

ANNUAL REPORT:  
PINNIPED MONITORING AT WILLAMETTE FALLS, 2023-2024

October 16, 2024



*California sea lions hauled out overnight at Willamette Falls*



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## TABLE OF CONTENTS

TABLE OF CONTENTS.....	i
LIST OF FIGURES .....	ii
LIST OF TABLES.....	iii
LIST OF APPENDICES.....	iv
INTRODUCTION .....	1
METHODS .....	2
<i>Study area</i> .....	2
<i>Pinniped species accounts</i> .....	2
<i>Fish species accounts</i> .....	3
<i>Pinniped counts</i> .....	3
<i>Pinniped predation estimation</i> .....	4
<i>Additional activities</i> .....	6
RESULTS .....	6
<i>River conditions</i> .....	6
<i>Salmonid fishway passage</i> .....	6
<i>Pinniped counts</i> .....	6
<i>Predation</i> .....	7
DISCUSSION.....	8
ACKNOWLEDGMENTS .....	9
LITERATURE CITED.....	10

LIST OF FIGURES

Figure 1. Map of general study area showing key features such as formal observation sites at Willamette Falls (1-6 in yellow), boat ramps, and river mile markers. .... 12

Figure 2. Illustration of the spatial (left) and temporal (right) coverage of the sampling frame by season. Red shaded areas depict time and area included in the sampling frame; dark black lines on the graph at right indicate sunrise and sunset, adjusted for daylight savings..... 13

Figure 3. Height (a) and temperature (b) of the Willamette River upstream of Willamette Falls by year..... 14

Figure 4. Annual fish passage at Willamette Falls by run and year; 11-year averages denoted by dashed line. Note that the y-axis scale varies by run and the 2024 summer steelhead passage is only through September 8<sup>th</sup> ..... 15

Figure 5. Weekly counts of California sea lions (CSL) and Steller sea lions (SSL) in the Willamette Falls study area, 2017-2024. Numbers translocated or euthanized are summed over the week; numbers observed are the minimum number of unique individuals observed for that week and may include animals translocated or euthanized. See text for details. .... 16

Figure 6. Individual locations (map at left) and total counts (table at right) for California sea lions (CSL) and Steller sea lions (SSL) observed during vessel-based surveys of the Willamette River beginning at Willamette Falls in Oregon City and proceeding downriver to the location noted in table. .... 17

Figure 7. Estimated run-specific salmonid predation by California sea lions and Steller sea lions at Willamette Falls based on Monte Carlo modelling of the probability sample data; 95% confidence intervals are for the combined total. Estimates only apply to the sampling frames and therefore are minimum estimates due to undercoverage of the target population. Dashed lines indicate sea lion removal authorization dates under Section 120 of the Marine Mammal Protection Act. .... 18

Figure 8. Estimated run-specific salmonid predation expressed as percent of potential passage above falls by California sea lions and Steller sea lions at Willamette Falls based on Monte Carlo modelling of the probability sample data; 95% confidence intervals are for the combined total. Percent potential passage = estimate / (estimate + passage) x 100. Estimates only apply to the sampling frames and therefore are minimum estimates due to undercoverage of the target population. Summer steelhead passage through 9/8/2024. Dashed lines indicate sea lion removal authorization dates under Section 120 of the Marine Mammal Protection Act. .... 19

LIST OF TABLES

Table 1. Estimated predation by California sea lions and Steller sea lions at Willamette Falls based on the probability sampling design. Annual totals are only directly comparable for 2017-2024 due to changes in the sampling frame during the first three years of the project. Estimates only apply to the sampling frames and therefore are minimum estimates due to undercoverage of the target population. Negative lower confidence bounds were replaced with zeros. .... 20

Table 2. Estimated run-specific salmonid predation by California sea lions at Willamette Falls based on Monte Carlo modelling of the probability sample data. Annual totals are only directly comparable for 2017-2024 due to changes in the sampling frame during the first three years of the project. Estimates only apply to the sampling frames and therefore are minimum estimates due to undercoverage of the target population. Percent potential passage (%PE) = estimate / (estimate + passage) x 100. Negative lower confidence bounds were replaced with zeros. .... 21

Table 3. Estimated run-specific salmonid predation by Steller sea lions at Willamette Falls based on Monte Carlo modelling of the probability sample data. Annual totals are only directly comparable for 2017-2024 due to changes in the sampling frame during the first three years of the project. Estimates only apply to the sampling frames and therefore are minimum estimates due to undercoverage of the target population. Percent potential passage (%PE) = estimate / (estimate + passage) x 100. Negative lower confidence bounds were replaced with zeros. .... 22

LIST OF APPENDICES

Appendix A. Sampling design metadata describing the Willamette Falls sea lion monitoring program, 2014-2024..... 23

## INTRODUCTION

The Marine Mammal Protection Act (MMPA) of 1972 provides federal protection to all marine mammal species in U.S. waters. As one result of this legislation, the U.S. stock of California sea lions (*Zalophus californianus*) and the eastern stock of Steller sea lions (*Eumatopias jubatus*) have increased to the point that they are now likely within their Optimum Sustainable Population ranges (Caretta et al. 2021, Muto et al 2021). Over this same period, many salmon and steelhead (*Oncorhynchus* spp.) populations in the Pacific Northwest experienced significant declines in their abundance and were subsequently listed as threatened or endangered under the Endangered Species Act (ESA). While pinniped predation was not the ultimate cause of these declines, in areas where salmonid abundance is low and pinniped numbers are high, increased predation can result in significant negative impacts to the survival and recovery of individual salmonid populations.

One such area of relatively low salmonid and high pinniped abundance is Willamette Falls on the Willamette River, approximately 206 km (128 mi) upriver from the Pacific Ocean. While the first known record of a California sea lion at Willamette Falls was of a single animal in the 1950s (Beach et al. 1985), it wasn't until the mid-1990s there were frequent observations of California sea lions foraging there for winter steelhead and spring Chinook salmon attempting to pass the Falls (Oregon Department of Fish and Wildlife [ODFW], unpublished data). Concerned that Willamette Falls would become another "Ballard Locks"—a site in Washington where California sea lions effectively extirpated a run of steelhead (*O. mykiss*) (Fraker and Mate 1999)—ODFW began a predation monitoring program at Willamette Falls in 1995, as well as a California sea lion marking program at Astoria in 1997 to identify and track California sea lions in the Columbia River Basin (Brown et. al 2020).

Intermittent predation monitoring at the falls by ODFW occurred from 1995-2003, after which the agency's limited resources were shifted to Bonneville Dam on the Columbia River where California sea lion predation on salmonids also began increasing (e.g., Keefer et al. 2012, Braun et al. 2023). Attention soon returned to Willamette Falls, however, as winter steelhead passage decreased, and sea lion activity increased. This led ODFW to conduct non-lethal hazing at Willamette Falls in 2010, 2011, and 2013 in an attempt to deter sea lions from consuming threatened winter steelhead near the fish ladder entrances. However, as has been seen elsewhere (e.g., see review in Scordino 2010), non-lethal deterrents had only limited and short-term effects as pinnipeds eventually adapted to them.

Hazing was discontinued after 2013 to shift limited resources to a rigorous monitoring effort. That effort showed that California sea lion abundance had increased from the late 1990s and early 2000s and that California sea lion predation had become particularly acute for threatened winter steelhead populations (e.g., see Appendix 2 of ODFW et al. 2019). In addition, Steller sea lions also began showing notable increases in abundance and residency starting in 2017. Based on the results of this monitoring, the state of Oregon requested lethal removal authority for California sea lions under Section 120 of the MMPA, which was subsequently granted on November 14, 2018 (NMFS 2018) and later expanded to include Steller sea lions on August 25, 2020 (NMFS 2020). This report summarizes the 11th consecutive year of pinniped monitoring at

Willamette Falls and partially fulfills reporting requirements under our MMPA management authorization.

## METHODS

### *Study area*

The study area was located from Willamette Falls on the Willamette River downstream to the mouth of the Clackamas River, although formal observations were only conducted in the immediate vicinity of the falls (sites 1-6, Figure 1). The falls are located approximately 42 km (26 mi) upriver from the confluence with the Columbia River and approximately 206 km (128 mi) from the ocean. It is the second largest waterfall in the United States by volume after Niagara Falls (ECONorthwest 2014).

### *Pinniped species accounts*

Three pinniped species have been known to occur seasonally at Willamette Falls: California sea lions, Steller sea lions, and Pacific harbor seals (*Phoca vitulina*).

California sea lions—California sea lions have been the most common and abundant pinniped observed at Willamette Falls, although their numbers and duration of occurrence have been declining due to the success of recent management actions. California sea lions in Oregon belong to the U.S. stock for which the most recent (2014) estimate was approximately 257,606 animals (minimum population size estimate = 233,515 individuals) (Laake et al. 2018, Carretta et al. 2023). The stock is not listed as "endangered" or "threatened" under the ESA, nor as "depleted" or "strategic" under the MMPA (Carretta et al. 2023). California sea lions in the Pacific Northwest are seasonal migrants that begin arriving in Oregon in late July and have mostly departed by late June on their way back and forth from the breeding grounds in southern California and Mexico (Wright et al. 2010, Elorriaga-Verplancken et al. 2014, Brown et al. 2020). This seasonal population is comprised primarily of  $\geq 3$ -year-old males (Mate 1975, Maniscalco et al. 2004, ODFW unpublished data), recently estimated to number approximately 50,000-75,000 animals (Laake et al. 2018).

Steller sea lions—Steller sea lions have been observed sporadically at Willamette Falls over the last decade, albeit more consistently and in increasing numbers in recent years. Steller sea lions in Oregon belong to the eastern Distinct Population Segment (DPS). Not accounting for animals at sea, the most recent (2017) estimate of the eastern DPS was 18,450 (95% credible interval of 15,030-22,253) pups and 58,699 (95% credible interval of 50,312-68,052) non-pups (Young et al. 2023); these estimates cannot be used to represent a total population abundance estimate, however, as they do not account for animals at sea. The stock is not listed as "endangered" or "threatened" under the ESA, nor as "depleted" or "strategic" under the MMPA (Young et al. 2023).

Harbor seals—Harbor seals, while common and abundant throughout coastal Oregon, are relatively rare and inconspicuous visitors to upriver sites such as Willamette Falls. Harbor seals

in Oregon belong to the Oregon/Washington coastal stock. The most recent (1999) estimate of the total stock was 24,732 animals (Carretta et al. 2023). However, since this estimate is out of date the current population abundance and trend for this stock is unknown. The stock is not listed as "endangered" or "threatened" under the ESA nor as "depleted" or "strategic" under the MMPA (Carretta et al. 2023).

### *Fish species accounts*

Fish species primarily preyed upon by pinnipeds at Willamette Falls are winter and summer steelhead, marked (hatchery) and unmarked (wild) spring Chinook salmon (*O. tshawytscha*), Pacific lamprey (*Entosphenus tridentatus*), and white sturgeon (*Acipenser transmontanus*). All these species are of conservation or management concern, and two—winter steelhead and wild spring Chinook salmon—are listed as "threatened" under the ESA.

Winter and summer steelhead—All naturally produced winter-run steelhead populations in the Willamette River and its tributaries above Willamette Falls to the Calapooia River are part of the ESA-listed Upper Willamette River (UWR) steelhead DPS (National Marine Fisheries Service [NMFS] 2024). These fish pass Willamette Falls from November through May, co-occurring to some extent with introduced marked summer steelhead that pass the falls from March through October. While there is no directed fishery for winter-run steelhead in the upper Willamette River, hatchery-origin summer steelhead are not ESA-listed and support popular recreational fisheries in the Santiam, McKenzie and Middle Willamette subbasins.

Spring Chinook salmon—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 salmon Evolutionary Significant Unit (ESU) (NMFS 2024). These fish pass Willamette Falls from about April to August and co-occur with a more abundant run of hatchery-origin spring Chinook salmon. Hatchery-produced spring Chinook salmon support 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 timelapse video recorders are used to record fish passage, which is later reviewed to produce passage counts. Salmonid species are partitioned by run (e.g., winter/summer, unmarked/marked) based on passage date and the presence or absence of a hatchery fin clip.

### *Pinniped counts*

We estimated pinniped abundance in the study area based on a combination of direct observations as well as imagery from automated time-lapse cameras located at potential haul out sites throughout the study area. Counts at Willamette Falls (i.e., sites 1-6, Figure 1) were conducted during weekday, daytime observation shifts whereas camera counts were based on hourly images taken 24 hrs a day, 7 days a week. Both types of counts were then added together when appropriate to obtain a maximum count for that calendar day which was then used as an index of minimum abundance. Alternatively, if the tally of individual animals observed over a

given calendar day was greater than the maximum count, then that number was used for that day. For the fall and early winter period before formal observations began we only used camera counts and anecdotal observations to obtain daily maximum counts. As a result, fall and early winter counts may be biased low compared to the formal January-May study period. The maximum daily count for a given week was used as an index of the minimum number of individuals present in the study area for that week.

In addition to conducting pinniped counts immediately below Willamette Falls, we also conducted periodic boat-based surveys of the Willamette River to determine how much pinniped activity we might be potentially missing below the formal study area. Surveys were typically conducted in a single 24-ft closed cabin boat travelling downstream at approximately 5 knots with a minimum of two staff per survey. Surveys began in Oregon City below Willamette Falls and proceeded downriver, typically to the confluence with the Columbia River (42 km; 26 mi). Staff recorded the number, behavior, and location of each species of pinnipeds observed, which were also photographed when possible. Observations were generally only recorded while traveling downriver since the upriver return trip was made at higher speeds.

### *Pinniped predation estimation*

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, Hankin et al. 2019) to estimate the total number of adult salmonids consumed by sea lions over a spatio-temporal sampling frame. From 2014-2020 we estimated total surface predation of adult salmonids based on a (pseudo) probability sample generated from a three-stage cluster sampling design, with repeated systematic samples at each stage (e.g., Wright et al. 2020). In 2021, in order to mitigate COVID-19 risks, and in anticipation of decreased sea lion activity, we experimented with a new sampling design based on spatially balanced sampling methods, specifically Halton iterative partitioning (HIP) (Robertson et al. 2018, Hankin et al. 2020). After 2021 we resumed using the three-stage cluster sampling design.

The variable of interest was the initiation of a surface-feeding event whereby a sea lion was observed to surface and begin prey consumption within a given spatio-temporal observation unit. Since prey handling and consumption for some prey species such as large sturgeon can last over an hour and drift over a kilometer downstream, we only formally recorded events that included observations of the initial surfacing immediately after prey capture; all other events were treated as anecdotal. We included both predation on free swimming fish as well as depredation of hooked fish in the recreational fishery (collectively referred to as "predation" hereafter unless specifically noted). We assumed that the probability of detecting an event, given that it occurred, was one. Surface-feeding observations were conducted from shore by visually scanning a given area with unaided vision and/or binoculars. For each event, trained observers recorded the time, site, sea lion species, prey species, and whether the fish may have been taken from an angler. If prey appeared to escape without mortal wounds, then the event was noted but not included in the tally used for estimation.

Observers followed a schedule of when and where to observe based on a probability sample generated from a three-stage cluster sampling design, with repeated systematic samples at each stage (see Figures 1 and 2, and Appendix A, for descriptions of the design; see Lohr 1999 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 of the week (e.g., 0700-1530 at specified site(s)). The third stage or tertiary sampling units (TSUs) were 30-min observation bouts within a site-shift (i.e., three out of every four 30-min periods at a given site). 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 to believe that sea lion foraging behavior should vary systematically with observer breaks or weekends/holidays, then imposing some restrictions on randomization is unlikely to introduce bias into estimation.

The spatial component of the sampling frame consisted of six sites in a single stratum (Figure 1). This is identical to the 2016-2023 study years but in contrast to 2014-2015, which had sites spread over two strata (Figure 2). Sites 1-6 were each approximately 0.9 ha in area and occurred immediately below the falls where predation activity is typically greatest. The temporal component of the sampling frame consisted of a subset of daylight hours, ranging from 0800-1630 PST (8.5 hours) in January to 0600-1900 PDT (13 hours) in May (Figure 2).

In 2024, there were 1,375 half-hour observation units (i.e., elements) in the sample out of a sampling frame of 20,520 units, resulting in an element-wise sampling fraction of 6.7%; the cluster-wise sampling fraction was also 6.7% (120 clusters out of 1792; see Appendix A). The sampling weight was 14.93, meaning that each observed predation event represented itself and 13.93 additional unobserved events. Based on previous pilot testing of the design against simulated data it was anticipated that the total salmonid predation estimate would have a coefficient of variation (CV) of 10% or less (estimates with CVs over 33% are generally considered unreliable). Missing elements (e.g., due to holidays, unsafe weather conditions, missed assignments, etc.) were assumed to be missing-completely-at-random but were imputed as zeros, which likely contributed to small negative bias in the predation estimates.

Observed salmonid predation events were assigned to a run (i.e., summer/winter steelhead, unmarked/marked spring Chinook salmon) based on a combination of field observations, fishway window counts, and Monte Carlo methods. We did this using a two-step approach. In the first step, we either used observer identification of salmonids to species (if available), or we treated all salmonid as unknown regardless of whether they may have been identified in the field to species. In the second step, we assumed prey consumption was proportional to the run composition derived from window counts which we computed by pooling counts over 1, 7, or 14 days after an observed event (see Keefer et al. 2004).

As an example, if a steelhead was killed on Monday and the window count composition for steelhead on Tuesday was 50% winter steelhead and 50% summer steelhead, then the observed kill would be assigned to a run based on a metaphorical coin toss. For the case of "unknown" salmonids, if a salmonid was killed on Monday and the window count composition on Tuesday was 90% winter steelhead, 5% summer steelhead, 4% marked spring Chinook salmon, and 1%

unmarked spring Chinook salmon, 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.

Each of the six models was run for 1000 iterations and means were computed for run-specific total predation and associated measures of uncertainty. Predation relative to potential passage was calculated as the estimated predation total divided by the sum of passage and estimated predation. Prior to 2024 we only estimated run-specific predation for California sea lions due to the relatively small number of salmonids taken by Steller sea lions. However, this number has been increasing in recent years and in 2024 there were sufficiently large numbers of salmonids consumed by Steller sea lions to meaningfully partition take by run. For completeness, we retroactively estimated annual run-specific take by Steller sea lions for the entire study period from 2014-2024.

#### *Additional activities*

The predation monitoring design in 2024 was implemented using a single, full-time staff member who was assisted when needed by additional staff. 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 administrative tasks, conducting anecdotal predation observations, haul-out counts, and photographing pinnipeds to identify individual animals.

## RESULTS

#### *River conditions*

River height and temperature near Willamette Falls are summarized in Figure 3. The most notable hydrologic event during the study included above-average water levels in late January, which reached action-stage.

#### *Salmonid fishway passage*

Salmonid passage by run over Willamette Falls is summarized in Figure 4. Passage of ESA-listed winter steelhead was the highest since the study began in 2014 and the highest on record since 2004. Summer steelhead passage was similarly high with its largest passage since 2016. Spring Chinook salmon numbers, however, for both marked and unmarked fish were below average for the study period.

#### *Pinniped counts*

Pinniped counts based on automated cameras and incidental observations by staff at the Sportcraft haulout area began July 2023 before sea lions migrated into the study area and continued through June 2024 when sea lions had migrated out of the study area. Counts based on

formal observations at Willamette Falls began in January 2024 and continued through May 2024. Boat-based river surveys began late September 2023 and continued through May 2024.

California sea lions—There were no known occurrences of California sea lions in the study area during the last half of 2023 (Figure 5). The first California sea lion sighting occurred on January 8, 2024, but that animal only appeared to stay for three days. The next subsequent sighting was February 15, but that animal only appeared to stay for one day. It wasn't until March 11 that the spring cohort of California sea lions began arriving. They increased from one animal to a high of at least 12 on April 16<sup>th</sup>, with the last sighting on May 17<sup>th</sup>. Although boat survey effort was relatively low in 2024, results showed a similar phenology and relative abundance throughout the river as what was seen at the falls (Figure 6).

Only one individually identifiable California sea lions was documented at Willamette Falls in 2024: X834. Originally marked in Astoria on April 3, 2017, this animal recruited into the Willamette Falls population in spring 2023. After mistakenly thought to have died on the southern Oregon coast in the fall of 2023 it returned to Willamette Falls for a second consecutive spring and was sighted from April 4 to May 16.

Steller sea lions— There were no known occurrences of Steller sea lions in the study area during the last half of 2023 (Figure 5) although it seems likely at least one animal may have been intermittently present but undetected based on the river surveys (Figure 6). The first individual to be detected at the falls was on the first formal observation day, January 2, 2024. This animal, while not branded, had uniquely identifiable scar patterns identifying it as an animal that had been seen at the falls previously for several consecutive years. The maximum number of Steller sea lions observed on a single day was three, occurring on March 27, April 3, and April 12. The last date a Steller sea lion was observed was April 23<sup>rd</sup>.

### *Predation*

California sea lions—The estimated number of salmonids consumed by California sea lions over the 6-site, 1710-hour sampling frame was 1030 fish (95% confidence interval: 688-1373) (Table 1). In addition, we estimated that they consumed a total of 329 lamprey (95% confidence interval: 77-580 fish). Partitioning salmonids to run based on Monte Carlo modeling, we estimated that California sea lions consumed 237 winter steelhead (2.6% of potential passage), 389 summer steelhead (2% of potential passage), 110 unmarked spring Chinook salmon (2.2% of potential passage), and 295 marked spring Chinook salmon (1.7% of potential passage) (Table 2, Figures 7-8).

Steller sea lions— The estimated number of salmonids consumed by Steller sea lions over the 6-site, 1710-hour sampling frame was 299 fish (95% confidence interval: 166-432) (Table 1). Partitioning salmonids to run based on Monte Carlo modeling, we estimated that Steller sea lions consumed 195 winter steelhead (2.1% of potential passage), 59 summer steelhead (0.3% of potential passage), 15 unmarked spring Chinook salmon (0.3% of potential passage), and 30 marked spring Chinook salmon (0.2% of potential passage) (Table 3, Figures 7-8).

## DISCUSSION

This year marked the 11<sup>th</sup> consecutive season of monitoring pinniped abundance and foraging behavior below Willamette Falls. It was most notable for the return of the largest run of ESA-listed winter steelhead in 20 years. The downside to this abundance, however, was that it provided increased foraging opportunities for the small number of primarily Steller sea lions present during the late winter and early spring months when winter steelhead pass the falls. This resulted in the largest estimated number of salmonids consumed by Steller sea lions since our monitoring began in 2014 (Table 1). In fact, 2024 was the first year that Steller sea lion predation on salmonids was high enough to allow for relatively precise run-specific estimation (Table 3). While the combined sea lion total for number of winter steelhead consumed was the highest since 2018 (Figure 7), the predation rate was still relatively low due to the large run size (Figure 8).

It should be noted, however, that the predation estimates reported here apply only to the 6-site, 1710-hour sampling frame. And while the 95% confidence intervals reflect the sampling error in the estimates, non-sampling errors are often a greater source of uncertainty than sampling errors. In this study, the non-sampling error of greatest concern is undercoverage. As in previous years, spatial and temporal undercoverage in our sampling frame likely resulted in our estimates of predation being biased low. Spatial undercoverage likely occurred because we only sample a 6-ha area just below the falls whereas predation can and does occur further downriver. Temporal undercoverage also likely occurred because some sea lions likely foraged outside of our daily sampling times (i.e., before sunrise and after 7 p.m.) or before our study started in January.

Along with large steelhead returns, 2024 also saw the continued increase in the use of haul out areas other than the original site located near the Sportcraft boat ramp (Figure 1). For example, we saw a dramatic increase in California sea lions hauling out overnight at Willamette Falls near the Sullivan Hydroelectric Plant. Similarly, we saw an increase in the use of private docks by Steller sea lions near the Cedaroak boat ramp. While we were ultimately able to remove three California sea lions late in the season at the original Sportcraft haulout site, trapping efforts near Cedaroak were unsuccessful.

Despite the undercoverage issues noted above, and continued challenges with capturing and removing sea lions, it's still the case that sea lion management under MMPA Section 120/120(f) has resulted in substantial and sustained decreases in predator abundance (Figure 5) and associated predation compared to pre-management years, particularly for listed winter steelhead (Figures 7-8). This might not remain true, however, if sea lions continue evading capture and the habituated population increases.

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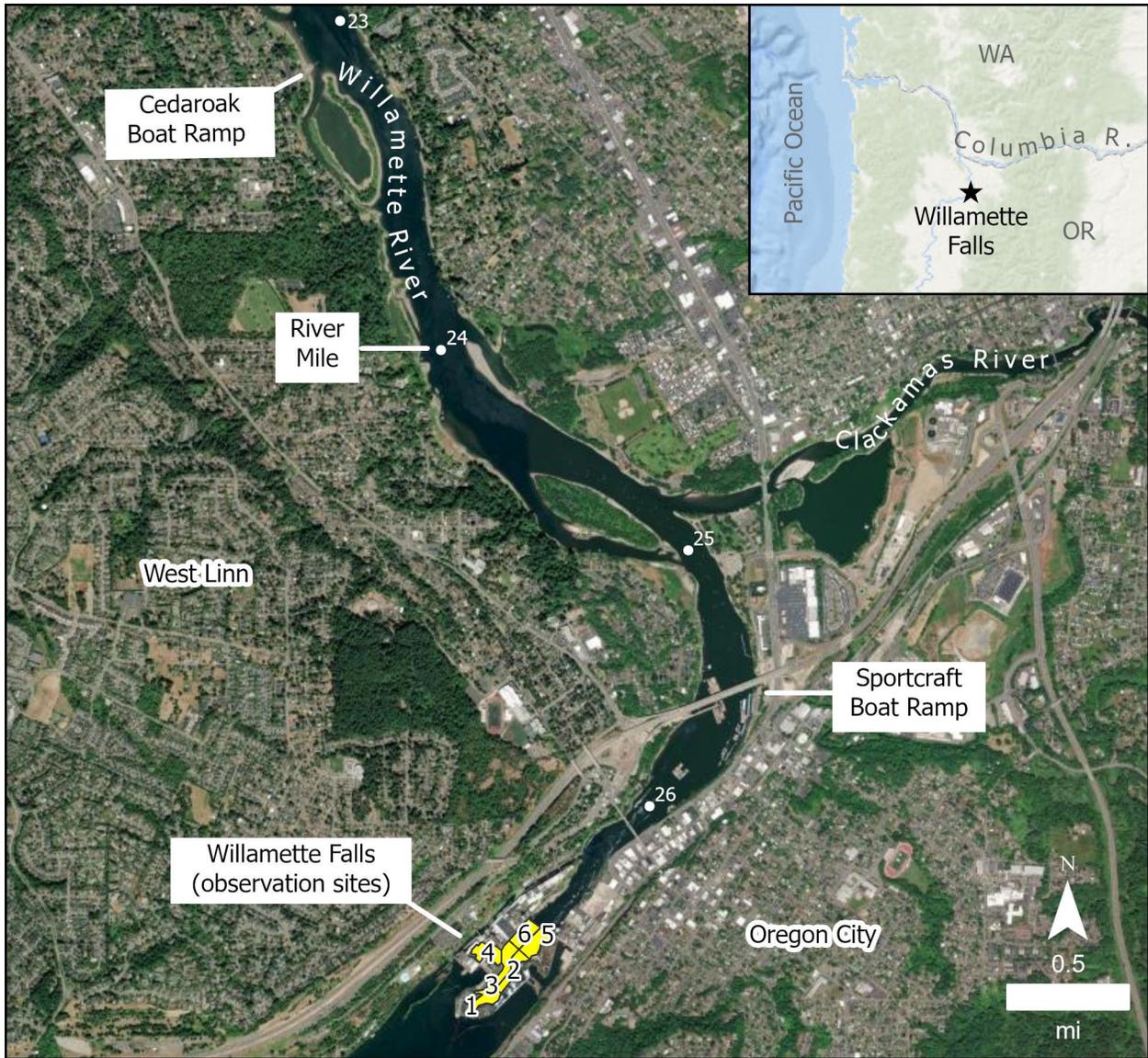


Figure 1. Map of general study area showing key features such as formal observation sites at Willamette Falls (1-6 in yellow), boat ramps, and river mile markers.

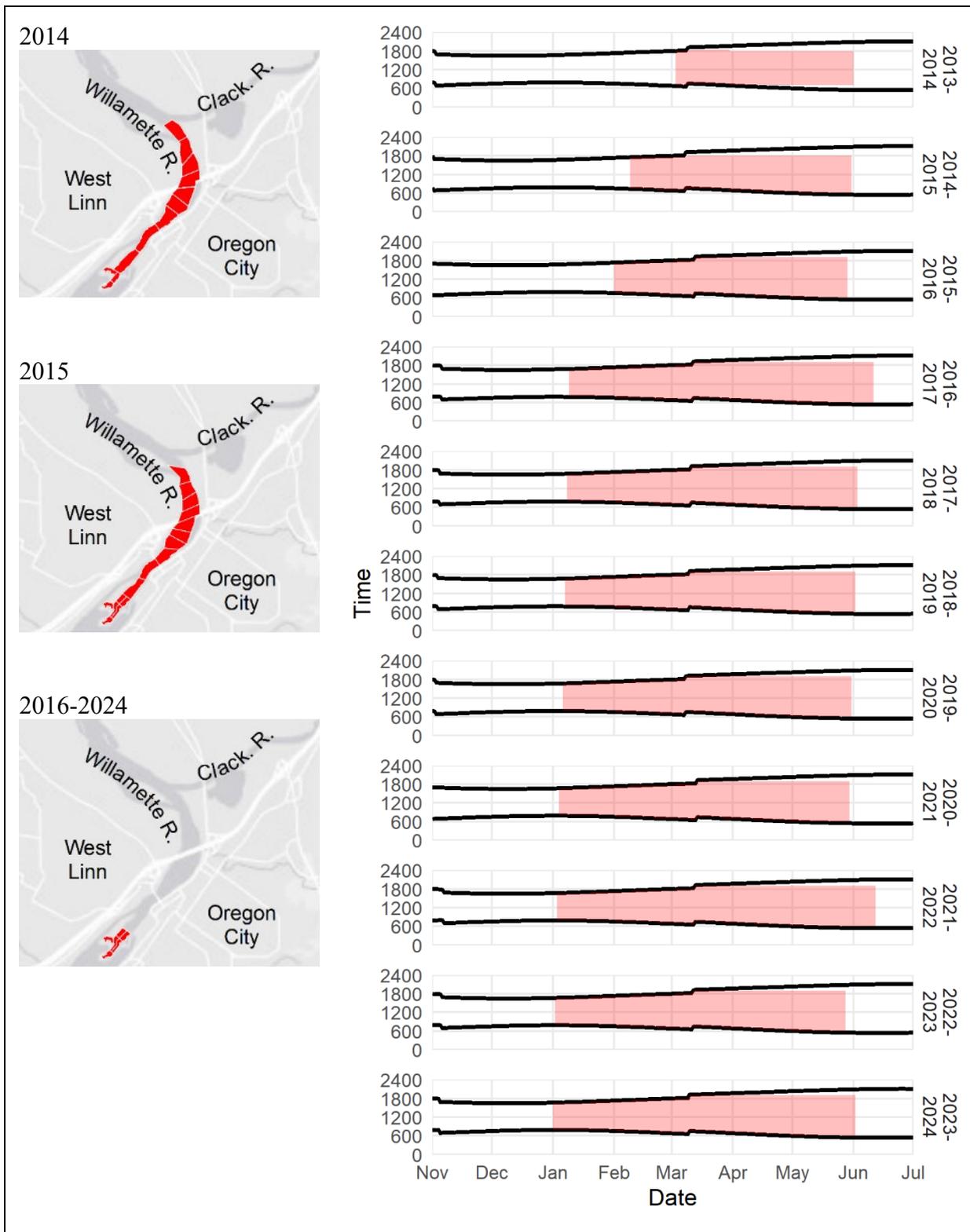


Figure 2. Illustration of the spatial (left) and temporal (right) coverage of the sampling frame by season. Red shaded areas depict time and area included in the sampling frame; dark black lines on the graph at right indicate sunrise and sunset, adjusted for daylight savings.

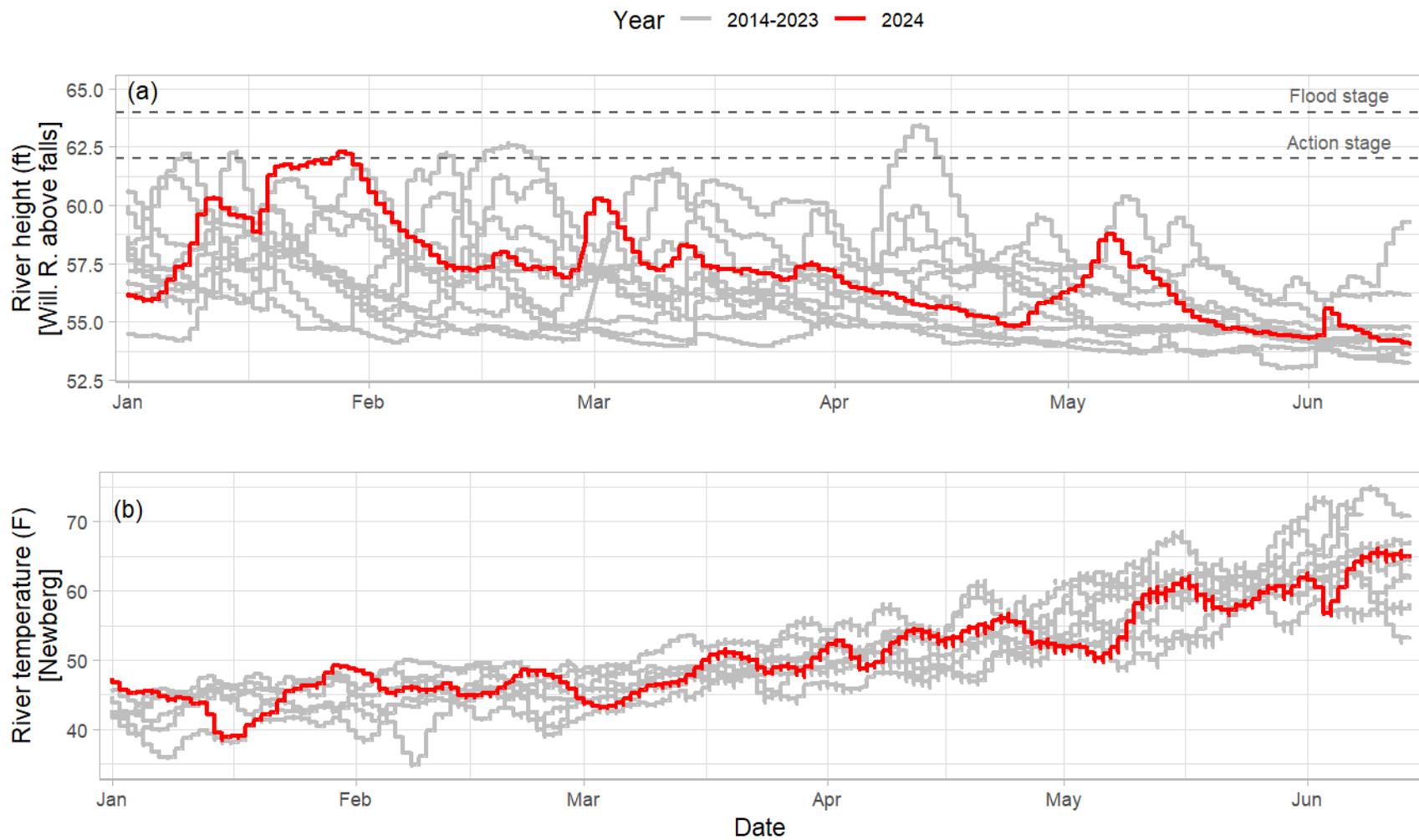


Figure 3. Height (a) and temperature (b) of the Willamette River upstream of Willamette Falls by year.

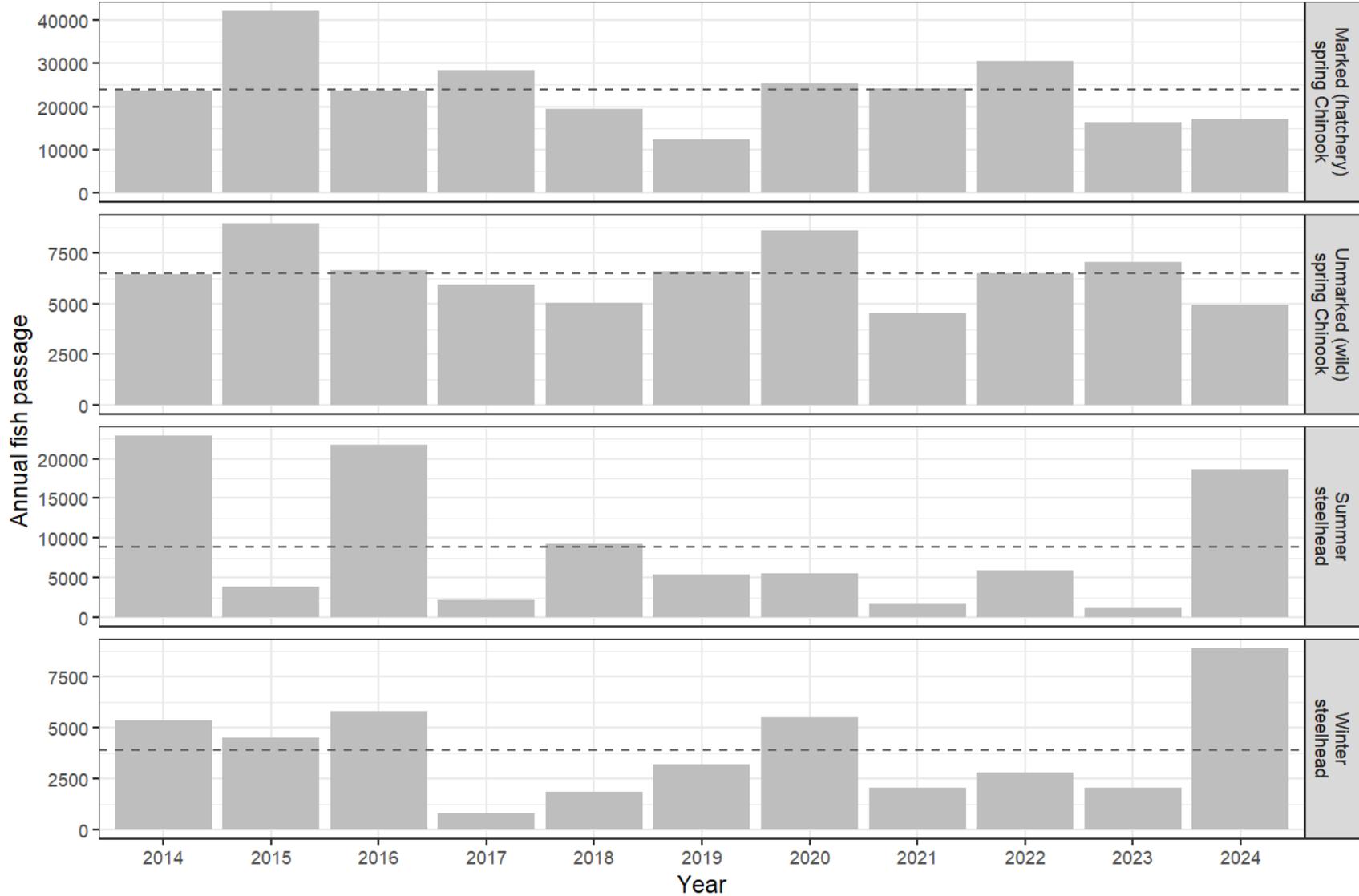


Figure 4. Annual fish passage at Willamette Falls by run and year; 11-year averages denoted by dashed line. Note that the y-axis scale varies by run and the 2024 summer steelhead passage is only through September 8<sup>th</sup>.

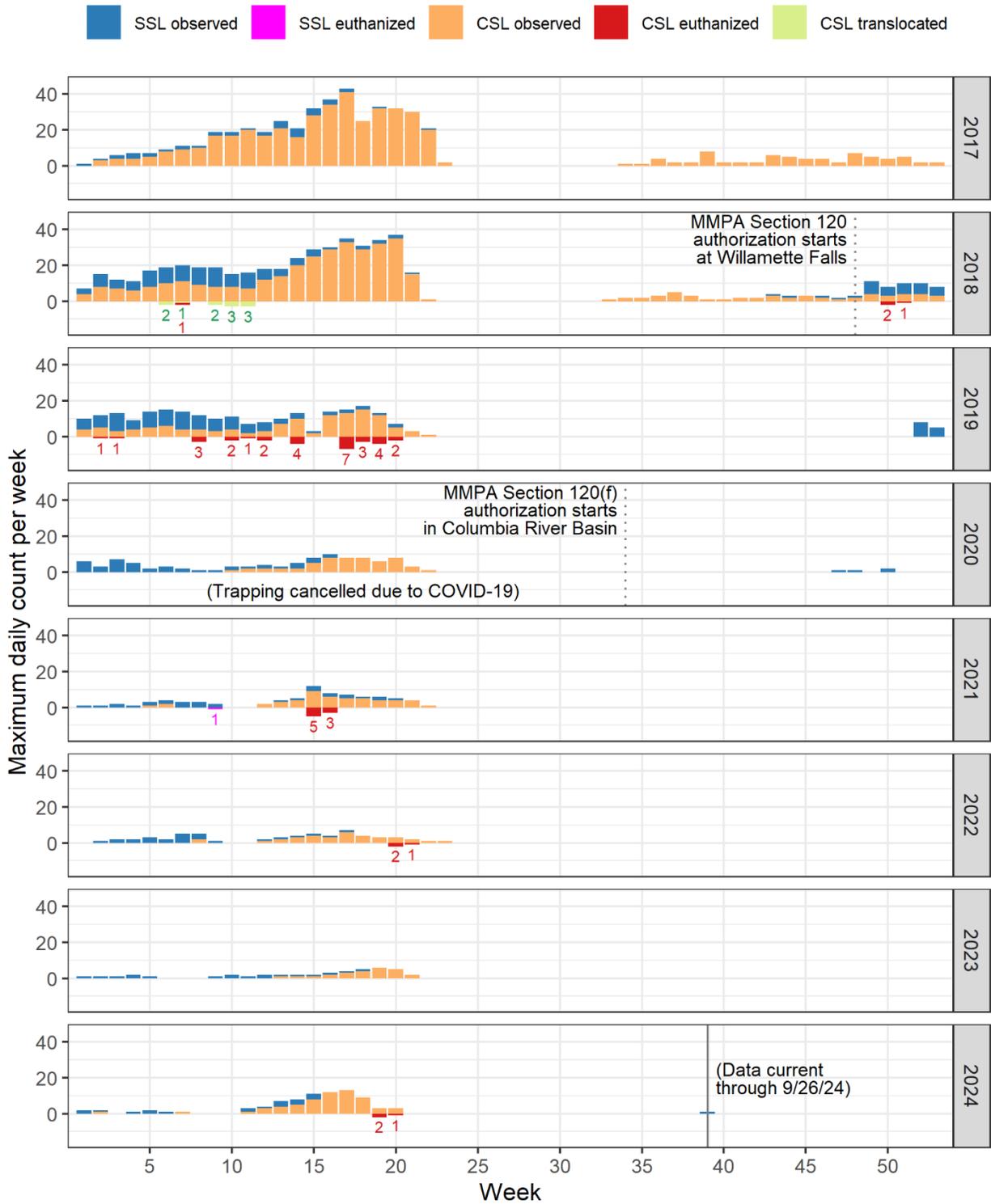


Figure 5. Weekly counts of California sea lions (CSL) and Steller sea lions (SSL) in the Willamette Falls study area, 2017-2024. Numbers translocated or euthanized are summed over the week; numbers observed are the minimum number of unique individuals observed for that week and may include animals translocated or euthanized. See text for details.

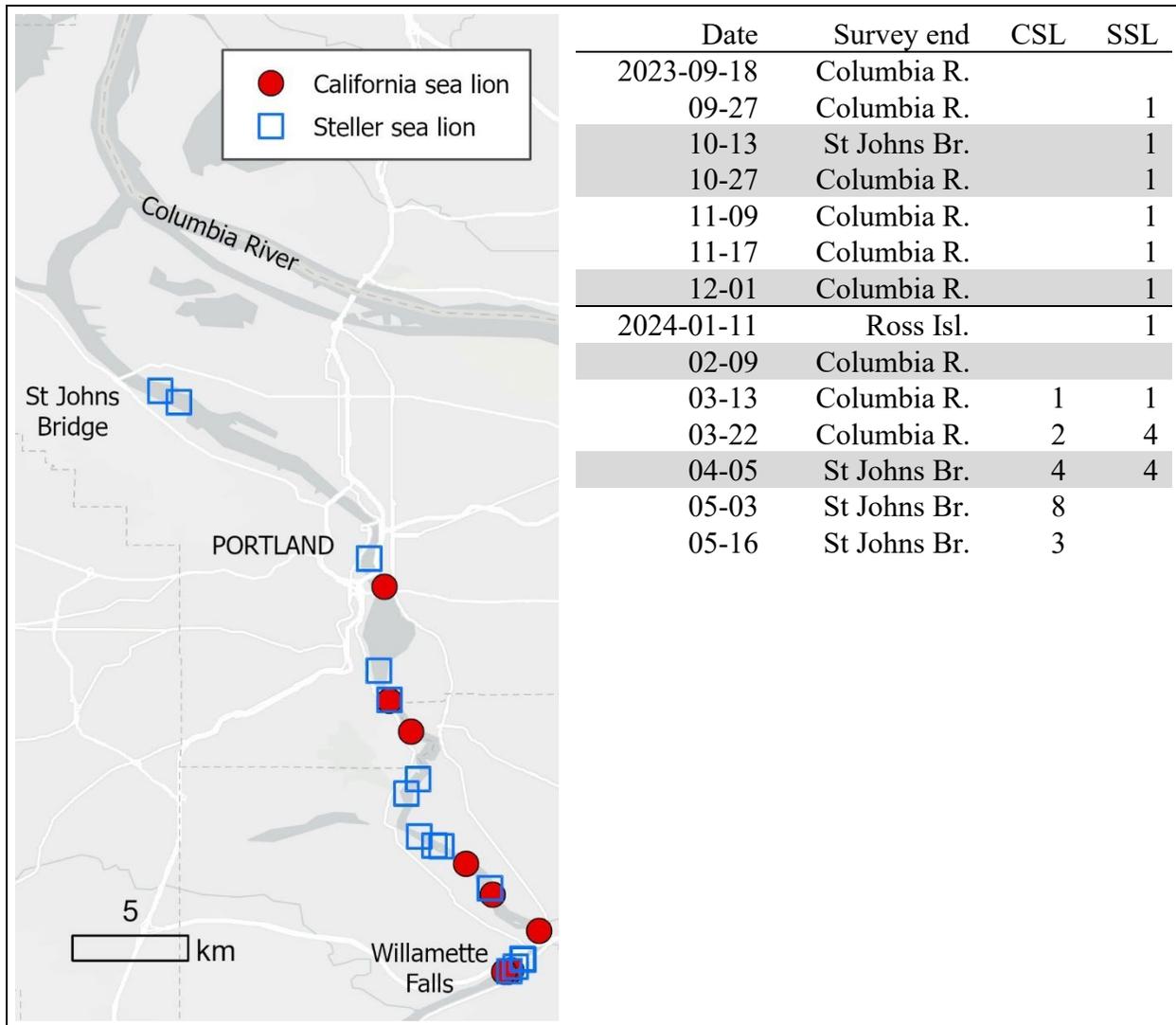


Figure 6. Individual locations (map at left) and total counts (table at right) for California sea lions (CSL) and Steller sea lions (SSL) observed during vessel-based surveys of the Willamette River beginning at Willamette Falls in Oregon City and proceeding downriver to the location noted in table.

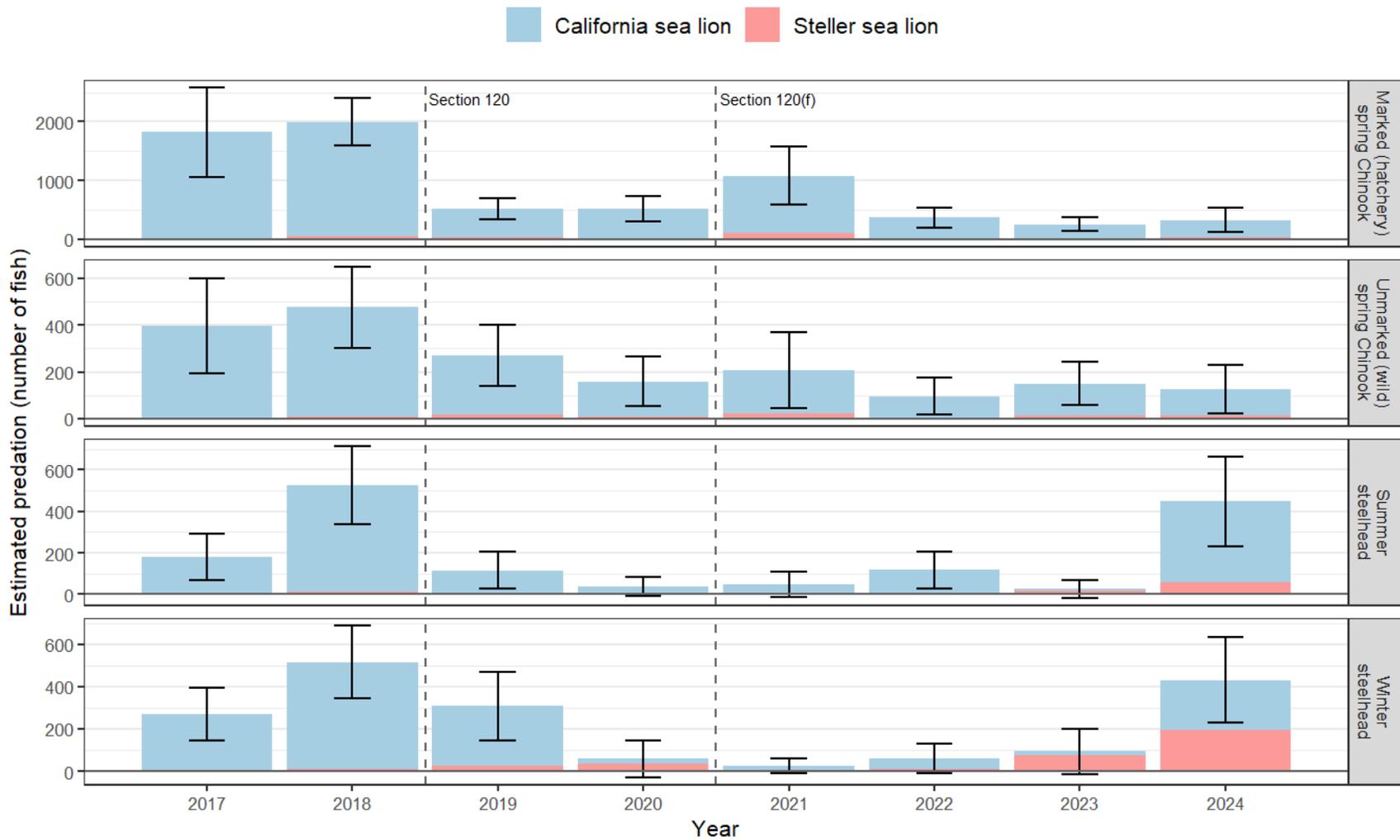


Figure 7. Estimated run-specific salmonid predation by California sea lions and Steller sea lions at Willamette Falls based on Monte Carlo modelling of the probability sample data; 95% confidence intervals are for the combined total. Estimates only apply to the sampling frames and therefore are minimum estimates due to undercoverage of the target population. Dashed lines indicate sea lion removal authorization dates under Section 120 of the Marine Mammal Protection Act.

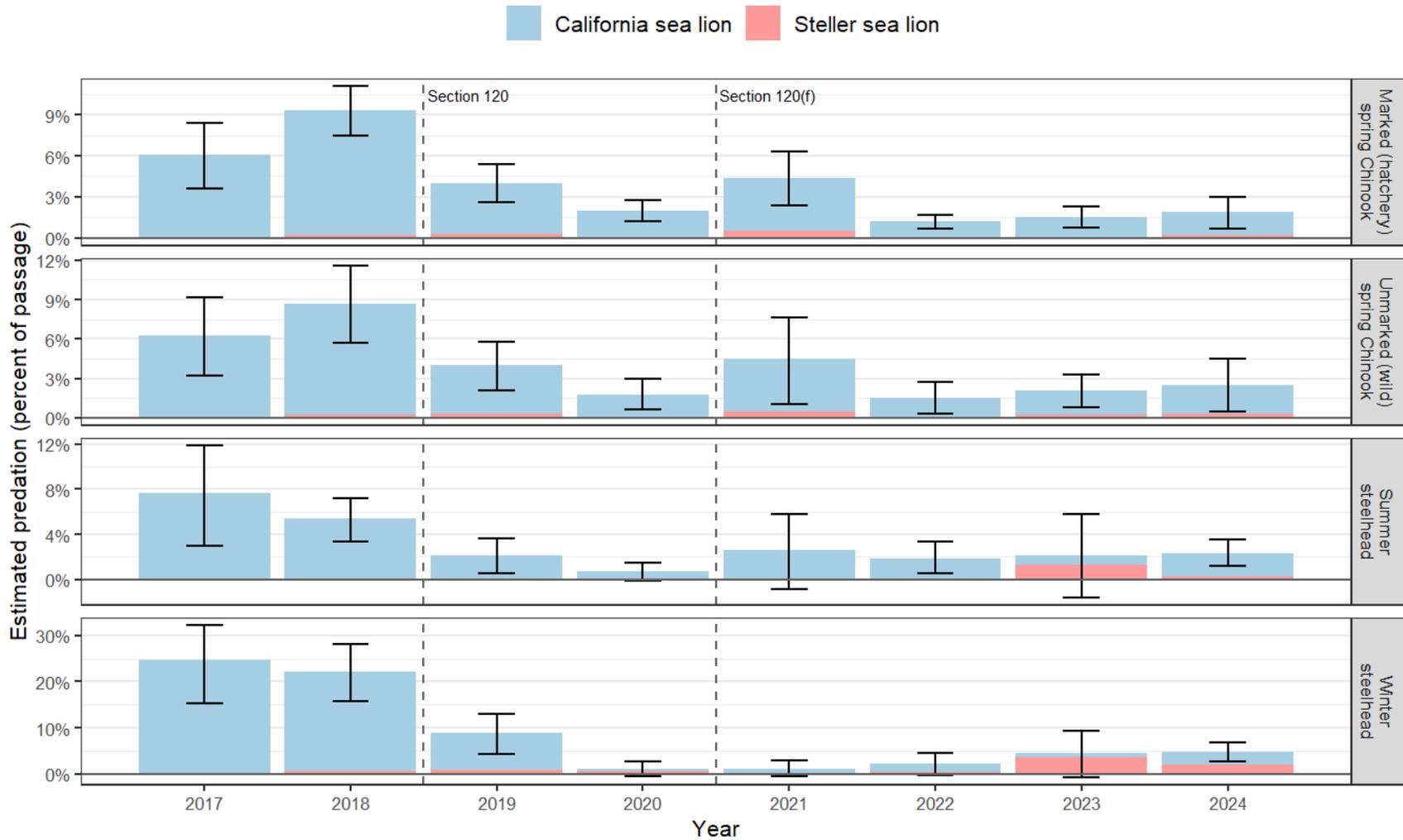


Figure 8. Estimated run-specific salmonid predation expressed as percent of potential passage above falls by California sea lions and Steller sea lions at Willamette Falls based on Monte Carlo modelling of the probability sample data; 95% confidence intervals are for the combined total. Percent potential passage = estimate / (estimate + passage) x 100. Estimates only apply to the sampling frames and therefore are minimum estimates due to undercoverage of the target population. Summer steelhead passage through 9/8/2024. Dashed lines indicate sea lion removal authorization dates under Section 120 of the Marine Mammal Protection Act.

Table 1. Estimated predation by California sea lions and Steller sea lions at Willamette Falls based on the probability sampling design. Annual totals are only directly comparable for 2017-2024 due to changes in the sampling frame during the first three years of the project. Estimates only apply to the sampling frames and therefore are minimum estimates due to undercoverage of the target population. Negative lower confidence bounds were replaced with zeros.

Year	Estimated California sea lion predation Total (95% CI)				Estimated Steller sea lion predation Total (95% CI)			
	Salmonids	Lamprey	Sturgeon	Other/ unknown	Salmonids	Lamprey	Sturgeon	Other/ unknown
2014	3690 (3321-4059)	493 (361-624)	19 (0-54)	20 (2-37)	0 NA	0 NA	37 (0-108)	0 NA
2015	5775 (5096-6455)	758 (531-984)	0 NA	106 (36-177)	0 NA	0 NA	34 (0-80)	0 NA
2016	4585 (3680-5490)	1254 (696-1813)	0 NA	45 (0-111)	15 (0-43)	0 NA	15 (0-43)	0 NA
2017	2673 (1658-3688)	747 (415-1078)	0 NA	0 NA	0 NA	0 NA	15 (0-43)	0 NA
2018	3435 (3019-3850)	687 (515-859)	0 NA	0 NA	75 (22-127)	15 (0-43)	194 (28-360)	0 NA
2019	1120 (963-1277)	508 (118-897)	0 NA	0 NA	90 (25-154)	45 (0-90)	60 (3-117)	0 NA
2020	702 (479-924)	134 (37-232)	0 NA	30 (0-86)	75 (0-163)	0 NA	60 (10-109)	30 (0-86)
2021	1227 (844-1610)	443 (242-644)	0 NA	68 (0-150)	136 (0-311)	68 (0-148)	102 (3-201)	0 NA
2022	597 (406-789)	105 (43-166)	0 NA	15 (0-43)	45 (0-98)	30 (0-68)	105 (28-182)	0 NA
2023	403 (296-510)	254 (92-416)	0 NA	15 (0-43)	119 (2-237)	45 (0-106)	0 NA	15 (0-43)
2024	1030 (688-1373)	329 (77-580)	0 NA	0 NA	299 (166-432)	0 NA	0 NA	15 (0-43)

Table 2. Estimated run-specific salmonid predation by California sea lions at Willamette Falls based on Monte Carlo modelling of the probability sample data. Annual totals are only directly comparable for 2017-2024 due to changes in the sampling frame during the first three years of the project. Estimates only apply to the sampling frames and therefore are minimum estimates due to undercoverage of the target population. Percent potential passage (%PE) = estimate / (estimate + passage) x 100. Negative lower confidence bounds were replaced with zeros.

Year	Winter steelhead		Summer steelhead		Unmarked (wild) spring Chinook salmon		Marked (hatchery) spring Chinook salmon	
	Total (95% CI)	%PE (95% CI)	Total (95% CI)	%PE (95% CI)	Total (95% CI)	%PE (95% CI)	Total (95% CI)	%PE (95% CI)
2014	780 (563-998)	12.7% (9.5%-15.7%)	710 (499-922)	3% (2.1%-3.9%)	496 (349-643)	7.2% (5.2%-9.1%)	1704 (1413-1994)	6.7% (5.6%-7.8%)
2015	561 (370-752)	11.1% (7.6%-14.3%)	172 (74-270)	4.2% (1.9%-6.5%)	901 (668-1133)	9.1% (6.9%-11.2%)	4142 (3594-4689)	9% (7.9%-10%)
2016	916 (635-1196)	13.7% (9.9%-17.2%)	767 (543-990)	3.4% (2.4%-4.4%)	651 (436-866)	8.9% (6.2%-11.5%)	2252 (1744-2759)	8.7% (6.9%-10.4%)
2017	270 (148-392)	24.7% (15.2%-32.3%)	180 (68-291)	7.6% (3.1%-11.8%)	397 (196-599)	6.3% (3.2%-9.2%)	1826 (1064-2588)	6.1% (3.6%-8.4%)
2018	503 (351-655)	21.6% (16.1%-26.4%)	517 (341-694)	5.3% (3.5%-6.9%)	467 (308-627)	8.5% (5.8%-11.1%)	1947 (1589-2304)	9.1% (7.5%-10.6%)
2019	280 (156-405)	8% (4.6%-11.2%)	109 (32-186)	2% (0.6%-3.4%)	254 (149-358)	3.7% (2.2%-5.2%)	477 (345-608)	3.7% (2.7%-4.7%)
2020	22 (0-51)	0.4% (0%-0.9%)	34 (0-73)	0.6% (0%-1.3%)	151 (60-242)	1.7% (0.7%-2.7%)	495 (318-671)	1.9% (1.2%-2.6%)
2021	25 (0-60)	1.2% (0%-2.8%)	44 (0-102)	2.5% (0%-5.6%)	186 (56-316)	4.0% (1.2%-6.5%)	971 (629-1314)	3.9% (2.5%-5.2%)
2022	50 (0-102)	1.8% (0%-3.5%)	110 (34-185)	1.8% (0.6%-3.0%)	90 (23-156)	1.4% (0.4%-2.3%)	348 (212-485)	1.1% (0.7%-1.6%)
2023	18 (0-44)	0.9% (0%-2.1%)	10 (0-25)	0.9% (0%-2.2%)	138 (65-212)	1.9% (0.9%-2.9%)	237 (144-329)	1.4% (0.9%-2.0%)
2024	237 (131-342)	2.6% (1.5%-3.7%)	389 (228-549)	2%* (1.2%-2.9%)	110 (28-193)	2.2% (0.6%-3.8%)	295 (127-463)	1.7% (0.7%-2.6%)

\*Summer steelhead passage through 9/8/2024.

Table 3. Estimated run-specific salmonid predation by Steller sea lions at Willamette Falls based on Monte Carlo modelling of the probability sample data. Annual totals are only directly comparable for 2017-2024 due to changes in the sampling frame during the first three years of the project. Estimates only apply to the sampling frames and therefore are minimum estimates due to undercoverage of the target population. Percent potential passage (%PE) = estimate / (estimate + passage) x 100. Negative lower confidence bounds were replaced with zeros.

Year	Winter steelhead		Summer steelhead		Unmarked (wild) spring Chinook salmon		Marked (hatchery) spring Chinook salmon	
	Total (95% CI)	%PE (95% CI)	Total (95% CI)	%PE (95% CI)	Total (95% CI)	%PE (95% CI)	Total (95% CI)	%PE (95% CI)
2014	0 NA	0 NA	0 NA	0 NA	0 NA	0 NA	0 NA	0 NA
2015	0 NA	0 NA	0 NA	0 NA	0 NA	0 NA	0 NA	0 NA
2016	4 (0-13)	0.1% (0%-0.2%)	3 (0-8)	<0.1% (0%-<0.1%)	5 (0-13)	0.1% (0%-0.2%)	7 (0-20)	<0.1% (0%-0.1%)
2017	0 NA	0 NA	0 NA	0 NA	0 NA	0 NA	0 NA	0 NA
2018	12 (0-34)	0.6% (0%-1.8%)	9 (0-24)	0.1% (0%-0.3%)	9 (0-23)	0.2% (0%-0.5%)	45 (1-89)	0.2% (0%-0.5%)
2019	27 (0-63)	0.8% (0%-1.9%)	6 (0-18)	0.1% (0%-0.3%)	17 (0-42)	0.3% (0%-0.6%)	40 (0-86)	0.3% (0%-0.7%)
2020	37 (0-96)	0.7% (0%-1.7%)	3 (0-8)	0.1% (0%-0.2%)	9 (0-24)	0.1% (0%-0.3%)	26 (0-60)	0.1% (0%-0.2%)
2021	1 (0-2)	<0.1% (0%-0.1%)	1 (0-4)	0.1% (0%-0.2%)	21 (0-52)	0.5% (0%-1.1%)	113 (0-260)	0.5% (0%-1.1%)
2022	12 (0-31)	0.4% (0%-1.1%)	8 (0-22)	0.1% (0%-0.4%)	6 (0-17)	0.1% (0%-0.3%)	19 (0-45)	0.1% (0%-0.1%)
2023	75 (0-157)	3.6% (0%-7.2%)	15 (0-43)	1.3% (0%-3.6%)	12 (0-31)	0.2% (0%-0.4%)	18 (0-45)	0.1% (0%-0.3%)
2024	195 (97-292)	2.1% (1.1%-3.2%)	59 (4-114)	0.3%* (0%-0.6%)	15 (0-37)	0.3% (0%-0.7%)	30 (0-66)	0.2% (0%-0.4%)

\*Summer steelhead passage through 9/8/2024.

Appendix A. Sampling design metadata describing the Willamette Falls sea lion monitoring program, 2014-2024.

Year	Stratum	Sites	Full-time staff	Dates	Weeks	Hours	$N$ PSUs	$M$ SSUs	$K$ TSUs	Frame clusters	$n$ PSUs	$m$ SSUs	$k$ TSUs	Sample clusters	Sampling fraction	Weight	Frame elements	Sample elements	Elements per cluster
2014	F	3	2	Mar 3 - Jun 1	13	1,001	7	7	16	784	5	2	12	120	15.3%	6.53	6,006	929	7.66
	R	9	2	Mar 3 - Jun 1	13	1,001	7	20	16	2,240	5	2	12	120	5.4%	18.67	18,018	966	8.04
		12	4							3,024				240	7.9%		24,024	1,895	
2015	F	6	2	Feb 9 - May 31	16	1,239	7	14	16	1,568	5	2	12	120	7.7%	13.07	14,868	1,101	9.48
	R	10	2	Feb 9 - May 24	15	1,155	7	22	16	2,464	5	2	12	120	4.9%	20.53	23,100	1,122	9.37
		16	4							4,032				240	6.0%		37,968	2,223	
2016	F	6	2	Feb 1 - May 29	17	1,389	7	16	16	1,792	5	2	12	120	6.7%	14.93	16,668	1,114	9.30
2017	F	6	2	Jan 9 - Jun 9	22	1,750	7	16	16	1,792	5	2	12	120	6.7%	14.93	21,000	1,413	11.71
2018	F	6	2	Jan 8 - Jun 3	21	1,653.5	7	16	16	1,792	5	2	12	120	6.7%	14.93	19,842	1,337	11.14
2019	F	6	2	Jan 7 - Jun 2	21	1,647	7	16	16	1,792	5	2	12	120	6.7%	14.93	19,764	1,327	11.05
2020	F	6	2	Jan 6 - May 31	21	1,642.5	7	16	16	1,792	5	2	12	120	6.7%	14.93	19,710	1,329	11.08
2021	F	6	1	Jan 4 - May 30	21	1,636	na	na	na	3,272	na	na	na	96	2.9%	34.08	19,632	576	6
2022	F	6	1	Jan 3 - Jun 5	22	1,721.5	7	16	16	1,792	5	2	12	120	6.7%	14.93	20,658	1,388	11.6

Appendix A. cont.

Year	Stratum	Sites	Staff	Dates	Weeks	Hours	$N$ PSUs	$M$ SSUs	$K$ TSUs	Frame clusters	$n$ PSUs	$m$ SSUs	$k$ TSUs	Sample clusters	Sampling fraction	Weight	Frame elements	Sample elements	Elements per cluster
2023	F	6	1	Jan 2 – May 28	21	1,624.5	7	16	16	1,792	5	2	12	120	6.7%	14.93	19,494	1,289	10.7
2024	F	6	1	Jan 1 – Jun 2	22	1,710	7	16	16	1,792	5	2	12	120	6.7%	14.93	20,520	1,375	11.5