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EVALUATION OF PINNIPED PREDATION ON ADULT SALMONIDS AND OTHER FISH IN THE BONNEVILLE DAM TAILRACE, 2019

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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 – 31 May), which has had documented sea lion presence since 2001. At the request of NOAA Fisheries, we also sampled during the fall and winter months (19 August – 31 December) to monitor the growing SSL presence at Bonneville Dam to evaluate pinniped predation on fall- and winter-run salmonid stocks.

2018 FALL AND WINTER SAMPLING PERIOD:

The following is a summary of the 2018 fall and winter period which monitored sea lion abundance across all tailraces (14 July – 31 December) and fish predation at the Powerhouse 1 tailrace (19 August – 31 December) of Bonneville Dam. Abundance monitoring began when pinnipeds returned to the BON tailrace in July. Predation monitoring began after the first point count of ≥ 20 pinnipeds was reached. 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 21.1 ± S.D. 12.3 SSLs and 0.2 ± S.D. 0.5 CSLs were observed each day.

Species	Number of Fish Killed (95% CI)	Percent Run Consumed During Weeks Sampled
All Salmonids	982 (884 – 1078)	1.0%
Chinook Salmon (*O. tshawytscha*)	419 (354 – 484)	0.6%
Coho Salmon (*O. kisutch*)	269 (214 – 323)	1.4%
Summer and Winter steelhead (*O. mykiss*)	293 (244 – 342)	1.6%
White Sturgeon (*Acipenser transmontanus*)	359 (301 – 416)	N/A

2019 SPRING SAMPLING PERIOD:

The following is a summary of the 2019 spring period (1 January – 31 May), which monitored sea lion abundance and fish predation across all three tailraces of Bonneville Dam.

Abundance – An average of 9.7 ± S.D. 11.3 SSLs and 0.8 ± S.D. 1.6 CSLs were observed each day.

Species	Number of Fish Killed (95% CI)	Percent Run Consumed
All Salmonids	2,201 (1,939 – 2,446)	3.3%
Chinook Salmon	1,974 (1,756 – 2,199)	3.1%
Steelhead - Jan. – May	208 (109 – 289)	8.7%
Winter steelhead - Nov. – Mar.	201 (116 – 286)	13.1%
Pacific Lamprey (*Entosphenus tridentatus*)	14 (3 – 21)	0.02%
White Sturgeon	187 (83 – 262)	N/A

Data provided by the 18 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 as a result 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 92% 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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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 (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 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 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 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 (Tidwell et al. 2019).

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, 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 Sockeye Salmon (*Oncorhynchus nerka*), 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 upstream migration periods. Predation of any of these ESA-listed stocks could damage run viability and make recovery efforts difficult, however there is a lack of quantitative data 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 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 continue to be depredated throughout the year at BON. The fall and winter period was identified last year as a particularly heavy period for White Sturgeon predation (Tidwel et al. 2019).

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 RPAs 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 spp.*), 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 17 years. On July 7, 2017, NOAA Fisheries requested that the USACE extend the monitoring program to the fall and winter period (15 August – 31 December) to monitor the growing SSL presence at Bonneville Dam 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.

The USACE pinniped monitoring program provides monitoring data, access to 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. The authorization for removal was renewed 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 2018 - 25 May 2019 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, contrasts 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 eight years (Table 1). Prior research has found that pinnipeds, primarily SSLs, aggregate at the dam in the fall and winter months to eat adult salmonids, but consumption estimates have not been regularly described (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. 2019), and prompted reason for concern due to the sensitive fish stocks near BON during the fall winter period.

In response to the increased abundance of SSLs in the fall of 2017, NOAA fisheries requested 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 in 2017. The result was nine weeks of sampling that found salmonid and White Sturgeon predation, some of which was higher than previously documented or perceived.

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 for four hours per day in a stratified random fashion. Sampling that focused on predation began once the daily abundance of pinnipeds in the BON tailrace reached 20 animals on a single day for the fall and winter study period. Once this trigger was met, we sampled for predation each week until the end of the study period (31 December 2018). 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 tailrace as opposed to all three, a 20 pinniped threshold to initiate sampling, and a reduced sampling duration of four hours per weekday.

Here we present the same methods applied to the fall and winter period of 2018 to determine the abundance of pinnipeds near BON, and evaluate the number of fish they consumed. We start with a high level overview of methods, then present the findings, and discuss the findings relative to the previous years' work in the discussion.

Table 1. Average daily combined pinniped presence by month for the fall and winter sampling period at Bonneville Dam for the years 2011 to 2018.

Month	2011	2012	2013	2014	2015	2016	2017	2018
Aug.	0	0	0	1	1.9	5.2	10.8	15.2
Sept.	0	0	1.5	6.8	16.6	30.7	13.2	23.9
Oct.	2.4	2.6	13.3	11.7	22.5	26.6	14.8	32.8
Nov.	4.9	2.8	15.9	16.8	22.3	18.9	18.5	31.2
Dec.	7	4.1	10.2	9.2	16.1	16.4	16.4	15.4

QUANTIFY ABUNDANCE

We used the same methods as those employed during the spring abundance sampling (Appendix 1), wherein, FFU staff conducted independent point counts once a day at known haul-out locations and in the three tailraces of the dam 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 usually conducted during morning civil twilight when the majority of pinnipeds are still hauled out after the nighttime and only a small portion of the animals have moved into the tailraces to start hunting. 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 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 including the last 17 years at BON and six 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. 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.

Abundance monitoring occurs year-round at BON to detect and enumerate pinniped presence. During the fall and winter sampling period, we began fish predation monitoring for the study when pinniped numbers were greater than or equal to 20 animals. Once this 20 pinniped trigger was met we continued sampling each week until the end of the study period on 31 December. 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 1 (PH1) tailrace exclusively due to *a priori* knowledge of scheduled mid-winter dewatering at the Powerhouse 2 (PH2) fishway which makes it impassable to migrating fish after 1 December. 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 PH1 for four hours per day, five days a week. 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. This is similar to the sampling used in the 2017 spring period (Tidwell et al. 2018, Appendix 1).

We provide estimates of pinniped abundance across all tailraces of BON and predation estimates for fish passing the Bradford Island fish ladder at PH1. For analysis of impact to fish species, we present the number of fish crossing the Bradford Island fish ladder between 19 August and 31 December (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.

We present the consumption of the run estimates in the same way as the spring period, wherein the impact to run is calculated as: the number of fish consumed by pinnipeds divided by the fish consumed plus the fish the passed the dam. We note that this is unlike the estimates presented in the 2017 fall and winter analysis, where the consumption estimates were derived by dividing the number of fish consumed by the number of fish passed, and support this change due to the fact that this season we had sampling during every week. This continuous sampling allowed passage by fish stocks and species to be accounted for in their entirety rather than assigning sporadic sample week consumption estimates to the entire run of select salmon. 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 excel and all analyses were done in statistical program R (Version 3.2.2) and SAS (Version 12).

RESULTS

ABUNDANCE

Annual Individual Pinniped Abundance

Pinnipeds were not observed at BON between 15 June (two weeks after the end of the spring sampling period) and 13 July, 2018, after which they were present in single digit numbers until 12 August when the count of SSLs increased to double digits. More than 10 animals were present daily until the end of December when pinniped numbers dropped back into single digits. Abundance monitoring is continuous year-round at BON and predation monitoring started 19 August 2018 when abundance crossed the 20 animal trigger. All observations ceased on 31 December.

We documented two individual CSLs and 47 individual SSLs during the 20 August – 31 December time period (Table 2). No harbor seals were observed. Of the 47 identified SSLs, 19 were individually identifiable animals that have been observed at BON prior to this season. The number of unique individuals was estimated as the highest daily point count of the fall and winter period when 47 SSLs 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 SSLs during the fall and winter period (Tidwell et al. 2018), the number of unique individuals is likely much higher than 47.

Table 2. Number of individually identifiable pinnipeds observed at Bonneville Dam tailrace areas between July and December since 2011. *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, 7/21 in 2017, and 7/14 in 2018.

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
2018	2	47	49

Daily Pinniped Abundance

The first SSL of the fall-winter period was observed at BON on 14 July 2018. Steller sea lions were present in low numbers (i.e. 0-2 individuals) until early August when their abundance steadily increased from 4 individuals on 4 August to an initial peak of 32 individuals on 23 August. Another peak occurred on 22 October with 47 SSLs present and their numbers stayed relatively high (i.e. ≥ 10 animals) until the last week of December when daily abundance dropped below ten animals (Figure 1B).

Thus, from 4 August 2018, SSLs were continuously present at BON throughout the remainder of the calendar year (Figure 1B).

California sea lions were rarely present in the BON tailrace during the fall and winter sampling period. The first two CSLs were observed on 5 November 2018 and were observed sporadically until 9 December 2018 (Figure 1A). One of the CSLs observed at BON was removed by ODFW at Willamette Falls on 12 December. No CSLs were observed at BON for the rest of the fall and winter sampling period. Our maximum observed daily number of CSLs during this time period was on 5 November when 2 CSLs were present.

Across the fall and winter period, the daily average abundance of SSLs was 21.1 ± S.D. 12.3 animals, whereas CSLs averaged 0.2 ± S.D. 0.5. Due to the variable nature of the daily abundance data we present the median estimate as well. The median number of SSLs was 22.5 and the median for CSL was 0.

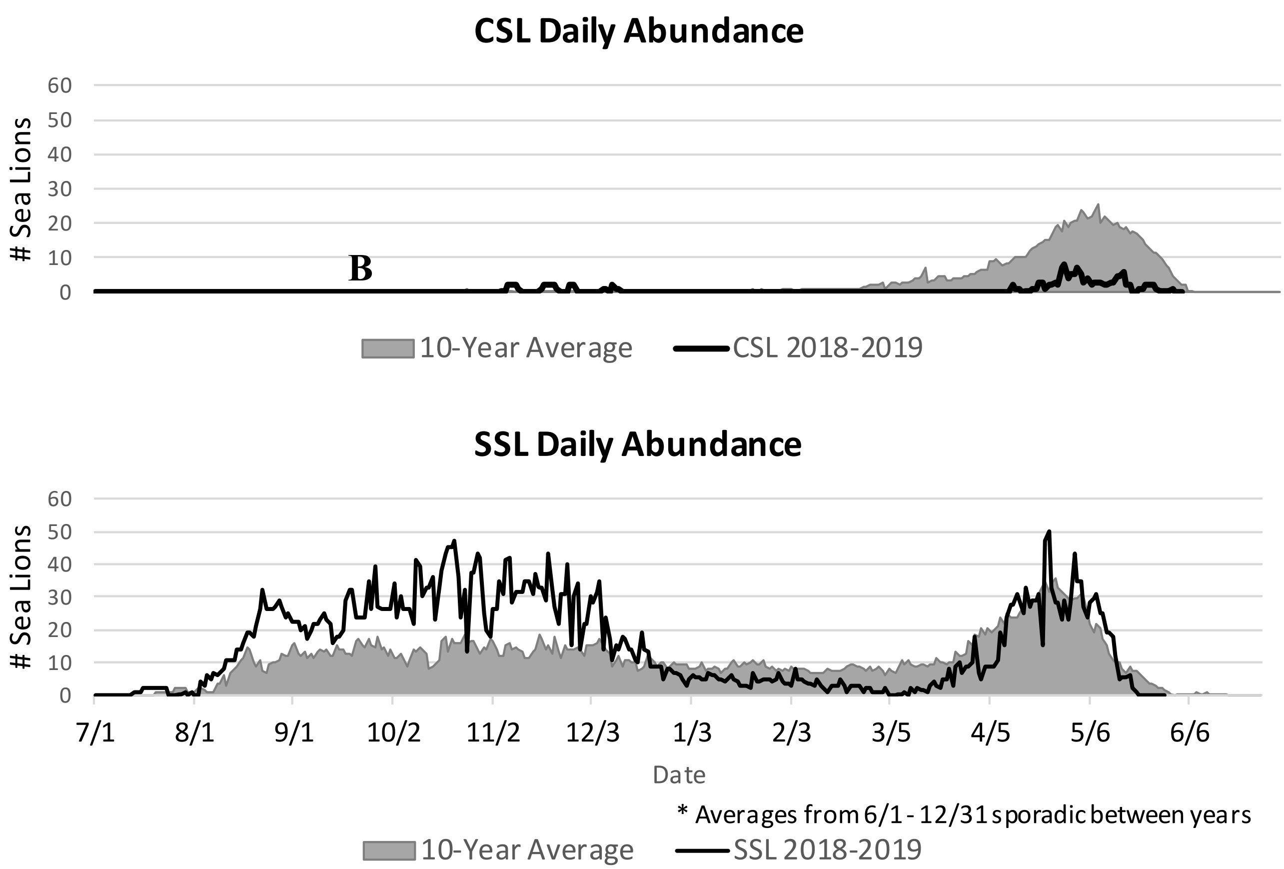

Figure 1. Maximum daily count of pinnipeds by species (SSL: Steller sea lions, CSL: California sea lions) at Bonneville Dam from 1 July 2018 through 30 June 2019 compared to the 10-year maximum daily average. For reference: fall and winter sampling period = 15 August – 31 December 2018 and spring period = 1 January – 31 May 2019. * Averages from 6/1 - 12/31 begin in 2011, sporadic between years.

PREDATION

Below we present the predation of all salmonid species combined, and then delineate predation impact for each fish species for the fall and winter study period. 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 bootstrapped estimates were done in Program R (Version 3.2.2).

Between 19 August and 31 December 2018, we recorded 16 weeks with ≥ 20 pinnipeds and sampled 369 independent one hour (*i.e.* paired 30 minute intervals) predation observation periods. The first sampled week began on 19 August 2018 and is the starting point for predation impact estimates. An estimated 312,924 total salmonids passed Bonneville Dam between 19 August and 31 December 2018. Of these fish, 102,119 passed through the Bradford Island fish ladder which is associated with the observation area of PH1 tailrace. Please note that fish migrating upstream can also enter the Bradford Island fish ladder from the Spillway tailrace, although it is likely that very few adult salmonids enter from the Spillway during this time period due to the lack of flow coming from this area.

Predation on Adult Salmonids

An estimated 982 (884 – 1,078) adult salmonids were consumed, which equates to 1.0% of the salmonids that passed the PH1 tailrace between 19 August and 31 December, 2018 (Table 3). Of these, we estimate 419 (354 – 484) were Chinook; 269 (214 – 323) were Coho; and 293 (244 – 342) were steelhead. (Table 3).

Predation on White Sturgeon

An estimated 359 (301 – 416) White Sturgeon were consumed (Table 3). All White Sturgeon consumed were observed to have been approximately 1 – 5 feet in length with the majority being between 2 and 4 feet in length.

Predation on Other Fish Species

An estimated 83 (55 – 112) American Shad (*Alosa sapidissima*) were consumed.

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 2018 fall and winter sampling period in the Powerhouse 1 tailrace from 19 August to 31 December 2018.

	Adjusted Fish Consumption Estimates	Range of Consumption Estimate	Bradford Island Passage 19 Aug.–31 Dec.	% Passage Consumed 19 Aug.- 31 Dec.
All Salmonids	982	884 – 1078	102,119	1.0%
Chinook	419	354 – 484	64,856	0.6%
Coho	269	214 – 323	18,588	1.4%
Steelhead	293	244 – 342	18,605	1.6%
Sturgeon	359	301 – 416	N/A	N/A

DISCUSSION

An estimated 1,340 Chinook Salmon, Coho Salmon, steelhead, and White Sturgeon were consumed between 19 August and 31 December 2018 by SSLs in the PH1 tailrace. Pinniped abundance and arrival to BON have continued to increase in the fall and winter period, and the data are suggestive that the subsequent increase in predators is relating to increased fish predation. Below we discuss the data presented currently and provide contrast with the previous year's fall and winter monitoring, albeit the previous fall and winter months only had nine weeks of predation observation (Tidwell et al. 2019).

Over the last seven years we have documented increasing numbers and earlier arrival of SSLs to BON. 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 approximately six weeks, meaning the last SSL departed the BON tailrace at the end of May and the first returning SSL was back in mid-July and SSLs were consistently seen thereafter. In the fall and winter of 2017 we estimated an average of 14.5 SSL each day at BON, this year we found an average of 21 SSL. 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 arrival of the pinnipeds 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).

We estimate that 982 adult salmonids were consumed at the PH1 tailrace during the fall and winter sampling period. Of the adult salmonids crossing the Bradford Island PH1 ladder when we sampled, we found approximately 0.6% of the Chinook Salmon, 1.4% of the Coho Salmon, and 1.6% of the steelhead were consumed by pinnipeds. Collectively, of all the adult salmonids counted at the PH1 fish count window during the sampled weeks, 1.0% were consumed by pinnipeds.

During the nine weeks of sampling during the fall and winter of 2017 at the PH2 tailrace, we found differences in species specific consumption, but similar trends in predation impacts: 1.2% of all salmon were consumed. We estimated that 0.7% of the Chinook, 3.1% of the Coho, and 1.5% of the steelhead run were consumed. Differences in these two years data are likely the result of sampling nine weeks of the run in 2017 and 22 weeks of sampling in 2018.

We estimate that 359 White Sturgeon were consumed at the PH1 tailrace during the fall and winter sampling period. During the nine weeks of fall and winter sampling in 2017 we estimated that 238 White Sturgeon were killed. These fall and winter data stand in contrast to the five month spring sampling period of 2018 when approximately 148 White Sturgeon were consumed across all three tailraces. White Sturgeon consumption by SSL began in 2006, and peaked in 2011 with more than 3,000 being killed. Consumption during the spring is now relatively minimal (i.e. 2015-2017 seasonal average = 53 sturgeon killed), but consumption during the fall and winter are higher. The last two years of monitoring during the fall and winter show that White Sturgeon are vulnerable to predation at almost any time of year and are now depredated most heavily during the August – December period when SSL are present.

As discussed last year and validated this year, consumption of Coho Salmon and steelhead is occurring during the fall and winter period. The relative impact to the ESA listed stocks of these species is perhaps most pertinent to the B-run summer and winter steelhead. Since winter steelhead run through March 31, a full evaluation of winter steelhead impact will be presented and discussed in the following chapter.

We emphasize that the fish consumption estimates presented herein apply only to the period sampled between 19 August and 31 December. Moreover, 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 power house priority that determine flow and impact the routes of fish passage.

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, this year the pinnipeds left BON during the last week of May and therefore we did not conduct predation sampling during the last week of May.

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 (i.e. there was not a trigger based on number of pinnipeds present on when to start predation sampling) and monitoring at all three tailraces during the spring. One alteration employed again this season 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 at BON and predation estimates for various fish species. 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 31 May (www.FPC.org) and provide an estimate of the percent of these fish consumed during the spring sampling period (Appendix 1). All bootstrapped estimates were done in Program R (Version 3.2.2).

RESULTS

ABUNDANCE

Daily Pinniped Abundance

During the spring, CSLs were only present during April and May, albeit in low numbers compared to the 10-year average (Figure 1A). The first CSL of the season was observed on 9 April. During April and May, the CSL daily mean was two individuals. The abundance of CSL peaked on 25 April (n = 8) and fluctuated between 0 and 7 animals until 23 May, when only one animal remained. No CSL were observed during the last week of May until May 28 when one CSL was present for the day (Figure 1A). SSLs fluctuated between 0 and 10 animals through the end of March, gaining individuals throughout April to a seasonal high of 50 animals on 25 April. The animals remained until 23 May when the last SSL was observed (Figure 1B). During April and May, the SSL daily mean was 18.6 individuals. Across the spring season, CSLs averaged 0.8 ± SD 1.6 animals per day, whereas SSLs averaged 9.7 ± SD 11.3 (Supplementary Table 1).

Inspection of the 2019 spring sampling period daily abundance relative to the 10-year average reveals that CSL numbers were below average for the entirety of the season, 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 2).

Table 4. Minimum estimated number of individual pinnipeds observed at Bonneville Dam tailrace areas and the hours of observation during the spring sampling period, 2002 to 2019.

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

* Observations did not begin until March 18 in 2005.

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

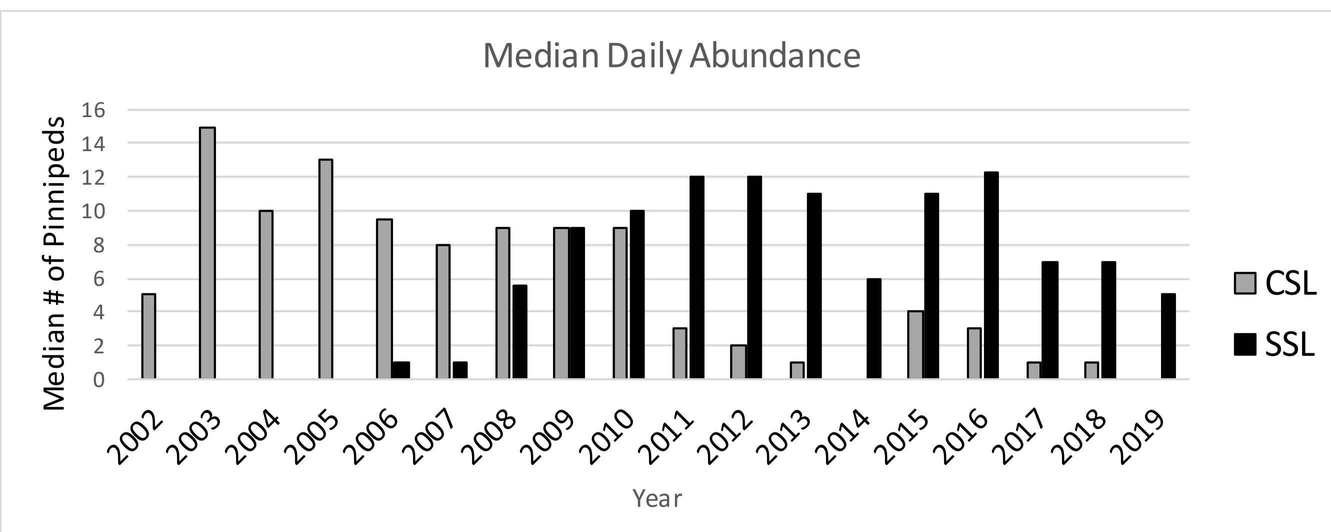

Figure 2. Annual median daily abundance of Steller sea lions (SSL) and California sea lions (CSL) at Bonneville Dam during the spring sampling period from 2002 to 2019.

Residence Times

We found that the number of observed days for CSLs averaged 3.1 ± 0.6 days, whereas the potential number of days present averaged 7.5 ± 1.5 days. Additionally, the number of days present had a much larger spread between the observed and potential (i.e. 1 – 13 days vs 1 – 29, 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 19 August 2018 – 25 May 2019.

Table 5. 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 2019 spring sampling period.

	Days Observed			Potential Days Present		
	$\bar{x}$ ± S.E.	Range	*n*	$\bar{x}$ ± S.E.	Range	*n*
All CSL						
	3.1 ± 0.6	1 - 13	26	7.5 ± 1.5	1 - 29	26
All CSL by removal status						
Removed	3.4 ± 0.8	1 - 13	19	7.9 ± 1.8	1 – 29	19
Not removed	2.1 ± 0.8	1 - 7	7	6.8 ± 2.6	1 – 19	7

Recurrence

We documented a total of 26 branded CSLs, 22 of which had been previously identified at BON using brand re-sight data and 4 were “new” to BON (Table 7). Of the new CSLs, 3 were branded at BON in 2019 and 1 was branded at Astoria, Oregon, but was sighted at BON for the first time this year. Of the 19 CSLs removed by the States, 17 were documented at BON in previous years, and 15 had been documented for ≥ 3 seasons (Table 7).

There were 50 SSLs on project this year based on the highest daily point count during the season. We documented 21 individuals, 20 of which can be confirmed to have been at the dam in previous seasons and three of them have been coming to BON seasonally for 12 years (Table 7).

Table 6. The number of years that California sea lions (CSL) and Steller sea lions (SSL) identified in 2019 were observed at Bonneville Dam. Of the identified CSLs in 2019, the number of CSLs removed and listed for removal is shown. Individuals observed for one year were defined as newly identified animals in 2019.

Number of Years Observed	All Identified SSL	All Identified CSL	Listed for Removal CSL	Removed CSL
12	3	0	0	0
11	0	0	0	0
10	0	0	0	0
9	0	0	0	0
8	1	0	0	0
7	1	0	0	0
6	1	0	0	0
5	1	2	2	2
4	0	13	13	11
3	10	2	2	2
2	3	5	4	2
1	1	4	3	2
Totals	21	26	24	19

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 2019, we observed one CSL upstream of BON near the mouth of the Wind River on 11 June. This individual appeared to have used the navigation lock and was lethally removed by ODFW personnel.

PREDATION

We recorded 836 independent one hour (i.e. paired 30 minute intervals) observation periods during the 21 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.

Chronology of Fish Passage

The adult salmonids passing BON during April and May of 2019 experienced river outflow and temperatures that were similar to the 10 year average (Figure 3). The majority of the adult salmonids passing BON during the spring months are Chinook Salmon (also termed Spring Chinook). Spring Chinook Salmon passage at BON was below the 10 year average and the run reached BON later in the spring compared to the 10 year average. This late run could be attributed to the below average river temperatures that were seen in March (Figure 3).

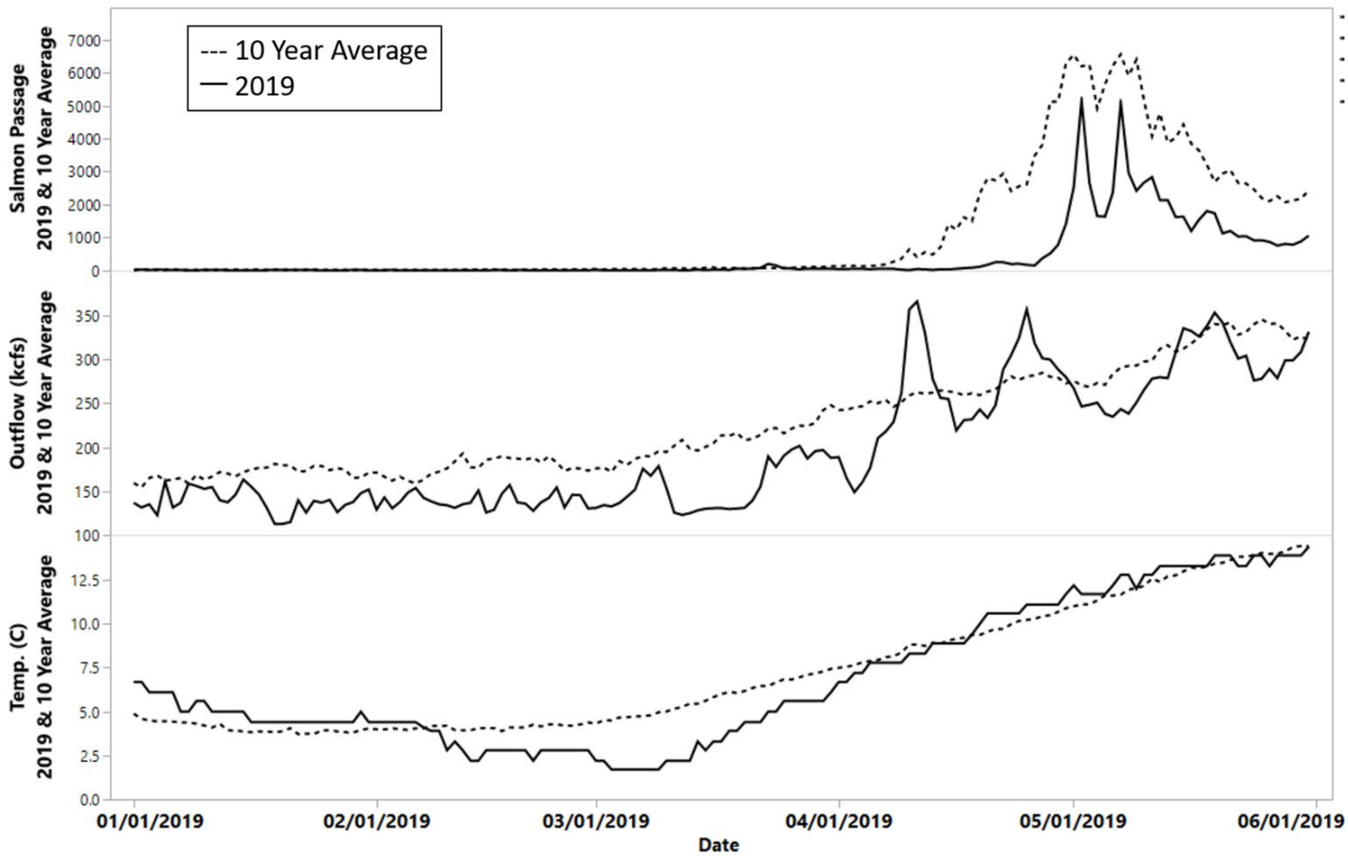

Figure 3. Chronology of salmonid passage, temperature, and outflow (spill + turbine flow) at Bonneville Dam during the spring sampling period. Solid lines indicate the 2019 season and dashed lines denote the 10-year average for each variable. Data obtain from www.cbr.washington.edu/dart.

Predation on Adult Salmonids

An estimated 2,201 (1,939 – 2,446) adult salmonids were consumed by both pinniped species in the spring sampling period of 2019, which equates to 3.3% of the salmonids that passed during the spring. Of these, SSLs consumed 2,022 (1,772 – 2,262) which equates to 3.1% of the run, whereas CSLs consumed 176 (108 – 242) which was 0.3% of all adult salmonids (Table 8, Figure 4). No depredation by harbor seals was documented.

Table 7. 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 2019.

		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%
2019	63,591	176	0.3%	2,022	3.1%	2,201	3.3%

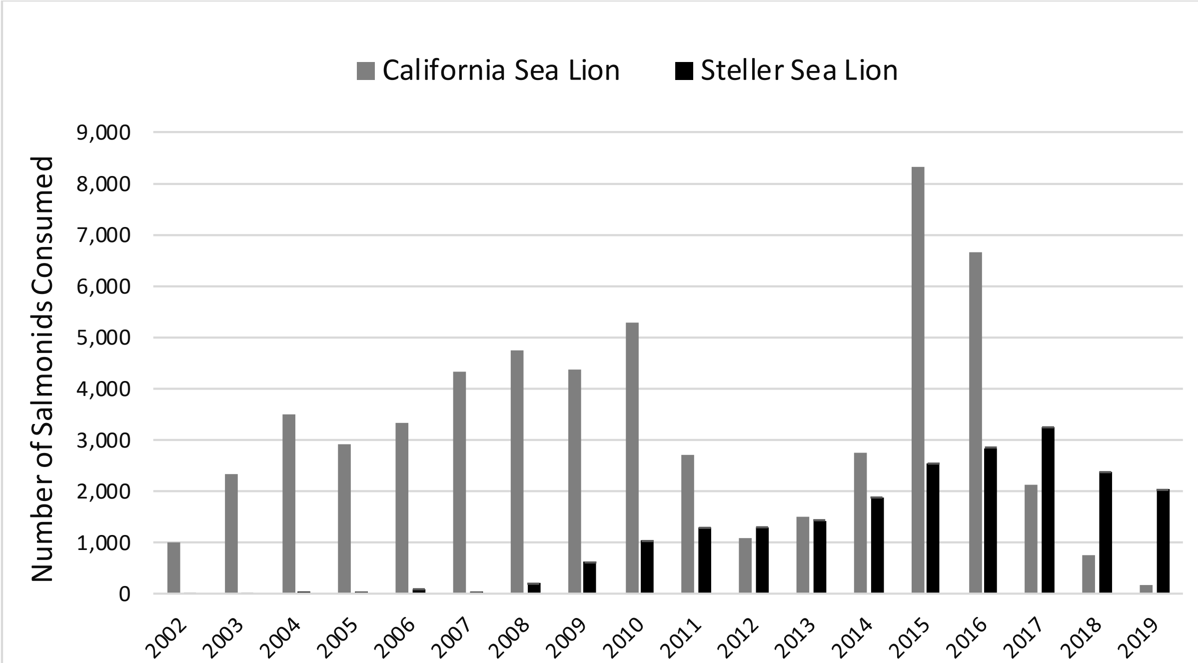

Figure 4. Adjusted estimates of salmonid consumption by California and Steller sea lions at Bonneville Dam during the spring sampling period from 2002 to 2019.

Predation on Chinook Salmon

An estimated 1,974 (1,756 – 2,199) spring Chinook Salmon were consumed, which equates to 3.1% of the run. Of these, SSLs consumed 1,820 (1,581 – 2,050) which equates to 2.9% of the run, and CSLs consumed 175 (103 – 234) which was 0.3% of the spring Chinook Salmon run (Table 9).

Table 8. Consumption of spring Chinook Salmon by pinnipeds at Bonneville Dam tailrace during the spring sampling seasons from 2002 to 2019. 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	4,501	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%

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 Plan run criteria of 1 January – 31 May. Data will differ relative to previously published data.

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 2018 – 31 March 2019). As such, we now provide estimates of the impacts to this stock. An estimated 1,535 steelhead crossed BON during this time and 201 (116 – 286) were consumed by sea lions Figure 5. Thus, 13.1% of the run was consumed. Note that consumption estimates recorded during the fall and winter were only at the PH1 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 = 2), and no observations of CSL–winter steelhead predation events occurring, we attribute all of the predation to SSLs.

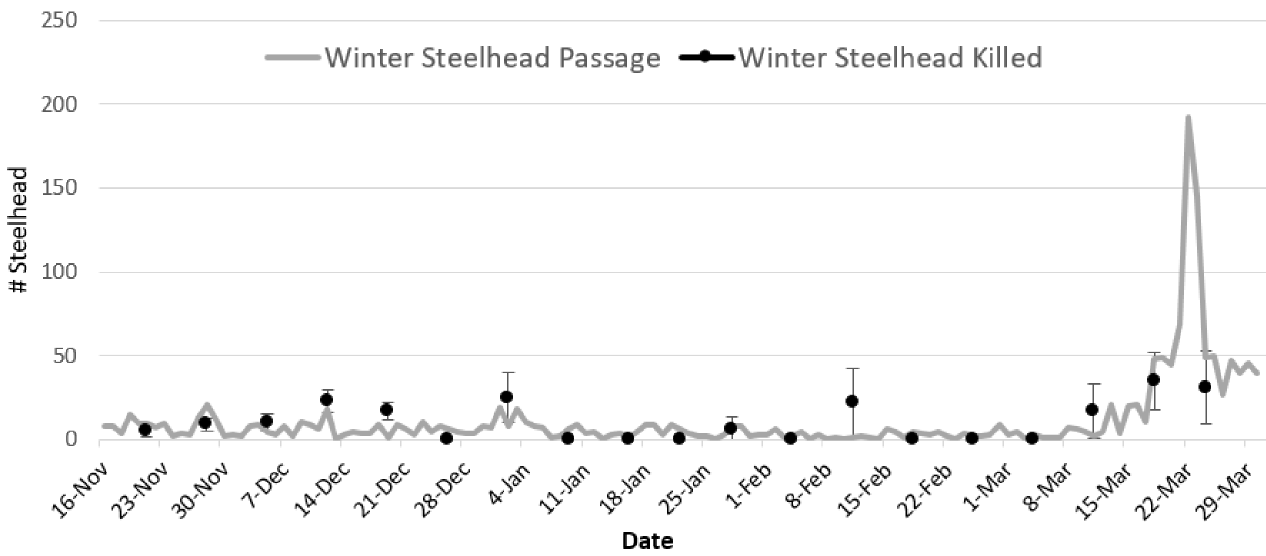

Figure 5. Adjusted estimates of winter steelhead consumption by Steller sea lions at Bonneville Dam between 16 November 2018 and 31 March 2019.

Predation on Winter and Summer Steelhead Combined

An estimated 208 (109 – 289) summer and winter steelhead were consumed during the spring, which equates to 8.7% of the combined run (Table 10). All steelhead were observed to be consumed by SSLs.

Table 9. Consumption of summer and winter steelhead by pinnipeds at Bonneville Dam tailrace during the spring sampling period from 2007 to 2019.

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%
2019	2,172	208	8.7%

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

Predation on White Sturgeon

Annual consumption of White Sturgeon increased until 2012 after which the numbers of sturgeon consumed dropped considerably (Table 11). This season an estimated 187 (83 – 262) White Sturgeon were consumed. All observed sturgeon catches were attributed to SSLs. The size of consumed sturgeon ranged from 1 – 5 feet in length. The majority (68%) of the predation events occurred in the Spillway tailrace, and the balance in the tailraces of PH1 and PH2.

Table 10. Consumption of White Sturgeon by pinnipeds at Bonneville Dam tailrace during the spring sampling period from 2005 to 2019.

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

Predation on Pacific Lamprey

An estimated 14 (3 – 21) Pacific Lamprey were consumed by pinnipeds in 2019. Of these, SSLs were estimated to have consumed 8 (0 – 16), and CSLs consumed 6 (0 – 12) Pacific Lamprey (Table 12). A total of four predation events were observed on Pacific Lamprey, two by SSL and two by CSL. All observations occurred in May.

Table 11. Consumption of Pacific Lamprey by pinnipeds at Bonneville Dam tailrace during the spring sampling period from 2002 to 2019.

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%

Temporal Distribution of Salmonid Predation Events

An estimated 63,591 salmonids passed during the spring sampling period of 2019, a smaller run estimate compared to the 10-year average of 179,214 between 1 January and 31 May. Review of Figure 6 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 6). 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 presence at BON.

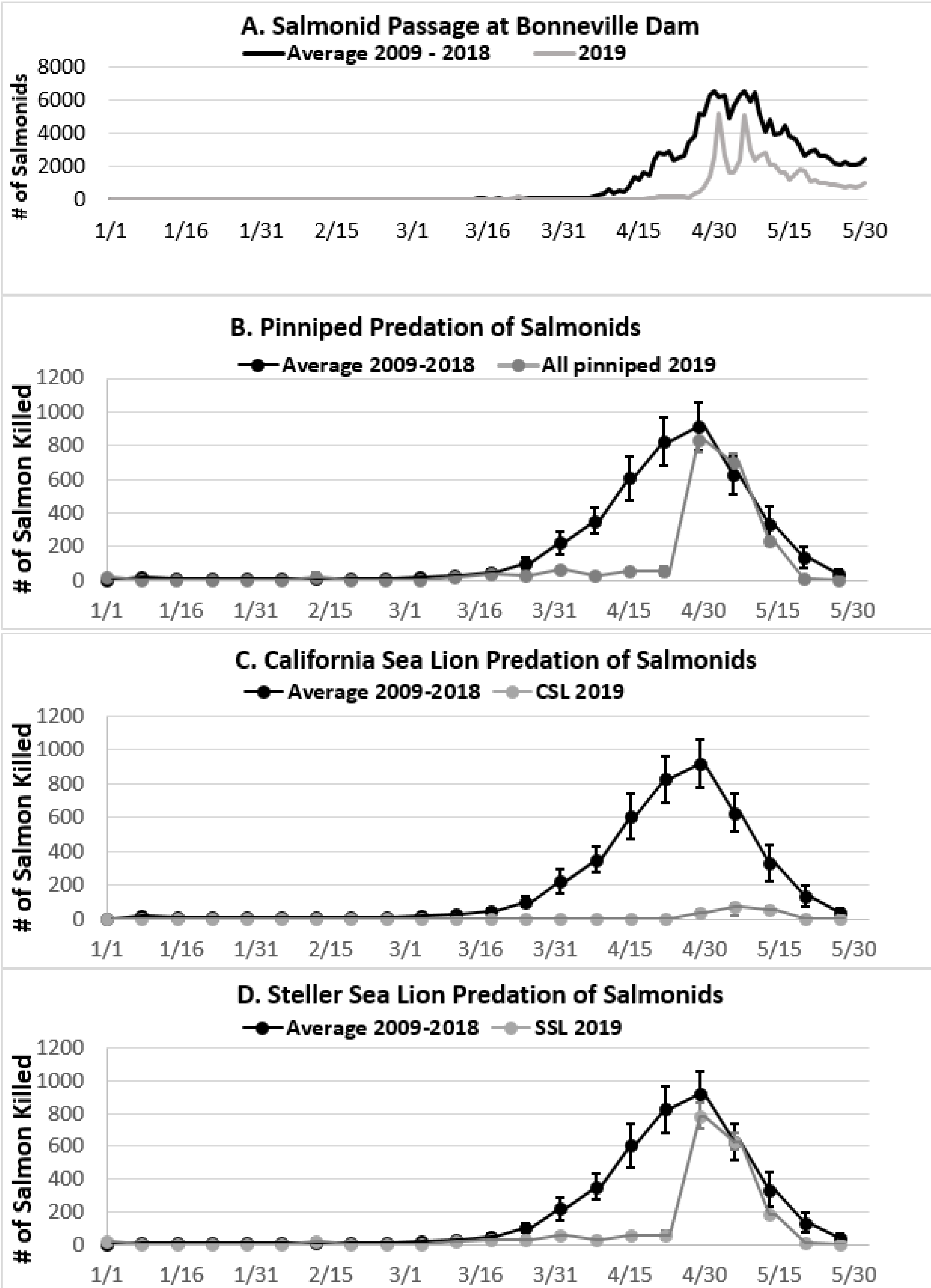
A. Salmonid Passage at Bonneville Dam
Average 2009 - 2018
2019
# of Salmonids
8000
6000
4000
2000
0
1/1
1/16
1/31
2/15
3/1
3/16
3/31
4/15
4/30
5/15
5/30
B. Pinniped Predation of Salmonids
Average 2009-2018
All pinniped 2019
# of Salmon Killed
1200
1000
800
600
400
200
0
C. California Sea Lion Predation of Salmonids
Average 2009-2018
CSL 2019
D. Steller Sea Lion Predation of Salmonids
Average 2009-2018
SSL 2019

Figure 6. 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 2009–2018" 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 339 hours at PH1, 172 hours at SPW, and 324 hours at PH2. During this time, there were 491 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 7 and Figure 8). The combined spatial distribution of observed salmonid predation events by pinnipeds was 27.7% (n = 136) at PH1, 25.3% (n = 124) at PH2, and 47.0% (n = 231) at SPW.

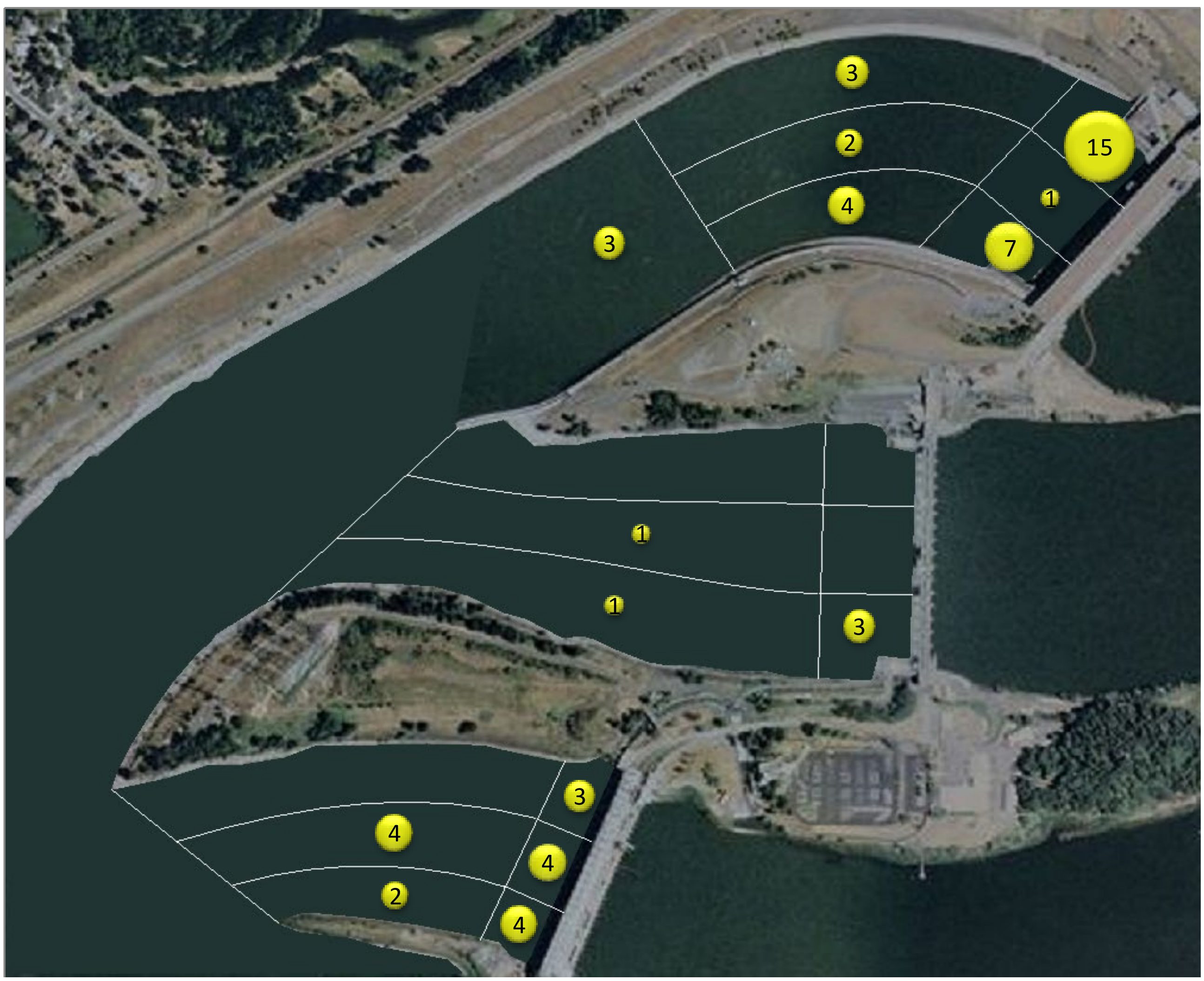

Figure 7. Spatial distribution of observed salmonid predation by California sea lions at Bonneville Dam during the 2019 spring sampling period.

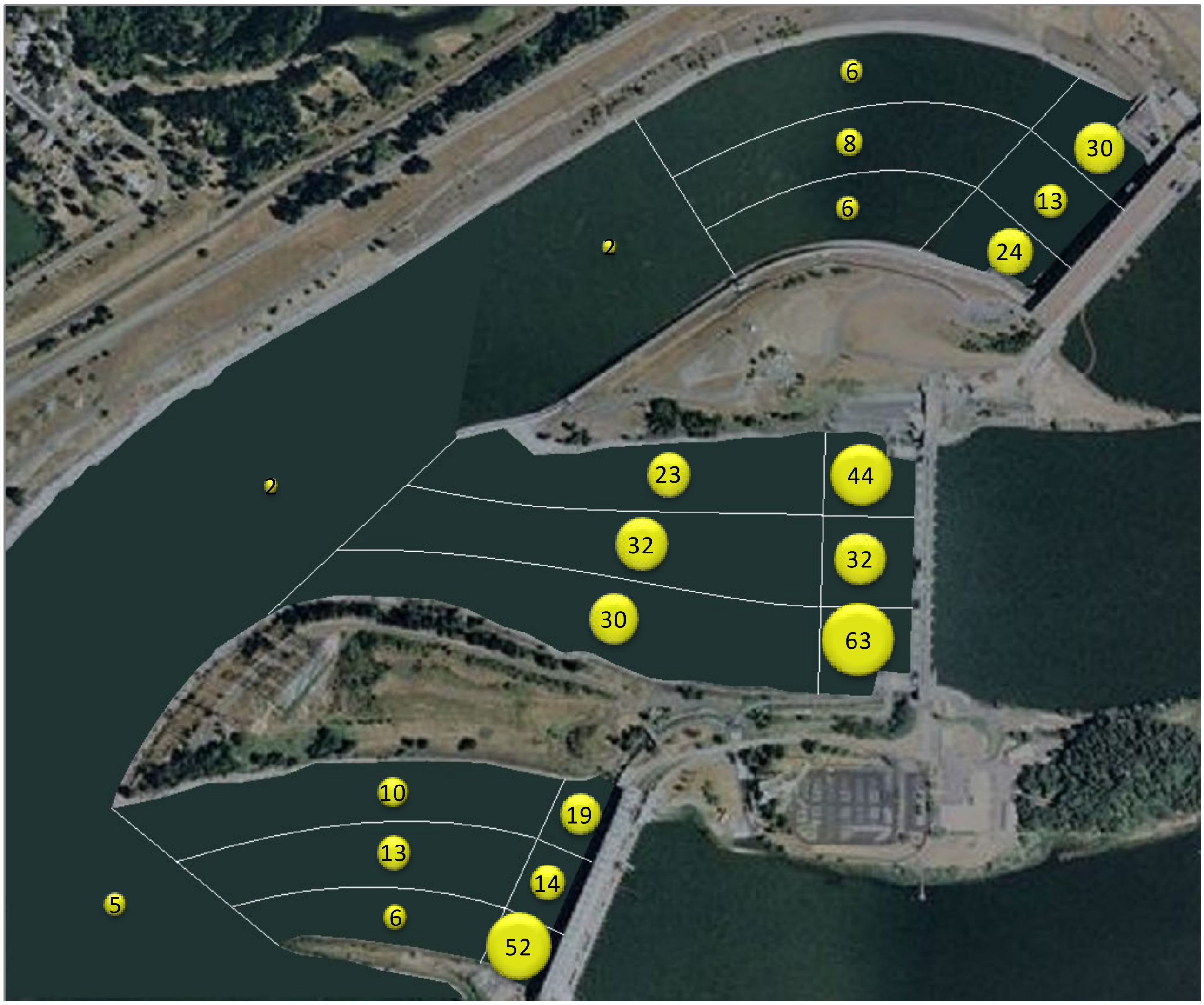

Figure 8. Spatial distribution of observed salmonid predation by Steller sea lions at Bonneville Dam Bonneville Dam during the 2019 spring sampling period.

Clepto-parasitism

A total of five clepto-parasitism events were recorded. All clepto-parasitism events were SSL stealing fish from CSL. 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 the week of February 24 and ended the week of May 5. A total of 30 days of hazing were conducted. During the season, CRITFC boat-based hazers deployed 1,435 cracker shells and 957 "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 1 March and continued on a daily basis through May 31. Working eight and ten hours per day, dam based hazers worked with explosive cracker shells and rubber buckshot to deter pinnipeds from tailrace areas.

Trapping and Removal

The states conducted trapping operations in the tailrace area from April 30 to May 22 during which time they permanently removed 19 CSLs under the states' MMPA Section 120 LOA. In addition, 3 CSLs were branded and released in the tailrace at BON (Steingass et al. 2019). 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, one SSL was branded with a unique, identifiable brand (Table 13). Traps were closed and moved to storage in late May. For additional information about these activities see Steingass et al. (2019).

Table 12. Summary of California sea lion (CSL) branding and removals (captivity, euthanasia, accidental mortality) and Steller sea lion (SSL) branding at Bonneville Dam, 2007 to 2019. 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
2019	92	3	19	1
Total	984	281	236	55

* 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 2019 was 11 fish which is the lowest on record for a fully sampled season (see Table 14 for details). This individual was observed for 4 days and recorded eating 11 salmonids (Table 14).

Table 13. Maximum number of salmonids observed consumed by an individual California sea lion (CSL) at Bonneville Dam during the spring sampling period from 2002 to 2019.

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†
2019	11†

* In 2005, the observation season began late therefore we didn't have an opportunity to train observers on individual CSL identification.
† In 2016, 2017, 2018, and 2019 all three tailraces were not observed simultaneously thus decreasing observation time for individual CSL.

DISCUSSION

The pinniped impact to the spring salmonid runs at BON were comparable to previous years, and our documentation this year supports the recent trend that SSL are now the primary salmonid predator in the system. 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. 2019) and, where possible, the 10-year average. To elucidate the full impact to winter steelhead we draw on the fall and winter sampling this season in conjunction with the traditional spring period to provide estimates of the entire run and the associated pinniped impact.

Abundance

The number of SSLs during the spring was 24.2% less than last year, and 26.5% lower 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 50 SSLs.

The number of CSLs during the spring continues to decline in both presence and abundance. We documented a 61.2% reduction in CSL abundance relative to last year, and a 70.0% reduction relative to the 10-year average. CSL numbers were below the 10-year average for the entire season. The 2019 spring season was marked by the lack of CSL. They did not arrive at BON until early April and only averaged two animals per day during April and May, a time that their numbers are customarily the greatest to take advantage of the spring Chinook Salmon run. The daily abundance of CSL was never in the double-digits and the maximum daily count was eight on 25 April.

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 22.5% from 4.0 days in 2018 to 3.1 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 decreased by 60.7% relative to last year and the number of individuals returning for three or more years has decreased by 52.5%. Thus, albeit fewer individuals were documented this year and 19 were removed, some returning individuals continue to be at BON and evade removal. The escapement of some individuals is likely linked to the delay between initial occurrence at BON, policy-mandated delays for LOA listing, and finally removal, but the trend over the last three years suggest that changes made to the LOA are working and that efficiencies are being realized as a result.

The recurrence of SSLs is difficult to monitor given the low numbers of branded SSLs. However, we infer a high level of recurrence due to high site fidelity for most animals that are branded. For example, three individual SSL have been observed at BON for 12 years and seven 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 a targeted removal program, 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, as expressed as percent of the run consumed, in 2019 on all species of adult salmonids during the spring was 0.3% greater than 2018 and was 0.2% more than the 10-year average (i.e. 3.1%). Of the adult salmonid run consumed this year, SSLs consumed 0.8% more of the run than the previous year, and 1.9% more than the 10-year average (i.e. 1.2%). This year CSLs consumed 0.4% less of the run than the previous year, and decreased salmonid run consumption by 1.5% relative to the 10-year average (i.e. 1.8%). 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, of the size of the fish runs, the spring Chinook Salmon was the smallest, and the combined summer and winter steelhead runs were the sixth smallest since pinniped monitoring data started being recorded for the two species 2007.

Spring Chinook Salmon– Predation on Spring Chinook Salmon during the spring was 0.2% more than the previous year and was 0.2% more than the 10 year average (i.e. 2.9%). Of the spring Chinook consumed this year, SSLs consumed 0.7% more than the previous year, and 1.7% more than the 10-year average (i.e. 1.2%). This year CSLs consumed 0.4% less than the previous year, which was 1.5% less than the 10-year average (i.e. 1.8%). More than 92% of the spring Chinook consumption was attributed to SSLs predation 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). This season, Chinook consumption was far below the 10-year average until the middle of May due to the late run of fish, but when the fish arrived to BON consumption jumped to a point that exceeded the 10-year average and remained near or above the average until the end of May. This is of note because it infers that the early arriving fish were consumed at a greater rate (i.e. fish per week) than previously documented. A result, perhaps, of the predominant predator being the larger and more capable SSL. The late run also equated to pinnipeds leaving the dam before the run ceased which allowed escapement of much of the latter part of the run.

Summer and Winter steelhead – Pinnipeds consumed an estimated 8.7% 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 lower and therefore a larger 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 6.1%, the combined consumption was 2.6% higher this year.

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 November 16 and March 31, and the summer run which cross after March 31 (Withler 1966, Busby et al. 1996). We found that more than 13% of the winter steelhead run was consumed by pinnipeds with the vast majority being consumed by SSLs. This is a greater impact than any other salmonid in the study and carries with it sever concern for the run. Last fall and winter we estimated that 6.8% of the run was consumed, but that was with nine weeks of observation. The estimate of 13% represents the first analysis conducted to survey the full impact to the run with every week of the winter being surveyed. However, the estimates between August and December represent the predation that occurred in only one tailrace, thus the realized predation is likely higher than 13%.

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.

White Sturgeon –White Sturgeon consumption increased from 148 in 2018 to 187 in 2019. SSL are the primary predator of sturgeon at BON and this year all observed catches were performed by SSL. The long term trend shows that between 2008 and 2012 over a thousand White Sturgeon were consumed each year 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 found that more than 350 White Sturgeon were consumed during the fall and winter sample period. Therein, almost twice as many White Sturgeon were killed during the fall and winter sampling period than 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 75.9% less than the previous year and 89.9% less than the 10-year average. During the spring sampling period we only observed four lamprey catches; two were by CSL and two by SSL. The crepuscular and nocturnal migration habits of Pacific Lamprey have previously been validated with the majority of the pinniped-lamprey predation events occurring during lowlight hours. This year however all four catches occurred between 0800 and 1400. This small sample likely lacks the power to make creditable inference about the observation.

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 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). 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.

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.

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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.

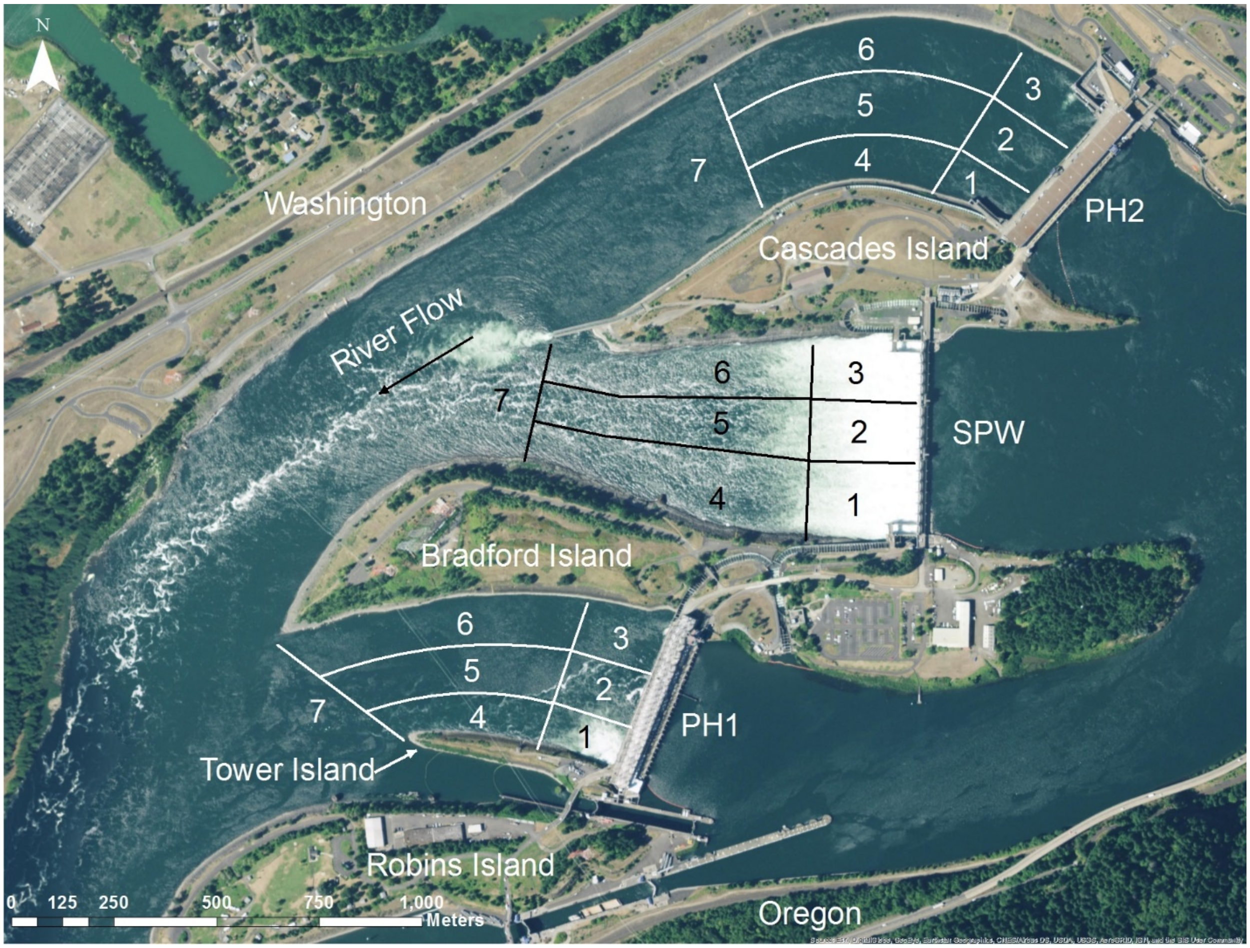

Figure A1. Bonneville Dam study area with Powerhouse One (PH1), Spillway (SPW), and Powerhouse Two (PH2) tailrace sub-areas separated into zones for assigning the location of predation events.

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 A1) 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 31 May 2019.

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 – 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 2018. During the spring sampling period there were 22 strata weeks between 1 January and 31 May 2019. 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 $\geq$ 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 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. We did not observe animals in the spillway prior to mandatory spill this year. 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 $\bar{x}$ is the sample mean The bootstrap 95% confidence intervals for μ is as: $[\bar{x} - \delta^{*}_{0.025}, \bar{x} - \delta^{*}_{0.975}]$.

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. $\bar{x} \pm$ 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 (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 18 years and the ten year average (2009-2018).

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
2019	5	11.25	9.72	0.92	1.15	0-50	8.5	13	151
10 year	9.62	11.15	13.36	0.88	0.83	0-47.8	12.6	6.7	150.3

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	0-67	16	176	159
2019	0	1.61	0.81	0.13	1.98	0-8	1	104	151
10 Year	3.2	8.19	6.92	1.11	1.3	0.1-37	12.5	54.9	150.3

SUPPLEMENTARY TABLE 2. Summary of clepto-parasitism events by California sea lions (CSL) and Steller sea lions (SSL) observed at Bonneville Dam, 2002 to 2019.

	CSL		SSL		
Year	*From* CSL	*From* SSL	*From* CSL	*From* SSL	Total
2002	0	0	0	0	0
2003	14	0	0	0	14
2004	366	22	0	0	388
2005	22	0	22	0	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
2019	0	0	5	0	5