WILLAMETTE FALLS PINNIPED MONITORING PROJECT, 2014

August 22, 2014

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INTRODUCTION

California sea lions (*Zalophus californianus*) are seasonal migrants in the Pacific Northwest, generally arriving around August and departing by the following June. With few exceptions, the majority of California sea lions in the Pacific Northwest are juvenile and adult males, whereas females and young generally stay in the breeding range in California and Mexico (Odell 1981). California sea lions typically occur at upriver sites such as Bonneville Dam and Willamette Falls only in the spring, peaking around late April and early May (Wright et al. 2010, Stansell et al. 2013).

While archaeological data indicate that California sea lions were present along the Oregon coast during at least the last 3,000 years (Lyman 1988), there is no similar archaeological evidence of their presence in the lower Columbia River or its tributaries (Lyman et al. 2002). In contrast, there is abundant evidence of harbor seals (*Phoca vitulina*) in the lower Columbia River that date back 10,000 years. Until recently, Steller sea lions (*Eumetopias jubatus*) were the dominant sea lion species in the Pacific Northwest and harbor seals were the most commonly observed pinniped in the lower Columbia River (Pearson and Verts 1970). Prior to enactment of the Marine Mammal Protection Act (MMPA) in 1972, Oregon and Washington had bounties in place in an effort to keep pinniped populations low, and a seal hunter was employed to drive pinnipeds out of the Columbia River until 1970 (Pearson and Verts 1970). By the mid-1970s, observations of California sea lions in the Pacific Northwest began to increase but they were still relatively uncommon in the lower Columbia River until the mid- to late-1980s (Beach et al. 1985).

By the early 1990s, several hundred California sea lions were regularly found in the Astoria area, hauling out on jetties, floats, and navigation markers (Washington Department of Fish and Wildlife (WDFW), Oregon Department of Fish and Wildlife (ODFW), unpublished data). At that time, sea lions were foraging in the lower river to near Wallace Island (river mile 48), often targeting salmonids (*Oncorhynchus* spp.) caught in nets during commercial gillnet fishing seasons. However, these sea lions also 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).

In the mid-1990s observations of California sea lions in the Willamette River and at Willamette Falls (128 miles upstream from the ocean) began to increase. By the late 1990's roughly a dozen California sea lions were regularly found foraging for winter steelhead and spring Chinook below the fishways at Willamette Falls. Concerned that this would result in another "Ballard Locks"—a site in Washington where California sea lions effectively extirpated a run of steelhead (*Oncorhynchus mykiss*) (Fraker and Mate 1999)—ODFW began monitoring sea lion occurrence and predation on salmonids at the Falls beginning spring 1995. Continuing through 2003, results from these observations showed that sea lions at the Falls generally numbered a dozen or fewer animals each year, and predation losses were generally a few hundred or less (see Appendix A). In addition, the trend in predation activity appeared to be flat or declining while the winter steelhead runs were increasing. Monitoring at the Falls was discontinued after 2003 due to a shift in limited resources to Bonneville Dam on the Columbia River, where, in contrast, newly occurring sea lion predation on salmonids was increasing and beginning to number in the thousands (Naughton et al. 2011, Keefer et al. 2012, Stansell et al. 2013).

While not subject to monitoring from 2004-2008, anecdotal reports from Willamette Falls continued of sea lions predating on salmonids there each spring. Beginning in 2009, students from Portland State University (PSU) began conducting observations at the Falls as part of a field studies class. It was soon clear from PSU's observations that an increase in predation activity by California sea lions was occurring below the Falls. With increased pinniped abundance came increased damage to docks where sea lions hauled out, increased angler frustration and safety risk from sea lions stealing hooked fish, and increased noise from 'barking' California sea lions.

Low winter steelhead passage above the Falls in 2008 and 2009 (Appendix A), coupled with the increase in sea lion activity, led ODFW to test hazing techniques in 2010, and implement hazing projects in 2011 and 2013 in an attempt to deter sea lions from consuming threatened winter steelhead near the fish ladder entrances at Willamette Falls. While hazing was effective at moving California sea lions downstream away from the fish ladder entrances, once hazing stopped predator activity would resume. In addition, it is unknown whether hazing had any significant effect on the total predation rate on winter steelhead. Hazing was discontinued after 2013 in order to shift the agency's limited resources to a new monitoring effort focused on obtaining estimates of predation at this location. In contrast to previous monitoring efforts, the 2014 program was based on a probabilistic sampling design which covered not only the Willamette Falls tailrace and fish ladder entrances, but also the stretch of river from the Falls downstream to the mouth of the Clackamas River. This report summarizes that project.

METHODS

Study area

The study area was located from Willamette Falls on the Willamette River, downstream to the mouth of the Clackamas River (Figure 1). Willamette Falls is located 42 km (26 mi) upriver from the confluence with the Columbia River and 206 km (128 mi) from the ocean. It is the largest waterfall in the Pacific Northwest by volume and the 17th widest in the world.

Pinniped species accounts

Three species of pinnipeds are known to occur seasonally at Willamette Falls: California sea lions, Steller sea lions, and Pacific harbor seals. The U.S. stock of California sea lions is not listed as "threatened" or "endangered" under the Federal Endangered Species Act (ESA), nor as "depleted" or "strategic" under the MMPA (Carretta et al. 2013). The population has been growing at 5.4% per year and is estimated to number approximately 300,000 animals. Steller sea lions have been observed rarely at the Falls, albeit more frequently in recent years. Steller sea lions in Oregon belong to the eastern Distinct Population Segment (DPS), which was delisted as "threatened" under the ESA in 2013. Pacific harbor seals, while abundant throughout coastal

Oregon and the lower Columbia River, are relatively rare and inconspicuous visitors to upriver sites such as Bonneville Dam and Willamette Falls.

Fish species accounts

Fish species principally preyed upon by pinnipeds at Willamette Falls include winter and summer steelhead, spring Chinook salmon (*Oncorhynchus tschawytscha*), Pacific lamprey (*Entosphenus tridentatus*), and white sturgeon (*Acipenser transmontanus*). With the exception of the non-indigenous summer steelhead, all of these species are of conservation concern and two—naturally spawning winter steelhead and spring Chinook—are listed as "threatened" under the ESA.

All naturally produced winter-run steelhead populations in the Willamette River and its tributaries above Willamette Falls to the Calapoolia River are part of the ESA-listed Upper Willamette River (UWR) steelhead DPS (ODFW and National Marine Fisheries Service (NMFS) 2011). These fish pass Willamette Falls from November through May, co-occurring with introduced summer steelhead which pass the Falls from March through October. Almost all summer steelhead are unlisted hatchery-origin fish.

All naturally produced populations of spring Chinook salmon in the Clackamas River and in the Willamette Basin upstream of Willamette Falls are part of the ESA-listed UWR Chinook Evolutionary Significant Unit (ESU) (ODFW and NMFS 2011). These fish pass Willamette Falls from about April to August and co-occur with a more abundant run of hatchery-origin spring Chinook. The hatchery-produced spring Chinook are the target of economically and culturally important fisheries in the lower Columbia and Willamette rivers, part of which takes place in the study area below Willamette Falls.

Migrating salmonids pass Willamette Falls by entering one of four entrances to three fishways through the Falls. Video cameras and time lapsed video recorders are used to record fish passage which is later reviewed to produce passage counts. Salmonid species are partitioned to run (e.g., winter/summer, wild/hatchery) based on passage date and the presence or absence of a hatchery fin clip.

Sampling design

While pinnipeds can consume small prey underwater they usually must surface to manipulate and consume larger prey such as an adult salmonid (Roffe and Mate 1984). We utilized this aspect of their foraging behavior (i.e., surface-feeding), in conjunction with statistical sampling methods (e.g., Lohr 1999) to estimate the total number of adult salmonids consumed by sea lions over a given area and time frame.

The variable of interest was a surface-feeding event (also referred to as a predation event) whereby a sea lion was observed to capture, kill, and/or commence consuming prey within a prescribed spatio-temporal observation unit. We assumed that the probability of detecting an event, given that it occurred, was one. Surface-feeding observations were conducted from shore. Observers conducted observations by visually scanning a prescribed area with unaided vision and 10 x 42 binoculars. For each predation event, observers recorded the time, site, sea lion species, prey species, and whether the fish may have been taken from an angler.

Observers followed a schedule of when and where to observe based on a probability sample generated from a stratified, three-stage cluster design, with repeated systematic samples at each stage (see Appendix B for a simplified description of the design; see Lohr 1999 and Scheaffer et al. 1990 for background on sampling; see Wright et al. 2007 for implementation of this design elsewhere). The first stage or primary sampling units (PSUs) were "days of the week" (i.e., Sunday, Monday, etc.). The second stage or secondary sampling units (SSUs) were "site-shifts" within a day. The third stage or tertiary sampling units (TSUs) were 30-min observation bouts within a site-shift. Due to constraints imposed by work schedules (e.g., lunch breaks, days off), some deviations from a truly randomized design were unavoidable. However, since there is no reason that sea lion foraging behavior should vary systematically with observer breaks or days off, then imposing some restrictions on randomization is unlikely to introduce bias into estimation.

The spatial component of the sampling frame consisted of twelve sites divided into two spatial strata (Figure 1). Sites 1-3 (stratum 1) were each approximately 1-ha in area and occur immediately below the Falls where predation activity was presumed to be highest. Sites 4-12 (stratum 2) were each approximately 4.5-ha in area and occurred from the Falls to the mouth of the Clackamas River. The temporal component of the sampling frame consisted of daylight hours between 0700 and 1800 (11 hrs), with a temporary ½-hr shift to compensate for the change to daylight savings time (Figure 2). The sampling frame spanned 13 weeks from March 3 to June 1.

There were 1895 half-hour observation units in the sample out of a sampling frame of 24,024 units (i.e., 91 days × 22 half-hr observation bouts per day × 12 sites = 24,024). The overall sampling fraction was 7.9% of the frame. Sampling weights in stratum one and two were 6.53 and 18.67, respectively (i.e., each observed fish kill was multiplied by the appropriate weight in order to estimate total predation). Based on extensive pilot testing of the design against simulated data it was anticipated that the salmonid predation estimate would have a percent coefficient of variation (CV) of less than 10% (as a "rule-of-thumb", estimates with CVs over 33% are considered unreliable).

It should be noted that non-sampling errors are often a greater source of uncertainty than sampling errors (see Lohr 1999 for overview of non-sampling errors). In this study, the non-sampling error of greatest concern is likely that of undercoverage (see Figure 2). If pinniped predation on salmonids occurred in February or June, and/or outside the 0700 to 1800 sampling window, then the estimate of total predation would be underestimated.

Assignment of "salmonid" predation events to run

Since it is sometimes difficult to differentiate steelhead from Chinook during a predation event (e.g., due to long distance, viewing angle, short duration of event), and usually difficult to differentiate winter from summer steelhead or hatchery from wild, predation events involving salmonids were assigned to a 'run' (winter/summer steelhead, wild/hatchery Chinook) using one of two conceptual models. Each model was based on fish passage window counts where fish were identified to run based on date and the presence or absence of hatchery fin clips. Since extensive radio telemetry studies in the Columbia and Snake Rivers by Keefer et al. (2004) showed that most adult salmonids pass dams in less than 2 days we used a one-day lag for both models.

The first approach ("Model 1") ignored field observer identification to steelhead or Chinook and probabilistically assigned salmonids to one of the four runs (winter/summer steelhead, wild/hatchery Chinook) based on the run composition at the fish counting window on the following day. For example, if a salmonid was killed on Monday and the window count composition on Tuesday was 90% winter steelhead, 5% summer steelhead, 4% hatchery Chinook, and 1% wild Chinook, then the observed kill would be assigned to a run based on a metaphorical toss of a 100-sided die where 90 sides were winter steelhead, 5 were summer steelhead, etc.

The second approach ("Model 2") used the field observer identification to either steelhead or Chinook (when available) and probabilistically assigned steelhead to winter/summer, and Chinook to wild/hatchery based on their respective run composition at the fish counting window on the following day. For example, if a steelhead was killed on Monday and the window count composition for steelhead on Tuesday was 50% winter and 50% summer, then the observed kill would be assigned to a run based on a metaphorical fair coin toss. In the case of "unknown" salmonids, fish were assigned to run based on the approach described for Model 1.

Each model was run 1000 times and the means were computed for total predation, standard error, CV, and 95% confidence intervals. Predation rates were calculated for the four runs based on total run passage through August 15, 2014. Rates were calculated as the predation total divided by the sum of the window count plus the predation total.

Additional activities

The sampling design was implemented using a crew of four staff, working 8 hours a day, five days a week. Training and orientation occurred during the last two weeks of February with data collection beginning the first week of March. Due to the nature of random sampling, as well as limits on how long one can sustain intense concentration, not all hours of every day were devoted to conducting sample-based observations. Any time not needed for sample-based observations was used for data entry, conducting anecdotal observations (e.g., targeting sites with high predation rates or potential for interactions with the fishery), conducting haul-out counts, collecting sea lion scat, photographing brands, and cross-training.

RESULTS AND DISCUSSION

Observations

At least 27 California sea lions, two Steller sea lions, and one harbor seal were observed during the study, including at least 19 branded animals (Table 1). These numbers, however, represent only a fraction of the true number of pinnipeds that occurred at the Falls since it was usually not possible to keep track of unmarked animals over the course of the study. Not surprisingly, the majority of branded sea lions at the Falls this year had been seen in previous years at the Falls or Bonneville Dam, including two that occurred at both places this year (Figure 3). Over one-quarter of branded animals at the Falls this season were on the list of animals authorized for permanent removal under Oregon's MMPA Section 120 Letter of Authorization from NMFS.

Observers documented a total of 1,110 predation events over the course of the project (Table 2). This includes predation events seen at pre-assigned, sample-based observation units, as well as anecdotal observations. Salmonids were the most frequently observed prey item (86.5%) followed by lamprey (11.4%), unknown or other fish (1.6%), and sturgeon (0.5%). California sea lions accounted for nearly all of the observed predation events (99.6%) as Steller sea lions occurred only occasionally early in the season. Steller sea lions accounted for three of the six sturgeon killed and one salmonid.

Surprisingly, only three observed predation events (0.3%) were of fish stolen from anglers in the fishery. All were anecdotal observations of Chinook salmon taken by California sea lions in either site 7 or 8. While it may be that observers were unable to always determine whether a fish was stolen from anglers, conversations with anglers suggest that fishery interactions were lower than last year, perhaps due to the absence of hazing at the Falls which may have had the effect of pushing sea lions into the fishery.

Predation estimates

An estimated 3,690 salmonids were consumed by sea lions over the 12 sites from March 3 to June 1, 2014 (Table 3). The only other prey for which sufficient observations were made for reliable estimation was lamprey, of which sea lions consumed an estimated 493 individuals. The estimated number of sturgeon killed was 56 but the large CV of 70% indicates that the estimate is unreliable.

Design-based predation estimates were based solely on sampling units from the stratified, three-stage cluster sampling design and do not include anecdotal observations. The 95% confidence intervals in Table 3 reflect the sampling error in the estimates, which arises from taking a sample rather than a census of a population. A different sample would have produced a different estimate and confidence interval, but 95 times out of 100 the procedure will correctly capture the true population total within the interval.

Non-sampling errors in the form of missing data occurred on three days: May 12, May 26, and May 30. The last two days were due to the Memorial Day holiday and the final day of the season when administrative work was required. Missing data from these two days were likely inconsequential as nearly all sea lions had previously migrated from the Falls by that time. Missing data on May 12 resulted from a crew scheduling error and resulted in seven observation units being missed. This likely resulted in missed predation and thus contributed to a small underestimate in total predation.

Predation estimates by run

Daily salmonid run composition and associated river conditions are presented in Figure 4. Winter steelhead dominated returns in March, followed by hatchery Chinook and summer steelhead during April and May. Two notable dips in Chinook passage occurred in late April and early May due to brief decreases in river temperature and spikes in river levels associated with significant rain events.

Estimates of salmonid predation by run (winter/summer steelhead, wild/hatchery Chinook) for salmonid assignment Models 1 and 2 are presented in Tables 4 and 5, respectively. In general, results from the two conceptual models were similar, differing by only one or two percentage points when expressed as percent of the run taken. However, given that the field crew was experienced at salmonid identification we chose Model 2 as the basis for further analyses. For Model 2 (Table 5), estimated winter steelhead predation was 797 adult fish or approximately 13% of the potential escapement above the Falls. For wild spring Chinook, estimated predation was 535 adult fish or 8% of the potential escapement above the Falls.

Predation estimates by site and week

While the sampling design was not structured to provide precise estimates of predation by site or week, it is possible to calculate such subpopulation or "domain" estimates (see Lohr 1999 for details on domain estimation). These are presented for site (Table 6) and week (Table 7). Note, however, that large or incalculable CVs indicate unreliable estimates.

As expected, the spatial distribution of salmonid kills was skewed toward stratum 1 (Table 6). Predation hot spots occurred near the base of individual waterfalls and shifted up or downriver based on river flows (e.g., during high flows predation was concentrated in site 4 whereas when flows dropped it shifted upriver to sites 1 and 2). In contrast to steelhead predation, which was almost exclusively upstream of site 6, at least some Chinook predation occurred across all 12 sites, albeit with the majority occurring in stratum 1.

Similarly, the temporal distribution of salmonid kills was as one would expect, with the majority of winter steelhead predation occurring early in the season, and summer steelhead and Chinook predation occurring later in the season (Table 7). Lamprey predation occurred throughout the season but was concentrated in the latter half of the study.

Conclusions and recommendations

Despite differences in monitoring methodology over the years, the results from 2014 support the conclusion that a substantial increase in pinniped abundance and predation has occurred at the Falls since the late 1990s and early 2000s. Estimated salmonid predation at Willamette Falls in 2014 even surpassed salmonid take by California sea lions at Bonneville Dam in each of the past several years (see Stansell et al. 2013). It should be noted too that predation totals from this study are underestimates due to undercoverage of the target population. Nonetheless, further monitoring is necessary in order to determine whether 2014 was an unusually high year or whether it represents a point on an increasing trend.

Recommendations for future monitoring include starting earlier in the year and earlier each day in order to account for the two most likely sources of undercoverage. Given limited funding, an earlier start date could be accomplished by reducing the spatial coverage of the study, such as eliminating some of the downriver sites. Other recommendations include: trapping, marking, and possibly re-locating sea lions; expanding efforts to document sea lion abundance and residency rates throughout the Willamette River; and reducing or eliminating haul-out space near the Falls (e.g., at Sportcraft Marina).

Initiating limited sea lion trapping and marking at the Falls is particularly important in order to further document individual sea lion presence and foraging behavior. Under current federal law, knowing sea lions as individuals is a prerequisite to undertaking management (such as at Bonneville Dam) should it be deemed necessary. Furthermore, limited trapping operations at the Falls may provide an opportunity to take sea lions that are already authorized for removal, of which there were five at the Falls this year.

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Figure 1. Illustration of spatial components of Willamette Falls Pinniped Monitoring Project study design. Sites 1-3 (stratum 1) are each approximately 1-ha in area and Sites 4-12 (stratum 2) are each approximately 4.5-ha in area.

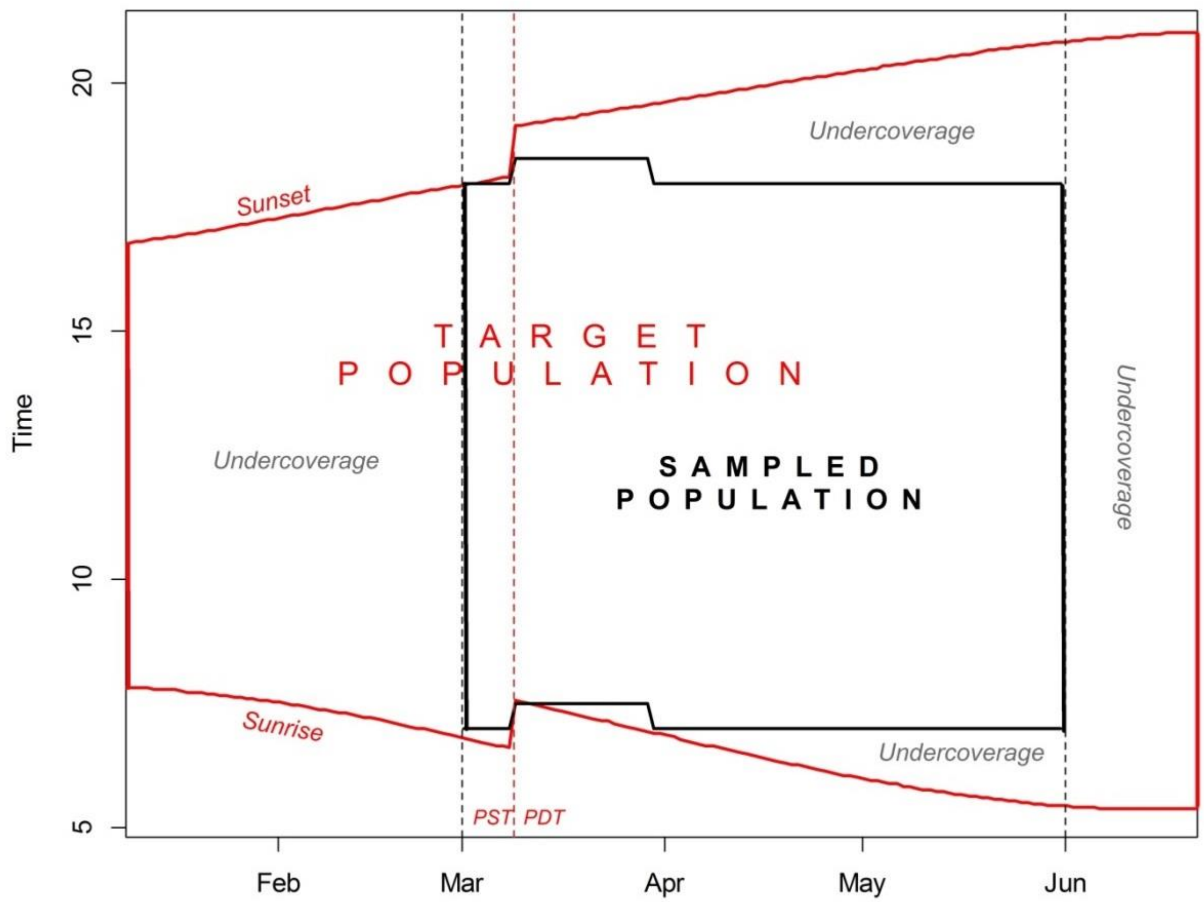

Figure 2. Illustration of temporal components of Willamette Falls Pinniped Monitoring Project study design. The 13-week, 11-hr per day sampling frame constitutes the "sampled" population (black polygon) whereas all daylight hours when sea lions are present constitutes the "target" population (red plolygon). Differences between the target and sampled population are termed "undercoverage" and represent potential for underestimation of total predation.

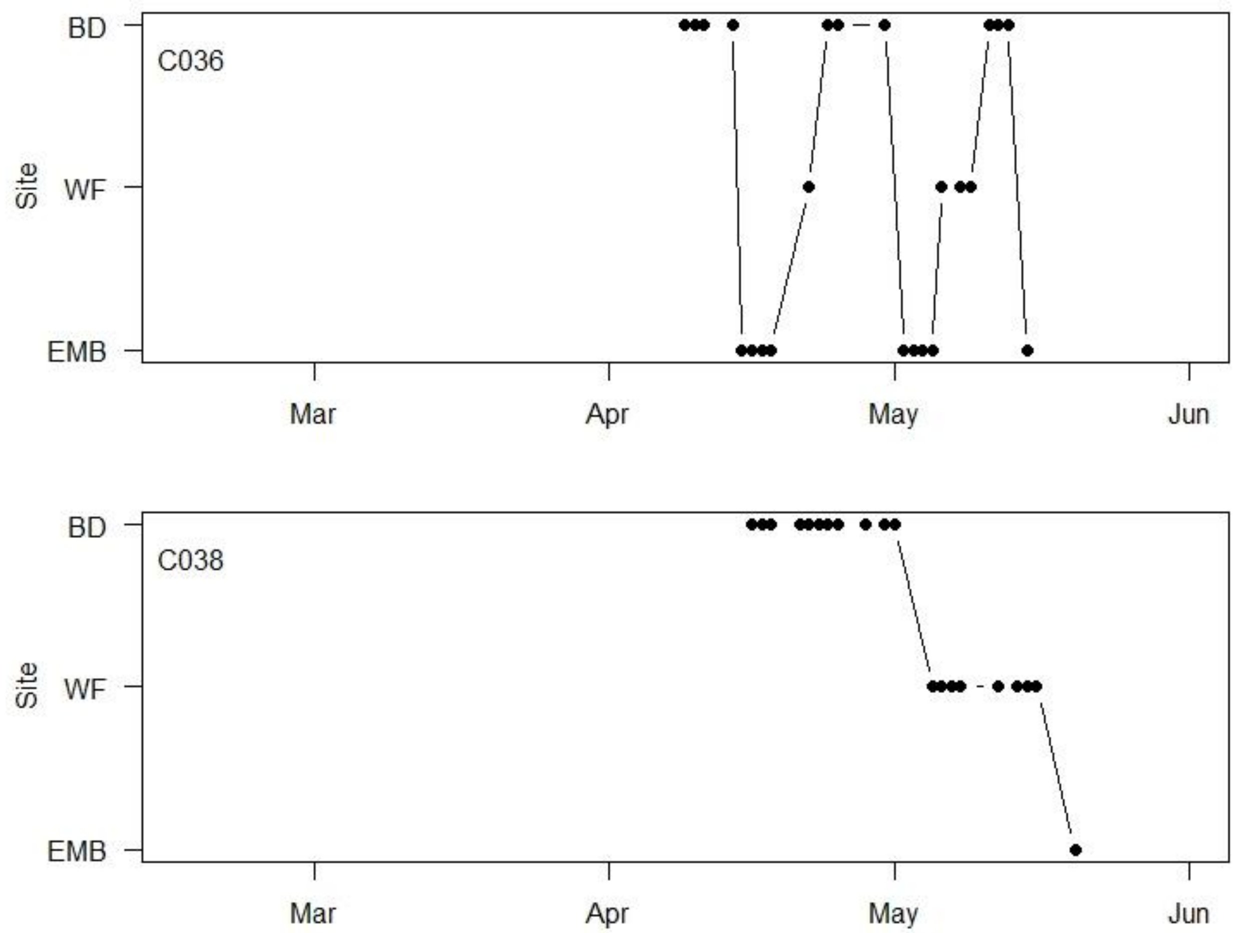

Figure 3. Movement summaries of two California sea lions—C036, C038—that were known to occur at multiple sites* during the study.

*BD=Bonneville Dam, WF=Willamette Falls, EMB=East Mooring Basin, Astoria. See inset of Figure 1 for map of locations.

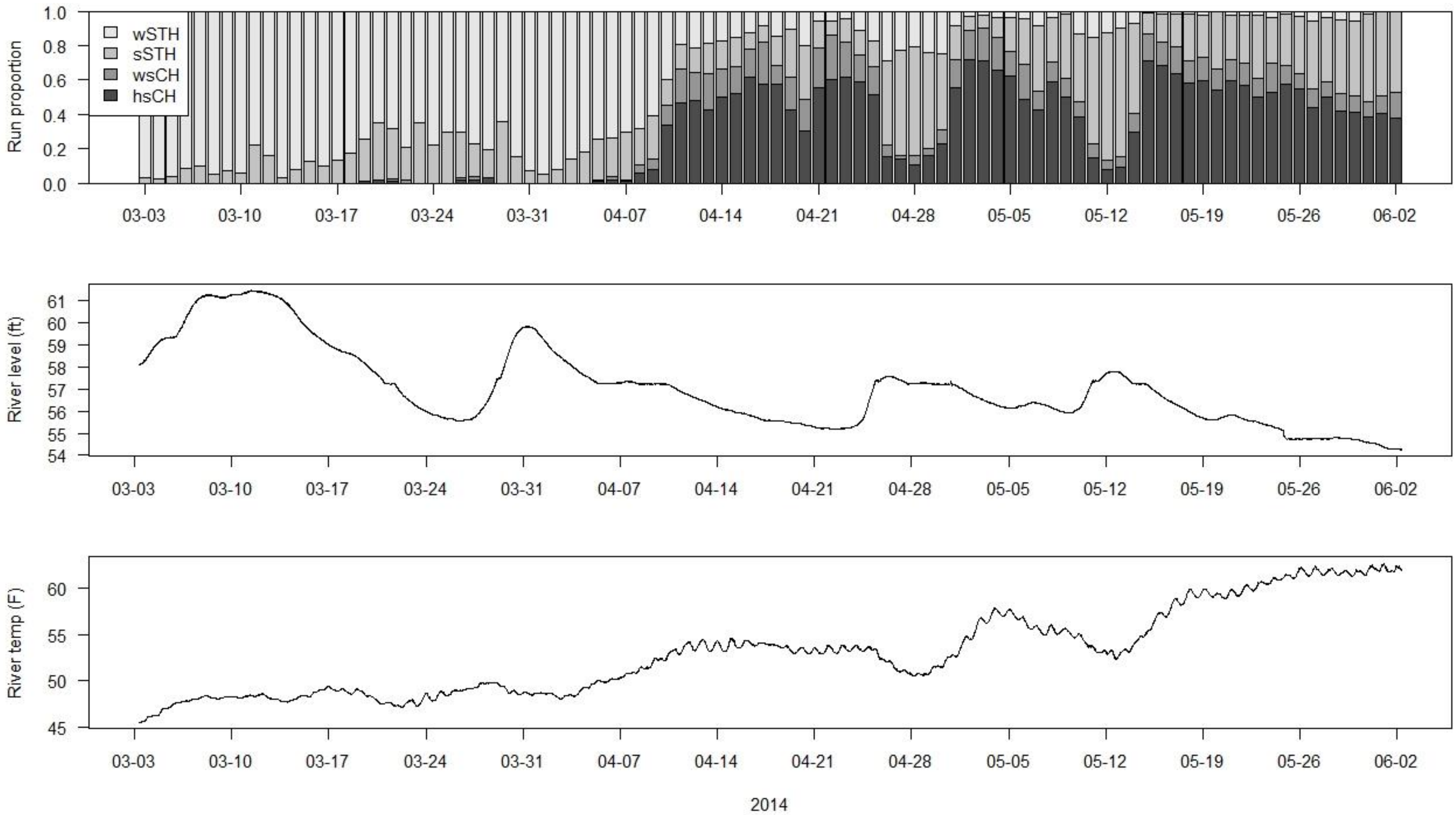

Figure 4. Summary of daily run composition* based on counts at Willamette Falls (top panel), river level based on gage above Willamette Falls (middle panel), and water temperature based on gage at Newberg (bottom panel).

*wSTH=winter steelhead, sSTH=summer steelhead, wsCH=wild spring Chinook, hsCH=hatchery spring Chinook.

Table 1. Summary of observations for branded California sea lions at Willamette Falls Study area, 2014.

Brand	First seen*	Last seen	Duration	Days seen	Observed salmonid kills	Seen previously		On Section 120 removal list
						Willamette Falls	Bonneville Dam	
U117	2/19/2014	5/15/2014	85	38	15	Yes	Yes	
C742	2/24/2014	5/1/2014	66	34	31	Yes		
C010	2/25/2014	5/12/2014	76	29	5	Yes	Yes	Yes
U65	2/25/2014	5/6/2014	70	23	9	Yes	Yes	
C885	3/3/2014	5/9/2014	67	35	18	Yes		
U278	3/3/2014	5/6/2014	64	23	3	Yes		
C257	3/5/2014	5/9/2014	65	19	5	Yes	Yes	Yes
U253	3/13/2014	5/1/2014	49	22	15	Yes		
C942	3/26/2014	5/19/2014	54	32	26	Yes		
U110	3/27/2014	5/12/2014	46	22	20		Yes	
U449	4/4/2014	5/28/2014	54	24	8			
U190	4/7/2014	5/12/2014	35	9	0			
U404	4/9/2014	5/5/2014	26	9	0			
U163	4/10/2014	5/9/2014	29	16	12			
U78	4/15/2014	5/16/2014	31	14	4			
C025	4/16/2014	5/20/2014	34	12	0	Yes	Yes	
C036	4/22/2014	5/9/2014	17	4	0		Yes	Yes
C026	4/23/2014	5/19/2014	26	15	8		Yes	Yes
C038	5/5/2014	5/16/2014	11	8	1		Yes	Yes

*Part-time field observations began 2/19/2014; full-time observations began 3/3/2014.

Table 2. Summary of all predation events observed below Willamette Falls from February 25 to May 29, 2014. Includes events from anecdotal observations as well as those seen during assignments from stratified, three-stage cluster sampling design.

Prey	California sea lion	Steller sea lion	Total
Chinook	527	0	527
Steelhead	399	1	400
Unknown salmonid	33	0	33
Lamprey	126	0	126
Sturgeon	3	3	6
Unknown fish	17	0	17
Other	1	0	1
Total	1,106	4	1,110

Table 3. Summary of estimated predation below Willamette Falls based on stratified, three-stage cluster sampling design (anecdotal observations are not included).

Prey	Observed predation	Estimated predation	Standard error	Coefficient of variation	95% confidence interval	
					Lower bound	Upper bound
Salmonids	381	3,690	188	5%	3,322	4,059
Lamprey	68	493	67	14%	361	624
Sturgeon	3	56	39	70%	6*	133

*Lower bound for sturgeon was negative and was therefore replaced with the observed number killed from Table 2.

Table 4. Salmonid assignment model 1: salmonid predation proportional to next day window counts. Means for total, standard error (SE), percent coefficient of variation (CV), and lower and upper bounds (LB, UB) from 95% confidence intervals (95CI) are presented from 1000 runs of the model. Run size and predation as percent of run size (i.e., predation/(predation + run size))*100) are also presented for estimated totals and confidence intervals.

	Predation						Predation as % of run		
Prey	Total	SE	CV	95CI LB	95CI UB	Run size	Total	95CI LB	95CI UB
Winter steelhead	906	130	14%	653	1160	5,349	14%	11%	18%
Summer steelhead	797	99	12%	603	991	21,299*	4%	3%	4%
Spring Chinook-wild	453	73	16%	310	597	6,412	7%	5%	9%
Spring Chinook-hatchery	1,533	169	11%	1,202	1,865	23,659	6%	5%	7%

* Run size as of August 15.

Table 5. Salmonid assignment model 2: observer-identified steelhead and Chinook predation proportional to next day window counts for winter/summer steelhead and marked/unmarked Chinook, respectively. Means for total, standard error (SE), percent coefficient of variation (CV), and lower and upper bounds (LB, UB) from 95% confidence intervals (95CI) are presented from 1000 runs of the model. Run size and predation as percent of run size (i.e., predation/(predation + run size))*100) are also presented for estimated totals and confidence intervals.

	Predation						Predation as % of run		
Prey	Total	SE	CV	95CI LB	95CI UB	Run size	Total	95CI LB	95CI UB
Winter steelhead	797	106	13%	590	1,004	5,349	13%	10%	16%
Summer steelhead	620	115	19%	395	845	21,299*	3%	2%	4%
Spring Chinook-wild	535	79	15%	381	689	6,412	8%	6%	10%
Spring Chinook-hatchery	1,738	150	9%	1,445	2,031	23,659	7%	6%	8%

* Run size as of August 15.

Table 6. Domain estimates for total predation by site based on salmonid assignment model 2.

Site	Winter steelhead	CV	Summer steelhead	CV	Spring Chinook-wild	CV	Spring Chinook-hatchery	CV	Lamprey	CV
1	68	33%	95	24%	128	24.6%	375	16%	118	22%
2	136	25%	93	38%	51	34.9%	178	22%	209	22%
3	109	26%	133	21%	101	28.0%	376	30%	92	21%
4	245	32%	221	47%	68	NA	249	35%	37	97%
5	161	42%	44	NA	57	NA	149	48%	0	NA
6	60	NA	15	NA	9	NA	28	NA	19	97%
7	0	NA	0	NA	22	NA	72	74%	0	NA
8	17	NA	2	NA	20	NA	54	NA	0	NA
9	0	NA	0	NA	15	NA	60	NA	0	NA
10	0	NA	0	NA	39	NA	110	52%	0	NA
11	2	NA	17	NA	3	NA	16	NA	0	NA
12	0	NA	0	NA	21	NA	72	NA	19	97%

Table 7. Domain estimates for total predation by week based on salmonid assignment model 2.

Statistical week	Winter steelhead	CV	Summer steelhead	CV	Spring Chinook-wild	CV	Spring Chinook-hatchery	CV	Lamprey	CV
10 (3/3/2014)	155	47%	9	NA	0	NA	0	NA	26	37%
11 (3/10)	37	NA	7	NA	0	NA	0	NA	0	NA
12 (3/17)	191	38%	56	NA	0	NA	0	NA	33	58%
13 (3/24)	117	36%	48	NA	12	NA	15	NA	13	62%
14 (3/31)	46	67%	11	NA	3	NA	3	NA	6	92%
15 (4/7)	95	44%	52	NA	26	NA	56	44%	33	48%
16 (4/14)	24	NA	34	NA	150	31%	509	23%	45	50%
17 (4/21)	11	NA	15	NA	114	34%	320	22%	104	42%
18 (4/28)	89	53%	203	52%	118	39%	407	24%	83	39%
19 (5/5)	28	NA	138	30%	62	NA	243	29%	38	58%
20 (5/12)	5	NA	41	37%	33	NA	116	32%	59	36%
21 (5/19)	0	NA	6	NA	16	NA	68	36%	52	38%
22 (5/26)	0	NA	0	NA	0	NA	0	NA	0	NA

Appendix A. Summary of pinniped monitoring at Willamette Falls from 1995 to 2013.

		Sea lion sighting[3]		Monitoring[4]					Max 1-day total[8]		Observed predation[9]			
Year[1]	Observers[2]	First	Last	Start	End	Area[5]	Obs Days[6]	% SL present[7]	CSL	SSL	SAL	LA	STG	W. STH run[10]
1995	ODFW	Feb	24-May	1-May	28-May	Falls	10	60%	4	0	15	0		4,693
1996	ODFW	2-Apr	4-May	2-Apr	31-May	Falls	46	57%	4	0	89	26		1,801
1997	ODFW	9-Apr	15-May	1-Apr	23-May	Falls	48	69%	4	0	164	1		4,544
1998	ODFW	25-Mar	15-May	26-Mar	4-Jun	Falls	62	65%	3	0	144	23		3,678
1999	ODFW	2-Mar	19-May	16-Mar	28-May	Falls	56	66%	3	0	164	6		6,904
2000	ODFW	3-Feb	1-Jun	7-Feb	9-Jun	Falls	87	47%	3	0	141	11		4,761
2001	ODFW	22-Mar	18-May	27-Mar	2-Jun	Falls	50	42%	2	0	34	4		12,525
2002	ODFW	4-Apr	15-May	18-Mar	24-May	Falls	49	45%	4	0	98	6		16,658
2003	Volunteer	19-Feb	4-Jun	26-Feb	13-Jun	Falls	74	50%	4	0	48	10		9,092
2004	None													11,842
2005	None													5,963
2006	None													6,404
2007	None													5,474
2008	None													4,915
2009	PSU	26-Jan	22-May	26-Jan	6-Jun	Falls	92	89%	8	0	86	39	0	2,813
2010	PSU[1]	10-Jan	10-Jun	10-Jan	13-Jun	Falls	147	95%	15	0	618	50	1	7,337
2011	PSU	Fall 2010	5-Jun	9-Jan	9-Jun	Falls	139	99%	16	1	449	43	0	7,441
2012	PSU[1]	?	3-Jun	8-Apr	17-Jun	Falls	?	?	13	?	226	79	19	7,616
2013	PSU[1]	Fall 2012	?	?	?	Falls+R.	?	?	?	?	?	?	?	4,944

[1] Hazing of sea lions by ODFW occurred in 2010 (pilot study), 2011, and 2013.

[2] Observations by ODFW during early years (1995-2003) were largely on an *ad hoc* basis, concluding with an ODFW volunteer program in 2003. There were no formal observations conducted during 2004-2008. Observations by Portland State University (2009-2013) were conducted as part of a field research class.

[3] First and last dates are based on either the formal monitoring programs or anecdotal reports from local ODFW staff or mill employees.

[4] Approximate start and end dates of formal monitoring.

[5] Area covered by monitoring was generally immediately below the falls and sometimes as far downriver to the Highway 43 bridge; areas further downriver were added in 2013.

[6] Number of days during monitoring period on which observations occurred.

[7] Percent of observed days on which at least one sea lion was observed.

[8] Actual or estimated maximum single day totals for California sea lions (CSLs) and Steller sea lions (SSLs) in study area. Over the course of a season, however, this represents only a fraction of the number of animals that may have occurred in the study area.

[9] Unexpanded observed totals for salmonid (SAL), lamprey (LA), and sturgeon (STG) predation.

[10] Total winter steelhead run size is from November 1 of previous year through May 15 (May 31 after 2010).

Appendix B. Simplified example illustrating three-stage cluster sampling design. Each observed cell has a sampling weight of 3.38 or equivalently an inclusion probability of 0.30. The population estimate is the sum of the observations multiplied by their sampling weights. The estimator is unbiased over all possible samples. Variance, confidence interval, and CV are calculated using appropriate sampling formulas.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1		1st stage				2nd stage				3rd stage							
2		Primary sampling units (PSUs)				Secondary sampling units (SSUs)				Tertiary sampling units (TSUs)				Observed samples - y			
3		0	0	0		0	0	0		0	0	0		0		0	
4		0	0	1		0	0	1									
5		3	3	0		3	3	0		3	3	0		3	3		
6																	
7		1	1	2		1	1	2		1	1	2			1	2	
8		1	1	3		1	1	3		1	1	3		1		3	
9		3	3	3		3	3	3									
10										Cells within rows							
11		2	3	0		Rows within tables				K	3						
12		1	2	3		M	3			k	2						
13		0	1	2		m	2							SUM(N3:P8)	13	sum y	
14														(C15/C16)*(G11/G12)*(K10/K11)	3.38	sampling weight	
15		Tables												1/O14	0.30	inclusoin probability	
16		N	3														
17		n	2											O13*O14	43.9	population total estimate	
18														SUM(B3:D13)	39	true population total	
19														O17-O18	4.9	difference	