EVALUATION OF PINNIPED PREDATION ON ADULT SALMONIDS AND OTHER FISH IN THE BONNEVILLE DAM TAILRACE, 2016

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EXECUTIVE SUMMARY

California sea lions (*Zalophus californianus*) and Steller sea lions (*Eumetopias jubatus*) aggregate seasonally at the base of Bonneville Dam, where they feed on several fish species including stocks of Pacific salmon and steelhead (*Oncorhynchus spp.*), many of which are protected under the Endangered Species Act. The U.S. Army Corps of Engineers has been monitoring the seasonal presence, abundance, and predation activities of pinnipeds at the dam since 2002. In 2016, we documented the second largest number of pinnipeds at the dam and the second largest estimate of salmonid predation to date. Non-lethal pyrotechnic deterrents were used with limited effectiveness. Since 2008, Oregon Department of Fish & Wildlife and Washington Department of Fish & Wildlife (the States) have staffed a branding and removal program for California sea lions. The States removal program was their most successful to date.

This season, from January 1 to May 31, 190 unique individual pinnipeds were documented: 149 California sea lions, 41 Steller sea lions, and no harbor seals (*Phoca vitulina*). The maximum number of pinnipeds observed at the project on any one day was 120 (daily mean abundance was 28.8 pinnipeds). The daily mean abundance of California sea lions was 10.8. The daily mean abundance of Steller sea lions was 18.0.

Surface observation was used to estimate the number of fish consumed by pinnipeds in the Bonneville Dam tailrace. The estimated consumption of adult salmonids (including jacks) was 9,525 fish or 5.8% of adult salmonid passage between January 1 and May 31, 2016. This is the highest percentage of the run taken by pinnipeds in the Bonneville Dam tailrace since monitoring began in 2002. California sea lions consumed an estimated 6,676 adult salmonids and Steller sea lions consumed an estimated 2,849 adult salmonids. An estimated 143 winter steelhead were consumed by pinnipeds with Steller sea lions consuming the majority, 122 or 4.4% of the steelhead passing the dam between January 1 and March 31. Pacific lamprey (*Entosphenus tridentatus*) estimated consumption was 501, of which 82.2% (412) were attributed to California sea lions, the third highest consumption estimate since 2004. The estimated consumption of white sturgeon (*Acipenser transmontanus*) was 90 fish, with 93% (83) attributed to Steller sea lions. This is the second lowest on record since 2005 when Steller sea lions were first observed feeding on sturgeon at Bonneville Dam.

Non-lethal deterrents were utilized concurrent to the States removal program. Exclusion gates installed at all fishladder entrances kept pinnipeds out of the fishways. Additional barriers were constructed and installed to increase the height of the floating orifice gates at Powerhouse Two to prevent Steller sea lions from climbing into the fish channel. Active hazing from the dam face and by boat crews utilizing acoustic and tactile deterrents continued to have short-term effectiveness. Since 2008, the States have staffed a removal program for California sea lions regularly observed eating salmon at Bonneville Dam. In 2016, they removed 59 California sea lions. To this point, the States have not requested authority to remove Steller sea lions under Section 120 of the Marine Mammal Protection Act.

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INTRODUCTION

The U.S. Army Corps of Engineers (USACE) Fisheries Field Unit (FFU) has been monitoring pinnipeds since fish managers became concerned about their foraging activities in the tailrace at Bonneville Dam. California sea lions (*Zalophus californianus)* have been sporadically documented in the Bonneville Dam tailraces throughout the 1980's, with one or two noted predating on adult salmonids (Stansell 2004). In 2001, during one of the largest spring Chinook salmon (*Oncorhynchus tshawytscha)* runs ever recorded since the completion of Bonneville Dam in 1938, up to six California sea lions (CSL) were observed at one time feeding in the tailrace. By 2002, the FFU initiated surface observations to monitor pinniped abundance and predation activities at the dam. In that year, at least 30 CSL were documented in the tailrace consuming approximately 1,000 adult salmonids (Stansell 2004). Several years of strong spring Chinook salmon runs from 2001 – 2004 were concurrent with an increasing aggregation of CSL at the dam and predation of adult salmonids more than doubled. The first Steller sea lions (*Eumetopias jubatus)* were observed in the Bonneville Dam tailrace in 2003 and their numbers have increased annually. One or two harbor seals (*Phoca vitulina)* have occasionally been observed in the tailraces during monitoring. Although the current abundance of CSL and Steller sea lions (SSL) in the Columbia River at Bonneville Dam is a recent trend, archeological phocid "seal" remains have been found as far up the Columbia River basin as river kilometer 323 (river mile 201) at Celilo Falls, which is now inundated by The Dalles Reservoir (Lyman et al. 2002).

The USACE pinniped monitoring program was developed to fulfill requirements set forth in the Federal Columbia River Power System Biological Opinion (NMFS 2000, 2008). This Biological Opinion outlines operational criteria for dams in order not to jeopardize the continued existence of fish species listed as threatened or endangered under the Endangered Species Act (ESA).

Two Reasonable and Prudent Alternatives (RPA) outlined under the predation management strategy, are specific to pinnipeds at Bonneville Dam:

RPA Action 49 - Marine Mammal Control Measures
The Corps will install and improve as needed sea lion excluder gates at all main adult fish ladder entrances at Bonneville Dam annually. In addition, the Corps will continue to support land and water based harassment efforts by the National Oceanic and Atmospheric Administration (NOAA) Fisheries, Oregon Department of Fish &Wildlife (ODFW), Washington Department of Fish & Wildlife (WDFW), and the Tribes to keep sea lions away from the area immediately downstream of Bonneville Dam.

RPA Action 69 - Monitoring Related to Marine Mammal Predation
The Action Agencies will estimate overall sea lion abundance immediately below Bonneville Dam. Monitor the spatial and temporal distribution of sea lion predation attempts and estimate predation rates. Monitor the effectiveness of deterrent actions (e.g., exclusion gates, acoustics, harassment and other measures) and their timing of application on spring runs of anadromous fish passing Bonneville Dam.

The pinniped monitoring program is part of a collaborative effort to better understand and manage pinniped impacts on salmonid runs, particularly on evolutionarily significant units (ESU) of Columbia River spring Chinook salmon and distinct population segments of steelhead (*Oncorhynchus mykiss*) listed under the ESA. Due to high density of predators and low prey density, data suggests that early migrating salmonid stocks are disproportionately impacted by pinniped predation (Keefer et al. 2012), specifically ESU stocks from the Icicle, Salmon, Deschutes, Clearwater, and Umatilla rivers which have the greatest temporal overlap with pinnipeds. Of these, the Icicle and Salmon River populations are listed as threatened under the ESA (Good et al. 2005). To address these concerns, the USACE and its agency partners have used a variety of deterrents and barriers to inhibit predation in and around fishway entrances and to dissuade naïve pinnipeds from becoming habituated to Bonneville Dam.

On January 27, 2016, the states of Oregon, Washington, and Idaho (the States) submitted a request to NOAA Fisheries to extend the letter of authorization (LOA) granted on March 15, 2012 under Section 120 of the Marine Mammal Protection Act (MMPA) to permanently remove CSL at Bonneville Dam that were having significant negative impacts on the recovery of ESA-listed Chinook salmon and steelhead stocks (NOAA 2015). The States did not request any changes or modifications to the terms and conditions of the 2012 LOA. The requested extension was approved on July 7, 2016 for an additional five years (U.S. Office of the Federal Register 2016). To date, 161 CSL have been removed under the initial authorization from 2008.

This report is a summary of monitoring and deterrence efforts implemented in 2016 by, or coordinated with, the USACE, ODFW, WDFW, NOAA, Columbia River Inter-Tribal Fish Commission (CRITFC), and the U.S. Department of Agriculture (USDA). Data from 2002-2015 are also presented here for comparison.

OBJECTIVES

1. Determine the seasonal timing and abundance of pinnipeds present at the Bonneville Dam tailrace, documenting individual California sea lion (CSL) and Steller sea lion (SSL) presence and predation activity when possible.

2. Monitor the spatial and temporal distribution of pinniped predation attempts and estimate the number of adult salmonids (*Oncorhynchus sp*.), white sturgeon (*Acipenser transmontanus*), Pacific lamprey (*Entosphenus tridentatus*), and other fishes consumed by pinnipeds in the Bonneville Dam tailrace and estimate the proportion of the adult salmonid run consumed.

3. Monitor the effectiveness of deterrent actions (e.g., exclusion gates, acoustics, harassment and other measures) and their timing of implementation on spring runs of anadromous fish passing Bonneville Dam.

METHODS

STUDY AREA

Bonneville Lock and Dam is located on the Columbia River at river kilometer 235 (river mile 146) from the confluence of the Pacific Ocean. The dam spans the Columbia River between the states of Oregon and Washington and is comprised of three main concrete structures separated by islands. Pinniped observations were taken at each of the three tailrace sub-areas downstream of Powerhouse One (PH1), Powerhouse Two (PH2), and the Spillway (SPW) (Figure 1). Each tailrace sub-area is divided into seven zones to designate the location of predation events. Pinniped observations were also conducted at Tower Island, a landmass that separates PH1 tailrace from the downstream approach to the old navigation lock. It is regularly used as a haul-out for pinnipeds at Bonneville Dam. In 2016, the States anchored three floating sea lion traps in the vicinity of Tower Island and one in the PH1 forebay during the months that CSL were present. Additional observations were conducted at Tanner Creek, approximately 1 mile downstream of Bonneville Dam.

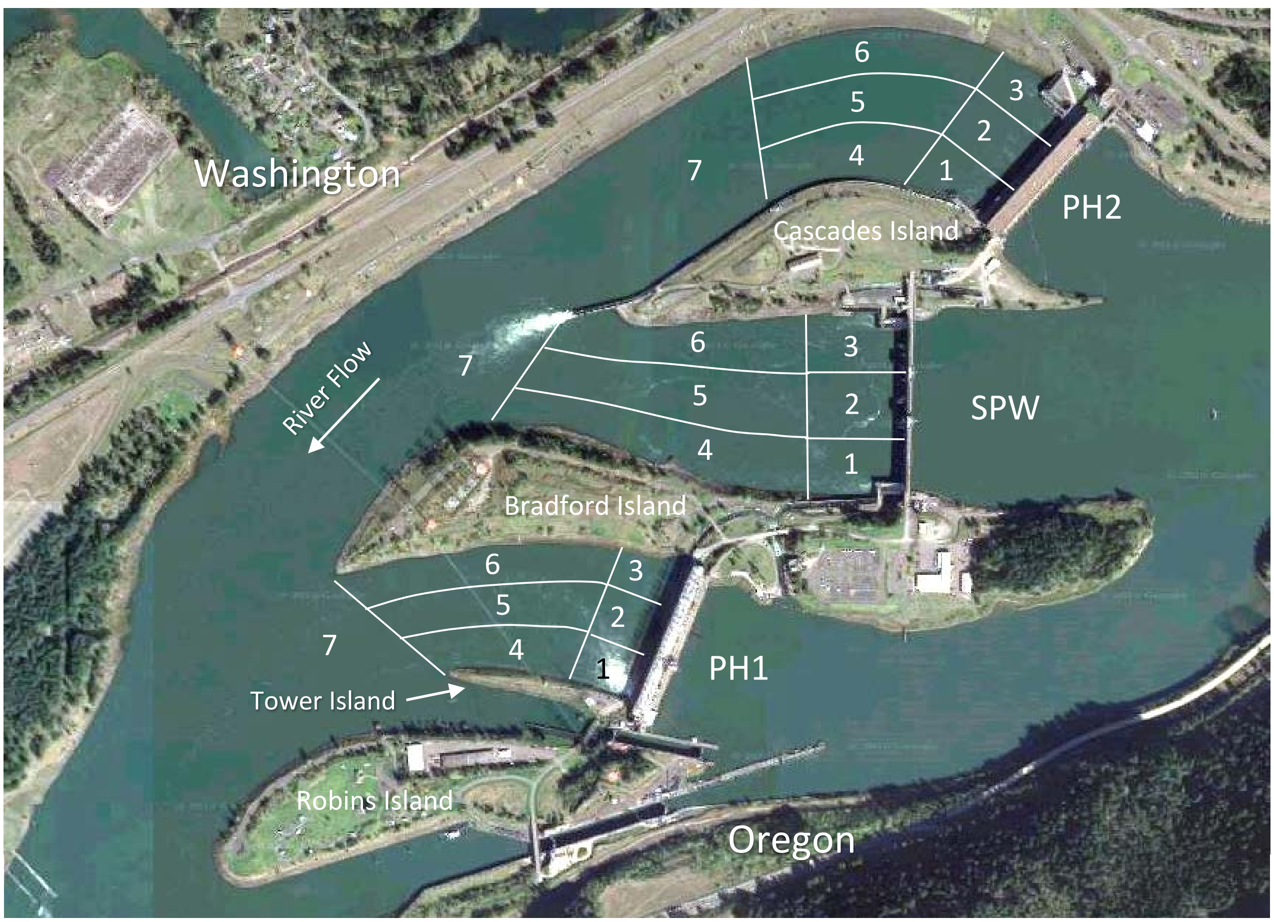

Figure 1. Bonneville Dam study area with Powerhouse One (PH1), Spillway (SPW), and Powerhouse Two (PH2) tailrace sub-areas separated into zones for assigning the location of predation events.

SAMPLING DESIGNS

The number of sampling hours and duration of the pinniped monitoring program from 2002 to 2016 has varied but the methods of data collection have remained the same. Samplers perform surface observation with the aid of binoculars (8x42, 10x50) to collect abundance and predation data. For a more complete description of data collection protocols and assumptions refer to Tackley et al. (2008) and Stansell et al. (2010). Data collection in previous years has suggested that sampling effort could be reduced through the early part of the study period without decreasing the accuracy of the predation estimates. Therefore in 2016 sampling effort was reduced in January through February in order to focus limited personnel to conduct observations March through May when the bulk of the predation occurs. When comparing data among years caution is advised as varying start dates over the years and differing levels of observation effort between seasons has occurred.

In 2016, pinniped predation on Chinook salmon, steelhead, white sturgeon, and Pacific lamprey were estimated using data collected with a stratified sampling design (Cochran 1977). Two types of stratified sampling designs were applied during the main field season. As past data illustrates, pinniped abundance is typically low in January and February, and thus a stratified random sampling design was used from January 3 until February 6. A stratified systematic sampling design was used from February 7 until May 28. We switched sampling designs to make scheduling of observation hours less cumbersome. We found that using a random sampling design made it difficult to allow observers to work a normal 8 hour per day schedule with set start and end times. By switching to a systematic sampling design we assured more even coverage of three tailrace sub-areas while allowing the observers to have a set schedule for each strata. Predation data from both sampling designs were processed as stratified random samples (Cochran 1977).

The stratum used in both sample designs was a seven-day week (Sunday-Saturday). There were 21 strata (weeks) during the study period between January 3 and May 31. Five of seven days (Monday-Friday) were sampled during each stratum except the weeks with a federal holiday when four days were sampled. The sample rate for each stratum was chosen prior to the start of each week's sampling. The sample rate, expressed as the percentage of daylight hours sampled per stratum, was based on the number of personnel available in a given week and the expected level of pinniped abundance and predation. The sample period was a 1-hr block during daylight at a given tailrace sub-area (e.g. 0800-0859 at PH2 tailrace).

The first half of the study period (strata 1-10) had sample rates ranging from 18.5 to 25.4 percent of daylight hours sampled per stratum across all three sites. The difference in sample rates between the first and second halves of the study period were chosen based on data from previous years. Specifically, January through March typically has 90% fewer pinnipeds and less predation compared to April and May when the number of pinnipeds increases concomitant to the arrival of the spring Chinook salmon run (Stansell et al. 2014). The second half of the study period (strata 11-21) sample rates were increased ranging from 40.5 to 47.6 percent of daylight hours sampled per stratum across all three sites.

Stratified random sampling design

Two observers sampled from January 3 through February 6, 2016. The sample rate at the start of each stratum (week) was based on the number of potential daylight hour blocks that could be sampled. Daylight hours were determined by looking at the times of civil twilight (morning), sunrise, sunset, and civil twilight (night) for Cascade Locks, OR located six miles west of Bonneville Dam. Sampling began during the first full hour there was enough daylight to successfully identify pinnipeds and see predation events. The last hour of the potential sample period is handled in the same manner as the first hour.

Due to staffing restrictions and coverage necessity there were deviations from a truly randomized sample. The first deviation was that sampling was only conducted Monday through Friday. The next deviation was that sample hours were equally spread throughout the five day period. This was accomplished by selecting a starting tailrace sub-area for the week using a 'true random number generator' (Haahr). Once the starting tailrace sub-area was chosen, a 'random integer generator' was used to produce a list of 100 random integers of the daylight hour blocks associated with each stratum. This list was then used to populate the hours that would be sampled for the entire stratum. The total number of hour blocks to be sampled during the stratum were divided equally among the five sample days. From the designated starting tailrace sub-area, observation areas were assigned the randomized hours of observation in the order of location from south to north. Since there were two observers available, all three tailrace sub-areas could not be observed during the same hour. If this did occur when assigning the randomized sample hours, then the third identical number chosen would be discarded and the next number on the randomized list would be used for the sample hour at that location.

Stratified systematic sampling design

The sample rate was based on the number of daylight hour blocks that could be sampled. This was determined in the same manner as described in the stratified random sampling design section. The number of observers increased from two to four during this time period as the number of daylight hours increased.

From February 7 until March 12, observations were conducted in one of the three tailrace sub-areas during each hour block throughout the daylight hours. Two observers conducted the bulk of observations, one would work the morning shift and the other would work the afternoon shift. A tailrace sub-area was randomly chosen to be the first sample location for each day in the stratum. Once the initial tailrace sub-area was chosen, then the observer would move in order from south to north through the other sub-areas. This order of sampling would be maintained throughout the day until observations for that day ended.

From March 13 until May 28, observations were conducted in two tailrace sub-areas simultaneously during each sample hour. Four primary observers were used to conduct the bulk of the observations with additional observers covering the break hour for the primary observers. Two tailrace sub-areas were randomly selected as the starting points for each day. The tailrace sub-areas were systematically sampled in the same manner as the early portion of the stratified systematic sampling frame.

Additional observations were conducted at the mouth of Tanner Creek as time allowed. Tanner Creek is in close proximity to the Bonneville Dam tailrace and is a known location of salmonid predation by pinnipeds. Observations conducted at Tanner Creek were sporadic and were not used to estimate predation in the Bonneville Dam tailrace.

ABUNDANCE

Pinniped abundance was estimated daily and for the entire season to track the number of pinnipeds present in the immediate tailrace of Bonneville Dam during 2016 and to compare with previous years. Point counts of pinnipeds were conducted to determine the minimum number of CSL and SSL present in the tailrace each observation day. Point counts were taken a minimum of three times per day and were spread throughout the day so that the morning, mid-day, and evening each had at least one point count. Point counts included tallying both pinniped species at the three tailrace sub-areas, the Tower Island haul-out, and the mouth of Tanner Creek. Point counts from all areas were compiled to calculate the total point count (abundance) for the Bonneville Dam tailrace. The highest point counts for each pinniped species were combined to calculate the daily pinniped abundance estimate for the Bonneville Dam tailrace for each observation day.

Identification of individual CSL and SSL was used to determine the annual pinniped abundance which equates to the overall minimum number of individual pinnipeds present during the entire study period. Individual identification is also utilized to track individual pinnipeds within and among years. We used photography, videography, field sketches and observer notes to identify individual CSL and SSL and to confirm the identities of individual pinnipeds. Individual pinnipeds were identified by noting a combination of physical characteristics such as human-applied brands, scars, color patterns, body size, maturity, and also behaviors. Unique brands are applied by the States to captured CSL in order to identify individuals from within the population. Some CSL occur at the dam prior to being individually identified therefore, as stated above, within and among year comparisons should be considered minimum estimates. A catalog of photos and sketches of all individual pinnipeds is maintained and updated annually.

Pinniped abundance estimates were also completed during the fall. In recent years it has been noted that pinnipeds (mainly SSL) are arriving at the Bonneville Dam tailrace as early as August. To address data needs, USACE began monitoring the number of pinnipeds present from August through December in 2011. Abundance estimates from August through December are focused at four locations in the tailrace. The four locations are PH1, PH2, SPW and the Tower Island haul out site. Predation data were collected from 2011 to 2013 (Stansell et al. 2014).

The movement of pinnipeds from the Bonneville Dam tailrace to the forebay is documented through sightings collected in the Bonneville pool above the dam, and further upriver at The Dalles marina docks, and The Dalles Dam tailrace. Pinnipeds captured on the trap in the forebay that are not listed for removal are moved back down stream and released. To reduce pinniped access to the forebay, Bonneville Dam has developed a policy to keep the downstream gates of the navigation lock closed at all times, except for the time that it takes for vessels to enter or exit the lock.

PREDATION

Surface observations are a useful tool for assessing pinniped predation (Roffe and Mate 1984) as CSL and SSL come to the surface to thrash large prey, such as Chinook salmon, into pieces small enough to swallow. However, in recent years, SSL (larger than CSL) have been observed with steelhead and Chinook jacks already partially swallowed when they arrive at the water's surface. This ability to swallow adult salmonids whole suggests that SSL may be able to consume them entirely underwater. Nonetheless, we have no information on how frequently this might happen. All adult salmonid consumption estimates outlined in this report should be considered minimum estimates.

Methods to account for the number of salmonids and other fish eaten by pinnipeds during the life of this monitoring program have been consistent, but there have been some refinements to improve them. Primarily to integrate unidentified fish species catches the initial 'consumption estimate' evolved to the latter 'adjusted consumption estimate' (Tackley et al. 2008). We believe the adjusted consumption estimate is our best estimate and the truest reflection of what we observe in the field. For continuity's sake, we report both here.

Consumption Estimates

Surface observation data was used to estimate pinniped consumption of fish in these categories: salmonids, Chinook salmon, steelhead, white sturgeon, Pacific lamprey, and unidentified fish which are typically too far away for an observer to identify. Using Cochran's stratified sampling design, we calculated the estimated mean catch per stratum and the overall mean catch, with 95% confidence intervals (CI), as described in Appendix A (Cochran 1977). Unidentified fish are accounted for with the adjusted consumption estimate.

Adjusted Consumption Estimates

The adjusted consumption estimate assigns unidentified fish catches per stratum divided by identified fish catches that were recorded for each pinniped species for that stratum. For example, if there were 20 identified fish catches and four unidentified fish catches during that week occurred and 10 of those were Chinook salmon and 10 of those were steelhead then the four unidentified fish catches would be proportionally distributed to two Chinook salmon and two steelhead. Once unidentified fish catches are partitioned, then the adjusted consumption estimate can be made by calculating in the same manner as the consumption estimate from the previous section.

We also report the percentage of salmonids passing Bonneville Dam that were consumed by pinnipeds. This is calculated by dividing the salmonid consumption estimate (above) by the total adult salmonid passage count (daytime counts, all adult salmonids including jacks) from January 1 through May 31 or as described plus the salmonid consumption estimate then multiplied by 100. Salmon counts were taken from the USACE Fish Counts and Reports adult fish count website.

DETERRENTS AND MANAGEMENT ACTIVITIES

To protect migrating adult salmonids in the Bonneville tailrace, non-lethal deterrents (hazing) are used to chase pinnipeds from the tailrace area. Hazing was conducted from both ground and boat. Sea lion deterrents used by USDA dam-based (ground) hazers at Bonneville Dam included cracker shells and rubber buckshot fired from 12 gauge shotguns from the tailrace deck. Boat-based hazing was conducted by CRITFC and included boat chasing, cracker shells fired from 12 gauge shotguns, and underwater percussive devices known as seal bombs. The CRITFC hazing boat mainly operated in the Bonneville Dam tailrace boat restricted zone. The boat crew typically consisted of a pilot, a hazer, and one or more spotters to help locate pinnipeds. For fish passage and safety, boat-based hazing is not allowed within 100 feet of dam structures or within 165 feet of fishway entrances. In order to minimize the impact to fish, the use of seal bombs was prohibited within 330 feet of fishways, collection channels, or fish outfalls for the PH2 corner collector and smolt monitoring facility. The use of seal bombs in 2016 ceased completely in the tailrace on April 9 after adult salmonid passage exceeded 1,000 fish per day at Bonneville Dam. More detailed information on boat-based hazing activities are described by Wright et al. 2007 and Brown et al. 2014.

Pinnipeds have been documented entering fishways (fish ladders) at Bonneville Dam (Tackley et al. 2008). California sea lions entered the fishway through the ladder entrance in 2005, then SSL entered by climbing over the floating orifice gates (FOGs) in 2016. In response, specially designed gates called Sea Lion Exclusion Devices (SLEDs) have been installed prior to February 1 at all eight main fishway entrances of Bonneville Dam (Appendix B). They are essentially huge grates with rounded edges (for fish safety and hydraulic efficiency) creating openings of 15.4” wide slots. They allow migrating fish to enter the fishway but exclude pinnipeds. In addition to the eight sea lion exclusion gates, there are smaller sea lion exclusion grating installed on the sixteen FOGs along the face of PH2 that allow fish to enter the collection channel and pass via the Washington shore fishway. The FOGs at PH2 provide additional fishway entry points for migrating adult salmonids, but the installed gratings are sized to preclude pinniped entry. In 2016, temporary sea lion incursion barriers (SLIBs) were constructed for the purpose of providing four feet of additional height on top of the FOGs (Appendix B).

The States operated three floating sea lion traps (Brown et al. 2016) in the Bonneville Dam tailrace and one in the forebay during April and May. A camera mounted at the sea lion traps recorded images of hauled out pinnipeds and aided in verifying the presence of individually branded CSL. The sea lion traps were used to capture CSL for branding, outfitting with transmitters, and permanent removal of individual CSL that qualified under Section 120 of the MMPA. Steller sea lions that were captured in the floating sea lion traps were released back into the tailrace without additional handling.

RESULTS

ABUNDANCE

<u>Annual Pinniped Abundance</u>

The minimum estimated number of individual pinnipeds that were observed in the tailrace areas of Bonneville Dam since monitoring began in 2002 are displayed in Table 1. California sea lion abundance has ranged from 30 in 2002 to a high of 195 in 2015 and SSL abundance has ranged from 0 in 2002 to a high of 89 in 2011. In 2016, we documented a total of 149 individual CSL at Bonneville Dam, all of which were branded. Of these, 90 have been seen in multiple years and 59 were newly identified. This represents the second largest annual number of identified CSL to date. We documented 41 unique individual SSL this season. Of these, 36 were observed in previous years and five were newly identified.

Table 1. Minimum estimated number of individual pinnipeds observed at Bonneville Dam tailrace areas and the hours of observation from January 1 to May 31, 2002 to 2016.

Year	Total Hours Observed	California Sea Lions	Steller Sea Lions	Harbor Seals	Total Pinnipeds
2002	662	30	0	1	31
2003	1,356	104	3	2	109
2004	516	99	3	2	104
2005*	1,109	81	4	1	86
2006	3,650	72	11	3	86
2007	4,433	71	9	2	82
2008	5,131	82	39	2	123
2009	3,455	54	26	2	82
2010	3,609	89	75	2	166
2011	3,315	54	89	1	144
2012	3,404	39	73	0	112
2013	3,247	56	80	0	136
2014	2,947	71	65	1	137
2015	2,995	195	69†	0	264
2016	1,974	149	54‡	0	203

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

† In 2015, the minimum estimated number of Steller sea lions was 55. This number was less than the maximum number of Steller sea lions observed on one day, so the maximum number observed on one day was used as the minimum estimated number.

‡ In 2016, the minimum estimated number of Steller sea lions was 41. This number was less than the maximum number of Steller sea lions observed on one day, so the maximum number observed on one day was used as the minimum estimated number.

Daily Pinniped Abundance

California sea lions were first observed in the tailrace areas of the dam on February 26, increasing in numbers through early May before departing by the end of May (Figure 2). The daily average of CSL was 3.5 (CI 2.7-4.3) in March, 22.2 (CI 18.7-25.7) in April, and 26.8 (CI 20.0-33.7) in May. The maximum number of CSL observed on a single day at the dam was 66 on May 4.

Steller sea lions were present when observations began January 4, increasing in number through April before departing by the end of May (Figure 2). The daily average of SSL was 12.8 (CI 12.0-13.7) in January, 4.7 (CI 3.8-5.7) in February, 13.6 (CI 10.7-16.6) in March, 40.1 (CI 37.6-42.6) in April, and 18 (CI 11.4-24.6) in May. The maximum number of SSL observed on a single day at the dam was 54 on May 4.

Pinniped abundance has increased substantially in the last two years. In 2016, the maximum number of pinnipeds (CSL and SSL combined) on a single day was 120 on May 4 which surpassed the previous recorded single day high of 116 on April 22, 2015. Pinniped abundance for 2016 (January 1 through May 31) in comparison with the 10 year average is shown in Figure 3. The mean daily number of pinnipeds present in 2016 was 28.8 (CI 24.2-33.3), which is less than mean of 37.8 in 2015 but more than any other year since 2002 (Figure 4).

Figure 2. Maximum daily count of pinnipeds by species (interpolated for weekends) at Bonneville Dam from January 1 through May 31, 2016. No harbor seals were observed in 2016.

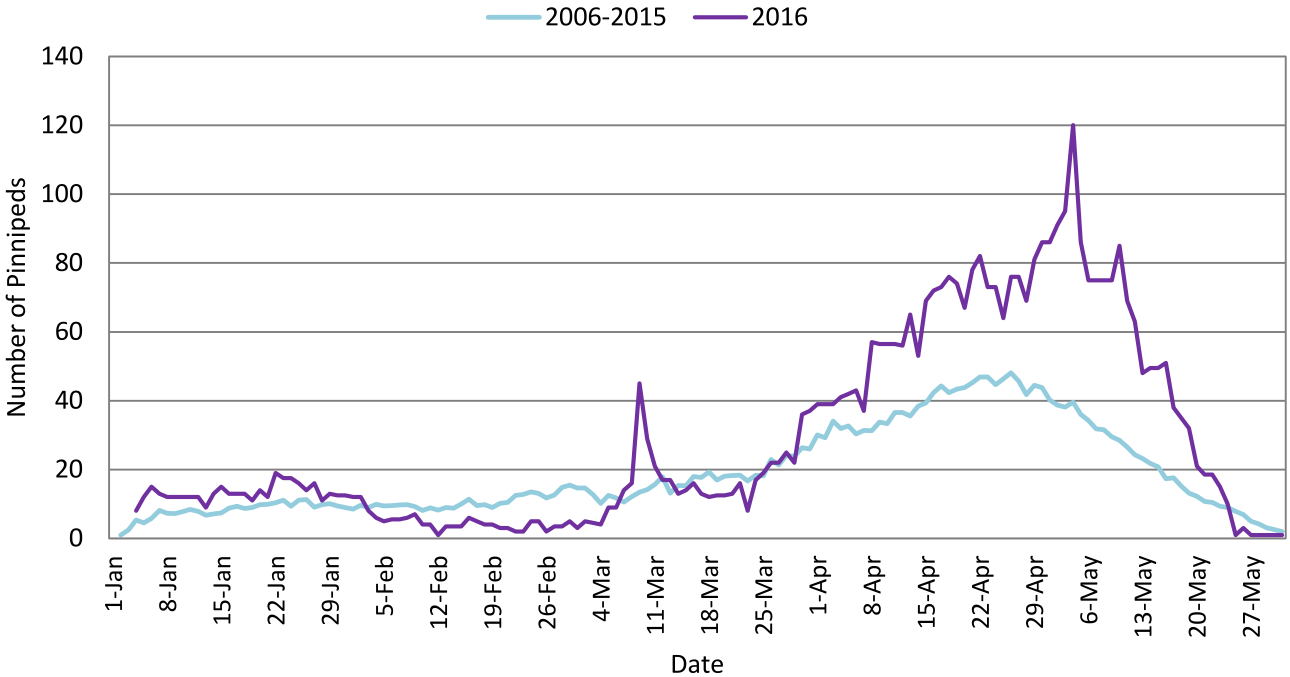

Figure 3. California and Steller sea lion combined maximum daily count (interpolated for weekends) at Bonneville Dam from January 1 through May 31, 2016 compared to the 10-year average (2006-2015).

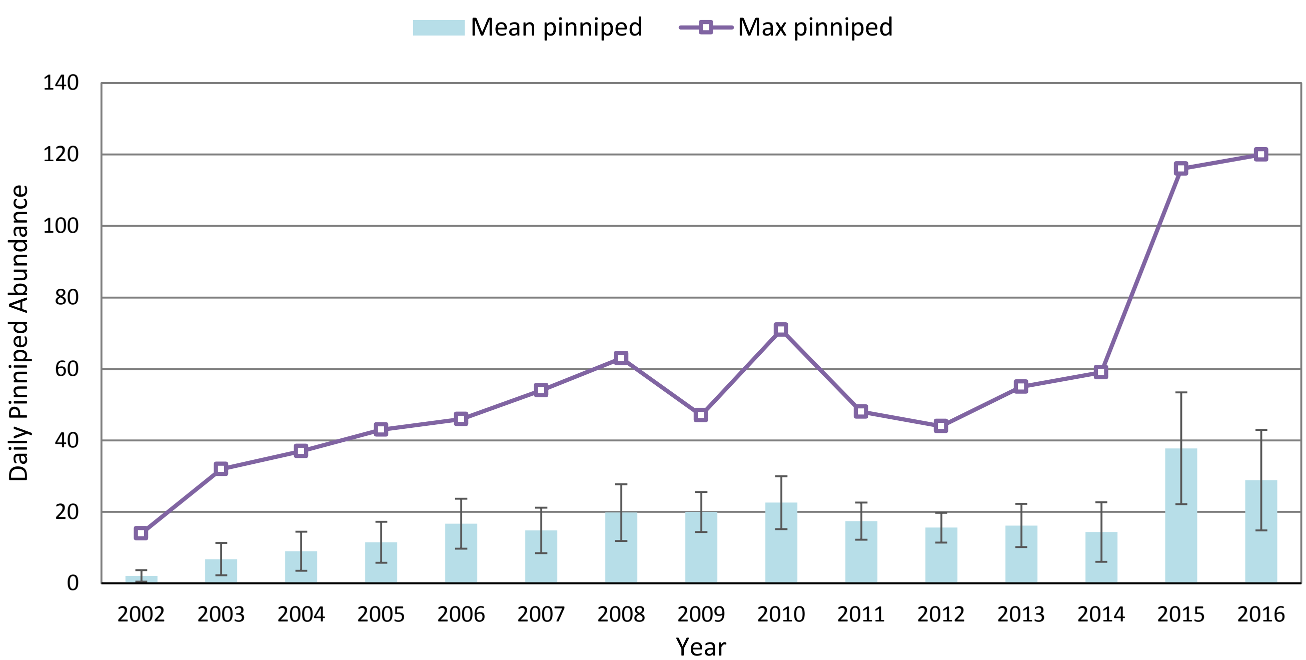

Figure 4. Annual mean daily and maximum abundance of pinnipeds present at Bonneville Dam between January 1 and May 31, 2002 to 2016. Error bars are ± one standard deviation.

The average daily number of CSL present in 2016 was 10.8 (CI 8.4-13.2) per day ranking sixth highest over the past 15 years (Figure 5). The highest average daily abundance of 18.5 occurred in 2015 and the lowest in 2002. The maximum daily count of 66 CSL ranked second highest behind the maximum daily count of 70 CSL in 2015. The lowest maximum daily count of 14 CSL occurred in 2002 and 2012.

The average daily number of SSL present in 2016 was 18.0 (CI 15.5-20.5) per day ranking second over the past 15 years (Figure 5). The highest average daily abundance of 19.3 occurred in 2015 and the lowest in 2003. The maximum daily count of 54 SSL ranked second highest behind the maximum daily count of 69 SSL in 2015. There were no SSL at Bonneville Dam in 2002.

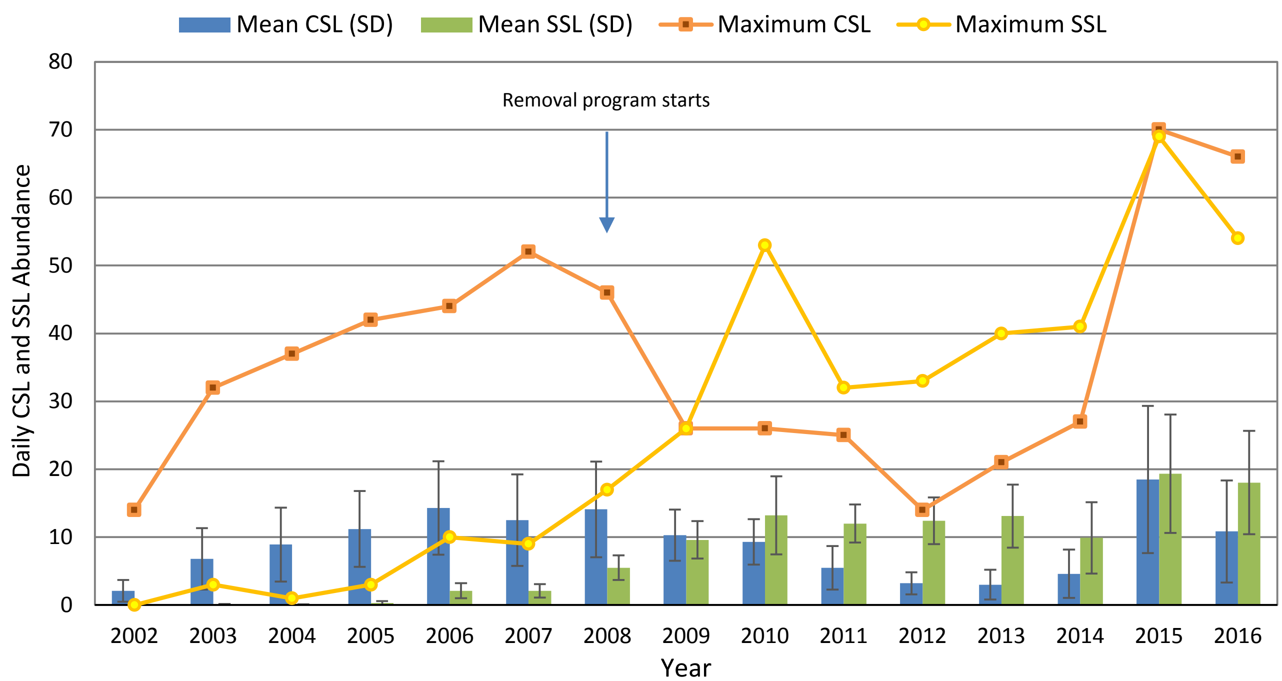

Figure 5. Abundance of California sea lions (CSL) and Steller sea lions (SSL) present at Bonneville Dam from January 1 through May 31, 2002 to 2016. Error bars are ± one standard deviation.

<u>Fall Abundance</u>

During the period between August and December, SSL have been observed in increasing numbers (USACE 2016). The mean daily abundance of SSL has ranged from 3 per day in October 2011 to a mean of 22 per day in 2015. The maximum fall count of 30 SSL occurred on Nov 25, 2015. Residence times for SSL has increased to 10 months of the year. California sea lions have occasionally been observed in the fall but unlike SSL their numbers have remained low averaging less than one per day.

Residence Times

Residence times for CSL were among the shortest recorded over the past 15 years. The mean number of days that individually identified CSL were observed in the Bonneville Dam tailrace in 2016 was 4.7 (CI 4.0-5.3) (Figure 6). This is similar to that of the last five years, 2011-2015, during which time the mean number of days ranged from 8.5 to 4.1 and well below the five years before that, 2006-2010, when the mean number of days ranged from 9.7 to 19.7. The maximum number of days that an individual CSL was observed this year at Bonneville Dam was 23 days. Only three years were fewer than that, 2002 and 2013, at 16 days and 2014 at 20 days. Residence times have decreased since 2009 the year after pinniped removals were initiated by the States.

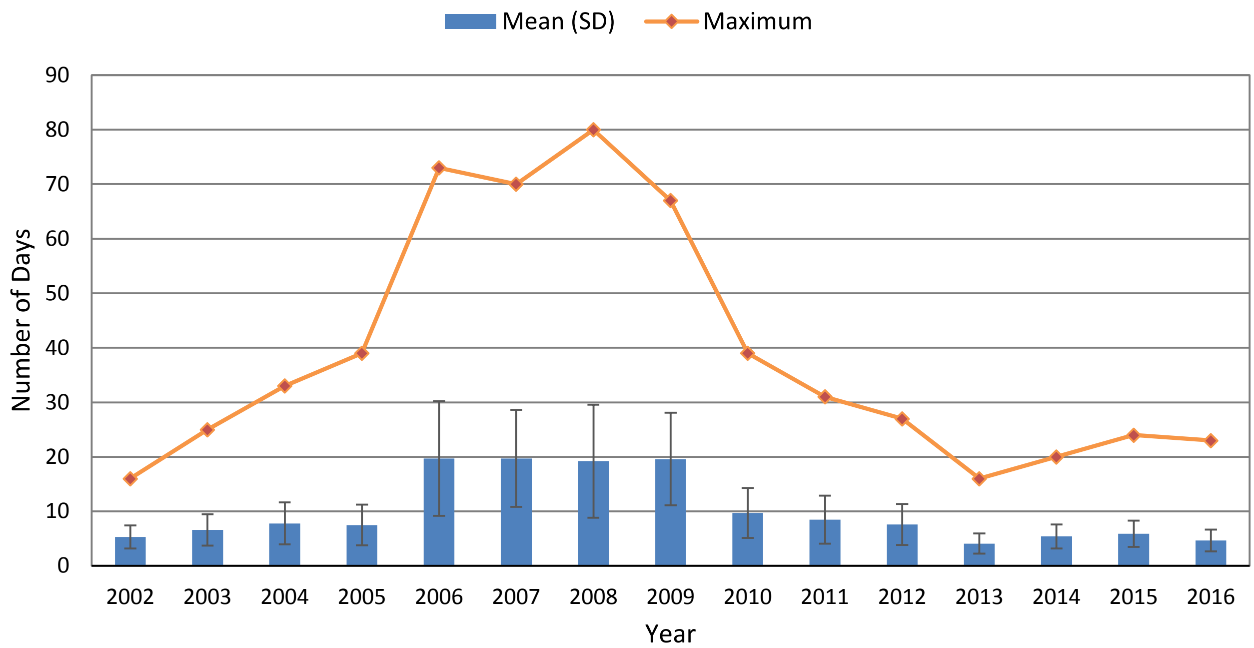

Figure 6. The mean and maximum number of days individually identified California sea lions (CSL) were observed at Bonneville Dam between January 1 and May 31, 2002 to 2016. Error bars are ± one standard deviation.

Recurrence

The ability to identify individual CSL through brands and/or unique natural markings has been essential in tracking the recurrence of repeat animals at Bonneville Dam both within and among years. During 2016 there were 149 identified individual CSL, 40% (59) of which were newly identified and 60% (90) were repeat animals. The majority of repeat animals, 89% (80), were returning individuals first identified in 2015. Very few (10) identified CSL were documented as repeat animals for more than two seasons (Table 2). Of the CSL identified in 2016, the maximum number of seasons that an identified CSL was observed was seven and that individual was captured and removed in 2016. As some CSL may occur at the dam prior to individual identification (i.e. branding) recurrence is likely biased low.

Of the 149 individually identified CSL in 2016, 90 of them were animals listed either prior to or during the season. All but two of the CSL observed for three or more seasons have been permanently removed by the States as authorized by their Letter of Authorization under section 120 of the MMPA.

There were 41 individually identified SSL documented in 2016 (Table 2). Of these, 12% (5) were newly identified and 88% (36) were repeat animals. Of the repeat animals, 75% (27) have been documented for more than two seasons. The maximum number of seasons an individually identified SSL recurred is 10. In comparison with the CSL, few SSL have brands making identification of individual SSL more challenging. Similar to CSL, the actual number of repeat SSL is likely higher.

Table 2. Number of years that individual Steller sea lions (SSL) and California sea lions (CSL) identified in 2016 were observed at Bonneville Dam. Of the identified CSL in 2016, the number of CSL listed for removal and the number of CSL removed. Individuals present for one year were newly identified animals in 2016.

Number of Years Observed	All Identified SSL	All Identified CSL	Listed for Removal CSL	Removed CSL
10	1	0	0	0
9	1	0	0	0
8	1	0	0	0
7	3	1	1	1
6	3	0	0	0
5	8	0	0	0
4	2	2	2	2
3	8	7	6	5
2	9	80	67	48
1	5	59	14	3
Totals	41	149	90	59

Note: Data in this table includes trap camera photo identification data shared by the States.

<u>Forebay Observations</u>

In 2016, there were fewer reports of pinniped sightings in the forebay compared to the previous year. In early March, FFU personnel received reports of two unbranded CSL that were observed in the forebay of Bonneville Dam. On March 8, a navigation lock operator reported a SSL inside the lock after the downstream gates were closed. The operator opened the downstream gates and the SSL exited the navigation lock into the tailrace. A branded CSL (U625) was first observed in the forebay May 18, 2015. Throughout the following fall and winter U625 remained in the forebay and was seen consistently using the trap. On January 26 2016, ODFW personnel trapped the CSL (U625), transported and released the animal on the Oregon Coast.

In 2016, The Dalles Dam (TDA) fisheries personnel noted at least two individual CSL swimming in the tailrace near the dam. A CSL (C014) has been seen occasionally at TDA since 2012 and another branded CSL (1-31) was seen briefly from April 29 to May 4. The CSL (1-31), was subsequently observed in the tailrace at Bonneville Dam on May 13. From March 28 through May 25 2016, TDA fisheries personnel documented 23 pinniped sightings.

Since April 2011, an unbranded CSL designated as B325 was observed regularly hauling out on a dock at The Dalles Marina and foraging at TDA. In March 2016, WDFW personnel found a CSL carcass along the shore near Bingen, Washington. The CSL was confirmed to be B325.

PREDATION

A total of 1,974 one hour surface observations completed during daylight hours were used to calculate predation estimates between January 4 and May 31, 2016. The percentage of daytime hours observed per week ranged from 18.5% in January to 47.6% in May. During this time pinnipeds were directly observed predating on 4,105 Chinook salmon, 102 steelhead, 232 Pacific lamprey, 30 white sturgeon, 16 smolt, 39 other fish (bass, carp, sucker, pikeminnow, etc.), and 260 unidentified fish. There were deviations from our sampling schedule during the field season that resulted in an unequal distribution of sub-area observations during some of the strata.

An additional 16.4 hours of unscheduled observations were also collected at PH1, PH2, SPW, and Tanner Creek. During this time observers recorded pinnipeds predating on 15 Chinook, 1 steelhead, 1 Pacific lamprey, and 1 unidentified fish. Additional observations can range from 5 minutes up to an hour. These data are not included in predation estimates.

Predation on Adult Salmonids

An estimated 8,969 (CI 8,602 – 9,336) adult salmonids were consumed by pinnipeds in 2016, which equates to 5.5% of salmonid passage at Bonneville Dam (Table 3 and Appendix C). This is the second highest estimated salmonid consumption since monitoring began in 2002, ranking behind the high of 9,981 in 2015. During 2015 and 2016 there has been a distinct increase in predation and the percent of salmonid passage taken has doubled previous years, with the exception of 2005-2008. The high percentages of the run that were taken in 2005 and 2007 demonstrates the impacts that pinnipeds can have on smaller run sizes. In 2016, salmonid passage (154,074) through May 31 was the sixth lowest over the past 15 years while 2015 passage was the third highest. After adjusting for unidentified fish catch the estimated consumption increased to 9,525 (CI 9,136 – 9,913) adult salmonids which equates to 5.8% of the salmon passage through May 31 (Table 3 and Appendix C). This is the highest percentage ever recorded in the Bonneville Dam tailrace since monitoring began.

The total estimated consumption of adult salmonids from January 1 to May 31 was 6,371 (CI 6,081.6 – 6,660.8) for CSL and 2,598 (CI 2,444.8 – 2,751.4) for SSL (Table 4). An estimated 71% of adult salmonid consumption was by CSL, which is 3.9% of Bonneville Dam salmonid passage for this time. Steller sea lion predation accounts for the remaining 29% of adult salmonid consumption which was

1.6% of Bonneville Dam salmonid passage from January 1 to May 31 (Table 4). The highest number of salmonid catches observed on a single day in 2016 by an individual CSL (Brand 1-57) was seven, the record high is 12 salmonids consumed by CSL (Brand C287) in 2012. From 2011 to 2014 adult salmonid consumption by CSL was at the lowest levels since monitoring began in 2002. In contrast, the last two years have had the highest salmonid consumption estimates to date (Figure 7). Additionally SSL consumption of salmonids has steadily increased every year since 2008. The adjusted consumption estimate of adult salmonids by CSL is 6,676 (CI 6,373.6 – 6978.0) and by SSL is 2,849 (CI 2,682.4 – 3015.6) (Table 4 and Appendix C).

Table 3. Consumption of adult salmonids by all pinnipeds combined, Bonneville Dam tailrace. Salmonid passage includes both adult and jack salmonids that passed Bonneville Dam from January 1 through May 31, 2002-2016.

Year	Bonneville Dam Salmonid Passage (Jan 1- May 31)	Expanded Salmonid Consumption Estimate		Adjusted Salmonid Consumption Estimate	
		Estimated Consumption	% of run (Jan 1- May 31)	Estimated Consumption	% of run (Jan 1- May 31)
2002	284,732	1,010	0.4 %	1,010	0.4 %
2003	217,934	2,329	1.1 %	2,329	1.1 %
2004	186,771	3,533	1.9 %	3,533	1.9 %
2005	81,252	2,920	3.4 %	2,920	3.4 %
2006	105,063	3,023	2.8 %	3,401	3.1 %
2007	88,474	3,859	4.2 %	4,355	4.7 %
2008	147,558	4,466	2.9 %	4,927	3.2 %
2009	186,056	4,489	2.4 %	4,960	2.7 %
2010	267,167	6,081	2.2 %	6,321	2.4 %
2011	223,380	3,557	1.6%	3,970	1.8%
2012	171,665	2,107	1.2%	2,360	1.4%
2013	120,619	2,714	2.2%	2,928	2.4%
2014	219,929	4,314	1.9%	4,621	2.1%
2015	239,326	9,981	4.0%	10,859	4.3%
2016	154,074	8,969	5.5%	9,525	5.8%

Table 4. California sea lion (CSL) and Steller sea lion (SSL) predation on adult salmonids at Bonneville Dam, from January 1 through May 31, 2016.

Predator	Observed Salmonid Catch	Expanded Salmonid Consumption Estimate		Adjusted Salmonid Consumption Estimate	
		Estimated Consumption	% of Run (1/1 to 5/31)	Estimated Consumption	% of Run (1/1 to 5/31)
California Sea Lion	3,006	6,371	3.9%	6,676	4.1%
Steller Sea Lion	1,201	2,598	1.6%	2,849	1.7%

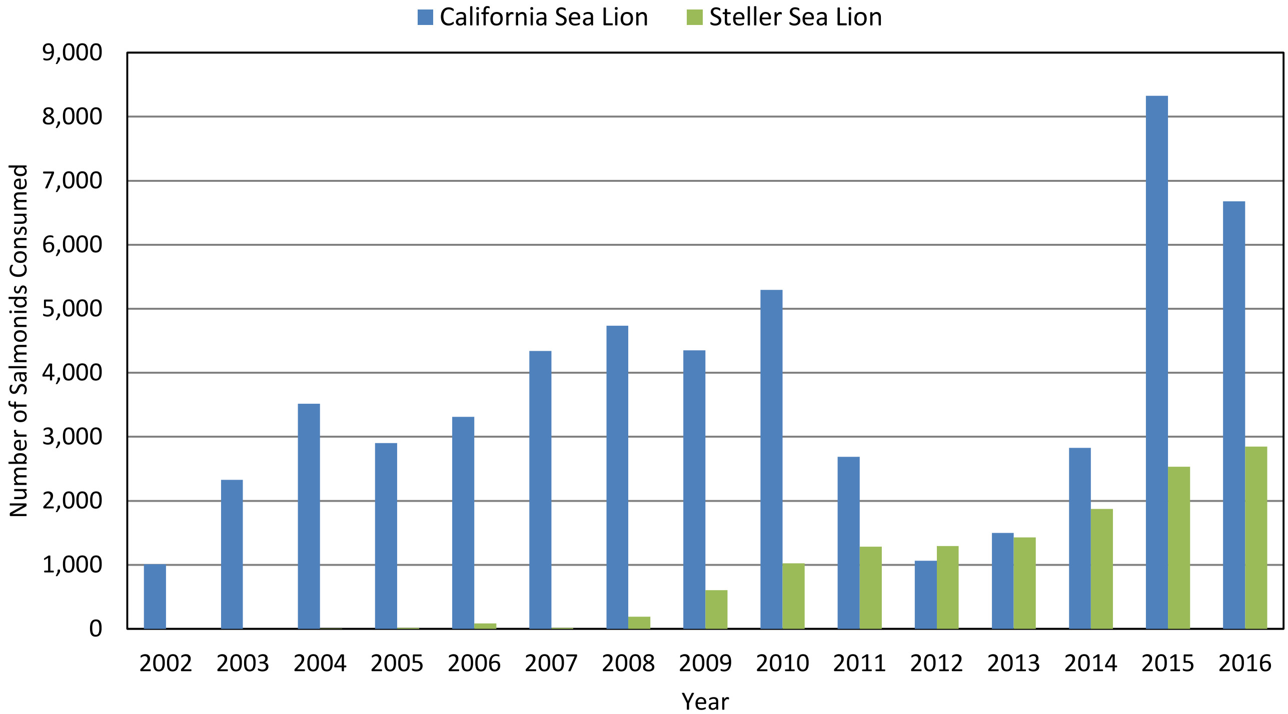

Figure 7. Adjusted estimates of salmonid consumption by California and Steller sea lions at Bonneville Dam, from January 1 to May 31, 2002 to 2016. Expanded for hours not observed, and adjusted for unidentified fish catch.

<u>Predation on Chinook Salmon</u>

Chinook salmon was the main salmonid species consumed by pinnipeds, comprising 97.6% (4,105) of observed adult salmonid catch in 2016. The spring Chinook salmon consumption estimate of 8,709 (CI 8,346 – 9,072) by all pinnipeds combined fell short of surpassing the 2015 all-time high of 9,780 but the percent of Chinook passage taken (4.5%) is the largest to date (Table 5). Note that this time period differs from the passage season used for total salmonid estimates in Table 3. The time period from January 1 through June 15 is the defined Columbia River spring Chinook passage season at Bonneville Dam, which extends beyond the period thru which sea lions are typically present. Adjusted Chinook salmon consumption was estimated to be 9,222 (CI 8,840 – 9,605). Of which, CSL were estimated to have consumed 6,538 (CI 6,238 – 6,837). The 2016 spring Chinook salmon passage numbers through June 15 of 185,633 were well below last years and ranked tenth in overall run-size since 2002. The 2007 estimated passage of 101,068 ranked the lowest and 2002's estimated passage of 316,468 ranked the highest.

Table 5. Consumption of spring Chinook salmon by pinnipeds at Bonneville Dam tailrace from January 1 through May 31, 2002 to 2016. Passage counts of Chinook salmon includes both adult and jack sized salmon.

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%
2011	272,469	3,298	1.2%
2012	196,667	1,750	0.9%
2013	155,729	2,525	1.6%
2014	257,354	4,209	1.6%
2015	283,696	9,780	3.3%
2016	186,633	8,709	4.5%

* 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. After April 25, we used observed catch distribution to divide unidentified salmonid consumption.

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

Predation on Winter and Summer Steelhead

An estimated 302 (CI 242.9 – 361.1) steelhead were consumed by pinnipeds in 2016. Winter steelhead, are defined here as steelhead passing Bonneville Dam between November 16 and March 31 (USACE 2016 Fish Passage Plan from Table BON-4). The adjusted winter steelhead consumption estimate for pinnipeds combined at Bonneville Dam was 143 fish (CI 90.2 – 196.6) or 4.9% of the steelhead passing during our observations from January 1 through March 31, 2016 (2,775 fish). Steller sea lions were responsible for 85% (122) of the estimated winter steelhead consumed. The adjusted summer steelhead consumption estimate by pinnipeds at Bonneville Dam was 159 fish (CI 133.1 – 185.5) or 6.3% of the steelhead passing (2,537 fish) from April 1 through May 31, 2016. California sea lions were responsible for 72% (114) of the estimated summer steelhead consumed.

Predation on White Sturgeon

Predation on sturgeon has declined drastically since SSL first began appearing at Bonneville Dam. White sturgeon consumption hit a high in 2011 with an estimated 3,003 sturgeon consumed (Table 6). Since then, it has decreased steadily to an adjusted consumption estimate of 44 in 2015 and 90 (CI 62.4 – 117.5) in 2016 (Table 6). Steller sea lions were responsible for 92.7% of the sturgeon consumed in 2016. The majority of documented sturgeon consumption occurred at the PH2 tailrace followed by the SPW, and PH1 tailrace. Observers also estimated the total lengths (in one foot increments) for 25 of the captured sturgeon (Figure 8). They ranged from less than 2 ft. (0.6 m) to over 7 ft. (2.7 m).

Table 6. Consumption of white sturgeon by pinnipeds at Bonneville Dam tailrace from January 1 through May 31, 2005 to 2016.

Year	Total Hours Observed	Observed Sturgeon Catch	Expanded Sturgeon Consumption Estimate	Adjusted Sturgeon Consumption Estimate
2005	1,109	1	N/A	N/A
2006	3,650	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
2011	3,315	1,353	2,178	3,003
2012	3,404	1,342	2,227	2,498
2013	3,247	314	552	635
2014	2,947	79	126	146
2015	2,995	24	39	44
2016	1,974	30	82	90

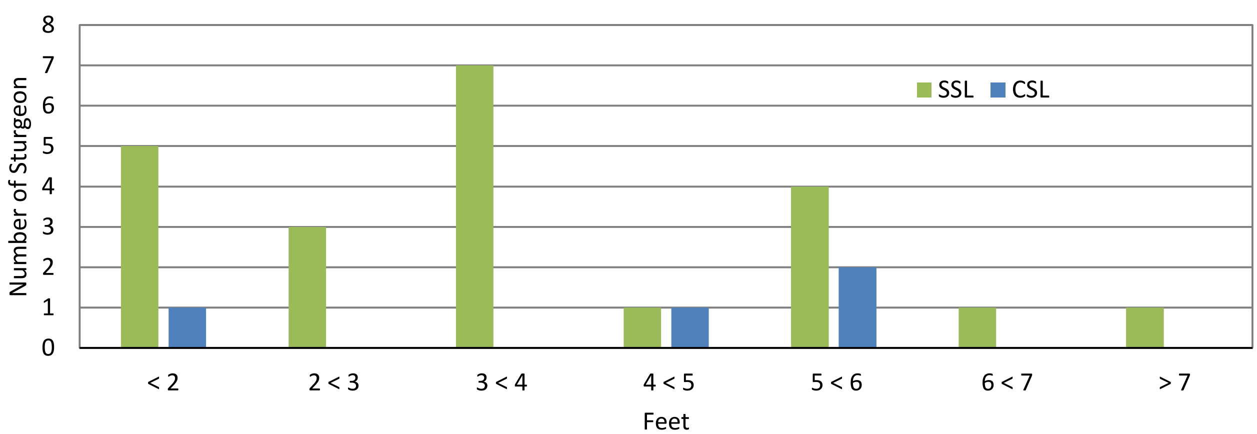

Figure 8. Estimated total lengths (per foot) of sturgeon consumed by pinnipeds in the Bonneville Dam tailrace from January 1 through May 31, 2016.

Predation on Pacific Lamprey

Pacific lamprey were the second most consumed fish species by pinnipeds. There were 232 lamprey caught, comprising 4.8% of the total observed fish catch (Table 7). The majority of those, 82.8% (192), were catches by CSL and the remaining 17.2% (40) by SSL. The highest number of lamprey catches observed on a single day by an individual CSL in 2016 was seven by CSL brand 2-11. California sea lions consumed an estimated 82.2% (412) of the 501 (CI 428.8 – 572.4) total estimated lamprey consumption from January 1 through May 31, 2016.

Table 7. Consumption of Pacific lamprey by pinnipeds at Bonneville Dam tailrace from January 1 through May 31, 2002 to 2016.

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	516	120	816	12.8%
2005	1,109	613	810	25.1%
2006	3,650	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%
2011	3,315	16	33	0.4%
2012	3,404	40	79	1.4%
2013	3,247	38	66	1.7%
2014	2,947	41	85	1.5%
2015	2,995	108	196	1.6%
2016	1,974	232	501	4.8%

Spatial Distribution of Predation Events

In 2016, predation on salmonids was concentrated in the near-dam areas of the tailrace and fishway entrances. We observed for 664 hours at PH1, 643 hours at SPW, and 667 hours at PH2. During this time, there were 4,207 observed predation events on adult salmonids in the Bonneville Dam tailrace (Figure 9 and Figure 10). The observed salmonid predation occurred most frequently in near dam zones 1-3, 70%; while zones 4-6 had 26%, and only 4% of predation occurred in zone 7 (zones are depicted in Figure 1).

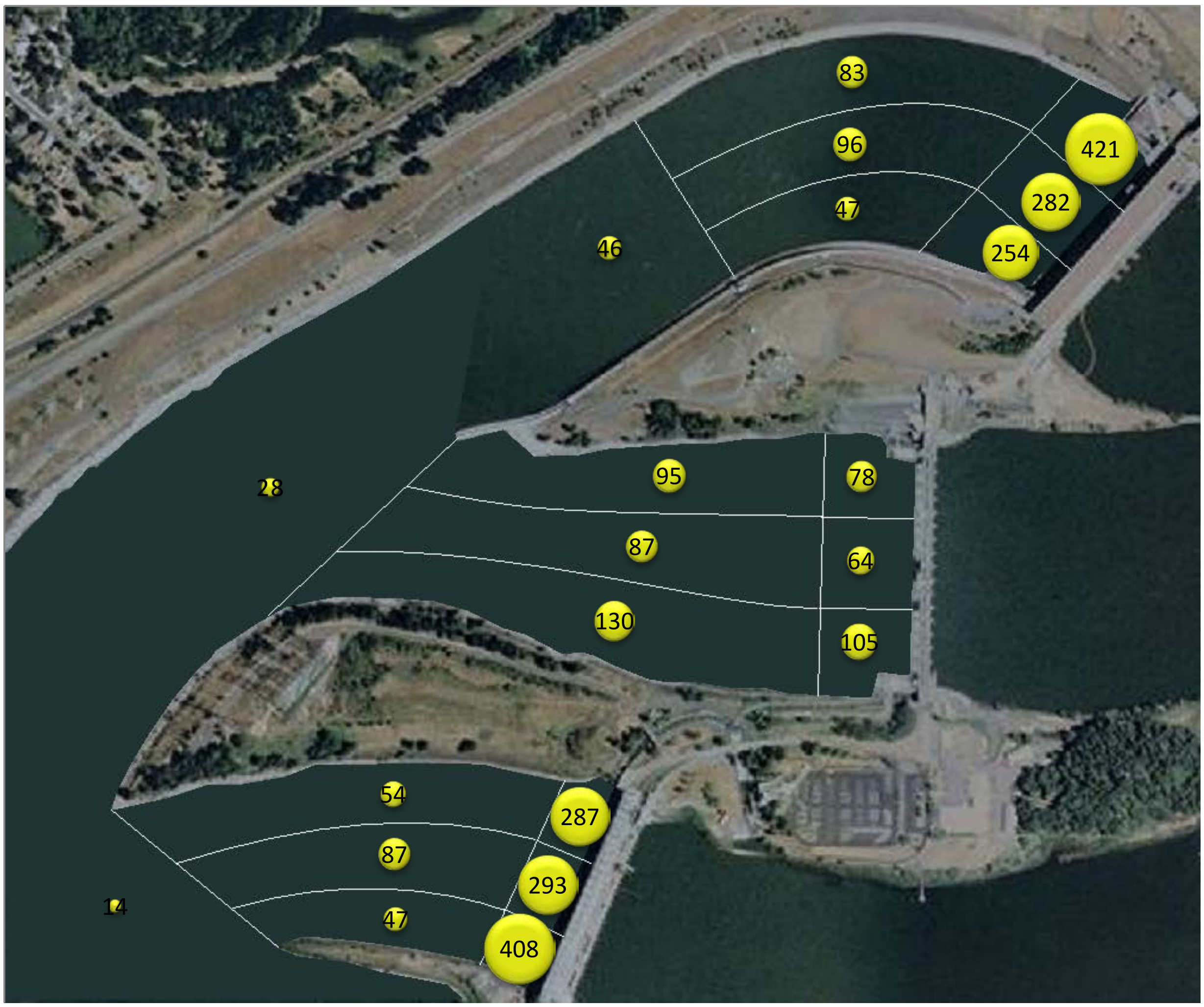

Figure 9. Spatial distribution of observed salmonid predation by California sea lions at Bonneville Dam from January 1 through May 31, 2016.

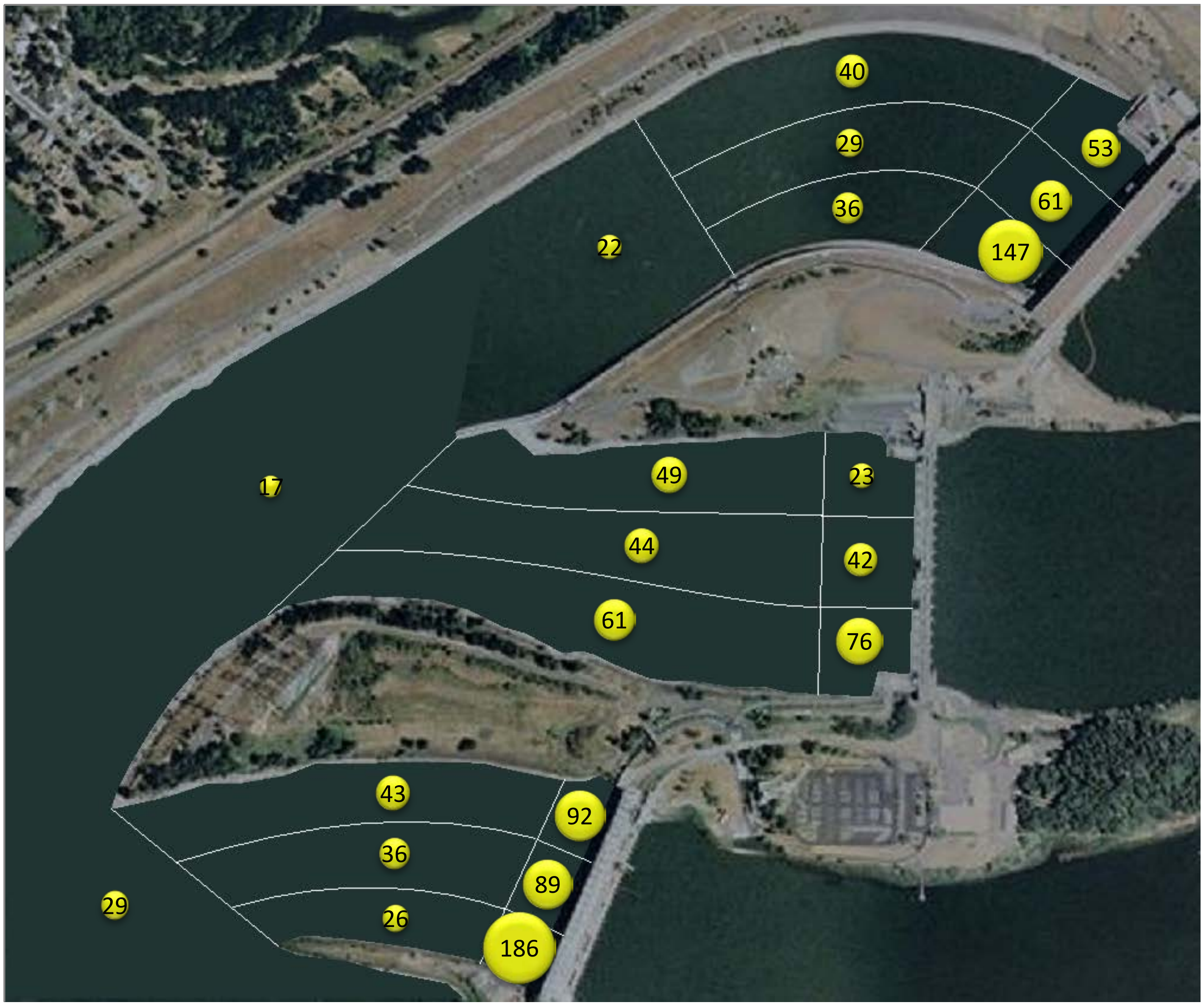

Figure 10. Spatial distribution of observed salmonid predation by Steller sea lions at Bonneville Dam from January 1 through May 31, 2016.

Predation on salmonids was highest at the powerhouses. The combined spatial distribution of salmonid predation events by pinnipeds was 40.3% (1,689) at PH1, 38.2% (1,599) at PH2, and 21.5% (899) at SPW. This is a similar distribution to previous years where more predation occurs at the powerhouses, except in 2013 and 2015. In 2013, predation appeared to be evenly spread across all tailraces. While in 2015, the power generation at PH1 was greatly reduced and observers recorded the lowest predation in the PH1 tailrace since monitoring began (Figure 11).

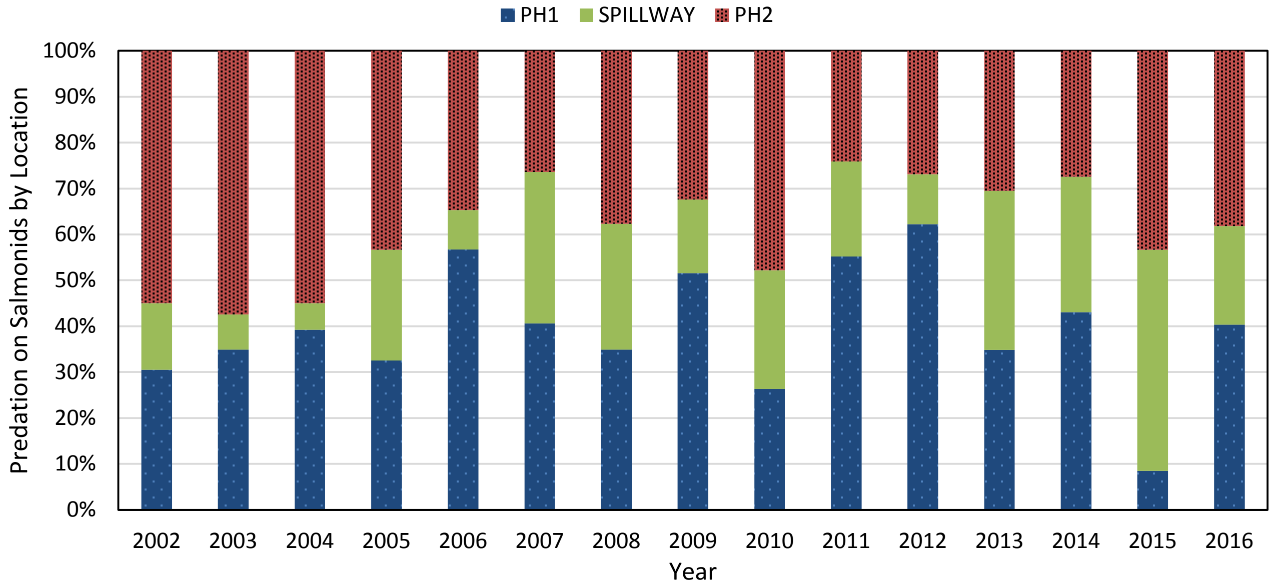

Figure 11. Proportional consumption of salmonids by California and Steller sea lions at Bonneville Dam by tailrace location, Powerhouse 1 (PH1), Spillway, or Powerhouse 2 (PH2), and year (2002-2016).

Temporal Distribution of Predation Events

Salmonids were observed being consumed throughout the study period in 2016. Prior to the arrival of spring Chinook salmon, SSL primarily consumed steelhead during January and February. An estimated 31% of steelhead predation by pinnipeds occurred from January through March, this is a decrease from last year's 68% during the same time period. The first observed Chinook salmon catch was on February 10 by a branded SSL. Steller sea lions primarily consumed Chinook salmon during April and May, 27% of the estimated consumption and the peak of SSL predation on salmonids was during the week of May 2 (Figure 12).

In 2016, CSL were rarely seen at Bonneville Dam prior to the first week of March. By the beginning of April, CSL were staying in the tailrace longer and predation on salmonids began to increase (Figure 12). Chinook salmon were the primary prey for CSL from March through May. We estimated that CSL predation of Chinook salmon also peaked the week of May 2, with 71.01% of the Chinook salmon consumed during April and May.

Predation on white sturgeon remained low in 2016. The predation of white sturgeon occurred primarily from January through March, 63.3%, with 90% of that attributed to SSL. This decreased from the previous five years when 83.3-99.2% of white sturgeon predation was observed during this timeframe.

Predation on Pacific lamprey increased slightly in 2016 from previous years. Lamprey predation was sparse in April but increased in May as the number of lamprey passing the dam increased (Figure 13). Observers recorded 89.7% of the Pacific lamprey catches in May. In comparison, from 2011 to 2015 predation of Pacific lamprey in May was 81.3%; 60.0%; 64.1%; 90.2%; and 83.3% respectively.

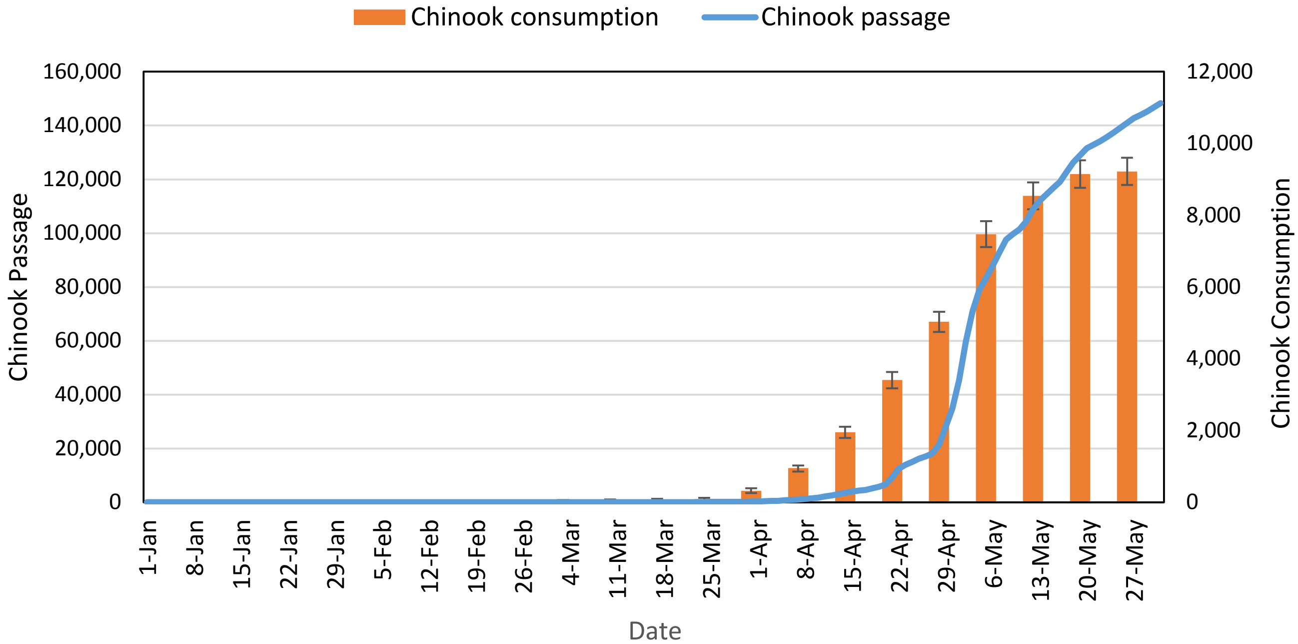

Figure 12. Chinook salmon passage and adjusted consumption estimates by pinnipeds at Bonneville Dam, January 1 through May 31, 2016. Error bars are 95% CI.

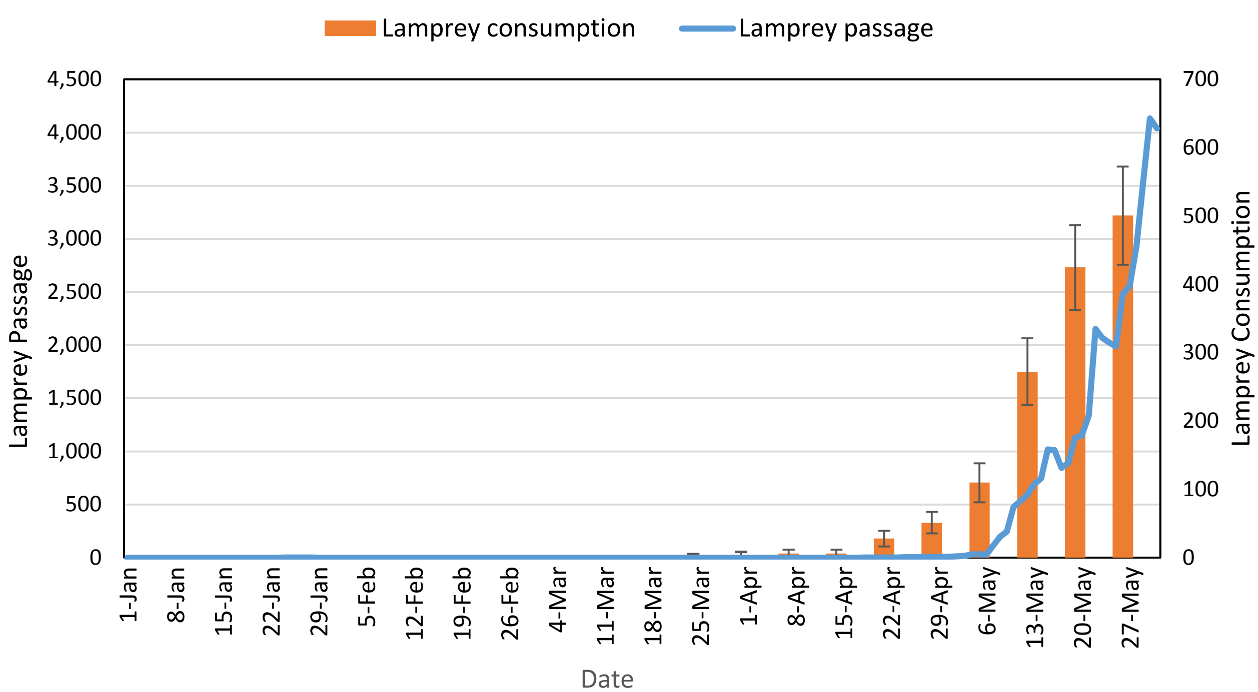

Figure 13. Pacific lamprey passage (24 hour counts) and adjusted consumption estimates by pinnipeds at Bonneville Dam, January 1 through May 31, 2016. Error bars are 95% CI.

Clepto-parasitism

Overall, 438 clepto-parasitism (taking prey from others) events were observed this year (Table 8). Of these, 90% (393) were SSL taking prey from CSL and 8% (34) were CSL taking prey from other CSL. This is up from last year when SSL clepto-parasitism on CSL was 76% (273) of the 359 observed events. As a result the "victim" of this behavior often continues to hunt for additional prey. Consequently the rate of CSL consumption of adult salmonids may be an inflated description of the number of salmonids observed caught by CSL, but not fully consumed.

Table 8. Summary of clepto-parasitism events by California sea lions (CSL) and Steller sea lions (SSL) observed at Bonneville Dam, 2002 to 2016.

	CSL		SSL		
Year	*From* CSL	*From* SSL	*From* CSL	*From* SSL	Total
2002	0	0	0	0	0
2003	14	0	0	0	14
2004	366	22	0	0	388
2005	22	0	22	0	22
2006	12	0	5	0	17
2007	33	0	4	0	37
2008	161	0	135	4	300
2009	152	4	324	7	486
2010	58	2	801	37	898
2011	2	0	279	12	293
2012	2	0	35	55	92
2013	1	0	67	19	87
2014	0	0	58	4	62
2015	67	7	273	12	359
2016	34	2	393	9	438

DETERRENTS AND MANAGEMENT ACTIVITIES

Physical Barriers

Sea lion exclusion devices (SLEDs) were deployed at PH2 on October 26, 2015 and PH1 on March 1, 2016. All remaining SLEDs at fishway entrances were installed by March 5, 2016. Once installed SLEDs were effective in keeping pinnipeds out of the fishways. The PH2 SLEDs were removed for the season on June 16 and from PH1 and B-branch (south side of SPW) on June 20, 2016. At Cascades Island (north side of SPW) the SLEDs remain installed.

Steller sea lions were accessing the Washington Shore fishway in early winter. On January 28, observers recorded a SSL in the PH2 Washington Shore fishway. On February 1 and 2, SSLs were observed climbing over the FOGs and entering the PH2 fishway. To prevent this behavior from recurring SLIBs were installed on top of all FOGs by February 11. There were no additional sightings by observers or reports of sea lions accessing the fishway channel via the FOGs.

Non-Lethal Harassment

In a coordinated effort to deter pinnipeds from consuming ESA-listed Columbia River salmon and steelhead congregating at the base of the dam, boat and dam (ground) based hazing were implemented. Boat-based hazing by CRITFC began on March 7 and was conducted on 25 separate days, ending the year on May 16. Dam-based hazing of pinnipeds by USDA began on March 8 and continued on a daily basis through May 31. Dam hazers used cracker shells, bangers, and rubber buckshot on pinnipeds within the tailrace areas. Most of the hazing effort was concentrated at PH1 and PH2 due to a larger presence of pinnipeds and easier accessibility. At SPW, pinnipeds proved to be more difficult to haze due to the inability of the boat to safely navigate the choppy waters during spill and pinnipeds often being out of range of dam-based hazers.

Of the 1,974 observed hours across all sites, dam-based hazers were recorded as being present at least once during 370 different hours, and boat-based hazers were recorded as being present during 90 different hours (Table 9). The total time spent hazing during observed hours was 120.8 hours for dam-based efforts and 18.8 hours for boat-based efforts (Table 9). Both dam and boat-based hazing efforts occurred at sites during hours that were not recorded by observers and are not included in these data.

Many individually identifiable pinnipeds, branded or otherwise, were hazed regularly during the season but were recorded to be present multiple days or weeks after being hazed. In some cases, these same individuals were also reported to be returning to hazed areas as soon as 20 minutes after the end of hazing efforts. This suggests that hazing is only temporarily effective in deterring pinnipeds from predating at Bonneville and it is not a long-term solution.

Table 9. Total hours of hazing activity in the Bonneville Dam tailrace observation area in 2016. Data excludes hours when observers were not present.

	Number of Times Hazers were Present in an Hour		Total Hours Hazers were Present in Observation Areas	
	Boat hazing	*Dam hazing*	*Boat hazing*	*Dam hazing*
Powerhouse 1	42	154	9	52.3
Powerhouse 2	38	197	8.6	65.2
Spillway	10	19	1.2	3.3
Total	90	370	18.8	120.8

Trapping and Removal

The States conducted trapping operations in the tailrace area from early April to late May during which time they permanently removed 59 CSL under the State's MMPA Section 120 LOA. This is the largest number of listed CSL removals to date (Table 10). In addition, 50 CSL were branded and released in the tailrace at Bonneville Dam (Brown et al. 2016). As both SSL and CSL use the traps as a haul out location, SSL are often captured along with CSL during trapping operations. All SSL captured on the traps were released back into the tailrace without additional handling. Traps were closed and moved to storage in late May. Additional information about these activities can be found in Brown et al. 2016, and Hatch et al. 2016.

Table 10. Summary of California sea lion (CSL) branding and removals (captivity, euthanasia, accidental morality) and Steller sea lion (SSL) branding at Bonneville Dam, 2007 to 2016.

Year	CSL Branded	CSL Removed	SSL Branded
2007	8	N/A	N/A
2008	4	8*	N/A
2009	3	15	N/A
2010	9	14	8
2011	9	1	9
2012	6	13	19
2013	11	4	3
2014	21	15	0
2015	131	32	0
2016	50	59†	0
Total	252	161	39

* Does not include 3 accidental mortalities of CSL not listed for removal.

† Does not include 2 accidental mortalities of CSL not listed for removal.

Impact of the Removal of Listed California Sea Lions

Salmonid predation by CSL was the second highest since monitoring began (Table 11). Salmonid consumption per capita for 2016 was estimated to be 44.8 fish/CSL. This was similar to that of 2006, 2014, and 2015 per capita but around half that of the high of 2009 (83.4 fish/CSL) (Table 11). In 2016, identification of every unbranded pinniped was not plausible, even though 50 of the CSL were given unique brands during the season, therefore the per capita estimates for both CSL and SSL may be biased high. Note that this is the first season that SSL salmonid consumption per capita (52.8 fish/SSL) was higher than that of CSL.

Table 11. Adjusted consumption estimates on adult salmonids by California and Steller sea lions at Bonneville Dam between January 1 and May 31, 2002 to 2016.

	California Sea Lions			Steller Sea Lions		
Year	Adjusted Salmonid Consumption Estimates	Salmonid Consumption Per Capita	% of Run (Jan 1 – May 31)	Adjusted Salmonid Consumption Estimates	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	3.5%	16	4.0	0.0 %
2006	3,428	47.6	3.2%	88	8.0	0.1 %
2007	4,492	63.3	4.8%	15	1.7	0.0 %
2008	4,901	59.9	3.2%	198	5.1	0.1 %
2009	4,505	83.4	2.4%	628	24.2	0.3 %
2010	5,481	61.6	2.0%	1,061	14.1	0.4 %
2011	2,713	50.2	1.2%	1,294	14.5	0.6%
2012	1,077	27.6	0.6%	1,305	17.9	0.8%
2013	1,510	27.0	1.2%	1,444	18.1	1.2%
2014	2,855	40.2	1.3%	1,891	29.1	0.8%
2015	8,324	42.7	3.3%	2,535	36.7	1.0%
2016	6,676	44.8	4.1%	2,849	52.8	1.7%

The number of adult salmonids observed to be consumed by an identified individual CSL in 2016 was lower than any season since 2005. The maximum number of adult salmonids consumed by an identified individual CSL in 2016 over nine days of observations was 25 or 12.5% of the salmonid catches attributed to an individual (Table 12). This was similar to 2015 (28) while the highest number of salmonid catches (198) attributed to a single individual CSL occurred in 2010.

Table 12. Maximum number of salmonids observed consumed by an individual California sea lion (CSL) at Bonneville Dam between January 1 and May 31, 2002 to 2016.

Year	Maximum Number of Salmonids Caught by an Individual CSL	Percentage of Salmonid Catches Attributed to Individual CSLs
2002	51	85.6%
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%
2011	125	41.7%
2012	41	53.0%
2013	59	42.1%
2014	59	26.3%
2015	28	14.1%
2016†	25†	12.5%†

* In 2005, the observation season began late therefore we didn't have an opportunity to train observers on individual CSL identification.
† In 2016, all three tailraces were not observed simultaneously thus decreasing observation time for individual CSL.

DISCUSSION

We documented a large number of returning pinnipeds and newly recruited CSL, the second largest salmonid consumption estimate since monitoring began, and continued prey selection toward steelhead and salmonids by SSL. Non-lethal deterrent methods were deployed with similar results to prior efforts, however, the States euthanized the largest number of listed CSL (59) in a single year since lethal removal authority was granted in 2008. Naïve CSL and SSL exploring upriver foraging opportunities, likely following habituated animals, continues to keep abundance high. The lack of a management plan for the expanding residency and increased abundance of SSL is an ongoing issue that will need to be addressed in the future.

In 2016, observers documented the second highest pinniped abundance since monitoring began. As El Nino conditions persisted in the southern coastal waters driving temperatures up and the abundance of temperature-sensitive prey to northern waters, an influx of large numbers of male CSL have been aggregating at the mouth of the Columbia River. Counts collected at the East Mooring Basin in Astoria, Oregon on March 11 of 2016 hit an all-time high of 3,834 pinnipeds (Brown et al. 2016). Over the past two years the swelling number of pinnipeds downriver has coincided with an increase in CSL aggregating at Bonneville Dam. Many of these animals have been identified at the dam for the first time. In 2015, the greatest number of individual pinnipeds (264) and the highest estimate of salmonid consumption (10,859) were recorded compared to any prior season of the pinniped monitoring program (USACE 2016). In 2016, many of these animals returned to the dam resulting in the second highest estimated consumption of adult salmonids (9,525) to date. Recent increases in pinniped abundance may also be a reflection of an ever increasing number of habituated SSL as well as increasing CSL recruitment to upriver foraging (Schakner et al. 2016). Since 2010, many SSL exhibit site fidelity returning to Bonneville Dam as early as August and are observed throughout the remainder of the year. It's concerning that not only are SSL residence times expanding to ten months of the year but they are returning in increasing numbers earlier every year. The expanding population of pinnipeds is not only occurring at Bonneville, increased numbers of pinnipeds concurrent with increasing predation has also been documented at Willamette Falls off the main stem Columbia River (Wright et al. 2014, 2015).

Unbranded pinnipeds, particularly younger animals, make individual identification and thus abundance estimates difficult. Young CSL often have no natural markings, such as scars, needed for individual identification from one tailrace to the next or one day to the next. Thus our estimates of seasonal abundance is likely biased low. Young SSL are also similarly difficult to differentiate. The branding of SSL at Bonneville Dam has not occurred since 2013 and only a small number (39) have been branded. Continued branding of newly recruited CSL captured by the States and expanding the number of branded SSL would assist with future identification and monitoring of these animals.

Predation of adult salmonids in 2016 was slightly less than 2015 (highest year to date). The spring Chinook salmon run was smaller (283,696 in 2015 vs. 186,633 in 2016) and early migrating Chinook salmon were particularly at risk because they have the greatest temporal overlap with pinniped predators (Keefer et al. 2012). The estimated consumption of salmonids in 2016 had the potential to be the highest season yet, however smaller Chinook run size, later run arrival, and the largest removal (59) of predatory CSL factored into keeping the consumption rate from surpassing the previous season. Additionally, pinnipeds had shorter residence times and departed en masse by May 24 compared to 2015 when pinnipeds remained at Bonneville Dam until the end of May (USACE 2016). The maximum number of salmonids observed caught and consumed by an identified individual (25) was lower than in years past. However, our observation effort in 2016 was also reduced, as not all tailraces were covered at the same time. The number of hours that observers are present from year to year affects the number of opportunities to observe salmonid catches by an individual CSL. This disparity could help explain why 2016 had the second lowest number of salmonids caught by an identified individual CSL since monitoring began.

Up until 2014, sturgeon were the primary prey consumed by SSL. In recent years this has changed as sturgeon predation has dropped from an estimated high of 3,003 fish in 2011 to 90 fish in 2016. Chinook salmon and steelhead have in turn become their main prey. Steller sea lions have been predating on steelhead more readily prior to the arrival of spring Chinook salmon. In addition, past observations have confirmed that SSL are able to swallow steelhead and jack Chinook whole, thus indicating that consumption estimates may be underestimated for SSL more so than CSL (Stansell et al. 2011). The reason for the change in SSL prey selection from white sturgeon to salmonids is unknown but may be driven by factors including prey abundance and accessibility or shorter handling time during predation. The availability of sturgeon in the tailrace areas at the dam may have decreased in response to, or because of, heavy predation by pinnipeds, mainly SSL. Unlike salmonids and lamprey where passage data is collected annually, there are no annual estimates of sturgeon abundance at the dam with which to compare and track trends between years. Steller sea lions are opportunistic predators known to switch prey in response to changes in prey abundance, and often migrate to take advantage of seasonal availability (Sigler et al. 2009). Researchers analyzing remnants in stomach samples and scats indicated that while SSL consume a wide variety of prey, they often target prey in spawning, overwintering, or migratory aggregations (Tollit et al. 2015).

Pacific lamprey were the second most consumed fish species this season comprising 4.8% of predation events. Observed lamprey catches began increasing by the end of April corresponding with the beginning of their upriver migration, which occurs from May through September. Increased lamprey predation coincided with the largest count of Pacific lamprey passing Bonneville Dam in May (3,429 - USACE Fish Counts and Reports) since monitoring began. Lamprey predation was observed most often in zones closest to the dam (Figure 1). As lamprey are consumed more rapidly than salmonids, and the usual thrashing during a predation event does not occur, these catches may be more easily missed. In addition, while pinnipeds bring large prey to the surface to break it apart during consumption they are capable of consuming smaller prey items underwater (London et al. 2002; Scheffer 1950). Therefore, lamprey consumption may be grossly underestimated as due to its body shape and size, underwater consumption is highly probable (Stansell et al. 2014).

The spatial distribution of predation events was similar between species. Both CSL and SSL caught most of their fish close to the fishway entrances. Although at PH2, SSL were observed to catch salmonids more often on the south side in zone 1 while CSL were observed to catch salmonids more often on the north side in zone 3 (Figure 9, Figure 10). The protocol for recording the zone of predation is the location where the pinniped is first observed with a fish. It is common to observe pinnipeds, more often CSL, making fish catches in zones 1-3 and then dragging the fish downriver into zones 4-7 (Figure 1) to consume them. It is therefore possible that a fish may be caught in one zone and dragged to a different zone before being noticed by an observer. This is especially true at SPW where zones 1-3 have the added difficulty of observing predation in turbulent water created by the spill.

Deterrent methods used at Bonneville Dam had varying degrees of effectiveness. Pinniped behavior changes with their environment and trying to deter them requires dynamic responses. The installation of the SLEDs successfully kept pinnipeds from entering into the fishways. However, pinnipeds have been observed in the fishway during the fall of 2015 when SLEDs were not installed. This suggests that it is important to keep them installed whenever pinnipeds are in the tailrace. In February it was discovered through direct observation that SSL were entering the PH2 collection channel by climbing over the FOGs of which there are several along the downstream face of the powerhouse (Appendix B). The USACE responded quickly by constructing and installing temporary sea lion incursion barriers (SLIBs) over all FOGs. The USACE is currently in the process of designing permanent SLIBs to remedy this action (fish biologist Ida Royer pers comm). As in previous years, hazing with pyrotechnics and rubber buckshot had a short-term impact on pinniped behavior. Pinnipeds typically moved out of the area for a short duration but returned once the hazer had departed. While hazing does not seem to be very effective, it is a criteria under the removal permit that CSL must be present under hazing conditions.

The States removal program resulted in decreased recurrence of CSL at Bonneville Dam. One of the most notable impacts of the removal program is the lack of long term repeat CSL in the population aggregating at the dam. In addition to the largest removal of CSL to date (59), most of the animals that have returned to Bonneville Dam for several years were among those removed (56 of 90). By the end of the 2016 field season, only two CSL had been present at Bonneville for longer than two seasons. In contrast, 27 SSL had been present longer than two seasons. The impact of the removal program on overall CSL abundance has been hard to discern as we continue to see recruitment of new CSL to Bonneville Dam (Stansell et al. 2014) in addition to the aforementioned record numbers of CSL documented at the Astoria basin. This coupled with increasing numbers of SSL habituating to Bonneville Dam complicates the issue further as their predation on salmonids and stealing prey from CSL has also increased. However, the successful removal of increasing numbers of predatory CSL feeding at the dam could result in lower CSL recruitment over time. While the impacts of CSL removals on predation rates may be positive for salmon, the increasing presence and consumption rates of SSL is concerning and may warrant a management strategy in the future.

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Wright, B.S., Tom Murtagh, and Robin Brown. 2015. Willamette Falls Pinniped Monitoring Project 2015. Oregon Department of Fish and Wildlife, 7118 NE Vandenberg Avenue Corvallis, OR 97330

Appendix A. Calculation of Estimates.

To calculate the estimated consumption of salmon, Chinook salmon, steelhead, White sturgeon, or Pacific lamprey we set up our data in excel using the stratified systematic approach (Cochran 1977). Data for each specific estimate calculation was separated into weekly stratum from which the mean catch ($\overline{y}$), standard deviation (SD), and sample variance (s^2) for each stratum was calculated using standard formulas in MS Excel. The total overall consumption estimate is derived from the sum of the strata. Calculations are included to better describe how we arrived at reported estimates.

Where:

y = *the total catch in one hour sample block*
n = *the total number of sample blocks*
N = *the total number of possible sample blocks*
$\bar{y}$ = *mean catch per stratum (week)*
K = *the number of strata (21 weeks)*

Mean catch per hour for stratum "*h*" is then:

$$\overline{y}_h = \sum_{i=1}^{n} y_h \Big/ n \qquad (1)$$

The overall stratum mean was then calculated as:

$$N_h * \overline{y}_h \Big/ N \qquad (2)$$

Here "*h*" denotes the individual stratum, so if week 2 had 189 possible sample blocks with the total sample blocks possible being 5,334 and the mean catch per hour for week 2 was .081 then (189 * .081/5,334) = 0.00287 would be the overall mean for that stratum.

The overall stratum means, calculated in equation (2), were then summed for all strata (K) to give us the estimated mean catch (EMC) for each stratum. Using the (EMC) we were then able to calculate a total catch estimate.

The estimated total catch (TC) was calculated as:

$$TC = EMC * N \tag{3}$$

The variance of the mean for each stratum is calculated:

$$VAR_h = \left({s^2}/{n_h}\right) * \left(1 - {n_h}/{N_h}\right) \tag{4}$$

The overall variance for each stratum is then calculated:

$$OVAR_h = \left({N_h}/{N}\right)^2 * (VAR_h) \tag{5}$$

The variance (VAR) of the (EMC) is the sum of the overall variance $(OVAR_h)$ for all strata (K).

To calculate the standard error (SE) of the (EMC):

$$SE = \sqrt{VAR} \tag{6}$$

The margin of error (ME):

$$ME = Critical\ value * SE \tag{7}$$

As we used the 95% probability level, it is calculated as $1.96 * SE$. To calculate the upper and lower confidence intervals we multiplied the (ME) by (N) and added or subtracted this value from the (EMC).

Appendix B. Images of the sea lion exclusion devices.

A.

B.

C.

D.

Figure 14. Sea lion exclusion device (SLED) at Bonneville Dam fishway entrance (A) (Tackley et al. 2008) and installed (B) (photo by Bjorn van der Leeuw, USACE FFU), floating orifice gate (FOG) (C) (unknown source), and sea lion incursion barriers on top of FOGs (D) (photo by Patricia Madson, USACE FFU).

Appendix C. Table of progressive estimates of pinniped predation on salmonids (also broken out by pinniped species) at Bonneville Dam, 2002-2016, adjusted for unidentified fish prey caught.

ADJUSTED FOR DAYLIGHT HOURS AND DAYS NOT OBSERVED

			ALL PINNIPEDS		CALIFORNIA SEA LIONS		STELLER SEA LIONS	
	TOTAL HOURS OBSERVED	TOTAL SALMONID PASSAGE	ESTIMATED SALMONID CATCH	% RUN TAKEN	ESTIMATED SALMONID CATCH	% RUN TAKEN	ESTIMATED SALMONID CATCH	% RUN TAKEN
2002	662	284,732	1,010	0.35%	1,010	0.35%	0	0.00%
2003	1,356	217,934	2,329	1.06%	2,329	1.06%	0	0.00%
2004	516	186,771	3,533	1.86%	3,516	1.85%	7	0.00%
2005	1,109	81,252	2,920	3.47%	2,904	3.45%	16	0.02%
2006	3,650	105,063	3,023	2.80%	2,944	2.72%	76	0.07%
2007	4,433	88,474	3,859	4.18%	3,846	4.17%	13	0.01%
2008	5,131	147,558	4,466	2.94%	4,292	2.82%	174	0.11%
2009	3,455	186,056	4,489	2.36%	4,037	2.12%	452	0.24%
2010	3,609	267,167	6,081	2.23%	5,095	1.86%	986	0.36%
2011	3,315	223,380	3,557	1.57%	2,527	1.11%	1,030	0.45%
2012	3,404	171,665	2,107	1.21%	998	0.57%	1,109	0.64%
2013	3,247	120,619	2,714	2.20%	1,402	1.14%	1,312	1.06%
2014	2,947	219,929	4,314	1.92%	2,615	1.17%	1,699	0.76%
2015	2,995	239,326	9,981	4.00%	7,779	3.12%	2,202	0.88%
2016	1,974	154,074	8,969	5.50%	6,371	3.9%	2,598	1.6%

ADJUSTED FOR UNIDENTIFIED FISH

			ALL PINNIPEDS		CALIFORNIA SEA LIONS		STELLER SEA LIONS	
	TOTAL HOURS OBSERVED	TOTAL SALMONID PASSAGE	ESTIMATED SALMONID CATCH	% RUN TAKEN	ESTIMATED SALMONID CATCH	% RUN TAKEN	ESTIMATED SALMONID CATCH	% RUN TAKEN
2002	662	284,732	1,010	0.35%	1,010	0.35%	0	0.00%
2003	1,356	217,934	2,329	1.06%	2,329	1.06%	0	0.00%
2004	516	186,771	3,533	1.86%	3,516	1.85%	7	0.00%
2005	1,109	81,252	2,920	3.47%	2,904	3.45%	16	0.02%
2006	3,650	105,063	3,401	3.14%	3,312	3.05%	85	0.08%
2007	4,433	88,474	4,355	4.69%	4,340	4.68%	15	0.02%
2008	5,131	147,558	4,927	3.23%	4,735	3.11%	192	0.13%
2009	3,455	186,056	4,960	2.60%	4,353	2.28%	607	0.32%
2010	3,609	267,167	6,321	2.31%	5,296	1.94%	1,025	0.37%
2011	3,315	223,380	3,971	1.75%	2,689	1.18%	1,282	0.56%
2012	3,404	171,665	2,360	1.36%	1,067	0.61%	1,293	0.74%
2013	3,247	120,619	2,928	2.37%	1,497	1.21%	1,431	1.16%
2014	2,947	219,929	4,621	2.10%	2,747	1.25%	1,874	0.84%
2015	2,995	239,326	10,859	4.34%	8,324	3.33%	2,535	1.01%
2016	1,974	154,074	9,525	5.80%	6,676	4.1%	2,849	1.7%

ADJUSTED FOR NIGHT HOURS NOT OBSERVED (AN ADDITIONAL 3.5% ADDED 2006-2010, 0.9% 2011-2016)

			ALL PINNIPEDS		CALIFORNIA SEA LIONS		STELLER SEA LIONS	
	TOTAL HOURS OBSERVED	TOTAL SALMONID PASSAGE	ESTIMATED SALMONID CATCH	% RUN TAKEN	ESTIMATED SALMONID CATCH	% RUN TAKEN	ESTIMATED SALMONID CATCH	% RUN TAKEN
2002	662	284,732	1,010	0.35%	1,010	0.35%	0	0.00%
2003	1,356	217,934	2,329	1.06%	2,329	1.06%	0	0.00%
2004	516	186,771	3,533	1.86%	3,516	1.85%	7	0.00%
2005	1,109	81,252	2,920	3.47%	2,904	3.45%	16	0.02%
2006	3,650	105,063	3,520	3.24%	3,428	3.16%	88	0.08%
2007	4,433	88,474	4,507	4.85%	4,492	4.83%	15	0.02%
2008	5,131	147,558	5,099	3.34%	4,901	3.21%	198	0.13%
2009	3,455	186,056	5,134	2.69%	4,505	2.36%	628	0.33%
2010	3,609	267,167	6,542	2.39%	5,481	2.00%	1,061	0.39%
2011	3,315	223,380	4,007	1.76%	2,713	1.19%	1,294	0.57%
2012	3,404	171,665	2,382	1.37%	1,077	0.62%	1,305	0.75%
2013	3,247	120,619	2,954	2.39%	1,510	1.22%	1,444	1.17%
2014	2,947	219,929	4,662	2.12%	2,771	1.26%	1,891	0.85%
2015	2,995	239,326	10,957	4.37%	8,399	3.39%	2,557	1.06%
2016	1,974	154,074	9,610	5.87%	6,736	4.18%	2,875	1.83%