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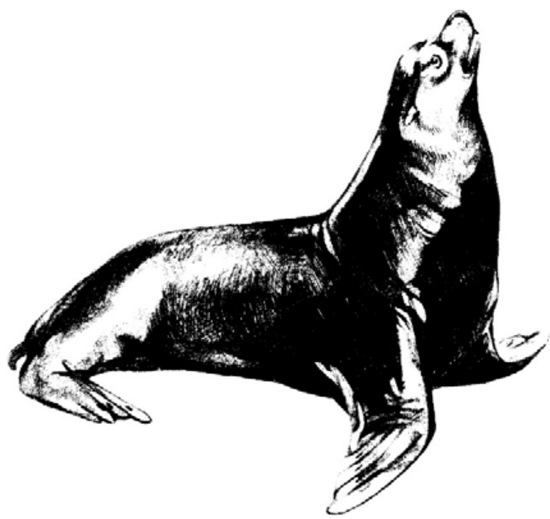
EVALUATION OF PINNIPED PREDATION ON ADULT SALMONIDS AND OTHER FISH IN THE BONNEVILLE DAM TAILRACE, 2018



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Past reports and more information on the Pinniped Monitoring Program at Bonneville Lock and Dam can be found at the following link:

http://pweb.crohms.org/tmt/documents/FPOM/2010/Task%20Groups/Task%20Group%20Pinnipeds/

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EXECUTIVE SUMMARY

California sea lions (CSL; *Zalophus californianus*) and Steller sea lions (SSL; *Eumetopias jubatus*) aggregate at the base of Bonneville Dam where they feed on Pacific salmon and steelhead (*Oncorhynchus spp.*), some of which are listed as threatened or endangered under the Endangered Species Act (ESA). The 2014 Federal Columbia River Power System Biological Opinion requires the U.S. Army Corps of Engineers to monitor the seasonal presence, abundance, and predation activities of sea lions at Bonneville Dam. This season we monitored the traditional spring period (1 January – 2 June), which has had documented sea lion presence since 2001. At the request of NOAA Fisheries, we also sampled during the fall and winter months (15 August – 31 December) to monitor the growing SSL presence at Bonneville Dam to evaluate pinniped predation on fall- and winter-run salmonid stocks.

2017 FALL AND WINTER SAMPLING PERIOD:

The following is a summary of the 2017 fall and winter period (15 August – 31 December) which monitored sea lion abundance across all tailraces and fish predation at the Powerhouse 2 tailrace of Bonneville Dam when sea lion abundance was ≥ 20 animals. Note: total predation at Bonneville Dam during this time is likely higher than these estimates due to predation in other tailraces.

Abundance – An average of 14.5 ± S.E. 1.3 SSLs, and 0.2 ± S.E. 0.1 CSLs were observed each day.

Species	Number of Fish Killed (95% CI)	Percent Run Consumed During Weeks Sampled
All Salmonids	892 (737 – 1,046)	1.2%
Chinook Salmon (*O. tshawytscha*)	401 (281 – 506)	0.7%
Coho Salmon (*O. kisutch*)	368 (296 – 432)	3.1%
Summer and Winter steelhead (*O. mykiss*)	123 (63 – 172)	1.5%
White Sturgeon (*Acipenser transmontanus*)	238 (183 – 281)	N/A

2018 SPRING SAMPLING PERIOD:

The following is a summary of the 2018 spring period (1 January – 2 June), which monitored sea lion abundance and fish predation across all three tailraces of Bonneville Dam.

Abundance – An average of 14.6 ± S.E. 1.3 SSLs and 2.6 ± S.E. 0.3 CSLs were observed each day.

Species	Number of Fish Killed (95% CI)	Percent Run Consumed
All Salmonids	3,112 (2855 – 3,373)	3.0%
Chinook Salmon	2,813 (2,554 – 3067)	2.9%
Steelhead - Jan. – May	295 (227 – 356)	7.2%
Winter steelhead - Nov. – Mar.	159 (140 – 178)	6.8%
Pacific Lamprey (*Entosphenus tridentatus*)	58 (17 – 91)	0.04%
White Sturgeon	148 (105 – 185)	N/A

The impact SSLs have on salmonid passage continues to increase and has surpassed the predation impact CSLs were having when fish and wildlife managers first received authorization under section 120 of the Marine Mammal Protection Act (MMPA) to remove predatory CSLs in 2008. The near record low runs of ESA-listed winter and summer steelhead and small run of ESA-listed spring Chinook Salmon that passed Bonneville Dam this sampling season had to swim past high numbers of SSLs, however numbers of CSLs are slightly lower than past years. Our estimates show that in general: CSL abundance and fish consumption are down, SSL abundance and fish consumption are up, and the total number of salmonids killed this year by both species of pinniped, although lower than previous years, is similar to the ten year average. We documented increasing trends in White Sturgeon predation that are of concern, and identified that ESA-listed winter steelhead are being impacted by prolonged SSL presence and predation.

As the winter steelhead passing Ballard Locks are now functionally extinct, in part, due to pinniped predation, the Upper Willamette River winter steelhead are reportedly facing the same challenges to some extent due to pinniped predation. Data collected in previous years have suggested, and novel data collected this year indicate, that the winter steelhead near Bonneville Dam are also at risk. Fish and wildlife managers need to take action to ensure the continued existence of steelhead, and other threatened and endangered anadromous fish species. This should entail a review of the current CSL management plan, and the development of an equitable SSL management plan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION & BACKGROUND

Interspecific competition by marine mammals and humans for anadromous salmonids in the Columbia River has been present for hundreds of years (SBFC 1889, Thwaites 1969), and has contributed to persecution of some marine mammal species in the Pacific Northwest (Scheffer 1950, Newby 1973, Braje and Rick 2011). Chief among these competing species, the pinnipeds (seals and sea lions) in Oregon and Washington were targeted for population reduction through bounty-incentivized removal programs by state wildlife managers which contributed to reducing populations to all-time lows (Peterson and Bartholomew 1967, Pearson and Verts 1970, NOAA 2016a). In response to the universal decline of marine mammal stocks, the Marine Mammal Protection Act (MMPA) was initiated in 1972 and effectively buoyed some northwest pinniped stocks to all-time high levels in the following 30 years (Jefferies et al. 2003, Brown et al. 2005). Concomitant to the success of the MMPA (Magera et al. 2013), salmonid stocks declined to a point where many are now listed under the Endangered Species Act of 1973, especially those of the Columbia River and its tributaries (NFSC 2015). Thus, the flux of predator and prey in the Columbia River has now transitioned to high numbers of protected pinnipeds, and low levels of threatened and endangered salmonids.

Analyses of pinniped-salmonid interactions in or near the Columbia River suggest that all life stages of salmonids are at risk of predation by pinnipeds (Brown et al. 2017, Chasco et al. 2017), and that some salmonid runs are at greater risk of predation and potential extinction than others (Keefer et al. 2012, Falcy 2017). As such, pinniped predation on imperiled salmonids in the Columbia River has garnished considerable attention and continues to be a focus of concern and research (Kinsey 2007).

Historical pinniped distribution in the Columbia River system has been detailed through archeological records, whereby, seal (Family: Phocidae [true seals]) remains were documented at river kilometer 323 (mile 201) near Celilo Falls (Lyman et al. 2002), a falls now inundated by The Dalles Reservoir. Sea lions (Family: Otariidae [eared seals]) have historically frequented the lower portions of the Columbia River system (i.e. the Columbia Estuary), but there is no evidence of congregations of these animals in the river section of what is now Bonneville Dam (BON) in the time preceding dam construction (i.e. 1938) or the six decades following construction (Keefer et al. 2012). The dam is largely impassable to pinnipeds and is now commonly frequented by sea lions and an occasional harbor seal (*Phoca vitulina*).

Sea lions were first documented at BON in the late 1980's when California sea lions (CSL; *Zalophus californianus*) were sporadically observed depredating spring Chinook Salmon (*Oncorhynchus tshawytscha*) (Stansell 2004). Steller sea lions (SSL; *Eumetopias jubatus*) were first documented at BON in 2003 (Keefer et al. 2012). Anecdotal observation suggested the duration of residency and level of salmonid predation by pinnipeds increased in subsequent years, leading fish managers to question the potential impact such predators may be having on migrating adult salmonid fish runs (NMFS 1997).

Potential impacts of fish predators at hydroelectric dams have long been of concern to fish managers (Schilt 2007, Evans et al. 2016), and can present challenges to management agencies (Friesen and Ward 1999, McKinney et al. 2001). The Columbia River System of hydroelectric dams is one of the most advanced hydropower systems in the world, and has been subject to in-depth study of fish predator activities and deterrence (Roscoe and Hinch 2010, Patterson et al. 2017). Historically, focus was given to the predation of cohorts of out-migrating juvenile salmonids given the extensive suite of predators that can depredate these younger age classes (e.g. warm water fish [Poe et al. 1991, Mesa et al. 1994, Sorel et al. 2016] and piscivorous birds [Collis et al. 2002]). However, attention has now been turned to upstream migrating adult fish exposed to pinniped predation. Like natural fish passage impediments (e.g., waterfalls, cascades, chutes), hydroelectric dams can delay up-stream fish passage and congregate fish searching for ladder entrances (Kareiva et al. 2000, Quinones et al. 2015). Such delays can make fish vulnerable to predation by pinnipeds (Stansell 2004, Naughton et al. 2011), a clade known to be efficient predators of Pacific Northwest fish (Weise and Harvey 2005).

An extreme example of deleterious pinniped-salmonid predation near a man-made impoundment was the functional extirpation of the Ballard Locks winter steelhead (*Oncorhynchus mykiss*) run in Washington State in the late 1980's (Jefferies and Scordino 1997, Fraker and Mate 1999). More recently, pinniped impacts have been documented on a number of ESA-listed salmonid species in the Columbia River and associated rivers and tributaries (Madson et al. 2017, Wright et al. 2016). For instance, pinniped predation on Upper Willamette River (UWR) winter steelhead has recently been hypothesized to be the primary cause of decline and potential extinction risk factor for the species (Falcy 2017). Similarly, winter steelhead and some spring Chinook Salmon at and below BON are ESA-listed (NFSC 2015), and have been documented prey of pinnipeds for over a decade (Stansell 2004).

Because BON is the lowermost Columbia River dam, it passes a greater diversity and number of anadromous migrants than any other dam on the river, and as such, has the potential to have the most impact on fish passage (Evans et al. 2016). The ESA-listed stocks of steelhead present a unique situation insofar that Bonneville Reservoir is the only reservoir on the Columbia River with both winter (ocean maturing) and summer (stream maturing) steelhead variants (Withler 1966) spawning in attached tributaries (e.g. Wind River, Little White Salmon River, Big White Salmon River, Hood River, and Klickitat River [Nehlsen et al. 1991]). Thus, pinniped predation of these fish can occur over a sustained period of time while the fish stage for spawning migration and during the post-spawn kelt downstream migration. Due to disorientation of kelts that occurs during downstream dam passage (Wertheimer and Evans 2005), this important life history type (Fleming 1998, Keefer et al. 2008a) may be particularly vulnerable to pinniped predation in the dam tailrace areas.

Other threatened or endangered salmonid species exposed to pinniped predation near BON include Chum Salmon (*Oncorhynchus keta*) and Coho Salmon (*Oncorhynchus kisutch*). Pinniped presence in the Columbia River is aligned with the Spring Chinook run during the pinniped pre-breeding season, while the post-breeding season appears to be synchronized with the fall Chinook, Coho and Chum Salmon migration period. Predation of any of these ESA-listed stocks could damage run viability and make recovery efforts difficult, however quantitative data have not been collected regarding pinniped predation of these salmonids species in the Columbia River during the fall and winter months.

Pacific Lampreys (*Entosphenus tridentatus*), a species of concern, are also exposed to predation by pinnipeds. The chronology of Pacific Lamprey migration overlaps with the later part of the spring pinniped residency at BON, and as such, do not risk predation throughout their entire passage season at BON. White Sturgeon (*Acipenser transmontanus*) however, are known pinniped prey items and the level of predation has been consistently dropping over the last six years. The reason for these decreased estimates are unknown, but of concern to fish managers (ODFW 2015).

In response to these concerns, and to fulfill the requirements set forth in the Federal Columbia River Power System Biological Opinion (NMFS 2000, 2008, 2014) – which outlines operational criteria for dams to protect ESA-listed fish – the U.S. Army Corps of Engineers (USACE) Fisheries Field Unit (FFU) initiated a pinniped monitoring program to fulfill the Reasonable and Prudent Alternatives (RPA) outlined under the predation management strategy of the Biological Opinion. These RPA's are specific to pinnipeds at BON and state:

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 BON 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 BON.

RPA Action 69 - Monitoring Related to Marine Mammal Predation

The Action Agencies will estimate overall sea lion abundance immediately below BON. 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 BON.

Specifically, the objectives of the FFU pinniped monitoring program are to:

1. Determine the seasonal timing and abundance of pinnipeds present at the BON tailrace, documenting individual CSL and 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 BON 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 runs of anadromous fish passing BON.

Consistent with RPA Action 69, the USACE FFU conducts sampling during the spring Period (1 January – 31 May) and has done so for the last 16 years. On July 7, 2017, NOAA Fisheries requested that the USACE extend the monitor program to the fall and winter Period (15 August – 31 December) to monitor the growing SSL presence at Bonneville Dam predation impacts of SSL on fall and winter-run salmonids. As such, this report documents the monitoring activities of both periods.

The USACE pinniped monitoring program provides monitoring data, access to the dam facilities, and collaborates with state, tribal, and federal agencies charged with managing fish and pinniped species. Since 2008, the states of Oregon, Washington, and Idaho (the states) have implemented a pinniped removal program at BON, under section 120 of the MMPA to permanently remove predatory CSLs that are having significant negative impacts on the recovery of ESA-listed Chinook Salmon and steelhead stocks. A new authorization was issued to the states on 28 June 2016, and expires on 30 June 2021. The Columbia River Inter-Tribal Fish Commission (CRITFC) collaborates with the program with personnel and boat-based hazing efforts, and the U.S. Department of Agriculture (USDA) provides dam-based hazing (i.e. deterrence) efforts under contract to the USACE.

This report is a summary of abundance and predation monitoring and deterrence efforts implemented from 15 August 2017 - 2 June 2018 by, or coordinated with, the aforementioned agencies. For brevity and ease of communication we have appended the description of the BON tailrace system, life history of the pinniped and fish species studied, and the general study approach to Appendix 1. We present each study period (i.e. fall-winter and spring) separately by chapter. Each chapter starts with a brief overview of the study design and methods then presents current data partitioned by species and, where possible, contrast it to previous estimates to elucidate the trends of pinniped presence and predation on adult migratory fish at BON.

CHAPTER 2: FALL AND WINTER SAMPLING PERIOD

BACKGROUND & STUDY DESIGN

Pinniped presence during the fall and winter months at BON has increased in the last six years (Table 1). Prior research has found that pinnipeds, primarily SSLs, aggregate at the dam in the winter months to eat adult salmonids (Stansell et al. 2011, 2012, 2013). Recently, the abundance and residency of SSLs during the fall and winter months has increased significantly (Table 1, Tidwell et al. 2018), and fish predation has anecdotally been noted.

In response to the increased abundance of SSLs, and NOAA fisheries request that information on pinniped presence and adult salmonid predation be collected during the fall and winter months at BON we modified the spring monitoring methods to fit the fall and winter conditions of the Columbia River system and started sampling one month after the request was issued. Appendix 1 contains a thorough account of methods and assumptions of sampling, and the specific changes made for the fall and winter period, but in brief; we sampled the priority tailrace (as determined by planned winter outages) and sampled only that tailrace four hours per day in a stratified random fashion whenever the daily abundance counts were greater than 20 pinnipeds (as per study plan provided and approved by the NOAA in March 2017). Visual observation of predation events were incorporated by fish and pinniped species separately into a probability based estimation calculation to assess the mean level of predation each week. Bootstrap sampling of these estimates provide bounded estimates of predation by week, for each fish species, and by each species of pinniped. Thus, the only differences between the fall and winter monitoring and spring sampling period are: the use of only one powerhouse tailrace as opposed to all three, a 20 animal threshold to initiate sampling, and a reduced sampling duration of four hours.

Table 1. Average daily combined pinniped presence by month at Bonneville Dam.

Month	2011	2012	2013	2014	2015	2016	2017
Aug.	0.0	0.0	0.0	1.0	1.9	5.2	10.8
Sept.	0.0	0.0	1.5	6.8	16.6	30.7	13.2
Oct.	2.4	2.6	13.3	11.7	22.5	26.6	14.8

Nov.	4.9	2.8	15.9	16.8	22.3	18.9	18.5
Dec.	7.0	4.1	10.2	9.2	16.1	16.4	16.4

QUANTIFY ABUNDANCE

We used the same methods as those employed during the spring abundance sampling (Appendix 1), wherein, FFU staff conducted independent point counts twice a day at known haul-out locations and in the three tailraces of the dam using field glasses. Counts were conducted in a short period of time (i.e. <15 min.) to ensure animals in transit between locations are not counted twice. We derived a daily maximum pinniped abundance by summing the individual count data at each location and for each species, then selected the highest count for that day and for each species. Linear interpolation was used on days counts were not taken (i.e. weekends and holidays). In doing so, we present the maximum number of animals observed at the dam on each day irrespective of time of day. As this was a novel study that dealt with primarily SSL that have very few brands, we did not attempt to describe the residency or recruitment metrics for each species of sea lion as done during the spring. For more specifics regarding methodological assumptions and techniques see Appendix 1.

QUANTIFY PREDATION

Surface observations of pinniped-prey interactions have been utilized to measure the number of fish and species consumed by pinnipeds at several locations of fish-pinniped interactions including the last 16 years at BON and five years at Willamette Falls (Roffe and Mate 1984, Wright et al. 2018, Tidwell et al. 2018). Trained observers documented all surface predation events that occurred within a select sampling location and period using field glasses. These methods are identical to those used in the spring sampling period. For further details of sampling procedure and assumptions see Stansell (2004; and Appendix 1).

During the fall and winter sampling period, we visually monitored fish predation when pinniped numbers were greater than or equal to 20 animals. If the abundance dropped below the 20 animal threshold during the sampling week, that week was continuously sampled through Friday at which point sampling would cease until the threshold was reached again. This continuous week long interval is a function of the probability sampling methods briefly described below, and thoroughly explained in Appendix 1.

We utilized the 20 animal threshold as this level has been found to consistently produce fish captures within the one hour sampling interval, a factor critical to sampling with a reduced effort design. Moreover, previous data suggests that more than 20 pinnipeds can result in weekly predation of > 20% of the adult salmonid runs passing BON in one week (Tidwell, unpublished data). As such, with 20 or more pinnipeds there is a high probability of documenting predation events.

A stratified random sampling design with bootstrap analysis was employed to estimate the number of fish consumed per strata (week) with confidence intervals (Tidwell et al. 2018). We elected to sample at Powerhouse 2 (PH2) tailrace exclusively due to *a priori* knowledge of scheduled mid-winter de-waterings at Power House 1 (PH1) fish ladders which make them impassable to migrating fish, and the low flows of late summer reducing attraction water to the PH1 tailrace. Based on previous low abundance and predation data in the spillway, and low attraction flow for fish when spill is ceased, we inferred that minimal predation would occur in the spillway where fish attempt to enter the Cascade Island entrance and Bradford Island B-branch entrance. As such, we monitored the spillway for abundance, but not predation. We sampled predation at PH2 for four hours per day, five days a week when pinniped abundance was ≥20 animals. This is similar to the sampling used in the 2017 spring period (Tidwell et al. 2018, Appendix 1).

Collecting predation data at the area most prone to have fish passage and the tailrace associated with Adult Fish Facility (AFF) sampling aligns with assessing pinniped-fish stock specific impacts. Electing to work at PH2 not only provided insight to potential migration impacts for the entirety of the fish passage season, it also provided the select advantage of allowing future investigations of stock specific impacts. The Tribes (CRITFC) and WDFW sample fish crossing BON during the fall at the AFF at the Washington Shore fish ladder of PH2, and can provide data on which fish stocks are crossing and when.

We provide estimates of pinniped abundance across all tailraces of BON and predation estimates for fish passing the Washington Shore fish ladder at PH2. For analysis of impact to fish species, we present the data in two ways: First we present the number of fish crossing the Washington Shore fish ladder between 30 August and 31 December (www.FPC.org), and provide an estimate of the percent of these fish consumed during the sampled weeks. Next, we provide weekly passage estimates for the weeks when pinniped numbers were ≥ 20 animals and predation sampling occurred. Any inference of these data to the entire tailrace area or locations downstream need be made with caution. All analyses were done in statistical program R (Version 3.2.2).

RESULTS

Pinnipeds were not observed at BON between 2 June (end of the spring sampling period) and 20 July, 2017, after which they were omnipresent in low numbers until 11 August when the count of SSLs increased to six or more animals for the rest of 2017. Intensive (i.e. two times/day) abundance monitoring started 15 August and predation monitoring started 30 August 2017 and all observations ceased at on 31 December. The following sections detail the results of each aspect of the abundance and predation monitoring.

ABUNDANCE

Annual Individual Pinniped Abundance

We documented 3 individual CSLs and 36 individual SSLs during the 15 August – 31 December time period (Table 2). No harbor seals were observed. Two of the identified CSL were branded individuals; one had been documented at BON since 2015, and the other, a known Willamette Falls foraging individual, had not previously been documented at BON. Of the 36 identified SSL, six were individually identifiable animals that have been observed at BON before. As such, the number of unique individuals was estimated as the highest point count of the fall and winter period when 36 individuals were present. The low number of individually identifiable SSLs is due to the low branding levels put toward this species (Wright et al. 2018). Based on the ingress and egress of individuals during the fall and winter period (Tidwell et al. 2018), the number of unique individuals is likely much higher than 36.

Table 2. Minimum number of pinnipeds observed per day at Bonneville Dam tailrace areas for the August – December time period each year. *Note: first pinniped not present at dam until 10/3 in 2011, 10/1 in 2012, 9/3 in 2013, 8/20 in 2014, 8/26 in 2015, 8/15 in 2016, and 7/21 in 2017.

Year	California Sea Lions	Steller Sea Lions	Total Pinnipeds
2011	1	12	13
2012	2	7	9
2013	1	25	26
2014	1	26	26
2015	3	30	33
2016	1	56	57
2017	3	36	39

Daily Pinniped Abundance

The first SSLs were observed on project on 21 July 2017, and fluctuated in low numbers (i.e. one to two individuals) until 18 August when SSLs first peaked at 27 individuals. The number of SSLs stayed relatively high (i.e. ≥ 10 animals) until mid-September, when another peak occurred on 26 October with 36 individuals, and a third maximum on 4 December again at 36 animals which remained relatively constant through the start of the spring period (January – May) (Figure 1B). Thus, from 21 July 2017, SSLs were continuously present at BON throughout the entirety of the year (Figure 1B).

The first CSL was observed on 2 November 2017 and sporadically until 4 December 2017 when two individual CSLs were present (Figure 1A). Our maximum observed daily number of CSLs during this time period was on 15 December when 3 CSLs were present. Across the 21 July – 31 December period, SSLs averaged 14.5 ± S.E. 1.3 animals, whereas CSLs averaged 0.2 ± S.E. 0.1. Due to the variable nature of the daily abundance data we present the median estimate as well. The median number of SSLs was 13 and the median for CSL was 0.

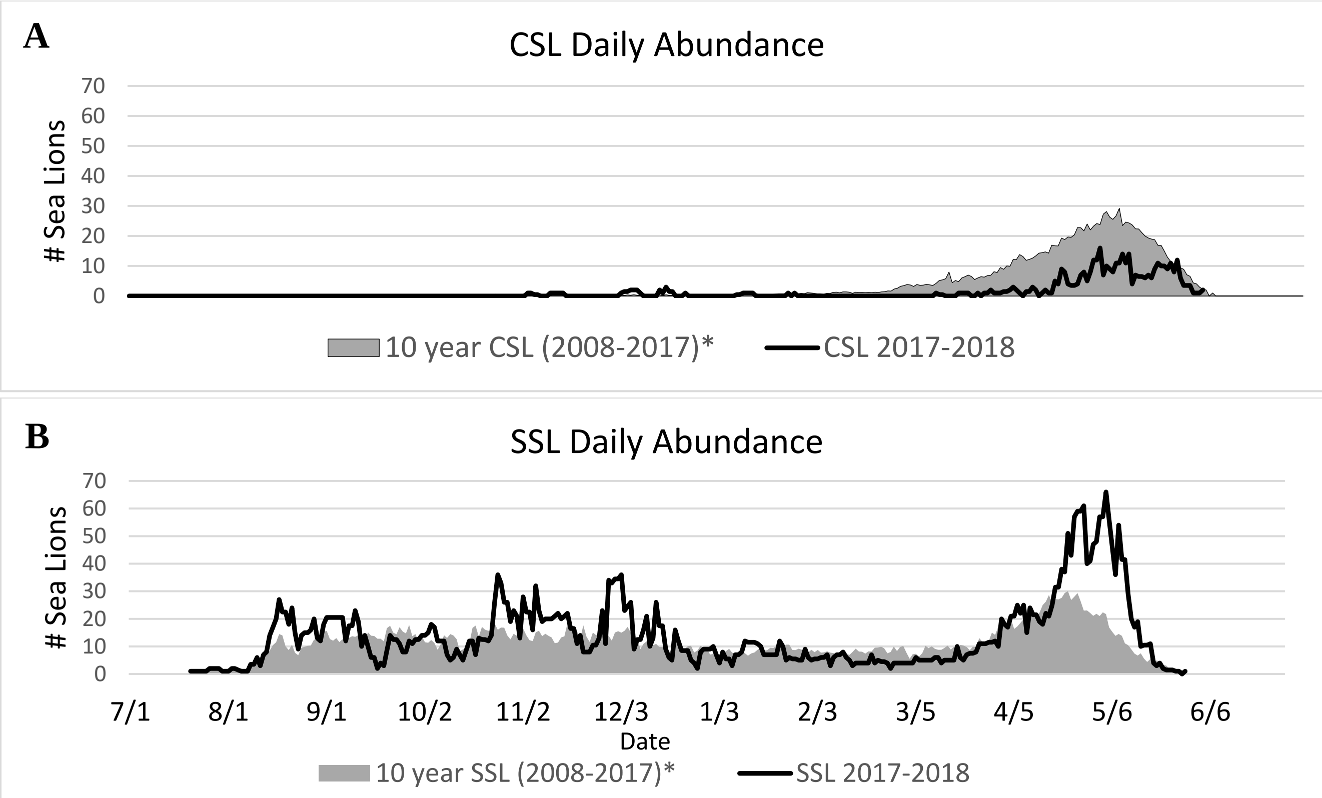


Figure 1. Maximum daily count of pinnipeds by species (SSL: Steller sea lions, CSL: California sea lions) at Bonneville Dam from 31 July 2017 through 1 June 2018 compared to the 10-year maximum daily average. For reference: fall and winter sampling period = 15 August – 31 December 2017 and spring period =1 January – 2 June 2018. * Averages from 6/1 - 12/31 begin in 2011, sporadic between years.

PREDATION

Between 15 August and 31 December 2017, we recorded nine weeks with ≥ 20 pinnipeds and 139 independent one hour (*i.e.* paired 30 minute intervals) predation observation periods (Figure 2). The first sampled week was 30 August 2017 and is the starting point for predation impact estimates. Below we present the chronology of fish passage, the predation of all salmonid species combined, and then delineate predation impact for each fish species for the nine weeks sampled. All predation estimates are presented as the bootstrap calculated adjusted estimate (i.e. raw count data expanded for missing hours and adjusted for unidentified fish catches) and are followed by their associated 95% confidence bounds to display the strength of the estimate.

To assess impact to the run and provide estimates that can be used in the future for inter-year comparisons, we present the number of fish consumed divided by the number of fish that crossed the dam that week. We did not add the consumed fish estimate to the fish passage estimate before dividing by fish passage as has been done during the spring sampling season (Tidwell et al. 2018). We do this for two reasons: first, the incomplete run passage estimates (in-season sampling as opposed to across season sampling like the spring) make determining the total number and rate of fish passage unclear and second, the sporadic sampling periods that are a result of the 20 pinniped threshold made estimating between week passage unrealistic. For further justification of methods and assumptions made, see Appendix 1.

Predation on Adult Salmonids

An estimated 892 (737 – 1,046) adult salmonids were consumed, which equates to 1.2% of the salmonids that passed the PH2 tailrace between 30 August and 31 December, 2017 (Figure 3A). Of these, we estimate 401 (281 – 506) were Chinook; 368 (296 – 432) were Coho; and 123 (63 – 172) were steelhead. (Table 3, Figure 2).

Predation on White Sturgeon

An estimated 238 (183 – 291) White Sturgeon were consumed (Table 3). All White Sturgeon consumed were observed to have been approximately 2 – 4 feet in length.

Predation on other Fish Species

An estimated 234 (145 – 320) American Shad (*Alosa sapidissima*) were consumed and one Pacific Lamprey (*Entosphenus tridentata*) was observed consumed on 31 August 2017. Predation estimate expansion is not feasible for Pacific Lamprey due to the single sample event.

Table 3. Adjusted consumption estimates on adult salmonids (including adults and jacks) and White Sturgeon by California and Steller sea lions at Bonneville Dam during the 2017 fall and winter sampling period in the Washington Shore tailrace when ≥ 20 animals were present.

	Adjusted Salmonid Consumption Estimates	Range of Consumption Estimate	WA Shore Salmonid Passage During Sample Weeks	% Passage Consumed During Sampled Weeks	WA Shore Salmonid Passage 30 Aug.–31 Dec.	% Passage Consumed 30 Aug.- 1Dec
Chinook	401	281 – 506	54,519	0.7%	204,707	0.2%
Coho	368	296 – 432	11,866	3.1%	49,630	0.7%
Steelhead	123	63 – 172	7,952	1.5%	26,169	0.5%
Sturgeon	238	183 – 291	N/A	N/A	N/A	N/A
All Salmon	892	737 – 1,046	74,354	1.2%	280,563	0.3%

Temporal Distribution of Salmonid Predation Events

An estimated 426,162 total salmonids passed Bonneville Dam between 30 August and 31 December 2017. Of these, 280,563 passed through the observation area of PH2 tailrace (i.e. Washington Shore fish ladder) (Figure 3A). The level of salmonid consumption relative to run size over time is displayed in Figure 3. It shows that most Chinook Salmon depredation occurred primarily in mid-September (Figure 3B) while steelhead depredation was heaviest during late-August and early-December periods (Figure 3C) and Coho were the dominant prey fish from mid-October through mid-November (Figure 3D).

The chronology of passage and consumption rates for the nine sampled weeks when pinniped abundance was ≥ 20 animals are listed in Table 4 and depict a highly variable consumption rate. Predation on Chinook Salmon was high in September when passage was also peaking, whereas Coho and steelhead predation was high after the peak of the runs (Table 4). Note that the majority of weeks sampled were after the bulk of the fall salmonid runs had passed (Figure 3A).

Table 4. Adjusted pinniped consumption and fish passage estimates of adult salmonids (including adults and jacks) in the Washington Shore tailrace of Bonneville Dam during the 2017 fall and winter sampling period when sea lion abundance was ≥ 20 individuals.

Sample week	Chinook Consumption ± SE / Passage	% Chinook Consumed	Coho Consumption ± SE / Passage	% Coho Consumed	Steelhead Consumption ± SE / Passage	% Steelhead Consumed
30 Aug. – 1 Sep.	92 ± 32 / 7008	1.3%	0/ 450	N/A	28 ± 16 / 2547	1.1%
12 Sep. – 15 Sep.	140 ± 73 / 46,284	0.3%	10 ± 8 / 8738	0.1%	20 ± 10 / 5013	0.4%
25 Oct. – 27 Oct.	45 ± 15 / 169	26.6%	83 ± 20 / 1781	4.7%	0 / 132	N/A
31 Oct. – 3 Nov.	50 ± 11 / 555	9.0%	122 ± 17 / 274	44.5%	17 ± 7 / 32	53.1%
7 Nov. – 9 Nov.	32 ± 9 / 233	13.7%	79 ± 11 / 302	26.2%	8 ± 5 / 28	28.6%
14 Nov. – 17 Nov.	35 ± 13 / 191	18.3%	40 ± 13 / 184	21.7%	0 / 21	N/A
28 Nov. – 1 Dec.	8 ± 5 / 50	16.0%	27 ± 9 / 56	48.2%	12 ± 10 / 45	26.7%
4 Dec. – 8 Dec.	0 / 18	N/A	0 / 54	N/A	22 ± 6 / 47	46.8%
11 Dec. – 15 Dec.	0/ 11	N/A	6 ± 3 / 27	22.2%	18 ± 5 / 87	20.7%

Temporal Distribution of White Sturgeon Predation Events

White Sturgeon predation intensity was highest during the first week of November (Figure 2). No predation was observed in August or September, but became consistent when sampling re-initiated in October.

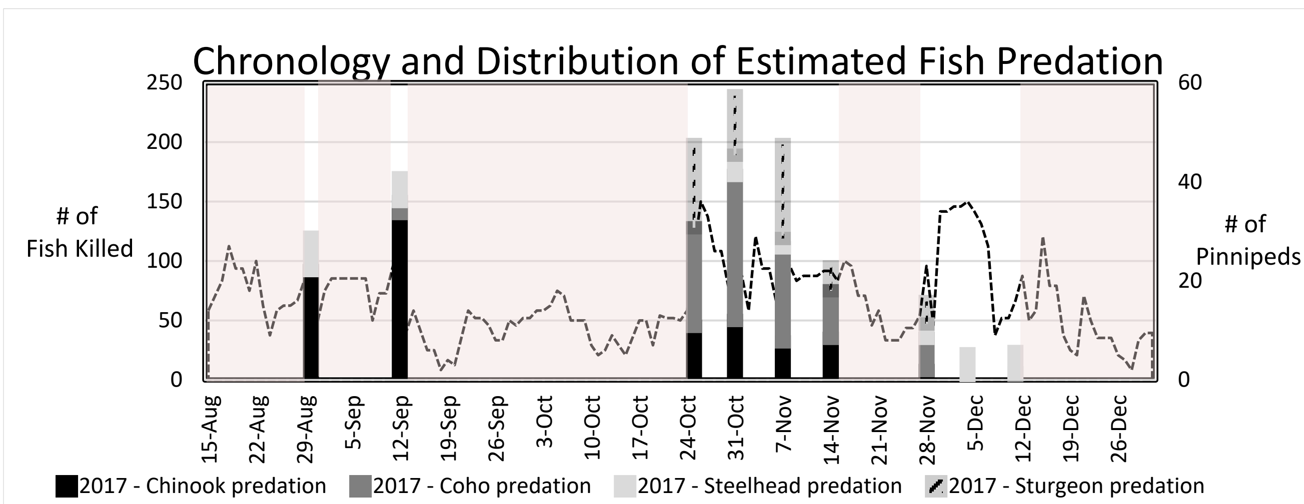
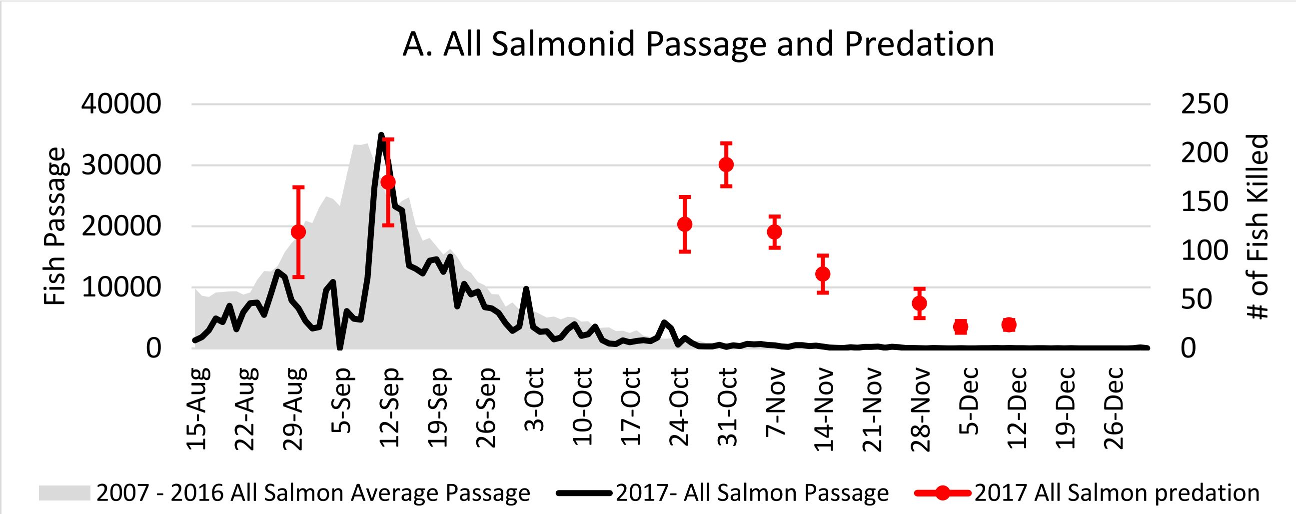
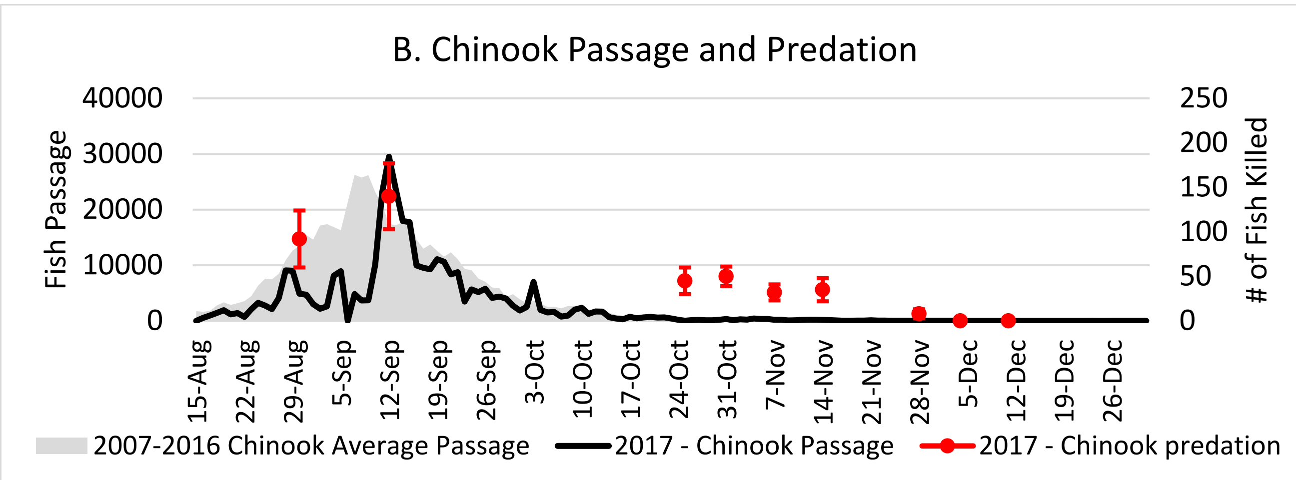
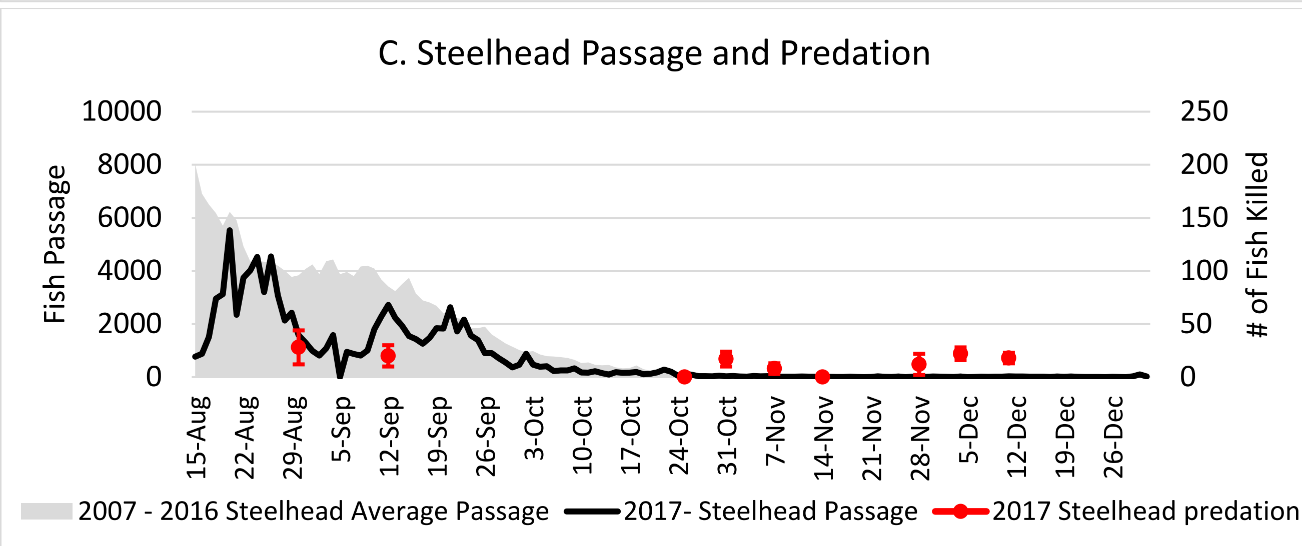


Figure 2. Estimated number of fish consumed per week by pinnipeds at the Washington Shore tailrace of Bonneville Dam during the 2017 fall and winter period when pinniped abundance was ≥ 20 individuals. Pinniped abundance is represented by the dashed line and periods not sampled (<20 animals) are in shaded boxes.


A. All Salmonid Passage and Predation
Fish Passage
# of Fish Killed
40000
30000
20000
10000
0
250
200
150
100
50
0
15-Aug
22-Aug
29-Aug
5-Sep
12-Sep
19-Sep
26-Sep
3-Oct
10-Oct
17-Oct
24-Oct
31-Oct
7-Nov
14-Nov
21-Nov
28-Nov
5-Dec
12-Dec
19-Dec
26-Dec
2007 - 2016 All Salmon Average Passage
2017- All Salmon Passage
2017 All Salmon predation


B. Chinook Passage and Predation
Fish Passage
# of Fish Killed
40000
30000
20000
10000
0
250
200
150
100
50
0
15-Aug
22-Aug
29-Aug
5-Sep
12-Sep
19-Sep
26-Sep
3-Oct
10-Oct
17-Oct
24-Oct
31-Oct
7-Nov
14-Nov
21-Nov
28-Nov
5-Dec
12-Dec
19-Dec
26-Dec
2007-2016 Chinook Average Passage
2017 - Chinook Passage
2017 - Chinook predation


C. Steelhead Passage and Predation
Fish Passage
# of Fish Killed
10000
8000
6000
4000
2000
0
250
200
150
100
50
0
15-Aug
22-Aug
29-Aug
5-Sep
12-Sep
19-Sep
26-Sep
3-Oct
10-Oct
17-Oct
24-Oct
31-Oct
7-Nov
14-Nov
21-Nov
28-Nov
5-Dec
12-Dec
19-Dec
26-Dec
2007 - 2016 Steelhead Average Passage
2017- Steelhead Passage
2017 Steelhead predation

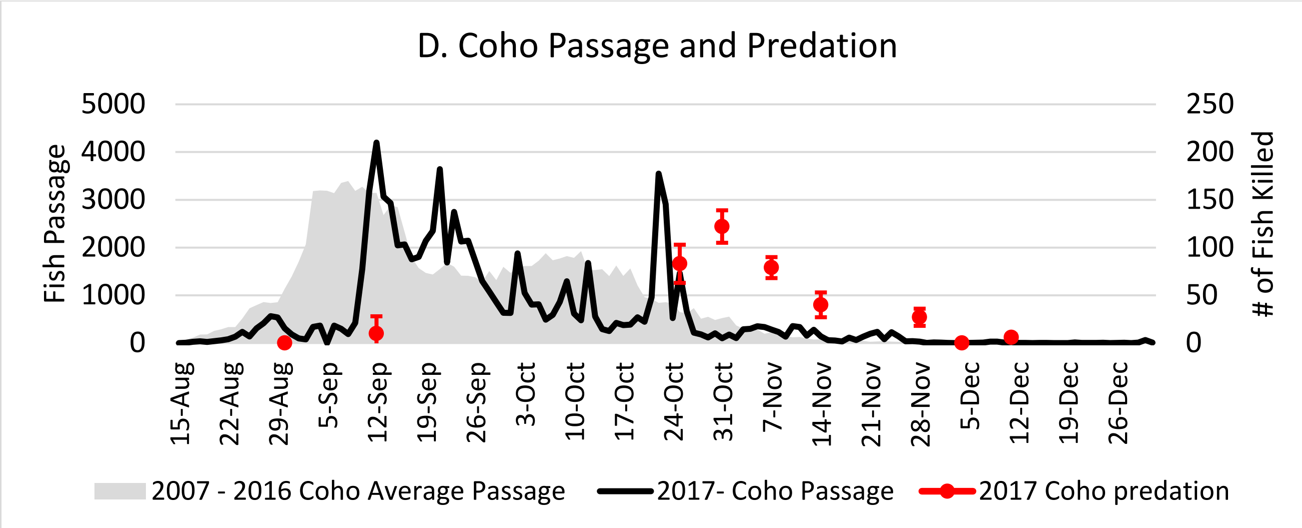


Figure 3. Temporal distribution of Salmonid passage (ten year average and 2017) at the Washington Shore count station of Bonneville Dam. Points in red is estimated predation number by pinnipeds for each sampled week bars are Standard Error of mean estimates. Note differences in Y-axis for each plot.

DISCUSSION

Here, we discuss the trends of pinniped abundance and fish predation to BON and explore the relative impacts these animals have on the various fish species. We estimated that more than 1,000 Chinook Salmon, Coho Salmon, steelhead, and White Sturgeon were consumed between 30 August and 31 December 2017 by SSLs. In some weeks, salmonid predation was equal to the number of fish passing BON. White Sturgeon were also heavily depredated for three weeks. We discuss the impacts to fish runs by assessing pinniped consumption as an aggregate of all salmon that passed the Washington Shore PH2 ladder (i.e. Cascades Island entrance of the SPW and all four fish way entrances of PH2) during the nine sampled weeks when there were ≥ 20 pinnipeds. We keep the discussion focused on the data presented currently and emphasize that these data represent one sample season and a subset of the weeks pinnipeds were at BON. Due to fish and wildlife management's interest in stock specific impacts, we highlight the temporal periods of predation that are most severe, and emphasize that the circumstances at BON are progressively showing an increased SSL impact.

We have documented increasing numbers and earlier arrival of SSLs over the last six years. The arrival date for SSL has been, on average, 11.6 days earlier each year since 2011, and this year, the BON SSLs were away from the tailraces for less than six weeks, meaning the last SSL departed the BON tailrace toward the end of May and the first returning SSL was back in July and was consistently seen thereafter. Thus, SSL recruitment to the system during the fall and winter period has continued to increase in both the number of animals and the number of days they are present. The recruitment of new CSLs has increased during the same time period, but at a much slower rate. The arrival of the CSL from the Willamette Falls site, 64 river miles away, enforces the connectivity of the systems and suggest that both sites are now used as foraging grounds during the fall and winter. This relationship of using both sites has been well documented during the spring (Stansell 2004, Tidwell et al. 2018).

The chronology of fish passage did not match the arrival and foraging pattern of pinnipeds at BON. Concomitant to peak salmonid passage in late-August and early-September, pinniped numbers dropped to the lowest abundance estimates of the fall and winter period. Between the last week of October and the third week of November pinniped numbers increased and the number of fish killed peaked to the highest of the sampling period. This time frame coincides with a pulse of Coho Salmon passage, but a general decline of fall salmonid passage. This temporal disconnect between predator and prey arrival to the BON tailrace suggests that the pinnipeds foraged elsewhere during the peak of the fall salmonid run and returned to BON as the fall salmonid run dissipated, where they foraged on the remaining salmon in the tailrace of PH2.

We estimate 892 adult salmonids were consumed at the PH2 tailrace during the nine sampled weeks of the fall and winter sampling period. Of the adult salmonids crossing the Washington Shore PH2 ladder when we sampled, we found approximately 0.7% of the Chinook Salmon, 3.1% of the Coho Salmon, and 1.5% of the steelhead were consumed by pinnipeds. Collectively, of all the adult salmonids counted at the PH2 fish count window during the sampled weeks, 1.2% were consumed by pinnipeds.

Further investigation revealed that the latter portion of the salmonid passage season had high levels of consumption relative to the number of fish counted at the Washington Shore fish ladder. For instance, relative to the number of fish counted in the ladder during the first week of November, approximately 14% of Chinook Salmon, 26% of Coho Salmon, and 29% of steelhead were consumed by pinnipeds.

The magnitude and timing of these consumption rates suggest that late running Coho Salmon and the B-run summer and winter steelhead run components are being disproportionately consumed relative to other earlier passing fish. As mentioned above, the winter steelhead run component will be more fully assessed when the estimates are provided across the entire passage season, but these preliminary numbers suggest the impact of predatory sea lions may be biologically significant.

We estimate 238 sturgeon were consumed at the PH2 tailrace during the nine sampled weeks of the fall and winter sampling period. These data stand in stark contrast to the five month spring sampling period of 2017 when approximately 24 White Sturgeon were consumed across all tailraces. The increase in consumption may indicate that changes have occurred in the system relative to the last seven years. Beginning in 2006, SSL predation on White Sturgeon increased, and in 2012 it peaked at more than 3,000 fish per spring season. Since 2016 there have been less than 100 fish killed during each five-month spring sampling season. The consumption documented during the nine-week fall and winter sampling season of 2017 exposes that white sturgeon are vulnerable to predation at almost any time of year and may now be consumed more heavily during the fall and winter period.

In the past, monitoring during the spring has found that pinnipeds follow fish runs to BON, thus predator numbers increase as the prey increase in number. However during the fall and winter of 2017, peak fall salmonid passage in September were coupled with low pinniped numbers, and when the salmonids runs slowed in late-October, pinniped numbers peaked.

One possible explanation for this may be that Chum Salmon (*Oncorhynchus keta*) spawn near the Pierce-Ives island complex less than 2 river miles downstream from BON and have been observed being consumed on and near their redds by SSL with increasing frequency (Todd Hilson [WDFW] personal communication). Notwithstanding the drivers of the variable SSL numbers at BON during the fall salmonid passage season, the result is a prolonged presence of predatory SSLs that are consuming larger number of White Sturgeon and potentially consuming ESA listed Chum Salmon.

We emphasize that the fish consumption estimates presented herein apply only to the nine weeks sampled between 30 August and 31 December. Moreover, the estimates represent only one of the three tailraces near BON. Run impact estimates are presented relative to all 18 weeks of passage crossing the PH2 fish ladder and then separately for the passage of the nine sampled weeks. Therein, these measurements represent minimal estimates of fish predation in PH2 when pinniped abundance was ≥20 animals. Extrapolation of these consumption estimates to all three tailraces are beyond the scope of the requested work. However, if requested the analyses would need to simultaneously account for the number of pinnipeds foraging in each of the three tailraces, the salmon passage at all tailraces, and the fish ladder outages and changing power house priority that determine flow and impact the routes of passage. Withstanding these caveats, it becomes clear that the estimates of fall Chinook Salmon, steelhead, Coho Salmon, and White Sturgeon predation from the PH2 tailrace are concerning and deserves particular attention from the agencies that manage these species.

The SSL abundance and predation estimates presented during the fall and winter document impacts to adult salmonids that to this point, had not been rigorously investigated. We documented weekly predation estimates of up to 27%, 53%, and 48%, for the Chinook salmon, steelhead, and Coho salmon (respectively) relative to the number of fish counted passing the dam during a specific week. These levels of consumption are a direct result of the increasing presence of predatory SSLs at BON and the growing population of BON-habituated SSL. Columbia River salmonids now contend with quasi-resident SSL predators that have increased in abundance and predatory impact.

CHAPTER 3: SPRING SAMPLING PERIOD

BACKGROUND & STUDY DESIGN

The spring sampling Period has been monitored at BON for pinniped abundance and predation since 2002 to fulfill RPA 49 of the Biological Opinion. The techniques and methods have adapted through the years to fit the changing biological system and requests from managers, but the approach to sampling has remained the same. The methods used this year are detailed in Appendix 1, and include surface observations of fish predation, visual inspections of pinniped abundance, and individual pinniped identification. Historically the sampling Period ran from 1 January – 31 May, however, due to increased pinniped residency in the last three years, we now extend sampling to the last day when pinnipeds are documented near the Bonneville Dam tailrace. This spring sampling season ended on 2 June 2018.

Similar to previous years, we employed a probability sampling design to reduce effort and provide bounded estimates of mean predation on each species of fish (Madson et al. 2017, Tidwell et al.

2018). The differences between the sampling of the fall - winter and spring sampling periods include: daily monitoring of fish predation regardless of pinniped abundance, and monitoring at all three tailraces during the spring. One alteration employed this season relative to previous years' spring sampling included the selective exclusion of Spillway sampling when no pinnipeds were present prior to the fish attraction flow of mandatory spill occurring. This increased the efficiency of observations by excluding the tailrace that had no pinnipeds in it (see Appendix 1 for details).

Below, we provide estimates of pinniped abundance across all tailraces of BON and predation estimates for fish. We also present the metrics of pinniped deterrence and management activities conducted this year at BON. For analysis of impact to fish species, we present the number of fish crossing the Washington Shore and Bradford Island fish ladders between 1 January and 2 June (www.FPC.org) and provide an estimate of the percent of these fish consumed during the sampled weeks (Appendix 1). All analyses were done in Program R (Version 3.2.2).

RESULTS

ABUNDANCE

Daily Pinniped Abundance

During the spring, individual CSLs were sporadically present in low numbers (n = 0 - 3) until April 16, after which more than three individuals were consistently observed. The numbers peaked on 30 April (n = 16) and fluctuated between 6 and 14 animals until 25 May, then decreased until the last animal left between 1 June and 4 June (Figure 1A). SSLs fluctuated between 5 and 11 animals through the end of March, gaining individuals throughout April to a seasonal high of 66 animals on 7 May, then decreased to one animal by June 1 (Figure 1B). Across the spring season, CSLs averaged 2.6 ± 0.3 animals per day, whereas SSLs averaged 14.6 ± 1.3 (Supplementary Table 1).

Inspection of the 2018 spring sampling Period daily abundance relative to the 10-year average reveals that CSL numbers were below average for the entirety of the season except for the last week, whereas SSLs abundance equaled the 10-year average until late April when they exceeded the average for the remainder of the spring Period (Figure 1).

Descriptive statistics facilitating inter- and intra-year comparisons of daily pinniped abundance are available in Supplementary Table 1. Of particular interest is the differential abundance of each species in recent years, wherein since 2009 the mean and median numbers of SSLs are far greater than CSLs (Supplementary Table 1). Given the high level of stochasticity in the daily counts of pinnipeds (Figure 1), the median counts, rather than mean, may provide a clearer indication of general abundance of each species. Inspection of the data reveals an increasing temporal distribution and abundance of SSLs at BON since 2008, wherein the median number of days present has increased, and the number of days without SSLs has decreased to almost zero (Supplementary Table 1, Figure 4).

Table 5. Minimum estimated number of individual pinnipeds observed at Bonneville Dam tailrace areas and the hours of observation during the spring sampling period, 2002 to 2018.

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
2017	1,142	92	63†	1	156
2018	1,410	67	66†	1	134

* Observations did not begin until March 18 in 2005.
† In 2015, 2016, 2017, and 2018 the minimum estimated number of Steller sea lions (SSL) was 55, 41, 32, and 35 respectively. These counts were 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. This difference is driven by a focus on CSLs and lack of brands or unique markers on SSL.

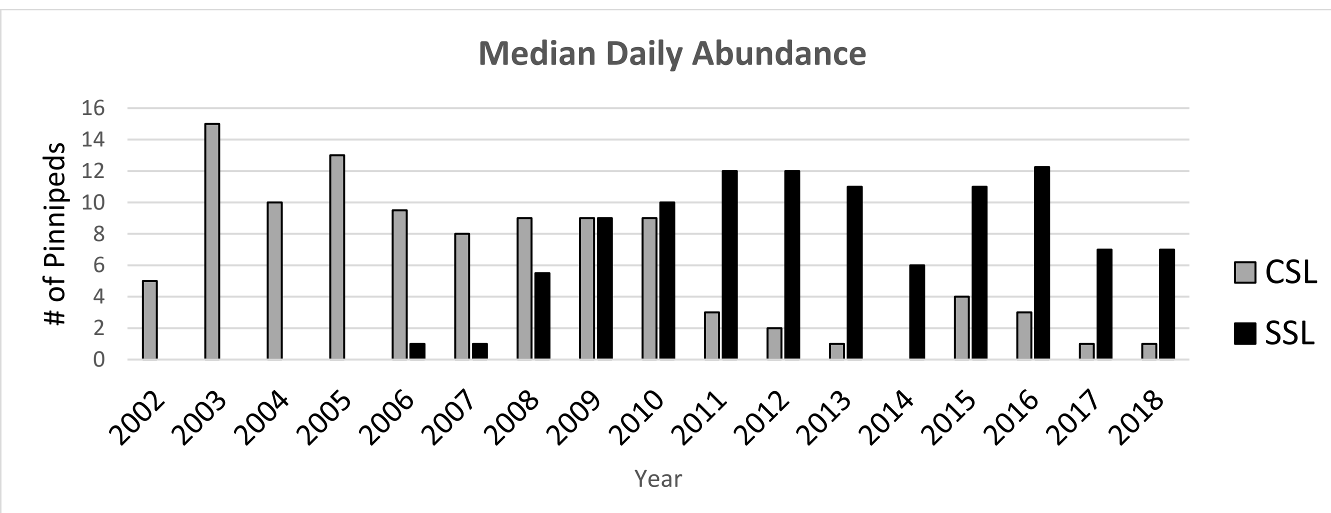


Figure 4. Annual median daily abundance of Steller sea lions (SSL) and California sea lions (CSL) at Bonneville Dam during the spring sampling period from 2002 to 2018.

Residence Times

We found that the number of observed days for CSLs averaged 4.0 ± 0.4 days, whereas the potential number of days present averaged 12.0 ± 1.5 days. Additionally, the number of days present had a much larger spread between the observed and potential (i.e. 1 – 12 days vs 1 – 46, respectively) (Table 6).

Residency times for individual SSLs are not reported due to low sample size (i.e. few branded/known individuals). However, anecdotal accounts suggest that many of the individuals were consistently at the dam with some individuals documented almost every observation day from 15 August – 2 June 2018.

Table 6. Residency (i.e. number of days observed and potential number of days present) in reference to year branded and removed for individual California sea lions (CSL) at Bonneville Dam during the 2018 spring sampling period.

	Days Observed			Potential Days Present		
	$\bar{x}$ ± S.E.	Range	*n*	$\bar{x}$ ± S.E.	Range	*n*
All CSL						
	4.0 ± 0.4	1 - 12	67	12.0 ± 1.5	1 - 46	67
All CSL Removed in 2018						
Yes	3.8 ± 0.5	1 - 11	27	11.9 ± 2.1	1 – 33	27
No	4.1 ± 0.5	1 - 12	40	12.1 ± 2.1	1 – 46	40

Recurrence

We documented a total 67 branded CSLs, 56 of which had been previously identified at BON using brand re-sight data and 11 were “new” to BON (Table 7). Of the new CSLs, 8 were branded at BON in 2018 and 3 were branded at Astoria, Oregon, but were sighted at BON for the first time this year. Of the 27 CSLs removed by the States, 26 were documented at BON in previous years, and 19 had been documented for ≥ 3 seasons (Table 7).

There were 66 SSLs on project this year based on the highest point count during the season. We documented 34 individuals, 30 of which can be confirmed to have been at the dam in previous seasons and four of them for 10 seasons or more (Table 7).

Table 7. The number of years that California sea lions (CSL) and Steller sea lions (SSL) identified in 2018 were observed at Bonneville Dam. Of the identified CSLs in 2018, the number of CSLs removed and listed for removal is shown. Individuals observed for one year were defined as newly identified animals in 2018.

Number of Years Observed	All Identified SSL	All Identified CSL	Listed for Removal CSL	Removed CSL
12	1	0	0	0
11	3	0	0	0
10	0	0	0	0
9	0	0	0	0
8	1	0	0	0
7	3	0	0	0
6	3	0	0	0
5	3	0	0	0
4	3	14	9	9
3	2	28	16	10
2	11	14	9	7
1	4	11	1	1
Totals	34	67	35	27

Observations Upstream of the Dam

Historically, pinnipeds have been documented transiting the navigation locks of BON to the forebay and this year was no exception. We documented four CSLs that transited between the tailrace and forebay. Three were branded habitual users of the navigation lock and listed for removal, one was not branded. Three of these animals have previously been observed foraging at The Dalles Dam with one of them remaining there year-round.

PREDATION

We recorded 1,410 independent one hour (i.e. paired 30 minute intervals) observation periods during the 22 week spring sampling period. Below we present predation on all salmonid species combined, then delineate predation impact for each fish species by pinniped species. All predation estimates are presented as the bootstrap calculated adjusted estimate (i.e. raw count data expanded for missing hours and adjusted for unidentified fish catches) and are followed by their associated 95% confidence bounds to display the spread. More information on analytical methods can be found in Appendix 1. For reference to previous years' estimates, we present just the expanded estimates of predation in Supplementary Table 2.

Chronology of Fish Passage

The salmonids passing BON during the spring had to contend with high water flow and cold temperatures. Relative to the 10-year average, the river was colder and moving significantly more water during the spring of 2018 (Figure 5). These co-factors likely contributed to a delayed run of spring Chinook Salmon.

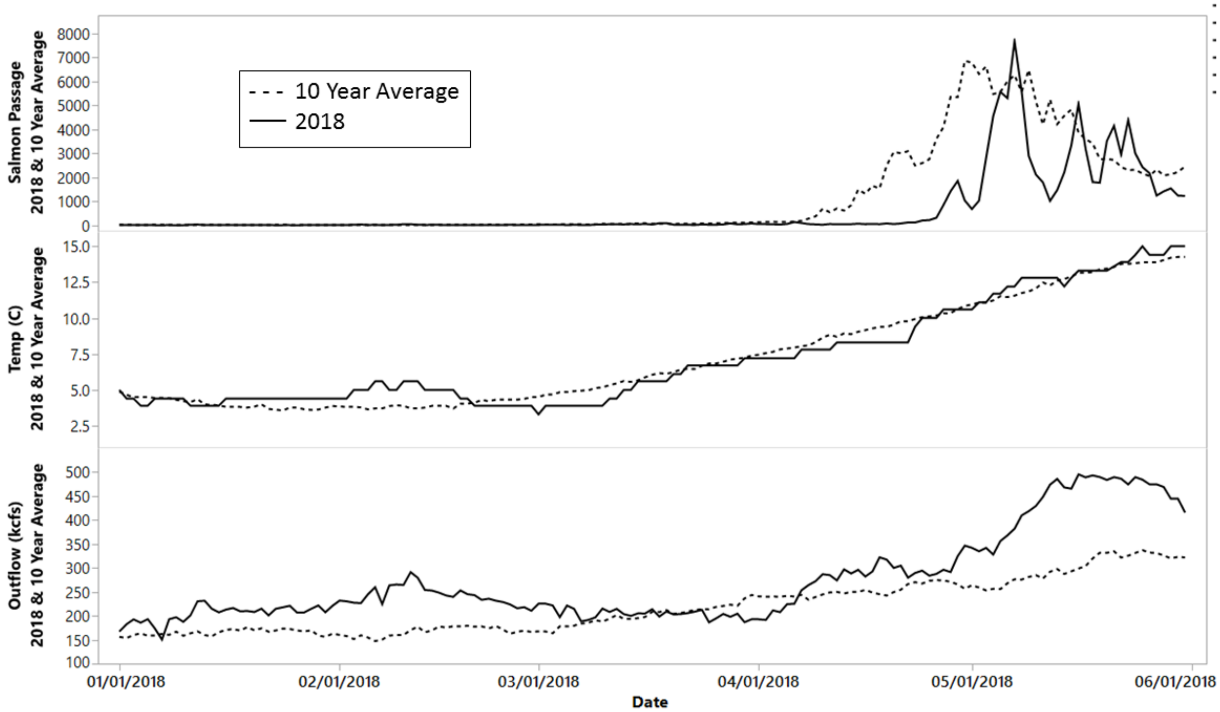


Figure 5. Chronology of salmonid passage, temperature, and outflow (spill + Turbine flow) at Bonneville Dam during the spring sampling period. Solid lines indicate the 2018 season and dashed lines denote the 10-year average for each variable. Data obtain from www.cbr.washington.edu/dart.

Predation on Adult Salmonids

An estimated 3,112 (2,855 – 3,373) adult salmonids were consumed by both pinniped species in the spring sampling Period of 2018, which equates to 3.0% of the salmonids that passed during the spring. Of these, SSLs consumed 2,368 (2,120 – 2,588) which equates to 2.3% of the run, whereas CSLs consumed 746 (635 – 848) which was 0.7% of all adult salmonids (Table 8, Figure 6). No depredation by harbor seals was documented.

Table 8. Adjusted consumption estimates on adult salmonids (including adults and jacks) by California and Steller sea lions at Bonneville Dam during the spring sampling period from 2002 to 2018.

		California Sea Lions		Steller Sea Lions		All pinnipeds	
Year	Bonneville Dam Salmonid Passage	Adjusted Salmonid Consumption Estimates	% Run	Adjusted Salmonid Consumption Estimates	% Run	Adjusted Salmonid Consumption Estimates	% Run
2002	284,732	1,010	0.4%	0	0.0%	1,010	0.4%
2003	217,934	2,329	1.1%	0	0.0%	2,329	1.1%
2004	186,771	3,516	1.9%	7	0.0%	3,533	1.9%
2005	81,252	2,904	3.5%	16	0.0%	2,920	3.4%
2006	105,063	3,312	3.1%	85	0.1%	3,401	3.1%
2007	88,474	4,340	4.7%	15	0.0%	4,355	4.7%
2008	147,558	4,735	3.1%	192	0.1%	4,927	3.2%
2009	186,056	4,353	2.3%	607	0.3%	4,960	2.7%
2010	267,167	5,296	1.9%	1,025	0.4%	6,321	2.4%
2011	223,380	2,689	1.2%	1,282	0.6%	3,970	1.8%
2012	171,665	1,067	0.6%	1,293	0.7%	2,360	1.4%
2013	120,619	1,497	1.2%	1,431	1.2%	2,928	2.4%
2014	219,929	2,747	1.2%	1,874	0.8%	4,621	2.1%
2015	239,326	8,324	3.3%	2,535	1.0%	10,859	4.3%
2016	154,074	6,676	4.1%	2,849	1.7%	9,525	5.8%
2017	109,040	2,142	1.9%	3,242	2.8%	5,384	4.7%
2018	100,887	746	0.7%	2,368	2.3%	3,112	3.0%

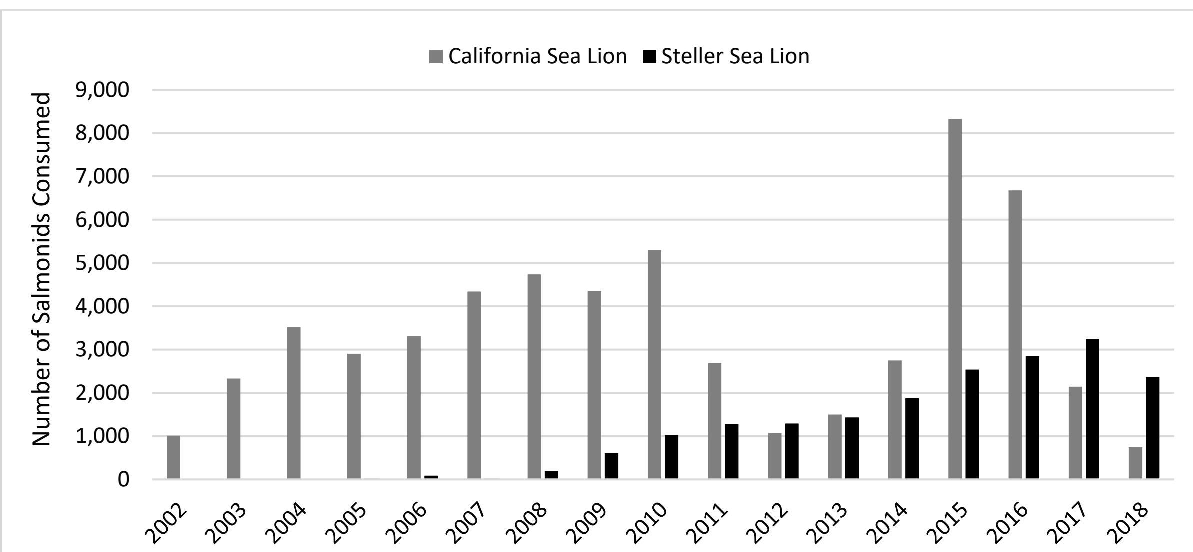


Figure 6. Adjusted estimates of salmonid consumption by California and Steller sea lions at Bonneville Dam during the spring sampling period from 2002 to 2018.

Predation on Chinook Salmon

An estimated 2,813 (2,554 – 3,067) spring Chinook Salmon were consumed, which equates to 2.9% of the run. Of these, SSLs consumed 2,120 (1,897 – 2,327) which equates to 2.2% of the run, and CSLs consumed 698 (592 – 795) which was 0.7% of the spring Chinook Salmon run (Table 9).

Table 9. Consumption of spring Chinook Salmon by pinnipeds at Bonneville Dam tailrace during the spring sampling seasons from 2002 to 2018. Passage counts of Chinook Salmon includes both adult and jack salmon.

Year	Bonneville Dam Spring Chinook Passage	Chinook Consumption Estimate	% Run
2002 [x,⊥]	275,290*	880[†]	0.3%
2003 [x,⊥]	210,028	2,313	1.1%
2004 [x,⊥]	179,193	3,307	1.8%
2005 [x,⊥]	78,341	2,742[‡]	3.4%
2006 [x,⊥]	99,366	2,580	2.5%
2007 [x,⊥]	83,252	3,403	3.9%
2008	143,139	4,500	3.0%
2009	181,174	4,360	2.3%
2010	257,036	5,909	2.2%
2011	218,092	3,634	1.6%
2012	165,681	1,960	1.2%
2013	117,165	2,710	2.3%
2014	214,177	4,576	2.1%
2015	233,794	10,622	4.3%
2016	148,360	9,222	5.9%
2017	101,734	4,951	4.6%
2018	94,350	2,813	2.9%

[x] Adjusted estimates did not start until 2008 (Tackley et al. 2008), as such these values are expanded estimates.

* 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 observations did not start until March 18.

[⊥] Passage data altered to meet the Fish Passage Center run criteria of 1 January – 31 May. Data will differ relative to previously published data.

Predation on Winter and Summer Steelhead Combined

An estimated 295 (227 – 356) summer and winter steelhead were consumed during the spring, which equates to 7.2% of the combined run (Table 10). Of these, SSLs consumed 247 (188 – 302) which equates to 6.1% of the run, and CSLs consumed 47 (22 – 70) which was 1.1% of the winter and summer steelhead run.

Table 10. Consumption of summer and winter steelhead by pinnipeds at Bonneville Dam tailrace during the spring sampling period from 2007 to 2018.

Year	Bonneville Dam Steelhead Passage	Adjusted Steelhead Consumption Estimate	% Run
2007[x]	5,188	609 [x]	10.5%
2008	4,367	391	8.2%
2009	4,829	599	11.0%
2010	9,972	413	4.0%
2011	5,279	336	6.0%
2012	5,904	400	6.3%
2013	3,394	218	6.0%
2014	5,696	128	2.2%
2015	5,217	237	4.3%
2016	5,262	302	5.4%
2017	3,241	322	9.0%
2018	3,808	295	7.2%

[x] Adjusted estimates did not start until 2008 (Tackley et al. 2008), as such this value is an expanded estimate.

Predation on Winter Steelhead

We documented high levels of predation on winter steelhead this year which is the first year such an analysis could be conducted due to the fall, winter and spring sampling Periods completely enveloping the designated winter steelhead run (16 November 2017 – 31 March 2018). As such, we now provide estimates of the impacts to this stock. An estimated 2,181 steelhead crossed BON during this time and 159 (140 – 178) were consumed by sea lions. Thus, 6.8% of the run was consumed. Note that consumption estimates recorded during the fall and winter were only at the PH2 tailrace and therein represent a conservative estimate of the actual predation impact of sea lions during this time. Due to the low numbers of CSLs at BON during this time (*n* max = 3) almost all of the predation is attributed to SSLs.

Predation on White Sturgeon

White Sturgeon were first documented as prey of SSLs in 2005, and by 2006 were the primary prey item consumed by the species. Annual consumption increased until 2012 after which the numbers of sturgeon consumed dropped considerably (Table 11). This season an estimated 148 (105 – 185) White Sturgeon were consumed by both species of pinnipeds. Of these, SSLs consumed 144 (102 – 181), and CSLs consumed 4 (0 – 6). The size of consumed sturgeon ranged from 2 – 7 feet in length. One half of the predation events occurred in the Spillway tailrace, and the balance in the tailraces of PH1 and PH2.

Table 11. Consumption of White Sturgeon by pinnipeds at Bonneville Dam tailrace during the spring sampling period from 2005 to 2018.

Year	Total Hours Observed	Observed Sturgeon Catch	Adjusted Sturgeon Consumption Estimate
2005	1,109	1	N/A
2006	3,650	265	413
2007	4,433	360	664
2008	5,131	606	1,139
2009	3,455	758	1,710
2010	3,609	1,100	2,172
2011	3,315	1,353	3,003
2012	3,404	1,342	2,498
2013	3,247	314	635
2014	2,947	79	146
2015	2,995	24	44
2016	1,974	30	90
2017	1,142	6	24
2018	1,410	46	148

Predation on Pacific Lamprey

An estimated 58 (17 – 91) Pacific Lampreys were consumed by pinnipeds in 2018. Of these, SSLs consumed 20 (3 – 34), and CSLs consumed 38 (0 – 68) (Table 12). Of the observed predation events: ten Pacific Lampreys were consumed in the PH1 tailrace, three in the PH2 tailrace, and three in the Spillway tailrace. The first predation event was documented on May 1, 2018, and was followed by increasing levels of predation throughout the month of May with a peak of four fish killed on June 1. The temporal distribution of Pacific Lamprey consumption was primarily documented in the crepuscular hours as previously observed at BON in 2017 (Tidwell et al. 2018).

Table 12. Consumption of Pacific Lamprey by pinnipeds at Bonneville Dam tailrace during the spring sampling period from 2002 to 2018.

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%
2017	1,142	41	191	1.7%
2018	1,410	16	58	0.04%

Temporal Distribution of Salmonid Predation Events

An estimated 100,887 salmonids passed during the spring sampling Period of 2018, a smaller run estimate compared to the 10-year average of 183,881 between 1 January and 2 June. Review of Figure 5 indicates the spring Chinook run began later than the 10-year average and had two large pulses peaking on the first and third week of May.

Predation by pinnipeds started prior to the increase of fish crossing the dam, a trend that holds consistent over the last 10 years (Figure 7). Salmonid predation by pinnipeds tracked the pulsatile fish runs described above with increased predation when fish numbers increased. However, predation ceased when pinniped abundance dropped to zero, and salmon runs continued after the pinnipeds were gone. Thus, the late run resulted in delayed predation and the later arriving fish passed the dam with no pinniped predation at BON.

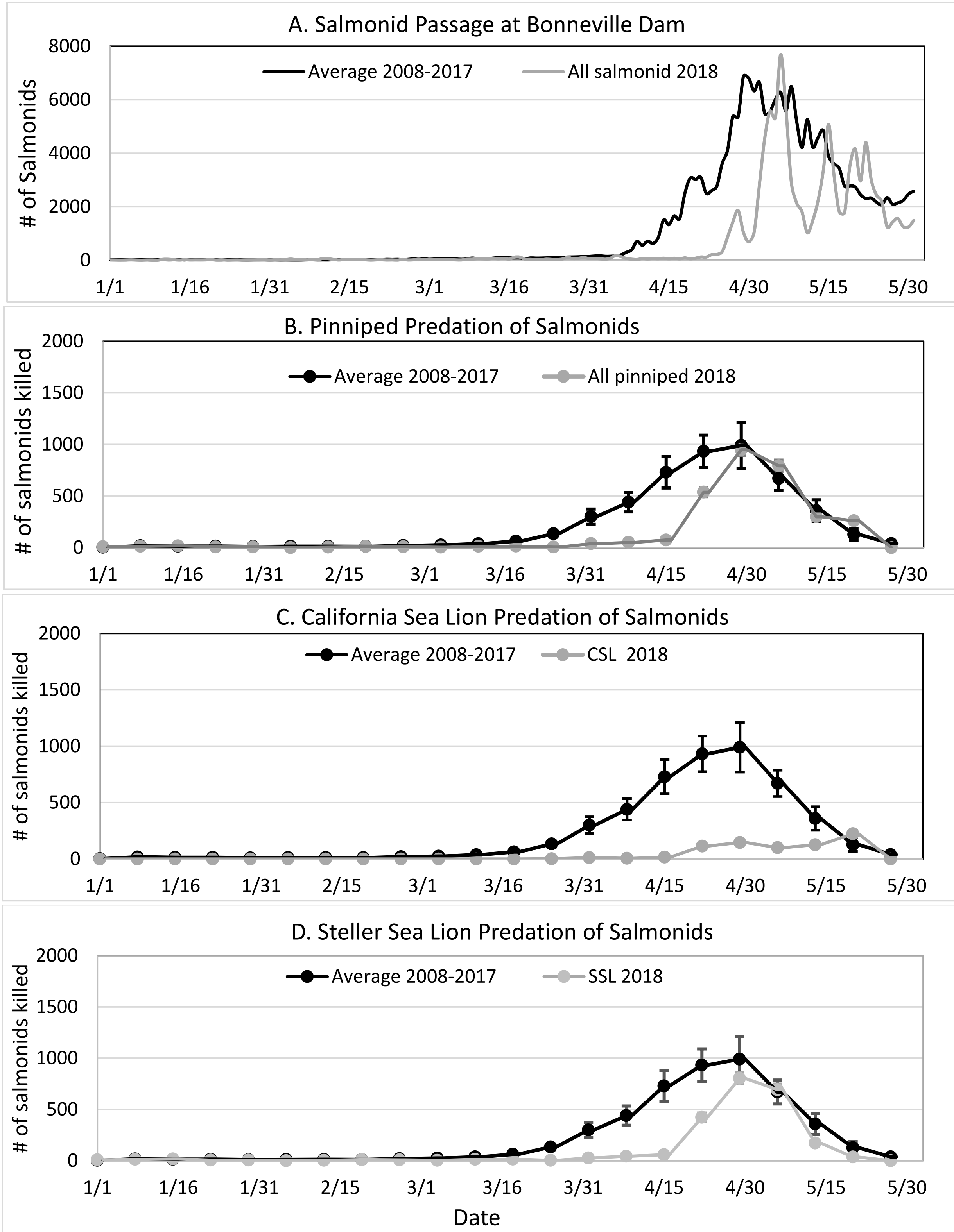


Figure 7. Temporal distribution of all salmonids that crossed Bonneville Dam and weekly adjusted predation estimates (i.e. # of salmonids killed) of these salmonids by Steller sea lions (SSL) and California sea lions (CSL) during the spring sampling period at Bonneville Dam. The predation data labeled "Average 2008– 2017" is the combined weekly average predation by both pinniped species over the last ten years. All error bars represent the Standard Error of the estimates.

Spatial Distribution of Monitoring and Salmonid Predation Events

We observed for 544 hours at PH1, 283 hours at SPW, and 583 hours at PH2. During this time, there were 991 observed salmonid predation events distributed across all sampling areas of the dam's tailraces. Similar to all other years, the bulk of the predation was concentrated in the near-dam areas of the tailrace that have fish ladder entrances (Figure 8 and Figure 9). The combined spatial distribution of observed salmonid predation events by pinnipeds was 41.2% (n = 408) at PH1, 29.0% (n = 287) at PH2, and 29.8% (n = 296) at SPW.

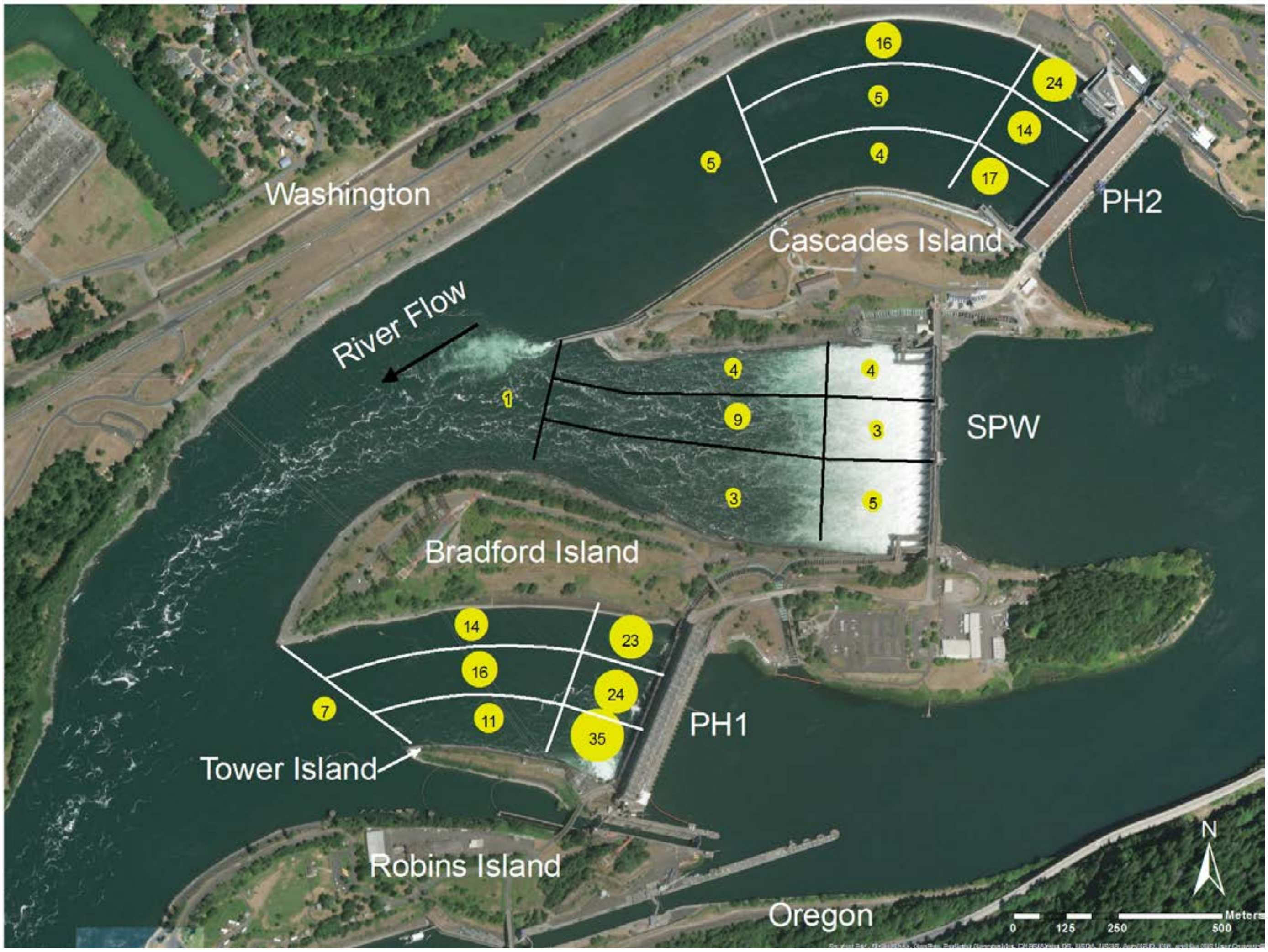


Figure 8. Spatial distribution of observed salmonid predation by California sea lions at Bonneville Dam during the 2018 spring sampling period.

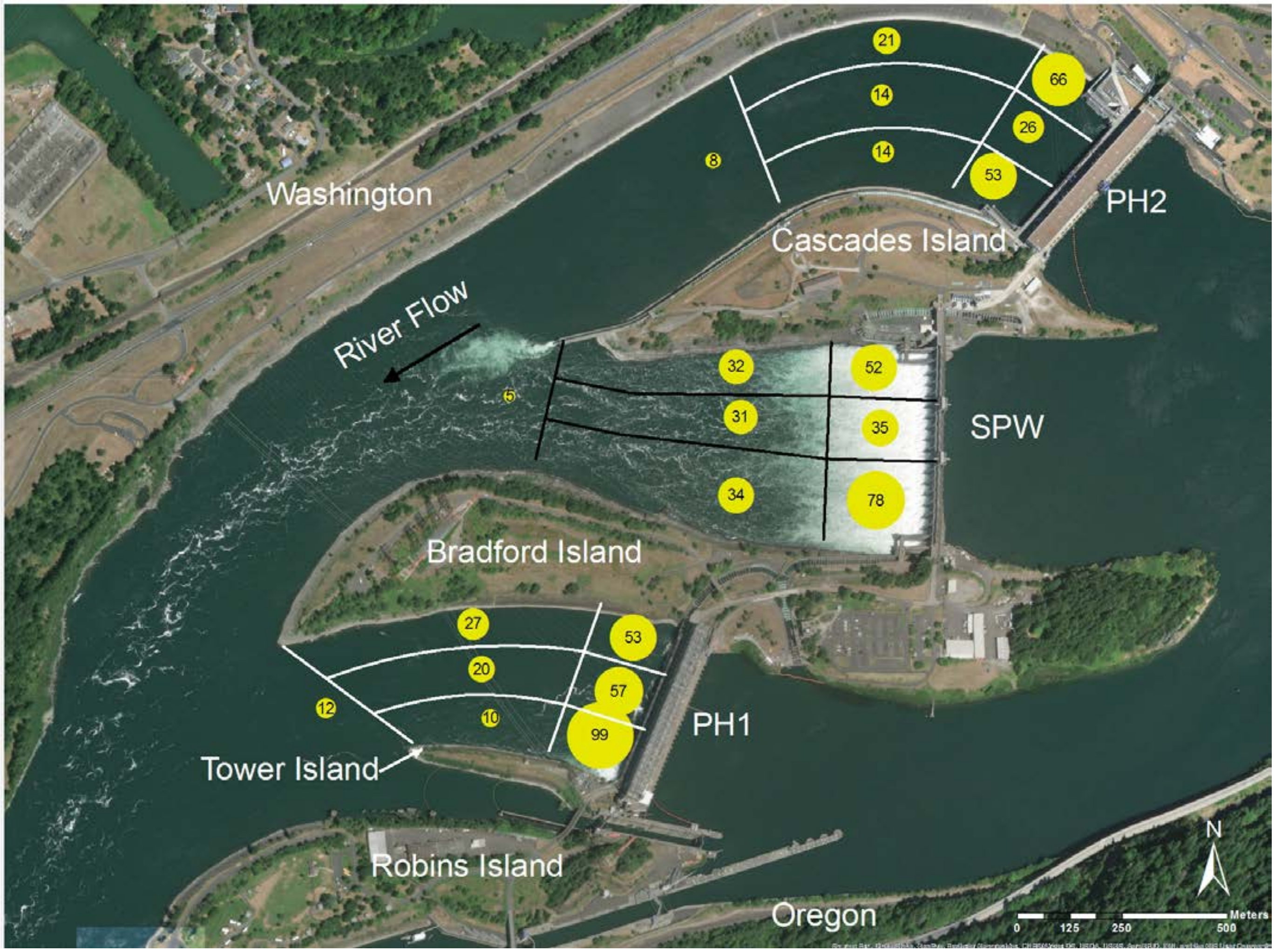


Figure 9. Spatial distribution of observed salmonid predation by Steller sea lions at Bonneville Dam Bonneville Dam during the 2018 spring sampling period.

Clepto-parasitism

A total of 30 clepto-parasitism events were recorded – SSLs stole 8 fish from other SSLs, and 19 fish from CSLs, while CSLs stole one fish from SSLs and two fish from other CSLs. For comparison, historical accounts of clepto-parasitism are presented in Supplementary Table 3.

DETERRENTS AND MANAGEMENT ACTIVITIES

Physical Barriers

Due to pinnipeds entering the fishways of BON, physical barriers have been developed to preclude entry of pinnipeds into the fishways. Metal grating installed at the fishway entrances called Sea Lion Exclusion Devices (SLEDs) were deployed at all entrances for the duration of the monitoring period. SLEDs continue to be effective at keeping pinnipeds out of the fishways, as none were observed in fishways this season (Appendix 2). This is noteworthy because the water levels this season were higher than the SLEDS for more than three weeks. No pinnipeds were documented in the fish ladders, but the possibility exists that animals could have transited to and from the fish ladders without being observed.

Non-Lethal Harassment

Boat-based hazing by CRITFC began on March 4 and ended May 19. A total of 31 days of hazing were conducted. During the season, CRITFC boat-based hazers deployed 2,204 cracker shells and 838 “Seal Bombs” (e.g. small charges of explosive that detonate under water) (Wright et al. 2018). Boat-based hazing is not feasible in the spillway given the highly turbulent water conditions, as such boat-based hazing occurred only in PH1 and PH2 tailraces.

Dam-based hazing of pinnipeds by USDA began on 5 March and continued on a daily basis through May 31. Working eight and ten hours per day, dam based hazers worked 1,696 hours actively hazing pinnipeds away from the dam’s tailraces. Dam hazers used 5,834 explosive cracker shells and 16 rubber buckshot within the tailrace areas.

Trapping and Removal

The states conducted trapping operations in the tailrace area from the second week of April to the last week of May during which time they permanently removed 27 CSLs under the states’ MMPA Section 120 LOA. In addition, 8 CSLs were branded and released in the tailrace at BON (Wright et al. 2018). As both SSLs and CSLs use the traps as a haul-out location, SSLs are often captured along with CSLs during trapping operations. This season, three of the smaller SSLs were captured and branded with a unique, identifiable brands (Table 13). Traps were closed and moved to storage in late May. For additional information about these activities see Wright et al. (2018).

Table 13. Summary of California sea lion (CSL) branding and removals (captivity, euthanasia, accidental mortality) and Steller sea lion (SSL) branding at Bonneville Dam, 2007 to 2018. Note: CSL removals include all animals removed by the States under the Section 120 LOA of the MMPA.

Year	CSL Authorized for removal	CSL Branded	CSL Removed	SSL Branded
2007	N/A	8	N/A	N/A
2008	85	4	11*	N/A
2009	85	3	15	N/A
2010	85	9	14	8
2011	85	9	1	9
2012	92	6	13	19
2013	92	11	4	3
2014	92	21	15	0
2015	92	131	32*	0
2016	92	50	59	0
2017	92	18	24	12
2018	92	8	27	3
Total	892	278	217	54

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

Impact of Individual California Sea Lions

The highest number of adult salmonids observed to be consumed by an identified individual CSL in 2018 was 19 fish which is the lowest on record for a fully sampled season (see Table 14 for details). This individual was observed for 9 days and recorded eating 19 salmonids (Table 14).

Table 14. Maximum number of salmonids observed consumed by an individual California sea lion (CSL) at Bonneville Dam during the spring sampling period from 2002 to 2018.

Year	Maximum Number of Salmonids Caught by an Individual CSL
2002	51
2003	52
2004	35
2005	11*
2006	79
2007	64
2008	107
2009	157
2010	198
2011	125
2012	41
2013	59
2014	59
2015	28
2016	25†
2017	23†
2018	19†

* In 2005, the observation season began late therefore we didn't have an opportunity to train observers on individual CSL identification.
† In 2016, 2017, and 2018 all three tailraces were not observed simultaneously thus decreasing observation time for individual CSL.

DISCUSSION

We documented increased abundance and prolonged residence of pinnipeds this year which resulted in predation of multiple fish species and runs, some of which had not previously been documented. Sampling during the fall and winter and then the traditional spring sampling period exposed impacts to Coho Salmon, fall Chinook Salmon, summer, winter, and B-run steelhead, spring Chinook Salmon, Pacific Lamprey, and White Sturgeon. For evaluation of this year's spring data (presented presently) to previous spring data, we contrast inter- and intra-year trends of each metric of the monitoring program by presenting percent change relative to the previous year (i.e. Tidwell et al. 2018) and, where possible, the 10-year average. The inclusion of the fall and winter sampling this season in conjunction with the traditional spring period provides a better picture of the combined pinniped impact at BON. When pertinent, we discuss the impacts assessed by combining the documented predation during the fall, winter, and spring to elucidate how the system continues to change and the impacts these changes have to migratory fish.

Abundance

The number of SSLs during the spring was 4.7% greater than last year, and 4.8% greater than the 10-year average. The majority of the individuals that returned in the fall and winter remained at the dam through the spring which contributed to the growing number of SSLs. However, given the limited brands these animals have, the number of individuals that foraged at BON this year is difficult to estimate and is likely much higher than this year's daily maximum count of 66 SSLs.

The number of CSLs during the spring continues to decline in both presence and abundance. We documented a 27.1% reduction in CSL abundance relative to last year, and a 23.9% reduction relative to the 10-year average. CSL numbers were below the 10-year average for most of the season and did not begin aggregating at the dam with frequency until the end of April 2018. The peak of CSL aggregation seems to be occurring later each year.

Calculations of residency times and recurrence are impacted by the ability to identify individuals (i.e. the number of brands). Most individually identifiable SSLs this year were observed for longer than a month, and some for the majority of the spring sampling period. The number of days observed for branded CSLs has decreased 21.6% from 5.1 days in 2017 to 4.0 days this year. Reduced CSL residency times are corollary to the states' removal efforts which likely contributes to the reduction in the number of days individual CSLs stay at BON.

Recurrence at BON is a measure of site fidelity, and has been suggested to be a learned trait that is socially transmitted from previously educated individuals to naive animals downstream of BON (Schakner et al. 2016). Recurrence of habitual BON CSLs increased by 5.3% relative to last year and the number of individuals returning for three or more years has increased by 22.8%, even though overall abundance declined 27.1%. Thus, albeit fewer individuals were documented this year and some were removed, some returning individuals continue to be at BON and evade removal. The trends documented here may be linked to the removal of reoccurring individuals and the delay between occurrence, policy-mandated delays for LOA listing, and removal. Alternatively, it may be a result of the increased social transmission rates due to the previous seasons record high CSL abundance. Disentangling these competing hypotheses would be difficult due to the confounding nature of removal of individuals and the construct of social transmission. Regardless of the mechanism for increased recurrence it is clear that the remaining individually identifiable CSLs using BON display site fidelity, which likely contributes to increased recruitment, and are being removed at a slower rate than previously documented. These patterns will likely continue unless the current protocols are changed.

The recurrence of SSLs is difficult to monitor given the low numbers of branded SSLs. However, we infer that a high level of recurrence due to high site fidelity for most animals that are branded. For example, one individual has been observed for 12 consecutive years and many have been observed every year for the last five years. Although individual accounts are difficult to obtain, the high daily point counts, consistent inter-year abundance estimates, and lack of removal, all suggest that the same unbranded individuals are likely returning every year. If that is true, SSL recurrence is very high for most animals observed at BON. Individual marking and identification efforts could provide much needed clarity to these issues.

Predation

All salmonids **–** Predation in 2018 on all species of adult salmonids during the spring was 1.7% less than 2017 and was 0.1% less than the 10-year average (i.e. 2.9%). Of the adult salmonid run consumed this year, SSLs consumed 0.5% less of the run than the previous year, and 0.7% less than the 10-year average (i.e. 3.0%). This year CSLs consumed 1.2% less of the run than the previous year, and decreased salmonid run consumption by 2.8% relative to the 10-year average (i.e. 3.5%). These changes are likely due to the increasing number of SSLs, decreased number of CSLs relative to the last three years, and the late spring Chinook Salmon run this season.

The delayed run of spring Chinook Salmon was likely a result of the high water volumes passing the dam and cold water temperatures, both co-factors that have been found to delay the run chronology of the species in the Columbia River (Keefer et al. 2008b). Moreover, the spring Chinook Salmon and combined summer and winter steelhead runs were the third smallest and sixth smallest respectively, since pinniped monitoring began in 2002.

Spring Chinook Salmon– Predation on Spring Chinook Salmon during the spring was 1.6% less than the previous year and was the same as the 10 year average (i.e. 2.9%). Of the spring Chinook consumed this year, SSLs consumed 0.4% less than the previous year, and 0.7% more than the 10-year average (i.e. 1.5%). This year CSLs consumed 1.2% less than the previous year, which was 1.2% less than the 10-year average (i.e. 1.9%). More than 78% of the spring Chinook consumption was attributed to SSLs this season.

It has been hypothesized that the early returning spring Chinook Salmon are disproportionately consumed relative to the later returning fish due to the presence of pinnipeds aggregated at the dam when the fish first arrive. The early arriving spring Chinook Salmon are also hypothesized to be most often composed of ESA listed stocks (Keefer et al. 2012). Thus, this season, the high level of SSLs holding over from the fall and winter consumed some of the early arriving ESA listed spring Chinook Salmon and the majority of the spring Chinook Salmon run encountered CSL and SSL. The last pulse of spring Chinook Salmon crossing BON escaped predation due to the pinnipeds dispersing prior to their arrival.

Steelhead **–** Pinnipeds consumed an estimated 7.2% of the combined Columbia River summer and winter steelhead runs during the spring. While the number of steelhead consumed was similar to last year, steelhead passage was higher and therefore a smaller percentage of the run was consumed this year. Steelhead predation by SSLs was 1.5% lower than the previous year, while predation by CSLs was 0.4% lower than last year. Relative to the combined pinniped 10-year average of 6.2%, the combined consumption 1.0% higher this year.

Steelhead crossing BON during the spring have historically been reported as two distinct varieties: the winter run, defined as those steelhead crossing BON between November 16 and March 31, and the summer run which cross after March 31 (Withler 1966, Busby et al. 1996). This season we elected to present the consumption estimates for both runs of steelhead regardless of run composition for comparison to historical data (discussed above). We now also present the impacts to the winter steelhead component across the entire run (November – March), an estimate that previously was not available due to the lack sampling during the fall and winter period. However, the sampling from this year allows this estimate to be formulated using the partial sampling design of the fall and winter data (i.e. only PH2 tailrace when 20 or more pinnipeds were present at BON) and the total sampling estimates produced from the spring up to the 31 March cutoff.

We found that more than 6.8% of the winter steelhead run was consumed by SSLs. This is a greater impact than the 10 year average impact assessed for spring Chinook Salmon during the spring period.

Both pre-spawn steelhead and post-spawn steelhead kelts are vulnerable to pinniped predation at BON. Due to the magnitude of the kelt outmigration from the Snake and Columbia Rivers (Evans et al. 2004, Colotelo et al. 2014), and because each powerhouse at BON has effective adult downstream passage routes (Wertheimer 2007), it is likely that the adults consumed include some kelts. Thus, the impacts documented herein, and from the fall and winter period above, suggest that steelhead consumption is as great, if not greater than the impacts to other species of concern. In part due to ecological variables (e.g. cold waters) and in part due to the steelhead's complex life histories (e.g. iteroparity), the now assessed impacts of SSL predation on ESA-listed winter and B-run summer Steelhead is an issue of concern that needs to be addressed and managed accordingly.

White Sturgeon – More White Sturgeon were killed this year than last, but the overall trend of less sturgeon predation continues to be supported and is alarming. The slight increase in sturgeon consumption this year is seemingly driven by the increasing number of SSLs. This season, White Sturgeon consumption increased from 24 in 2017 to 148, with the vast majority (i.e. 97%) being consumed by SSL. The long term trend however shows that between 2005 and 2012 thousands of White Sturgeon were consumed each year, and after 2012, White Sturgeon predation dropped to < 100 fish per season. This trending decline of predation has been most pronounced for the last five years. This year however, we found that several hundred White Sturgeon were consumed during the nine sample weeks of the fall and winter. Therein, more White Sturgeon were killed during the nine weeks of winter sampling than the five month sampling effort of the spring sampling period.

Why more fish are killed in the fall and winter than the spring is unclear, but the additive mortality of white sturgeon over time by SSLs may be contributing to the declining status of the stock.

Pacific Lamprey – Pacific Lamprey predation was 69% less than the previous year and 60.1% less than the 10-year average. The bulk of Pacific Lamprey predation continues to be by CSLs. Some CSLs appear to have a higher occurrence of consumed Pacific Lamprey than other CSLs as evidenced by one euthanized CSL dietary tract that was dissected and found to contain the mouth parts of 26 Pacific Lampreys at the time of death (Brown et al. 2017).

The consumption of these Pacific Lampreys occurred consistently during the crepuscular hours as previously documented and suggest that if night time foraging by CSLs is occurring, then these fish may be consumed at a higher rate than estimated herein. That said, our monitoring of CSL activity suggests that very little night time foraging occurs. Moreover, the short duration of overlap between CSL presence at BON and the Pacific Lamprey run also suggests that impacts are minimized at BON.

Deterrence and Management Actions

The recurrence of pinnipeds following a bout of hazing continues to be an issue. Our results indicate that an order of magnitude more tactile and acoustic deterrent ordinances were deployed than the total number of pinnipeds documented again this season. Thus, it is highly likely that every pinniped was hazed numerous times. After significant durations of hazing, pinnipeds have been shown to immediately return to foraging areas when the hazing pressure ceases (Jefferies and Scordino 1997, Schakner and Blumstein 2013). Albeit arguments concerning naive animal exposure to, and subsequent dispersal from, the hazed area are valid (Brown et al. 2017), our data calls into question the effectiveness of these treatments. These techniques seem to be only temporary nuisances to distract pinnipeds. Recently branded CSLs (i.e. newly recruited individuals [potentially naive] and individuals not previously branded) that were not removed have been found to spend the same number of days (both observed and the potential number of days present) as those animals previously branded (Tidwell et al. 2018). This suggests that some newly recruited individuals, even after being trapped, handled, marked and exposed to hazing, spend the same length of time foraging at BON as habituated animals that have been hazed for the last three years.

The most functional benefit of current hazing techniques are for the brief moments of time when active hazing is occurring which has been found to dissuade active foraging behaviors (Götz and Janik 2013). Dam-based hazing is seemingly most effective when coupled with boat-based hazing to effectively haze animals away from the fish ladder entrances and "drive" hazed animals downstream, providing a period of time when no pinnipeds are at the fish ladder entrances. Observations indicate that this period of time is commonly less than 20 minutes (KST unpublished data). Habituation to current hazing techniques is most notably observed in SSLs that have been at the dam for years. These individuals can endure many bouts of hazing prior to moving downstream and out of range of the hazing implements. The short term effects of hazing call to question the relative value of such techniques and begs for better, more effective alternatives.

Physical barriers at fish ladder entrances (i.e. SLEDs, FOGs) continue to be the most effective deterrent mechanism currently employed (Appendix 2). They successfully excluded all pinnipeds from entering the fish ladders this season despite higher than normal water levels. Given the near year-round residency of SSLs, continuing to deploy the devices year-round is warranted.

Evaluating the efficacy of CSL removal on salmonids population recovery is difficult due to the dynamic interplay of fluctuating fish runs, inter-annual environmental stochasticity, inter-annual and seasonally-abundant pinniped numbers, and the variable number of CSL removals that have yet to reach the LOA limits for Potential Biological Removal. However, the abundance and residency metrics of CSL are considerably lower in the last two years and lower relative to the ten year average. Habitually recurring animals continue to evade capture (i.e. removal) and keep the metrics higher than expected based on the removal effort by the states in recent years. The documented reduction of CSL abundance and residency relative to last year (27% and 22% decrease respectively) and the ten year average (24% and 54% decrease respectively) has likely contributed to the reduced number of fish killed by CSL. Based on the 2017 report of management activities at BON, the states found almost every CSL removed in 2016 and 2017 had salmonid remains in their digestive tracts (Brown et al. 2017), reaffirming that CSLs consume primarily migrating salmonids at BON. The removal of 27 predatory CSLs this year undoubtedly allowed more fish to pass, but the rate of removal has been hypothesized to be too low to significantly impact the rate of recruitment to the BON CSL population (Schakner et al. 2016).

Closing remarks

The tides of pinniped predation on threatened and endangered fish have changed at BON, wherein the primary predator of these fish is now the Steller sea lion. The management tools developed for CSLs can be implemented for SSLs and the data to show the impact of Steller sea lions for the last 16 years, are collected and presented above.

Preliminary data from the fall and winter period and the current data from the spring sampling period found evidence suggesting biologically significant impact to ESA listed B-run and winter steelhead. The potential impact to ESA listed Chum Salmon downstream of BON further highlights the issue of the prolonged residency and increased presence of regionally-abundant Steller sea lions foraging near BON, and provide reason for prompt examination of this dynamic.

The deterrence measures currently employed are functional to keep pinnipeds out of the fish ladders and away from the fish ladder entrances when hazing is actively occurring, but actions to reduce predation immediately downstream of the fish ladder entrances have not been functional. As Ballard Locks steelhead are functionally extinct due to pinniped predation, the Upper Willamette River winter steelhead now also face the potential threat of pinniped-mediated extinction. The novel findings of this report illustrate that a similar pattern may be unfolding for select ESA listed stocks at and around Bonneville Dam. Managers need to recognize the threats and act before a failed salmonid recovery effort like Ballard Locks is potentially repeated.

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APPENDIX 1. Description of the BON tailrace system, life histories of the pinniped and fish species studied, and the methods employed to study pinniped abundance, residency, and the level of fish predation during the fall – winter and spring sampling periods.

APPENDIX 1: METHODS

STUDY AREA

Bonneville Lock and Dam is located on the Columbia River at river mile 146 (river kilometer 235) 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 concrete structures separated by islands. Pinniped activities historically occur in the tailraces of the dam between the islands. Using the *a priori* knowledge of pinniped behavioral patterns at the dam, we observed pinniped abundance and predation from each of the three tailrace sub-areas downstream of Powerhouse One (PH1), Powerhouse Two (PH2), and the Spillway (SPW) (Figure A1). Elevated observation platforms at these tailraces were used to observe pinniped activity. To facilitate comparison of predation events by tailrace area, and provide continuity to previous reports (Madson et al. 2017), we divided each tailrace sub-area into seven zones (Figure A1). Pinniped abundance counts and brand re-sightings were conducted in the three tailrace sub-areas and at Tower Island, a site consistently used as a resting area for pinnipeds (Figure A1). Abundance estimates and brand re-sightings were also collected at Tanner Creek, the nearest downstream tributary approximately one mile from the dam. The States anchored three floating sea lion traps in the vicinity of Tower Island and one in the PH1 forebay during the spring months that CSLs were present, which served as areas for pinnipeds to rest on, facilitating abundance counts and brand re-sighting.

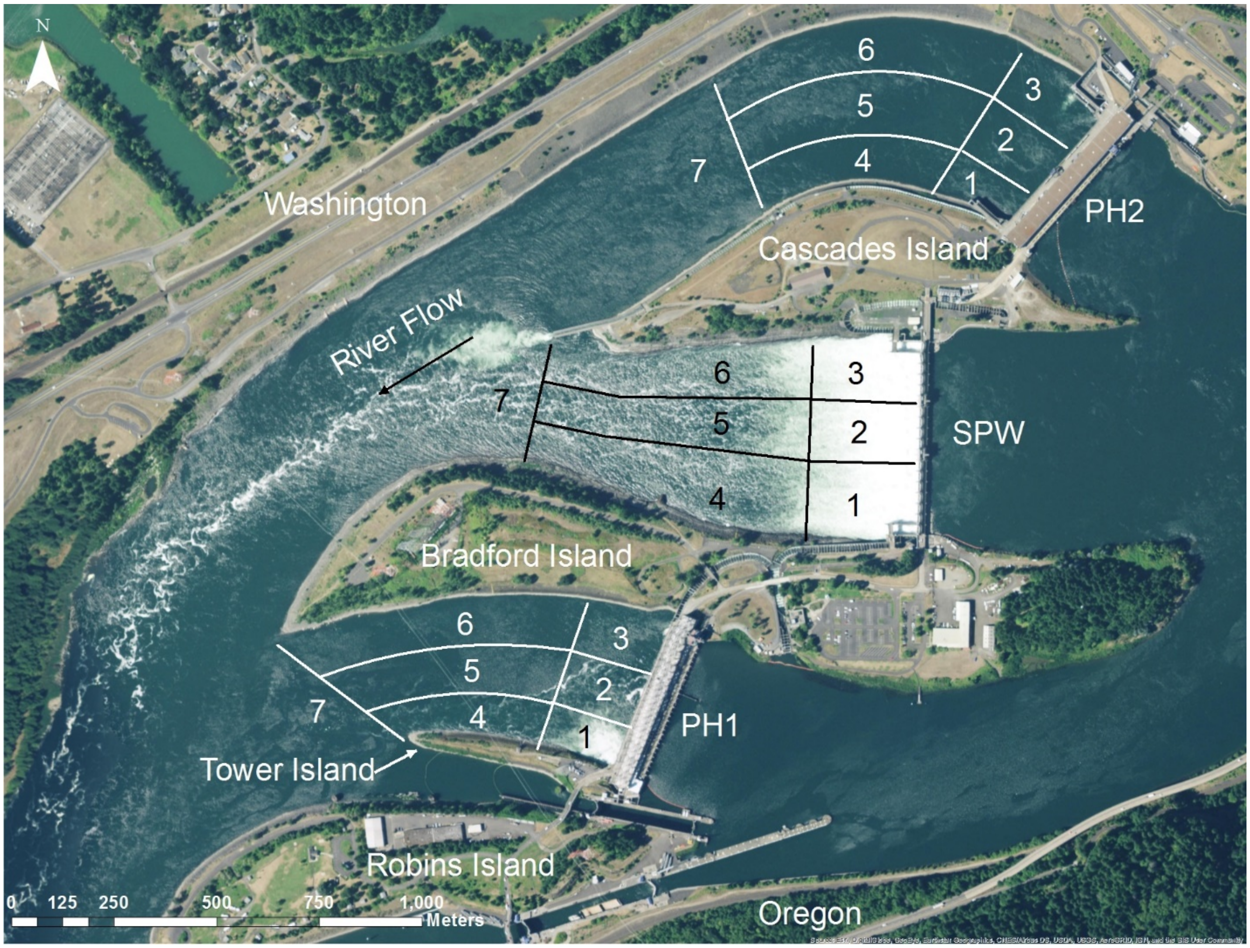

Figure A1. Bonneville Dam study area with Powerhouse One (PH1), Spillway (SPW), and Powerhouse Two (PH2) tailrace sub-areas separated into zones for assigning the location of predation events.

FOCAL SPECIES

Pinnipeds

The Order Pinnipedia evolved ≥ 20 million years ago and has likely overlapped in distribution with anadromous Pacific salmonids for the bulk of this time (Naughton et al. 2011). The co-occurrence and predation of salmonid fish by pinnipeds undoubtedly led to long-standing anthropogenic disdain for the species in the Pacific Northwest, so much so that State wildlife agencies authorized bounty programs to kill as many pinnipeds as possible (Beddington et al. 1985). Since the Marine Mammal Protection Act of 1972, the stocks of CSLs and the Eastern stock of the SSLs have rebounded (NOAA 2014, 2016b), and are now frequently observed along the Pacific Coast.

The rookeries (i.e. breeding and rearing grounds) for the sea lions entering the Columbia River system are primarily the Channel Islands off the coast of southern California for the CSLs, and the Rogue Reef outcroppings off the coast of southern Oregon for the Eastern stock of SSLs (B. Wright personal comm.). Males of both species disperse from rookeries after breeding to forage in waters different from that of the females and sub-adults to regain the weight lost during the prolonged terrestrial breeding periods. Thus, all CSLs and SSLs entering the Columbia River system are males that have left their respective breeding grounds in search of foraging opportunities. Sea lions have been documented at the mouth of the Columbia for several hundred years (Lyman et al. 2002), but have only recently (i.e. < 20 years) been documented consistently traveling to BON to forage. Brand re-sighting and telemetry data suggest that approximately 7% of the CSLs occurring near the mouth of the Columbia River travel to BON to forage (NOAA 2017). These animals represent a mixture of several cohorts including juvenile (2-4 years), sub-adult (5 – 8 years) and adults (> 8 years) (Laake et al. 2016).

Natural History of Pinnipeds at Bonneville Lock and Dam

Pinnipeds that travel to, and forage at, BON consistently forage in the tailraces of the dam during the day and utilize rock outcroppings and riprap infrastructure to rest on, a process called "hauling out" during the night. Hunting forays from the rocks to the tailraces occur by almost all animals just prior to sunrise after which they can be observed transiting between the tailraces and haul-out locations during daylight hours. They return to the haul-out locations just after sundown where they remain through the evening. One feature of CSL behavior that occurs during peak abundance periods and periods of increased temperature is rafting – multiple animals floating in the water not touching the substrate but touching each other – a behavior less often observed in SSLs.

Pinnipeds can be observed periodically surfacing to breathe when foraging then submerging to pursue prey below the surface. The maximum time submerged under normal conditions for CSLs is 9.9 minutes (Feldkamp et al. 1989), however, at BON foraging dives are generally less than five minutes for both species of pinniped (KST personal obs.) Once captured, larger prey items are brought to the surface and broken through a series of violent head shakes reducing the prey to multiple pieces of manageable size (Jones et al. 2013). Of particular note for monitoring purposes is the prey handling time and capacities of each species; adult SSLs can swallow sizeable spring Chinook Salmon almost whole in a matter of seconds, whereas adult CSLs typically stay at the surface and break the fish into smaller pieces. Thus, handling time differs for each species of sea lion, a difference which likely influences the ability and confidence of observers to document predation and therein may influence inter- and intra-species differences enumerated in this report – SSL predation may be biased low as a result.

Fish

Pacific salmon and steelhead (*Oncorhynchus spp*.) of the Columbia River system are composed of several species, many of which have distinct evolutionarily significant units (ESU-salmon) or distinct population segments (DPS-steelhead) that have been listed under the ESA. During the fall and winter period the primary salmon species passing BON are: Fall Chinook Salmon (1 August – 15 November), Coho Salmon (15 July – 15 November), summer steelhead (A run: June – August; B run: August – October), and winter steelhead (16 November – 31 March). The primary species passing during the spring sampling period are the Columbia River spring Chinook Salmon and DPS of winter and summer steelhead. These runs are historically classified by the periods of time at which they cross the dam: spring Chinook Salmon: 14 March – 31 May, ocean-maturing winter steelhead: 16 November – 31 March, and stream-maturing summer steelhead: 1 April – 15 November (Busby et al. 1996).

For some figures we combine fish counts and provide inclusive counts of all fish through 31 May. We do this to align with historical reports to enable inter-year contrast. To that end, it must be noted that for spring Chinook Salmon, the historical reports listed the run through 15 June and assessed the percent of run taken metric through 15 June. This year, we alter this metric to end at 31 May which is the date used by the Fish Passage Plan (FPP), and Federal Columbia River Power System to manage the system for the species.

Due to the temporal overlap of pinnipeds and migrating salmonids, data suggests that early migrating salmonid stocks may be disproportionately impacted by pinniped predation (Keefer et al. 2012), specifically ESU stocks of spring Chinook 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).

Different salmonid species and various runs of steelhead and Chinook Salmon are encountered by pinnipeds due to the temporal overlap and misalignment of run chronology as a result of environmental conditions and migration patterns, however the bulk (i.e. > 95%) of salmonids consumed during the spring sampling period are of the spring Chinook and winter steelhead runs (Stansell 2004, Madson et al. 2017). Stocks consumed during the fall and winter include ESA listed B run steelhead, lower Columbia River Coho, select ESU's of the fall Chinook run, and winter steelhead. Analyses of stock specific impacts are beyond the scope of this report, but are warranted. Other fish species observed as prey of pinnipeds at BON include: White Sturgeon (*Acipenser transmontanus*), Pacific Lamprey (*Entosphenus tridentatus*), American Shad (*Alosa sapidissima*), and various warm water and introduced fishes (e.g. *Micropterus spp.*, *Cyprinus spp.*). Here we enumerate the number of salmonids, Pacific Lampreys, and White Sturgeon consumed.

SAMPLING METHODS

The pinniped monitoring project has evolved since its initiation in 2002 to better capture the information required by the Biological Opinion and to facilitate research efforts by the States and collaborative agencies. Data informed modifications to sampling schemes and observer effort have produced a robust and yet cost-effective system to estimate salmonid consumption and pinniped abundance. In short, biological observers trained in fish and pinniped identification use field glasses (8 X 42 magnification) to document pinniped activity at predetermined locations above the tailraces of the dam (Figure 1) at a scheduled interval to develop estimates of predation and abundance.

This year we had two focal observation periods. The fall and winter sampling period (i.e. 15 August – 31 December) and the historical spring sampling period (i.e. 1 January – 31 May). Due to increased residency of pinnipeds in the last three years (Madson et al. 2017), we now extend sampling to the last day when pinnipeds are documented near the Bonneville Dam tailrace. This spring sampling season ended on 2 June 2018.

Monitoring: Abundance, Residency, and Recurrence

We quantified the number of pinnipeds present at the BON project each day by conducting point counts of animals from a distance using field glasses. Sampling began when the first pinniped was observed in the summer, and terminated when the last pinniped left in the spring. To maximize the accuracy of point counts, we used historical data and pinniped behavior to inform the optimal times at which to perform point counts. Previous data revealed a strong diel pattern (Stansell 2004, KST unpub.

data), whereby, the greatest number of pinnipeds are consistently observed hauled out during the evening and crepuscular hours, a pattern consistent with some pinniped natural foraging cycles (Boehme et al. 2016, but see: Watts, 1996, Sepulveda et al. 2012). As such, we conducted point counts twice each day: at sunrise and as late in the evening as schedules allowed.

The abundance data provided herein represent a conservative estimate of pinnipeds at BON on any one day. All pinnipeds in the three tailraces and on Tower Island were counted, however, submerged animals, animals in transit between locations but out of sight, and the ingress and egress of animals to BON occurs and may potentially influence our abundance estimates. To avoid double counting animals transiting between count locations, we sampled all locations in one five-minute period at each site, a period of time short enough to individually count animals before they could move between sites and long enough to ensure submerged animals will have surfaced and could be counted.

Abundance – The daily pinniped abundance for each species is presented as the highest point count taken for each species each day irrespective of time of day. For periods when FFU staff were not present to collect point count data (i.e. weekends, holidays), linear interpolation between the most recent days surrounding the missing period was used to estimate abundance. In doing so, we present the estimated maximum number of pinnipeds that could have been near BON each day.

Yearly maximums of individually identifiable animals are presented to document how many pinnipeds of each species were observed throughout the season. Since not all CSLs are branded and very few SSLs are branded, we present the yearly maximum count as either: 1) the greatest number of animals in any one point count (sum of all three sub-tailraces, Tower Island, and Tanner Creek), or 2) the cumulative number of uniquely identifiable animals observed during the season, whichever is higher. This approach combines two metrics (annual individual accounts or daily high counts) and provides the estimated yearly maximum because either, all the animals were individually identified at some point or were observed in one point count and thus were mutually exclusive counts of individuals. However, the latter method does have the potential to be biased low, as a non-identifiable individual could have been to BON during the season but was not present during the highest daily point count of the season. This is most often applied to the SSLs due to the limited brands on the animals. Thus, the yearly maximum abundance is a conservative measure of the most animals documented throughout the year.

Residency – To provide insight to the duration of time spent at BON for any individual pinniped we report the number of days each animals spent at BON. Pinnipeds were trapped and branded by the States, and tracked with alpha-numeric brands placed on their dorsal surface. Other markers used to identify individuals include: scars, skeletal and tissue deformities, and unique color patterns. The brands and unique markers were recorded during predation monitoring, abundance point counts, and with photo-archival via camera traps at haul-out locations. Based on the seasonal variation of unique (non-brand) markers, chronology of pinniped arrival and branding efforts, ingress and egress of animals, and the reduced monitoring effort during the predation sampling season (described below) – the data provided for individual pinniped residency and abundance should be considered minimum estimates.

Individual pinniped residency estimates are reported as the number of days each animal was documented at BON (as historically reported) and the potential number of days the animal could have been on project (i.e. the difference in days between first and last observation within the current season).

Recurrence – For previously documented individuals (i.e. observed in prior years) we present the number of days spent at BON, the percentage of these animals that have been to BON previously, and the number of years each individual has been documented. Given the small number of branded SSLs, the reduced numbers of sampling personnel, and the emphasis placed by the States on CSL identification, individual identification of each SSL was not targeted as a priority. As such, we relied on brands (both previously applied and those applied this year) and distinctive markings on previously documented individuals to calculate recurrence for SSLs. Recurrence of CSL was recorded only for previously branded animals due to the high brand rates observed for these animals.

The removal efforts of the States confounds residency and recurrence calculations with CSLs that were removed in the same year as they were branded. Thus, we present the data as estimates of residency for the animals that were not removed.

Monitoring: Chronology of Fish Passage, Methods of Estimating Fish Predation

Chronology of Fish Passage

We present total salmonids passage for each sampling period of each year and the ten year average to inform how the passage and abundance of salmonids may interact with the estimated consumption by pinnipeds. With these passage estimates, we also provide measures of river spill past the dam and river temperature as these environmental co-factors have been shown to influence passage rates (Keefer et al. 2008b, Evans et al. 2016).

Estimating Fish Predation

Surface observations of pinniped-prey interactions were used to enumerate the number and species of each fish killed by each pinniped species. This method is useful and has been employed elsewhere (see Roffe and Mate 1984, Wright et al. 2014), and consistently applied at BON for > 15 years. All attempted (i.e. loss) and successful (i.e. catch/stolen) predation events were recorded, as well as the time and location of the predation event, species of fish, species of pinniped, unique pinniped identification (if possible), length of sturgeon (if applicable), and interactions with other pinnipeds during the predation event (i.e. cleptoparasitism).

Sub-surface predation and consumption has been documented previously, particularly with the larger SSL and smaller fish, and may artificially truncate the estimated number of fish consumed (Stansell 2004). However, as noted, this is almost exclusively a SSL issue and likely only influences the counts of the smallest spring Chinook (i.e. jacks) and smaller steelhead. However, we recognize that some CSL sub-surface predation may occur. Due to the nature of observing wild animals *in situ* with field glasses, not all predation events were easily recognizable. In instances when fish were too mangled, actively being swallowed, or too far from the observer to be recognized, the predation event was recorded with all pertinent data and the fish species was listed as "unidentifiable."

The process of accounting for the unidentifiable fish in the predation estimate has evolved over the years. Historically, the program monitored pinniped activity extensively (i.e. all daylight hours and some nighttime observations) and therein justified using the raw data of observed predation events with a correction factor applied based on *a priori* knowledge of observer skill level, program structure, and pinniped behavior (Stansell 2004). Presently we use the "adjusted consumption estimate" developed by Tackley et al. (2008) which incorporates the unidentifiable fish predation events evenly across other predation events based on the number and species of fish consumed that day. For example, assume 24 fish were caught in one day, 20 identified, and four unidentified. Of the identified fish, 10 were Chinook Salmon and 10 steelhead. The four unidentified fish catches would be proportionally distributed to two Chinook Salmon and two steelhead. In this manner we provide the adjusted estimate – a parsimonious estimate of how many of each fish species were consumed each day – which is the functional unit utilized to estimate the total number of fish consumed for the season.

Being readily identifiable and not easily mistaken for any other fish in the Columbia River, the Pacific Lamprey was not applied to the adjusted estimates. Therein, Pacific Lamprey consumption estimates reported here are merely expanded for hours not observed and have not been adjusted. It is possible that Pacific Lampreys are consumed underwater albeit observers rarely report Pacific Lampreys being brought to the surface in a mostly consumed state. However, since it is possible, the estimates provided here are minimum consumption estimates. Moreover, based on the tendency for Pacific Lampreys to pass at night time and the lack of night-time predation monitoring there is potential for Pacific Lamprey predation to go unrecorded, again indicating that the estimates provided herein, are minimal estimates.

Sampling Design for Predation Estimates

As in previous years, a Stratified Random Sampling design (SRS) (Cochran 1977) was implemented to account for hours not observed across the three tailraces of the dam each week (Madson et al. 2017). This season we elected to consistently apply a systematic sampling design with even coverage within each strata week. A design that is different from last season which involved a combination of simple and stratified random sampling within weeks. We describe the methods and assumptions of these designs below.

Each seven-day week (arbitrarily assigned as Sunday-Saturday) served as a stratum. For the fall and winter sampling period there were nine strata weeks from 15 August – 31 December 2017. During the spring sampling period there were 22 strata weeks between 1 January and 2 June 2018. Five of seven days (Monday-Friday) were sampled during each stratum with the exception of federal holidays. These missing samples were incorporated with weighting (sampling effort to sample total) to the predation estimate. Given the diel foraging activity of the pinnipeds at BON, the sample coverage for each stratum was based on civil twilight (morning), sunrise, sunset, and civil twilight (night) for Cascade Locks, OR (six miles east of BON). We conducted observations for the maximum number of two conjoined 30 minute sampling units between morning and night. If the 60 minute sampling unit was ≥ 15 minutes before or after civil twilight, the first 30 minute interval was removed from the daily sample and the next 30 minute sample block was used to sample for 60 minutes. Doing so ensured enough light to facilitate positive identification of both pinniped and fish species and maximized the potential to randomly select a sampling unit during all hours of daylight. The sample rate, expressed as the percentage of daylight hours sampled per total daylight hours available in the week (i.e. stratum), was variable between 21.3 and 34%.

For the fall and winter period the observation occurred exclusively at the PH2 tailrace. During the spring, the distribution of observations was selected by assigning a number to each tailrace and randomly selecting one of the tailraces for sampling. Once the initial tailrace was selected, the sampling occurred in a systematic step-wise progression across each tailrace for that day. The process was then repeated for every Monday – Friday of each week for the entire season. This random systematic process, when sampled by a two-person team of observers working tailraces independently, facilitates two important components of the sampling design: first, it eliminates travel between sites which, therefore, allows assumptions of equal and complete coverage to be upheld, and second, ensures equal and random assignment of sampling to all tailrace areas during all daylight hours.

We elected to reduce monitoring of tailraces devoid of pinnipeds by selecting *a priori* to not sample the spillway from 1 January – 10 April, at which point mandatory spill started and thus attraction flow brought prey and predator into the tailraces. We informed this decision using previous years' data and found that few animals were present in the Spillway during this time period. However, we did not want to miss potential predation activity, and as such, made a conditional sampling scheme wherein the spillway was sampled for pinniped presence daily and if an animal was observed, predation monitoring would be implemented. During the spring sampling period there was a one week period of spill (2 February – 9 February) and that one week was sampled due to attraction flow and the presence of foraging pinnipeds during this week. This pattern reinforced the pattern of spill attracting fish which attracts predators. After mandatory spill started, the spillway was continuously sampled in the standard sampling scheme for the rest of the spring sampling period. This modification of sampling scheme based on behavioral patterns previously documented maximizes confidence of our estimates, minimizes observation of a forage area not being utilized, and streamlines the use of personnel. The excluded portions of the weeks not sampled in the spillway were accounted for in the probability estimation described below by excluding the spillway area for the total available hours sampled.

Given that the levels of pinnipeds and fish fluctuate across the five-month sampling season (i.e. high heterogeneity), but remain relatively consistent within weeks (i.e. high homogeneity), we utilized a bootstrap resampling method, a technique widely applied to provide more robust measures of confidence for stratified sampling designs (Efron 1982), to estimate the mean catch and associated confidence intervals (CI) of fish consumed during the focal sampling period.

We elected to bootstrap across the entire sample due to the highly stochastic runs of fish and pinniped numbers. We treated the hourly observation samples as the target population and sampled, with replacement, 999 times from the observations over the focal sampling period to measure the population parameter of interest, the mean number of (adjusted) fish consumed. With this approach, some data points can appear at multiple times during the resampling. Among the 999 resampled data sets, the entire sample (all observation data) and the total observations during each week were kept constant. For example, if there were 35 and 40 observations during week 1 and week 2, respectively, our resampling maintained the same observation size for each of the 22 weeks (e.g., 35 for week 1, 40 for week 2, etc).

For the fall and winter periods when no sampling occurred due to pinniped abundance being below the 20 animal threshold, we bootstrapped across only the sampled weeks accounting for available daylight hours and the number of hours observed.

We estimated the total catch of every resampled table (999 estimates) and calculated the confidence intervals for the true mean (μ) using the distribution of delta [$\delta^* = \overline{x}^*$ -$\overline{x}$)]. $\overline{x}^*$is the mean of the bootstrap sample and $\overline{x}$ is the sample mean The bootstrap 95% confidence intervals for μ is as: [$\overline{x} - \delta^*_{0.025}, \overline{x} - \delta^*_{0.975}$].

In doing so, we provide the bootstrap estimated number of each fish caught by pinniped species with bootstrapped measures of variance for each estimate. If confidence intervals overlapped zero as a result of small sample sizes, we report the estimated number of fish consumed as the lower bound of variation and the calculated 95% confidence boundary as the upper level of predation.

All calculations and comparisons of consumptions were conducted with the adjusted consumption data unless otherwise noted. For comparison to previous years, we report the expanded consumption data as supplementary materials.

Calculation of Predation Estimates for Percent of Run Taken

To facilitate inter-year comparisons and determine estimated total predation by pinnipeds by run size, we present the percentage of fish species taken by each species of pinniped calculated as the estimated number of salmonids consumed divided by the total passage count (e.g. fish over the dam and the estimated number of fish consumed by sea lions) from the beginning of the spring sample period multiplied by 100. Salmon count data (daytime counts, all adult salmonids including jacks) were obtained from the USACE Fish Counts and Reports adult fish count website (WWW.FPC.ORG).

The fall and winter sampling period was assessed differently wherein the number of fish crossing the dam each week were used as the relative comparison to predation estimates to assess impact. That is, the number consumed was not added to the number of fish that passed the dam before determining the quotient of fish consumed per passage. We do this for two reasons: first, the incomplete run passage estimates (in season sampling as opposed to across season sampling like the spring period) make determining the total number and rate of fish passage unclear and second, the sporadic sampling period's that are a result of the 20 pinniped cut point made estimating between week passage unrealistic.

DATA ANALYSIS AND REPORTING

Descriptive statistics are reported throughout with the mean and associated standard error as the measure of spread (i.e. $\overline{x}$ ± S.E.). Adjusted estimates of predation are reported as the bootstrapped mean with associated 95% confidence intervals (CI). Analyses were performed with JMP (version 12) and Program R (version 3.3.2).

DETERRENTS AND MANAGEMENT ACTIVITIES

Deterrents to Fish Predation

A variety of methods have been implemented to deter pinnipeds from eating salmonids near priority areas (Jefferies and Scordino 1997, Gotz and Janik 2013, Schakner and Blumstein 2013). Presently, hazing and physical exclusion devices are used in concert to deter pinnipeds at BON. Hazing consists of a combination of non-lethal deterrents including cracker shells (small charges of explosive ordinance), rubber buckshot, boat chasing, and underwater percussive devices known as seal bombs. USDA personnel haze from the face of the dam to deter pinnipeds from approaching the fish ladder entrances and boat-based CRITFC crews haze the pinnipeds downstream from the dam tailraces. We report the descriptive statistics of these efforts and discuss their use throughout the season.

Due to the repeated entry of pinniped to the fish ladders at BON, physical exclusion devices were constructed starting in 2006 to block pinnipeds but allow fish passage. Specially designed gates called Sea Lion Exclusion Devices (SLEDs) are now installed throughout the season at all eight fishway entrances of BON (Appendix 2). In addition to the eight SLEDS, there is smaller physical exclusion grating installed on the 16 Floating Orifice Gates (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. Temporary Sea Lion Incursion Barriers (SLIBs) were constructed for the purpose of providing additional height on top of the FOGs. We detail the chronology of installation and efficacy of these physical exclusion devices herein.

Management Activities

Pursuant to the Section 120 authorization of the Marine Mammal Protection Act issued to the states, and to facilitate detailed studies of pinniped population dynamics at BON, the USACE supported the states operation of floating pinniped traps in the tailrace and forebay of the dam. From these traps, alpha numeric “hot” brands were placed on otherwise non-branded CSLs and SSLs. The traps also serve to allow for lethal removal of CSLs listed for removal. Here, we enumerate the basic operations conducted during the season, and direct attention to the involved agencies for further details about sea lion management activities (e.g. http://www.dfw.state.or.us/fish/sealion/).

APPENDIX 2. 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).


A.


B.

C.


D.

SUPPLEMENTARY TABLE 1. Descriptive statistics for Steller sea lion (SSL) and California sea lion (CSL) daily abundance from point counts at Bonneville Dam during the spring sampling period for the last 15 years and the ten year average.

SSL	Median	S.D.	Mean	S.E	CV	Range	IQR	n days = 0	Days Observed
2002	0	0	0	0	0	0-0	0	0	59
2003	0	0.36	0.05	0.04	6.90	0-3	0	75	77
2004	0	0.24	0.06	0.03	3.71	0-1	0	92	99
2005	0	0.61	0.27	0.05	2.21	0-3	0	105	131
2006	1	2.19	2.09	0.19	1.05	0-10	4	40	150
2007	1	1.96	2.16	0.16	0.91	0-9	3	32	147
2008	5.5	3.55	5.5	0.28	0.64	0-17	4.5	15	150
2009	9	5.4	9.64	0.45	0.57	0-26	6	11	145
2010	10	11.52	13.21	0.96	0.87	0-53	11.5	2	144
2011	12	5.86	11.98	0.48	0.49	0-32	7	10	145
2012	12	6.86	12.24	0.56	0.56	0-33	7.5	15	152
2013	11	9.25	13.03	0.75	0.71	0-41	9	5	151
2014	6	10.26	9.92	0.84	1.04	0-41	7.5	13	151
2015	11	16.82	18.26	1.37	0.92	0-69	18.2	1	151
2016	12.2	15.12	17.89	1.22	0.85	0-54	25	1	152
2017	7	16.42	15.42	1.33	1.07	0-63	17.5	4	153
2018	6	14.02	11.96	0.87	1.17	0-66	17	5	159
10 year	10	11.69	12.74	0.30	1.69	0.0 - 69	22.5	N/A	151

CSL	Median	S.D.	Mean	S.E	CV	Range	IQR	n days= 0	Days Observed
2002	5	2.93	5.36	0.38	0.55	0-14	3.5	2	59
2003	15	8.61	13.27	0.98	0.65	0-32	14	5	77
2004	10	10.75	13.73	1.08	0.78	0-37	17.5	4	99
2005	13	11.05	12.9	0.96	0.86	1-42	21	0	131
2006	9.5	13.78	14.3	1.12	0.96	0-44	27	39	150
2007	8	13.47	12.85	1.11	1.05	0-52	18.5	18	147
2008	9	14.08	14.12	1.15	0.99	0-46	26	7	150
2009	9	7.53	10.25	0.63	0.73	1-26	14	0	145
2010	9	6.64	9.28	0.55	0.72	0-26	12	5	144
2011	3	6.41	5.45	0.53	1.18	0-25	9	46	145
2012	2	3.27	3.08	0.26	1.06	0-14	5	46	152
2013	1	4.35	2.96	0.35	1.47	0-21	4	69	151
2014	0	7	4.34	0.57	1.61	0-27	6	84	151
2015	4	21.11	16.57	1.71	1.27	0-70	31.5	0	151
2016	3	14.94	10.63	1.21	1.41	0-66	18	57	152
2017	1	7.42	5.13	0.60	1.44	0-28	9.5	66	153
2018	0	3.20	1.51	4.70	2.11	0	16	176	159
10 Year	3	11.69	8.18	0.30	3.51	0-70	15.1	N/A	151

SUPPLEMENTARY TABLE 2. Table of expanded estimates (i.e. not accounting for unidentified fish catches) of pinniped predation on salmonids, by pinniped species at Bonneville Dam, 1 January – 31 May, 2002-2018.

			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	0.12%
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	0.37%
2011	3,315	223,380	3,557	1.57%	2,527	1.11%	1,030	0.46%
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	1.08%
2014	2,947	219,929	4,314	1.92%	2,615	1.17%	1,699	0.77%
2015	2,995	239,326	9,981	4.00%	7,779	3.12%	2,202	0.91%
2016	1,974	154,074	8,969	5.50%	6,371	3.91%	2,598	1.66%
2017	1,142	109,040	4,949	4.34%	2,024	1.78%	2,925	2.61%
2018	1,410	100,887	2,732	2.64%	640	0.62%	2,098	2.02%

SUPPLEMENTARY TABLE 3. Summary of clepto-parasitism events by California sea lions (CSL) and Steller sea lions (SSL) observed at Bonneville Dam, 2002 to 2018.

Year	CSL		SSL		Total
	From CSL	*From* SSL	*From* CSL	*From* SSL	
2002	0	0	0	0	0
2003	14	0	0	0	14
2004	366	22	0	0	388
2005	22	0	22	0	44
2006	12	0	5	0	17
2007	33	0	4	0	37
2008	161	0	135	4	300
2009	152	4	324	7	487
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
2017	2	0	62	11	75
2018	2	1	19	8	30