Oregon
Kate Brown, Governor

Department of Fish and Wildlife
17330 SE Evelyn Street
Clackamas, OR 97015
Tel: 971-673-6000
Fax: (971)-673-6070

November 1, 2021

Barry Thom
Regional Administrator, West Coast Region
National Marine Fisheries Service
1201 Northeast Lloyd Boulevard, Suite 1100
Portland, OR 97232

Dear Mr. Thom:

The following information comprises our 2021 annual report to the National Marine Fisheries Service (NMFS) from the Oregon Department of Fish and Wildlife (ODFW), documenting compliance with the terms and conditions of our authorization for the lethal removal of predatory California sea lions (CSLs) in the vicinity of in the vicinity of Willamette Falls (Oregon City, Oregon) under §120 of the Marine Mammal Protection Act (MMPA). This authorization was granted November 14, 2018, for a 5-year period until November 14, 2023; this report covers the period from November 1, 2020, through October 31, 2021. Please note, however, that we may soon be requesting that this authority be rescinded since we have also started conducting concurrent removals under the broader Columbia River Basin MMPA §120(f) authorization granted on August 14, 2020. For completeness we have noted removals under both concurrent authorities during this reporting period although removals under §120(f) will also be reported separately at a later date.

Terms and Conditions

No. 1
The State of Oregon lethally removed 2 individually identifiable predatory CSLs that were having a significant negative impact on ESA-listed salmonids at Willamette Falls. (An additional 6 CSLs and 1 Steller sea lion (SSL) was also removed during this period at Willamette Falls under concurrent MMPA §120(f) authority.)

No. 2
Under our the new and concurrent MMPA §120(f) authorization, CSLs are not required to meet the removal criteria defined in condition 1 of our Willamette Falls §120 authorization. We therefore did not request that any new CSLs be added to the Appendix of individuals meeting the criteria for removal at this location.

No. 3
The State of Oregon did not exceed the limit of taking more than one percent of the current PBR (14,011) (i.e., 2 actual removals ≤ 140 potential removals).

No. 4
The State of Oregon consulted with our Institutional Animal Care and Use Committee (IACUC) prior to conducting work during the 2020-2021 field season in order to review protocols for capture, holding, and euthanasia of individually identifiable predatory CSLs.

No. 5
No pre-approved permanent holding facilities requested CSLs and therefore all animals meeting the criteria for removal were euthanized according to IACUC-approved methods.

No. 6
The State of Oregon has ensured that transfer or disposal of any carcass or parts were done in accordance with applicable laws, and worked with researchers to make carcasses, tissues or parts of lethally removed animals available for research and/or education.

No. 7
The State notified the Regional Administrator, NMFS West Coast Region, in writing of all sea lion removal operations within the required three-day period.

No. 8
The State of Oregon developed and began implementation of a multi-year monitoring plan to evaluate 1) the impacts of CSL predation on UWR spring-run Chinook salmon and UWR winter steelhead; and 2) the effectiveness of permanent removal of individually identifiable predator CSLs as a method to reduce adult salmonid mortality. The State has or will perform by the end of the authorization period, the following actions:

a) monitored and reported specific CSLs observed, including when animals were removed and residence time at Willamette Falls;
b) monitored and reported the number of prey observed and estimated to have been taken;
c) monitored, evaluated, and reported on expedience (number of days animal present before removal) of removal;
d) monitored and reported key population parameters for UWR spring-run Chinook salmon and UWR winter steelhead populations so that changes in population status can be detected;
e) ensured that monitoring efforts included other pinnipeds that occurred in the vicinity of Willamette Falls;
f) will update the population viability analysis for UWR spring-run Chinook salmon and UWR winter steelhead after 5 years of implementation (after December 2023) to determine, to the extent possible, any changes in the estimated extinction risk to the salmonid stocks in question.

No. 9
This letter describing our compliance with the terms and conditions of the 2018 LOA and the attached two reports on monitoring and management activities conducted in 2020-2021 represents our annual monitoring reports to NMFS. The State of Oregon is currently planning to conduct similar work in 2021-2022 albeit under our concurrent MMPA §120(f) authority.

No 10
See condition 2.

No. 11
We understand that the authorization may be modified, suspended, or revoked by NMFS at any time given 72 hours' notice to the State.

No. 12
We understand that this authorization is valid until November 14, 2023, at which time it may be extended by NMFS for an additional period to be determined by NMFS. Please note, however, that we may soon be requesting that this authority be rescinded since we have also started conducting concurrent removals under the broader Columbia River Basin MMPA §120(f) authorization granted on August 14, 2020.

The State of Oregon remains committed to pursuing all reasonable approaches to reduce pinniped predation on threatened Willamette River salmonids. As you know, however, existing non-lethal tools have proven ineffective, and no effective new options have been identified. While we would prefer to find and implement successful non-lethal methods for reducing predation, permanent removal of some number of habituated predatory sea lions may continue to be necessary for the foreseeable future.

We thank you for your assistance and support of our work to monitor and reduce sea lion predation on threatened salmonids below Willamette Falls and elsewhere in the lower Columbia River basin. Please let us know if we can provide further information related to our annual reporting obligations.

Sincerely,

Michael Brown
Supervising Fish and Wildlife Biologist/Project Leader
Marine Mammal Program

Attached:
ANNUAL REPORT: PINNIPED MANAGEMENT AT WILLAMETTE FALLS, 2020-2021
ANNUAL REPORT: PINNIPED MONITORING AT WILLAMETTE FALLS, 2020-2021

ANNUAL REPORT:
PINNIPED MANAGEMENT AT WILLAMETTE FALLS, 2020-2021

November 1, 2021

Oregon Department of Fish and Wildlife

Project staff:

Mike Brown, Sheanna Steingass, Bryan Wright, Susan Riemer, Shay Valentine
Zane Kroneberger, Brad Tripplet, Buddy Phibbs
Julia Burco DVM, Colin Gillin DVM

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INTRODUCTION

Willamette Falls is a natural waterfall located approximately 26 miles from the confluence of the Columbia and Willamette Rivers. While sea lions were not historically present there, they increasingly began occurring in the 1990s, prompting the Oregon Department of Fish and Wildlife (ODFW) to begin a monitoring program at this location in 1995. Due to further increases in the 2000s, ODFW conducted a non-lethal hazing program in 2010, 2011, and 2013. The non-lethal hazing program, despite expending considerable resources, had minimal effect on reducing predation or the number of sea lions present and was discontinued in favor of implementation of a rigorous monitoring program. In 2014, 27 individual sea lions were noted in the area. This increased to 35 individuals in 2016, and more than 40 individuals in 2017. Because of these growing numbers of sea lions, the State initiated management action to prevent a scenario similar to those seen at Ballard Locks, WA (see Fraker and Mate 1999) and Bonneville Dam on the lower Columbia River (see Tidwell et al. 2021).

In 2017, the State of Oregon submitted an application to the National Marine Fisheries Service (NMFS) to remove a number of California sea lions (CSLs) present below Willamette Falls under Section 120 of the Marine Mammal Protection Act (MMPA). This was in part due to findings of the Upper Willamette River Winter Steelhead Population Viability Study conducted by ODFW scientists (ODFW 2019), which concluded the upper Willamette River native (winter) steelhead were at significant risk of extinction due to predation by CSLs present at this location. On November 14, 2018, NMFS approved the state's application and the first removals of CSLs at Willamette Falls began on December 12, 2018.

At this same time, the Endangered Salmon Predation Prevention Act of 2018 became law on December 18, 2018. This law amended the MMPA by replacing the existing Section 120(f) titled "California sea lions and Pacific harbor seals; investigation and report" with a new Section 120(f) titled "Temporary Marine Mammal Removal Authority on the Waters of the Columbia River or its Tributaries". On June 13, 2019, ODFW, along with its many state and tribal co-management partners, submitted an application to NMFS under the newly amended MMPA to remove CSLs—and for the first time Steller sea lions (SSLs; *Eumetopias jubatus*, eastern stock)—in the lower Columbia River Basin (CRB), including the Willamette River. NMFS subsequently approved this application and issued a letter of authorization to ODFW and its managing partners on August 14, 2020.

This report summarizes work conducted under our MMPA Section 120 authority at Willamette Falls during the fall 2020-spring 2021 field season. (There was no management report for the fall 2019-spring 2020 season since it was largely suspended due to COVID-19.) For completeness, we report on removals taken under both our original 2018 authorization (WF §120) as well as our jointly held 2020 authorization (CRB §120(f)) although removals under the latter will also be reported separately at a later date. Specifically, we report here on the management aspects of this work whereas the monitoring requirements are provided in a separate report (see Wright et al. 2021).

METHODS

Trapping

Sea lions were captured using haul-out traps placed at the upstream end of Sportcraft Landing Moorages on the Willamette River approximately 1.7 km downstream of Willamette Falls. Sea lions use these traps as haul-out sites, entering and exiting traps via a vertically sliding door, which was pad-locked open prior to a scheduled capture attempt. Armed traps were monitored in person, or remotely via game cameras by ODFW staff. Wireless trap monitoring sensors were installed on all trap doors to automatically notify project staff by text in the event of an unplanned trap closure. In addition, new, manually operated safety pin devices were fabricated and installed to further protect against the event of an unplanned trap closure.

Trap doors were closed using a remote-controlled magnetic release mechanism. Once sea lions were captured, they were herded into holding cages on a barge built specifically to handle sea lions. Once animals were moved from the trap to a transfer cage on the barge, plywood boards were placed on all sides of the transfer cage to reduce visual stimuli and stress on the animal. Two boats were then used to move the barge downriver to a boat ramp where sea lions were transferred onto trucks for transport to a secure off-site facility.

Animals may be held up to 48 hours as per the Willamette Falls IACUC, although animals are typically held for less than three hours in the covered transfer cage either indoors or outdoors, and are regularly monitored and wet down with a hose to reduce the chance of thermal stress. If an approved zoo or aquarium facility were available to receive candidate sea lions for permanent holding, then captured animals would be given a health screening by field staff and veterinarians, including members of the States' Institutional Animal Care and Use Committee. If an animal passed the health screening it would be transferred to an approved temporary housing facility prior to shipment to a zoo or aquarium. If an animal failed the health exam, or if there were no approved facilities prepared to accept an animal, then it would be chemically euthanized. Euthanized animals were necropsied and various samples (e.g., teeth, stomachs, whiskers) were collected and stored for later analysis.

Diet analysis

Stomachs and large intestines from euthanized animals were collected and processed following standard procedures (e.g., see Lance et al. 2001) in order to gather dietary information. Undigested remains were washed through a series of nested sieves (2mm, 1mm and .05mm) and all parts were collected for later identification. Samples were identified using a dissecting microscope to the lowest possible taxonomic level by comparing all identifiable prey remains (e.g., bones, otoliths, cartilaginous parts, lenses, teeth and cephalopod beaks) against a reference collection of fish from the northeastern Pacific Ocean and Oregon estuaries. Prey were enumerated by pairing of skeletal structures (otoliths, tail structures, mouthparts, etc.) to achieve the greatest number of prey in the sample. Enumeration takes into account both left and right sides of paired structures and also size of recovered prey remains.

Effect of removals

The effect of the sea lion removal program at Willamette Falls was assessed in several ways. First, we compared monitoring data from pre- and post- removal authority years. This included 1) estimates of sea lion abundance and 2) estimates of predation on salmonids and other prey. See Wright et al. (2021) for methodological details and additional results not presented here. Second, the effect of removals was characterized by estimating how many salmonids would have been required over the expected post-removal lifetimes of individual sea lions had they not been removed. This was done using an agent-based modeling (ABM) approach (see Sibley et al. 2013, Macal 2016, and An et al. 2021 for background and examples). Results are based on summaries of 100 model runs. Note that this work is ongoing and subject to revision as new data becomes available and as new modeling approaches are evaluated. Details of the model are provided in the Appendices; model code (R) is available upon request.

RESULTS

Trapping

Trapping effort below Willamette Falls occurred over approximately 13 weeks from early March through late May 2021 (Table 1, Figure 1). Trapping resulted in 12 sea lion captures although sea lions may be captured more than once. One SSL and eight CSLs were euthanized. The average weight of the euthanized CSLs (n = 8) was 258 kg (569 lbs), with a range of 111-385 kg (245-850 lbs); the weight of the euthanized SSL was approximately 635 kg (1400 lbs). Age data based on sectioned teeth are not yet available

Diet analysis

Nine gastro-intestinal (GI) tracts were collected from euthanized sea lions, all of which contained undigested prey remains (Table 2). The single SSL GI-tract contained a single sturgeon whereas 5 CSL GI-tracts contained undigested remains of at least 15 adult spring Chinook salmon and 1 unidentified adult salmonid. Additional prey recovered from CSL GI-tracts were Pacific lamprey (*Entosphenus tridentatus*) (5 GI-tracts, 188 individual fish) as well as other unidentified lamprey species.

Effect of removals

Monitoring results (see Wright et al. 2021) suggest that the CSL management started in December 2018 has resulted in substantial decreases in both CSL abundance (Figure 1) and salmonid predation (Figure 2), particularly during the late fall and winter months when listed winter steelhead are most at risk from sea lion predation. Initial results from agent-based modelling of the 35 CSLs removed under WF §120 authority indicate that the median post-removal lifetime requirement for these individuals was approximately 18,000 salmonids (Figure 3); the 95% confidence interval was approximately 5,000 to 43,000 salmonids. Median daily biomass requirement (all prey) was estimated to be 14.7 kg, which as a percent of body mass was estimated to be 4.6%. Median annual and lifetime residency was estimated to be 54 days and 163 days, respectively.

DISCUSSION

The third season of the Willamette Falls Section 120 program was largely successful despite having lost nearly the entire second season due to COVID-19 restrictions. The eight CSLs that were removed during 2020-2021 represented two-thirds of the approximately dozen that were observed below the falls throughout the season; the one SSL that was removed, however, was only one of an approximately half-dozen in the study area. These removals bring the grand total to 43 sea lions that have been removed at the traps below Willamette Falls under multiple MMPA Section 120 authorities (see Appendix 1). Despite this continued progress, however, it was clear that overall predation during the spring 2021 season increased slightly relative to 2020 (Figure 2) for which there are several likely reasons.

First and probably foremost for the apparent increase in predation was the aforementioned lost ground due to COVID-19. Since the number of habituated sea lions coming out of the spring 2020 season was relatively high (perhaps numbering a dozen) their return in spring 2021 likely led to some new recruitment and a further increase in site fidelity. One important exception, however, is the fact that there continued to be no replacement of the fall and early winter cohort of CSLs which was completely removed in the 2018-2019 season. As a result, predation on winter steelhead continued to be minimal in 2020-2021 whereas most of the predation impact fell to hatchery spring Chinook (see Wright et al. 2021).

A second reason for an increase in predation in 2021 was due to a decrease in trap use, thus preventing timely removals. For example, two CSLs occurred below the falls for two weeks in February but never used the traps and were therefore not removed. And while eight CSLs were successfully removed by mid-April, there were still at least four animals foraging daily at the falls through May that were never captured. We plan to address this issue if it occurs again with additional capture methods.

A final reason for increased predation was the continued increase in foraging activity around the Falls by SSLs. While SSLs continue to primarily forage for sturgeon in the lower sections of the river (see Figure 7 of Wright et al. 2021), their occurrence at the falls and predation on salmonids continues to increase relative to previous years (see Table 2 of Wright et al. 2021). However, under the new CRB §120(f) removal authority granted in the fall of 2020 the first SSL was removed at Willamette Falls in spring 2021 (Tables 1 and 2). Coupled with SSL management at nearby Bonneville Dam on the Columbia River, SSL abundance in the Willamette River should begin decreasing in the coming years the same way that CSL abundance has declined due to management at both sites.

Management efforts at Bonneville Dam and Willamette Falls continue to serve as an effective inter-agency effort to solve a difficult and complex natural resource problem. Continued trapping, monitoring, and data analysis will help determine whether these efforts are successful in increasing the long-term survival probability for listed Columbia River Basin salmonids.

ACKNOWLEDGEMENTS

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- ODFW: Shaun Clements, Chris Kern, Tucker Jones, Dave Fox, Jeff Boechler, Kevleen Melcher, and Debbie Ames
- Confederated Tribes of the Grande Ronde: Kelly Dirksen
- PSMFC: Dave Colpo, Sarah Kirk
- NMFS: Robert Anderson
- Oregon State Police
- Clackamas County Sheriff Marine Unit
- Sportcraft Landing Moorages

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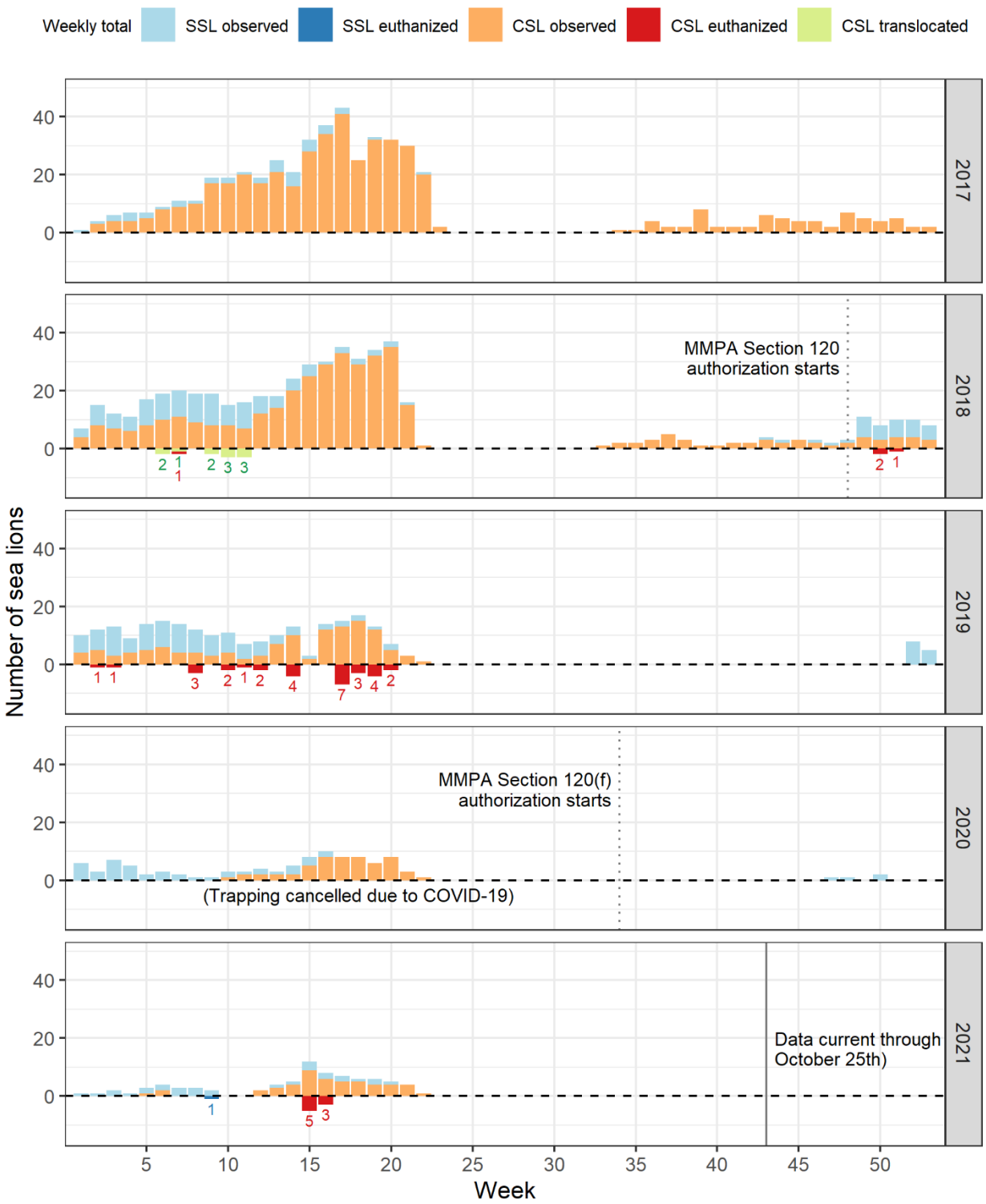


Figure 1. Weekly counts of California sea lions (CSL) and Steller sea lions (SSL) at Willamette Falls, 2017-2021. Non-mutually exclusive count categories include numbers observed, euthanized, or translocated. Observed counts represent the maximum daily count for a given week based on direct observations and/or automated cameras.

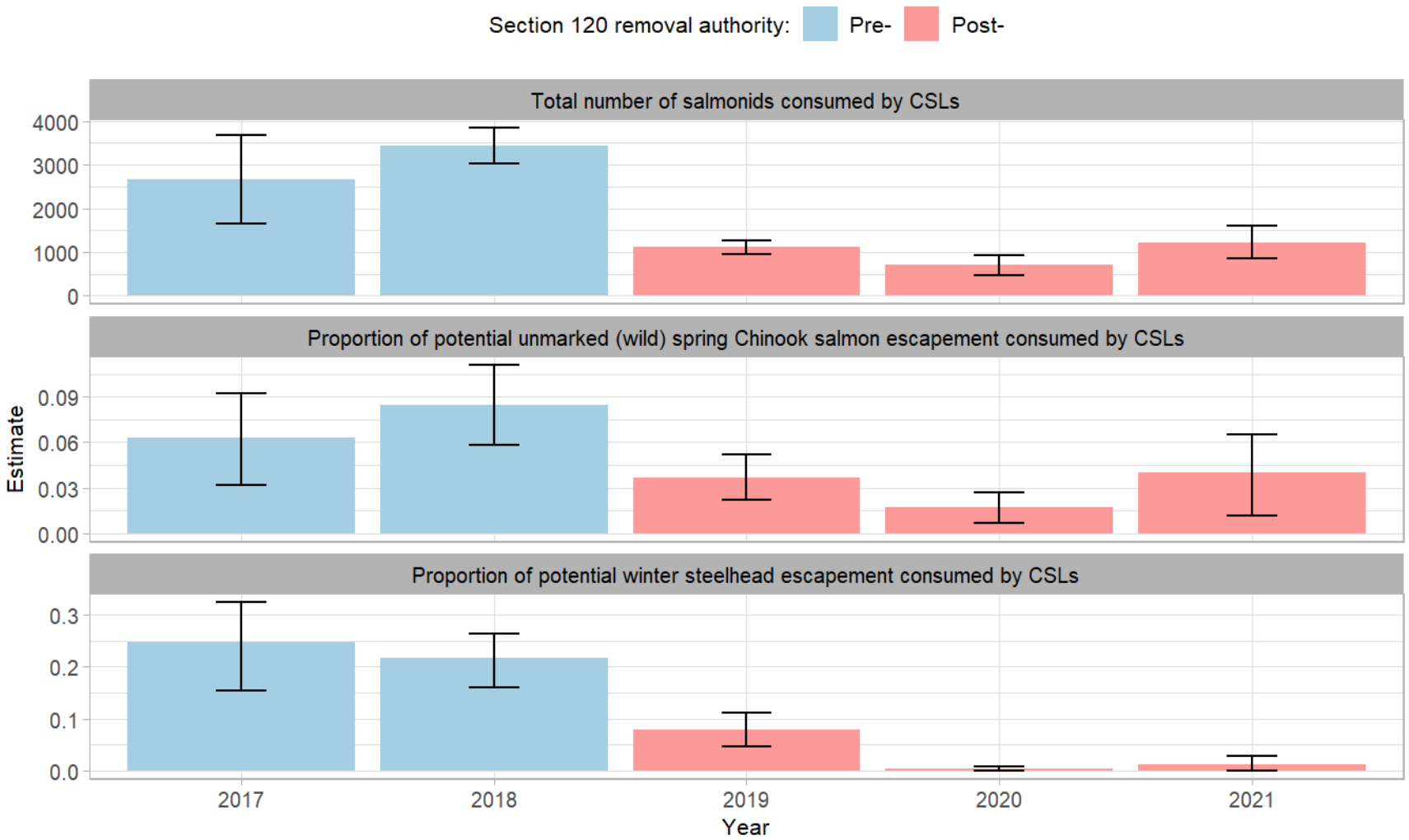


Figure 2. Comparison of estimated predation by California sea lions (CSLs) between years with and without management authority; error bars indicate 95% confidence interval limits. Estimates only apply to the sampling frame and therefore are minimum estimates due to undercoverage of the target population. Percent potential escapement (%PE) = estimate / (estimate + escapement) x 100.

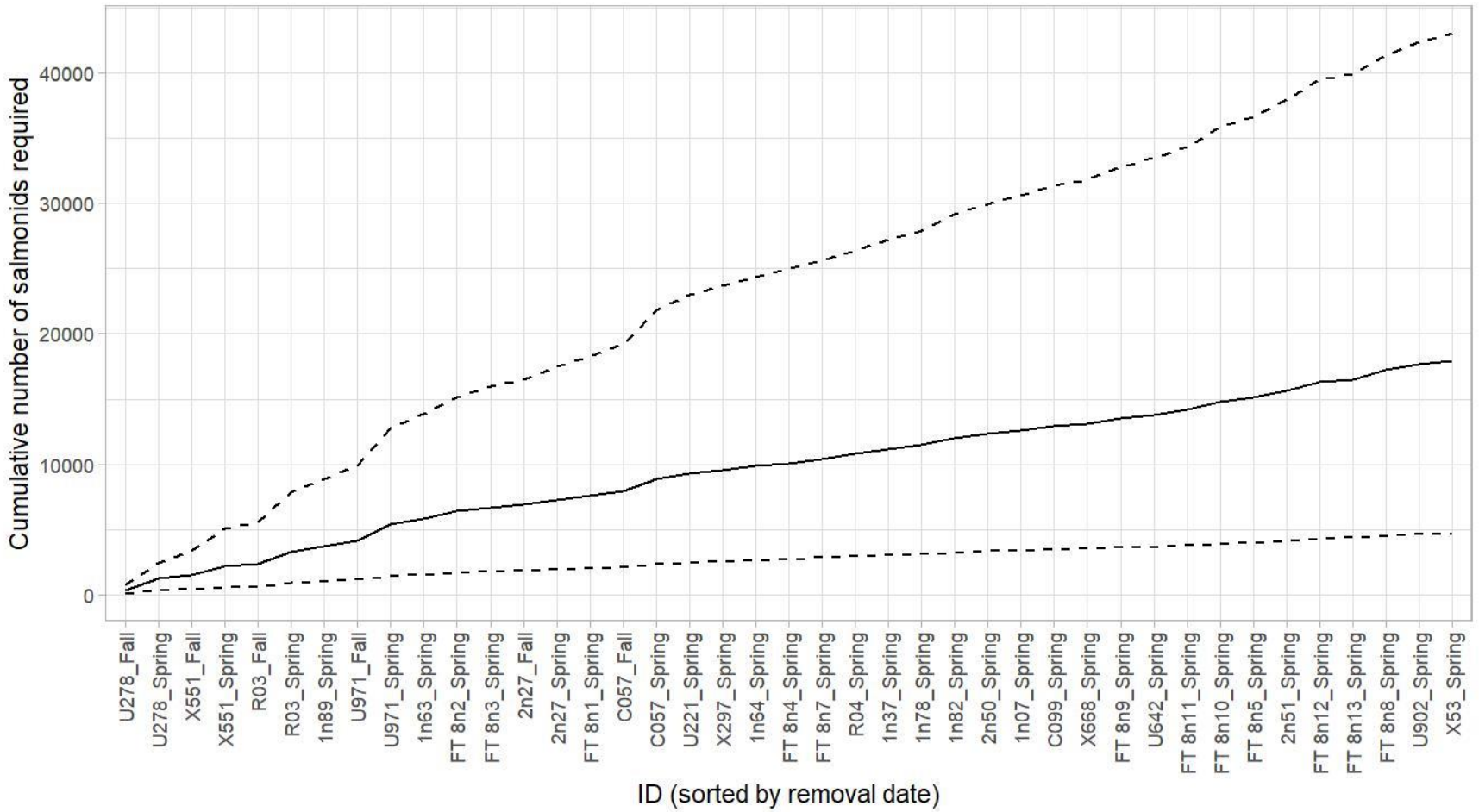


Figure 3. Estimated post-removal lifetime salmonid requirements for 35 California sea lions removed at Willamette Falls under MMPA Section 120. Solid line equals median estimated requirements; dashed lines equal 2.5th and 97.5th percentiles. See Appendices X and Y for model details.

Table 1. Weekly summary of sea lion capture effort and outcomes at Willamette Falls, 11/1/2020-10/31/2021. List includes animals removed under letters of authorization for Willamette Falls MMPA §120 (valid 11/14/2018-11/14/2023) and Columbia River Basin MMPA §120(f) (valid 8/14/2020-8/14/2025).

		Steller sea lions		California sea lions	
Week of	Trap effort (days)	Released	Euthanized*	Marked/ released	Euthanized*
2021-03-01	2		1		
2021-03-08	0	*(No sea lions occupying traps)*			
2021-03-15	0	*(No sea lions occupying traps)*			
2021-03-22	0	*(Limited staff availability)*			
2021-03-29	0	*(Limited staff availability))*			
2021-04-05	0	*(No sea lions occupying traps)*			
2021-04-12	4	1		2	5
2021-04-19	4				3
2021-04-26	2				
2021-05-03	4				
2021-05-10	4				
2021-05-17	2				
2021-05-24	0	*(No sea lions occupying traps; migration out of area)*			
	22	1	1	2	8

*See Table 2 for specific MMPA authority under which each animal was euthanized.

Table 2. Minimum number of individual prey recovered from gastro-intestinal tracts (stomach and large intestines) collected from eight euthanized California sea lions (CSL) and one Steller sea lion (SSL) captured at Willamette Falls, 11/1/2021-10/31/2021. List includes animals removed under letters of authorization for Willamette Falls (WF) MMPA §120 (valid 11/14/2018-11/14/2023) and Columbia River Basin (CRB) MMPA §120(f) (valid 8/14/2020-8/14/2025).

Date	Sea lion species	ID	Removal authority	Adult Chinook salmon	Adult salmonid	Pacific lamprey	Sturgeon	Other
2021-03-02	SSL	EW001	CRB §120(f)				1	
2021-04-13	CSL	ZW001	CRB §120(f)			116		
	CSL	ZW002	CRB §120(f)	1	1			
	CSL	ZW003	CRB §120(f)		1	17		
	CSL	U902	WF §120					1 [a]
2021-04-15	CSL	ZW004	CRB §120(f)			34		6 [b]
2021-04-20	CSL	ZW005	CRB §120(f)	5		18		
	CSL	ZW006	CRB §120(f)	6		3		
	CSL	X53	WF §120	3				
Total				15	2	188	1	7

[a] Unidentified lamprey species

[b] 1 unidentified fish, 5 *Lamptera* species (brook or river lamprey)

Appendix 1. Complete list of 42 California sea lions (CSL) and 1 Steller sea lion (SSL) captured and removed from below Willamette Falls under multiple MMPA §120 authorities (1 BD §120, 35 WF §120, 7 CRB §120(f)).

#	Date	Species	ID	Removal authority*	Reporting period
1	2018-02-14	CSL	U605	BD §120	2017-2018
2	2018-12-12	CSL	U278	WF §120	2018-2019
3	2018-12-12	CSL	X551	WF §120	2018-2019
4	2018-12-20	CSL	R03	WF §120	2018-2019
5	2019-01-09	CSL	1-89	WF §120	2018-2019
6	2019-01-15	CSL	U971	WF §120	2018-2019
7	2019-02-20	CSL	FT 8-2	WF §120	2018-2019
8	2019-02-20	CSL	FT 8-3	WF §120	2018-2019
9	2019-02-20	CSL	1-63	WF §120	2018-2019
10	2019-03-06	CSL	2-27	WF §120	2018-2019
11	2019-03-06	CSL	FT 8-1	WF §120	2018-2019
12	2019-03-13	CSL	C057	WF §120	2018-2019
13	2019-03-22	CSL	U221	WF §120	2018-2019
14	2019-03-22	CSL	X297	WF §120	2018-2019
15	2019-04-03	CSL	FT 8-4	WF §120	2018-2019
16	2019-04-03	CSL	FT 8-7	WF §120	2018-2019
17	2019-04-03	CSL	1-64	WF §120	2018-2019
18	2019-04-05	CSL	R04	WF §120	2018-2019
19	2019-04-23	CSL	1-37	WF §120	2018-2019
20	2019-04-23	CSL	1-78	WF §120	2018-2019
21	2019-04-24	CSL	2-50	WF §120	2018-2019
22	2019-04-24	CSL	1-82	WF §120	2018-2019
23	2019-04-25	CSL	C099	WF §120	2018-2019
24	2019-04-25	CSL	1-07	WF §120	2018-2019
25	2019-04-25	CSL	X668	WF §120	2018-2019
26	2019-04-30	CSL	FT 8-9	WF §120	2018-2019
27	2019-05-01	CSL	U642	WF §120	2018-2019
28	2019-05-02	CSL	FT 8-11	WF §120	2018-2019
29	2019-05-07	CSL	FT 8-5	WF §120	2018-2019
30	2019-05-07	CSL	FT 8-10	WF §120	2018-2019
31	2019-05-08	CSL	FT 8-12	WF §120	2018-2019
32	2019-05-08	CSL	2-51	WF §120	2018-2019
33	2019-05-14	CSL	FT 8-8	WF §120	2018-2019
34	2019-05-14	CSL	FT 8-13	WF §120	2018-2019
35	2021-04-13	CSL	U902	WF §120	2020-2021
36	2021-04-20	CSL	X53	WF §120	2020-2021

37	2021-03-02	SSL	EW001	CRB §120(f)	2020-2021
38	2021-04-13	CSL	ZW001	CRB §120(f)	2020-2021
39	2021-04-13	CSL	ZW002	CRB §120(f)	2020-2021
40	2021-04-13	CSL	ZW003	CRB §120(f)	2020-2021
41	2021-04-15	CSL	ZW004	CRB §120(f)	2020-2021
42	2021-04-20	CSL	ZW005	CRB §120(f)	2020-2021
43	2021-04-20	CSL	ZW006	CRB §120(f)	2020-2021

* Bonneville Dam (BD) MMPA §120 (valid 6/28/2016-6/30/2021)
Willamette Falls (WF) MMPA §120 (valid 11/14/2018-11/14/2023)
Columbia River Basin (CRB) MMPA §120(f) (valid 8/14/2020-8/14/2025)

Appendix 2. ODD (Overview, Design concepts, Details) protocol for agent-based model of sea lion prey requirements.

This draft model description follows the ODD protocol for describing individual- and agent-based models (Grimm et al. 2006), as updated by Grimm et al. (2020). Additional detail will be added in future reports.

1. Overview: Purpose and pattern

The primary purpose of the sea lion management ABM is to predict the number of prey (particularly salmonids) required over the post-removal lifetime of California sea lions and Steller sea lions that were captured in the Columbia River Basin under Section 120/120(f) of the Marina Mammal Protection Act from 2008-present.

We define two patterns as the criteria for model usefulness: estimates of per capita biomass consumption consistent and per capita biomass consumption as a percent of body mass that are consistent with the published literature.

2. Overview: Entities, state variables, and scales

Entities in the model are individual sea lions.

Sea lions each have a unique ID and have state variables for age in years, whether or not they survived an annual time step, growth in body mass per annual time step, whether or not they returned (site fidelity) to an upriver site per annual time step, and the residency duration per annual time step. Within an annual time step, state variables include biomass requirements for up to three prey items. Species (CSL, SSL), sex (male), location (Bonneville Dam, Willamette Falls), season (fall = July-December; spring = January-June), and diet composition are not considered state variable since they do not change during time steps.

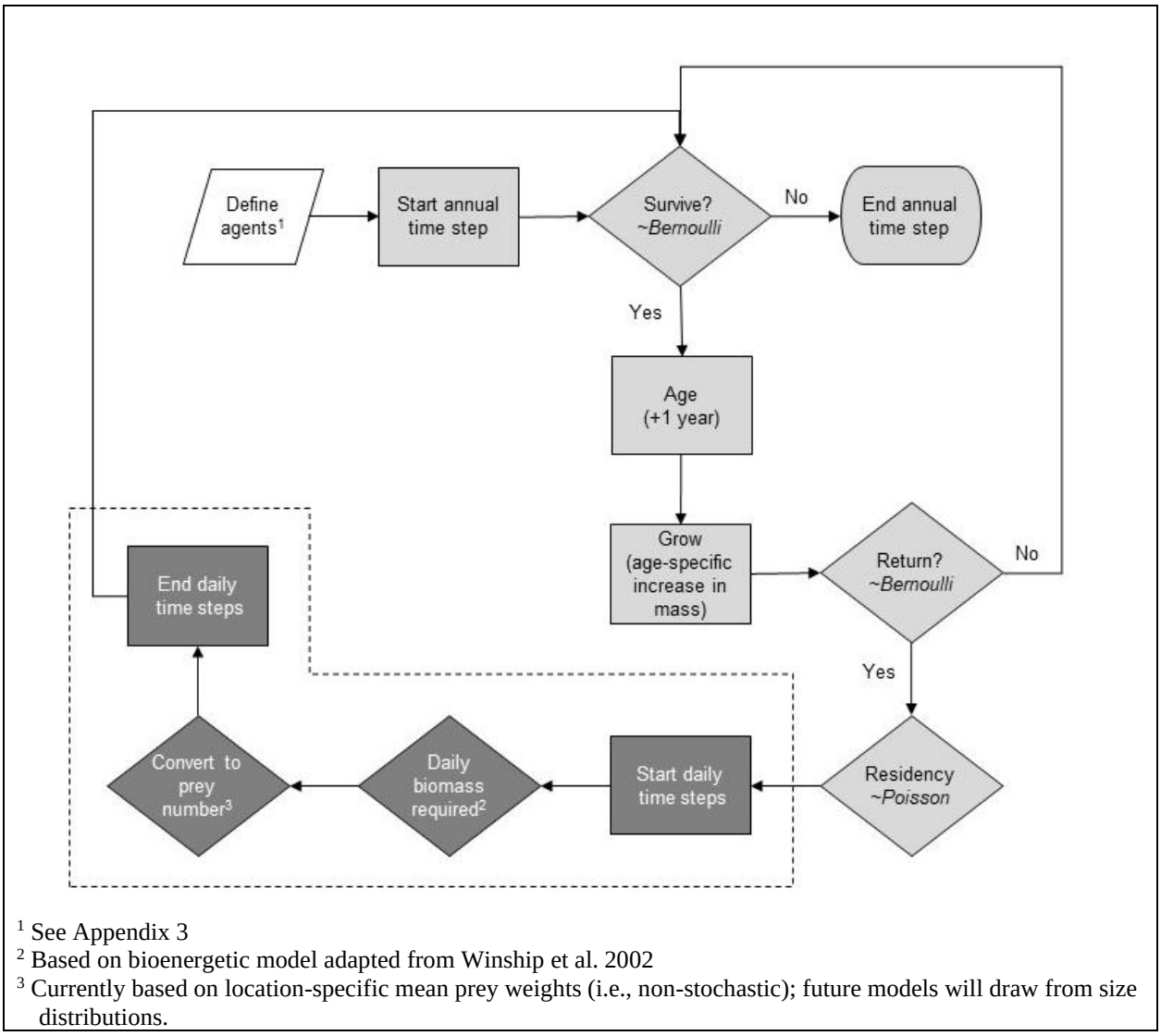
The model is non-spatial so the environment is not represented and sea lions only have one location (Bonneville Dam or Willamette Falls). The model runs at two different time scales: annual for survival, growth, fidelity, and residency; daily for biomass consumption requirements.

3. Overview: Process overview and scheduling

Processes: The model was developed to cover the life-cycle of nuisance sea lions as it pertains to their time at terminal upriver feeding sites in the Columbia River Basin. It is structured in a combination of several deterministic and stochastic processes (see flowchart below).

Schedule: The simulation starts one year post-removal for each sea lion (within year biomass requirements will be added to future model). Each animal's probability of surviving to the first year post-removal is governed by a species, sex (male), and age-specific survival probability as defined in a Bernoulli trial where the probability of survival is based on the published literature. If an animal survives then its age is incremented and body mass increases by an age-specific factor based on the published literature (stochasticity in growth may be added at a later date). Next, the probability of returning to an upriver site for a given location and season is determined independently for each sea

lion based on a Bernoulli trial where the site fidelity (return probability) is based on empirical data from marked animals from Bonneville Dam and Willamette Falls. Next, residency duration is estimated independently for each sea lion based on a single sample from a Poisson distribution where the parameter is based on empirical data from marked animals from Bonneville Dam and Willamette Falls. A within-year daily loop then starts based on the residency realization where for each day, location- and season- specific biomass requirements are estimated based on a bioenergetics model for up to three diets. Currently the biomass requirement is converted to number of fish at the end of the simulation based on mean prey weights but future updates to the model will likely convert biomass to fish numbers at the daily level. At the end of the residency period the sea lion migrates and repeats the annual loop beginning with the survival step.



[1] See Appendix 3
[2] Based on bioenergetic model adapted from Winship et al. 2002
[3] Currently based on location-specific mean prey weights (i.e., non-stochastic); future models will draw from size distributions.

Flowchart of sea lion management ABM.

4. Design: Design concepts

The 11 design concepts (basic principles, emergence, adaptation, objectives, learning, prediction, sensing, interaction, stochasticity, collectives, and observation,) will be included at a later date

5. Details: Initialization

Each individual's state variable (age, mass, fidelity, residency) is initialized by based on either individual-specific empirical data or estimated from such data. Estimated or actual state data is indicated in Appendix 3 by variable suffixes ending in "_est" whose values are "1" for estimated and "0" for actual. Additional initialization details will be included at a later date.

6. Details: Input data

Three input files (besides agent data in Appendix 3) are imported into the model: survival data, growth data, and diet composition data. These are defined in separate model scripts and are based on either the published literature or empirical data.

7. Details: Sub-models

Sub-model details will be provided at a later date.

Appendix 3. Agent input file for sea lion management ABM.

	ID	Capture_location	Capture_date	Age	Age_est	Mass_lbs	Mass_est	Season	Fidelity	Fidelity_est	Residency	Residency_est
1	U278	Willamette Falls	20181212	9	0	563	1	Fall	1.00	0	52.70	1
	U278	Willamette Falls	20181212	9	0	563	1	Spring	1.00	0	100.20	0
2	X551	Willamette Falls	20181212	7	0	563	1	Fall	1.00	0	52.70	1
	X551	Willamette Falls	20181212	7	0	563	1	Spring	1.00	0	82.50	0
3	R03	Willamette Falls	20181220	9	0	694	0	Fall	1.00	0	36.50	0
	R03	Willamette Falls	20181220	9	0	694	0	Spring	1.00	0	116.00	0
4	1n89	Willamette Falls	20190109	8	0	482	0	Spring	1.00	0	67.50	0
5	U971	Willamette Falls	20190115	8	0	760	0	Fall	0.67	0	83.00	0
	U971	Willamette Falls	20190115	8	0	760	0	Spring	1.00	0	103.00	0
6	1n63	Willamette Falls	20190220	8	0	507	0	Spring	1.00	0	61.33	0
7	FT 8n2	Willamette Falls	20190220	8	0	658	0	Spring	1.00	1	52.81	1
8	FT 8n3	Willamette Falls	20190220	8	0	426	0	Spring	1.00	1	52.81	1
9	2n27	Willamette Falls	20190306	9	0	547	0	Fall	0.50	0	52.70	1
	2n27	Willamette Falls	20190306	9	0	547	0	Spring	1.00	0	60.00	0
10	FT 8n1	Willamette Falls	20190306	10	0	625	0	Spring	1.00	1	52.81	1
11	C057	Willamette Falls	20190313	7	0	661	0	Fall	0.67	0	52.70	1
	C057	Willamette Falls	20190313	7	0	661	0	Spring	1.00	0	96.33	0
12	U221	Willamette Falls	20190322	8	0	714	0	Spring	1.00	0	44.00	0
13	X297	Willamette Falls	20190322	10	0	672	0	Spring	1.00	0	47.00	0
14	1n64	Willamette Falls	20190403	9	0	497	0	Spring	1.00	0	56.00	0
15	FT 8n4	Willamette Falls	20190403	12	0	616	0	Spring	1.00	1	52.81	1
16	FT 8n7	Willamette Falls	20190403	12	0	793	0	Spring	1.00	1	52.81	1
17	R04	Willamette Falls	20190405	11	0	738	0	Spring	1.00	1	52.81	1
18	1n37	Willamette Falls	20190423	8	0	743	0	Spring	1.00	0	38.50	0
19	1n78	Willamette Falls	20190423	9	0	650	0	Spring	1.00	0	35.50	0
20	1n82	Willamette Falls	20190424	8	0	792	0	Spring	1.00	0	50.00	0
21	2n50	Willamette Falls	20190424	9	0	489	0	Spring	1.00	0	52.81	1
22	1n07	Willamette Falls	20190425	9	0	650	0	Spring	1.00	0	30.50	0
23	C099	Willamette Falls	20190425	8	0	420	0	Spring	1.00	0	47.33	0

24	X668	Willamette Falls	20190425	9	0	572	0	Spring	1.00	0	28.50	0
25	FT 8n9	Willamette Falls	20190430	7	0	437	0	Spring	1.00	1	52.81	1
26	U642	Willamette Falls	20190501	8	0	514	0	Spring	1.00	0	30.50	0
27	FT 8n11	Willamette Falls	20190502	9	0	700	0	Spring	1.00	1	52.81	1
28	FT 8n10	Willamette Falls	20190507	7	0	703	0	Spring	1.00	1	52.81	1
29	FT 8n5	Willamette Falls	20190507	9	0	493	0	Spring	1.00	1	52.81	1
30	2n51	Willamette Falls	20190508	8	0	744	0	Spring	1.00	0	52.81	1
31	FT 8n12	Willamette Falls	20190508	7	0	825	0	Spring	1.00	1	52.81	1
32	FT 8n13	Willamette Falls	20190517	14	0	736	0	Spring	1.00	1	52.81	1
33	FT 8n8	Willamette Falls	20190517	7	0	674	0	Spring	1.00	1	52.81	1
34	U902	Willamette Falls	20210413	8	1	563	1	Spring	1.00	1	52.81	1
35	X53	Willamette Falls	20210420	8	1	563	1	Spring	1.00	0	32.50	0