REQUEST FOR MARINE MAMMAL PROTECTION ACT SECTION 120 AUTHORIZATION TO LETHALLY REMOVE CALIFORNIA AND STELLER SEA LIONS FROM A SECTION OF THE MAINSTEM COLUMBIA RIVER AND ITS TRIBUTARIES THAT CONTAIN SPAWNING HABITAT FOR ESA LISTED SALMON AND STEELHEAD

Submitted by the Oregon Department of Fish and Wildlife, the Washington Department of Fish and Wildlife, The Idaho Department of Fish and Game, the Nez Perce Tribe, the Confederated Tribes of the Umatilla Indian Reservation, the Confederated Tribes of the Warm Springs Reservation of Oregon, the Confederated Tribes and Bands of the Yakama Nation, and the 3.6.D Committee

June 13, 2019

Contents

I. APPLICATION

The Oregon Department of Fish and Wildlife (ODFW), the Washington Department of Fish and Wildlife (WDFW), and the Idaho Department of Fish and Game, on behalf of their respective states (hereafter called “the States”), and the Nez Perce Tribe (NPT), the Confederated Tribes of the Umatilla Indian Reservation (CTUIR), the Confederated Tribes of the Warm Springs Reservation of Oregon (CTWSR), the Confederated Tribes and Bands of the Yakama Nation (YN), and the 3.6.D Committee[1] submit this application under subsection 120(f) of the Marine Mammal Protection Act of 1972 (MMPA; 16 USC 1389 et seq.; section 120 of the MMPA) to the National Marine Fisheries Service (NMFS) for the intentional lethal removal of individually identifiable California sea lions (*Zalophus californianus*) and Steller sea lions (*Eumetopias jubatus*: Eastern stock) that are located in the mainstem of the Columbia River between river mile 112 and McNary Dam, or in any tributary to the Columbia River that includes spawning habitat of salmon or steelhead (*Onchorynchus* spp.) that are listed as threatened and endangered under the Endangered Species Act of 1973 (ESA; 16 U.S.C. §1531 et seq.), and which are having a significant negative impact on the following stocks:

- Upper Columbia River Spring Chinook (Endangered)
- Snake R. Spring/Summer Chinook (Threatened)
- Lower Columbia River Steelhead (Threatened)
- Mid-Columbia River Steelhead (Threatened)
- Snake River Steelhead (Threatened)
- Lower Columbia River Chinook (Threatened)
- Upper Willamette River Spring Chinook (Threatened)
- Upper Willamette River Winter Steelhead (Threatened)
- Upper Columbia River Steelhead (Threatened)
- Snake River Fall Chinook (Threatened)
- Columbia River Chum (Threatened)
- Lower Columbia River Coho (Threatened)
- Snake River Sockeye (Endangered)
- Southern Distinct Population Segment of Eulachon (Threatened)

Removal of these sea lions is also intended to protect species of lamprey or sturgeon that may not be listed as endangered or threatened but are listed as a species of concern.

[1] The Committee fulfills the requirements for an eligible entity per Section 120(f)(6)(A)(iii) of the MMPA. Pursuant to this section of the statute, the Committee members include ODFW, CTUIR, CTWSR, the Confederated Tribes of the Grand Ronde Community, and the Confederated Tribes of the Siletz Indians of Oregon.

(A) PROPOSED REMOVAL PROCEDURES

1. Identification of animals for removal

For the purposes of this application, a California or Steller sea lion present within the following areas is deemed to be individually identifiable and to be having a significant negative impact within the meaning of Section 120(b)(1) as defined by Section 120(f)(7) & (8) (MMPA; 16 U.S.C. 1389(f)(7) and (8)), and so could be removed by the States, CTUIR, CTWSR, YN, NPT, or the Columbia River Inter-Tribal Fish Commission, if so delegated per subsection 120(f)(6)(B), within the specified area:

- The mainstem of the Columbia River upstream of river mile 112 (I-205 bridge) and below McNary Dam; or
- Any tributary to the Columbia River within Washington that includes spawning habitat of threatened or endangered salmon or steelhead
- Any tributary to the Columbia River in Oregon that is above Bonneville Dam but below McNary Dam and includes spawning habitat of threatened or endangered salmon or steelhead.

For the purposes of this application, a California (CSL) or Steller (SSL) sea lion present within the following area is deemed to be individually identifiable and to be having a significant negative impact within the meaning of Section 120(b)(1) as defined by Section 120(f)(7) & (8) (MMPA; 16 U.S.C. 1389(f)(7) and (8)), and so could be removed by the 3.6.D Committee within the specified area:

- Any tributary to the Columbia River that is within Oregon and below Bonneville Dam and that includes spawning habitat of threatened or endangered salmon or steelhead

2. Non-lethal deterrence

We request that removals are not contingent on non-lethal hazing activities as they have repeatedly been shown to be ineffective at preventing habituation and recruitment of additional CSL and SSL at these and other similar locations (see Section III(C) of this application for details). We propose to instead invest all available resources in rapid removal of CSL and SSL currently at these locations with the intent of both removing fewer sea lions over time (by reducing the social component to recruitment) and more quickly reducing predation levels on fish.

3. Proposed communication, capture, handling, euthanization, and disposal procedures

We propose the following procedures and conditions to implement removal of CSL and SSL. The capture, transport, holding, and euthanasia protocols will be subject to the review and approval of an Institutional Animal Care and Use Committee (IACUC). The removal program will be implemented such that areas of highest sea lion occupancy are prioritized for removal of CSL and SSL (as described in the Capture narrative below and in section III(B)(2) of this application). However, this prioritization is not intended to prevent eligible entities from removing animals in mid and lower priority areas before the problem is fully addressed in higher priority areas. This approach is intended to address the areas of highest conservation concern first, while reducing the largest source populations of animals that can disperse to other locations, but retain the flexibility to proactively remove CSL or SSL that appear to be habituating to a location outside these high priority areas.

Communication: The applicants will designate a single point of contact representing all entities on a rotational basis. The point of contact will be responsible for reporting to NMFS per the terms and conditions of the permit.

Capture: The primary capture sites will be within the vicinity of Willamette Falls and Bonneville Dam (defined as category 1 sites in section III(B)(2) of this application-and see Figure 1). At these sites, we will use 2-8 traps per site (see Appendix 1 for description of the trapping procedure). The traps in the vicinity of Willamette Falls will be maintained year-round and animals may be captured and removed at any time. The traps at Bonneville Dam will be maintained during a spring and fall period of up to three months each, though this period may be modified/extended based on animal behavior and available resources.

Secondarily, SSL and CSL may be captured in the Category 2 areas (listed in section III(B)(2) of this application-and see Figure 1). The timing of capture at these locations will be dependent on animal behavior and staffing availability, but may occur at any time of year when animals are present. Animals at these sites will be captured using 1-2 traps, if conditions are favorable, or by live capture of free ranging animals using established wildlife darting techniques (see Appendix 1 for description).

Third, SSL and CSL may be captured at Category 3 sites (listed in section III(B)(2) of this application-and see Figure 1) should their behavior change such that trapping at the above sites is no longer successful OR should animals begin to habituate at these locations. We would use the most efficient method of those described above to capture animals at these sites.

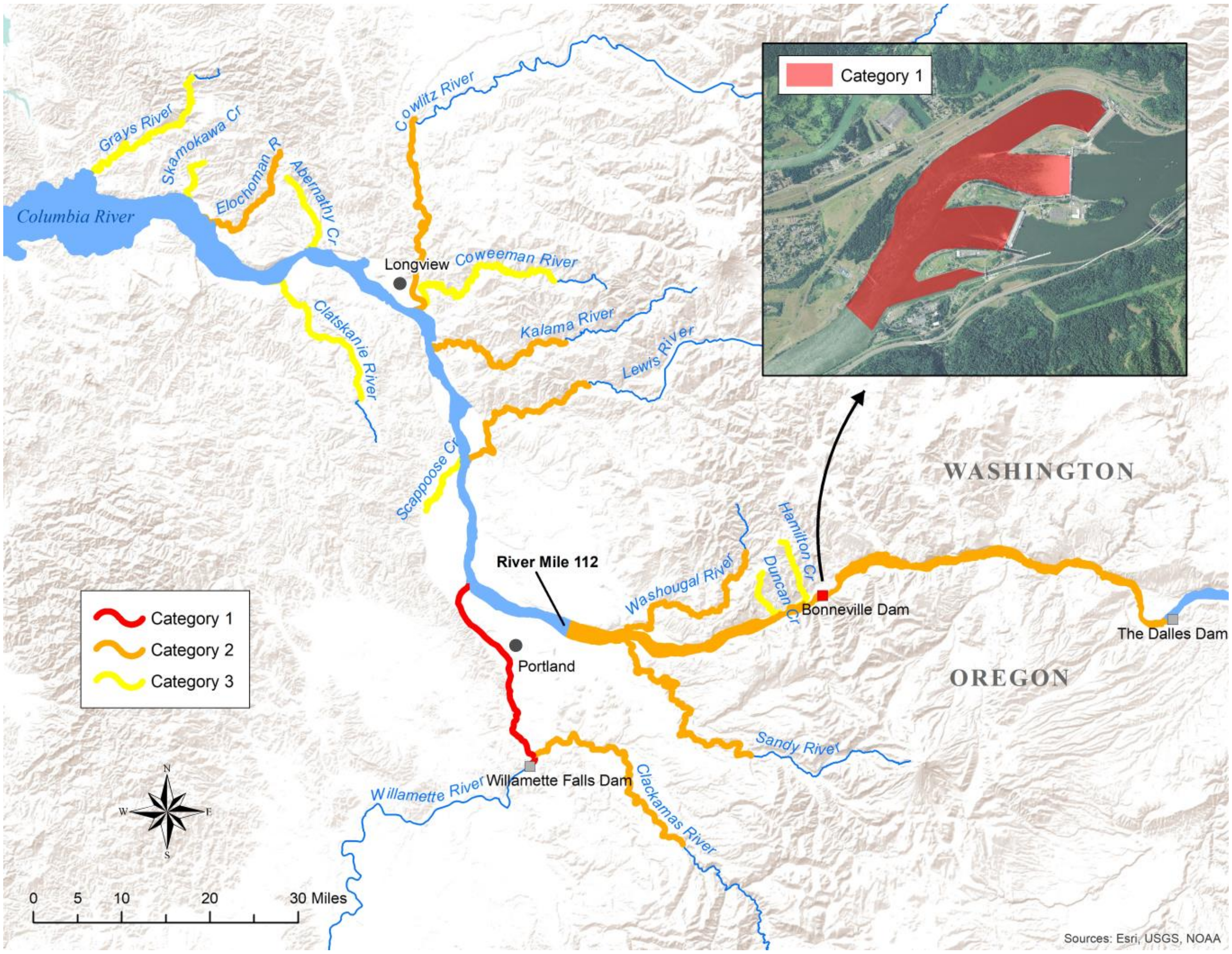


Figure 1. Map of locations where sea lions may be removed under this authorization. Category 1 includes areas that currently have high numbers of CSL and/or SSL (e.g., >20) that are often present for the majority of the year. This high occupancy constitutes an immediate and ongoing conservation risk for fish stocks. Category 2 includes areas that currently have low to moderate numbers of CSL and/or SSL (e.g., <10) that are present only periodically. This level of occupancy constitutes a conservation concern for fish stocks if left unmanaged. Category 3 includes areas where CSL or SSL have not been officially documented but contain spawning habitat for ESA listed salmonids, or have documented presence that managers are monitoring but do not deem a conservation risk at present. Only the first 20 miles of the tributary is mapped as all observations to date have been in the lower river. However, sea lions may be removed above this point if present.

Handling and euthanization: A detailed description of the proposed procedures is given in Appendix 1. When possible, we will facilitate the transfer of eligible sea lions to pre-approved holding facilities for permanent placement at accredited zoos or aquaria. When placement is not an option:

- Euthanasia will be performed by a qualified veterinarian
- Firearms will **not** be used to euthanize live, free ranging animals.
- The primary means of euthanasia shall be chemical per MMPA; 16 U.S.C. 1389(f)(4)(B).
- Secondary methods of euthanasia will include chemical methods or a captive bolt gun subject to review and approval of an IACUC.

Disposal: Following euthanasia, we will collect tissue samples for research purposes. If requested by a tribe that is party to this application and approved by NOAA, the carcass will be provided to the tribe for cultural use. If a carcass is not requested for cultural use, they will be disposed of following all applicable rules and regulations.

4. Number of animals to be removed.

We estimate there may currently be at least 144-286 CSL and 105-130 SSL within the geographical scope of the application.

Summary

With this application, the eligible entities are requesting that approval for intentional lethal taking of CSL and SSL, by qualified individuals as described in subsection 120(f)(4) of the MMPA, be granted to the appropriate entities within the areas described above for a period of 5-years per the stipulations in subsection 120(f)(2)(d).

The expected benefit of the requested authority, above and beyond existing authorities, will be to:

1) Allow the eligible entities to reduce predation on ESA listed salmon/steelhead and sturgeon by Steller sea lions, which are not currently authorized for lethal removal under existing permits
2) Improve the efficiency of the currently authorized removal programs at Willamette Falls and Bonneville Dam by eliminating the need to mark and repeatedly handle animals and document their repeated presence in the area.
3) Prevent sea lions from self- or socially-habituating to tributary locations that are outside of the current geographic scope for authorizations at Bonneville Dam and Willamette Falls, but where sea lions have either been observed feeding on salmonids and/or lamprey and/or sturgeon or may forage in such areas in future.

II. BACKGROUND

Prior to European colonization tribal people lived in harmony with the natural world living a subsistence lifestyle. Nature provided sustenance in the form of many plants and animals. Seals and sea lions were among the animals that were hunted and provided food, clothing and tools to residents of the Columbia Basin. Use of marine mammals continues to this day by Alaska natives but, at some point in the nineteenth century, Columbia River tribes ceased to utilize this resource, possibly coinciding with development of the reservation system, restrictions on off-reservation travel, and overharvest by the non-tribal population (Walker, 2015).

In the late 1800's, associated with European settlement of the West Coast US, large numbers of sea lions were killed in commercial hunts because of the value of their oil and hides (Bonnot, 1928). As a result of declining profitability, this practice was largely eliminated by the 1870's. However, because of perceived conflicts with fish harvest, culling programs (often using a bounty to incentivize hunters) were established in the early 1900's to reduce seal and sea lion numbers and on the early 1900's and continued periodically up to the late 1960's. Together, these practices had a significant negative impact on the abundance of seals and sea lions along the Pacific Coast of the U.S.

In 1972, the U.S. Congress enacted the Marine Mammal Protection Act (MMPA). The Act provides protection for all marine mammals in U.S. waters, regardless of the conservation status of the population. As a result of these protections, the U.S. stock of CSL has increased from fewer than 75,000 individuals in the early 1970's to as many as 296,750 (Carretta *et al.*, 2017). The U.S. stock is now within its Optimum Sustainable Population (OSP)[2] range and is likely at its carrying capacity, thus exceeding the conservation objectives of the MMPA (Laake *et al.*, 2018). The Eastern stock of SSL has also been increasing in abundance at an overall annual rate of 4.76% and the total count estimate for Steller sea lions was 71,571 in 2015 (Muto *et al.*, 2017). This estimate was not corrected for animals that were at sea during the survey period and is thus considered a minimum population estimate. Because the counts of eastern Steller sea lions have steadily increased over a 30+ year period, Muto *et al.* (2017) conclude that the stock is likely within its Optimum Sustainable Population (OSP); however, no determination of its status relative to OSP has been made.

Over this same period, many salmon and steelhead populations in the Pacific Northwest have experienced significant declines in abundance and have consequently been listed as threatened or endangered under the ESA. In the Columbia River Basin, thirteen stocks are currently listed as threatened or endangered. These declines were initially and primarily a result of multiple factors unrelated to predation by pinnipeds. However, a growing body of evidence suggests that the rise in abundance of seal and sea lion populations on the US west coast is now having a significant negative impact on the survival of many salmon and steelhead populations, both in the ocean and freshwater (Chasco *et al.*, 2017; Falcy, 2017, 2018; Hanson *et al.*, 2017; Nelson *et al.*, 2018). This is important because in areas where salmonid abundance is low, even a modest unmanaged increase in mortality can result in a serious negative impact to the recovery of threatened and endangered individual

[2] Optimum Sustainable Population (OSP): defined by the MMPA section 3(9), with respect to any population stock, the number of animals which will result in the maximum productivity of the population or the species, keeping in mind the carrying capacity of the habitat and the health of the ecosystem of which they form a constituent element. (16 U.S.C. 1362(3)(9)). Optimum Sustainable Population is further defined by Federal regulations (50 CFR 216.3) as is a population size which falls within a range from the population level of a given species or stock which is the largest supportable within the ecosystem to the population level that results in maximum net productivity. Maximum net productivity is the greatest net annual increment in population numbers or biomass resulting from additions to the population due to reproduction and/or growth less losses due to natural mortality.

salmonid populations.

To address this increase in pinniped predation within the Columbia River basin, the States have previously submitted four separate applications for lethal removal authority through Section 120(b)(1)(A) of the MMPA. Three of these applications have been to address the increase in pinniped predation at Bonneville Dam on the mainstem Columbia River. The States originally applied for a permit from the National Marine Fisheries Service (NMFS) in December 2006 under Section 120(b)(1)(A) of the MMPA to lethally remove CSL at Bonneville Dam that were having a significant negative impact on the recovery of Pacific salmon and steelhead listed as threatened and endangered under the ESA[3]. NMFS partially approved that request in 2008 and issued letters of authorization to lethally remove individually identifiable predatory California sea lions at Bonneville Dam.

The Humane Society of the United States subsequently filed a lawsuit claiming that NMFS' decision violated the MMPA and National Environmental Policy Act. NMFS prevailed in district court, but the Ninth Circuit vacated and remanded the decision. In response the States reapplied for MMPA Section 120 authority in August 2011 and were again approved by NMFS, which issued a Letter of Authorization (LOA) in March 2012. In September 2013, the U.S. Court of Appeals for the Ninth Circuit affirmed and upheld NMFS' action to grant the States the 2012 LOA, which was reauthorized for a 5-year extension in 2016. A complete chronology of these events can also be found at the NMFS' West Coast Region website[4].

Most recently, ODFW applied for lethal removal authority to address predation at Willamette Falls, OR. Predation by CSL at this location is contributing to significant declines in the populations of threatened salmon and steelhead, and will likely result in extinction of winter Steelhead if left unmanaged (Falcy 2017). ODFW applied for and received a 5-year permit to lethally remove CSL at Willamette Falls in November 2018 through Section 120(b)(1)(A) authority.

The impact of CSL at Bonneville Dam and Willamette Falls has been well documented in previous applications. However, the applicants have also observed CSL colonizing other tributary systems that contain salmon and steelhead. Currently, the number of CSL entering these smaller river systems is low (1-10) however there is concern that the occupancy of CSL in these rivers will likely follow a similar pattern of social behavioral transmission, as previously observed at Ballard Locks (WA), Bonneville Dam, and Willamette Falls. Existing authorizations do not allow the applicants to prevent habituation of sea lions at these new locations.

Although CSL have been the primary focus of management efforts to date, the abundance of Steller sea lions (SSL) has also been increasing in the basin, particularly in the past 2-4 years, and this species is also having a negative impact on salmon, steelhead, and sturgeon populations. Existing authorizations do not allow the applicants to effectively manage predation by SSL. At Bonneville Dam, predation on salmonids by SSL now exceeds that of CSL (Tidwell *et al.*, 2019). In the lower Willamette River, SSL abundance now exceeds that of CSL at some times of the year. SSL were not previously considered for lethal removal action because: 1) up until 2015 they retained a protected status under the MMPA that prohibited lethal take under Section 120 and 2) up until 2015 they were primarily preying on white sturgeon which was also not sufficient justification for lethal removal under section 120 at the time. However, changes in SSL stock status, recent trends in SSL abundance and predation, the ineffectiveness of non-lethal control measures, and changes in the MMPA justify

---

[3] https://www.westcoast.fisheries.noaa.gov/publications/protected_species/marine_mammals/pinnipeds/sea_lion_removals/sec120-appl-2006.pdf (accessed 4/8/19)

[4] https://www.westcoast.fisheries.noaa.gov/protected_species/marine_mammals/removal_chronology.html (accessed 1/29/2019)

the need and provide the regulatory pathway needed to intervene with lethal removal measures.

Prior to 2019, the stipulations of Section 120 of the MMPA limited fish and wildlife managers' ability to effectively manage pinniped-fish interactions. Our experience at Ballard Locks, Bonneville Dam, and Willamette Falls have shown that multi-year delays in permitting lethal removal only allow more animals to habituate to an area during the timeframe and result in the status of fish populations worsening before action can be approved. Once approved, the requirement to verify a link between individual sea lions and fish predation lengthens the removal process and has resulted in more animals recruiting to a site and correspondingly higher predation rates on fish. This same pattern is being observed in other areas as an increasing number of CSL, and now SSL, have migrated upriver and into tributaries. For example, sea lions are now regularly documented in the Sandy and Clackamas rivers in Oregon and the Cowlitz, Kalama, Elochamon, Washougal, and Lewis rivers in Washington. Although there is no official monitoring of sea lion predation in these rivers, there have been multiple reports from state and tribal biologists, sport fishers, guides, and others of predation events on salmon and steelhead in these systems.

To more effectively manage pinniped fish interactions, the applicants propose to manage proactively by not allowing CSL and SSL to habituate within the geographical scope of this application. This approach is consistent with the intent of recent amendments to the MMPA, specifically subsection 120(f). It is anticipated that this will result in more efficient management by reducing the number of sea lions removed over time, and increasing annual spawner escapement (Buhnerkempe *et al.*, 2016).

III. APPLICATION CONSIDERATIONS

The Marine Mammal Protection Act requires that any application for lethal removal authorization include information to justify the proposed action such that the Pinniped Fish Interaction Taskforce and NMFS can make informed recommendations or decisions, respectively. The following is a summary of the relevant information referenced in Section 120 of the MMPA (footnotes indicate the relevant subsections of Section 120 of the MMPA)

- *Pinniped population trends*[5]: This information is used to determine whether the relevant stock of pinnipeds is sufficiently healthy that the proposed action will not have a significant impact on its viability.
- *Description of the problem interaction*[6]: This information is intended to describe the nature of the interaction between pinnipeds and fish within the geographical scope of the application. It includes a description of the spatial and temporal trends in abundance of CSL and SSL within the Columbia River basin. Additionally, we categorize the locations where pinnipeds are currently abundant, locations where they are less abundant but have been documented, and areas where they are absent currently, but could colonize in future.
- *A description of past efforts to nonlethally deter such pinnipeds*[7]: This information is intended to assist NMFS and the Taskforce in making a determination whether the applicant has demonstrated that no feasible and prudent alternatives exist and that the applicant has taken all reasonable nonlethal steps without success.
- *A description of the extent to which such pinnipeds are causing undue injury or impact to, or imbalance with, other species in the ecosystem, including fish populations*[8]: The intent of this information for applications under subsection 120(b) was to establish whether pinnipeds were having a significant negative impact (120(b)(1)) that would justify the proposed action. However, subsection 120(f)(8) establishes that pinnipeds within the area referenced in this application are having a significant negative impact. Our application outlines the information that supported this designation by describing the impact that has been observed at specific locations and that therefore might be expected at other locations within the area defined in subsection 120(f)(7) and (8) in the absence of the action.
- *The extent to which such pinnipeds are exhibiting behavior that presents an ongoing threat to public safety*[9].
- *A detailed description of the expected benefits of the taking of sea lions*[10].

---

[5] Intended to address elements of the problem interaction description that are referenced by subsection 120(d)(1)
[6] Descriptions of the problem interaction, or elements of the problem interaction, are referenced in subsections 120(b)(2), 120(d)(1), and 120(d)(3) but modified by subsections 120(f)(7) & (8).
[7] Intended to address information referenced by subsection 120(d)(2)
[8] Intended to address elements of the problem interaction description that are referenced by subsection 120(d)(3) but modified by subsection 120(f)(8)
[9] Intended to address information referenced by Section 120(d)(4)
[10] Intended to address information referenced by Section 120(b)(2)

The following information is intended to address the information needs summarized above and referenced in subsections 120(b)(2) and 120(d), but modified by subsections 120(f)(7) & (8) of the MMPA.

(A) PINNIPED POPULATION TRENDS

The most recent NOAA Stock Assessment Reports for the US stock of CSL (Carretta *et al.*, 2017) and the Eastern stock of SSL (Muto *et al.*, 2017) provide a detailed analysis of the stock status. The following is a brief summary of the relevant status metrics from the report:

1. U.S. stock of California sea lions:

Currently, this stock is not listed as "threatened" or "endangered" under the ESA, nor as "depleted" or "strategic" under the MMPA. The population has been growing at 5.4% per year. The most recently published population estimate was 296,750 animals and the Potential Biological Removal (PBR) level was 9,200 animals per year (Carretta *et al.*, 2017). The stock is now within its OSP range and is likely at its carrying capacity (Figure 1; Laake *et al*. 2018).

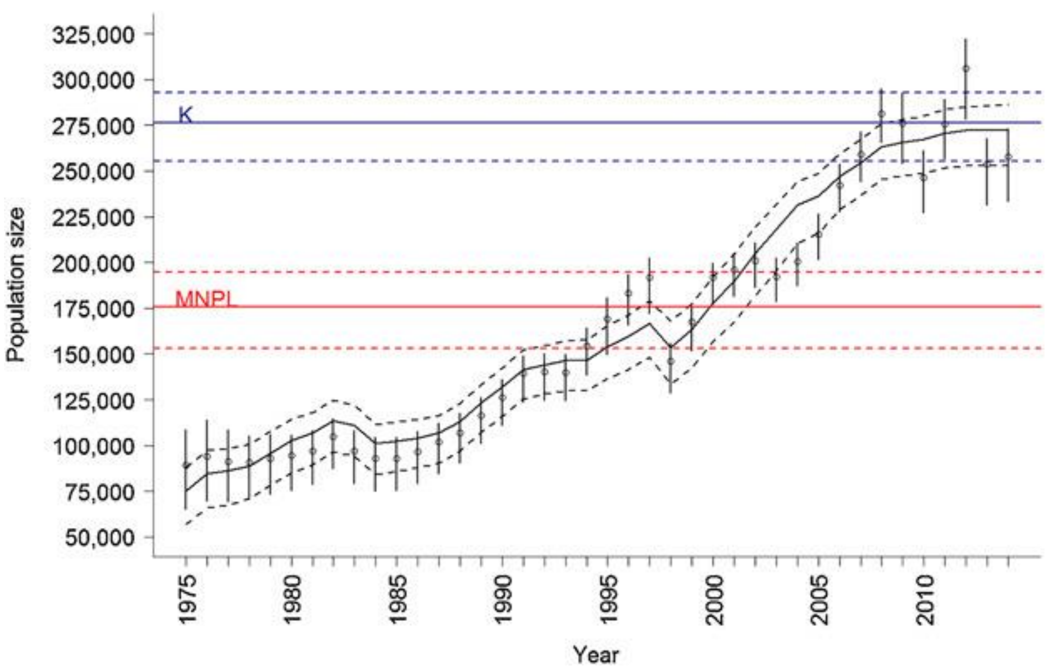


Figure 1. Reproduced from Laake et al. (2018). Fitted logistic growth curve (solid line) and 95% bootstrap intervals (dashed line) for reconstructed California sea lion annual population sizes in the United States, 1975–2014. Vertical lines are 95% bootstrap confidence intervals for reconstructed annual population sizes. We also present estimated carrying capacity (K; solid blue line) with 95% confidence intervals (dashed blue line) and maximum net productivity level (MNPL; red solid line) with 95% confidence intervals (dashed red line).

2. The eastern stock of Steller sea lions:

Currently, this stock is not listed as "threatened" or "endangered" under the ESA, nor as "depleted" or "strategic" under the MMPA. For the period 1989-2015 the pup population increased at a rate of 4.76% (95%CI: 4.09-5.45) annually and the non-pup population increased at a rate of 2.84% (95% CI: 2.36-3.33) annually. The total Eastern stock population estimate was 52,139 non-pups and 19,423 pups (Figure 2). The current PBR estimate for the eastern stock of Steller sea lions is 2,498 animals annually. Because the counts of eastern Steller sea lions have steadily increased over a 30+ year period, Muto *et al*. (2017) conclude that the stock is likely within its Optimum Sustainable Population (OSP); however, no determination of its status relative to OSP has been made.

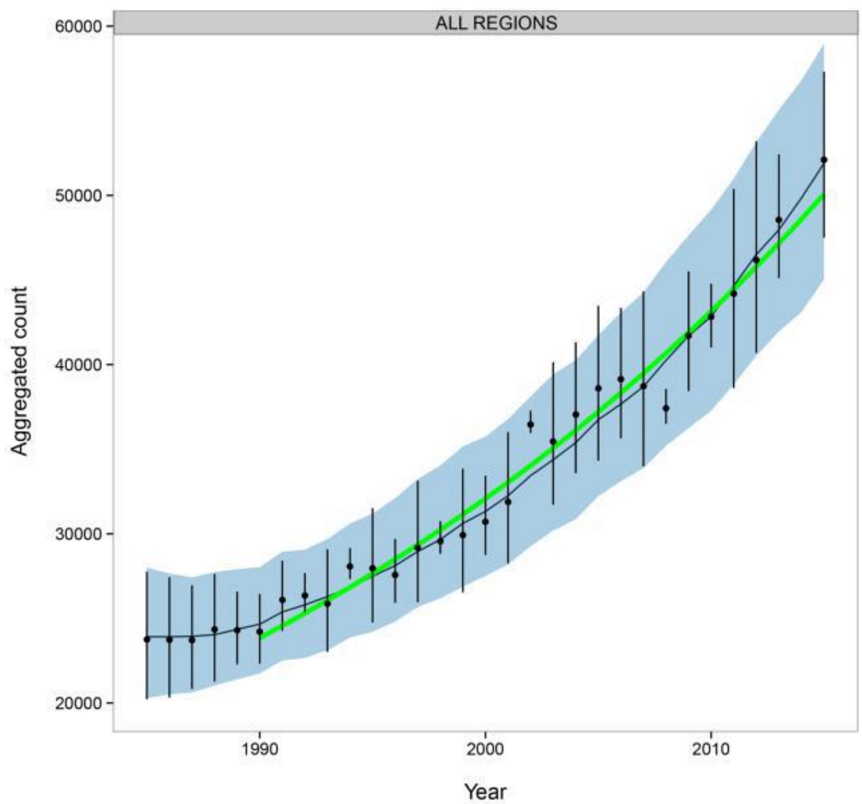


Figure 2. Reproduced from Muto et al. 2017. Estimated counts (modeled with agTrend) of eastern Steller sea lion non-pups (adults and juveniles) for the period from 1989 to 2015, with estimated trend (green line) from 1990 to 2015 for all regions.

(B) THE PROBLEM INTERACTION

1. Spatial and temporal trends in the abundance of CSL and SSL in the Columbia River Basin.

California sea lions: In the mid-1970s, observations of CSL in the Pacific Northwest began to increase, but animals were still relatively uncommon in the lower Columbia River (i.e., the basin below Bonneville Dam) until the mid- to late-1980s (Beach *et al.*, 1985). In the early 1990s, several hundred CSL were regularly observed in the Astoria area, hauling out on jetties, floats, and navigation markers (WDFW, ODFW; unpublished data). During this period, the majority of CSL tended to be distributed lower in the river, below Wallace Island (river mile 48), often targeting salmon caught in nets during commercial gillnet fishing seasons. Beginning in the mid 1990's, some individuals began to forage farther upriver in search of prey, including anadromous smelt or eulachon (*Thaleichthys pacificus*) that returned to tributaries such as the Cowlitz River (river mile 70). The abundance of CSL within the basin remained at this level (100's of animals) until 2013 when numbers increased significantly, and have since fluctuated in the range of 1000 to 3800[11] animals (Figure 3). CSL are currently present in the Columbia River basin from August-June, though abundance is typically highest in April when spring and summer Chinook are migrating upriver (Wright, 2018; Hatch *et al.*, 2019; Tidwell *et al.*, 2019).

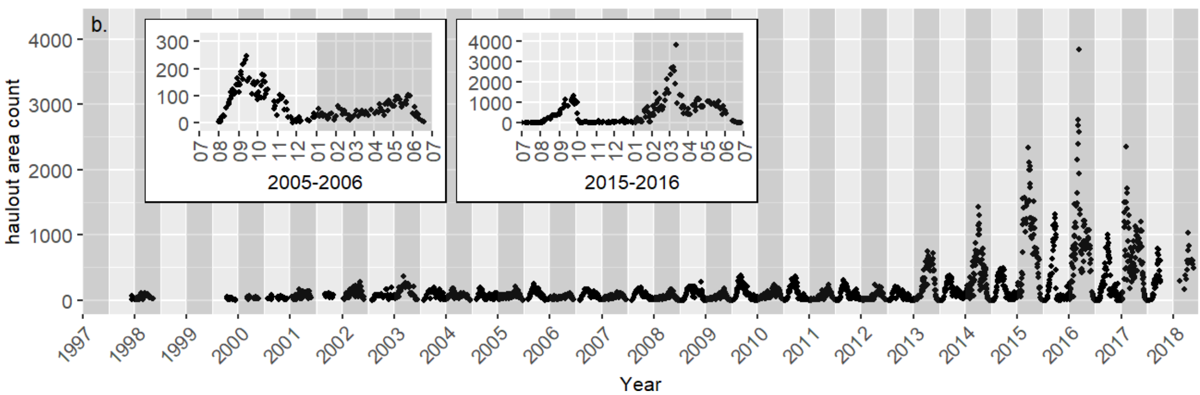


Figure 3. Time series of California sea lion haul-out area counts at the East Mooring Basin (EMB) in Astoria from December 1997 to June 2018. Insets illustrate the changes in magnitude and seasonality of California sea lion occurrence over the study period (x-axis denotes month; note difference in magnitude of counts on the y-axis scale between the two inset figures).

Bonneville Dam: One to two CSL were observed during fishway inspections at Bonneville Dam beginning in the 1980's (Stansell 2004). In 2001, observations of CSL at Bonneville Dam increased, with reports of up to six CSL observed at one time. By 2002, the U.S. Army Corps of Engineers (USACE) estimated that 30 CSL were foraging at the dam for salmonids between January and May. CSL abundance continued to increase up to 2015 but has since decreased. During this same period animals have generally arrived earlier and have remained over a longer period of time, though peak occupancy occurs consistently in April/May (Figure 4). During the period 2002-2018 the number of CSL at Bonneville Dam has ranged between 30 and 195 annually (Table 1). During the period 2008-2019, the states have removed 238 CSL from Bonneville Dam.

[11] These counts are minimum estimates as some animals will not be hauled out during counts and others will be foraging upriver (e.g., Bonneville Dam or Willamette Falls)

Table 1. Reproduced from Tidwell et al. (2019). Minimum estimated number of individual pinnipeds observed at Bonneville Dam tailrace areas and the hours of observation during the spring sampling period, 2002 to 2018.

Year	Total Hours Observed	California Sea Lions	Steller Sea Lions	Harbor Seals	Total Pinnipeds
2002	662	30	0	1	31
2003	1,356	104	3	2	109
2004	516	99	3	2	104
2005*	1,109	81	4	1	86
2006	3,650	72	11	3	86
2007	4,433	71	9	2	82
2008	5,131	82	39	2	123
2009	3,455	54	26	2	82
2010	3,609	89	75	2	166
2011	3,315	54	89	1	144
2012	3,404	39	73	0	112
2013	3,247	56	80	0	136
2014	2,947	71	65	1	137
2015	2,995	195	69†	0	264
2016	1,974	149	54†	0	203
2017	1,142	92	63†	1	156
2018	1,410	67	66†	1	134

* Observations did not begin until March 18 in 2005.

† In 2015, 2016, 2017, and 2018 the minimum estimated number of Steller sea lions (SSL) was 55, 41, 32, and 35 respectively. These counts were less than the maximum number of Steller sea lions observed on one day, so the maximum number observed on one day was used as the minimum estimated number.

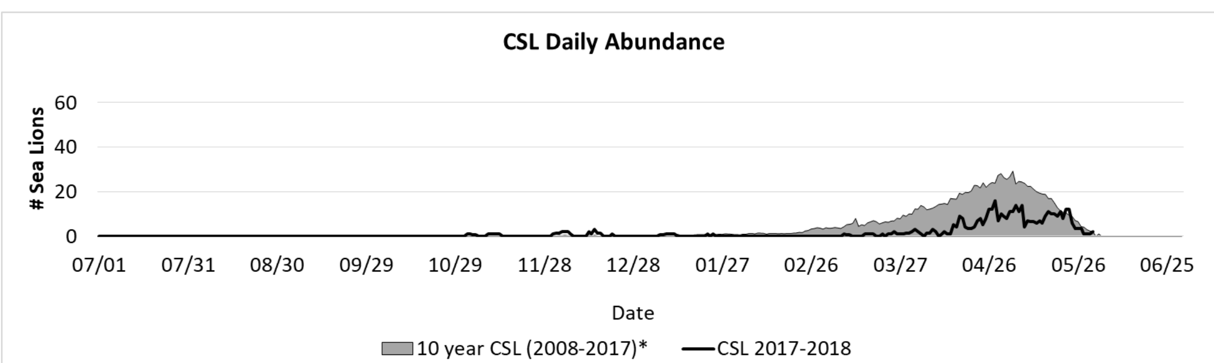


Figure 4. Reproduced from Tidwell et al. (2019). Maximum daily count of CSL at Bonneville Dam from 31 July 2017 through 1 June 2018 compared to the 10-year maximum daily average. For reference: fall and winter sampling period = 15 August – 31 December 2017 and spring period =1 January – 2 June 2018. * Averages from 6/1 - 12/31 begin in 2011, sporadic between years.

The majority of individually identifiable CSL have been observed at Bonneville Dam for two or more years (e.g., see Table 2) suggesting animals habituate to the location.

Table 2. Reproduced from Tidwell et al. (2019). The number of years that CSL and SSL identified in 2018 have been observed at Bonneville Dam.

Number of Years Observed	All Identified SSL	All Identified CSL
12	1	0
11	3	0
10	0	0
9	0	0
8	1	0
7	3	0
6	3	0
5	3	0
4	3	14
3	2	28
2	11	14
1	4	11
Totals	34	67

Willamette Falls: The first known record of a CSL at Willamette Falls (128 miles upstream from the ocean) is from the 1950s, when a single CSL was shot below the falls, with the next subsequent record not occurring until 1980 (Beach *et al.*, 1985). By the mid-1990s, however, there were frequent observations of CSLs in the Willamette River where they were observed foraging for winter steelhead and spring Chinook salmon below Willamette Falls (ODFW, unpublished data). Between 1995-2003, monitoring by ODFW suggested there was a minimum of 5-6 CSL in the area immediately below Willamette Falls. Monitoring from 2009-2012 by Portland State University (PSU) and from 2014-2017 by ODFW demonstrates that California sea lion abundance has increased from the late 1990s and early 2000s and is increasing annually (Figure 5).

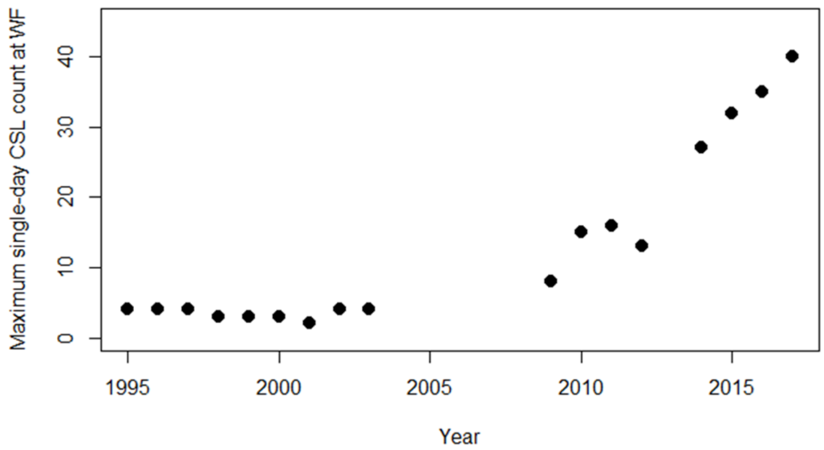


Figure 5. Maximum single-day CSL count at Willamette Falls by year. Monitoring from 1995-2003 and 2014-2017 was conducted by ODFW; monitoring from 2009-2012 was conducted by PSU.

As with Bonneville Dam, the majority of animals tend to return in subsequent years (Figure 6). At least one sea lion has been observed at Willamette falls in each of 11 seasons.

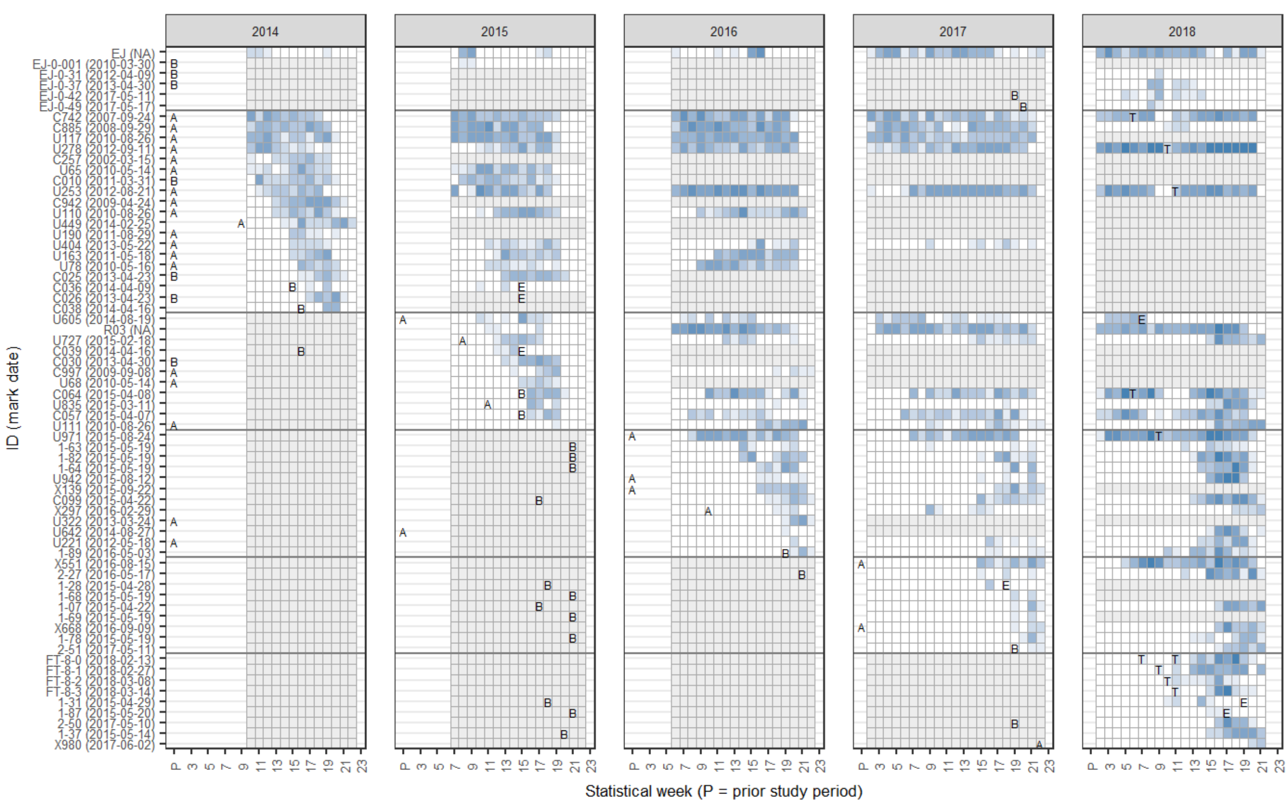


Figure 6. Weekly residency of Steller sea lions and California sea lions at Willamette Falls sorted by year (column) and week of first detection (row). Steller sea lions are indicated by prefix 'EJ' (with first row indicating presence only). Cell color indicates relative frequency of detection (darker hue = more days detected). Cell letters indicate location where it was branded ('A'=Astoria, 'B'=Bonneville), whether it was euthanized ('E') at Bonneville Dam, and/or whether it was translocated ('T') to the coast.

Bonneville Pool: CSL have been observed upstream of Bonneville Dam in each of the past 10 years. Installation of sea lion exclusion devices (SLEDS) at fish ladder entrances has effectively prevented sea lions from using the ladders, however, a few animals per year continue to pass through the navigation lock and some have taken up permanent residence in the area between Bonneville and The Dalles dams. Given the span of salmon and steelhead migration timing, pinnipeds in this area can prey on stocks year-round. This includes all ESA listed chinook, sockeye, and steelhead (winter and summer).

Tribal fishers in the Bonneville pool have reported negative interactions while fishing for approximately the last 10 years. A negative interaction is defined as one in which there is lost or damaged catch and/or damaged gear. These interactions occur year around, but are most commonly reported in the spring, particularly during ceremonial spring Chinook fishing. In early 2013, fishers were asked to report sea lion interactions to the Columbia River Inter-Tribal Fish Enforcement office where dispatchers monitor telephones 24 hours a day. Annual summaries of reported sea lion / fisher interactions are given in Table 3. The interactions occurred from the tailrace of The Dalles Dam to the forebay of Bonneville Dam. Reports were volunteered by fishers or made by enforcement officers and should be considered minimum estimates of actual sea lion / fisher interactions.

Table 3. Annual summary of reported fisher interactions with sea lions in the Bonneville pool (*2019 data as of 4/8).

Year	Sea lion interactions reported by tribal fishers or enforcement officers
2013	38
2014	9
2015	17
2016	8
2017	9
2018	3
2019	1*

Other tributaries: Recruitment of CSL at Bonneville Dam and Willamette Falls has been consistently occurring over a period of 15-20 years. More recently, CSLs have also been observed expanding their distribution into smaller tributaries to the Columbia River. Specifically, they have been observed feeding on salmonids in multiple tributaries in Washington and Oregon. In Oregon, CSL have been observed frequently feeding on salmonids in the Sandy River and Clackamas Rivers in Oregon since 2010. Typically, 1-2 animals are observed making daily foraging migrations into the lower reaches of these rivers. However, in 2017, 6 CSL were observed feeding on salmonids at RM 19 on the Clackamas River (Wright *et al.*, 2017). Confirmed observations for both States are listed in Table 4.

Table 4. Confirmed observations of CSL in Washington and Oregon tributaries. The upstream distance of CSL presence in these rivers and creeks varies, but they have at least been observed in the lower reaches and/or at the mouths of these systems.

Tributary	Source of Observation
Grays River, WA	WDFW staff
Skamokawa, WA	WDFW staff
Elochoman River, WA	WDFW staff
Abernathy Creek, WA	WDFW staff
Cowlitz River, WA	WDFW staff and public
Coweeman River, WA	WDFW staff
Kalama River, WA	WDFW staff and public
Lewis River, WA	WDFW staff and public
Washougal River, WA	WDFW staff
Duncan Creek, WA	WDFW staff
Hamilton Creek, WA	WDFW staff
Sandy River, OR	ODFW Staff, Public, Guides
Clackamas River, OR	ODFW Staff, Public, Guides
Scappoose River, OR	ODFW Staff
Clatskanie River, OR	ODFW Staff

Summary: The abundance of CSL has increased since the 1990's, both in the Columbia River basin and at specific upriver locations where fish are vulnerable to predation. The pattern of recruitment at each location has followed a common pattern: a small number of animals habituate to a location, recruitment of additional animals is initially low, but increases (sometimes rapidly) thereafter. Habituated animals generally arrive earlier and remain at a site/s over a longer period of time, subject to the presence of available fish prey. These animals appear to habituate easily and return to these sites year-after-year.

Steller Sea Lions. In the 1980's Steller sea lions were present at the tip of the South Jetty at the mouth of the Columbia River from September to mid-July, with peak occupancy of 250-300 animals in May (Beach *et al.*, 1985). While the authors note that CSL were present near the Cowlitz River and Bonneville Dam at the time, there were no similar references to SSL being in these areas, suggesting they primarily remained near the mouth of the estuary. ODFW has conducted point counts of SSL on the South Jetty using aerial photography since 1982. Abundance during these surveys has ranged from 0 to 707 (Figure 7)

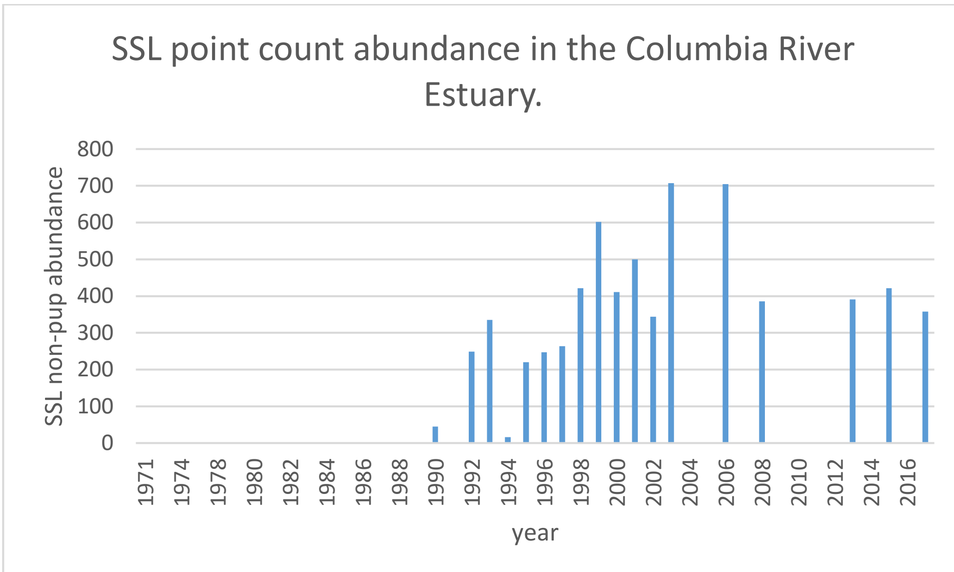


Figure 7. Point count abundance of SSL calculated from aerial photography of the South Jetty in June/Early July. No survey was conducted in years with no data.

Bonneville Dam: Steller sea lion abundance at Bonneville Dam has increased from a minimum of three animals in 2003, when SSL were first documented at the dam, to a minimum of 89 in 2011 (Table 1; Tidwell et al. 2019). In 2018, a maximum of 66 SSL were observed at Bonneville dam during a single day. These estimates represent a minimum number as a high proportion of SSL are unmarked and so are difficult to identify as a unique individual. Regardless, the total number of SSL present during the spring period is at least equal to that of CSL. While the highest abundance of pinnipeds tends to be during the spring, the abundance and residency of SSL during the fall and winter months has increased since 2011 and SSL are now present for 11 months per year at Bonneville Dam (Fig 8; Tidwell et al. 2019).

B

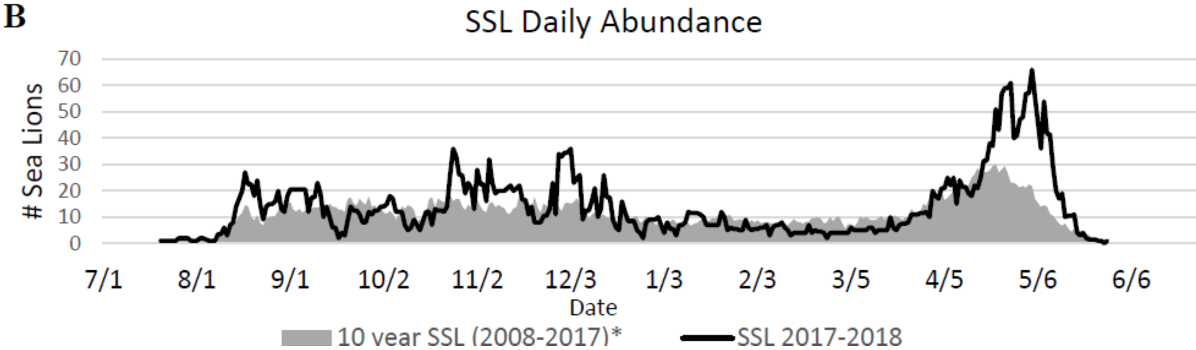


Figure 8. Reproduced from Tidwell et al. (2019). Maximum daily count of SSL at Bonneville Dam from 31 July 2017 through 1 June 2018 compared to the 10-year maximum daily average. For reference: fall and winter sampling period = 15 August – 31 December 2017 and spring period =1 January – 2 June 2018. * Averages for the period 6/1 - 12/31 are calculated since 2011, and do not include years for which sampling was not conducted.

Because SSL have not been lethally removed at Bonneville Dam to date, the average number of years an individual has been sighted at the Dam continues to increase and is now higher than that for CSL prior to the start of removals (Table 2 [above]). The increased abundance and residency has been coupled with increasing recruitment to the site, wherein, over the last three years the USACE has noted increasing abundance of sub-adult aged animals not previously observed (Tidwell et al. 2019). Of these sub-adult SSL, 13 have been branded and have consistently returned to Bonneville Dam.

Bonneville Pool: SSL are not currently observed in Bonneville Pool. But, given the numbers at Bonneville, and year-round residency of these animals, it is likely that some animals will enter the locks and move upstream into the Bonneville Pool.

Willamette River: The abundance of SSL has increased over the past decade in the Lower Willamette River, below Willamette Falls. Whereas CSL tend to forage directly at Willamette Falls, SSL are more dispersed throughout the 28 miles of the lower Willamette River, an area that is currently not monitored. Furthermore, as the majority of SSL are unmarked it is difficult to estimate the total abundance. Thus, the following estimates represent minimum numbers. ODFW first documented two SSL at Willamette Falls in 2014 (Table 5). Abundance remained low (<5 animals) until 2018 when 11 animals were observed on a single day at the Falls (Sport Craft Marina). Additionally in 2018, ODFW received a significant increase in reports from staff and public of SSL preying on sturgeon in the lower river, outside of the monitoring area, suggesting that the total count was significantly higher than 11. To date in 2019, ODFW has recorded a maximum of 10 SSL at the Falls on a single day. A survey of the lower River in January, 2019 documented 14 unique SSL whereas only 8 SSL were observed hauling out at the Sport Craft Marina, suggesting that Sport Craft counts underestimate the total abundance. ODFW continues to receive regular reports of SSL predation on white sturgeon downstream of the Falls, often of multiple predation events per day.

Table 5. SSL abundance at Willamette Falls (weekly max count) for 2014-2018 and max count to date in 2019

Year	Observation dates	SSL max count (date)
2014	2/25-5/29	2 (N/A)
2015	2/3-5/28	2 (multiple dates FEB)
2016	2/1-5/29	1 (multiple dates 2/4-4/16)
2017	1/9-6/11	4 (3/28/2017)
2018	1/8-6/3	11 (2/26/2018)
2019	AUG (2018)-3/19/19	10 (1/18/19, 2/15/19)

Summary: The abundance of SSL has increased at Bonneville Dam since ~2010 and at Willamette Falls since ~2017. The pattern of recruitment at each location has followed the same pattern as for CSL: a small number of animals habituate to a location, recruitment of additional animals is initially low, but increases (sometimes rapidly) thereafter. Habituated animals generally arrive earlier and remain at a site/s over a longer period of time, subject to the presence of available fish prey. These animals appear to habituate easily and return to these sites year-after-year.

Summary of current timing and abundance of SSL and CSL occupancy

In general, within the geographic scope of the application, the interaction between SSL and/or CSL and ESA-listed salmon and other at-risk fish species is currently occurring over an 11 month period, with a short break in July. The specific timing of the interaction varies depending on the location, species, and year. It is difficult to accurately determine the maximum number of animals involved as many are unmarked and are transitory between foraging sites.

Minimum estimates of CSL have ranged from 67-195 at Bonneville Dam and 27-41 at Willamette Falls during the past 5 years. The minimum estimates of SSL abundance have ranged from 54-69 at Bonneville Dam and 1-11 at Willamette Falls during the last 5 years.

The number of animals of each species within the geographic scope of the application that are not accounted for at Bonneville Dam and Willamette Falls is likely <50. Thus, we estimate the minimum number of animals within the geographical scope of the application[12] to be 144-286 CSL and 105-130 SSL. However, observations of marked and unmarked SSL suggest these minimum estimates are biased low.

2. Spatial categorization of the problem interaction

The pinniped-fish interactions within the geographical scope of this application can be divided into three categories based on current or future pinniped occupancy (as described above) and conservation risk to fish stocks (see Figure 1).

[12] The lower range is obtained by summing the higher of the past two years peak single day count at Bonneville Dam and Willamette Falls, then adding 50 to account for animals that do not reside at either location, or were not present during the single day count. The upper range is obtained based on best professional judgement taking into account known movement patterns and the marked to unmarked ratio.

Category 1: Areas within this category have high numbers of CSL and/or SSL (e.g., >20) that are often present for the majority of the year. This high occupancy constitutes an immediate and ongoing conservation risk for fish stocks. Interactions in this category are currently occurring at Willamette Falls, in the mainstem Willamette River below Willamette Falls, and at Bonneville Dam. These areas will be the primary focus of the removal program.

Category 2: Areas within this category currently have low to moderate numbers of CSL and/or SSL (e.g., <10) that are present only periodically. This level of occupancy constitutes a conservation concern for fish stocks if left unmanaged. Areas in this category include the main stem Columbia River above RM 112 but below The Dalles Dam (excluding Bonneville Dam); the Clackamas and Sandy Rivers, Oregon; and in the Cowlitz, Kalama, Lewis, Elochoman, and Washougal Rivers in Washington. The approach to manage these interactions will be to reduce the source populations at Bonneville Dam and Willamette Falls and conduct on-site removal where necessary.

Category 3: Areas within this category have no documented observations of CSL or SSL but contain spawning habitat for ESA listed salmonids, or have documented presence that managers are monitoring but do not deem a conservation risk at present. There may be a need for proactive action to implement removals in these areas if CSL and/or SSL presence increases and/or the pinnipeds exhibit signs of habituation. Areas in this category include the Skamakowa, Coweeman, and Grays Rivers, and Abernathy, Duncan and Hamilton Creeks in Washington and the Scappoose and Clatskanie Rivers in Oregon.

3. California and Steller Sea Lion Feeding Habits

Marine or estuarine resident CSL and SSL have a diverse diet that tends to consist primarily of marine fish species with opportunistic predation of salmonids or sturgeon at certain times of year. Conversely, the majority of the diet of CSL and SSL in the area proposed for removal consists of adult salmonids, lamprey, and/or sturgeon. For example, a comparison of scat samples collected in the lower estuary versus the upper river show that the most common prey of SSL and CSL in the estuary includes a range of marine species (categorized as “Other” in Tables 6 and 7), with salmonids, sturgeon, and lamprey being a much smaller component (Tables 6 and 7). Conversely, at upriver within the geographical scope of this application sturgeon, salmonids, and lamprey are much more common in the diet with other species being relatively rare.

Table 6. SSL food habits information collected in the Columbia and Willamette rivers. Prey separated by haul out location and presented as frequency of occurrence (FO). Scat samples were collected opportunistically across several years and months. Collections occurred in the estuary at the South Jetty (Columbia River Estuary: 2004, 2006-07, n=316 scat samples). Collections at Phoca Rock RM 132/Bonneville Dam RM 146 (2007-08, 2010-12) and Willamette River at Willamette Falls RM 26 (2018) are grouped into the Upper Columbia River category (n=103 scat samples). Frequency of occurrence does not equal 100% because scats can contain multiple prey types.

	Prey Species	Number	FO %
Columbia River Estuary	Other Prey	309	98.0
	Salmonids	83	26.3
	Pacific Lamprey	46	14.6
	Sturgeon	0	0.0
Upper Columbia River	Sturgeon	86	83.5
	Salmonids	17	16.5
	Other Prey	3	3.0
	Pacific Lamprey	2	2.0

Table 7. CSL food habits information collected in the Columbia and Willamette rivers. Prey separated by haul out location and presented as frequency of occurrence (FO). Scat samples were collected opportunistically across several years and months. Collections occurred in the estuary at the South Jetty (2003-05, 2007) and the East Mooring Basin (2002-04, 2015-18) are grouped into the Columbia River Estuary category (n=1649 scat samples). Collections at Bonneville Dam RM 146 (2006-08, 2010, 2015-16, 2018); Phoca Rock RM 132 (2016); and Willamette River at Willamette Falls RM 26 (2016-18) are grouped into the Upper Columbia River category (n=93 scat samples). Frequency of occurrence does not equal 100% because scats can contain multiple prey types.

	Prey Species	Number	FO %
Columbia River Estuary	Other Prey	1602	97.0
	Salmonids	394	24.0
	Pacific Lamprey	235	14.3
	Sturgeon	4	0.2
Upper Columbia River	Salmonids	84	90.3
	Other Prey	20	21.5
	Pacific Lamprey	17	18.3
	Sturgeon	6	6.5

At Bonneville Dam, direct observations of surface-feeding events by CSLs and SSLs from 2002-2018 demonstrate that the diet is primarily salmon, steelhead, lamprey, and white sturgeon, with some shad (Tidwell et al. 2019). Similarly, an analysis of 28 GI tracts collected from CSL that were lethally removed under Section 120 suggest that the most common prey items is adult salmonids (65 individual adult salmonids were found; 89% of samples contained at least one salmonid).

Fifty-seven of the adult salmonids were identified as Chinook salmon based on otolith identification. Other minor prey identified in GI tracts of Bonneville-captured sea lions included: Pacific lamprey (*Entosphenus tridentatus*) (22% of samples), Cyprinidae (pikeminnow/peamouth) (22%), American shad (*Alosa sapidissima*) (15%), eulachon (*Thaleichthys pacificus*) (4%), Pacific herring (*Clupea pallasii*) (4%), Cottidae (sculpin) (4%), and one small unidentified lamprey species (Petromyzontidae) (4%) (Wright et al. 2018). Juvenile salmonid remains were recovered in 44% of the 28 Bonneville animals from which a total of 295 individual juvenile salmonids were enumerated along with the recovery of 16 PIT tags. Six PIT tags were from spring Chinook salmon smolts, four from fall Chinook salmon smolts, and the remainder were from summer Steelhead smolts (*Oncorhynchus mykiss*).

At Willamette Falls, direct observations of surface-feeding events by CSLs from 2014-2017 demonstrate that approximately 85% of prey brought to surface are salmonids (Table 8), followed by lamprey (14%), and unidentified or other species (1%).

Table 8. Observed predation by California sea lions at Willamette Falls, 2014-2017.

	Observed predation					% of observations				
Prey	2014	2015	2016	2017	Total	2014	2015	2016	2017	Total
Salmonids	959	1139	1001	753	3852	86.7%	85.2%	83.8%	82.7%	84.7%
Lamprey	126	175	182	145	628	11.4%	13.1%	15.2%	15.9%	13.8%
Other/unk.	18	21	11	12	62	1.6%	1.6%	0.9%	1.3%	1.4%
Sturgeon	3	2	0	0	5	0.3%	0.1%	0.0%	0.0%	0.1%
Total	1,106	1,337	1,194	910	4547	100%	100%	100%	100%	100%

Direct observations of surface-feeding events by SSL's at Willamette Falls from 2014-2018 suggest that the majority of prey are currently white sturgeon (Table 9), with minor contributions from salmonids and lamprey. This is consistent with public reports and ODFW staff observations in the lower Willamette River. However, recent observations at Willamette Falls suggest that, during the April/May period some individuals are primarily targeting Spring Chinook.

Table 9. Summary of all Steller sea lion predation events observed below Willamette Falls by year (approximate dates of effort in parentheses). Includes events from anecdotal observations as well as those seen during probability-based sampling assignments.

Prey	2014 (2/25-5/29)	2015 (2/3-5/28)	2016 (2/1-5/29)	2017 (1/9-6/11)	2018 (1/8-6/3)
Chinook salmon	0	0	2	0	10
Unknown salmonid	0	0	7	0	8
Steelhead	1	2	0	1	1
Lamprey	0	0	0	0	4
Sturgeon	3	12	8	69	79
Unknown/other fish	0	0	0	5	2
Total	4	14	17	75	104

Summary:

Within the geographic scope of this application, the data indicate that the majority of the diet of individual CSL and SSL consists of adult salmonids, lamprey, and/or white sturgeon. The proportion of each of these fish species in the diet varies depending on location and sea lion species.

(C) PAST EFFORTS TO NONLETHALLY DETER SUCH PINNIPEDS.

1. Existing Nonlethal Deterrent Methods

A number of methods have been used in attempts to deter pinnipeds from feeding on fish or using specific areas, as described in (NMFS, 1997, Fraker and Mate, 1999, Bowen, 2004, Scordino, 2010. These methods include: seal bombs (underwater firecrackers), shell crackers (pyrotechnics discharged from a 12 gauge shotgun), aerial pyrotechnics (screamer rockets, poppers), acoustic deterrents (AHDs, ADDs), pulsed power, taste aversion, predator sounds (killer whales), predator models (killer whales), vessel chase, rubber projectiles, physical barriers or exclusion devices (e.g., at fish ladder entrances), electric barrier, and translocation. To date, efforts at finding an effective, long-term non-lethal solution to eliminating or reducing predation on salmonids in an open river system have proven difficult and largely unsuccessful.

2. Nonlethal Deterrent Efforts at Environmental Pinch Points

WDFW, ODFW, CRITFC, and USACE have invested considerable time and resources in attempts to non-lethally deter sea lions from Ballard Locks, Bonneville Dam tailraces, and at Willamette Falls (Stansell, 2004; Brown *et al.*, 2007, 2008, 2009, 2010; Wright *et al.*, 2007; Tackley, Stansell and Gibbons, 2008)

Bonneville Dam: Deterrent methods were first tested at the dam in 2005 and 2006, and have continued each spring through 2019. Methods have included aerial and underwater pyrotechnics, acoustic harassment devices, vessel chase, rubber projectiles, and capture-relocation. For example, in 2018 alone, boat-based hazing crews used approximately 2,204 rounds of cracker shells, and 838 seal bombs in attempts to deter sea lions from the Bonneville Dam tailraces (Table 10). Additionally, dam-based hazing of pinnipeds by USDA began on 5 March and continued on a daily basis through May 31, 2018. Working eight and ten hours per day, dam based hazers used 5,834 explosive cracker shells and 16 rubber buckshot within the tailrace areas (Tidwell *et al.*, 2019). While originally thought to be potentially effective at deterring new animals arriving at the dam for the first time, these efforts have been ineffective at deterring habituated animals and more recent evidence suggests they have minimal effect on naïve animals (Tidwell, Unpublished data).

Table 10. Annual summary of boat-based hazing activity conducted by CRITFC at the Bonneville Dam tailrace.

			Take*		Deterrents	
Year	Days	Events	#CSL	#SSL	Cracker Shells	Seal Bombs
2009	38	277	395	104	6667	1154
2010	23	196	158	207	3431	697
2011	38	257	173	359	7839	2439
2012	31	288	112	371	1183	401
2013	34	299	114	359	740	392
2014	35	252	188	171	711	440
2015	31	361	476	222	1254	735
2016	28	308	358	452	1006	715
2017	29	222	311	592	1487	824
2018	31	204	105	488	2204	838

Willamette Falls: In response to the arrival of CSL at Willamette Falls in the late 1990s, ODFW installed Sea Lion Excluder Devices (SLEDs) at each of the fish-way entrances and intermittently hazed animals with shell crackers and seal bombs. With the increase in California sea lion activity in the late 2000s, ODFW conducted increasingly intensive nonlethal hazing operations during 2010, 2011, and 2013 (there was no hazing during 2012 due to a state hiring freeze) in an attempt to move sea lions downriver and away from the falls and fish ladders (see Table 11). These efforts were largely ineffective and so were discontinued in 2014. In 2017, ODFW captured 11 CSL and transported them to the Oregon Coast. All animals subsequently returned to the Falls (~220 miles) within 3-6 d. One animal was relocated twice and returned on both occasions.

Table 11. Summary of ODFW hazing efforts at Willamette Falls from 2010-2013.

	Effort			Deterrents			Animals Exposed to Hazing	
Year	Start	End	Days	Shell Crackers	Rubber projectiles	Seal bombs	CSLs	SSLs
2010	3/26	4/30	8	~800	~30	~400	NA	0
2011	2/7	4/26	49	6,863	135	2,771	860	0
2013	2/4	4/29	81	10,976	601	8,042	1,871	45

3. Efficacy of Nonlethal Deterrents

As noted in ODFW's Section 120(b)(1)(A) application for Willamette Falls, in his exhaustive review of pinniped deterrent method, Scordino (2010) concluded that

"In most cases, non-lethal deterrence measures were found to have limited or short-term effectiveness because pinnipeds appeared to learn to avoid or ignore the measure applied. The use of noise or other stimuli that cause a startle and flight response in pinnipeds were found to cause initial fright reactions and short-term avoidance, but the measures were eventually ignored or avoided by pinnipeds that had prior exposure. During many years of attempting to deter California sea lions from foraging on steelhead at the Ballard Locks (Scordino and Pfeifer 1993), NMFS and WDFW found that non-lethal deterrence measures had to inflict physical pain to the pinniped in order to effectively deter the pinniped beyond the initial startle response especially when the pinniped had previously foraged on salmonids at the site (NMFS 1996). Otherwise, the only effective measure was removal of the pinniped. ODFW and WDFW had the same results in attempting to deter California sea lions from Bonneville Dam (Brown et al. 2008)."

Additionally, in 2010 the Pinniped-Fishery Interaction Task Force for the Bonneville Dam Section 120 program was tasked by NMFS to address the following question:

Does non-lethal hazing appear to be an effective aid in reducing sea lion predation on salmonids in the area? Should non-lethal efforts be modified (increased, reduced, or re-directed) to improve effectiveness? Have new non-lethal techniques been shown to be effective at deterring pinnipeds from predation that may be applicable to this interaction?

The Task Force agreed by majority consensus to the following recommendation in response to Question 2:

The Task Force finds that the current hazing program does not appear to be effective at reducing predation in the area at this time. *As such, the Task Force recommends removing non-lethal hazing as a condition of the States' permit*. [emphasis added] Instead, allow the management agencies to modify the hazing plan as they deem necessary to enhance removal efforts and ask that any methods utilized continue to be monitored, evaluated and adapted to meet the overall goal of reducing predation to 1% or less.

While these analyses have focused on the effectiveness of non-lethal deterrence on CSL, observations at Bonneville dam over the past decade and more recent research also suggest that hazing is also ineffective at reducing SSL predation. Anecdotal observation of the behavioral responses of SSL to hazing when they first appeared at Bonneville Dam (approximately 2005) suggested they may be more easily deterred. These anecdotal accounts noted that SSL were more startled than CSL and were generally easier to move away from the tailrace area. However, observations and data collected since that time do not support the hypothesis that nonlethal hazing is effective at reducing fish predation. Currently, there is no obvious distinction between the species in their behavior to hazing. At Bonneville Dam, most animals move back into feeding positions within approximately 20 minutes of being subject to hazing (K. Tidwell, USACE personal communication). Furthermore, SSL's appear to quickly habituate to hazing and habituated individuals will endure many applications of hazing prior to moving downstream and out of range of the hazing (Tidwell *et al.*, 2018). The majority of individually marked SSLs at Bonneville Dam have been at Bonneville Dam in previous years and at least 44% of the marked SSL population have been observed during each of four previous years (Tidwell *et al.*, 2018), despite consistent application of hazing.

In 2018, the USACE conducted a study to quantify hazing effectiveness on SSL (Tidwell, In Prep). SSL behavior was recorded using an interval scan sampling design. Behavior was classified as either *foraging* (animal is below water searching for food) or *transiting* (animal is at surface moving in a directed manner towards a location). Behavior was monitored before, during, and after hazing in three separate months. Preliminary analysis suggests there was a slight reduction in proportion of time spent foraging during the initial 2 d hazing event but as soon as hazing ceased, foraging frequency increased. The responses were similar, but diminished in each subsequent month, and after three months of hazing (i.e. May) the animals had returned to near baseline levels of foraging frequency (Figure 9). Also, it is important to note that even while hazing is ongoing, SSL are still foraging >80% of the time.

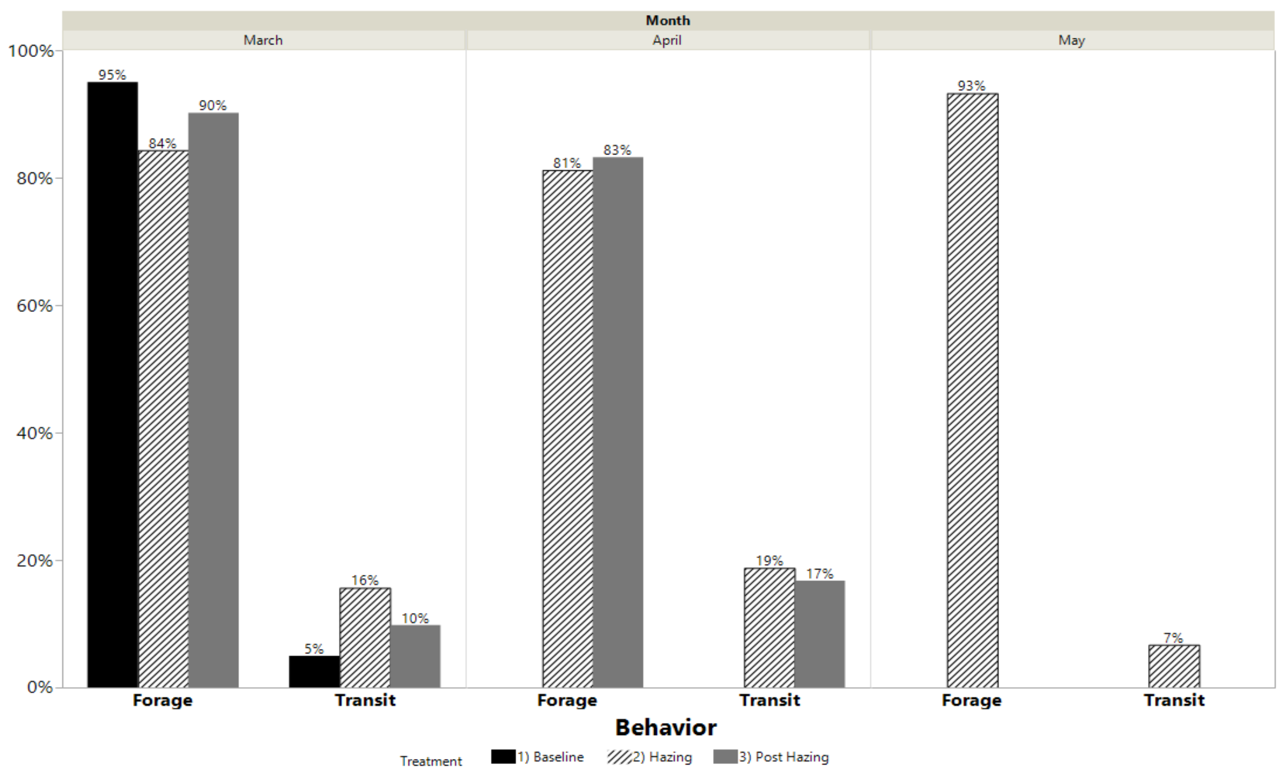


Figure 9. Effect of hazing on proportion of time spent foraging or transiting below Bonneville Dam. Baseline behavior was recorded for 2 d prior to hazing. Hazing was applied for a 2 d period and behavior was recorded. Post hazing behavior was recorded for the 2 d after the cessation of hazing. The hazing treatment was reapplied in two subsequent months.

Given these conclusions, and our own experiences with years of hazing CSL and SSL at Ballard Locks, Bonneville Dam, Willamette Falls, and other locations, we do not propose to conduct any non-lethal hazing activities in association with this application.

(D) <u>THE EXTENT TO WHICH SUCH PINNIPEDS ARE CAUSING UNDUE INJURY OR IMPACT TO, OR IMBALANCE WITH, OTHER SPECIES IN THE ECOSYSTEM, INCLUDING FISH POPULATIONS</u>

For the purposes of this application, subsection 120(f)(8) establishes as a matter of law that CSL and SSL within the geographic scope of the application are having a significant negative impact on fish populations. A summary of the data collected at Bonneville Dam, Willamette falls, and in the mainstem Columbia River in support of this designation is included below.

1. Status of Salmon, Steelhead, and Eulachon in the Columbia Basin

Currently there are eight Evolutionary Significant Units (ESUs) of salmon and five Distinct Population Segments (DPS) of steelhead in the Columbia Basin listed under the ESA (Table 12). All are subject to predation by CSL and/or SSL based on temporal and spatial overlap within the geographic scope of this application.

Table 12. Status of ESA-listed Columbia Basin salmon, steelhead, and eulachon.

ESA-listed Columbia Basin salmonids	Status
Upper Columbia R. Spring Chinook	Endangered
Snake R. Spring/Summer Chinook	Threatened
Lower Columbia R. Steelhead	Threatened
Mid-Columbia R. Steelhead	Threatened
Snake R. Steelhead	Threatened
Lower Columbia R. Chinook	Threatened
Upper Willamette R. Chinook	Threatened
Upper Willamette R. Steelhead	Threatened
Upper Columbia R. Steelhead	Threatened
Snake R. Fall Chinook	Threatened
Columbia R. Chum	Threatened
Lower Columbia R. Coho	Threatened
Snake R. Sockeye	Endangered
Southern DPS of Eulachon	Threatened

Within each ESU/DPS there are multiple populations at various levels of risk of extirpation.

2. Pinniped Predation at Bonneville Dam

The US Army Corps of Engineers Fisheries Field Unit (USACE FFU) has monitored predation by CSL and SSL in the Bonneville Dam tailrace since 2002. Prior to 2017, annual monitoring only occurred during the period from January to June. However, because pinnipeds have recently been observed almost year round below the dam, the USACE began conducting limited monitoring between August-December. Total predation of salmonids by CSL and SSL during the Jan-June period has varied among years (Table 13).

Table 13. Reprinted from Tidwell et al. (2019). Estimated consumption of adult salmonids (including adults and jacks) by CSL and SSL at Bonneville Dam during the Jan-Jun sampling period from 2002 to 2018

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

In 2017, the USACE monitored predation by CSL and SSL during nine weeks within the period Aug-Dec. Monitoring in this time period was only conducted in the tailrace of the Washington shore powerhouse when there were >20 pinnipeds present (see Tidwell et al. 2019 for details). During this period, the percent of the weekly run of Chinook, Coho, or Steelhead that was depredated by pinnipeds varied from 0-53% (Table 14). The majority of this predation was attributed to SSL (only 3 CSL were present during this period). It is not currently possible to estimate predation over the entire late summer/fall/early winter period to obtain estimates that are comparable to those for the late winter/spring monitoring period. However, the data currently suggests that, although total predation is lower during the late summer/fall/early winter period, the proportional impact of predation by SSL and CSL may be highest at this time, and is particularly high for winter steelhead.

Table 14. Reprinted from Tidwell et al. (2019). Estimated pinniped predation and fish passage estimates of adult salmonids (including adults and jacks) in the Washington Shore tailrace of Bonneville Dam during the 2017 fall and winter sampling period when sea lion abundance was ≥ 20 individuals.

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

3. Predation impact at Willamette Falls

ODFW has monitored predation at Willamette Falls between 2014 and 2018 to estimate the total number of adult salmonids consumed by sea lions (see Wright *et al.*, 2007; Wright, 2014 for details). Total salmonid predation was partitioned by fish run (i.e., summer/winter steelhead, marked/unmarked spring Chinook salmon) based on a combination of field observations, fish ladder window counts, and Monte Carlo methods (Table 15). These predation estimates only apply to the sampling frame and are therefore minimum estimates as we have documented predation activity outside of the sampling frame during each study season. Additionally, sampling frames varied by year so annual predation estimates are not directly comparable across years without further assumptions.

Table 15. Estimated salmonid predation by California sea lions at Willamette Falls, 2014-2018.

	Estimated predation					% of potential escapement				
Run*	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018
wSTH	780	557	915	270	503	13%	11%	14%	25%	22%
nmCH	496	899	650	399	466	7%	9%	9%	6%	9%
sSTH	712	172	768	181	516	3%	4%	3%	8%**	6%
mCH	1,703	4,149	2,252	1,824	1950	7%	9%	9%	6%	9%

*wSTH = winter steelhead; nmCH = spring Chinook salmon (not marked); sSTH = summer steelhead; mCH = spring Chinook salmon (marked)

To evaluate the impact of predation at Willamette Falls on the population viability of UWR steelhead, ODFW conducted a 100-year population viability analysis (PVA; Appendix 2). The PVA was run under four different scenarios for each population (Table 6), where the assumptions under each scenario were held for all 100 years of the PVA simulation. In the scenario called "No Sea Lions" it was assumed that there is no additional mortality beyond incidental fishery mortality during the adult life stage. The scenario called "2015 Sea Lions" perpetuated the lowest predation mortality rate observed since 2014 and the scenario called "2017 Sea Lions" perpetuated the highest predation mortality rate observed since 2014. The results of the PVA indicated that sea lions had a large negative effect on the viability of winter steelhead in the three major populations (North and South Santiam and the Molalla) (Table 16). A similar analysis for spring Chinook concluded that CSL predation at the falls increased the extinction risk by 1.5-1.65 fold (Falcy 2018; Appendix 3).

Table 16. Probabilities of quasi-extinction over a 100 year period in four populations of Willamette River winter steelhead under four different scenarios. Scenarios with sea lions assume that the predation mortality estimated during that year will continue indefinitely. The lowest predation rate was observed in 2015 and the highest predation rate was observed in 2017.

	Population			
Scenario	N. Santiam	S. Santiam	Calapooia	Molalla
No Sea Lions	0.015	0.048	0.993	0.000
2015 Sea Lions	0.079	0.158	0.998	0.001
Average Sea Lions	0.274	0.335	0.999	0.021
2017 Sea Lions	0.644	0.599	0.999	0.209

ODFW collects data regarding SSL predation impact as part of the CSL monitoring that occurs at Willamette Falls. The majority of observed predation events near Willamette Falls have targeted white sturgeon, though some salmonids and lamprey are also depredated (Table 17). ODFW does not monitor predation below the area observable from Willamette Falls so there are no estimates of total predation by SSL, which tend to forage throughout the entire lower river. Bioenergetic modeling and anecdotal reports from staff and public suggest total predation on white sturgeon could be >1000 animals annually.

Table 17. Summary of all Steller sea lion predation events observed below Willamette Falls by year (approximate dates of effort in parentheses). Includes events from anecdotal observations as well as those seen during probability-based sampling assignments.

Prey	2014 (2/25-5/29)	2015 (2/3-5/28)	2016 (2/1-5/29)	2017 (1/9-6/11)	2018 (1/8-6/3)
Chinook salmon	0	0	2	0	10
Unknown salmonid	0	0	7	0	8
Steelhead	1	2	0	1	1
Lamprey	0	0	0	0	4
Sturgeon	3	12	8	69	79
Unknown/other fish	0	0	0	5	2
Total	4	14	17	75	104

4. Overall predation impact

The data collected at Bonneville Dam and Willamette Falls have established the significant impact that pinnipeds can have on fish runs at these environmental pinch points. It is important to note that estimates of predation at these two locations are minimum estimates because they apply only to daylight predation at the surface of the water within a <1/2 mile area of the river. Many more predation events occur at night or further downriver that the observers cannot see and thus do not record. A recent NOAA study suggests that the overall impact of predation that is occurring throughout the river is much higher than originally thought. Rub *et al.* (2019) estimated that non harvest mortality of spring Chinook varied from 20-44% between the mouth of the Columbia River and Bonneville Dam. The authors attributed the majority of this mortality to pinniped predation. Using these estimates and the CSL abundance data, the authors calculated that the odds of survival for spring Chinook decrease by 32% (95% CI: 6%-51% decrease) for every additional 467 sea lions present within the basin. While we do not have similar estimates for other salmonids in the mainstem Columbia River or in tributaries, the spatial and temporal overlap between sea lions and fish combined with data on feeding habits in these areas suggest that the overall impact is being significantly underestimated.

(E) <u>THE EXTENT TO WHICH SUCH PINNIPEDS ARE EXHIBITING BEHAVIOR THAT PRESENTS AN ONGOING THREAT TO PUBLIC SAFETY.</u>

California sea lions have been known to exhibit bold and aggressive behaviors that include stealing hooked fish while they are being landed, even to the point of taking the fish from a landing net or the hands of an angler bringing the fish into the boat. There have been reports of anglers being bitten by sea lions in this situation as well as anglers being pulled overboard while holding onto a landing net that was grabbed by a sea lion[13]. Many sport angling vessels are small and could be capsized by these types of actions by large, aggressive sea lions taking hooked or netted fish from anglers close to the boat.

(F) <u>THE EXPECTED BENEFITS OF THE PROGRAM.</u>

Removal of CSL and SSL within the geographical scope of this application is expected to benefit salmon, steelhead, sturgeon, lamprey, and eulachon by reducing predation on migratory or spawning fish. Following implementation of the program, it is expected that the predation documented in Section III D will be reduced to negligible levels and that the extinction risk for Willamette spring Chinook and winter Steelhead will be reduced to the level in the “no Sea lion” scenario (see Table 16 and Appendices 2 and 3). The expected benefit of removing any given individual sea lion will depend on the length of time it would have otherwise remained in the area and preyed on fish and the extent of social transmission of this behavior from the individual to other sea lions. This benefit can be

[13] http://www.oregonlive.com/portland/index.ssf/2011/05/sea_lion_yanks_a_willamette_ri.html (accessed 1/29/2019)

estimated based on bioenergetics simulations.

1. Bioenergetic estimate of expected benefit

We calculated the mean number of fish (Chinook, Steelhead, sturgeon, eulachon) needed to meet daily or monthly resting metabolic requirements for CSL and SSL using a bioenergetic model. In the model, we assumed that the primary prey contributed 90% of the energetic density to the overall daily/monthly requirement (Table 18). The model parameters are given in Appendix 4.

Table 18. Mean number of fish required* per day or per month to meet resting metabolic needs based on primary prey contributing 90% of the energetic density to overall daily requirement (n = 10,000 reps each):

	Chinook		Steelhead		White Sturgeon		Eulachon	
Sea-lion species	1 day	1 month	1 day	1 month	1 day	1 month	1 day	1 month
CSL	2.4	72	3.2	96			202	6048
SSL	3.5	105	4.8	144	2.4	63	339	10167

*Actual consumption could be more or less, though most animals gain weight suggesting these estimates are biased low.

Using these daily values, the expected benefit of a range of management scenarios can be estimated for a site by modeling the starting abundance of sea lions, annual residence (number of days sea lions are present and preying on fish), removal rates (the percentage of animals removed each year), recruitment rate (number of new animals that migrate into the area), and diet (the proportion of steelhead, salmon, sturgeon in the daily diet).

Using this approach, we calculated the number of fish of each species (spring and fall chinook, coho, steelhead, sturgeon) that would be consumed during a 5 year period under scenarios of 1) no management, current management, 3) implementation of removals per this application. We modeled these scenarios for Bonneville and Willamette Falls only. These estimates are intended to serve as a rough indication of potential benefit. The actual benefit at a location may be higher or lower for each fish species depending on sea lion diet, annual sea lion abundance, removal program efficacy, fish run size, etc. Additionally, these estimates are based on a bioenergetics model that assumes sea lions are consuming a maintenance diet (i.e., not growing).

In all scenarios, we assumed that recruitment of new CSL/SSL (10% of the number of resident animals) would occur at the start of each season. We modeled estimated prey consumption separately for two time periods within a year, July-December and January-June, based on the observed behavior of sea lions. For both species, we assumed that any animals present in July-December period would also remain on site during the January-June period. This assumption is based on observations at Bonneville Dam and Willamette Falls. At each site, we modeled two different starting abundances of sea lion abundance. In the low abundance model, we started the 5 year period with the lower point estimate of minimum CSL or SSL abundance recorded in the past five years (see Section III B). In the high abundance model, we started with the higher point estimate of minimum abundance during the past five years. To reflect that individual sea lions are present for varying periods of time at a location, we modeled the impact of both high (42 days) and low (7 days) residency. Because the simulation is intended to provide a range of expected benefits that might reasonably be expected given empirical observations we only report the highest and lowest estimates. These were obtained, respectively, by multiplying the highest residency by the highest sea lion abundance (“high” in Table 19) and the lowest residency by the lowest sea lion abundance (“low” in Table 19). Other combinations of these two parameters will fall within this range.

At each site, we modeled three scenarios. In the “no management” scenario, no sea lions were removed and the population grew by 10% annually. In the “current management” scenario, we assumed that 29% and 66% of CSL were removed per year at Bonneville and Willamette Falls, respectively, and that recruitment of new animals was 10% of the remaining population. These removal estimates were based on data from the current removal program at each site. In the “proposed management” scenario, we assumed that the program would remove 75% of CSL and 50% of SSL, and that recruitment was 10% of the remaining population. Under the proposed management scenario we assumed that removals would be higher than under the current management scenario because of the reduced requirements and that removals of SSL would be lower than for CSL because of differences in behavior and handling constraints. The estimated change in CSL and SSL numbers under these scenarios over the 5 year period is graphed in Figure 10.

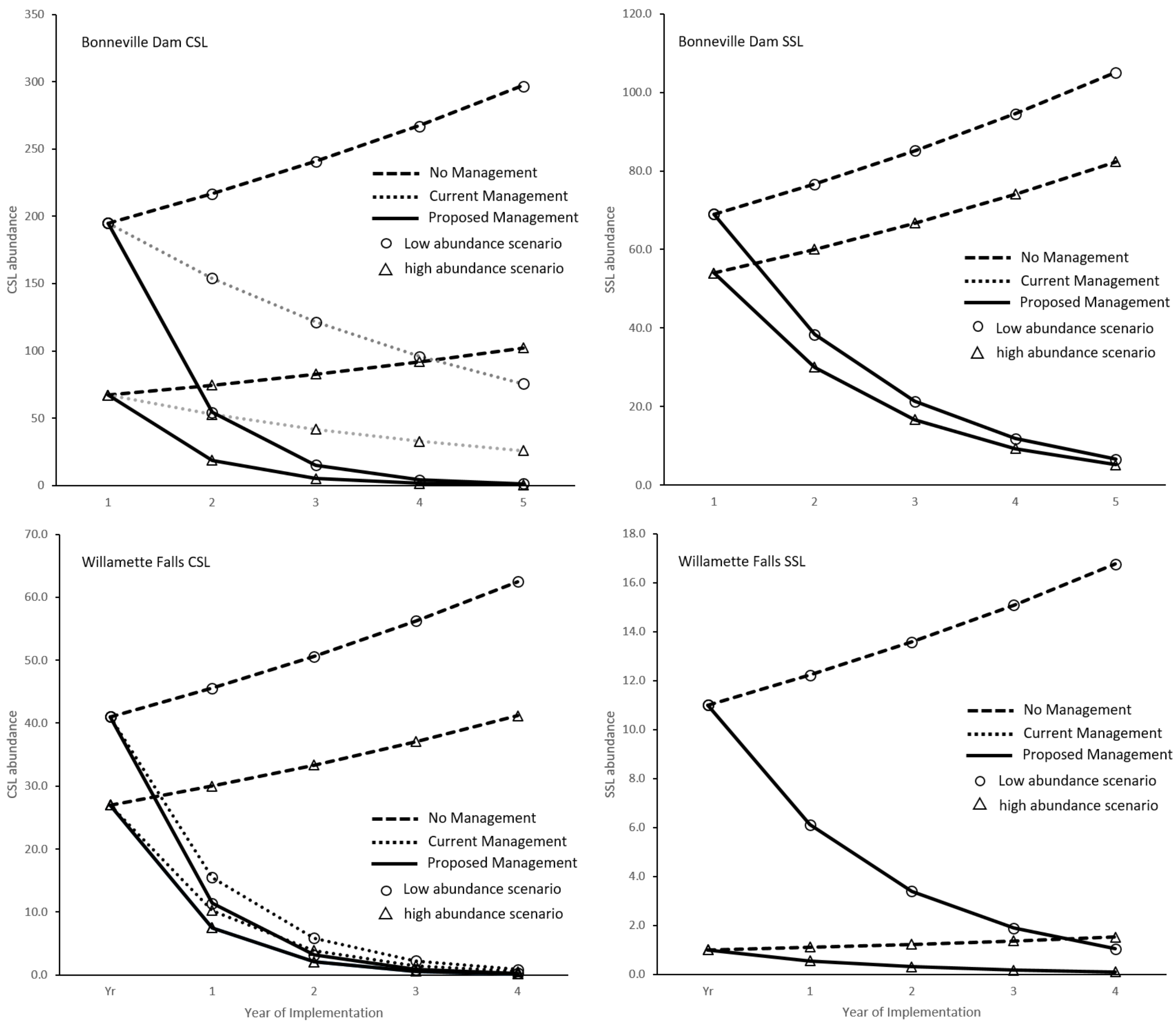


Figure 10. Modeled change in CSL (left panel) and SSL (right panel) abundance at Bonneville Dam (upper panel) and Willamette Falls (lower panel) under a “No Management” scenario (dashed line), “Current Management” scenario (dotted line), or a “Proposed Management” scenario (solid line). Circles and triangle symbols represent two scenarios of starting

sea lion abundance (high and low, respectively).

Using the modeled sea lion abundance from Figure 10, we calculated potential daily prey consumption based on the fish requirement values reported in Table 18. These values were then summed to give a 5 year total for each fish species (Table 19). For seasons where there were multiple potential prey species present we assumed that sea lions would consume each prey species in approximate proportion with their abundance (proportion of diet).

Table 19. Estimate of 5 year fish consumption under scenarios of “No Management”, “Current Management”, or “Proposed Management” at Bonneville Dam and Willamette falls and the number of fish potentially saved under the proposed management relative to no management or current management. Daily consumption requirements are based on a bioenergetics model. The estimates are for two different starting population abundances of CSL or SSL (see text for detail) and two different residence times for SSL or CSL (7 or 42 d).

							No Management		Current Management		Proposed Management		Fish Saved (vs “No Mgmt.”)		Fish Saved (vs “Proposed Mgmt.”)	
Sea lion Spp.	**Location**	**Season**	**Days**	**Prey spp.**	**Prey /day**	**Proportion in diet**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**
SSL	BONN	Jul-Dec	7-42	Sturgeon	2.4	0.21	595	4,558			203	1,556	392	3,002		
		Jul-Dec	7-42	Chinook	3.5	0.35	1,445	11,079			493	3,782	952	7,297		
		Jul-Dec	7-42	Steelhead	4.8	0.11	623	4,775			213	1,630	410	3,145		
		Jul-Dec	7-42	Coho	3.5	0.33	1,363	10,446			465	3,566	897	6,880		
		Jan-Jun	7-42	Sturgeon	2.4	0.05	142	1,085			48	371	93	715		
		Jan-Jun	7-42	Chinook	3.5	0.90	3,716	28,489			1,269	9,726	2,447	18,762		
		Jan-Jun	7-42	Steelhead	4.8	0.05	283	2,171			97	741	186	1,430		
	WF	Jan-Jun	7-42	Sturgeon	2.4	0.75	79	5,190			27	1,772	52	3,418		
		Jan-Jun	7-42	Chinook	3.5	0.20	31	2,019			10	689	20	1,329		
		Jan-Jun	7-42	Steelhead	4.8	0.05	10	692			4	236	7	456		
CSL	BONN	Jan-Jun	7-42	Chinook	2.4	0.95	6,674	116,550	3,518	61,426	1,478	25,812	5,196	90,738	2,039	35,613
		Jan-Jun	7-42	Steelhead	3.2	0.05	468	8,179	247	4,311	104	1,811	365	6,368	143	2,499
	WF	Jul-Dec	7-42	Steelhead	3.2	1.00	377	3,439	96	879	84	762	294	2,678	13	117
		Jan-Jun	7-42	Chinook	2.4	0.73	1,860	16,947	475	4,330	412	3,753	1,448	13,194	63	577
		Jan-Jun	7-42	Steelhead	3.2	0.27	917	8,358	234	2,135	203	1,851	714	6,507	31	284

(G) ADDITIONAL INFORMATION

1. Addressing Predation as Part of a Comprehensive Fish Recovery Strategy

In response to the ESA listing of many wild salmon populations in the Columbia Basin, there has been an extraordinary and unprecedented cooperative effort in the region to protect and recover salmon and steelhead. These efforts equate to hundreds of millions of dollars invested annually and billions over the past decade. This investment is associated with direct spending on recovery measures, such as habitat restoration and dam reconfiguration, as well as lost revenue- for example reduced hydro power generation and fishery season reductions or closures.

It is important to note that as part of this effort, all other sources of in-river mortality for ESA-listed salmonids in the Columbia basin are being actively managed (e.g., through harvest reductions; changes in hydrosystem project operations, configuration, and management of the basin water supply; habitat restoration; hatchery reform; and predator management). Furthermore, these efforts will continue into the foreseeable future as they seek to address the root cause of salmon declines.

All recovery actions are guided by federally managed planning and permitting processes. Harvest fisheries are managed to be consistent with recovery under the *U.S. v. Oregon* court order or federally approved Fishery Management and Evaluation plans (FMEPs). Other recovery actions, including hydro, habitat, and hatchery are guided by the FCRPS Biological Opinion (NMFS, 2014, 2019), the Willamette River Biological Opinion (NMFS, 2008), the Upper Willamette River Conservation and Recovery Plan for Chinook salmon and Steelhead (ODFW and NMFS, 2011), Middle Columbia River Steelhead Recovery Plan (NMFS, 2009), and Lower Columbia Recovery Plan (NMFS, 2013). The two Biological Opinions outline Reasonable and Prudent Alternatives (RPA's) and timelines for the action agencies to address the impact of hydro/flood control, hatchery, and associated habitat limiting factors and threats. The Recovery Plans incorporate all the RPA measures and include additional actions that are outside the scope of the Biological Opinion.

Actions implemented under the guidance of these documents include, but are not limited to, the following:

Habitat Restoration. Since the time of ESA listing there have been hundreds of millions of dollars invested in restoring habitat to improve degraded habitat conditions and restore fish passage throughout the basin. Efforts are being undertaken by both state and federal agencies and non-governmental organizations. Specific projects and planning efforts are too numerous to mention here though some key measures implemented to address the habitat limiting factors in the Recovery Plans include:

- *Establishment and funding of State agencies (e.g., Oregon Watershed Enhancement Board, Washington's Governor's Salmon Recovery Office) and local recovery boards or councils*. These organizations oversee and fund state and local implementation of habitat restoration called for in salmon/steelhead recovery plans. Each year, tens of millions of dollars are invested in habitat restoration or protection using state, federal, and non-governmental funding under this umbrella.
- *Tribal restoration initiatives*. Forty percent of the lower river tribes' Columbia Basin Fish

Accords funding ($224M) went to watershed restoration efforts from 2008 through 2017. The goal for these projects is watershed-scale habitat restoration to increase egg-to-smolt survival of naturally-spawning salmon and steelhead and to restore these populations to levels where ESA viability criteria or Wy-Kan-Ush-Mi Wa-Kish-Wit goals and objectives are met. Depending on the scope of damage, active habitat restoration is performed at scales ranging from repair of specific stretches of stream channels to broader work on a waterway's riparian zone, floodplain, or its entire watershed.

- *Establishment of the Columbia River Estuary Partnership*. The partnership consists of state, federal and tribal representatives and includes active involvement of local habitat restoration- focused environmental organizations. Estuary recovery actions have restored habitat on 23,758 acres as well as addressing water flow issues in the lower 145 miles of the Columbia River in which all listed populations pass through on the way to and from the ocean.

Dams. The Federal Columbia River Power System (FCRPS) and the Willamette Basin Project (WBP) are operated to benefit the citizens of the Northwest through flood control and generated clean energy. Operation of these dams also includes a legal obligation to operate in a manner that does not jeopardize the continued existence of endangered and threatened salmon and steelhead populations. The Biological Opinions for salmon protection and recovery commit the FCRPS and WBP to invest hundreds of millions of dollars to support both operational changes to improve fish passage through the hydro-system as well as funding support for other important actions involving habitat restoration, hatchery reform, fishery management, and reducing predation by fish, birds, and marine mammals. This mitigation commitment provides much of the funding for the actions developed in the local ESA recovery plans. The impact of non-federal dams in the basin is mitigated through a range of state and federal regulatory processes, including federal FERC relicensing and state passage rules.

Hatcheries. The federal, state, and tribal managers in the Columbia Basin have been and continue to develop and implement operational plans for Columbia River salmon hatcheries to ensure that they are operated in a way that supports wild salmon recovery while continuing to provide hatchery fish to support Pacific Ocean and Columbia River fisheries and the economies that depend on these fisheries.

Operation of each hatchery program is subject to NMFS review during development of the Biological Opinions and in review/approval of Hatchery Genetic Management Plans (HGMPs)[14]. ESA section 7 consultations have been completed for HGMPs for all hatcheries in the Basin above Bonneville Dam, and for the majority of hatcheries below the Dam. The *U.S. v. Oregon* 2018 Biological Opinion notes the status of the section 7 consultations for most, but not all, hatcheries in the Basin. Independent reviews, if needed, are provided by the Independent Scientific Review Panel (16 USC 839b (h)(10)) and the Independent Scientific Advisory Board.

Harvest. Fisheries that affect Columbia River salmon populations have been progressively reduced over the past several decades in response to the declining salmon populations. The states and tribes have implemented actions through management agreements to ensure fisheries are operated in a manner that protects the weaker salmon populations and does not jeopardize the long-term viability of the ESU or DPS while ensuring federal court orders that require salmon harvest to be shared equitably between treaty Indian and non-Indian citizens are upheld. Formal management frameworks include International Agreements through the Pacific Salmon Treaty

---

[14] See here for more detail: https://www.westcoast.fisheries.noaa.gov/hatcheries/salmon_and_steelhead_hatcheries.html

with Canada as well as *U.S. v. Oregon* court ordered agreements for Columbia River fisheries that include ESA provisions to ensure that Columbia River harvest does not jeopardize wild salmon populations. These harvest actions have greatly reduced fisheries from past levels with significant economic consequences to Northwest communities that rely on fisheries as well as economic and cultural effects on the Columbia River tribes. State managers, with federal assistance, are further developing selective fishery practices to enable better fishery access to hatchery-produced fish while avoiding or minimizing impacts to wild fish and these are covered under existing FMEPs.

Predation. The impact of some predators of salmonids in the basin have increased dramatically from historical levels. This is partly due to changes in habitat that have favored some predatory fish and bird species and partly due to increased numbers of predators as a result of various protection measures, including the Marine Mammal Protection Act (MMPA) and the Migratory Bird Treaty Act (MBTA). Although the predation of salmon by birds, fish, and marine mammals may be natural, there are specific circumstances in the Columbia River where the predation has grown to a level where it is significantly out of balance with historic levels and cannot be ignored in a comprehensive recovery strategy. Because of this reality, the hydropower operators have funded large programs to reduce northern pike minnow fish predation on juvenile salmon by shifting their size distribution through a bounty reward program and to relocate Caspian terns and gulls to alternative bird colony locations to reduce the impact on migrating salmon juveniles.[15] The federal agencies are also coordinating an action plan to address Cormorant predation of salmon in the lower Columbia River and there is a commitment to study and develop plans concerning predation of salmon by non-indigenous fish populations.[16]

Summary: These habitat, hydro, harvest, hatchery, and predation recovery actions represent a major monetary and social investment in the region, underscoring the importance of maintaining salmon populations to the citizens and governments of the four states and tribes that reside in the Columbia Basin. The people of the Northwest have supported restoration efforts, and are willing to bear the costs, because of the importance of salmon to our heritage, the cultural value to Native Americans, and the economic value of salmon to our communities. State and federal agencies, tribal and local governments, and the public, have developed these salmon recovery plans and management actions through an extraordinary collaborative effort and are committed to rebuild these depleted salmon populations.

[15] See here for more detail: http://www.birdresearchnw.org/about-brnw/
[16] See here for more detail: https://www.nwp.usace.army.mil/environment/cormorants/

(NMFS), N. M. F. S. (1997) *Impacts of California Sea Lions and Pacific Harbor Seals on Salmonids and on the Coastal Ecosystems of Washington, Oregon, and California*. Available at: http://www.krisweb.com/biblio/gen_nmfs_nmfs_1997_tm28.pdf.

Beach, R. J. *et al.* (1985) *Marine Mammals and Their interactions with Fisheries*.

Bonnot, P. (1928) *Report on the Seals and Sea Lions of California, 1928*. Available at: http://content.cdlib.org/view?docId=kt438n99zd&brand=calisphere&doc.view=entire_text.

Bowen, W. (2004) *Report of the Seal Exclusion Zone Workshop*. Available at: http://www.dfo-mpo.gc.ca/csas/Csas/proceedings/2004/PRO2004_022_E.pdf.

Brown, R. *et al.* (2007) *Field Report: 2007 Pinniped management activities at Bonneville Dam.*

Brown, R. *et al.* (2008) *Field Report: 2008 Pinniped management activities at Bonneville Dam*.

Brown, R. *et al.* (2009) *Field Report: 2009 Pinniped management activities at Bonneville Dam.*

Brown, R. *et al.* (2010) *Field Report: 2010 Pinniped management activities at Bonneville Dam.*

Buhnerkempe, M. G. *et al.* (2016) 'Epidemiological models to control the spread of information in marine mammals', *Proceedings of the Royal Society B: Biological Sciences*, 283(1844), p. 20162037. doi: 10.1098/rspb.2016.2037.

Carretta, J. V *et al.* (2017) *U.S. Pacific marine mammal stock assessments: 2016*. doi: 10.7289/V5/TM-SWFSC-577.

Chasco, B. E. *et al.* (2017) 'Competing tradeoffs between increasing marine mammal predation and fisheries harvest of Chinook salmon', *Scientific Reports*, 7(1), pp. 1–14. doi: 10.1038/s41598-017-14984-8.

Falcy, M. (2017) *Population Viability of Willamette River Winter Steelhead River Winter Steelhead*.

Falcy, M. (2018) *Spring Chinook Status Assessment*.

Fraker, M. and Mate, B. (1999) 'Seals, sea lions, and salmon in the Pacific Northwest.', in Twiss Jr, J. and Reeves, R. (eds) *Conservation and management of marine mammals*. Smithsonian Institution Press, Washington, D.C., USA., pp. 156–178.

Hanson, M. B. *et al.* (2017) 'Estimates of Chinook salmon consumption in Washington State inland waters by four marine mammal predators from 1970 to 2015', *Canadian Journal of Fisheries and Aquatic Sciences*, 74(8), pp. 1173–1194. doi: 10.1139/cjfas-2016-0203.

Hatch, D. R. *et al.* (2019) 'Sea Lion Monitoring and Non-Lethal Hazing', (March 2019). doi: 10.13140/RG.2.2.21673.03680.

Laake, J. L. *et al.* (2018) 'Population growth and status of california sea lions', *The Journal of Wildlife Management*. John Wiley & Sons, Ltd, 82(3), pp. 583–595. doi: 10.1002/jwmg.21405.

Muto, M. *et al.* (2017) *Alaska Marine Mammal Stock Assessments, 2017., Govt Reports Announcements & Index (GRA&I), Issue 03, 2005*. doi: 10.7289/V5/TM-AFSC-378.

Nelson, B. W. *et al.* (2018) 'Wild Chinook salmon productivity is negatively related to seal density and not related to hatchery releases in the Pacific Northwest', *Canadian Journal of Fisheries and Aquatic Sciences*, 16(June), pp. 1–16. doi: 10.1139/cjfas-2017-0481.

NMFS (2008) *2008 Willamette Biological Opinion*. Available at: https://www.westcoast.fisheries.noaa.gov/fish_passage/willamette_opinion/.

NMFS (2009) *Middle Columbia River Steelhead Distinct Population Segment ESA Recovery Plan*. Available at: https://www.westcoast.fisheries.noaa.gov/publications/recovery_planning/salmon_steelhead/domains/interior_columbia/middle_columbia/mid-c-plan.pdf.

NMFS (2013) *ESA Recovery Plan for Lower Columbia River Coho Salmon, Lower Columbia River Chinook Salmon, Columbia River Chum Salmon, and Lower Columbia River Steelhead*.

NMFS (2014) *NMFS 2014. Endangered Species Act Section 7(a)(2) Supplemental Biological Opinion. Consultation on remand for operation of the Federal Columbia River Power System. NMFS, West Coast Regional Office, Portland, Oregon.*

NMFS (2019) *Endangered Species Act Section 7(a)(2) Biological Opinion, and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation for the Continued Operation and Maintenance of the Columbia River System*. *NMFS, West Coast Regional Office,* Portland, Oregon.

ODFW and NMFS (2011) *Upper Willamette River conservation and recovery plan for Chinook salmon and steelhead*.

Rub, A. M. W. *et al.* (2019) 'Changes in adult Chinook salmon (Oncorhynchus tshawytscha) survival within the lower Columbia River amid increasing pinniped abundance', *Canadian Journal of Fisheries and Aquatic Sciences*, p. cjfas-2018-0290. doi: 10.1139/cjfas-2018-0290.

Scordino, J. (2010) 'West Coast Pinniped Program Investigations on California Sea Lion and Pacific Harbor Seal Impacts on Salmonids and Other Fishery Resources PACIFIC STATES MARINE FISHERIES COMMISSION', *Program*, (January).

Stansell, R. J. (2004) *Evaluation of pinniped predation on adult salmonids and other fish in the Bonneville Dam tailrace, 2002-2004*. Bonneville Lock and Dam, Cascade Locks, Oregon. 97014. Available at: http://pweb.crohms.org/tmt/documents/FPOM/2010/Task Groups/Task Group Pinnipeds/2002-2004 Pinniped Annual Report.pdf.

Tackley, S., Stansell, R. J. and Gibbons, K. M. (2008) *Pinniped predation on adult salmonids and other fish in the Bonneville Dam tailrace, 2005-2007*. Bonneville Lock and Dam, Cascade Locks, Oregon. Available at: http://pweb.crohms.org/tmt/documents/FPOM/2010/Task Groups/Task Group Pinnipeds/2008 PINNIPED REPORT.pdf.

Tidwell, K. *et al.* (2018) *Evaluation of Pinniped Predation on Adult Salmonids and Other Fish in the Bonneville Dam Tailrace, 2017*. Available at: http://pweb.crohms.org/tmt/documents/FPOM/2010/Task Groups/Task Group Pinnipeds/2017 USACE pinniped monitoring report.pdf.

Tidwell, K. S. *et al.* (2019) 'Evaluation of Pinniped Predation on Adult Salmonids and Other Fish in the Bonneville Dam Tailrace, 2018', 97014(541).

Walker, D. (2015) 'Seals and Sea Lions in the Columbia River: An Evaluation and Summary of Research', *Journal of Northwest Anthropology*, 49(179–217).

Wright, B. *et al.* (2007) *Field Report – Non-lethal pinniped deterrent activities at Bonneville Dam, spring 2006*.

Wright, B. (2014) ‘Willamette Falls Pinniped Monitoring Project , 2014’.

Wright, B. *et al.* (2017) *Willamette Falls Pinniped Monitoring Project, 2017*. Available at: https://www.dfw.state.or.us/fish/SeaLion/docs/Willamette Falls 2014 sea lion report.pdf.

Wright, B. (2018) *Willamette Falls Pinniped Monitoring Project, 2018*. Available at: https://www.dfw.state.or.us/fish/sealion/docs/Willamette_Falls_2018_sea_lion_report.pdf.

(H) APPENDIX 1: PROPOSED METHODS FOR CAPTURING AND HANDLING SEA LIONS IN THE COLUMBIA RIVER BASIN:

Introduction

Researchers and wildlife managers use a variety of methods to capture California sea lions (*Zalophus californianus)* and Steller sea lions (*Eumetopias jubatus*) across their range. The types of equipment used in these efforts have evolved over the years as changes were made to improve capture success, ease of operation, animal wellbeing, and human safety.

Although similar in a general way, each capture operation presents different challenges that must be met by altering equipment and methods as necessary to achieve the desired results. The most appropriate equipment, tools, and methods to capture animals will vary by species, location, season, and year. Thus, no single operational protocol can adequately describe all of the variables that might come into play during these operations.

This document is not intended to, and cannot, describe all of the various forms of equipment, tools, methods, and procedures that might be used during every sea lion trapping operation in the future. Instead, this document describes in general terms the two approaches (floating deck traps or darting of free ranging animals) that we propose to use to capture and handle and animals in the Columbia River basin.

Floating Traps

Floating traps have been the primary tool used by Oregon Department of Fish and Wildlife (ODFW) and Washington Department of Fish and Wildlife (WDFW) to capture California sea lions for lethal removal at Bonneville Dam and Willamette Falls[17]. This method relies on the natural behavior of sea lions to haul out on floating structures to rest.

Basic Trapping/Transfer Equipment Description

Float Deck The foundation of the trap is a floating deck of metal or wood. The trap deck generally floats 1-2 feet above the waterline, providing ready access to the flat surface used by sea lions as a resting area. Some early trap versions consisted of steel deck plates mounted atop a single large (battleship) buoy. The buoy provided ample flotation and was moored to the bottom by chains and submerged weights, usually concrete blocks. More recent trap deck systems consist of a sturdy wood deck mounted over commercially available black plastic float blocks used in the construction of marina docks where boats are moored. In this case, the sea lion trap deck surface is not much different than an enlarged section of a commercial grade dock. This type of trap float may also be moored to the bottom or it may be lashed to an adjacent dock or other nearby surface already being used by sea lions as a resting location. The size of the trap deck has varied, but recent deployments have used a 16x16 feet base

[17] All equipment and methods currently in use have been reviewed and approved by the Columbia River Predatory California Sea Lion Removal Project Institutional Animal Care and Use Committee (IACUC) established to oversee these activities with respect to the federal Animal Welfare Act of 1966 (7 U.S.C. 2131).

float. The number of individual animals that may rest on a trap at one time is limited by the size of the float area.

Trap Walls The four trap walls, usually 7-8 feet in height, have primarily consisted of heavy duty wire chain-link mesh. Recently, the more commonly available and less expensive chain-link fencing material has been mounted to sturdy wall frames made of heavy galvanized pipe, the type typically used in commercial fence construction. In either case, the trap walls are attached to heavier cylindrical upright corner posts using typical chain link fence clamping devices. The base plates of the four heavy corner posts are lag bolted to the deck surface. The chain-link trap walls are typically installed on custom built float but can also be installed on an existing dock or deck where a sea lion regularly hauls out to rest. This approach may be used to capture animals that have already habituated to haul out at a location and where a custom trap is not needed.

Trap Doors: Each trap has two doors (also mesh or chain link construction), one large vertically sliding door in the front wall, and one small door in the rear wall. The small door at the rear (usually about 4x4 feet) is kept closed (tied shut) while the trap is set. The large front door is held open (up) by different methods (pull-pin, electromagnet) as best fits each specific capture operation), allowing sea lions to enter and rest on the trap floor. In general, the trap door design includes safeguards to avoid accidental closure of the trap while animals are present.

Handling Barge and Cages: A sea lion handling barge is used to facilitate transfer of animals from the trap to a land based facility. These barges are generally 10x30 feet with a wooden deck surface mounted over a frame and pontoons that provide adequate floatation. The deck of each barge is fitted with one or two transfer cages and, when needed, a squeeze cage. Transfer cages are usually about 4x4x6-7 feet and have an aluminum frame with wooden slat sides and top, vertically sliding doors at each end, and is used to hold animals moved from the trap onto the barge, weigh them (if a platform scale is used under the cage), and move them into the squeeze cage. The steel or aluminum squeeze cage is custom built (various sizes and construction materials) and is designed to lower its sides of spaced bars down on top of a prone sea lion to restrain the animal for a variety of purposes (measuring, tagging, marking, biological sampling, etc.).

Basic Trapping Operation

Trap Placement: Trapping projects may involve the use of a single trap at one location, the use of multiple traps at separate locations within a project area, or the use of a trap array with multiple traps arranged together side by side. Traps may be moored to the bottom with weights or anchors or they may be secured to adjacent structures or shore. Traps that are secured to one another must still be moored with lines to the bottom or to other structures. Caution is used to avoid having loose lines or chains in exposed places where sea lions may become entangled, and any potentially hazardous lines or anchors will be clearly marked to prevent collisions or injury by boats or vessels. Traps are marked with lights when deployed in navigable waters. Barriers may be erected to prevent animals from hauling out in the narrow spaces between traps that are moored together if two or more traps are used.

Trap Preparation and Operation: When stored for long periods between dedicated trapping operations, both trap doors are shut and secured. During trapping seasons, when trapping is not expected to occur within about 24 hours, the small rear door is tied closed with line and the front door is secured in the open position with heavy chain and a keyed padlock. In anticipation of trapping animals sometime in the coming 24 hour period, traps equipped with electromagnetic door releases are unlocked and set in the open position. Traps that use a remote release electromagnetic door closing system may be equipped with a sensing device that detects and reports (via a cell phone text message) if the trap door has closed unintentionally. If such an event occurs then traps will be checked as soon as possible following receipt of closed door message.

Trapping operations may take place any time of the day or night, depending primarily on the behavior of the animals in a particular area and when they choose to use the trap float as a resting area. Night vision and remote camera equipment is used to observe the trap prior to closing. To capture the sea lions resting inside the trap, the front vertically sliding door is dropped to the trap deck surface. This may be accomplished in several ways, including remotely with an electronic release or rushing the door in a small boat to manually release the door. Traps equipped with an electromagnet mounted on the top of the door holding the door open (up) use a remote triggering device (similar to a garage door opener) to interrupt the electrical circuit which deactivates the magnet allowing the door to fall vertically, closing under its own weight.

Handling Trapped Sea Lions: The handling methods will vary depending on location, number of animals, species, and animal behavior. In general animals will be transferred to an on land facility for euthanization, though in limited instances they may instead be euthanized on trap then transferred to land.

Transfer to on land facility: As soon as possible following the closing of the trap door, the trap is approached by boat and the door of the transfer cage (on the handling barge) is aligned with the small door on the back of the trap. Once the barge is secured to the trap, the small door in the rear wall of the trap is opened, followed by the opening of the vertically sliding door of the transfer cage mated up with the back of the trap. Other doors in the transfer cages on the barge may be opened at this time to facilitate the movement of sea lions forward. Usually up to 4-6 sea lions can be moved onto the barge at once. If an animal is too large or otherwise poses a safety risk to staff it may be immobilized using anesthetic to facilitate transfer. If more animals were trapped than can be safely transferred, the remaining animals will either be released, held temporarily until they can be transferred, or immobilized using anesthesia then euthanized on the trap.

Euthanization on trap: In some cases, animals may be euthanized on trap following the IACUC approved protocols. For example, Steller sea lions in excess of 1,500 pounds pose a safety risk to staff and therefore may be immobilized using anesthesia in the trap and euthanized under anesthesia.

Basic Darting Description

Darting: Where trapping of animals is not feasible due to environmental or behavioral constraints animals may be darted to facilitate capture. The animal will be darted using standard wildlife darting equipment. When an animal is in the water or is likely to enter the water following darting it will only be darted if the capture crew members believe the setting or situation allows a reasonable probability of recovery of the anesthetized animal for handling and processing. This latter scenario is most likely to occur if an animal is foraging in smaller tributary rivers and does not haul out. If animals do enter the water upon darting or are already in the water at the time of darting it will be followed and seine or tangle nets, hoop or gaff will be used to recover the anesthetized animal. Animals will be administered approved drugs remotely to cause sedation and euthanasia by chemical overdose. Drugs will be administered by a veterinarian and the deployed dart will include an acoustic or radio transmitter to aid in tracking and recovering the animal, and recovery of the dart once deployed. Darts will include appropriate agency contact information and warnings in the event the dart or animal is located by a member of the public. Anesthetized or deceased animals, may be secured to the vessel via straps or a pole noose system for transfer to land for processing. Anesthetized animals may be euthanized boat side following IACUC approved procedures. Any darting operation will be evaluated by the IACUC post occurrence to determine whether the methodology should be modified or discontinued.

Darting: Where trapping of animals is not feasible due to environmental or behavioral constraints, animals may be darted to facilitate capture and removal. The animal will be darted using standard wildlife darting equipment (e.g., Daninject, Pneu-Dart). When an animal is in the water or is likely to enter the water following darting it will only be darted if the capture crew members believe the setting or situation allows a reasonable probability of recovery of the anesthetized animal for handling and processing. This latter scenario is most likely to occur if an animal is foraging in smaller tributary rivers and does not haul out. If an animal enters the water upon darting or is in the water at the time of darting, it will be followed and captured with seine or tangle nets, hoop or gaff while the animal is anesthetized. Animals will be administered approved drugs remotely to cause sedation, and ultimately euthanasia by chemical overdose. Drugs will be administered by an agency veterinarian and the deployed dart will include an acoustic or radio transmitter to aid in tracking and recovering the animal, and recovery of the dart once deployed. Darts will include appropriate agency contact information and warnings in the event the dart or animal is located by a member of the public. Anesthetized or deceased animals, may be secured to the vessel via straps or a pole noose system for transfer to land for processing. Anesthetized animals may be euthanized boat side following IACUC approved procedures. Any darting operation will be evaluated by the IACUC post occurrence to determine whether the methodology should be modified or discontinued.

Moving or transporting sea lions on land

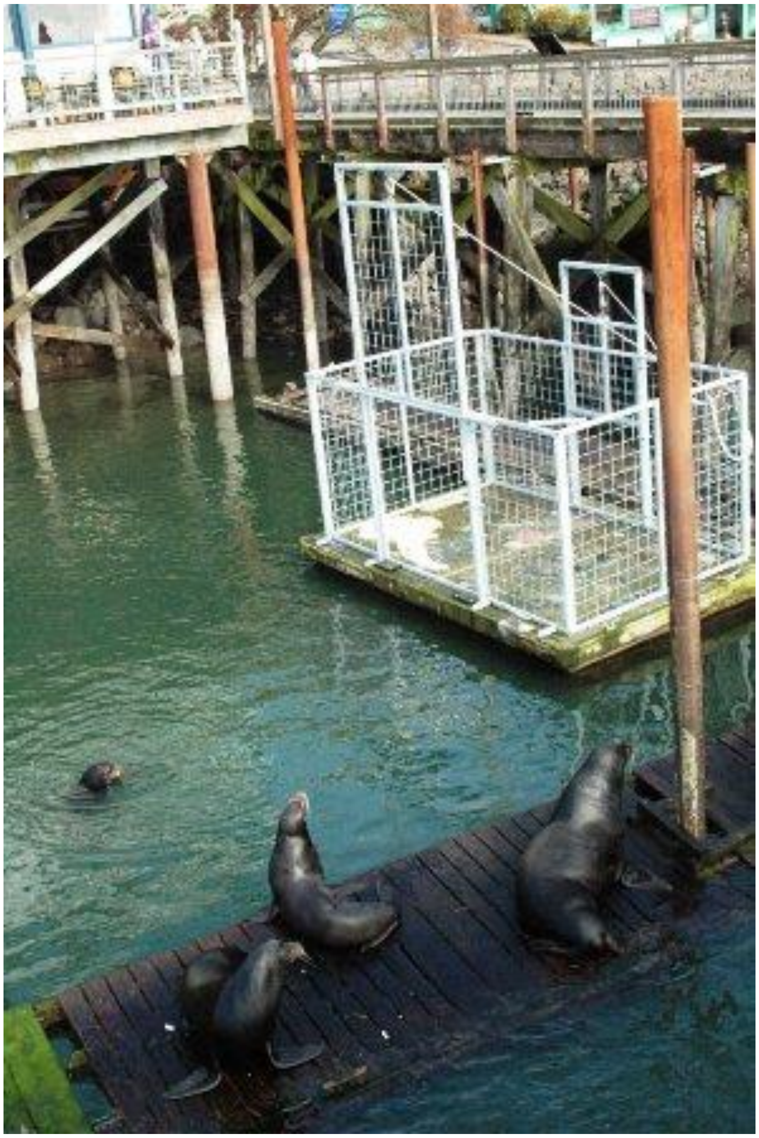
Animals are transferred to a transport truck either by lifting the entire transfer cage with an animal inside onto a truck by crane or transferring individual animals from the barge transfer cage to a second truck mounted cage at a boat launch or access site. To reduce stress during transport, visual barriers are placed around the sides of the transfer cage to limit the animal's view. The top of the cage remains open without a barrier to allow an adequate flow of air through the cage.

Attachments

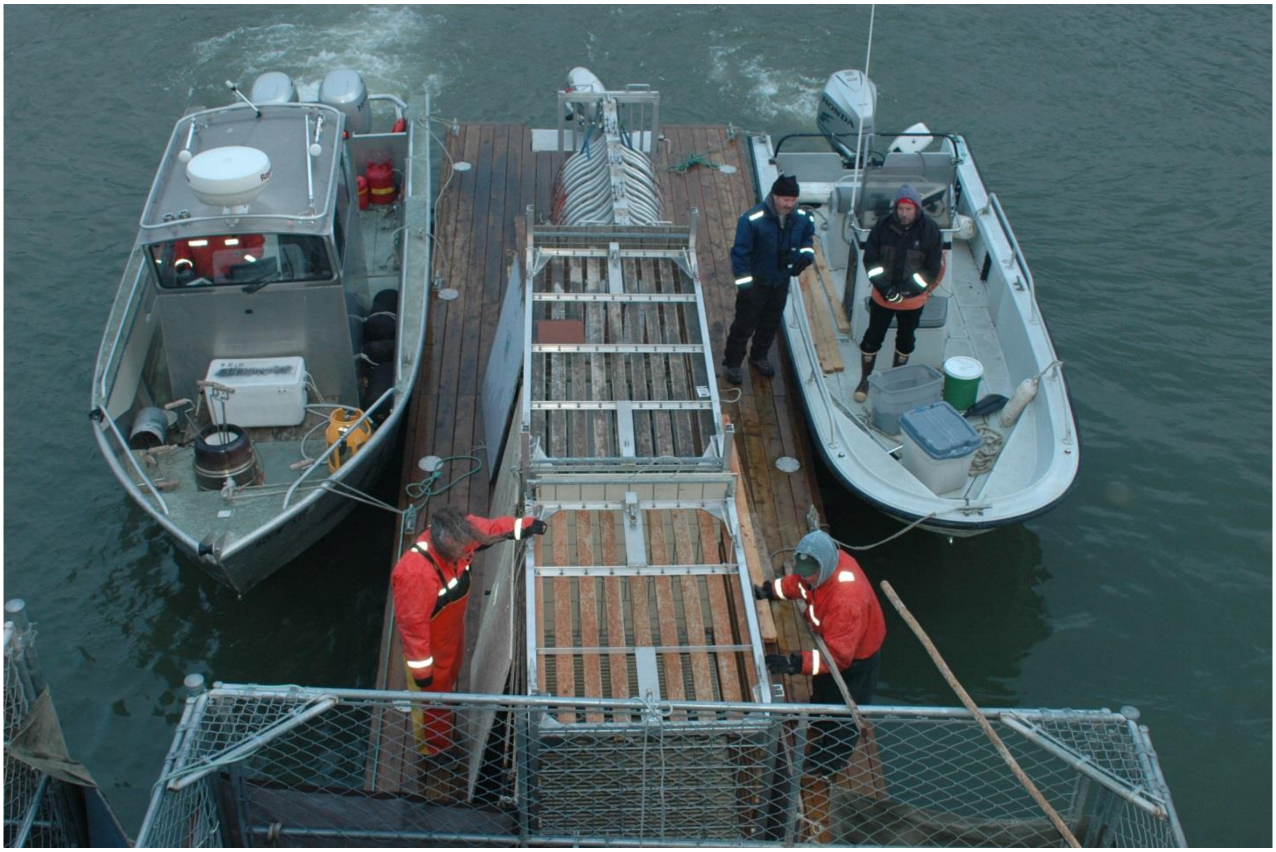
Trap photos

Sea lion traps below Bonneville Dam.

Sea lion trap in Bonneville Pool.


Sea lion trap at Newport, Oregon (Oregon Marine Mammal Stranding Network)


Sea lion trap at Newport, Oregon (Jim Rice)


Barge showing transfer cages and squeeze cage.

APPENDIX 2 POPULATION VIABILITY OF WILLAMETTE RIVER WINTER STEELHEAD: AN ASSESSMENT OF THE EFFECT OF SEA LIONS AT WILLAMETTE FALLS

July 7, 2017

Matt Falcy, PhD
Fish Conservation Biologist
Oregon Department of Fish and Wildlife

This document describes methods used to assess the effects of sea lions at Willamette Falls on the viability of four populations of wild winter steelhead. Several data sets were compiled, manipulated, statistically modeled, and ultimately used to project population dynamics through time. An accompanying webpage provides all the data and MATLAB computer code to replicate results: http://people.oregonstate.edu/~falcym/WillametteSteelhead.html

PVA Results

The results of the PVA indicate that sea lions have a large negative effect on the viability of winter steelhead (Table 1). The remainder of this document elaborates how these results were obtained.

***Table 1**. Probabilities of quasi-extinction over a 100 year period in four populations of Willamette River winter steelhead under four different scenarios. Scenarios with sea lions assume that the predation mortality estimated during that year will continue indefinitely. The lowest predation rate was observed in 2015 and the highest predation rate was observed in 2017.*

	Population			
Scenario	N. Santiam	S. Santiam	Calapooia	Molalla
No Sea Lions	0.015	0.048	0.993	0.000
2015 Sea Lions	0.079	0.158	0.998	0.001
2016 Sea Lions	0.274	0.335	0.999	0.021
2017 Sea Lions*	0.644	0.599	0.999	0.209

Population Viability Analysis

• • •

Population viability analysis (PVA) can be broadly defined as the use of quantitative methods to predict the future status of populations under defined conditions or scenarios. Here, a PVA is used to determine the probability of quasi-extinction over a 100 year period. The PVA scenarios perpetuate observed effects of sea lions at Willamette Falls.

* The 2017 sea lion predation estimate is a preliminary result.

Overview of Method

Sea lions feed on adult salmonids attempting to find passage over Willamette Falls. Mortality of adults during their spawning run is considered to have a density independent effect on subsequent survival rates. This is analogous to harvest mortality. Thus we can usefully employ common fisheries stock assessment models to capture population dynamics.

With a time series of spawner abundance, spawner age compositions, and mortality due to fishing and sea lions, it is possible to compute the adult recruits (progeny) associated with each year's spawner abundance. Density-dependence in these data can be modeled with Ricker or Beverton-Holt type stock-recruitment functions.

Bayesian analysis uniquely permits probabilistic interpretation of parameter estimates, and the Markov chain Monte Carlo methods used to fit Bayesian models conveniently preserves the covariance structure among parameters. Bayesian methods were therefore used to probabilistically describe parameter uncertainty a stock recruitment relationship.

The estimated stock-recruitment relationship with parameter uncertainty and residual autocorrelation is combined with age composition and adult mortality data. This is sufficient information to project population dynamics through time. The PVA program takes 1000 random draws from the parameter posterior distribution of the best stock recruitment model, and then replicates a 100-year time series 100 times. The total number of simulations where spawner abundance falls below a critical threshold across 4 consecutive year is divided by the total number of simulations (100,000). The result of this computation is the probability of quasi-extinction.

Density Dependence

• • •

Density dependence occurs when demographic parameters (e.g. birth rate or death rate) depend on the density of individuals in the population. For example, as the density (number) of fish increases, competition can cause survival rate to decrease. The form and magnitude of density dependence is a critical component of population dynamics, extinction risk, and optimal harvest rate.

Abundance of Willamette Winter Steelhead

The North Santiam, South Santiam, Calapooia, and Mollala river systems are used to delineate "populations" of winter steelhead. This delineation is consistent with previous conservation and planning efforts (ODFW 2008). Several sources of information were used to construct time series of spawner abundances in these focal populations.

A counting station on the fishway at Willamette Falls has produced a time series of annual abundances of winter steelhead dating back to 1946. Since Willamette Falls is below the focal populations, additional information is needed to apportion annual counts at the falls into each population.

A radiotelemetry study conducted in 2013 found that 106 out of 170 tagged fish (62%) reached their maximum migration point within one of the four focal populations (Jepson et al. 2014). This is assumed to reflect spawning distribution because fish were rarely observed to wander among river systems (Jepson 2017 personal communication). Thus we conclude that 38% of the winter steelhead that pass Willamette Falls are not members of the focal populations.

Fish are enumerated at the Minto fish facility in the upper North Santiam and at Foster Dam in the upper South Santiam. These "known fate" individuals were therefore subtracted out of the Willamette Falls count (N_{wf}) to obtain the number of fish whose spawning distribution needs to be determined N_{tbd}:

$$N_{tbd} = N_{wf} * 0.62 - N_{minto} - N_{foster}$$

The quantity N_{tbd} is apportioned to the focal populations based on miles of spawning habitat within each population (L_p) multiplied by the observed redd density ($D_{t,p}$). Note that L_p is temporally static quantity (no time subscript), whereas $D_{t,p}$ varies in time and across populations. In the North Santiam and South Santiam populations, only spawning habitat mileage below the counting facilities is used because there is already a known number of fish that go above the facility. Let $D_{t,p=NS}$ be the density of redds in year t within the North Santiam (NS) population. The population abundance that year is

$$N_{t,NS} = N_{tbd,t}\left(\frac{D_{t,NS} * L_{NS}}{\sum_p^4 (D_{t,p} * L_p)}\right) + Minto\ Count.$$

Observations of redd density have been made at multiple sites within each population since 1985. However, weather conditions and staff workload can prevent observation of redd density at some sites and years. If a given site generally has a high density of redds, then neglecting the site on a given year could give a false appearance of low redd density within the population relative to the years when observation are made at the site. Across all four populations, there are 30 redd survey sites. The date when most surveys began is 1985. There are 30 sites X 32 years = 960 potential observations of redd densities in the redd density data set. However there are 478 actual observations. The extent of missing values is therefore an issue that needs to be resolved so that all available data can be used while also minimizing biases associated with missing values from above average or below average sites.

A multiple imputation technique was developed to infer missing redd densities. Redd survey data from all four populations was combined with the Willamette Falls counts, Minto counts and Foster counts, yielding a matrix with 32 years (rows) and 33 locations (columns). Beginning with the first location, the first year with a missing value was identified. All existing redd densities in that location (across years) were linearly regressed on the redd densities in the next location. A prediction for the missing value was generated, and the log likelihood of the associated statistical model was recorded. A new linear regression was established from the next location, and the model prediction and log likelihood were once again recorded. This repeats across all locations, yielding 32 regressions for a single missing value. A final, model averaged prediction for the missing value was obtained as

$$\hat{D}_{t,p} = \frac{\sum_i^I \hat{y}_i * w_i}{\sum_i^I w_i},$$

where $\hat{y}_i$ is the model prediction from location *i* and w_i are individual model weights. The w_i are calculated

$$w_i = \frac{e^{-0.5BIC_i}}{\sum_i^I e^{-0.5BIC_i}},$$

where BIC_i is the Bayesian information criterion of regression *i*,

$$BIC_i = 2*nll + k*\log(n),$$

nll is the negative log likelihood, *k* is the number of estimated parameters (3) and *n* is the sample size used in the regression.

Likelihood

• • •

Likelihoods have provided a major theoretical foundation for scientific inference since the work of Ronald Fisher in 1922. Given a probability distribution function, one can find parameter values that maximize the likelihood of observed data. Such parameters are called maximum likelihood estimates, and the likelihood of the observed data given these parameter estimates is a relative measure of the adequacy of the model.

Imputed values are not used to impute other values. Imputation of data can be problematic because methods such as the one employed here will artificially reduce the variance of the data. However, this is not a problem in this particular application because the purpose is to merely avoid biasing an average across sites when a particular site has a missing value.

The result of the foregoing methods to apportion Willamette Falls counts of winter steelhead into time series of abundances in the four focal populations is presented in Figure 1.

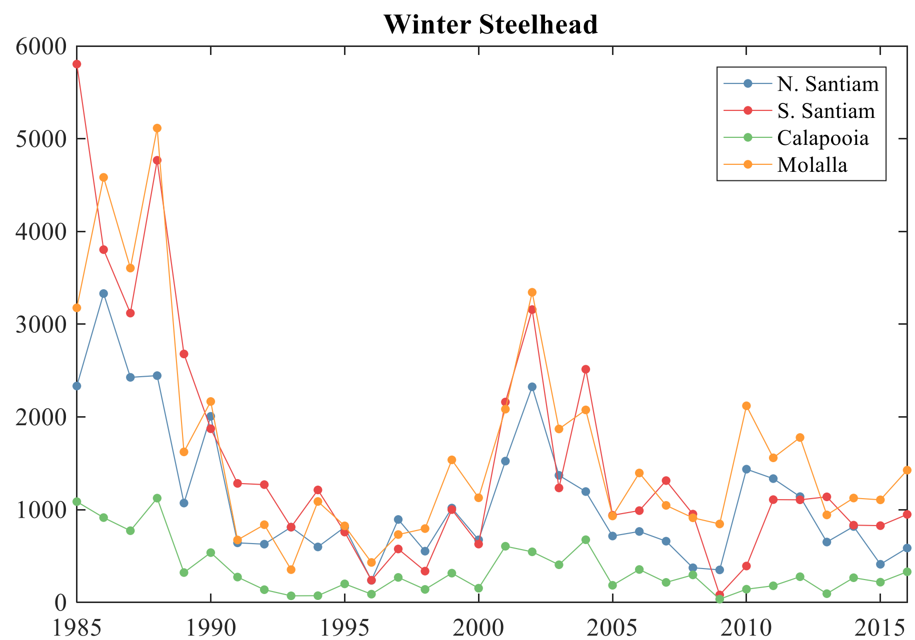


Figure 1. Estimated abundances of wild winter steelhead since 1985. Prior to 1985, it is not possible to apportion Willamette Falls counts because few or zero redd surveys were conducted within each population.

Mortality from Sea Lions

Sea lion predation on salmonids has been rigorously monitored by Wright et al. (2016) since 2014. The estimated number of winter steelhead killed by sea lions in 2014, 2015, and 2016 is 780, 557, and 915 respectively. Wright et al. (2016) note that the 2016 estimate applied to just the "falls strata" whereas monitoring in 2014 and 2015 included the fall and a "river" stratum just below the falls. Using information from years when both strata were monitored, Wright et al. (2016) find that the mortality in the river stratum is 0.385 of the falls plus river. The 2016 winter steelhead estimate in the falls stratum was expanded to a number reflecting mortality in the falls and river strata: 915/(1-0.385) = 1488.

However, as noted in the previous section, 38% of winter steelhead at Willamette Falls are not members of the four focal populations. Thus only 62% of the estimated mortality is on fish that pertain to the focal populations:

$$\begin{bmatrix} 780 \\ 557 \\ 1488 \end{bmatrix} * [0.62] = \begin{bmatrix} 486 \\ 347 \\ 927 \end{bmatrix}$$

An additional adjustment is needed because the mortality estimates pertain only to the time of the monitoring project, yet 23%, 30% and 22% of winter steelhead runs of 2014, 2015, and 2016, respectively, pass through the monitoring area before mortality monitoring begins (Figure 2). A loess quadradic polynomial local regression with span 0.4 was used to smooth daily counts of California sea lions (Figure 3, green). An "interaction index" was computed as the sum of the daily products between the loess smooth of California sea lions (CSL) and counts of winter steelhead (StW) at Willamette Falls:

$$Interaction\ Index = \sum_{day=Feb2}^{June1} CSLsmooth_{day} * StW_{day}$$

The leftmost point of the loess smooth was then extended further to the left (Figure 3, black), reflecting the assumption that California sea lions are present at low densities before the monitoring project began. The interaction index was then recomputed beginning November 1. The ratio between these interaction indices is a factor for expanding sea lion mortality to the entire run of winter steelhead. These factors were computed three times, once for each winter steelhead abundance time series in given in Figure 2. Each factor used the 2016 sea lion information.

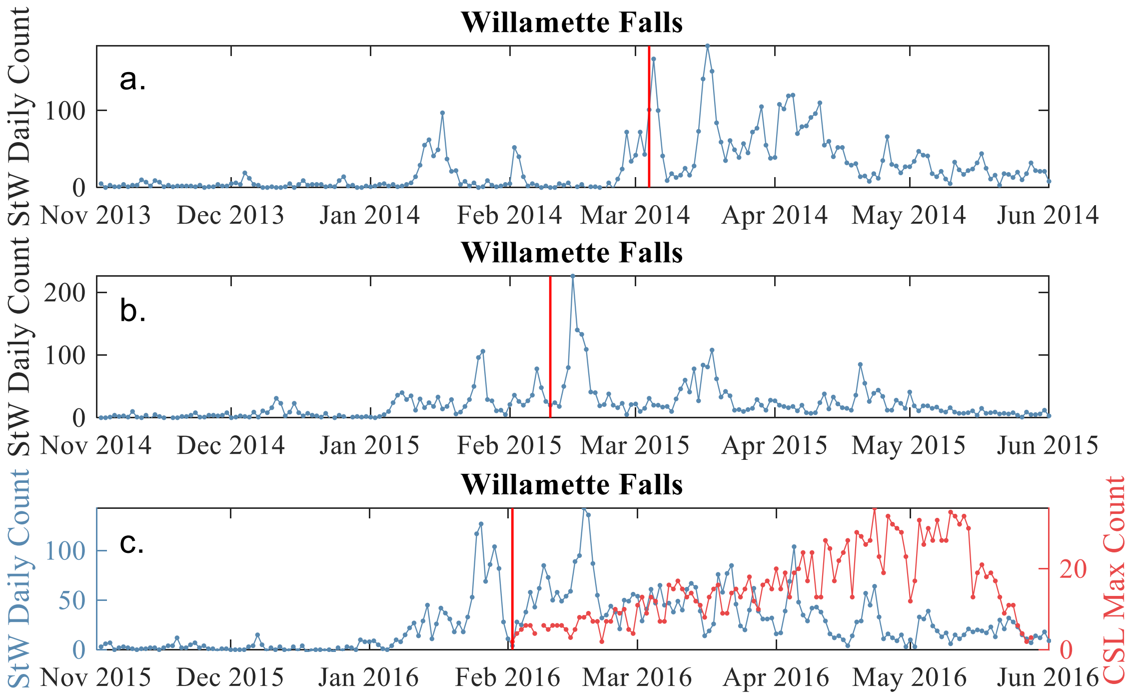


Figure 2. Vertical red bars give the initiation of the California sea lion (CSL) monitoring study relative to the run timing of winter steelhead (StW) at Willamette Falls.

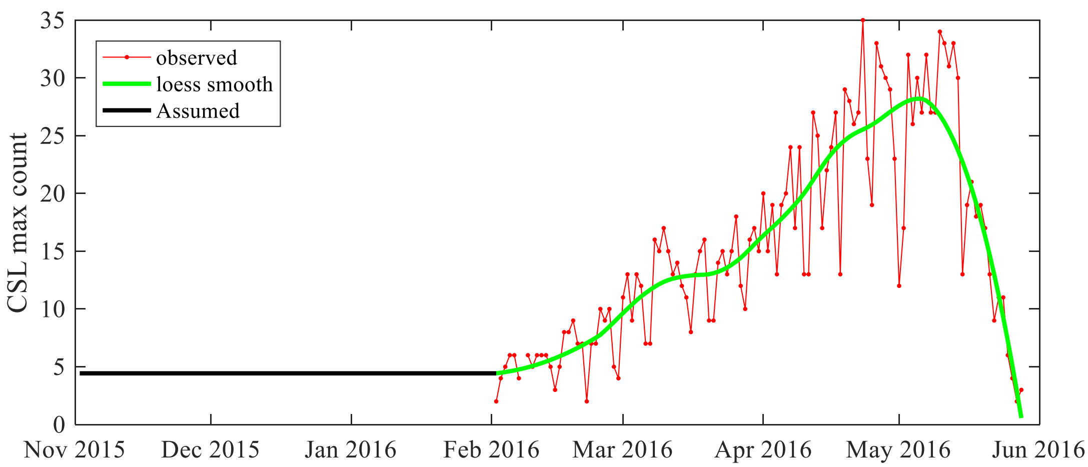


Figure 3. Maximum daily counts of California sea lion (CSL) are identical to Figure 2c.

The factor values are 1.10, 1.14, and 1.09. Even though 23%, 30% and 22% of the steelhead runs went unmonitored for sea lion mortality, expanding for the unmonitored component of the runs adds just 10%, 14% and 9% because California sea lion abundance is relatively low during this time. The final morality estimates for year 2014, 2015, and 2016 are: 486*1.10 = 531, 347*1.14=395, and 927*1.09=1016, respectively.

Wright et al. (2014) note that predation losses of salmonids were generally a few hundred or less at the Falls from the late 1990s through 2003. Starting with 150 salmonid mortalities, we made the same adjustments described above (expand for river stratum, deflate for proportion spawning outside the focal populations, expand by mean of three factors used to correct for early run timing) and then deflated the number again by the mean proportion of all the salmonid mortality during 2014, 2015, and 2016 that are winter steelhead (15%). This computation results in 33 winter steelhead. This amount of mortality was assumed to occur from 1995 through 2003, with linear increase in mortality until the study of 2014, and zero mortality prior to 1995. This time series of mortality is then apportioned to each of the four populations by the relative abundance of fish in each population, as calculated in the previous section. Mortality by California sea lions was 15%, 13% and 24% of the winter steelhead runs in 2014, 2015, and 2016, respectively.

In the spwner-recruit analysis below, the mortality caused by sea lions within each population on year t (denoted M_t) is added into the recruits.

Age Composition of Spawners

Age of spawning fish was determined through scale analysis. There were a total of 784 scales collected from 16 years. The composition of ages on a given year was applied to all populations. When age composition was missing for a given year, the average over all years with age data was used. The matrix of proportions of fish at age = 1,2,3, ..6, on given years (t) is denoted $A_{t,a}$ in the recruitment calculations below.

Angling Mortality

There has not been a directed retention fishery on Willamette River winter steelhead since 1992. Following previous conservation planning efforts (ODFW 2008), harvest rates on winter steelhead in the Willamette River system up through 1992 were assumed to be 21%, then decline to 5% to the present time for incidental mortality in fisheries targeting other stocks. A 2% incidental harvest rate is assumed in the Columbia River for all years. The vector of harvest rates (0.23 through 1993, 0.07 thereafter) it denoted HR_t in the recruitment calculations below.

Proportion of Hatchery-Origin Spawners

Hatchery winter steelhead have not be produced in the Willamette River since the late 1990s. The proportion of hatchery-origin fish spawning in the four focal populations in the 1980s and 1990s has been determined from scale analysis and used in previous conservation planning efforts (ODFW 2008, Appendix B). Specific values for each year and population can be found in the online supplement. Each population's vector of proportions of hatchery-origin spawners in year t is denoted $pHOS_t$ in the recruitment calculations below. This is needed because hatchery-origin fish should not be counted as recruits of the naturally spawning population. The PVA simulates dynamics of naturally spawning fish only.

Spawner-Recruit Analysis

The abundance of naturally produced ("wild") adult recruits associated with fish spawning on year *t* is

$$R_{S(t)} = \sum_{a=1}^{6} A_{t+a,a}\left(\frac{S_{t+a} * (1 - pHOS_{t+a})}{(1 - HR_{t+a})} + M_{t+a}\right).$$

From here it is possible to fit nonlinear models of the relationship between recruits and spawners. Errors in such models are customarily lognormal, reflecting the multiplicative survival processes that gives rise to uncertainty in the number of recruits.

Bayesian methods were adopted for recruitment modeling for two related reasons. First, Bayesian analysis uniquely yields probabilistic interpretation of parameters. Second, the Markov chain Monte Carlo (MCMC) methods used to fit Bayesian models allow parameter uncertainty to be easily folded into a PVA simulations. JAGS software was used to run the MCMC. JAGS called from MATLAB using matjags.m.

Beverton-Holt models were fitted to these data, but the posterior distribution for the productivity parameters always exactly matched the noninformative priors. These data therefore do not contain sufficient information to reliably identify the Beverton-Holt productivity parameter. A Ricker models were used instead (Table 2). Data from all four populations were combined into a "single" recruitment model. Three such models were constructed that make different assumptions about the across-population independence of parameters (Table 2). Model 1 assumes all parameters, including error variance, are unique in each population. Models 2 and 3 assume that some parameters can be shared across populations. Model 2 assumes there is a single error variance shared by all four populations, but each population has a unique productivity (α) and rate of compensatory density dependence (β). Model 3 assumes that productivity is identical across populations, while the magnitude of compensatory density dependence and error are unique to each population. In all

Table 2. Three Ricker recruitment models fitted to four populations of winter steelhead spawner-recruit data. The models make different assumptions about the number and structure of necessary parameters. WAIC measures relative out-of-sample predictive performance.

ID	Model	# Params	WAIC
1	$R_{t,p} = \alpha_p S_{t,p} e^{-\beta_p S_{t,p}} e^{\epsilon}, \epsilon \sim N(0, \sigma_p)$	12	224.8
2	$R_{t,p} = \alpha_p S_{t,p} e^{-\beta_p S_{t,p}} e^{\epsilon}, \epsilon \sim N(0, \sigma)$	9	248.9
3	$R_{t,p} = \alpha S_{t,p} e^{-\beta_p S_{t,p}} e^{\epsilon}, \epsilon \sim N(0, \sigma_p)$	9	217.6

three models, extremely diffuse (noninformative) uniform priors were used for α (Unif(1,200)), β (Unif(0,0.1)), and the standard deviation ε (Unif(0,4)).

Four MCMC chains per model were ran. The first 35,000 iterations were discarded as a "burn-in" period, and 10,000 samples per chain were retained after thinning 1:13 samples from the MCMC. Trace plots of the MCMC were visually inspected for signs of mixing and convergence. Extremely good estimates of the Gelman-Ruben diagnostic ($\hat{R} = 1 \mp 0.0001$) were obtained.

Watanabe-Akaike Information Criterion (WAIC) can be used to assess the relative out-of-sample predictive performance of Bayesian models (Gelman, Whang, and Vehtari, 2013). Each iteration of the MCMC yields a draw from the multidimensional posterior distribution. This parameter vector can be used to compute the probability density of each datum in the data set. This produces I-by-S matrix of densities, where I is the number of data points (4 populations X 32 years = 128), and S is the arbitrary number of MCMC samples in the posterior. Armed with this matrix, the computed log pointwise predictive density is

$$lppd = \sum_{i=1}^{I} log\left(\frac{1}{S}\sum_{s=1}^{S} p(y_i|\theta^s)\right).$$

A correction for effective number of parameters to adjust for overfitting is obtained with

$$pwaic = \sum_{i=1}^{I} V_{s=1}^{S}(\log p(y_i|\theta^s)),$$

where V is the sample variance. Thus *pwaic* is just the posterior variance (across MCMC iterations) of the log predictive density for each data point, summed over all data points, and

WAIC = -2*(*lppd*-*pwaic*).

The units of WAIC can be interpreted like the more familiar AIC and DIC. Specifically, smaller values indicate better models. There are 31.4 units separating model Model 2 and Model 3, indicating that there is no empirical support whatsoever for Model 2 (Table 2). There are 7.3 units separating Model 1 and Model 3, indicating that Model 1 is considerably inferior to Model 3. Model 3 is therefore the only model used hereafter. Hilborn and Waters (1992, page 271-272) argued from first principles that productivities (α) should be similar within a species over much of its range. The model selection results presented here support Hilborn and Walters' (1992) assertion.

The fit of Ricker Model 3 to the spawner-recruit data is given in Figure 4. Uncertainty in Ricker parameters gives rise to multiple potential recruitment functions. Random draws from the MCMC output ensures that parameter values and parameter covariance are obtained in proportion to the associated posterior probability densities.

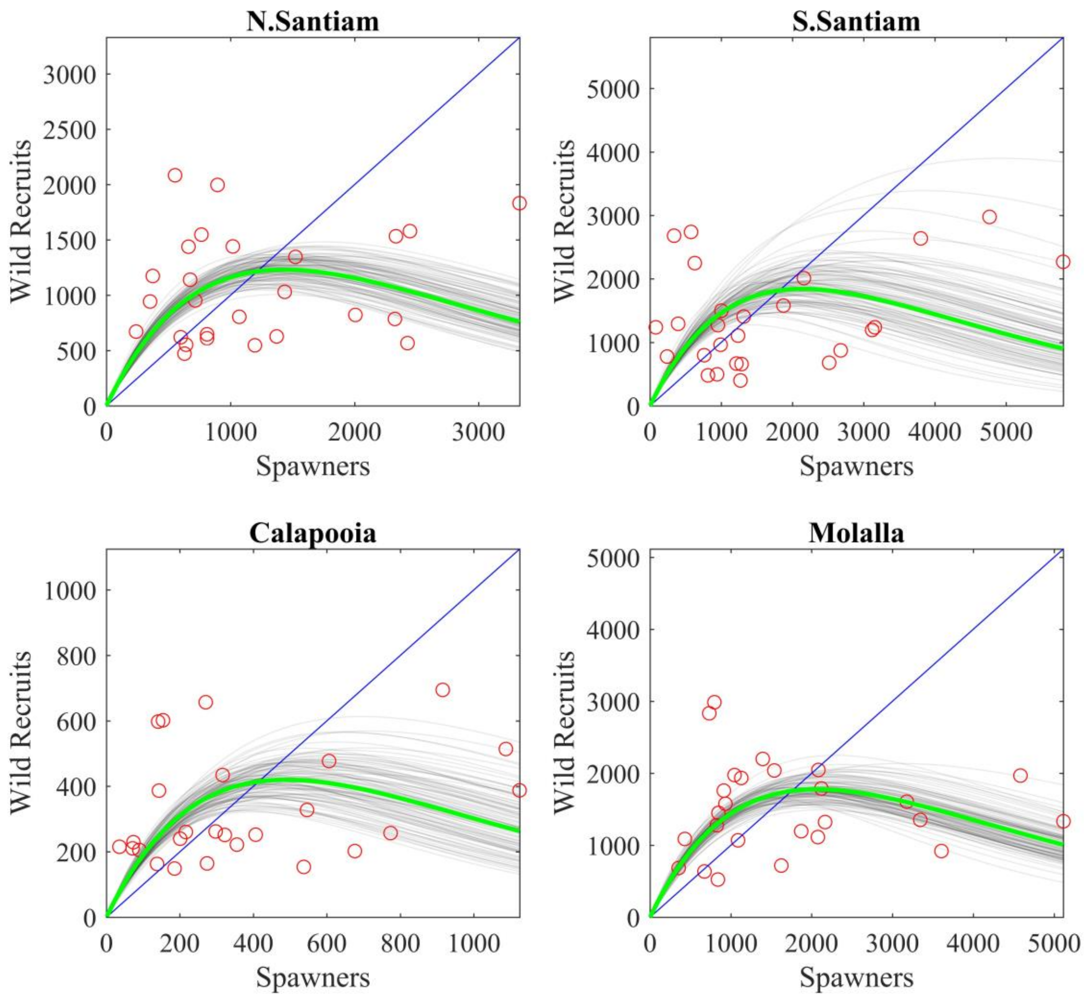


Figure 4. Spawner-recruit data and associated Ricker Model 3 fits. Thick green lines produced from the mean of the parameter posterior distribution. Thin grey lines produced from randomly chosen parameters in the posterior distribution. The blue diagonal line shows the 1:1 relationship between spawners and recruits.

PVA

The population viability analysis (PVA) model use here was also used in a previous assessment of coastal fall Chinook (ODFW 2011). The PVA is a computer model that uses information from the spawner-recruit analysis (see previous section) to project/simulate population abundances into the future. 100,000 repetitions of the 100-year simulation are conducted, and the fraction of these that result in an extinction event yields the probability of extinction. It is important to note that the word "extinction" refers to a population (i.e. "local extinction", or "extirpation"), not a species.

The PVA was ran under four different scenarios for each population. In the scenario called "No Sea Lions" (Table 1) it is assumed that there is no additional mortality beyond the incidental angling mortality during the adult life stage. This assumption holds for all 100 years in the simulation. The scenario called "2015 Sea Lions" perpetuates the lowest mortality rate observed since 2014 for all 100 years of the PVA simulation. The scenario called "2017 Sea Lions" perpetuates the highest mortality rate observed since 2014 for all 100 years of the PVA simulation.

The Ricker recruitment function that is fitted to each population (Model 3) is the model of intergenerational population dynamics that is used within the PVA to simulate spawner abundances through time. However, in the spawner-recruit analysis, "recruits" are defined as pre-angling and pre-sea lion adults. The very same inland mortality estimates that are used to estimate adult recruits from spawner abundances are also used by the PVA to convert adult recruits back into spawners. Indeed, the analytical steps used to estimate recruits for the spawner-recruit analysis are reversed inside the PVA. The PVA

1. takes a given spawner abundance on year t,
2. uses the recruitment function to compute adult recruits,
3. recruits are apportioned across years according to random permutations of the age composition data,
4. recruits are summed across ages within a year and then deflated by harvest rate sea lion mortality (if any).

A critically important aspect of all PVAs is the incorporation of stochasticty ("randomness"). Indeed, if stochasticity is neglected, then the steps outlined above would quickly result in static population and extinction risk would be zero. Stochasticity enters the PVA in several ways. First, the spawner-recruit data are ambiguous with respect to the parameters of the recruitment function (Figure 4). Thus, uncertainty in the estimates of recruitment parameters α and β are simulated within the PVA by repeating simulations with 1000 different values of α and β. The 1000 different values of α and β are selected in proportion to the probabilities of different values and their covariance. This is accomplished by fitting the Ricker spawner-recruit model with MCMC methods in a Bayesian context. Samples of the MCMC are saved, and the PVA randomly selects parameter values out of this pool.

The spawner-recruit data are not fully explained by the Ricker recruitment function, even though parameter uncertainty is acknowledged. In Figure 4, this can be seen as the vertical distances between spawner-recruit "points" and the line(s) representing the recruitment function(s). These "residual" deviations must also be simulated in the PVA. These residuals are lognormally distributed (note that the errors, ε, are exponentiated in the recruitment functions described above) and contain temporal autocorrelation. After the PVA receives a set of values for α and β, the variance of the errors is computed as well as the lag-1 autocorrelation of the errors. A 100-year time series of residual errors is then simulated using:

$$\varepsilon_t = \rho\varepsilon_{t-1} + \sqrt{\sigma^2}\sqrt{1-\rho^2}z_t \ ,$$

where ρ is the lag-1 autocorrelation of the errors, σ^2 is the variance of the errors, and z_t is a standard normal random deviate (Morris and Doak 2002, p. 139). These simulations are repeated 100 times for each of the 1000 random parameter draws. There are therefore 100*1000=100,000 repititions of a 100-year time series.

Extinction in the PVA model occurs when spawner abundance for four consecutive years falls below a "quasi-extinction threshold" (QET). A separate process called "reproductive failure threshold" (RFT) is used to zero-out recruitment at critically low spawner abundances. Both of these thresholds are implemented because processes like inbreeding depression, genetic drift, mate finding, and increased per-capita juvenile mortality will drive the population into extinction at critically low abundances. These negative density-dependent processes are very infrequently observed in nature, so they cannot be cannot be explicitly modeled. Collectively, both QET and RFT represent the boundary of an "extinction vortex" from which real populations are irrecoverable (Gilpin and Soulé1984, Courchamp et al. 2008, Jamieson and Allendorf 2012). The specific values used here are RFT=QET=100. The PVA counts the fraction of the 100,000 simulations where adult abundance falls below QET across 4 consecutive years.

The PVA model uses past abundances to infer extinction risk. Thus, the interpretation of the result is couched in the assumption that the conditions that were present when the data were collected will persist for 100 years. The model is not intended to capture effects of global warming, human population growth, or other anticipated future change. Of course, the future will not be like the past. Future food webs are uncertain, as is the adaptive potential of these fish. The purpose of the

PVA is not to forecast the future; rather, the PVA is a comparison of two different sea lion scenarios while holding everything else constant across scenarios.

The PVA needs to replicate observed patterns of variation in spawner abundance. A crude but effective method to determine if the PVA adequately captures observed population dynamics is to simply plot a randomly selected 100 year time series of simulated abundances and then superimpose the empirically observed/reconstructed abundances (Figure 4). This visual test indicates that the PVA performs well. It simulates abundances that are greater and less than the empirical abundances, the volatility of these deviations seems to match the volatility of the empirical

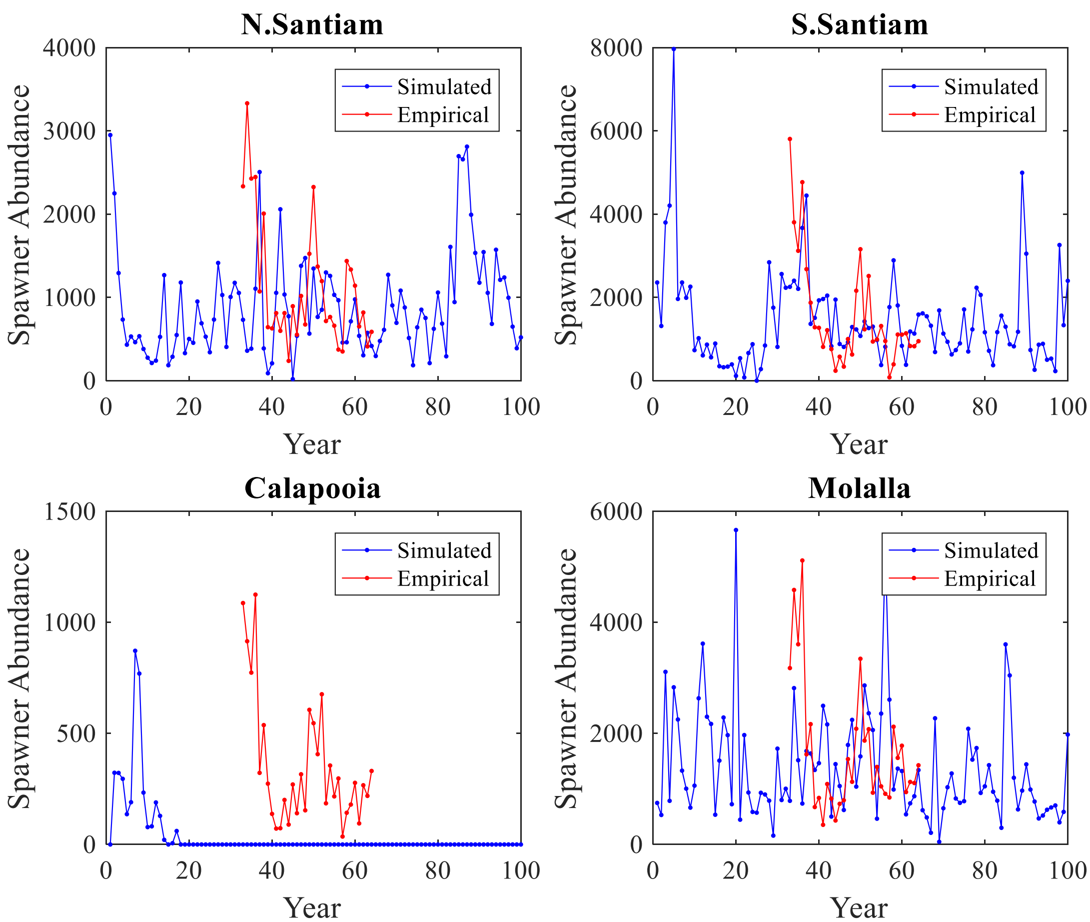


Figure 5. 100 year population simulation from the PVA (blue) with empirical spawner abundance (red). The PVA simulations of spawner abundances resembles the empirical time series.

abundances, and the average simulated abundance approximates the average of the empirical abundances.

References

Courchamp, F., L. Berec, and J. Gascoigne. 2008. Allee effects in Ecology and Conservation. Oxford University Press, Oxford, UK.

Gelman, A., Hwang, J., and Vehtari, A. 2014. Understanding predictive information criteria for Bayesian models. Statistics and computing 24: 997-1016.

Gilpin, M.E. and M.E. Soulé. 1984. Minimum viable populations: processes of species extinction. Pp 19-34 In Soulé, M.E. (Ed.). Conservation Biology: the science of scarcity and diversity. Sinauer, Sunderland, MA.

Hilborn, R., and Walters, C. J. 1992. *Quantitative Fisheries Stock Assessment: Choice, Dynamics & Uncertainty*. Routledge, Chapman & Hall

Jamieson, I.G. and F.W. Allendorf. 2012. How does the 50/500 rule apply to MVPs? Trends in Ecology and Evolution. 27:578-584.

Jepson, M.A. Keefer, M.L., Caudill, C.C., Clabough, T.S., and Sharpe, C.S. 2014. Migratory behavior, run timing, and distribution of radio=tagged adult winter steelhead, summer steelhead, and spring Chinook salmon in the Willamette River – 2013. Technical Report 2014-4 for U.S. Army Corps of Engineers.

Morris, W.F., and Doak, D.F. 2002. Quantitative Conservation Biology: Theory and practice of population viability analysis. Sinauer Associates.

ODFW 2008. Oregon Department of Fish and Wildlife. Upper Willamette River Conservation and Recovery Plan for Chinook Salmon and Steelhead. Appendix B: http://www.dfw.state.or.us/fish/CRP/docs/upper_willamette/UWR%20FRN2%20Master%20Appendix%20final.pdf

ODFW 2014. Oregon Department of Fish and Wildlife. Coastal Muli-Species Conservation and Management Plan. Appendix II: http://www.dfw.state.or.us/fish/CRP/docs/coastal_multispecies/CMP_main_final.pdf

Wright, B. Murtah, T., and Brown, R. 2014. Willamette Falls Pinniped Monitoring Project. http://www.dfw.state.or.us/fish/SeaLion/docs/Willamette%20Falls%202014%20sea%20lion%20report.pdf

Wright, B., Murtah, T., and Brown, R. 2016. Willamette Falls Pinniped Monitoring Project. http://www.dfw.state.or.us/fish/SeaLion/docs/Willamette_Falls_2016_sea_lion_report.pdf

APPENDIX 3: SPRING CHINOOK STATUS ASSESSMENT: MCKENZIE, CLACKAMAS, AND SANDY RIVER POPULATIONS

A memorandum to

Fish Division

Oregon Department of Fish and Wildlife

Submitted

June 6, 2018

Matt Falcy, PhD

Fish Conservation Biologist

Oregon Department of Fish and Wildlife

This document describes the results and methods of population status assessments of spring Chinook in the McKenzie, Clackamas, and Sandy Rivers. Trend analyses, spawner-recruit analyses, and population viability analyses are described below. All data and computer code used to generate these results are available online: https://falcy.weebly.com/chinook-pva.html.

Primary Results

Table 1 presents results of a spawner trend analysis. Table 2 presents the median and standard deviation of recruits per spawner. Table 3 presents results of a PVA analysis. The remainder of this document describes how these results were obtained.

***Table 1**. Spawner trends since 2002. Probabilities of decline in spawner abundance, point estimate of percent interannual change, and 95% highest probability density intervals around point estimates.*

	Population		
	McKenzie	Clackamas	Sandy
Probability of decline	0.998	0.34	0.02
Point Est of % annual change	-7.0	1.3	6.1
95% HPDI of % annual change	-11.1, -2.7	-5.2, 7.9	0.3, 11.9

***Table 2**. Recruits per spawner since spawn-year 2002 under three different assumptions about the relative reproductive success (RRS) of hatchery-origin fish on the spawning grounds.*

	Population								
	McKenzie			Clackamas			Sandy		
	RRS=1	RRS=0.5	RRS=0	RRS=1	RRS=0.5	RRS=0	RRS=1	RRS=0.5	RRS=0
Median	0.51	0.65	0.89	0.94	0.97	1.01	0.81	1.04	1.36
SD	0.25	0.29	0.35	0.55	0.58	0.63	0.50	0.50	0.59

***Table 3**. PVA results. Numerical entries are probabilities of quasi-extinction over a 100 year period. Scenarios include two different assumptions about the relative reproductive success (RRS) of hatchery-origin fish and two different statistical recruitment models. There is strong information-theoretic evidence that Model 2 is superior to Model 1. In the McKenzie, simulation scenarios included maximum observed California sea lion predation (CSL) and no California sea lion predation.*

	Population							
	McKenzie				Clackamas		Sandy	
	RRS=1		RRS=0.5		RRS=1	RRS=0.5	RRS=1	RRS=0.5
	Max CSL	No CSL	Max CSL	No CSL				
Model 1	0.35	0.23	0.28	0.22	0.007	0.006	0.010	0.004
Model 2	0.45	0.30	0.33	0.20	0.006	0.002	0.009	0.001

Overview

The purpose of this work is to assess the current population status of spring Chinook in the McKenzie, Clackamas, and Sandy River basins. The analyses are designed to facilitate comparisons among the populations on an "apples to apples" basis. Data prior to 2002 were not used because the proportion of hatchery-origin spawners in the McKenzie could not be reliably estimated, and the purpose of this work is to assess relatively contemporary conditions.

With a time series of spawner abundance, spawner age compositions, and mortality due to fishing and sea lions, it is possible to compute the adult recruits (progeny) associated with each year's spawner abundance. Density-dependence in these data was modeled with Ricker stock-recruitment functions. Two different Ricker models were used and information theoretic methods were used to determine the relative support in data for both models.

The Ricker models were fitted with Bayesian techniques in order to facilitate probabilistic interpretation of parameter estimates and their covariance. The estimated stock-recruitment relationship with parameter uncertainty and residual autocorrelation was combined with age composition and adult mortality data in order to project population dynamics through time in a population viability analysis (PVA). The PVA program takes 1000 random draws from the parameter posterior distribution of the stock recruitment model, and then replicates a 100-year time series 100 times. The total number of simulations where spawner abundance falls below a critical threshold across 4 consecutive year is divided by the total number of simulations (100,000). The result of this computation is the probability of quasi-extinction.

Relative Reproductive Success

• • •

Assessments of population status are focused on natural-origin fish. The presence of hatchery origin fish on the spawning grounds makes it difficult to know how much production is attributable to natural-origin fish. The relative reproductive success (RRS) of hatchery fish on the spawning grounds is therefore an important parameter. As RRS goes down, more and more production must be coming from natural-origin fish.

Scenarios in this assessment include different assumptions about the relative reproductive success (RRS, see inset) of hatchery fish, and effects of California sea lions (McKenzie population only).

Abundance Data

The abundance of natural and hatchery-origin spring Chinook in the in the Sandy and Clackamas rivers has been reported previously (ODFW 2017, Table 4). The McKenzie spring Chinook data were collated by the Willamette Salmonid Research, Monitoring, and Evaluation Program in ODFW. The abundance in the McKenzie River includes: (1) spawners above Leaburg Dam with a correction factor for fall back, (2) spawners below Leaburg Dam with a redd count expansion, and (3) spawners above and below Cougar Dam. Thus the entire McKenzie is treated as a single unit. For all populations, wild fish taken for broodstock are counted as recruits but not spawners.

Table 4. Basic abundance data used in this assessment. See also Figure 1.

	McKenzie		**Clackamas**		**Sandy**	
Year	Wild	Hatchery	Wild	Hatchery	Wild	Hatchery
2002	3361	1276	2140	948	919	201
2003	4178	1947	2633	730	871	125
2004	3982	1502	4051	1123	2416	88
2005	2135	832	1790	1092	1335	250
2006	2050	844	798	252	1070	114
2007	2562	1023	1175	480	1302	108
2008	1388	1044	1626	147	2722	2245
2009	1193	1347	754	64	856	965
2010	1265	2001	1251	90	1392	4686
2011	2511	1360	1588	178	1152	2287
2012	1769	1116	1729	101	2714	905
2013	1202	584	2133	101	1971	191
2014	1004	1049	915	69	1415	210
2015	1608	1268	2366	99	2728	219
2016	1716	1964	3376	104	3363	222
2017			3472	118		

Trend

Let the spawner abundance on year t, S_t, be a Poisson random variable:

$$p(S_t|\lambda) = \frac{\lambda^{N_t} e^{-\lambda}}{N_t!}.$$

Make the Poisson rate parameter, λ, a linear function of time on the log scale:

$$\lambda = e^{\alpha+\beta(t-\check{t})+\epsilon}.$$

The quantity $\check{t}$ is the midpoint of the time series, which simply centers the regressor to improve convergence. The quantity ϵ is zero-mean, normally distributed error:

$$p(\varepsilon|\sigma) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{\epsilon^2}{2\sigma^2}}.$$

Note that α and β play the roles of intercept and slope, respectively, in ordinary trend analysis. From here, we can define two additional quantities of interest. First, the predicted abundance is

$$\hat{S}_t = e^{\alpha+\beta(t-\check{t})+\frac{1}{2}\sigma^2}.$$

The term $\frac{1}{2}\sigma^2$ follows from probability theory used to translate the normal distribution across the log scale. The second quantity of interest is the geometric mean rate of interannual change (GMRIC). This is given on a percent scale by

$$GMRIC = 100\left(\left(\frac{S_{Tmax}}{S_{Tmin}}\right)^{\frac{1}{Tmax-Tmin}} - 1\right).$$

Box 1 provides the JAGS code used to fit the trend model described above. This model always has very nice convergence properties. A 95% highest probability density interval (HPDI) can be constructed from the posterior distribution of $\hat{S}_t$. Projecting the trend into the future is easily achieved by coding future observations of S_t as missing values (NA) and then making the Markov chain Monte Carlo simulation estimate them as parameters. Figure 1 gives the observed time series of spawner abundance and the 95% uncertainty envelope extrapolated into the future. Figure 2 presents the posterior distributions of GMRIC. Table 1 contains summary statistics of this trend analysis.

Trend Analysis

• • •

A trend analysis simply uses time as a predictor of abundance. Extrapolating a trend forward through time tacitly assumes that conditions do not change. Here, observed trends are extrapolated into the future merely to illustrate recent observations. The extrapolations are not predictions about future abundance.

Box 1. JAGS code used to fit trend model

```
model{
for (t in 1:Nyears){
    log(lambda[t])<- alpha + beta*(t-fixedyear)+epsilon[t]
    N[t]~dpois(lambda[t])
    epsilon[t]~dnorm(0,tau_epsilon)
    fitted[t]<-exp(alpha+beta*(t-fixedyear)+0.5*sd_epsilon*sd_epsilon)
  }
  ## Priors
  alpha~dnorm(0,1.0E-10)
  beta~dnorm(0,1.0E-6)
  #tau_epsilon~dgamma(0.001,0.001)#gamma used be be "uninformative" for tau
  tau_epsilon<-pow(sd_epsilon,-2) #tau=1/var
  sd_epsilon~dunif(0,6)#Gelman recommends uniform on SD

  ##Derived Params
  #sd_epsilon<-sqrt(1/tau_epsilon)
  B<-100*(pow(fitted[Nyears]/fitted[1],1/(Nyears-1))-1)
}
```

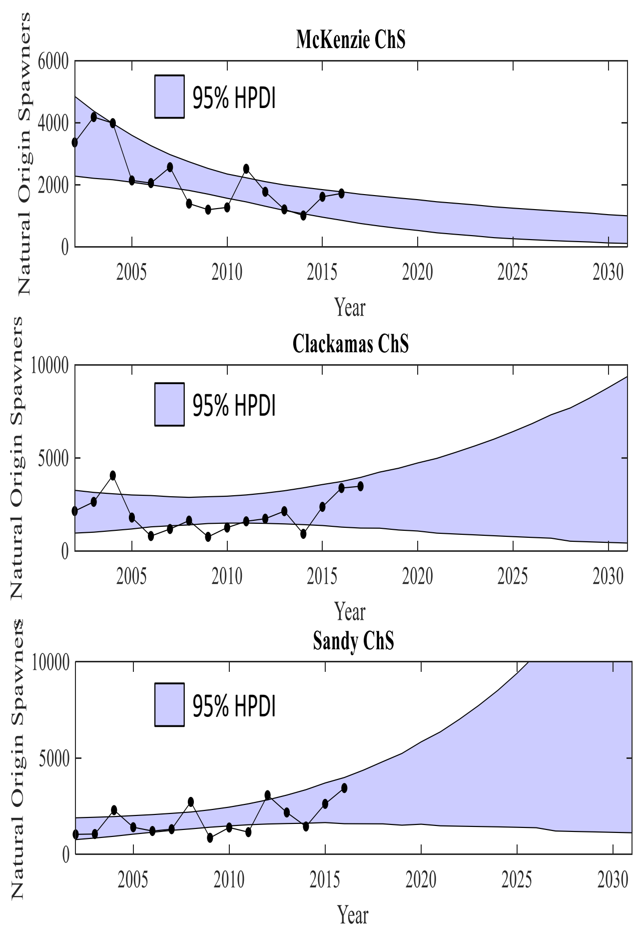


Figure 1. Trends through time in natural-origin spring Chinook spawners. Blue shaded area is a 95% highest probability density interval. See also Table 4.

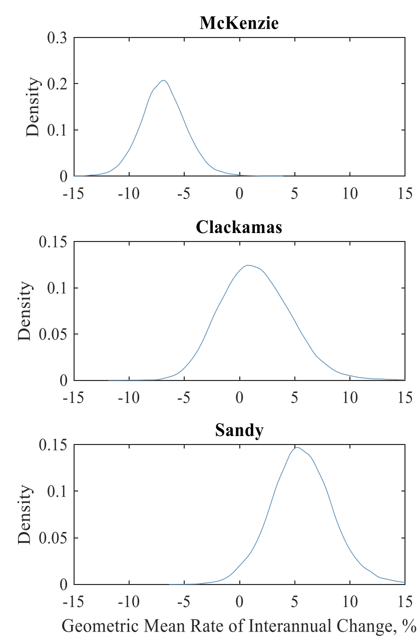


Figure 2. Posterior distributions of the annual rate of change in spawner abundance. The proportion of the area under each curve to the left of zero is the probability that the spawner abundance is declining during the period 2002-2016 (McKenzie and Sandy) or 2002-2017 (Clackamas). These probabilities are given in Table 1.

Mortality from Sea Lions- McKenzie

California sea lion predation on salmonids has been rigorously monitored by Wright et al. (2017) since 2014. Wright et al. (2017) note that the 2016 and 2017 estimates applied to just the “falls stratum” whereas monitoring in 2014 and 2015 included the fall and a “river stratum" just below the falls. Using information from years when both strata were monitored, it is possible to expand predation for 2016 and 2017 to include both strata. The resulting mortality of wild spring Chinook from 2014-2017 is: 496, 899, 1057, and 640. Dividing these mortality rates by spring Chinook abundances at the Willamette Falls counting window plus the estimates of mortality gives the "observed" mortality rates presented on the right-hand side of Figure 3.

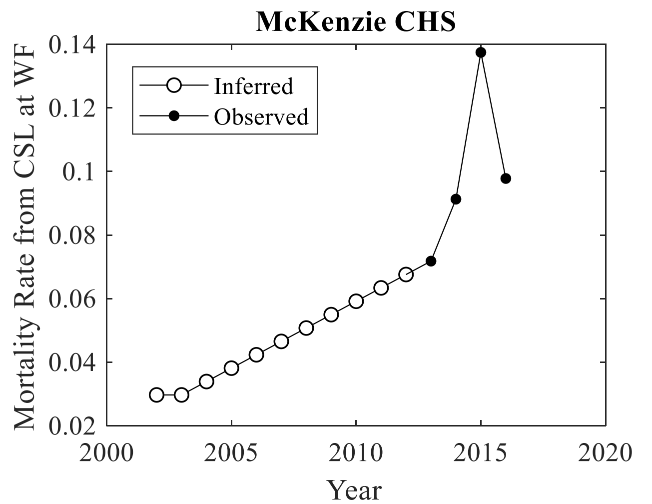


Figure 3. Estimated mortality rate of McKenzie Spring Chinook (CHS) from California sea lions (CSL) at Willamette Falls (WF).

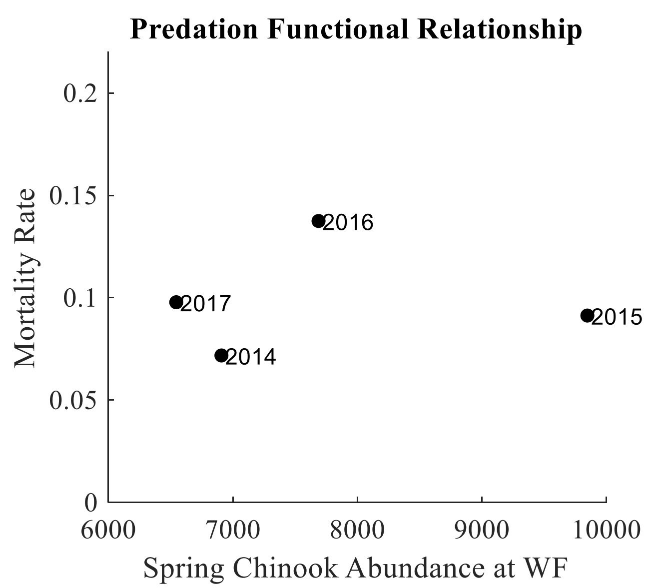


Figure 4. Mortality rate of spring Chinook at Willamette Falls (WF) from California sea lions does not appear to depend on the abundance of spring Chinook.

Wright et al. (2014) note that predation losses of salmonids were generally a few hundred or less at the Falls from the late 1990s through 2003. Starting with 150 salmonid mortalities, I first expand for river stratum and then deflated the estimate by the mean proportion of all the salmonid mortality during 2014-2017 that are wild spring Chinook (15%). This yields the number of wild spring Chinook taken per year during this early period. This number is then expressed as the proportion of observed contemporary mortality rate. A linear assumption was used to connect the early estimate of mortality rate to the to the 2014 estimate (left-hand side of Figure 3).

In the spawner-recruit analysis below, the mortality rate caused by sea lions on year *t* (denoted M_t below) is used to expand the recruits of McKenzie spring Chinook. The relationship between observed California sea lion predation rate on spring Chinook and the abundance of spring Chinook at Willamette Falls indicates a "Type I functional relationship" of predation (Figure 4). This relationship was used in the PVA for McKenzie spring Chinook.

Harvest

Freshwater harvest rates of wild spring Chinook in the Columbia and Willamette Rivers has been monitored since 2002 for compliance with the 2001 Fisheries Management and Evaluation Plan (ODFW 2017, Table 5). Incidental mortality on wild fish in the Sandy River was assumed to be 0.017 on all years. Total harvest rates for a population were computed as component products, reflecting the multiplicative survival process. For example, the freshwater harvest rate of McKenzie fish in 2017 is: 1- (1-0.014)*(1-0.001)*(1-0.024)*(1-0.001)*(1-0.002).

Table 5. Harvest rates used to compute recruits. From ODFW, 2017.

	Lower Columbia		Lower	Lower	Upper	
Year	Commercial	Recreational	Willamette	Clackamas	Willamette	McKenzie
2002	0.024	0.011	0.03	0.049	0.003	0
2003	0.011	0.012	0.024	0.008	0.003	0.054
2004	0.042	0.01	0.027	0.003	0	0.019
2005	0.02	0.007	0.03	0.005	0.001	0.007
2006	0.08	0.008	0.043	0.003	0.001	0.014
2007	0.027	0.008	0.042	0.001	0.001	0.013
2008	0.005	0.002	0.048	0.002	0.001	0.001
2009	0.015	0.008	0.036	0.002	0.001	0.013
2010	0.06	0.018	0.069	0.002	0.002	0.01
2011	0.047	0.006	0.062	0.002	0.001	0.011
2012	0.025	0.01	0.045	0.003	0.002	0.013
2013	0.046	0.005	0.028	0.003	0.001	0.008
2014	0.03	0.009	0.039	0.001	0.001	0.005
2015	0.034	0.007	0.04	0.001	0.001	0.004
2016	0.016	0.003	0.022	0.001	0.001	0.005
2017	0.014	0.001	0.024	0.003	0.001	0.002

Ocean harvest was not incorporated into this analysis. This means that "recruits" are defined as the abundance of fish entering the Columbia River. Ocean fishing is therefore treated as an unknown stochastic process exactly like natural ocean mortality. The consequence of this assumption is that the mean and variance of ocean harvest rates since 2002 is perpetuated into the PVA.

Age Composition of Spawners

Age of spawning fish was determined through scale analysis. Age composition has been previously reported by ODFW (ODFW 2016, Table 6). The matrix of proportions of fish at age = 1,2,3, ..6, on given years (t) is denoted $A_{t,a}$ in the recruitment calculations below.

***Table 6**. Age composition of spawners*

	McKenzie				Clackamas					Sandy			
Year	**Age3**	**Age4**	**Age5**	**Age6**	**Age3**	**Age4**	**Age5**	**Age6**	**Age7**	**Age3**	**Age4**	**Age5**	**Age6**
2002	0.01	0.69	0.30	0.00	0.00	0.59	0.39	0.02	0.00	0.00	0.46	0.51	0.03
2003	0.01	0.69	0.30	0.01	0.00	0.18	0.76	0.06	0.00	0.03	0.25	0.68	0.05
2004	0.01	0.54	0.45	0.00	0.00	0.45	0.53	0.02	0.00	0.00	0.74	0.25	0.00
2005	0.04	0.37	0.55	0.04	0.00	0.17	0.80	0.03	0.00	0.00	0.24	0.75	0.02
2006	0.00	0.68	0.30	0.02	0.00	0.49	0.47	0.04	0.01	0.01	0.41	0.57	0.01
2007	0.19	0.45	0.37	0.00	0.00	0.35	0.59	0.06	0.00	0.01	0.23	0.74	0.02
2008	0.24	0.64	0.11	0.00	0.01	0.35	0.61	0.03	0.00	0.00	0.43	0.55	0.02
2009	0.00	0.86	0.13	0.01	0.00	0.39	0.57	0.04	0.00	0.00	0.42	0.55	0.03
2010	0.14	0.57	0.29	0.00	0.01	0.32	0.63	0.04	0.00	0.05	0.43	0.51	0.00
2011	0.04	0.85	0.11	0.00	0.01	0.42	0.56	0.02	0.00	0.03	0.59	0.36	0.02
2012	0.06	0.52	0.40	0.02	0.01	0.34	0.60	0.05	0.00	0.00	0.55	0.43	0.02
2013	0.10	0.79	0.11	0.01	0.04	0.18	0.76	0.02	0.00	0.02	0.32	0.64	0.02
2014	0.11	0.62	0.26	0.01	0.09	0.59	0.30	0.01	0.00	0.03	0.51	0.46	0.01
2015	0.14	0.77	0.09	0.00	0.05	0.72	0.22	0.02	0.00	0.06	0.67	0.26	0.01
2016	0.15	0.61	0.25	0.00	0.03	0.57	0.40	0.00	0.00	0.07	0.66	0.27	0.00

Spawner-Recruit Analysis

The abundance of naturally produced ("wild") adult recruits associated with fish spawning on year t is

$$R_{S(t)} = \sum_{a=1}^{6} A_{t+a,a}\left(\frac{S_{t+a} * (1 - pHOS_{t+a})}{(1 - HR_{t+a}) * (1 - M_t)}\right).$$

From here it is possible to fit nonlinear models of the relationship between recruits and spawners. Errors in such models are customarily lognormal, reflecting the multiplicative survival processes that gives rise to uncertainty in the number of recruits. Summary statistics of recruits per spawner are given in Table 2.

Bayesian methods were adopted for recruitment modeling for two related reasons. First, Bayesian analysis uniquely yields probabilistic interpretation of parameters. Second, the Markov chain Monte Carlo (MCMC) methods used to fit Bayesian models allow parameter uncertainty to be easily folded into a PVA simulations. JAGS software was used to run the MCMC. JAGS called from MATLAB using matjags.m.

Ricker models were used to model spawner-recruit relationships (Table 7). Data from all three populations were combined into a "single" recruitment model. Two such models were constructed that make different assumptions about the error (Table 7). Model 1 assumes all parameters are unique to each population. Model 1 is equivalent to fitting a model to each population separately. Model 2 assumes there is a single error variance shared by all three populations, but each population has a unique productivity (α) and rate of compensatory density dependence (β). It is technically possible to construct a model that assumes that productivity is identical across populations. This may be prudent in many circumstances. However, this was not done here because there is an explicit focus on potential differences between populations and because there are significant geographical and hydrological differences between populations.

In both models, diffuse (noninformative) uniform priors were used for α (Unif(0.001,20)), β (Unif(0,0.1)), and the standard deviation ε (Unif(0,4)). Four MCMC chains per model were ran. The first 35,000 iterations were discarded as a "burn-in" period, and 10,000 samples per chain were retained after thinning 1:13 samples from the MCMC. Trace plots of the MCMC were visually inspected for signs of mixing and convergence. Extremely good estimates of

Table 7. Two Ricker recruitment models fitted to three populations of spring Chinook spawner-recruit data. The models make different assumptions about the number and structure of necessary parameters. Subscripts p and t denote population and time (year), respectively. WAIC measures relative out-of-sample predictive performance.

ID	Model	# Params	WAIC
1	$R_{t,p} = \alpha_p S_{t,p} e^{-\beta_p S_{t,p}} e^{\epsilon}, \epsilon \sim N(0, \sigma_p)$	9	466
2	$R_{t,p} = \alpha_p S_{t,p} e^{-\beta_p S_{t,p}} e^{\epsilon}, \epsilon \sim N(0, \sigma)$	6	481

the Gelman-Ruben diagnostic ($\hat{R} = 1 \mp 0.0001$) were obtained.

Watanabe-Akaike Information Criterion (WAIC) can be used to assess the relative out-of-sample predictive performance of Bayesian models (Gelman, Whang, and Vehtari, 2013). Each iteration of the MCMC yields a draw from the multidimensional posterior distribution. This parameter vector can be used to compute the probability density of each datum in the data set. This produces I-by-S matrix of densities, where I is the number of data points, and S is the arbitrary number of MCMC samples in the posterior. Armed with this matrix, the computed log pointwise predictive density is

$$lppd = \sum_{i=1}^{I} log\left(\frac{1}{S}\sum_{s=1}^{S} p(y_i|\theta^s)\right).$$

A correction for effective number of parameters to adjust for overfitting is obtained with

$$pwaic = \sum_{i=1}^{I} V_{s=1}^{S}(\log p(y_i|\theta^s)),$$

where V is the sample variance. Thus *pwaic* is just the posterior variance (across MCMC iterations) of the log predictive density for each data point, summed over all data points, and

WAIC = -2*(*lppd*-*pwaic*).

The units of WAIC can be interpreted like the more familiar AIC and DIC. Specifically, smaller values indicate better models. Model 2 is 15 units less than Model 1 (Table 7), indicating that it is a significantly superior model. The fit of Ricker Model 2 to the spawner-recruit data is given in Figure 5. Uncertainty in Ricker parameters gives rise to multiple potential recruitment functions. Random

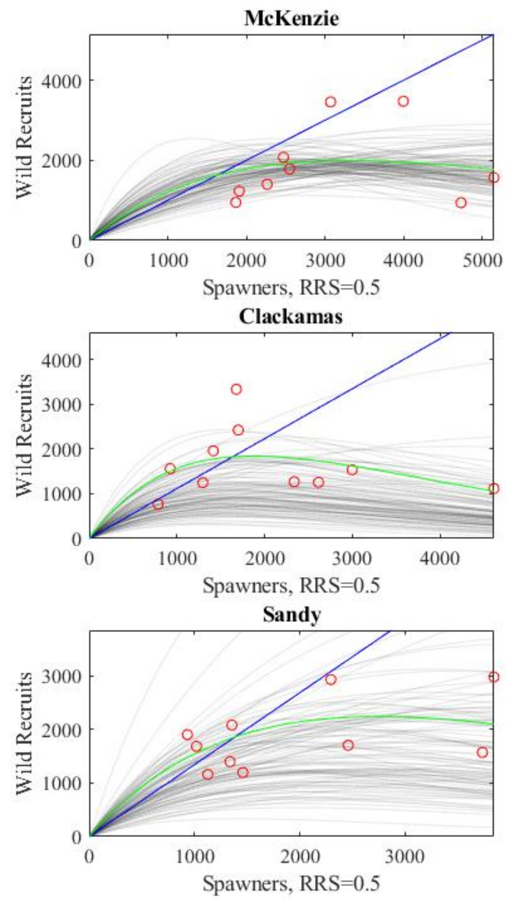


Figure 5. Spawner-recruit data and associated Ricker Model 2 fits, assuming the relative reproductive success (RRS) of hatchery fish is 0.5. Thick green lines produced from the mean of the parameter posterior distribution. Thin grey lines produced from randomly chosen parameters in the posterior distribution. The blue diagonal line shows the 1:1 relationship between spawners and recruits.

draws from the MCMC output ensures that parameter values and parameter covariance are obtained in proportion to the associated posterior probability densities.

PVA

The population viability analysis (PVA) model use here was also used in a previous assessment of coastal fall Chinook (ODFW 2014) and Willamette winter steelhead (Falcy 2017). The PVA is a computer model that uses information from the spawner-recruit analysis (see previous section) to project/simulate population abundances into the future. 100,000 repetitions of the 100-year simulation are conducted, and the fraction of these that result in an extinction event yields the probability of extinction. It is important to note that the word "extinction" refers to a population (i.e. "local extinction", or "extirpation"), not a species.

The PVA was ran under different scenarios for each population. In the scenario called "No CSL" (Table 3) it is assumed that there is no additional mortality beyond the incidental angling mortality during the adult life stage. This assumption holds for all 100 years in the simulation. The scenario called "Max CSL" perpetuates the highest mortality rate observed since 2014 for all 100 years of the PVA simulation.

The Ricker recruitment function that is fitted to each population is the model of intergenerational population dynamics that is used within the PVA to simulate spawner abundances through time. However, in the spawner-recruit analysis, "recruits" are defined as pre-angling and pre-sea lion adults. The very same inland mortality estimates that are used to estimate adult recruits from spawner abundances are also used by the PVA to convert adult recruits back into spawners. Indeed, the analytical steps used to estimate recruits for the spawner-recruit analysis are reversed inside the PVA. The PVA

5. takes a given spawner abundance on year t,
6. uses the recruitment function to compute adult recruits,
7. recruits are apportioned across years according to random permutations of the age composition data,

Population Viability Analysis

• • •

Population viability analysis (PVA) can be broadly defined as the use of quantitative methods to predict the future status of populations under defined conditions or scenarios. Here, a PVA is used to determine the probability of quasi-extinction over a 100 year period. The PVA scenarios explore different assumptions about RRS and the effects of sea lions at Willamette Falls (McKenzie only).

8. recruits are summed across ages within a year and then deflated by harvest rate and sea lion mortality (if any).

A critically important aspect of all PVAs is the incorporation of stochasticty ("randomness"). Indeed, if stochasticity is neglected, then the steps outlined above would quickly result in static population and extinction risk would be zero. Stochasticity enters the PVA in several ways. First, the spawner-recruit data are ambiguous with respect to the parameters of the recruitment function (Figure 5). Thus, uncertainty in the estimates of recruitment parameters α and β are simulated within the PVA by repeating simulations with 1000 different values of α and β. The 1000 different values of α and β are selected in proportion to the probabilities of different values and their covariance. This is accomplished by fitting the Ricker spawner-recruit model with MCMC methods in a Bayesian context. Samples of the MCMC are saved, and the PVA randomly selects parameter values out of this pool.

The spawner-recruit data are not fully explained by the Ricker recruitment function, even though parameter uncertainty is acknowledged. In Figure 5, this can be seen as the vertical distances between spawner-recruit "points" and the line(s) representing the recruitment function(s). These "residual" deviations must also be simulated in the PVA. These residuals are lognormally distributed (note that the errors, ε, are exponentiated in the recruitment functions described above) and contain temporal autocorrelation. After the PVA receives a set of values for α and β, the variance of the errors is computed as well as the lag-1 autocorrelation of the errors. A 100-year time series of residual errors is then simulated using:

$$\varepsilon_t = \rho\varepsilon_{t-1} + \sqrt{\sigma^2}\sqrt{1-\rho^2}z_t ,$$

where ρ is the lag-1 autocorrelation of the errors, σ^2 is the variance of the errors, and z_t is a standard normal random deviate (Morris and Doak 2002, p. 139). These simulations are repeated 100 times for each of the 1000 random parameter draws. There are therefore 100*1000=100,000 repetitions of a 100-year time series.

Extinction in the PVA model occurs when spawner abundance for four consecutive years falls below a "quasi-extinction threshold" (QET). A separate process called "reproductive failure threshold" (RFT) is used to zero-out recruitment at critically low spawner abundances. Both of these thresholds are implemented because processes like inbreeding depression, genetic drift, mate finding, and increased per-capita juvenile mortality will drive the population into extinction at critically low abundances. These negative density-dependent processes are very infrequently observed in nature, so they cannot be cannot be explicitly modeled. Collectively, both QET and RFT represent the boundary of an "extinction vortex" from which real populations are irrecoverable (Gilpin and Soulé1984, Courchamp et al. 2008, Jamieson and

Allendorf 2012). The specific values used here are RFT=QET=100. The PVA counts the fraction of the 100,000 simulations where adult abundance falls below QET across 4 consecutive years.

The PVA model uses past abundances to infer extinction risk. Thus, the interpretation of the result is couched in the assumption that the conditions that were present when the data were collected will persist for 100 years. The model is not intended to capture effects of global warming, human population growth, or other anticipated future change. Of course, the future will not be like the past. Future food webs are uncertain, as is the adaptive potential of these fish. The purpose of the PVA is not to forecast the future; rather, the PVA is useful for comparing the current status among populations and for comparing scenarios

The PVA needs to replicate observed patterns of variation in spawner abundance. A crude but effective method to determine if the PVA adequately captures observed population dynamics is to simply plot a randomly selected 100 year time series of simulated abundances and then superimpose the empirically observed/reconstructed abundances (Figure 6). This visual test indicates that the PVA performs well. It simulates abundances that are greater and less than the empirical abundances, the volatility of these deviations seems to match the volatility of the empirical abundances, and the average simulated abundance approximates the average of the empirical abundances.

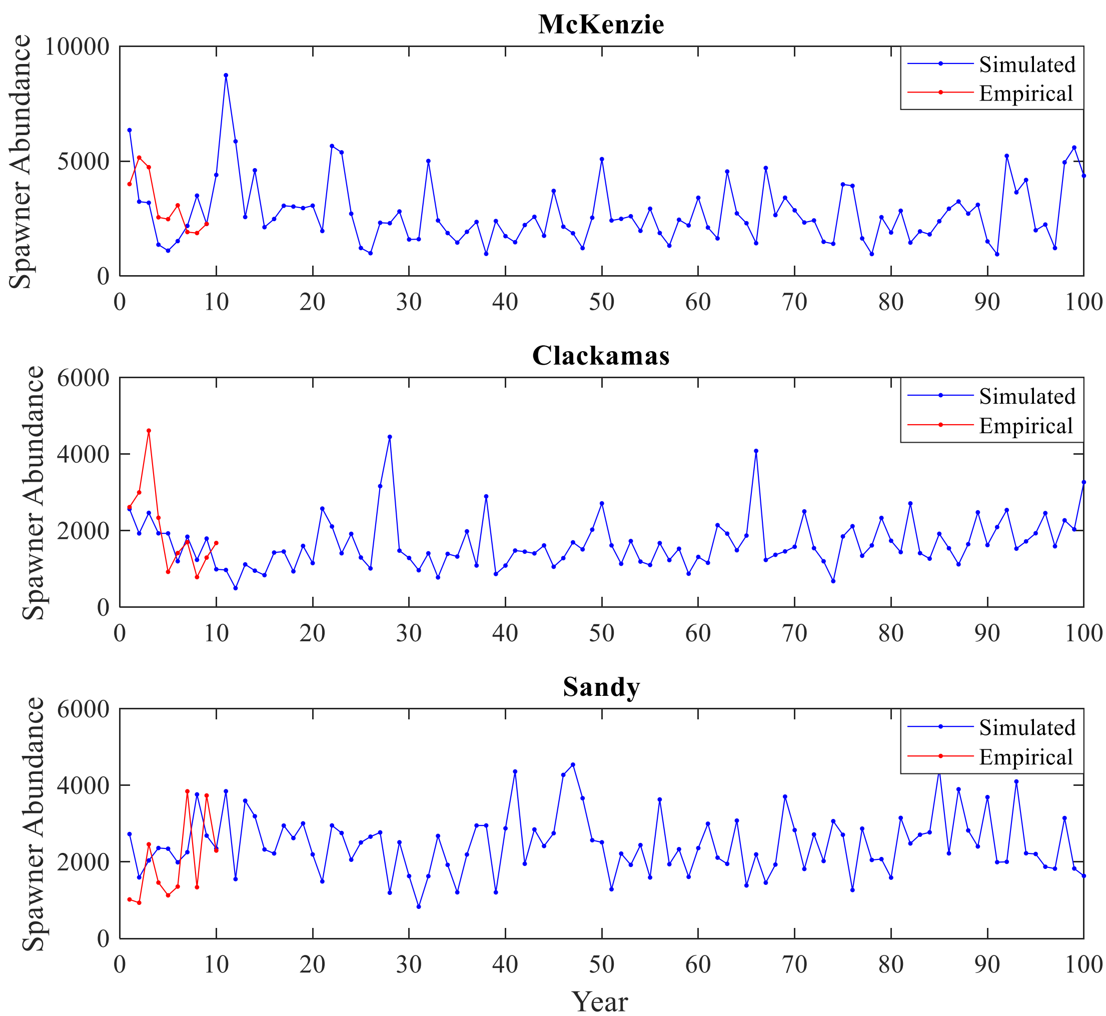


Figure 6. 100 year population simulation from the PVA (blue) with empirical spawner abundance (red). The PVA simulations of spawner abundances resembles the empirical time series.

Uncertainty

The PVA produces a single number- the probability of quasi-extinction over 100 years. There are no confidence intervals. A confidence envelope could have been constructed if only the point estimate of the recruitment function had been used. However, in this Bayesian analysis, it is possible to describe parameter uncertainty probabilistically. Parameter uncertainty collapses into the final extinction probability by repeating PVA runs while sampling parameters from the posterior.

Simulations are repeated because there are stochastic processes that create alternative outcomes. This form of uncertainty can be made arbitrarily small simply by increasing the amount of simulation replication. Simulation uncertainty is on the order of the decimal degrees of rounding in Table 3.

Model uncertainty is addressed in Table 7 with WAIC. Table 3 presents the PVA results of Model 1 to demonstrate sensitivity to model choice. Information theoretic evidence indicates that Model 2 is much superior. Of course, there are other potential models of these data that others could elaborate if they are interested.

Discussion

It is noteworthy that there is only one year since 2002 when McKenzie spring Chinook recruitment exceeded replacement (Figure 5). There are no data points to support the model assumption that recruitment in the McKenzie exceeds replacement at low spawner abundances. Indeed, there is very little evidence for density dependence for these fish. If a density independent PVA had been used, then extinction would be guaranteed and average time to the extinction would be the metric output. The results presented here are conservative in the sense that survival of McKenzie spring Chinook are assumed to increase when spawner abundance is very low. If this is not the case, then extinction risk is actually much worse.

Acknowledgements

Luke Whitman provided critical insights into some of the data used here.

References

Courchamp, F., L. Berec, and J. Gascoigne. 2008. Allee effects in Ecology and Conservation. Oxford University Press, Oxford, UK.

Falcy, M.R. 2017. Population Viability of Willamette River Winter Steelhead: An assessment of the effects of sea lions at Willamette Falls. https://falcy.weebly.com/uploads/1/1/4/9/114983925/willamettesthd.pdf

Gelman, A., J. Hwang, and A. Vehtari. 2014. Understanding predictive information criteria for Bayesian models. Statistics and computing 24: 997-1016.

Gilpin, M.E. and M.E. Soulé. 1984. Minimum viable populations: processes of species extinction. Pp 19-34 In Soulé, M.E. (Ed.). Conservation Biology: the science of scarcity and diversity. Sinauer, Sunderland, MA.

Jamieson, I.G. and F.W. Allendorf. 2012. How does the 50/500 rule apply to MVPs? Trends in Ecology and Evolution. 27:578-584.

Morris, W.F., and D.F. Doak. 2002. Quantitative Conservation Biology: Theory and practice of population viability analysis. Sinauer Associates.

ODFW 2014. Oregon Department of Fish and Wildlife. Coastal Multi-Species Conservation and Management Plan. Appendix II: http://www.dfw.state.or.us/fish/CRP/docs/coastal_multispecies/CMP_main_final.pdf

ODFW 2016. Oregon Department of Fish and Wildlife. Progress Report: Spring Chinook Salmon in the Willamette and Sandy Basins. https://odfw.forestry.oregonstate.edu/willamettesalmonidrme/sites/default/files/2016_sandy_basin_spring_chinook_spawning_survey.pdf

ODFW 2017. Oregon Department of Fish and Wildlife. Fisheries Management and Evaluation for 2017 Willamette River Spring Chinook.

Wright, B., T. Murtagh, and R. Brown. 2014. Willamette Falls Pinniped Monitoring Project. http://www.dfw.state.or.us/fish/SeaLion/docs/Willamette%20Falls%202014%20sea%20lion%20report.pdf

Wright, B., T. Murtagh, R. Brown, and S. Riemer. 2017. Willamette Falls Pinniped Monitoring Project, 2017. https://www.dfw.state.or.us/fish/sealion/docs/Willamette_Falls_2017_sea_lion_report.pdf

APPENDIX 4: PARAMETER VALUES FOR THE BIOENERGETICS MODEL TO ESTIMATE EXPECTED BENEFIT

Steelhead size
Normally distributed with mean = 10 lbs, SD = 1.7 lbs
Source: winter steelhead data collected by University of Idaho at the Willamette Falls adult trap in 2012-2014
ED (energy density): random uniform variable: 5-9 kJ/g wet mass (source: Winship et al. 2002)

Chinook size
Normally distributed with mean = 14.3 lbs, SD = 2.6 lbs
Source: spring Chinook weights from CRITFC passing Bonneville April-May 2004-2007
ED: random uniform variable: 5-9 kJ/g wet mass (source: Winship et al. 2002)

Sturgeon size
Normally distributed with mean = 4 ft, SD = 0.7 ft
Weight estimated based on length weight formula with end result of mean = 38.1 lbs, SD = 19.1 lbs
Source: combination of USACE length estimates of fish consumed by Steller sea lions at Bonneville Dam and ODFW length-weight formula
ED: 4.4 kJ/g wet mass (source: Peter Stevens, ODFW)

Eulachon size
Mean (constant) = 0.09 lbs (11.1 fish/lb)
Source:
https://www.westcoast.fisheries.noaa.gov/publications/protected_species/other/eulachon/section_6_eulachon_final_report_20140922.pdf
ED: mean = 9.97 kJ/g, SD = 1.1 kJ/g (source: Sigler et al. 2004)

Other Fish Species
For ‘other’ species in diet, the model uses a uniform random variable for ED of 3-11 kJ/g.

California sea lions
Normally distributed weight with mean = 600 lbs, SD = 100 lbs

Steller sea lions
Normally distributed weight with mean = 1200 lbs, SD = 267 lbs