swimming in the tailrace. Otherwise, there were no sea lions observed inside the fishways, nor did any observers note any sea lions attempting to get through the SLEDs or FOG barriers in either 2009 or 2008, despite significant predation activity near dam structures.

ODFW and WDFW deployed hundreds of concrete pier blocks along the PH2 tailrace Cascades Island west end shoreline concrete apron in 2010 (where the pinnipeds prefer to haul out) in an attempt to prevent the pinnipeds from hauling out and getting comfortable staying near the dam. A secondary goal was that this would make the floating traps more inviting as haul-out sites and therefore increase the likelihood of trapping. The result was that virtually no pinnipeds hauled out on the concrete apron in 2010, preferring instead to haul out on the rip-rap below the concrete or rest in pods near the shoreline, sometimes half in, half out of the water. At other times they would simply float in rafts near the traps. For the first few months, many pinnipeds did use the floating traps, however, these were mostly SSL which would fill up the trap and block access for most of the CSL.

Acoustic Deterrent Devices and Test for Impacts to Salmonids

ADDs were again installed at most fishway entrances in 2010. In response to recommendations by the International Marine Animal Trainers' Association (IMATA) group, we occasionally turned the acoustics off to see if pinnipeds were simply getting habituated to constant averse noise, and might react by staying away when the acoustics were turned on. As in all previous years, pinnipeds were observed swimming and eating fish within 20 ft of some of the ADDs, with no obvious deterrent effect observed whether the acoustics were on or off. This work was not rigorous (as some of the ADDs malfunctioned at times and on vs. off dates were not always recorded). In 2009, a Didson camera was used to examine possible impacts to salmonid fish passage. Using a block design test with the ADDs on or off, we found no indication of an adverse effect on fish behavior (Stansell, et al., 2009). ADDs were operated continuously in 2008.

Non-Lethal Harassment

ODFW, WDFW, and CRITFC hazed from boats five days a week most weeks between January and May, and their results will be presented in a separate report. USDA agents hazed from the dam on 92 days between March 1 and May 31. Table 9 shows the actual near dam hazing level for boat and dam-based hazing (data excludes weekends and boat hazing downstream of the BRZ as our observers were not present to record this information). Of this time, active daytime hazing (as opposed to the boat or dam hazer just being present at the site) occurred 41.4% of the time for boat hazing and 77.8% for dam hazing. These values are lower than those reported in 2008 (Tackley et al., 2008) and 2009 (Stansell et al., 2009), as boat hazing crews became more actively involved in trapping activities in 2009 and 2010, and later in the season the dam hazing crew combined pinniped and avian hazing activities and cut back to one 8-hr shift per day.

For all years, hazing activity temporarily moved some sea lions out of tailrace areas, but the animals typically returned and resumed foraging shortly after hazer's left the area. This can be shown by the slight shift in the diurnal predation activities before (2002-2005) and after (2006-2010) large scale active hazing occurred (Figure 14). A slight shift to more predation occurring in the first and last hour of light during the day can be seen, which corresponds to hazing activities start and end times. The high adult salmonid and sturgeon consumption estimates seen in 2010 suggest that, at best, hazing at the current level of intensity only slows the increase of predation.

Trapping and Removal

In 2008, personnel from ODFW and WDFW operated four traps along the PH2 tailrace Cascades Island west end shoreline in mid-March through May 4 (Appendix C). In 2009, two to three sea lion traps were deployed along the PH2 tailrace Cascades Island west end shoreline from February 2 through May 15 and one trap briefly in the old navigation lock entrance. In 2010, four floating sea lion traps were deployed along the PH2 tailrace Cascades Island west end shoreline from February 12 through May 19, 2010 and other locations afterwards (one trap briefly in the forebay on two different occasions).

Table 9. Total hours of hazing activity in the Bonneville Dam tailrace observation area in 2008 to 2010. Data excludes weekends for 2009 and 2010 as observers were not present.

.

2010

Location	Number of Hours Hazers were Present at Least Once in Hour		Actual Total Time (Hours) Hazers were Present	
	Boat hazing	*Dam hazing*	*Boat hazing*	*Dam hazing*
Powerhouse 1	218	190	32.2	79.3
Powerhouse 2	195	363	38.7	148.6
Spillway	145	333	16.6	80.8
Total	*558*	*886*	*87.5*	*308.7*

2009

Location	Number of Hours Hazers were Present at Least Once in Hour		Actual Total Time (Hours) Hazers were Present	
	Boat hazing	*Dam hazing*	*Boat hazing*	*Dam hazing*
Powerhouse 1	239	178	63.7	60.0
Powerhouse 2	191	209	41.7	62.5
Spillway	151	68	25.3	16.2
Total	*581*	*455*	*130.7*	*136.7*

2008

Location	Number of Hours Hazers were Present at Least Once in Hour		Actual Total Time (Hours) Hazers were Present	
	Boat hazing	*Dam hazing*	*Boat hazing*	*Dam hazing*
Powerhouse 1	280	527	78.3	230.8
Powerhouse 2	191	202	36.8	106.4
Spillway	200	53	50.5	4.1
Other	17	0	5.8	0
Total	*688*	*782*	*171.5*	*341.3*

In accordance with the Marine Mammal Protection Act (MMPA) Section 120 authority, captured animals on the list for removal were either selected for transfer to holding facilities or euthanized. Captured CSL that were not on the removal list were given brands (if not already branded), and some were given an acoustic tag and/or satellite tag, and released (either near Astoria or on site at Bonneville). Any SSL captured were released (2008 and 2009) or given brands, and acoustic and/or satellite tag, and released on-site (2010).

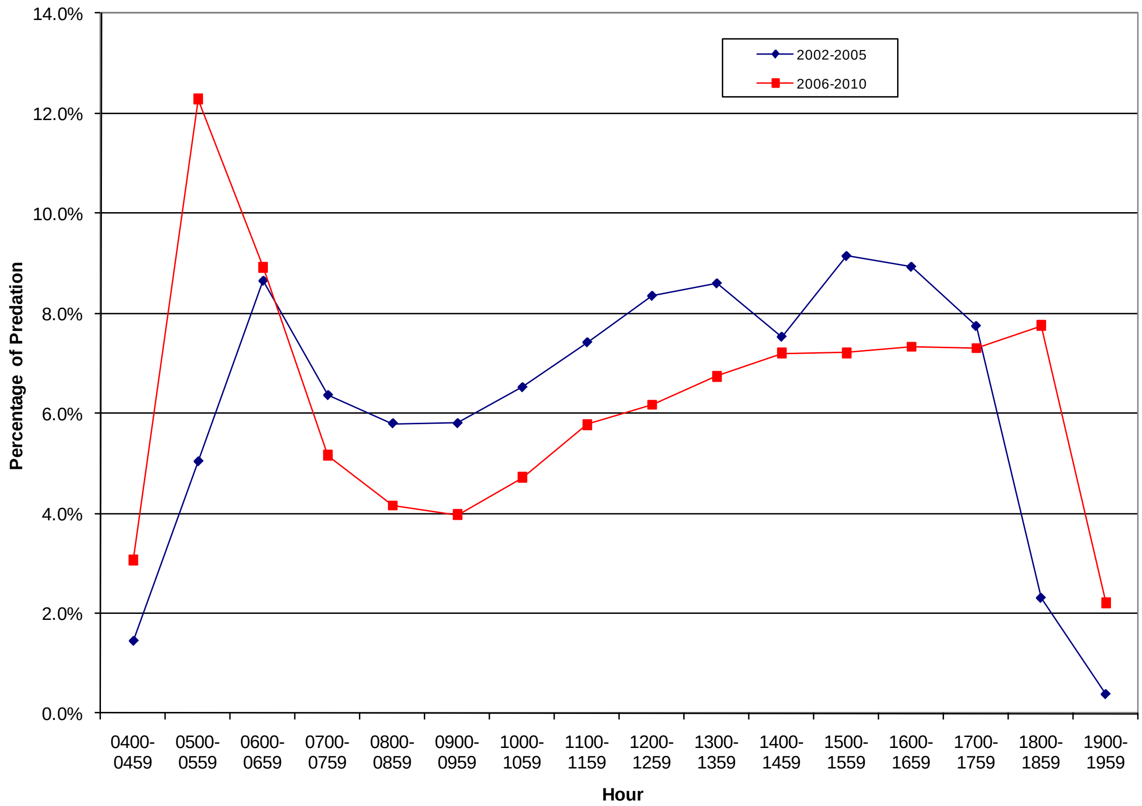


Figure 14. Diurnal distribution of predation events at Bonneville Dam before (2002 to 2005) and after (2006 to 2010) large-scale sea lion harassment efforts began.

Successful trapping events are summarized in Appendix C. In 2008, 15 CSL were trapped. Of those, four were without brands, so they were given brands and released (one, C805/B208 was on the list but positive identification on the trap was not possible, so the animal was branded C805 and released and later confirmed to have been B208). Six were on the list for removal and relocated to Sea World facilities. One additional animal was on the list but died under anesthetic while undergoing a health exam. This individual, B198, is the heaviest known CSL ever weighed (1,454 lbs, Brown et al., 2008). On May 4, 2008, the doors to the traps had become closed, trapping four CSL and two SSL, all of which died from heat exhaustion before they could be released. Of those CSL, one had been on the list for removal and one had qualified for the removal but had not yet been put on the list.

In 2009, 20 different CSL were captured (two were captured twice, and one SSL was trapped but immediately released). Of those 20, five were given brands and acoustic tags, and one was already branded but given an acoustic tag. Four were on the list for removal and relocated two to Gladys Porter Zoo and two to Shedd Aquarium. The remaining 10 were on the list for removal and were euthanized after the preliminary health screening showed them to have conditions that made them undesirable for zoos or aquariums where they might have spread their diseases to other animals.

In 2010, a total of 22 different CSL were captured (two were captured twice, one was captured three times). Of those 22, four were given brands and acoustic and/or satellite tags (C00-C03), five were branded only (C04-C08), one was already branded but given an acoustic tag. All of these were released. Fourteen were on the list for removal (including two of the above mentioned) and were euthanized as no zoo/aquarium facilities offered to take the animals. Acoustic tracking data will be presented by ODFW and CRITFC in a separate report (Brown et al., 2010).

Eight SSL were trapped in 2010, branded (O001-O008), and given acoustic and/or satellite tags. Most were seen multiple days at Bonneville after release.

Impact of the Removal of Selected California Sea Lions

In 2008, essentially 11 CSL were removed from the population of "Bonneville" animals, 15 were removed in 2009, and 12 were removed in 2010 (Appendix C). An additional two CSL were removed in September 2010, but this was too late to be included in this analysis. As mentioned in the Methods section, the impact of the removal of these animals had on salmonid predation were summarized using three metrics: 1) Estimated total annual salmonid predation, 2) CSL abundance, 3) Salmonid consumption and days present for removed individuals over the years.

Estimated total annual salmonid consumption estimate

The 2010 salmonid consumption estimate was higher than in any other year (Table 1), while the estimated percentage of the run consumed was the fourth lowest and has now decreased for three years in a row (2010 saw the second largest spring Chinook run size since 2002.) The salmonid consumption estimate for CSL in 2010 was the highest seen, while the SSL consumption estimate more than doubled from last year (Table 10) The estimated average number of salmonids consumed per CSL decreased in 2010 from 2009, but was otherwise the second highest since 2002 (Table 10). A closer examination of individually identified CSL that were seen to take salmon since 2002 also shows the highest maximum number of salmonids caught for an individual sea lion this year compared to previous years (Table 11).

Table 10. Consumption of adult (including jacks) salmonids by CSL and SSL at Bonneville Dam from January 1 through May 31, 2002 to 2010.

	California sea lions			Steller's sea lions		
Year	Expanded salmonid consumption	Salmonid consumption per capita	% of run (Jan 1 – May 31)	Estimated salmonid consumption	Salmonid consumption per capita	% of run (Jan 1 – May 31)
2002	1,010	33.7	0.4%	0	0.0	0.0 %
2003	2,329	22.4	1.1%	0	0.0	0.0 %
2004	3,516	35.1	1.9%	13	4.3	0.0 %
2005	2,904	35.9	3.4%	16	4.0	0.0 %
2006	2,944	40.9	2.7%	76	6.9	0.1 %
2007	3,846	54.2	4.2%	13	1.4	0.0 %
2008	4,294	52.4	2.8%	176	4.5	0.1 %
2009	4,014	74.3	2.1%	475	18.3	0.3 %
2010	5,095	57.2	1.9%	986	13.1	0.4 %

Table 11. Maximum number of salmonids observed consumed by identified CSL at Bonneville Dam from January 1 through May 31, 2002 to 2010.

Year	Maximum number of salmonids caught by an individual CSL	Percentage of salmonid catches attributed to individual CSLs
2002	51	58.6%
2003	52	67.7%
2004	35	54.3%
2005*	11*	8.9%*
2006	79	43.0%
2007	64	28.1%
2008	107	42.6%
2009	157	62.1%
2010	198	51.9%

* Began observation season late and did not have opportunity to train new observers on individual CSL identification.

California and Steller's sea lion abundance

The number of CSL identified in 2010 (89 including the 12 removed this year) was the highest since 2004 (Table 6). This appears to conflict with the mean (8.9) and maximum (26) number of CSL present per day (Table 12 and Figure 11). However, this is likely due to the large number of new, younger CSL exploring Bonneville Dam for a short time before leaving, unlike the older, more familiar CSL that come early and stay for many days at a time (many of which have now been removed). We have no reason to believe the increase in individuals is related to observation times or hazing levels between the years, as these have been relatively constant. The increase in the number of SSL observed in 2010 (75) is alarming (Table 12 and Figure 12), as they are becoming a growing presence at Bonneville Dam, much like the CSL before them. Whether these exploring CSL will return next year, and whether the SSL numbers will also continue to climb is a question we can only answer after next year's observations.

Table 12. Mean and maximum daily number of CSL and SSL observed at Bonneville Dam, from January 1 through May 31, 2002 to 2010. Linear interpolation was used to estimate the number of animals present on days for which observations were not recorded.

Year	California sea lions		Steller's sea lions	
	Mean daily count	Maximum daily count	Mean daily count	Maximum daily count
2002	2.3	14	0.0	0
2003	6.7	32	0.0	3
2004	8.9	47	0.0	1
2005	11.2	42	0.3	3
2006	14.3	44	2.1	10
2007	12.5	52	2.1	9
2008	14.1	46	5.5	17
2009	10.0	26	9.4	26
2010	8.9	26	12.6	53

Salmonid consumption and days present for removed individuals over the years

The removal of 40 CSL (including 3 that died on a trap in 2008 but were not on the list for removal) between 2008 and 2010 failed to reduce the overall salmonid consumption estimate. However, those same 40 CSL account for only about 9.5 % (40 of 420) of the sea lions identified over the years, yet they accounted for 36.5% (3,388 of 9,275) of all the salmonid catch events attributed to specific individuals (and 42% of those individuals on the removal list). These 40 individuals were present more days and consumed more salmonids per capita each year when compared to the rest of the CSL identified (Table 13). This indicates that the removal program has indeed targeted those animals most likely to stay for a long time and consume many salmonids. Consumption estimates and presence metrics for 2008, 2009, and 2010 undoubtedly would have been higher if these select sea lions had they not been removed. CSL that may be removed in 2011 that were observed in 2010 will alter the current figures for 2010. Of the 78 individuals remaining on the list (NOAA letter, September 7, 2010), 37 have not been seen for two or more years and 6 more were not seen last year, leaving an estimated 35 individuals on the list that could likely be removed in 2011 and beyond (excluding new animals that would qualify for listing). We know from observations of branded CSL seen at Bonneville Dam over the years, that if they do not return in consecutive years, they are unlikely to return at al. Of 311 CSL likely to be identified year to year excluding newly identified individuals for 2010, 17 (5.5%) returned after not being seen for one year at Bonneville Dam and 2 (0.6%) returned after 2 years. At least 86.7% (72 of 83) of branded CSL seen at Bonneville Dam returned in subsequent years (excluding new brands seen in 2010 (26), those removed in the same year first identified (4), and known to have died (3)).

Table 13. Observed number of days present and salmonids taken for all removed CSL compared to all other individual CSL identified at Bonneville Dam from 2002 to 2010. (Data includes 3 CSL that died inadvertently)

Year	Per capita salmonid consumption		Per capita days present	
	Removed CSL	All other CSL	Removed CSL	All other CSL
2002	9.0	9.9	6.3	5.1
2003	28.5	8.4	15.5	6.3
2004	6.9	4.0	10.1	7.6
2005	2.4	1.6	10.9	7.1
2006	25.6	11.3	32.2	16.6
2007	19.7	11.2	29.2	14.9
2008	32.7	13.7	33.6	11.0
2009	30.2	30.3	25.4	14.3
2010	20.8	17.9	18.6	7.9
Unique Animals All Years*	82.0	16.1	89.2	14.6

**- Some individuals were present for multiple year, therefore there are fewer individuals than adding for each year and thus a higher per individual per capita consumption.*

While there has yet to be a marked decline in the number of salmonids taken by CSL, the numbers of CSL are definitely lower, and the full impact of the removal of 12 animals this year should become more evident after next years monitoring program. Had the 40 animals not been removed in 2008, 2009, and 2010, the consumption estimates would likely have been much higher, perhaps by as much as 1,000 or more over the past two years (Brown et al., 2010), and this does not even address the issue of fall salmonid predation by some CSL. None of the 'salmon saved' estimates take into account the potential impact of C265 and C657, had they not been removed and returned in the fall as they had in 2008 to prey on fall Chinook salmon, coho salmon, and steelhead. C805, the other documented CSL to have been seen at Bonneville Dam in the fall, was removed after having been seen at the dam on two days in September and three days in October of 2009. The removal program appears to have targeted many of the multi-year individuals showing up at Bonneville Dam (Table 14). We expected the results from the 2010 season to show a steep decline in CSL numbers, which should have also resulted in reduced salmonid predation by CSL. However, this was not the case, as many new CSL ventured up to Bonneville Dam this year, if only briefly. It may be that removing 11 to 15 animals each year is not enough to prevent substantial recruitment of new individuals and increased predation, and that it would take more additional measures (e.g. the removal of about 30 individuals) each year to see and document a significant reduction in CSL numbers and salmonid predation. Perhaps more traps (frequently the available traps are full of SSL with only a few CSL), a loosening of the criteria for CSL to become listed (e.g. eliminating the need to document seeing them take a salmonid and/or be observed at Bonneville for 5 days), quicker turn around on getting individuals on the official list once they qualify, or additional methods of removal should be examined to make more of an impact on the Bonneville population of CSL.

Table 14. Comparison of CSL by removal status (listed, removed, or not listed). Data is for all nine years combined.

Category of CSL	*Number*	*Mean salmonids observed taken per capita*	*Mean number of days observed at Bonneville per year per capita*
All CSL	420	22.1	22.1
Listed CSL	115	65.7	64.3
Non-listed CSL	305	5.7	6.2
Intentionally removed CSL	37	91.0	101.5
Remaining listed CSL	78	53.7	46.6

However, the increasing presence and salmon predation by SSL at Bonneville Dam could continue to complicate the issue, if current trends persist. For example, the increase in SSL numbers can affect our determining the impact of the CSL removal program. This can be seen by examining the rate of clepto-parasitism (taking prey from others) committed by SSL upon CSL (Table 15). SSL expanded estimates of salmonid prey taken from CSL increased from 324 in 2009 to 801 in 2010, a 247% increase. This would require the "victims" to catch more fish to consume their fill. In contrast, the estimates of CSL take from other CSL dropped from 152 in 2009 to 58 in 2010, a 262% decrease in this activity. It appears SSL are learning that taking salmonid prey from the smaller CSL is an easy way to obtain salmonids, as this now accounts for 89% of observed clepto-parasitism interactions, whereas previous to 2009, CSL taking from other CSL was predominant. If the increase in SSL arriving each year continues, this may inflate the number of salmonids observed caught by CSL, but not necessarily consumed in whole. In order to get a better picture of the growing impact SSL are having on the salmonid population, the salmonids stolen from CSL by SSL were subtracted from the CSL total and added to the SSL total (Table 16). This is not completely fair as some of the fish are typically consumed by the "victim" before the fish is taken.

Table 15. Summary of expanded estimates of clepto-parasitism events seen at Bonneville Dam , 2002 to 2010. Virtually all involve salmonids (e.g. we observed 490 chinook, 20 steelhead, 4 sturgeon, and 16 unidentified prey stolen in 2010, the 4 sturgeon being SSL from SSL events).

Year	CSL from CSL	CSL from SSL	SSL from SSL	SSL from CSL	Other	Total
2002	0	0	0	0	0	0
2003	14	0	0	0	0	14
2004	366	22	0	0	0	388
2005	22	0	0	22	6	50
2006	12	0	0	5	0	17
2007	33	0	0	4	0	37
2008	161	0	4	135	5	305
2009	152	4	7	324	6	492
2010	58	2	37	801	0	898

Table 16. Estimated salmonid consumption by pinniped species adjusted for clepto-parasitism events.

	California sea lions			Steller's sea lions		
Year	Estimated salmonid consumption	Revised estimated salmonid consumption	% of run (1 Jan – 31 May)	Estimated salmonid consumption	Revised estimated salmonid consumption	% of run (1 Jan – 31 May)
2002	1,010	1,010	0.4%	0	0.0	0.0 %
2003	2,329	2,329	1.1%	0	0.0	0.0 %
2004	3,516	3,516	1.8%	13	13	0.0 %
2005	2,904	2,882	3.4%	16	38	0.0 %
2006	2,944	2,939	2.7%	76	81	0.1 %
2007	3,846	3,842	4.2%	13	17	0.0 %
2008	4,294	4,169	2.7%	176	297	0.2 %
2009	4,014	3,713	1.9%	475	776	0.4 %
2010	5,095	4,294	1.6%	986	1,787	0.7 %

Additional Observations, 2008-2010

Observations outside the standard tailrace viewing area were occasionally made. For example, we occasionally conducted observations in the forebay of Bonneville Dam when we knew pinnipeds were upstream of the dam. In addition, we collected chance sightings from Corps employees and biologists between Bonneville and The Dalles dam (rkm 308) (Appendix F). This past year was unusual in that we had one animal (C697) observed using the navigation lock to pass upstream into the forebay on May 16, 2009 where he remained until trapped by

ODFW/WDFW on January 25, 2010 and released near Astoria. Numerous sightings were reported from the tailrace of The Dalles Dam, Drano Lake (rkm 261), the mouth of the Wind River (rkm 249), and the forebay (especially near the fishway exits) of Bonneville Dam. Also in 2010, a CSL was observed in the forebay on April 22, at The Dalles Dam tailrace in early May, and back at Bonneville before he was trapped on May 18 and branded C03 and released about 5 miles below the dam. It is possible more than one sea lion may have accounted for some of the sightings, as individual identification was not possible for this animal until branded; however, we assumed it was the same animal as no further sighting were reported after his capture and removal downstream.

This year we also recorded one individual, C287, to take the most fish in one day at Bonneville Dam since we began observing in 2002. He was seen to take 12 Chinook (none were stolen by SSL) on April 12, 2010. If we use and average Chinook weight of 6.6 kg per fish (Brown, et al., 2010) this equates to about 85.8 kg in one day consumed. This is almost triple the maximum observed daily consumption by weight of that reported in Kastelein et al. (2000) from captive male CSL over 10 years old in the Netherlands. C287 was first observed at Bonneville Dam on March 22 this year, his sixth year observed at Bonneville Dam. He was subsequently observed every week day until April 30 (and was likely present every weekend as well) and was next observed in Astoria on May 2. He preferred to hunt and take fish near the face of PH2 and was rarely chased away by hazing so he gave us the best focal observations on an individual for a season that we have ever had. For the 30 days we observed C287, he was seen to take 195 Chinook (33 stolen by SSL), three steelhead (two stolen by SSL), and 4 unknown fish (1 stolen by SSL). This averages out to about 6.7 kg of fish per day taken, or 5.5 kg per day consumed (if we subtract the 36 “stolen” fish from the total taken). Again, this is almost triple the 11 kg per day Kaselein et al. (2000) reported for average daily consumption for a year. In 2005, he was observed to take two salmonids, three in 2006, 50 in 2007, 75 in 2008, 157 in 2009, and now 198 in 2010. This is not to say every CSL consumes this many fish, but it does give us an indication of how unusual a situation pinniped predation at Bonneville Dam has become when compared to natural or captive consumption studies, and what some CSL are capable of consuming.

Portland State University students observed at Willamette Falls Locks in 2009 and 2010. In 2009, they reported observing two branded CSL, C257 and C275, that we had observed at Bonneville in the past (C257 in 2002, 2003, 2004, and 2006 and C275 in 2003, 2004, and 2005). In 2010, they reported observing C257 again (Bryan Wright, personal comm.). Also, C917, observed at Willamette Falls Locks in 2009, was observed at Bonneville in 2010.

RECOMMENDATIONS

1. In light of continuing increases in estimated adult salmonid and white sturgeon catch, the earlier and more protracted presence of CSL and SSL from January through May (plus recent fall observations) in the Bonneville Dam tailrace, and potential management actions by wildlife management agencies, we strongly suggest a continuation of this monitoring program at this level for three more years. The full impact of removal of specific individual CSL can not be fully measured until the subsequent years' monitoring is completed. However, long term monitoring efforts need to be discussed among the action agencies to determine the usefulness, need, and costs of the information obtained.
2. The Corps should continue to coordinate with agency partners performing observations in the area downstream of our study area, such as PSU and CRITFC.
3. SLEDs and FOG barriers have proved effective and should continue to be used to prevent sea lions from entering the fishways of Bonneville Dam. If presence of sea lions in the fall becomes a regular occurrence, the Corps and regional fish passage agencies should consider installing these barriers in the fall, or leaving them in place for the entire fish passage season.
4. The use of ADDs should be discontinued. These devices have not demonstrated any usefulness as a sea lion deterrent at fishway entrances.
5. The Corps should continue to assist in the pursuit and evaluation of potential non-lethal deterrent technologies as part of a long-term strategy to reduce pinniped predation on adult salmonids, sturgeon, and lamprey in the Bonneville Dam tailrace.
6. The Corps and States should continue to work together to develop and refine the best methodology to estimate the potential number of "salmon saved" by the removal program, using the most reasonable assumptions and the best bioenergetics and observational data available to us.
7. The Corps should work with ODFW and WDFW to determine if the use of barriers to prevent sea lions from hauling out near the dam is effective and beneficial to the long term goal of reducing the presence and predation of sea lions near the dam. If so, the Corps should provide funding and resources to develop permanent structures to physically deter sea lions from hauling out near the dam, particularly along the PH2 tailrace Cascades Island west end shoreline. This could serve both to increase the rate of capture on floating traps (not seen in 2010) and perhaps deter animals from residing and resting so long at Bonneville Dam each spring (seen in 2010).
8. ODFW/WDFW should strongly consider adding additional traps and/or additional methods for removal, to remove more individuals each season (e.g. 30, not 10-15).
9. ODFW/WDFW should request modifications to the requirements for listing from NOAA to allow any CSL that is present at Bonneville Dam and highly identifiable to qualify for the removal list (abolish the 5 days present and seen to take one fish criteria) to allow more animals to be listed for removal. The process or time to get animals on the list should also be reduced, so as to allow prompt and opportunistic removals to occur when the animals are present, not weeks later.
10. Use of a critter-cam affixed to at least one multi-year CSL early in the season would allow biologists to get a better understanding of how and where the sea lions are taking prey, and possibly if there is significant underwater consumption going on unobserved by surface observations.

ACKNOWLEDGEMENTS

We would like to thank all who continue to help us provide the most accurate information on pinniped predation at Bonneville Lock and Dam. The Oregon Department of Fish and Wildlife, Washington Department of Fish and Wildlife, NOAA National Marine Fisheries Service, Pacific States Marine Fisheries Commission, and the Columbia River Inter-Tribal Fish Commission all contributed personnel and equipment to conduct the boat-based hazing program, while the USDA Wildlife Services continues to conduct the dam-based hazing program. Special thanks to Robin Brown (ODFW), Steve Jeffries (WDFW), Matt Tennis (PSMFC), and Bryan Wright (ODFW) for their advice, input, and cooperation. David Clugston and Bernard Klatte (USACE) helped with study objectives, funding, and program support. Just as in 2008 and 2009, the Bonneville Lock and Dam rigging crew should be commended for successfully deploying and removing SLEDs, and for assisting with sea lion trapping efforts in 2010.

A very big thank you goes to all the observers who collected valuable data for us this year. Observers from our own staff at the Fisheries Field Unit form the core of our observation team. Interns from the Student Conservation Association (SCA) did a great job of assisting with observations and data management. Hillary Griffin, Elizabeth Hawacker, Anna Laws, Terrah Owens, Eric Sims, Vanessa van Zerr, Meng Vue, Tom Glazer, Bill Ward, Jennifer Watson, Erika Ditmar, Heather Benedict, Alice Dou-Wang, Breena Apgar-Kurtz, Leah Trombley, Lindsey Albright, Tabitha Finch, and Tancy Moore endured particularly wet and harsh winter and spring weather conditions and performed admirably.

REFERENCES

Brown, R., S. Jeffries, D. Hatch, B. Wright, S. Jonkers, and J. Whiteaker. 2010. Field Report: 2010 Pinniped management activities at Bonneville Dam. 37pp.

Brown, R., S. Jeffries, D. Hatch, B. Wright, S. Jonkers, and J. Whiteaker. 2009. Field Report: 2009 Pinniped management activities at Bonneville Dam. 32pp.

Brown, R., S. Jeffries, D. Hatch, and B. Wright. 2008. Field Report: 2008 Pinniped management activities at Bonneville Dam. 8pp.

Brown, R. and B. Mate. 1983. Abundance, movements and feeding habits of Harbor Seals, *Phoca vitulina*, at Netarts and Tillamook Bays, Oregon. Seattle, Washington: Fishery Bulletin 81(2):291-300.

Kastelein, R., N. Schooneman, N. Vaughan, and P. Wiepkema. 2000. Food consumption and growth of California sea lions (Zalophus californianus californianus). Zoo Biology 19:143-159.

London, J., M. Lance, and S. Jeffries. 2002. Observations of harbor seal predation on Hood Canal salmonids from 1998 to 2000. Final Report Studies of expanding pinniped populations. NOAA grant number NA17FX1603. 19pp.

Roffe, T. and B. Mate. 1984. Abundance and feeding habits of pinnipeds in the Rogue River, Oregon. J. Wildl. Management 48(4):1262-1274.

Stansell, R. 2004. Evaluation of pinniped predation on adult salmonids and other fish in the Bonneville Dam tailrace, 2002-2004. . U.S. Army Corps of Engineers, CENWP-OP-SRF, Bonneville Lock and Dam, Cascade Locks, Oregon. 49pp.

Stansell, R., S. Tackley, W. Nagy, and K. Gibbons. 2009. 2009 Field Report: Evaluation of pinniped predation on adult salmonids and other fish in the Bonneville Dam tailrace. U.S. Army Corps of Engineers, Bonneville Lock and Dam, Cascade Locks, Oregon. 37pp.

Tackley, S., R. Stansell, and K. Gibbons. 2008a. Pinniped predation on adult salmonids and other fish in the Bonneville Dam tailrace, 2005-2007. U.S. Army Corps of Engineers, CENWP-OP-SRF, Bonneville Lock and Dam, Cascade Locks, Oregon. 51pp.

Tackley, S., R. Stansell, and K. Gibbons. 2008b. 2008 Field Report: Evaluation of pinniped predation on adult salmonids and other fishes in the Bonneville Dam tailrace. U.S. Army Corps of Engineers, Bonneville Lock and Dam, Cascade Locks, Oregon. 22pp.

Wright, B., S. Jeffries, R. Brown, R. Stansell, D. Hatch, and B. Norberg. 2007. Field Report – Non-lethal pinniped deterrent activities at Bonneville Dam, spring 2006. 24pp.

Appendix A. Maps (Figures A1-A3) of Bonneville Lock and Dam and vicinity, with predations zones shown.

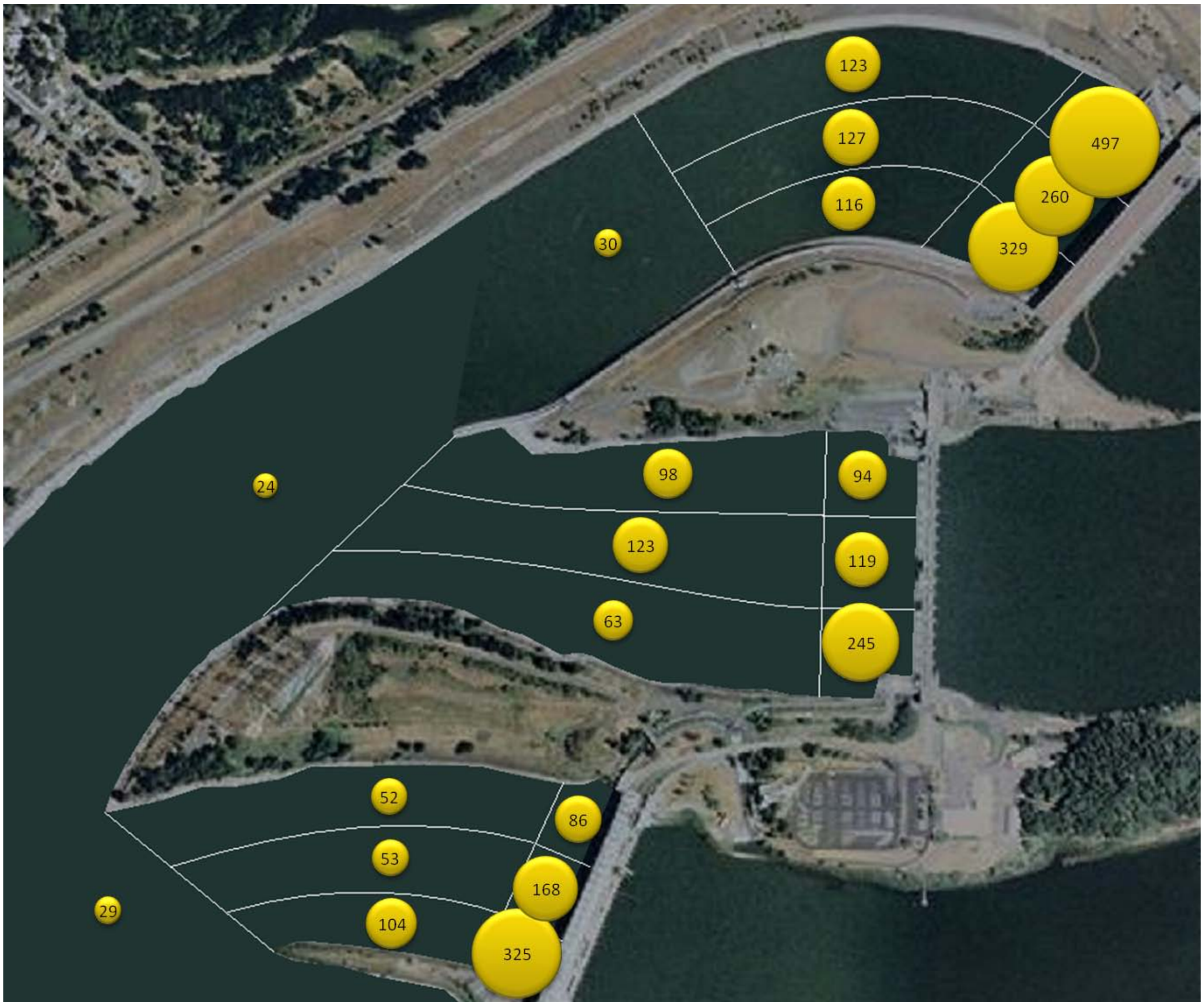


Figure A1. Frequency distribution by location of Chinook salmon caught by CSL at Bonneville Dam, 2010.

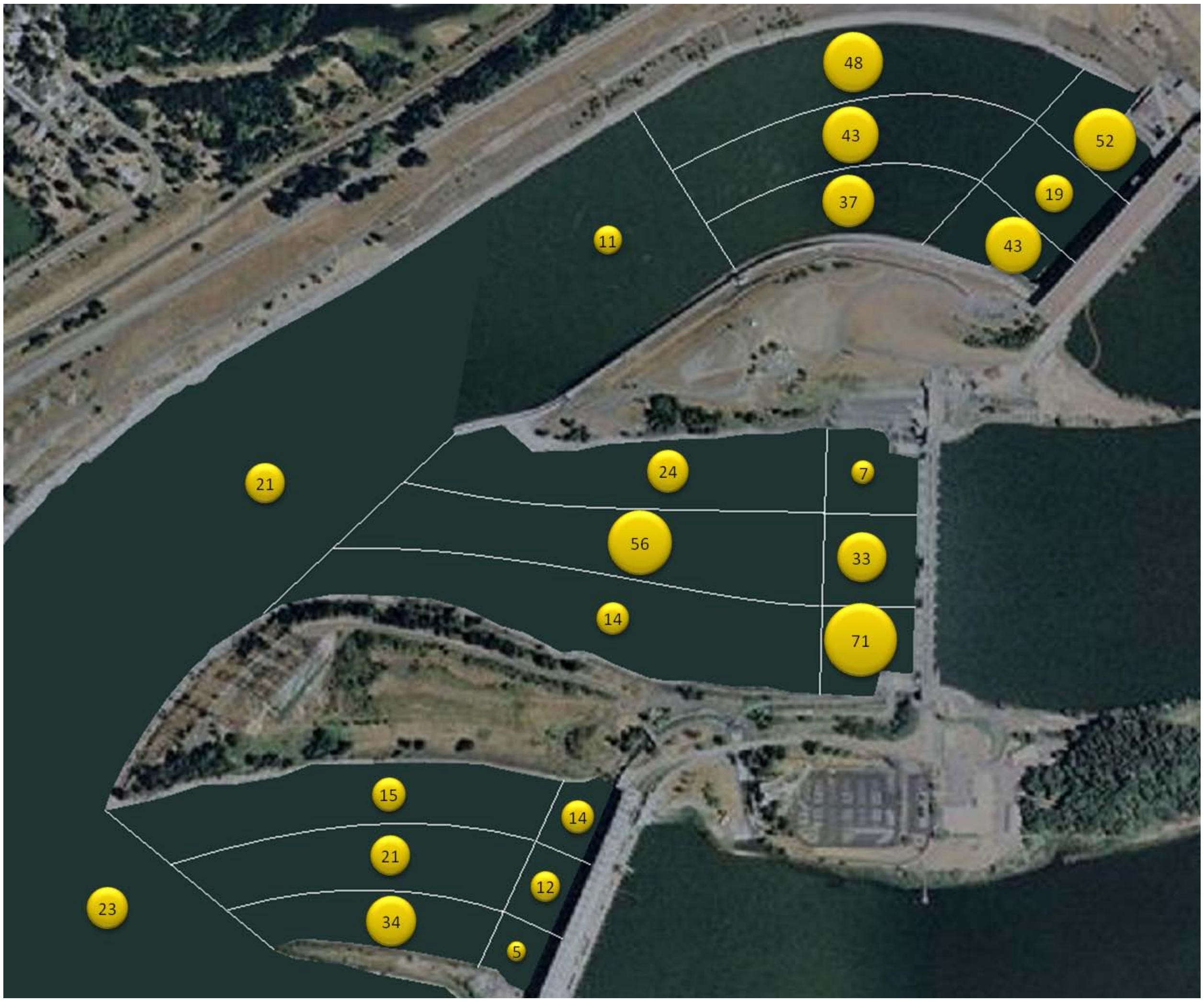


Figure A2. Frequency distribution by location of Chinook salmon caught by SSL at Bonneville Dam, 2010.

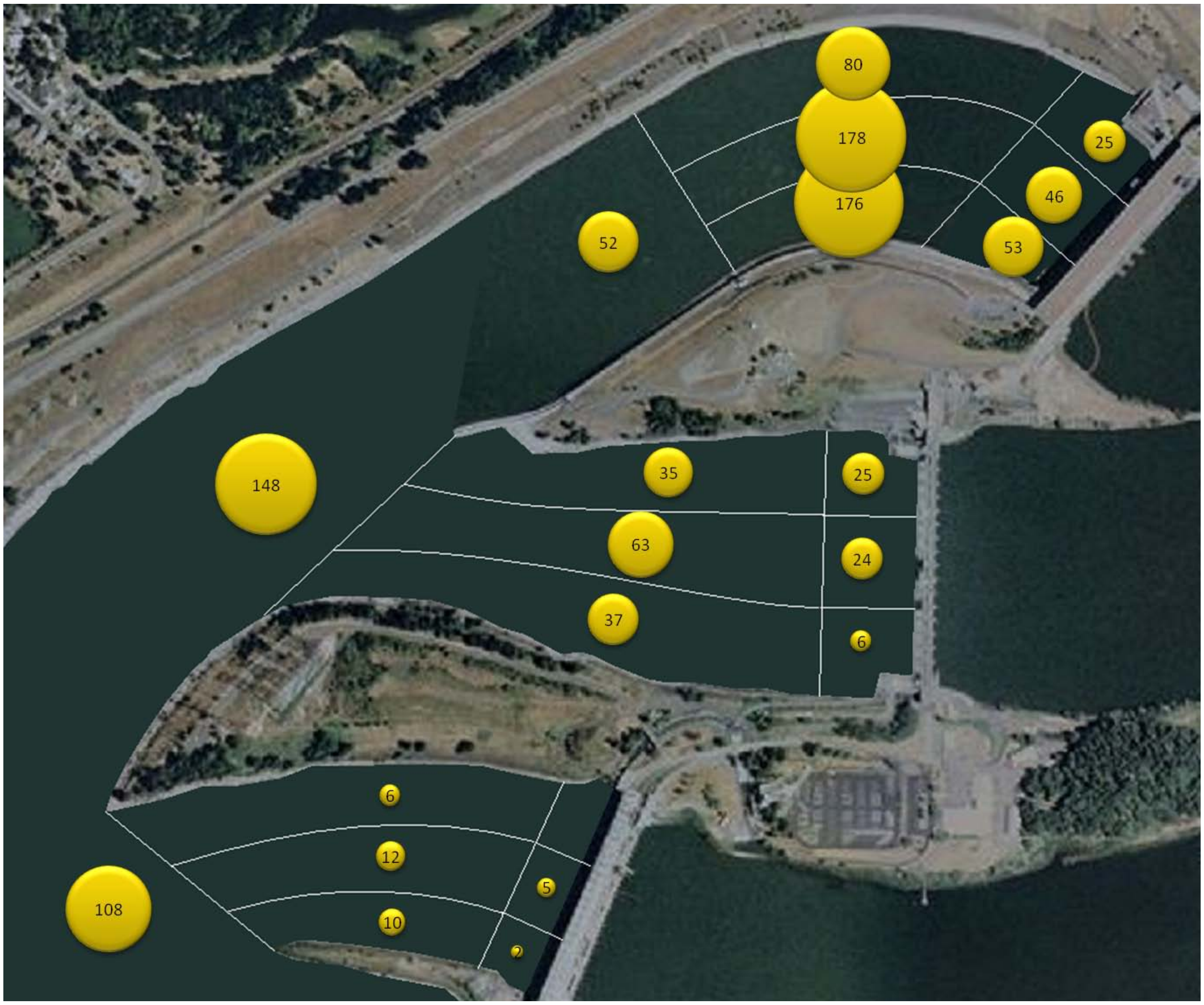


Figure A3. Frequency distribution by location of white sturgeon caught by SSL at Bonneville Dam, 2010.

Appendix B. Equations used to calculate predation estimates.

Equation 1. Likely additional consumption by California (A_c) and Steller's sea lions (A_s)

Observers were not always able to identify the species of fish being caught and consumed. Such catches were recorded as "unidentified" fish. The daily *identified* fish consumption distribution was used to calculate daily proportional allocation of *unidentified* catch. These daily totals were then added together to get the likely additional consumption for the season. The observed diets and catch rates of CSL and SSL differed substantially, with CSL diet dominated by adult salmonids and SSL diet dominated by sturgeon. To provide more accurate estimates, we estimated additional consumption separately by predator species.

For example, on April 7, 2008, CSL caught and consumed an estimated 82 adult salmonids (X_j), 1 lamprey, and an estimated 3 unidentified fish. When the single lamprey catch was excluded, 100% of identified catches (X_j divided by Z_j) were adult salmonids. This proportion was multiplied by the daily expanded unidentified consumption estimate for CSL (U_j), which were 3. So for April 7, we estimated that CSL likely consumed at least 3 additional adult salmonids, given that 100% of identified catches were adult salmonids. This same calculation was made for all days of the season and for both sea lion species, producing an additional catch estimate of 397 adult salmonids for CSL (A_c) and 64 salmonids for SSL (A_s). Thus:

$$A_c = \sum_{j=1}^{N} \left(\frac{X_j}{Z_j} \right) * U_j$$

where

N is the number of days of regular sea lion observations,

X_j is the daily expanded (salmonid *or* sturgeon) catch, calculated by dividing observed daily (salmonid or sturgeon) catch (by CSL *or* SSL) by a predator species-specific (CSL *or* SSL) daily expansion factor (K_j) for each tailrace,

Z_j is total daily identified fish consumption (excludes Pacific lamprey and smolts) by CSL *or* SSL, and

U_j is the daily expanded unidentified consumption estimate for CSL *or* SSL.

Equation 2. Adjusted consumption estimates (C_a)

Adjusted consumption estimates include both the expanded (adult salmonid *or* sturgeon) consumption estimate (C_e) and the likely additional (adult salmonid *or* sturgeon) consumption by CSL (A_c) and SSL (A_s). The likely additional consumption is determined by multiplying the observed percentage of salmonid or sturgeon in the diet of each predator by the number of unidentified fish caught each day.

For example, in 2008 the expanded adult salmonid consumption estimate (C_e) was 4,466 fish. CSL likely caught an additional 397 salmonids (A_c), and SSL likely caught an additional 64 salmonids (A_s). This brings the adjusted consumption estimate (C_a) up to 4,927 fish. Thus:

$$C_a = C_e + A_c + A_s$$

where

C_e is the expanded salmonid *or* sturgeon consumption estimate,

A_c is the likely additional salmonid *or* sturgeon consumption by CSL, and

A_s is the likely additional salmonid *or* sturgeon consumption by SSL.

Adjustment for additional night-time predation

Limited night-time observations in 2002 and 2003 (22 hours total) showed virtually no night-time predation occurring. However, after day-time hazing efforts began in 2006, we thought this may have caused some pinnipeds to hunt at night. In 2009 (Stansell et al.,(2009) we observed for 30 hours at night and determined that there was some early night-time predation, although still minor, and could add an additional 3.5% to the predation estimates. To account for this, we multiply the adjusted consumption estimate by 1.035 and get an estimate that includes likely night-time predation events.

Adjustment for clepto-parasitism events

Clepto-parasitism, the taking of prey by one species of predator from another, needs to be accounted for when we break down the various estimates by species as this will raise SSL consumption estimates and decrease CSL consumption estimates. Although the CSL still are the primary predator of salmonids at Bonneville Dam, the fact that much of their prey is stolen by SSL may cause them to catch even more salmon to fatten up for the upcoming breeding season. We can expand observed clepto-parasitism events the same as we do for normal predation events, and then we add the total salmonids stolen by the SSL from CSL to the SSL final estimate, and subtract from the CSL estimate. This is not entirely fair as the CSL typically get in several bites before the SSL take the salmon, but it does give a general idea of the impact the SSL are having on the salmon population.

Appendix C. List of CSL trapped at Bonneville Dam from 2008 thru 2010. (Yellow shading denotes animals removed from population known to visit Bonneville Dam)

Sea lion ID	Capture date	On removal list?	Passed health exam?	Action	Additional information
C319/B239	4/24/08	Yes	Yes	Relocated	Relocated to Sea World (Orlando, FL)
C606	4/24/08	Yes	Yes	Relocated	Relocated to Sea World (Orlando, FL)
C739/B136	4/24/08	Yes	Yes	Relocated	Relocated to Sea World (Orlando, FL)
C795/B291	4/24/08	No	-	Released	Branded and released
C796	4/24/08	No	-	Released	Branded and released
C797	4/24/08	No	-	Released	Branded and released
C640/B241	4/28/08	Yes	Yes	Relocated	Relocated to Sea World (Orlando, FL)
C668/B244	4/28/08	Yes	Yes	Relocated	Relocated to Sea World Orlando, FL)
C805/B208	4/28/08	Yes	-	Released	Branded and released
B66	4/28/08	Yes	Yes	Relocated	Relocated to Sea World (Orlando, FL)
B198	4/28/08	Yes	No	Died	Died while under anesthetic, did not recover
C347	5/4/08	Yes	-	Died	Died from heat exhaustion on trap
C672	5/4/08	No	-	Died	Died from heat exhaustion on trap
B252	5/4/08	No	-	Died	Died from heat exhaustion on trap
B275	5/4/08	No, but qualified	-	Died	Died from heat exhaustion on trap
C265/B237	3/10/09	Yes	No	Euthanized	Failed health examination, unsuited for zoos/aquariums
C635/B240	3/11/09	Yes	No	Euthanized	Failed health examination, unsuited for zoos/aquariums
C643/B242	3/17/09	Yes	No	Euthanized	Failed health examination, unsuited for zoos/aquariums
C507/B145	3/18/09	Yes	Yes	Relocated	Relocated to Shedd Aquarium (Chicago, IL)
C700/B247	3/18/09	Yes	Yes	Relocated	Relocated to Shedd Aquarium (Chicago, IL)
C554	4/1/09	Yes	No	Euthanized	Failed health examination, unsuited for zoos/aquariums
C578	4/1/09	Yes	No	Euthanized	Failed health examination, unsuited for zoos/aquariums
C579	4/1/09	Yes	No	Euthanized	Failed health examination, unsuited for zoos/aquariums
C586	4/1/09	Yes	Yes	Relocated	Relocated to Gladys Porter Zoo (Brownsville,TX)
C657/B127	4/1/09	Yes	Yes	Relocated	Relocated to Gladys Porter Zoo (Brownsville, TX)
C669/B110	4/1/09	Yes	No	Euthanized	Failed health examination, unsuited for zoos/aquariums
C697	4/1/09	No	-	Released	Tagged with acoustic transmitter for research (ODFW/CRITFC)
C697	4/8/09	No	-	Released	
C926/B278	4/1/09	Yes (‘09)	-	Released	Tagged with acoustic transmitter for research (ODFW), branded C926
C927/B283	4/8/09	No	-	Released	Tagged with acoustic transmitter for research (ODFW), branded C927
C927/B283	4/16/09	No	-	Released	
C928	4/16/09	No	-	Released	Tagged with acoustic transmitter for research (ODFW), branded C928
C858	5/11/09	Yes (‘09)	No	Euthanized	Failed health examination, unsuited for zoos/aquariums
C645	5/13/09	Yes	No	Euthanized	Failed health examination, unsuited for zoos/aquariums
C674	5/14/09	Yes	No	Euthanized	Failed health examination, unsuited for zoos/aquariums
C934/B300	5/14/09	No	-	Released	Tagged with acoustic transmitter for research (ODFW), branded C934
C935	5/14/09	No	-	Released	Tagged with acoustic transmitter for research (ODFW), branded C935
C928/B288	8/24/09	Yes (‘09)	-	Euthanized	

Appendix C (cont). List of CSL trapped at Bonneville Dam from 2008 thru 2010. (Yellow shading denotes animals removed from population known to visit Bonneville Dam)

Sea lion ID	Capture Date	On removal list?	Passed health exam?	Action	Additional information
C697	1/25/10	No	-	Released	Caught in Bonneville Dam forebay and released at Clatsop spit
C653	3/3/10	Yes	-	Euthanized	
C417	3/9/10	Yes	-	Euthanized	
C926	3/9/10	Yes	-	Euthanized	
B194	3/9/10	Yes	-	Euthanized	
B258	3/9/10	Yes	-	Euthanized	
B267	3/9/10	Yes	-	Euthanized	
C697	3/9/10	No	-	Released	Released at Bonneville Dam tailrace
C00/B305	3/9/10	No	-	Released	Tagged with acoustic transmitter for research (ODFW), branded C00
C805/B208	3/30/10	Yes	-	Euthanized	
C934/B300	3/30/10	Yes	-	Euthanized	
C697	4/6/10	Yes ('10)	-	Euthanized	
C01	4/29/10	No	-	Released	Tagged with acoustic transmitter for research (ODFW), branded C01
C00/B305	5/4/10	Yes ('10)	-	Euthanized	
C02	5/4/10	No	-	Released	Tagged with acoustic transmitter for research (ODFW), branded C02
C667	5/4/10	No	-	Released	Tagged with acoustic transmitter for research (ODFW)
C03/B324	5/19/10	No	-	Released	Tagged with acoustic transmitter (ODFW), branded C03
C04/B331	5/25/10	No	-	Released	Branded C04 and released at Bonneville Dam tailrace
C05/B334	5/26/10	No	-	Released	Branded C05 and released at Bonneville Dam tailrace
C06	5/26/10	No	-	Released	Branded C06 and released at Bonneville Dam tailrace
C07	5/26/10	No	-	Released	Branded C07 and released at Bonneville Dam tailrace
C08/B340	5/26/10	No	-	Released	Branded C08 and released at Bonneville Dam tailrace
C841	5/26/10	Yes ('10)	-	Euthanized	
C667	5/26/10	Yes ('10)	-	Euthanized	
U18	9/8/10	Yes	-	Euthanized	
C797	9.9.10	Yes	-	Euthanized	

Note – Some animals have both a "C" brand and a "B" code as these individuals were originally identified through documentation of natural physical features and were subsequently branded either at Bonneville Dam or Astoria.

Appendix D. Table of progressive estimates of pinniped predation on salmonids (also broken out by pinniped species) at Bonneville Dam, 2002-2010, adjusted for unidentified fish prey caught, night-time predation, and clepto-parasitism events.

ADJUSTED FOR DAYLIGHT HOURS AND DAYS NOT OBSERVED

	ALL PINNIPEDS				CALIFORNIA SEA LIONS				STELLER SEA LIONS			
	TOTAL HOURS OBSERVED	TOTAL SALMONID PASSAGE	ESTIMATE SALMONID CATCH	% RUN TAKEN	TOTAL HOURS OBSERVED	TOTAL SALMONID PASSAGE	ESTIMATE SALMONID CATCH	% RUN TAKEN	TOTAL HOURS OBSERVED	TOTAL SALMONID PASSAGE	ESTIMATE SALMONID CATCH	% RUN TAKEN
2002	662	281,785	1,010	0.36%	662	281,785	1,010	0.36%	662	281,785	0	0.00%
2003	1,356	217,934	2,329	1.06%	1,356	217,934	2,329	1.06%	1,356	217,934	0	0.00%
2004	516	186,770	3,533	1.86%	516	186,770	3,516	1.85%	516	186,770	13	0.01%
2005	1,109	81,252	2,920	3.47%	1,109	81,252	2,904	3.45%	1,109	81,252	16	0.02%
2006	3,650	105,063	3,023	2.80%	3,650	105,063	2,944	2.73%	3,650	105,063	76	0.07%
2007	4,433	88,476	3,859	4.18%	4,433	88,476	3,846	4.17%	4,433	88,476	13	0.01%
2008	5,131	147,534	4,466	2.94%	5,131	147,534	4,294	2.83%	5,131	147,534	172	0.12%
2009	3,455	186,060	4,489	2.36%	3,455	186,060	4,037	2.12%	3,455	186,060	452	0.24%
2010	3,609	267,184	6,081	2.23%	3,609	267,184	5,095	1.87%	3,609	267,184	986	0.37%

ADJUSTED FOR UNIDENTIFIED FISH

	ALL PINNIPEDS				CALIFORNIA SEA LIONS				STELLER SEA LIONS			
	TOTAL HOURS OBSERVED	TOTAL SALMONID PASSAGE	ESTIMATE SALMONID CATCH	% RUN TAKEN	TOTAL HOURS OBSERVED	TOTAL SALMONID PASSAGE	ESTIMATE SALMONID CATCH	% RUN TAKEN	TOTAL HOURS OBSERVED	TOTAL SALMONID PASSAGE	ESTIMATE SALMONID CATCH	% RUN TAKEN
2002	662	281,785	1,010	0.36%	662	281,785	1,010	0.36%	662	281,785	0	0.00%
2003	1,356	217,934	2,329	1.06%	1,356	217,934	2,329	1.06%	1,356	217,934	0	0.00%
2004	516	186,770	3,533	1.86%	516	186,770	3,516	1.85%	516	186,770	13	0.01%
2005	1,109	81,252	2,920	3.47%	1,109	81,252	2,904	3.45%	1,109	81,252	16	0.02%
2006	3,650	105,063	3,401	3.14%	3,650	105,063	3,312	3.06%	3,650	105,063	85	0.08%
2007	4,433	88,476	4,355	4.69%	4,433	88,476	4,340	4.68%	4,433	88,476	15	0.02%
2008	5,131	147,534	4,927	3.23%	5,131	147,534	4,738	3.11%	5,131	147,534	189	0.13%
2009	3,455	186,060	4,960	2.60%	3,455	186,060	4,353	2.29%	3,455	186,060	607	0.33%
2010	3,609	267,184	6,321	2.31%	3,609	267,184	5,296	1.94%	3,609	267,184	1,025	0.38%

ADJUSTED FOR NIGHT NOT OBSERVED (AN ADDITIONAL 3.5% SALMONIDS ADDED TO THE SALMON CATCH AFTER 2006 WHEN DAYTIME HAZING BEGAN)

	ALL PINNIPEDS				CALIFORNIA SEA LIONS				STELLER SEA LIONS			
	TOTAL HOURS OBSERVED	TOTAL SALMONID PASSAGE	ESTIMATE SALMONID CATCH	% RUN TAKEN	TOTAL HOURS OBSERVED	TOTAL SALMONID PASSAGE	ESTIMATE SALMONID CATCH	% RUN TAKEN	TOTAL HOURS OBSERVED	TOTAL SALMONID PASSAGE	ESTIMATE SALMONID CATCH	% RUN TAKEN
2002	662	281,785	1,010	0.36%	662	281,785	1,010	0.36%	662	281,785	0	0.00%
2003	1,356	217,934	2,329	1.06%	1,356	217,934	2,329	1.06%	1,356	217,934	0	0.00%
2004	516	186,770	3,533	1.86%	516	186,770	3,516	1.85%	516	186,770	13	0.01%
2005	1,109	81,252	2,920	3.47%	1,109	81,252	2,904	3.45%	1,109	81,252	16	0.02%
2006	3,650	105,063	3,520	3.24%	3,650	105,063	3,428	3.16%	3,650	105,063	88	0.08%
2007	4,433	88,476	4,507	4.85%	4,433	88,476	4,492	4.83%	4,433	88,476	15	0.02%
2008	5,131	147,534	5,099	3.34%	5,131	147,534	4,904	3.22%	5,131	147,534	196	0.13%
2009	3,455	186,060	5,134	2.69%	3,455	186,060	4,505	2.36%	3,455	186,060	628	0.34%
2010	3,609	267,184	6,542	2.39%	3,609	267,184	5,481	2.01%	3,609	267,184	1,061	0.40%

ADJUSTED FOR CLEPTO-PARASITISM

	ALL PINNIPEDS				CALIFORNIA SEA LIONS				STELLER SEA LIONS			
	TOTAL HOURS OBSERVED	TOTAL SALMONID PASSAGE	ESTIMATE SALMONID CATCH	% RUN TAKEN	TOTAL HOURS OBSERVED	TOTAL SALMONID PASSAGE	ESTIMATE SALMONID CATCH	% RUN TAKEN	TOTAL HOURS OBSERVED	TOTAL SALMONID PASSAGE	ESTIMATE SALMONID CATCH	% RUN TAKEN
2002	662	281,785	1,010	0.36%	662	281,785	1,010	0.36%	662	281,785	0	0.00%
2003	1,356	217,934	2,329	1.06%	1,356	217,934	2,329	1.06%	1,356	217,934	0	0.00%
2004	516	186,770	3,533	1.86%	516	186,770	3,516	1.85%	516	186,770	13	0.01%
2005	1,109	81,252	2,920	3.47%	1,109	81,252	2,881	3.42%	1,109	81,252	39	0.05%
2006	3,650	105,063	3,520	3.24%	3,650	105,063	3,421	3.15%	3,650	105,063	95	0.09%
2007	4,433	88,476	4,507	4.85%	4,433	88,476	4,488	4.83%	4,433	88,476	20	0.02%
2008	5,131	147,534	5,099	3.34%	5,131	147,534	4,761	3.13%	5,131	147,534	338	0.23%
2009	3,455	186,060	5,134	2.69%	3,455	186,060	4,145	2.18%	3,455	186,060	989	0.53%
2010	3,609	267,184	6,542	2.39%	3,609	267,184	4,621	1.70%	3,609	267,184	1,921	0.71%

Appendix E. Assumptions made to determine the number of individual sea lions present and to determine estimates of salmonids and other fish caught by pinnipeds.

- Catch rates and the hourly distribution of catches for hours and days not observed were assumed to be similar to the mean temporal catch distribution for each particular season. Expansion estimates for very early (0400 to 0500 h) hours or other hours with no observations were based on observations made in previous years.

- All adult salmonids caught by pinnipeds were assumed brought to the surface to be torn up and consumed. Some pinnipeds were observed apparently eating large chunks underwater and others dragged fish downstream, both at the surface, underwater, and at great distances before beginning to eat the fish. This behavior may have contributed to an underestimate of the number of salmonids caught, but we feel this occurred less than 1% of the time. Also, Steller's sea lions and some larger California sea lions have been observed in recent years to swallow steelhead whole, however, they still seem to need to bring the fish to the surface and orient it head first before swallowing. There may be some instances of steelhead and small Chinook salmon being swallowed underwater, but we have no evidence that suggests this is occurring in any significant amount. Overestimates may have occurred when several pinnipeds were present. A pinniped would catch a fish and take a long time before eating it. Near the end of the season, this behavior could sometimes make it appear as if another pinniped had caught a fish, particularly if the individual that caught the fish was not identified. Pinnipeds stealing a fish from one another were usually identifiable. However, stealing behavior may have been counted as a new fish being taken if the amount of fish originally consumed was not carefully monitored. Overall, these conditions were rare and likely did not significantly affect the expanded estimates. All smaller prey (e.g. lamprey, shad, or smolts) could have been consumed underwater and therefore not be recorded by our observers. The figures presented for smaller prey are likely underestimates.

- Lamprey were eaten quickly and sea lions would not always shake or throw lamprey but rather swallow them whole, head first, after a few quick bites to kill them. We likely underestimated the number of lamprey caught as the action was quick and distances involved made seeing a lamprey being eaten difficult. Adult shad were eaten quickly and some may have been missed. Harbor seals were present on a few occasions, and they rarely were seen catching salmon. Seals may have targeted lamprey, which could have been consumed underwater. Roffe and Mate (1984) found that lamprey were the primary prey consumed by harbor seals on the Rogue River after analyzing stomach contents.

- Observations were assumed equally successful at all locations, each observer had equal ability to detect the presence of pinnipeds and when fish were caught, and weather and lighting did not significantly affect these observations. However, when spill occurred (early April through May), it was often difficult to see pinnipeds, even when they caught a fish, so our detection and catch rate there may be negatively biased. Heavy rain or snow reduced visibility at all tailrace areas at times and distant events may have gone unnoticed.

- The chance of underestimating the numbers of pinniped present was assumed equal to the chance of overestimating the numbers when large groups were present. The behavior of a hunting CSL was to stay submerged for several minutes and only briefly surface to breathe. This made it difficult to know if a head or nose seen five minutes apart was from the same individual or a different individual. Some individuals hunted in predictable patterns while others would appear to randomly forage and surface. When more than five or six pinnipeds were in a tailrace, it became increasingly challenging to keep track of the number present, identify individuals, record all fish caught, and detect new arrivals and departures. We prioritized our effort as such: 1) Ensure all fish caught are seen and recorded; 2) Record and document individuals; 3) Determine the number of pinnipeds present.

- The presence of observers on the tailrace deck was assumed to not affect the presence of pinnipeds in the area or their ability to catch prey.

- For adjustments for clepto-parasitism events, when a fish was stolen, the whole fish was added to that species consumption total and subtracted from the victims' consumption total. However, at least part of the fish was consumed by the original predator before being stolen, usually the head and a few bites.

- Beginning in 2008 observers were instructed to identify all species of salmon prey (Chinook and steelhead) with a confidence of 1 (least confident) to 5 (most confident). Results showed very few instances of 1 or 2 ratings and averaged 4.54 (in 2010), the vast majority being 4's and 5's. We therefore considered any prey considered a Chinook to be a Chinook, regardless of confidence ratings. This eliminated the category of unknown salmonid species and helps to get a better estimate of impact to specific prey species. We retain the confidence requirements to help with our quality control procedures with observers each year.

Appendix F. Summary of CSL sightings upstream of Bonneville Dam (2002-2010).

Date	Location	Identified Sea Lion
5/16/2002	Bonneville Dam forebay	C257
5/18/2002	Wind River mouth (near Home Valley, WA)	C257
5/20/2002	Boat ramp at Stevenson, WA	C257
5/21/2002	Bonneville Dam forebay	C257
5/22/2002	Bonneville Dam forebay	C257
5/23/2002	Bonneville Dam forebay	C257
5/24/2002	Bonneville Dam forebay	C257
5/26/2002	Bonneville Dam forebay	C257
7/16/2002	Near Stevenson, WA	Unknown
4/9/2003	Bonneville Dam navigation lock (upstream)	Unknown
4/27/2004	Drano Lake (near Cook, WA)	Unknown
5/4/2004	Eagle Creek (near Cascade Locks, OR)	Unknown
5/17/2004	Drano Lake (near Cook, WA)	Unknown
5/26/2004	Bonneville Dam forebay	Unknown
3/2/2005	The Dalles Dam tailrace (The Dalles, OR)	Unknown
3/6/2005	Bonneville Dam forebay	Unknown
3/9/2005	Bonneville Dam forebay	Unknown
3/15/2005	Bonneville Dam forebay	Unknown
3/18/2005	Bonneville Dam forebay	Unknown
3/19/2005	Bonneville Dam forebay	Unknown
3/7/2006	Bonneville Dam forebay	C309
3/9/2006	Bonneville Dam forebay	C309
3/10/2006	Bonneville Dam forebay; navigation lock	C309
5/1/2007	Bonneville Dam forebay	Unknown
3/28/2008	Bridge of the Gods	Harbor Seal
4/12/2008	Bradford Island Exit	Harbor Seal
5/4/2008	Wind River (Near Carson, WA)	Unknown
5/16/2009	Bonneville Dam forebay (multiple sightings)	C697
1/25/2010	Bonneville Dam forebay (trapped)	C697
4/22/2010	Bonneville Dam forebay	(C03)
5/5/2010	The Dalles Dam tailrace (The Dalles, OR)	(C03)
5/10/2010	The Dalles Dam tailrace (The Dalles, OR)	(C03)
5/12/2010	Bonneville Dam forebay	(C03)
5/18/2010	Bonneville Dam forebay (trapped)	C03

Note – C03 was branded on May 18, 2010 after capture in the forebay. It is assumed this was the same sea lion observed up at The Dalles and in the Bonneville forebay on the other dates.