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EVALUATION OF PINNIPED PREDATION ON ADULT SALMONIDS AND OTHER FISH IN THE BONNEVILLE DAM TAILRACE, 2020

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Cover Photos: In memory of two dedicated biologists who passed away this year. Dan Heiner (left; photo courtesy of Julie Tennis)) who worked with the ODFW marine mammal program since 1997, and Bobby Begay (right; photo courtesy of CRITFC) who worked with the Columbia Inter-Tribal Fish Commission pinniped hazing program since 2003. The long-standing contributions these men made to the collective pinniped effort on the Columbia River are recognized. They will be missed.

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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/

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, steelhead (*Oncorhynchus spp.*), and White Sturgeon (*Acipenser transmontanus*), some of which are listed as threatened or endangered under the Endangered Species Act (ESA). The Federal Columbia River Power System 2019 interim Biological Opinion continued the requirement for the U.S. Army Corps of Engineers to monitor the seasonal presence, abundance, and predation activities of sea lions at Bonneville Dam. Here we report these data for the 2019-2020 season. Per requirements of NOAA, we monitor and report data for the fall and winter period of 2019 and the traditional spring period of 2020. Abundance was monitored daily, while predation sampling started when there were ≥ 20 pinnipeds in the tailrace of Bonneville Dam.

The first pinniped returned to Bonneville in July 2019. Between 17 July – 31 December 2019 we recorded an average of 31.8 ± S.D. 16.5 SSLs each day. CSLs were not observed during this period. Fish predation monitoring began on 25 August 2019 when abundance was ≥ 20 pinnipeds. Due to winter dam maintenance and fish ladder repair we sampled exclusively at the Powerhouse 2 tailrace between 25 August – 31 December. Note: total predation at Bonneville Dam during this time is likely higher than these estimates due to predation in other tailraces. Predation estimates for this period are seen in the table below.

Monitoring continued during the spring season (January – May) despite the COVID-19 pandemic and heavy fire smoke. However due to COVID-19 travel and work restrictions predation sampling did not start until 12 April and concluded when the pinnipeds left the dam on 20 May. Abundance was monitored daily, an average of 10.2 ± S.D. 10.8 SSLs and 1.1 ± S.D. 3.0 CSLs were observed each day during the spring period.

Fish Species	Number of Fish Killed (95% CI)	Percent Run Consumed During Observation Period
Fall Chinook	1,365 (1,222 – 1,497)	0.7 %
Spring Chinook	1,180 (1,006 – 1,350)	2.5 %
Steelhead – Aug. – Dec.	174 (129 – 217)	1.0 %
Coho	156 (99 – 210)	0.3 %
White Sturgeon – April - May	57 (16 – 93)	N/A
White Sturgeon – Aug. – Dec.	762 (583 – 915)	N/A

Data provided by the 19 years of USACE pinniped monitoring has been used to inform management actions and has contributed to significant changes that are now being realized. The number of CSL has been greatly reduced because of management efforts to remove qualifying animals. The number of SSL remain at high levels and impacts from this species during the fall and winter are now being documented. White Sturgeon and winter steelhead are disproportionately impacted by SSL presence and abundance at Bonneville Dam and SSL now account for more than 90% of the Spring Chinook predation events. The recent efforts by management to enact removal authority of SSL may curb these impacts, but the sustained impacts to these fish populations should be noted by fish managers.

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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 (Jeffries 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 archaeological records, whereby, seal (Family: Phocidae [true seals]) remains were documented at river kilometer 323 (river 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 but its tailrace area is now commonly frequented by sea lions and an occasional harbor seal (*Phoca vitulina*).

Sea lions were first documented at BON in the late 1980s 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 upstream 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 fishes (Weise and Harvey 2005).

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). Pinniped predation at the dam has spurred concern for impacts to ESA listed salmon for almost two decades. The U.S. Army Corps of Engineers (USACE) Fisheries Field Unit (FFU) initiated a pinniped monitoring program in the early 2000s in response to these concerns and to fulfill requirements established through various ESA consultations with NMFS regarding the operation and maintenance of the Federal Columbia River Power System. This monitoring effort, pinniped predation deterrence measures, and NMFS Biological Opinion (BiOp) requirements have been adjusted and refined over the past 18 years.

In November 2018, USACE, Bonneville Power Administration (BPA) and the U.S. Bureau of Reclamation (USBR) – collectively, the Action Agencies – reinitiated consultation with NMFS and submitted a Biological Assessment (BA) that included certain pinniped monitoring and management activities as part of the Proposed Action. The purpose of this consultation was to provide ESA coverage for operation and maintenance of the Columbia River system until the Columbia River System Operations (CRSO) Environmental Impact Statement (EIS) and associated Record of Decision (ROD) and ESA consultations were completed. NMFS issued an interim BiOp on 29 March 2019: this shaped USACE pinniped monitoring and management actions through much of the 2020 passage season. In association with the CRSO EIS, a new Biological Assessment was submitted by the Action Agencies in January 2020 and NMFS issued a new BiOp in July 2020 (Biological Opinion for Operation and Maintenance of the Fourteen Multiple-Use Dam and Reservoir Projects in the Columbia River System | NOAA Fisheries). The CRSO ROD (CRSO Home (army.mil)) was signed on 28 September 2020 and USACE began operating under the 2020 BiOp on that date. Overall requirements were similar under these two consultations.

In accordance with these ESA requirements, USACE implemented the following pinniped monitoring and management activities in 2020:

- Installed sea lion exclusion devices at all adult fish entrances at BON year-round.
- Continued to fund dam-based hazing of pinnipeds observed in the vicinity of fish ladder entrances at BON and on an ad hoc basis at The Dalles Dam. Hazing at BON was required from 1 March through 31 May and from 15 August through 31 October.

- Provided support to state wildlife management agencies and the Columbia River Inter-Tribal Fish Commission (CRITFC) pursuant to their sea lion management programs, including crane support and access.

- Monitored predation by sea lions at Bonneville Dam and reported results to NMFS and other regional partners via the Fish Passage Operations and Maintenance (FPOM) work group. This report will meet a requirement to submit an annual report to NMFS.

- Reviewed the Corps' current (i.e., 2019) Bonneville Dam pinniped predation monitoring objectives to develop a revised monitoring plan that reflects current and near-future management needs. This updated monitoring plan will be included in Appendix L of the 2021 FPP and will identify monitoring objectives (e.g., daily pinniped abundance), monitoring dates, and reporting requirements.

In 2020, the objectives of the FFU pinniped monitoring program were 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, estimate the number of adult salmonids (*Oncorhynchus spp.*), White Sturgeon (*Acipenser transmontanus*), Pacific Lamprey (*Entosphenus tridentatus*), and other fishes consumed by pinnipeds in the BON tailrace.

3. Estimate the proportion of the adult salmonid run consumed by pinnipeds.

4. 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 past practice, USACE conducted sampling during the spring period (1 January – 31 May). On 7 July 2017, NMFS requested that USACE extend the monitoring program to the fall and winter period (15 August – 31 December) to monitor the growing SSL presence at BON and to measure the predation impacts of SSL on fall and winter-run salmonids. As such, this report documents the monitoring activities of both periods, fall/winter 2019 and spring of 2020.

Of note this year is the altered sea lion management scope of the states of Oregon, Washington, and Idaho (collectively: the States) and the Columbia Inter-Tribal Fish Commission since the passage of the Endangered Salmon Predation Prevention Act (S. 3119) which allows these management agencies to lethally remove SSL and CSL at select areas on the Columbia River including below Bonneville Dam without the restrictions of the previous lethal removal authority for CSL. This change in authority removes the reporting requirements and documentation required previously. Specifically, requirements of residency and abundance metrics are no longer needed. As such, the reporting metrics presented this year will not have some data that have previously been reported.

This report is a summary of abundance and predation monitoring and deterrence efforts implemented from 17 July 2019 - 20 May 2020 by, or coordinated with, the aforementioned agencies. For brevity and ease of communication we have appended the study design, 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 a brief overview of the study design and methods to help orient readers then present 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. We encourage readers not familiar with the previous 18 years of reports to read the material in Appendix 1 before digesting the new data presented.

STUDY DESIGN

Appendix 1 contains a thorough account of methods and assumptions of sampling, but in brief; we sample the abundance of pinnipeds below BON using daily visual encounter surveys and watch for predation events in the three tailraces of BON with trained observers that sample daylight hours using a stratified sampling design to enable estimates of predation during times not observed. Bootstrap sampling of these estimates provides bounded estimates of predation by week, for each fish species, and by each species of pinniped and therein allow bounded estimates on impact to each fish run. We briefly expand on these methods below and encourage readers not familiar with the data to reference Appendix 1 for a detailed description of methods.

Pinniped abundance was documented daily to ensure predation sampling began as soon as the 20-animal trigger was met. Once this trigger was met, sampling began for predation. During the fall and winter period of 2019 we sampled exclusively at the Powerhouse 2 tailrace as it was the only tailrace that allowed fish passage due to winter maintenance at Powerhouse 1. This is consistent with the sampling conducted in 2018 wherein the priority was Powerhouse 1 (Tidwell et al. 2019). During the spring period of 2020, we would typically sample for predation each week after reaching the 20-animal trigger, until the daily abundance of pinnipeds dropped below 20 animals. However, the onset of the COVID-19 pandemic came at the same time as the pinnipeds this spring. As such, our travel, safety, and ability to sample were all constrained but every effort was made to safely provide the required data to the region. During the spring period we sampled all three tailraces of BON between 12 April and 20 May.

QUANTIFY ABUNDANCE

We conducted independent point counts once a day at known haul-out locations and in the three tailraces of BON using field glasses. The point count also includes the mouth of Tanner Creek which is just downstream of BON. This area is included because it is a known location of pinniped predation on adult salmonids. Counts were conducted in a short period of time (i.e. < 20 min.) to ensure animals in transit between locations are not counted twice. Point counts are conducted during morning civil twilight when most pinnipeds are hauled out. We derived a daily maximum pinniped abundance by summing the individual count data at each location and for each species. Linear interpolation was used for days that 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 management requirements have changed, we did not attempt to describe the residency or recruitment metrics for each species of sea lion. 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 including the last 18 years at BON and seven 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 time period using field glasses. We employed a stratified random sampling design with bootstrap analysis to estimate the number of fish consumed per strata (week) with confidence intervals (Tidwell et al. 2018). On weeks in which there was a federal holiday, we sampled at a rate of 5 hours per day to make up for the observations that were missed due to the holiday closure.

We provide estimates of fish predation during the fall and winter period at the Washington Shore fish ladder at Powerhouse 2. For analysis of impact to fish species, we present the number of fish crossing the Washington Shore fish ladder between 25 August - 31 December 2019 (www.FPC.org), and provide an estimate of the percent of these fish consumed during the study period. Any inference of these data to the entire tailrace area or locations downstream need be made with caution.

Similarly, we provide estimates of fish predation during the spring period but sampled all three tailraces between 12 April and 20 May 2020. This period was historically 1 January – 31 May, but COVID-19 restrictions and early departure of all pinnipeds by late May truncated the sampling period this year. We analyze impact to fish species by presenting the number of each species crossing both fish ladders of BON between 12 April - 20 May 2020 (www.FPC.org), and provide an estimate of the percent of these fish consumed during the study period. For further justification of methods and assumptions made, see Appendix 1.

All data were compiled and manipulated in the USACE Pinniped Access Database. Data were exported to Microsoft Excel and all analyses were done in Program R (Version 3.2.2) and SAS (Version 12).

RESULTS

ABUNDANCE

Pinnipeds were not observed at BON between 31 May 2019 (the end of the 2019 spring sampling period) and 16 July 2019. The first pinniped to return to the tailrace after the typical summer break was an SSL that was observed on 17 July 2019. Steller sea lions were observed sporadically during the second half of July and then were regularly present starting in late July and quickly reached double digits by 3 August. Across the fall and winter period, the daily average abundance of SSLs was 31.8 ± S.D. 16.5 animals. Due to the variable nature of the daily abundance data we present the median estimate as well; the median number of SSLs was 38.0.

We documented 54 individual SSLs during the 17 July – 31 December time period (Table 1). No California sea lions were observed in the fall observation season and one harbor seal was observed on two separate days in late August.

During the spring, CSLs were only present from March through May, albeit in low numbers compared to the 10-year average (Figure 1A). The first CSL of the season was observed on 3 March. During March through May, the CSL daily mean was 1.8 individuals. The abundance of CSL peaked on 31 March (n = 34) when there were large groups of subadult CSL that briefly visited the BON tailrace, but did not stay as this was the only day with double digit CSL numbers. In general, there were very few CSLs at BON in spring 2020 with most days having less than 5 CSLs present (Figure 1A). Aside from the day with 34 CSL, the maximum number of CSL observed was seven individuals on 6 May 2020.

Steller sea lions were present throughout the spring observation period, although in varied abundance. During January through March, SSLs were present in low numbers averaging 4.8 animals per day. The number of SSLs increased throughout April with an average of 17.8 animals per day and reached the seasonal peak of 45 animals on 29 April. During May, SSLs averaged 18.6 animals per day with greater than 40 animals present in the early part of the month and then generally decreasing until there were zero by the end of the month (Figure 1B). During April and May, the SSL daily mean was 18.2 individuals. Across the spring season, CSLs averaged 1.1 ± SD 3.0 animals per day, whereas SSLs averaged 10.2 ± SD 10.8.

Observations Upstream of the Dam

During the tenure of this monitoring program, pinnipeds have been documented transiting the navigation lock of BON to the forebay. Although uncommon, it has been documented multiple times over the years. Some CSLs have even taken up residence in the Bonneville Reservoir and have lived between Bonneville and The Dalles Dams for multiple years. In 2020, we observed one CSL upstream of BON near Stevenson, Washington on 12 April. The fate of this animal is unknown.

Table 1. Minimum estimated number of individual pinnipeds observed at Bonneville Dam tailrace areas and the hours of observation during the spring sampling period, 2002 to 2020.

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
2019	836	26	50†	0	76
2020	331	34	45†	2	81

* Observations did not begin until March 18 in 2005.

† In 2015, 2016, 2017, 2018, 2019, and 2020 the minimum estimated number of Steller sea lions (SSL) was 55, 41, 32, 35, 21, and 20 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.

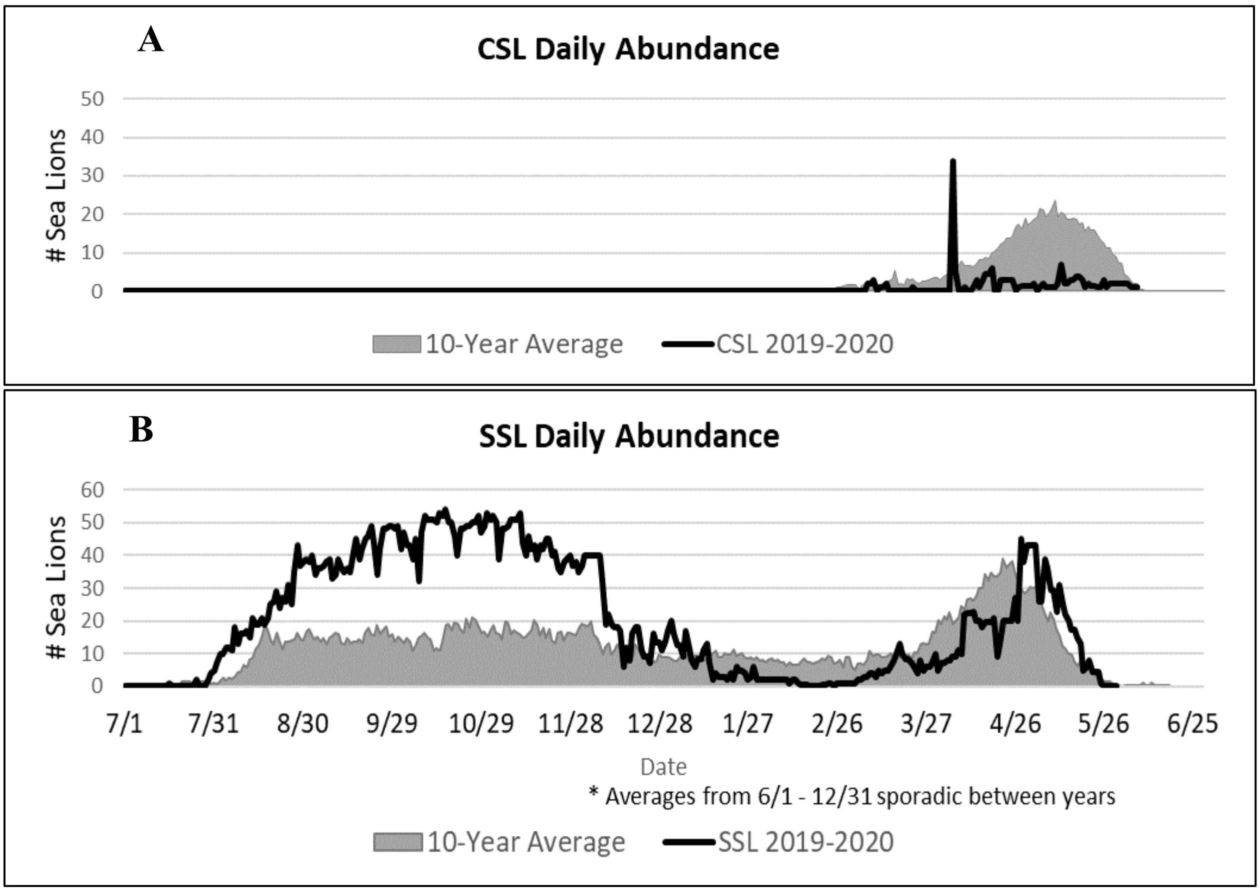

Figure 1. Maximum daily count of pinnipeds by species (SSL: Steller sea lions, CSL: California sea lions) at Bonneville Dam from 1 July 2019 through 30 June 2020 compared to the 10-year maximum daily average. For reference: fall and winter sampling period = 17 July – 31 December 2019 and spring period = 1 January – 31 May 2020. * Averages from 6/1 - 12/31 begin in 2011 but are sporadic between years.

PREDATION

We recorded 341 independent one-hour observation periods between 25 August 2019 and 31 December 2019 and 331 independent one-hour observation periods between 12 April 2020 and 20 May 2020. Below we present the predation impact of all fish species for each study period (Table 2). 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 confidence of the estimate. All estimates of impact to run are calculated as the number of fish consumed divided by the number of fish that passed the dam multiplied by 100.

Table 2. Fish predation by pinnipeds at Bonneville Dam between 25 August 2019 and 20 May 2020.

Fish Species	Number of Fish Killed (95% CI)	Percent Run Consumed During Observation Period
Fall Chinook	1,365 (1,222 – 1,497)	0.7 %
Spring Chinook	1,180 (1,006 – 1,350)	2.5 %
Steelhead – Aug. – Dec.	174 (129 – 217)	1.0 %
Coho	156 (99 – 210)	0.3 %
White Sturgeon – April - May	57 (16 – 93)	N/A
White Sturgeon – Aug. – Dec.	762 (583 – 915)	N/A

Predation on Fall Chinook Salmon

An estimated 1,365 (1,222 – 1,497) fall Chinook Salmon were consumed in the Powerhouse 2 tailrace between the observed days of 25 August and 31 December 2019. During this period 183,417 Chinook and jack Chinook crossed the Washington Shore fish ladder. Thus, we estimate that 0.7% of the passing fish were consumed by pinnipeds (Table 2). During this period there were only SSL present and as such, all predation occurred by SSL. For reference to historical consumption estimates see Tidwell et al. 2019.

Predation on Coho Salmon

An estimated 156 (99 – 210) Coho Salmon were consumed in the Powerhouse 2 tailrace between the observed days of 25 August and 31 December 2019. During this period 48,883 Coho and jack Coho crossed the Washington Shore fish ladder. Thus, we estimate that 0.3% of the passing fish were consumed by pinnipeds (Table 2). During this period there were only SSL present and as such, all predation occurred by SSL. For reference to historical consumption estimates see Tidwell et al. 2019.

Predation on Steelhead

An estimated 174 (129 – 217) steelhead were consumed in the Powerhouse 2 tailrace between the observed days of 25 August and 31 December 2019. During this period 17,560 steelhead crossed the Washington Shore fish ladder. Thus, we estimate that 1.0% of the passing fish were consumed by pinnipeds (Table 2). During this period there were only SSL present and as such, all predation occurred by SSL. For reference to historical consumption estimates see Table 3 & 4.

During the spring period of 12 April and 20 May 2020 we observed two steelhead predation events. This small sample does not justify probability sampling for an expanded consumption estimate. Both observed predation events occurred by SSL.

Predation on Spring Chinook Salmon

An estimated 1,180 (1,006 – 1,350) spring Chinook Salmon were consumed across the three tailraces sampled. We observed predation between 12 April and 20 May 2020. Across this period a total of 46,822 of Chinook and jack Chinook crossed BON. Thus, we estimate that 2.5% of the run was consumed by pinnipeds (Table 2). We estimate that SSL account for 808 (639 – 958) spring Chinook consumed, and CSL account for 371 (268 – 469) spring Chinook consumed. For reference to historical consumption estimates see Table 4 & 5.

Predation on White Sturgeon

An estimated 762 (583 – 915) White Sturgeon were consumed in the Powerhouse 2 tailrace between the observed days of 26 August and 31 December 2019 (Table 2). During this period there were only SSL present and as such, all predation occurred by SSL. For reference to historical consumption estimates see Table 6.

An estimated 57 (16 – 93) White Sturgeon were consumed across the three tailraces sampled during the observation period of 12 April 2020 and 20 May 2020. All but one of the White Sturgeon predation events occurred by SSL.

Predation on Pacific Lamprey

We observed one Pacific Lamprey predation event this year on 18 May at the Powerhouse 1 tailrace by an SSL. The run of Pacific Lamprey did not reach BON until 11 May in 2020. Half of the total Pacific Lamprey run had passed by 12 July and as such, had little temporal overlap with pinnipeds in the BON tailrace this year. For reference to historical consumption estimates see Table 7.

Predation on Other Fish Species

Between 25 August 2019 and 20 May 2020, we observed 13 Smallmouth Bass (*Micropterus dolomieu*), 8 Common Carp (*Cyprinus carpio*), 7 Walleye (*Sander vitreus*), and 10 Northern Pikeminnow (*Ptychocheilus oregonensis*) consumed across all three tailraces by both species of pinniped. An estimated 1,046 (811 – 1,199) American Shad (*Alosa sapidissima*) were consumed in the Powerhouse 2 tailrace between the observed days of 25 August 2019 and 31 December 2019 and across the three tailraces sampled during the observation period of 12 April 2020 and 20 May 2020 combined. Consumption occurred by both species of pinniped. We also observed 11 Chum Salmon (*Oncorhynchus keta*) consumed between 5 November and 27 November 2019.

Temporal Distribution of Salmonid Predation Events

Fall Chinook Salmon 2019 – An estimated 183,417 fall Chinook Salmon passed the Bonneville Washington Shore fish ladder between our sampled dates of 25 August and 31 December 2019; a smaller run estimate compared to the 10-year average of 377,589 during those same dates. Between 1

August and 24 August 2019, 15,531 fall Chinook passed WA Shore with the peak of the run occurring on 13 September 2019. Thus, despite delayed sampling due to the 20-animal trigger, the majority of the run was monitored for predation.

Coho Salmon 2019 – An estimated 48,883 Coho Salmon passed the Bonneville Washington Shore fish ladder between our sampled dates of 25 August and 31 December 2019; a smaller run estimate compared to the 10-year average of 76,214 during those same dates. Between 1 August and 24 August 2019, 1,143 Coho Salmon passed WA Shore with the peak of the run occurring on 13 September 2019. Thus, despite delayed sampling due to the 20-animal trigger, the majority of the run was monitored for predation.

Steelhead 2019 – An estimated 17,560 steelhead passed the Bonneville Washington Shore fish ladder between our sampled dates of 25 August and 31 December 2019; a smaller run estimate compared to the 10-year average of 58,379 during those same dates. Between 1 August and 24 August 2019, 19,923 steelhead passed WA Shore with the peak of the run occurring on 14 August 2019 which was outside of the fall sampling period for predation. Hence, the majority of the run was not monitored for predation.

Steelhead 2020 – An estimated 480 steelhead passed Bonneville Dam between 12 April and 20 May 2020; a smaller run estimate compared to the 10-year average of 1,488 during those same dates. Between 1 January and 11 April 2020, 2,634 steelhead passed with the peak occurring on 29 February 2020. Hence, the majority of the run was not monitored for predation. Moreover, we cannot produce estimates of impact to the winter Steelhead run (i.e. 16 Nov. – 31 March) this year.

Spring Chinook Salmon 2020 – An estimated 46,594 spring Chinook Salmon passed between 12 April and 20 May 2020, a smaller run estimate compared to the 10-year average of 136,844 during those same dates. Between 1 January and 11 April 2020, 364 Spring Chinook passed with the peak occurring on 10 May 2020. Thus, despite delayed sampling due to the COVID-19 pandemic, the majority of the run was monitored for predation.

DETERRENTS AND MANAGEMENT ACTIVITIES

Physical Barriers

Due to pinnipeds entering the fishways of BON in years past, physical barriers were 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 this monitoring period. SLEDs continue to be effective at keeping pinnipeds out of the fishways, as none were observed in fishways this season (Appendix 2).

Non-Lethal Harassment

Boat-based hazing by CRITFC began on 4 March 2020 but was suspended the next week due to COVID-19 restrictions. During the one week of hazing, 16 hazing events were recorded with 14 CSL and 30 SSL. Hazers deployed 169 cracker shells and 117 “Seal Bombs” (e.g. small charges of explosive that detonate under water) during the shortened season. Boat-based hazing is not feasible in the spillway given the highly turbulent water conditions, as such boat-based hazing occurred only in Powerhouse 1 and Powerhouse 2 tailraces.

Dam-based hazing of pinnipeds by USDA began on 1 March 2020 and continued daily through May 20, 2020. Working a mixture of avian and pinniped hazing, dam-based hazers worked across all daylight hours and conducted a total of 477 hours of pinniped hazing with approximately 1,700 cracker shells used.

Trapping and Removal

Due to the COVID-19 pandemic, the state managers were not able to operate the removal program in the spring of 2020 (Table 8). Removals did occur in the fall of 2020 and will be included in next year's report.

DISCUSSION

Despite COVID-19 and hazardous wildfire smoke, during 2019-2020 we sampled pinniped abundance and predation in the BON tailrace and found that: CSL abundance continued to decline, SSL abundance remained constant with high numbers, and predation on ESA and other runs of salmon and fish species now predominantly occurs by SSL and is similar to recent years. Below we explore the data in reference to previous years and discuss emerging trends.

Abundance

The average number of SSLs during the fall and winter of 2019 was 40.5% greater than last year and 83.9% greater than previous 8-year average (Figure 1B). Over the last nine years we have documented increasing numbers and earlier arrival of SSLs to BON. This year, SSLs were away from the BON tailrace for approximately 8 weeks, meaning the last SSL departed the tailrace on 23 May 2019 and the first returning SSL was back in mid-July 2020 and SSLs were consistently seen thereafter. The arrival of marked SSL documented at 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).

Most of the branded and identifiable SSL that returned in the fall and winter remained at BON 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 54 SSLs.

The average number of SSLs during spring season of 2020 was 5.0% greater than last year and 28.6% lower than the previous 10-year average.

The average number of CSLs during the spring continues to decline in both presence and abundance. We documented a 31.6% reduction in CSL abundance relative to last year, and more than a twofold reduction relative to the 10-year average (Figure 1A). Similar to the 2019 spring season, this year CSL were present but in very low numbers for a limited time of the spring Chinook run. This trend is undoubtably a result of management efforts to remove these animals.

Predation

The requirements of the emerging COVID-19 pandemic and the 20-animal sampling threshold limited predation sampling this year. We emphasize that the fish consumption estimates presented herein apply only to the period and tailrace sampled each season. This year we sampled Powerhouse 2 tailrace during the fall and winter period. As such, the estimates represent only one of the three tailraces near BON. 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 powerhouse priority that determine river flow and impact the routes of fish passage. We refer to previous fall and winter data collected since directed by NOAA in 2017, but caution that inference be made respective of dates and locations sampled. We also reiterate that impacts to fish runs were assessed differently by using the period sampled as the measure of run passage and pinniped impact, not the entire Fish Passage Plan defined passage dates.

Fall Chinook Salmon – Between 25 August and 31 December 2019, we estimate that 1,365 Chinook salmon were consumed at the Powerhouse 2 tailrace which constitutes 0.7% of the run during that time. Withstanding the above caution, we draw inference of consistent inter-year impacts by SSL based on the data collected at Powerhouse 1 last year. Wherein, between 19 August and 31 December 2018, we recorded 16 weeks of predation and estimated that 1,340 Chinook Salmon were consumed at the Powerhouse 1 tailrace during the fall and winter sampling period which accounted for 0.6% of the Chinook Salmon that passed during the observation period. Thus, our estimates this year are within 0.1% of last year's estimates.

Coho Salmon – Between 25 August and 31 December 2019, we estimate that 156 Coho Salmon were consumed at the Powerhouse 2 tailrace which constitutes 0.3% of the run during that time. The previous year we estimated 269 Coho Salmon were consumed which accounted for 1.4% of the run during the observation period. Thus, our estimates this year are less than the previous year both for fish consumed and impact to run.

Summer and Winter steelhead – Between 25 August and 31 December 2019, we estimate that 174 steelhead were consumed at the Powerhouse 2 tailrace which constitutes 1.0% of the run during that time. The previous year we estimated 293 steelhead were consumed which accounted for 1.6% of the run during the observation period (Table 3). Thus, our estimates this year are less than the previous year by both number of fish consumed and impact to run.

Winter steelhead – Steelhead crossing BON during the spring have historically been lumped together as done above, but they are functionally recognized as two distinct varieties: the winter run, defined as those steelhead crossing BON between 16 November and 31 March, and the summer run which cross after 31 March (Withler 1966, Busby et al. 1996). In 2019, we sampled the entire run period and found that more than 13% of the run was consumed by pinnipeds with the vast majority being consumed by SSLs. This season we cannot produce estimates because sampling did not occur between 1 January and 31 March. However, high SSL abundance and more than 2,000 winter steelhead passing at the time suggest that impacts to the species are still high.

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, suggest that steelhead consumption is 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.

Spring Chinook Salmon – Between 12 April and 20 May 2020, we estimate that 1,180 spring Chinook Salmon were consumed in the BON tailraces which constitutes 2.5% of the run during that time. The previous year we estimated 1,974 spring Chinook Salmon were consumed which accounted for 3.1% of the run during the observation period (Table 4 & 5). Thus, our estimates this year, despite the truncated sampling period are slightly less but similar to the previous year both for fish consumed and impact to run.

It has been hypothesized that early returning spring Chinook Salmon are disproportionately consumed relative to 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). This season, predation sampling did not occur during the early portion of the run and therein impacts to these stocks cannot be addressed. Similar to previous years the pinniped predators left the dam prior to run cessation and as such, the late running fish were able to pass BON without predator impact in the near-dam environment.

White Sturgeon – Between 25 August and 31 December 2019, we estimate that 762 White Sturgeon were consumed in Powerhouse 2 tailrace. The previous year we estimated 359 White Sturgeon were consumed during the same period in Powerhouse 1 tailrace. Thus, our estimates this year indicate a two-fold increase in predation and shows a trending increase since the fall period of 2017 when an estimated 238 sturgeon were consumed in Powerhouse 2 tailrace. Between 12 April and 20 May 2020, we estimate that 57 White Sturgeon were consumed across all three tailraces. The previous year we estimated 187 White Sturgeon were consumed between 1 January and 31 May 2019 (Table 5). Due to the highly truncated sampling period in spring 2020 (i.e. 6 weeks in 2020 *vs.* 21 weeks in 2019), we are unable to deduce a trend because SSL commonly consume more sturgeon in January-March than in April-May.

White Sturgeon consumption by pinnipeds at BON had primarily been documented during the spring season prior to 2017 when winter monitoring began. During the last 18 years of spring observations the number of White Sturgeon killed have fluctuated considerably. The long-term trend shows that between 2008 and 2012 more than one thousand White Sturgeon were consumed each year during the spring sampling period with a peak in 2011 of over 3,000 sturgeon consumed. After 2012, White Sturgeon predation dropped sharply and between 2015 and 2017 we estimate that less than 100 sturgeon were being consumed during each spring season.

This year however, we replicate our findings of the previous three years and provide data to suggest that the impact to the species is greater during the fall and winter months than during the spring. Why more fish are killed in the fall and winter than the spring is unclear but the additive mortality of White Sturgeon over time at BON may be contributing to the questionable status of the stock.

Pacific Lamprey – Across the spring observation period we observed just two Pacific Lamprey predation events which did not allow expanded estimation of impact. Pacific Lamprey predation has historically occurred in May when the run starts increasing and has been predominantly performed by CSL. The later run timing and low numbers of CSL likely explain the low number of Pacific Lamprey predation events this season.

Other Fish – Across both sampling periods we documented a small number of predation events on other fish species which is consistent with previous years. Of note, is the fall predation documented on ESA listed Chum Salmon. We have reported previously that Chum Salmon predation occurring in the BON tailraces is likely a smaller subset of predation events occurring immediately below the BON tailraces in the vicinity of Pierce and Ives islands where Chum Salmon spawn (Tidwell et al. 2019). The potential impact to Chum Salmon based on observed pinniped abundance and predation at BON is concerning and worth management's attention.

Deterrence and Management Actions

As discussed in previous reports, the value of hazing pinnipeds with conventional methods is questionable. The recurrence of habituated pinnipeds following increased and prolonged hazing events over the last decade suggest its functionality is minimal. The most functional benefit of current hazing techniques is for the brief moments of time when active hazing is occurring; which has been found to dissuade active foraging behaviors (Götz and Janik 2013). However, more detailed analyses that ascertain the benefit during the brief period of functional hazing might illuminate any derived function to benefit fish passage and shed light on how to better implement the current tools of management. Such a study was conducted in 2020 and the results are in review currently.

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. Given the near year-round residency of SSLs, continuing to deploy the devices year-round is warranted.

The passage of the Endangered Salmon Predation Prevention Act gives management the authority to remove SSL and CSL without requirements of predation, hazing, or residency. As shown through fish consumption and CSL abundance data, the removal of CSL over the last decade has contributed to a reduced impact. Future management actions for SSL may further reduce the impact to ESA listed salmon and sensitive stocks.

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Table 3. Consumption of summer and winter steelhead by pinnipeds at Bonneville Dam tailrace during the spring sampling period from 2007 to 2020.

Year	Bonneville Dam Steelhead Passage	Adjusted Steelhead Consumption Estimate	Percent of Run Consumed
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%
2019	2,172	208	8.7%
2020*	N/A	N/A	N/A

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

* 2020 sampling occurred between 12 April and 20 May due to COVID-19 pandemic. Only two steelhead observed killed.

Table 4. 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 2020.

Year		California Sea Lions		Steller Sea Lions		All Pinnipeds	
	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%
2019	63,591	176	0.3%	2,022	3.1%	2,201	3.3%
2020*	47,074	373	0.8%	813	1.7%	1,182	2.5%

* 2020 sampling occurred between 12 April and 20 May due to COVID-19 pandemic. Fish passage for 2020 depicts these dates.

Table 5. Consumption of spring Chinook Salmon by pinnipeds at Bonneville Dam tailrace during the spring sampling period from 2002 to 2020. Passage counts of Chinook Salmon includes both adult and jack salmon.

Year	Bonneville Dam Spring Chinook Passage	Chinook Consumption Estimate	Percent of Run Consumed
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	4,501	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	1,959	1.2%
2013	117,165	2,710	2.3%
2014	214,177	4,576	2.1%
2015	233,794	10,622	4.3%
2016	148,357	9,222	5.9%
2017	101,734	4,951	4.6%
2018	94,350	2,813	2.9%
2019	61,385	1,974	3.1%
2020 ˩	46,822	1,180	2.5%

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 pinniped observations did not start until March 18.

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

˩ 2020 sampling occurred between 12 April and 20 May due to COVID 19 pandemic. Fish passage depicts these dates.

Table 6. Consumption of White Sturgeon by pinnipeds at Bonneville Dam tailrace during the spring sampling period from 2005 to 2020.

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
2019	836	22	187
2020*	331	9	57

* 2020 sampling occurred between 12 April and 20 May due to COVID-19 pandemic.

Table 7. Consumption of Pacific Lamprey by pinnipeds at Bonneville Dam tailrace during the spring sampling period from 2002 to 2020.

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%
2019	836	4	14	0.02%
2020*	331	1	N/A	N/A

* 2020 sampling occurred between 12 April and 20 May due to COVID-19 pandemic.

Table 8. Summary of California sea lion (CSL) and Steller sea lion (SSL) branding and removals (captivity, euthanasia, accidental mortality) at Bonneville Dam, 2007 to 2020. Note: removals include all animals removed by the States under the old Sec 120 LOA and the new Section 120 (F) of the MMPA.

Year	CSL Authorized for Removal	CSL Branded	CSL Removed	SSL Authorized for Removal	SSL Branded	SSL Removed
2007	N/A	8	N/A	N/A	N/A	N/A
2008	85	4	11*	N/A	N/A	N/A
2009	85	3	15	N/A	N/A	N/A
2010	85	9	14	N/A	8	N/A
2011	85	9	1	N/A	9	N/A
2012	92	6	13	N/A	19	N/A
2013	92	11	4	N/A	3	N/A
2014	92	21	15	N/A	0	N/A
2015	92	131	32*	N/A	0	N/A
2016	92	50	59	N/A	0	N/A
2017	92	18	24	N/A	12	N/A
2018	92	8	27	N/A	3	N/A
2019	92	3	19	N/A	1	N/A
2020	540	0	0	176	0	0
Total	984	281	236	176	55	0

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

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 in 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.

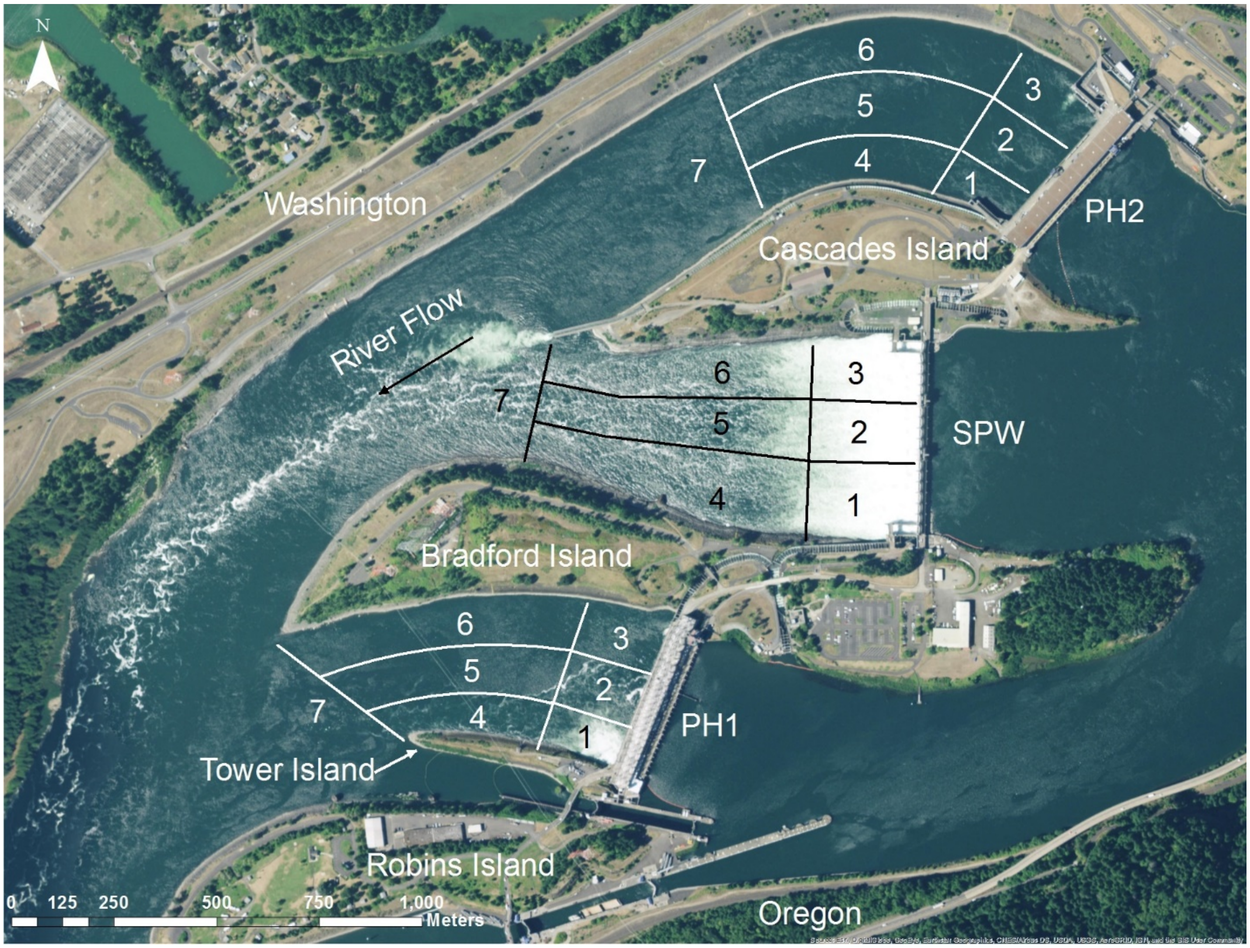

Figure A1. Bonneville Dam study area with Powerhouse One (PH1), Spillway (SPW), and Powerhouse Two (PH2) tailrace sub-areas separated into zones for assigning the location of predation events.

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 nighttime.

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 Species in BON Tailrace

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 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).

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 ESUs 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.*). Our monitoring program focus primarily on the number of salmonids, Pacific Lamprey, 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 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 A1) at a scheduled interval to develop estimates of predation and abundance.

This year we sampled continuously as allowed by COVID-19 restrictions whenever there were > 20 animals recorded.

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 generally conduct one point count per day during the morning civil twilight.

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 – Historically this metric was required to facilitate management of CSL in the BON tailrace. With the passing of the Endangered Salmon Predation Prevention Act these data are no longer required and therein were not reported this year. However, the data exist and if requested can be furnished.

Recurrence – Similar to Residency, this metric is no longer required but the data are available upon request.

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

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 > 18 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 an 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 Lamprey are consumed underwater albeit observers rarely report Pacific Lamprey 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 Lamprey to pass at nighttime 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 18 strata weeks from 26 August – 31 December 2019. During the spring sampling period there were 6 strata weeks between 12 April and 20 May 2020. Five of seven days (Monday-Friday) were sampled during each stratum except for 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 sample block was used. 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 19.6 and 27.1%.

For the fall and winter period the observation occurred exclusively at the PH 2 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 stepwise 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 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.

Given that the levels of pinnipeds and fish fluctuate across the sampling seasons (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).

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.

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 each fish species taken by each species of pinniped calculated as the estimated number of fish 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 sample period to the end of the 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 calculation of fish consumed divided by fish that passed only during the monitored interval is an adopted change based on last year's assessment that the treatment in this manner provided parsimony. That is, since predation is now monitored across the year when 20 animals or more are present there is disjunct monitoring across runs. As such, reporting on the impact to the run of estimated fish consumed divided by the number of fish that passed during the observation period is the most conservative measure of interpreting the data and most streamlined.

Chronology of Fish Passage

We present passage for each sampling period of each year and when needed compare to 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 recognize that environmental co-factors have been shown to influence passage rates (Keefer et al. 2008b, Evans et al. 2016).

DATA ANALYSIS AND REPORTING

Descriptive statistics are reported throughout with the mean and associated standard error as the measure of spread (i.e. $\overline{x} \pm$ 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 (Jeffries 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 in the dam tailraces and attempt to push them downstream and away from the fish ladder entrances. We report the descriptive statistics of these efforts and discuss their use throughout the season.

Due to the repeated entry of pinnipeds 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 Powerhouse 2 that allow fish to enter the collection channel and pass via the Washington Shore fishway. The FOGs at Powerhouse 2 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, alphanumeric "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. For specificity to state managers actions, we 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), floating orifice gate (FOG) (C) (unknown source), and sea lion incursion barriers on top of FOGs (D) (Photo by Patricia Madson, USACE).

A.

B.

C.

D.