Lower Coquille Tide Gate and Fish Passage Monitoring Project, 2021-2022

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Table of Contents

1. Introduction 1
2. Background 1
3. Project Area and Overview 2
4. Monitoring Questions 7
5. Methods 8
6. Analytical Approach 15
7. Results 18
8. Discussion 66
9. Conclusion 70
10. Literature Cited 71
11. Appendices 73

List of Tables

Table 1. Monthly duration of side-hinge tide gate door openness for Cochran, Seestrom, Winter Lake – Unit 1, Winter Lake – Unit 2 and Winter Lake – Unit 3. Both Cochran and Seestrom are manual mechanical MTR style tide gates that allow inflow and outflow. Inflow at Winter Lake is managed using the vertical slide gates (Figure 17). The side-hinged gates at Winter Lake are duplicative and only allow outflow. 20
Table 2. Fish sampling summary from the Dec 2021-May 2022 sampling season. 24
Table 3. Total species abundance for the Dec 2021-May 2022 fish-sampling season not including mainstem Coquille River sampling. 25
Table 4. Mean fork lengths (millimeters, ±95% CI) of juvenile coho salmon sampled in Beaver Slough, Winter Lake Unit 2, Winter Lake Unit 3, Cochran, Seestrom, and the mainstem Coquille River from December 2020 – April 2021 and December 2021 – May 2022. 'NA' indicates Not Applicable, where no juvenile coho salmon were sampled in the applicable month. 28
Table 5. Mean whole-body wet weight (grams, ±95% CI) of juvenile coho salmon sampled in Beaver Slough, Winter Lake Unit 2, Winter Lake Unit 3, Cochran, Seestrom, and the mainstem Coquille River from December 2020 – April 2021 and December 2021 – May 2022. 'NA' indicates Not Applicable, where no juvenile coho salmon were sampled in the applicable month. 29
Table 6. Mean condition factor, K (±95% CI), of juvenile coho salmon sampled in Beaver Slough, Winter Lake Unit 2, Cochran, Seestrom, and the mainstem Coquille River from December 2020 – April 2021 and December 2021 – May 2022. 'NA' indicates Not Applicable, where no juvenile coho salmon were sampled in the applicable month. 30
Table 7. Results of Kruskal-Wallis tests (Kruskal-Wallis H Statistic, degrees of freedom, p-value) comparing fork lengths, weights, and condition factor among locations (Beaver Slough, Winter Lake Unit 2, Cochran, Seestrom, and Mainstem) by month and with data pooled across months during the 2020-21 season. Critical values are Chi-squared approximated at $\alpha=0.05$ with k-1 degrees of freedom. Significant results are shown in bold. 31
Table 8. Results of Kruskal-Wallis tests (Kruskal-Wallis H Statistic, degrees of freedom, p-value) comparing fork lengths, weights, and condition factor among locations (Beaver Slough, Cochran, and Seestrom) by month and with data pooled across months during the 2021-22 season. Critical values are Chi-squared approximated at $\alpha=0.05$ with k-1 degrees of freedom. Significant results are shown in bold. 32
Table 9. Weight-length relationship parameters for juvenile coho salmon sampled in December 2020 – April 2021 (Beaver Slough, Winter Lake Unit 2, Cochran, Seestrom, & mainstem Coquille River) and December 2021 – May 2022 (Beaver Slough, Cochran & Seestrom). Parameters were estimated from the linear relationship between $\log_{10}$ transformed values for weight (g) and length (cm). 33
Table 10. Growth in length (Δ length, $\%\cdot d^{-1}$) and weight (Δ length, $\%\cdot d^{-1}$) determined from the growth of tagged and recaptured individuals and inferred from the mean length or weight of fish captured at fish sampling events at each location. Confidence Intervals are shown in parentheses. Growth was not inferred from capture events at Winter Lake Unit 2 in 2021-22 due to low captures (n = 2). 43
Table 11. Time (days) elapsed from tagging to final detection (single site coho) and the percentage of tagged fish detected at the tide gate PIT tag antenna arrays by month and location in the 2020-21

sampling season. Note: PIT tag antenna array not installed at Beaver Slough until after 2020-2021 sample year. 44
Table 12. Time (days) elapsed from tagging to final detection (single site coho) and the percentage of tagged fish detected at the tide gate PIT tag antenna arrays by month and location in the 2021-22 sampling season. 45
Table 13. Days at large for coho translocated to the mainstem Coquille River at Myrtle Point and detected at a single location after translocation. 53
Table 14. Migration rate for coho translocated to the mainstem Coquille River at Myrtle Point and detected at a single location after translocation. 53
Table 15. Time (days) elapsed from first to last detection by event and month for mobile coho, including fish translocated to the mainstem in the 2020-21 sampling season. Month is the start of the detection event (assumed entrance to the off channel habitat location). 54
Table 16. Winter Lake Unit 1. Kolmogorov-Smirnov results (K-S D Statistic and p value) comparing the distribution of conditions when passage was available (gates open) to conditions for detections assigned as entry or exit through the tide gate in 2020-21 and 2021-22. Parameters assessed were hour of day, velocity, upstream (landward) water level, rate of change of upstream water level, tidal bin, and hydraulic head (upstream – downstream water level). Detections were included in analyses only if they occurred when gates were open. Number of entrance and exit events are shown in parentheses. 55
Table 17. Winter Lake Unit 2. Kolmogorov-Smirnov results (K-S D Statistic and p value) comparing the distribution of conditions when passage was available (gates open) to conditions for detections assigned as entry or exit through the tide gate in 2020-21 and 2021-22. Parameters assessed were hour of day, velocity, upstream (landward) water level, rate of change of upstream water level, tidal bin, and hydraulic head (upstream – downstream water level). Detections were included in analyses only if they occurred when gates were open. Number of entrance and exit events are shown in parentheses. 55
Table 18. Winter Lake Unit 3. Kolmogorov-Smirnov results (K-S D Statistic and p value) comparing the distribution of conditions when passage was available (gates open) to conditions for detections assigned as entry or exit through the tide gate in 2020-21 and 2021-22. Parameters assessed were hour of day, velocity, upstream (landward) water level, rate of change of upstream water level, tidal bin, and hydraulic head (upstream – downstream water level). Detections were included in analyses only if they occurred when gates were open. Number of entrance and exit events are shown in parentheses. 56
Table 19. Cochran. Kolmogorov-Smirnov results (K-S D Statistic and p value) comparing the distribution of conditions when passage was available (gates open) to conditions for detections assigned as entry or exit through the tide gate in 2020-21 and 2021-22. Parameters assessed were hour of day, upstream (landward) water level, rate of change of upstream water level, tidal bin, and hydraulic head (upstream – downstream water level). Detections were included in analyses only if they occurred when gates were open. Velocity was not measured at Cochran. Number of entrance and exit events are shown in parentheses. 56
Table 20. Seestrom. Kolmogorov-Smirnov results (K-S D Statistic and p value) comparing the distribution of conditions when passage was available (gates open) to conditions for detections assigned as entry or exit through the tide gate in 2020-21 and 2021-22. Parameters assessed were hour of day, velocity, upstream (landward) water level, rate of change of upstream water level,

tidal bin, and hydraulic head (upstream – downstream water level). Detections were included in analyses only if they occurred when gates were open. Velocity was not measured at Seestrom in 2021-22. Number of entrance and exit events are shown in parentheses. 57
Table 21. Table of PIT antenna operation dates for the 2021-2022 field season. 73

List of Figures

Figure 1. Lower Coquille Tide Gate and Fish Passage Monitoring location map. 4
Figure 2. A 6' diameter aluminum side-hinged MTR tide gate was installed at the Cochran project in 2017. The tide gate door is installed on the riverside of the culvert..5
Figure 3. Winter Lake Project tide gate construction design drawing for box culverts and tide gates. Each Unit has one side-hinged tide gate door. Drawing depicts the river-side view of the tide gate structure...6
Figure 4. Aerial view of the landward side of the Winter Lake tide gate structures during construction phase. 6
Figure 5. An 8'x8' aluminum side-hinged MTR tide gate was installed at the Seestrom project in 2019. The landward side of the MTR structure uses a counter weight to keep the tide gate door open during rising tides (left photo). The tide gate door is installed on the riverside of the concrete culvert (photo right). 7
Figure 6. Winter Lake Unit 2 PIT antenna array on tide gate culvert 2B and 2C. The pass thru (gray fiberglass structure) and sail (white sail in water) antenna are installed on the landward (upstream) side of the tide gate culvert whereas the tide gate doors are installed on the river (downstream) side of the tide gate culvert. 9
Figure 7. A 4' hoop trap with 25ft leads installed at the Cochran site. Hoop traps were used at most sampling sites in the 2020-2021 field season (left) but only at Cochran, Seestrom and Beaver Slough in the 2021-2022 season. During flood periods a purse seine was used to sample in the flooded project site of Winter Lake (right)..11
Figure 8. High water levels at Winter Lake decreased trapping efficiencies when using the hoop traps due to juvenile coho swimming overtop the traps. The left photo shows Ivy Metzgus (CoqWA) and Morgan Davies (ODFW) in knee-deep water on the bank next to a sampling location. The right photo shows a marker buoy (circled in red) where the hoop trap leads are staked into the ground...12
Figure 9. Dawn and dusk beach seining replaced hoop traps as the primary method of capturing juvenile coho at Winter Lake from March through the remainder of the season for 2022. 12
Figure 10. Sampling locations for the LCM site Winter Lake and Beaver Creek (Slough). Fish sampling in Unit 3 is a light pink hexagon, sampling in Beaver Slough is an orange hexagon and both stayed constant throughout the season. Fish sampling in Unit 2 are dark pink hexagons with the solid pink hexagon denoting hoop trap sites and the pink hexagon with a black dot denotes beach or purse seining sites. Due to the difficulties with sampling in the deep water of Unit 2, locations were chosen that had slightly higher ground. 13
Figure 11. Sampling locations for LCM sites Seestrom and Cochran. At both locations, hoop traps were used throughout the season except the last sampling event when a beach seine was used..14
Figure 12. Mean daily water temperature at Cochran (blue), Seestrom (green), Winter Lake – Unit 1 (dashed orange), Winter Lake – Unit 2 (red), Winter Lake – Unit 3 (dashed black), Beaver Creek (black)...20
Figure 13. Mean daily conductivity (µS/cm) of the Coquille River at Cochran (blue), Seestrom (green), and Winter Lake (red). 21
Figure 14. Maximum daily velocity (ft/s) at Winter Lake – Unit 1 (green), Winter Lake – Unit 2 (red), Winter Lake – Unit 3 (black). Maximum daily velocity is also representative of the daily

range of velocities seen at the tide gate since velocity drops to zero when the tide gate door closes. Winter Lake – Unit 3(Gate 3A) experiences bi-directional flow, downstream flow is positive and upstream flow is negative. Velocity at Winter Lake – Unit 1 & 2 is from the culvert associated with Gate 1B and 2C, respectively, and experiences only downstream flow. 21
Figure 15. Daily maximum water surface elevations (m NAVD88) of the Coquille River at Cochran (blue), Seestrom (green), and Winter Lake (red) with their respect interior water levels represented as dashed lines. Winter Lake is positioned highest in the estuary and is influenced more by winter storm events than the other project sites. 22
Figure 16. Water surface elevation of the Coquille River at the three project sites, Cochran (yellow), Seestrom (green) and Winter Lake (red). These sites are spread throughout the Coquille Estuary and have different tidal signals. 22
Figure 17. Distance open of vertical slide gates at the Winter Lake site for Unit 2 and 3. Gate 1B, 2C and 3A are dual function slide and side-hinge gates. The slide gate function of Gate 1B, 2A, 2C and 2D was not used during the monitoring season. 23
Figure 18. Pre-smolt abundance estimates for OR Coast Coho salmon ESU Mid-South Coast Stratum by year. Source: StreamNet. 2022. https://www.streamnet.org/data/hli/presmolt/?hli-id=30. 26
Figure 19. Box plots of fork length (mm) by month and pooled across months for Beaver Slough (BS), Winter Lake Unit 2 (WL2), Cochran (Coc), Seestrom (See) and the Mainstem Coquille River (MS) in the 2020-21 season. An asterisk (*) indicates significant Kruskall-Wallis tests. Letters (A, B, C) above boxes indicate homogenous groups identified through post-hoc pairwise comparisons with Bonferroni-adjusted p-values, p* (p* = 0.017 in Dec, Feb, Mar; 0.008 in Jan; 0.005 in Apr & All Months). Winter Lake Unit 2 was not included in statistical analyses in February due to low sample size (n = 2). Post-hoc comparisons could not identify homogeneous groupings in December. 33
Figure 20. Box plots of whole-body wet weight (grams) by month and pooled across months for Beaver Slough (BS), Winter Lake Unit 2 (WL2), Cochran (Coc), Seestrom (See) and the Mainstem Coquille River (MS) in the 2020-21 season. An asterisk (*) indicates significant Kruskall-Wallis tests. Letters (A, B, C) above boxes indicate homogenous groups identified through post-hoc pairwise comparisons with Bonferroni-adjusted p-values, p* (p* = 0.017 in Dec, Feb, Mar; 0.008 in Jan, & 0.005 in Apr & All Months). Winter Lake Unit 2 was not included in statistical analyses in February due to low sample size (n = 2). April post-hoc comparisons could not identify homogeneous groupings at p* = 0.005). 34
Figure 21. Box plots of Fulton's Condition Factor (K, nondimensional) by month and pooled across months for Beaver Slough (BS), Winter Lake Unit 2 (WL2), Cochran (Coc), Seestrom (See) and the Mainstem Coquille River (MS) in the 2020-21 season. An asterisk (*) indicates significant Kruskal-Wallis tests. Letters (A, B, C) above boxes indicate homogenous groups identified through post-hoc pairwise comparisons with Bonferroni-adjusted p-values, p* (p* = 0.017 in Dec, Feb, Mar; 0.008 in Jan, & 0.005 in Apr & All Months). Winter Lake Unit 2 was not included in statistical analyses in February due to low sample size (n = 2); despite a significant Kruskal-Wallis Test in February, differences could not be discriminated with post-hoc comparisons at p* = 0.017. 35
Figure 22. Box plots of fork length (mm) by month and pooled across months for Beaver Slough (BS), Cochran (Coc), and Seestrom (See) in the 2021-22 season. An asterisk (*) indicates

significant Kruskall-Wallis tests. Letters (A, B) above boxes indicate homogenous groups identified through post-hoc pairwise comparisons with Bonferroni-adjusted p-values, p* (p* = 0.05 in Dec, May; 0.017 in Jan-Apr & All Months). Post-hoc comparisons could not identify homogeneous groupings in March. 36
Figure 23. Box plots of whole-body wet weight (grams) by month and pooled across months for Beaver Slough (BS), Cochran (Coc), and Seestrom (See) in the 2021-22 season. An asterisk (*) indicates significant Kruskall-Wallis tests. Letters (A, B) above boxes indicate homogenous groups identified through post-hoc pairwise comparisons with Bonferroni-adjusted p-values, p* (p* = 0.05 in Dec, May; 0.017 in Jan-Apr & All Months). Post-hoc comparisons could not identify homogeneous groupings in March....37
Figure 24. Box plots of Fulton's Condition Factor (K, nondimensional) by month and pooled across months for Beaver Slough (BS), Cochran (Coc), and Seestrom (See) in the 2021-22 season. An asterisk (*) indicates significant Kruskall-Wallis tests. Letters (A, B) above boxes indicate homogenous groups identified through post-hoc pairwise comparisons with Bonferroni-adjusted p-values, p* (p* = 0.05 in Dec, May; 0.017 in Jan-Apr & All Months). Post-hoc comparisons could not identify homogeneous groupings in March....38
Figure 25. Weight-Length Relationships for juvenile coho salmon in Beaver Slough, Winter Lake Unit 2, Cochran, Seestrom, and the Mainstem Coquille River during the 2020-21 (upper panel) and 2021-22 seasons (lower panel). Data points are omitted for figure clarity. Curves span the length ranges observed at each site. The relationship was not generated for the mainstem or Winter Lake Unit 2 for the 2021-22 season due to insufficient captures. The 2020-21 curve for Unit 2 is shown as a dashed line for comparison in the 2021-22 figure (lower panel). 39
Figure 26. Percent of tagged fish detected at tide-gate antenna arrays by tagging month for each location in 2020-21 (gray bars; Cochran, Seestrom, Winter Lake Unit 2) and 2021-22 (blue bars; Cochran, Seestrom, Beaver, Winter Lake Unit 2). The antenna array at Beaver Slough was first operated during the 2021-22 season....46
Figure 27. Coho movement depicted throughout the Coquille Estuary. There was significant migration from site to site by tagged coho throughout all project sites. 58
Figure 28. Minimum residence time (days from tagging until final detection at tide gate arrays), Average ±95% Confidence Intervals in 2020-21 (gray bars; Cochran, Seestrom, Winter Lake Unit 2) and 2021-22 (blue bars; Cochran, Seestrom, Beaver, Winter Lake Unit 2). The antenna array at Beaver Slough was first operated during the 2021-22 season. Months indicate month of initial capture and tagging. 59
Figure 29. Winter Lake Unit 1. Frequency distributions for available (gates open, blue) and used for entry (green) and exit (orange) for hour of day (panel A), upstream (landward) water level (panel B), rate of change of upstream (landward) water level (Panel C), tidal bin (Panel D), hydraulic head (US-DS Water Level, Panel E), and velocity (Panel F). Tidal bins are 1 (Slack after Flood), 2 (Ebb), 3 (Slack before Ebb), 4 (Slack after Ebb), 5 (Flood), and 6 (Slack before Flood). 60
Figure 30. Winter Lake Unit 2. Frequency distributions for available (gates open, blue) and used for entry (green) and exit (orange) for hour of day (panel A), upstream (landward) water level (panel B), rate of change of upstream (landward) water level (Panel C)....61
Figure 31. Winter Lake Unit 3. Frequency distributions for available (gates open, blue) and used for entry (green) and exit (orange) for hour of day (panel A), upstream (landward) water level (panel B), rate of change of upstream (landward water level (Panel C), tidal bin (Panel D), hydraulic

head (US-DS Water Level, Panel E), and velocity (Panel F). Tidal bins are 1 (Slack after Flood), 2 (Ebb), 3 (Slack before Ebb), 4 (Slack after Ebb), 5 (Flood), and 6 (Slack before Flood). 62
Figure 32. Cochran. Frequency distributions for available (gates open, blue) and used for entry (green) and exit (orange) for hour of day (panel A), upstream (landward) water level (panel B), rate of change of upstream (landward) water level (Panel C), tidal bin (Panel D), and hydraulic head (US-DS Water Level, Panel E). Tidal bins are 1 (Slack after Flood), 2 (Ebb), 3 (Slack before Ebb), 4 (Slack after Ebb), 5 (Flood), and 6 (Slack before Flood). 63
Figure 33. Seestrom. Frequency distributions for available (gates open, blue) and used for entry (green) and exit (orange) for hour of day (panel A), upstream (landward) water level (panel B), rate of change of upstream (landward) water level (Panel C), tidal bin (Panel D), hydraulic head (US-DS Water Level, Panel E), and velocity (Panel F). Tidal bins are 1 (Slack after Flood), 2 (Ebb), 3 (Slack before Ebb), 4 (Slack after Ebb), 5 (Flood), and 6 (Slack before Flood). 64
Figure 34. Beaver Slough. Frequency distributions for conditions during entry (green) and exit (orange) for hour of day (panel A), upstream (landward) water level (panel B), rate of change of upstream (landward) water level (Panel C), tidal bin (Panel D), and hydraulic head (US-DS Water Level, Panel E). Tidal bins are 1 (Slack after Flood), 2 (Ebb), 3 (Slack before Ebb), 4 (Slack after Ebb), 5 (Flood), and 6 (Slack before Flood). 65
Figure 35. A schematic of how tidal bins were calculated for the Lower Coquille Monitoring project. 74

1. Introduction

The Lower Coquille Tide Gate and Fish Passage Monitoring Program (LCM) leverages the close proximity both temporally (completed within a two year period) and spatially (seven river miles) of three tide gate upgrade and tidal floodplain habitat restoration projects within the lower Coquille River. The overarching program goal is a multi-partner collaboration to examine not only the functionality of individual tide gate projects but also how their proximal and potentially compounded uplift promotes recovery of the Oregon Coast coho ESU. It is important to complete this effectiveness monitoring and document fish life-history linkages to these types of projects that are at the forefront of the tide gate replacement movement growing along the Oregon Coast, to ensure we are maximizing ecological benefits and return on investment. These three tide gated projects are in the freshwater-marine ecotone, which makes it well situated to examine the cumulative benefit provided to overwintering juvenile salmonids.

The LCM began as a three-year monitoring project but has received additional funding to extend the project; therefore, monitoring will occur for a total of five years. The LCM is led by the Coquille Watershed Association (CoqWA) in collaboration with multiple branches of the Oregon Department of Fish and Wildlife (ODFW) and a burgeoning partnership with the US Fish and Wildlife Service (USFWS) facilitated by multiple individual grants. For detail on the collaboration and grant structure of the LCM program, please refer to the LCM Plan[1]. The LCM relies on Passive Integrated Transponder (PIT) technology and an expansive fish sampling effort to track juvenile coho movements and residency throughout the freshwater estuary and passage through tide gates. A combination of passive and active capture techniques (e.g., hoop trap nets, beach seines) are used to sample juvenile coho throughout the winter and spring in the restored project sites of Winter Lake, Seestrom and Lower Coquille River Wetland and Stream Enhancement (Cochran) (Figure 1), sampling also occurs at Beaver Slough (reference site) and in the lower Coquille River. Additionally, sampling structure and locations have been adjusted as need be, such as, the tagging of juvenile fall Chinook and fall sampling in the headwaters of the East Fork Coquille River at Laverne Park.

2. Background

Since the mid-1800s, land-use practices have substantially decreased the amount and quality of tidal floodplain complexes in the Coquille basin and anadromous fish returns, including ESA listed Oregon Coast coho, have decreased to an estimated 8% of historical abundance. Tidal floodplains and associated wetlands provide critical rearing habitat and slow water refugia for salmonids. Functional fish passage to these habitats in the Coquille Valley has been reduced to ~600 acres, or <5% of historical acreage, by the use of levees, ditches and tide gates. Historic tide gate styles are largely top-hinged wood or steel and restrict juvenile fish movements from the mainstem Coquille River into locations that would historically have provided high quality winter and spring rearing. The National Marine Fisheries Service (NMFS) ESA Recovery Plan for Oregon Coast Coho Salmon (2016), Oregon Department of Fish and Wildlife (ODFW) Oregon Coast Coho Conservation Plan (2014), and Coquille Indian Tribe (CIT) Coquille Subbasin Plan (2007) have all identified the depletion of slow-water refugia as one of the key limiting factors affecting the recovery of Oregon

[1] The Lower Coquille Tide Gate and Fish Passage Monitoring Plan, 2021. https://www.coquillewatershed.org/wp-content/uploads/2021/11/LCTGFPM-Monitoring-Plan.pdf

Coast coho salmon. Although these habitats are a restoration priority, there is little published science on the migratory habits of juvenile coho into and within the tidally influenced estuaries of the Oregon Coast and specifically within tide gated habitats. Therefore, it is unknown how restoration projects that increase access to tidal floodplains affect the recovery of the Oregon Coast coho population.

3. Project Area and Overview

The Lower Coquille Tide Gate and Fish Passage Monitoring (LCM) study area focuses on the Lower Coquille River (Coquille Estuary) in the Coquille watershed. The Coquille watershed encompasses approximately 1,000 sq. mi. predominately located in Coos County, OR. The Coquille watershed is the largest watershed to originate from the Coast Range and has the second longest tidally influenced estuary on the Oregon Coast at 41 miles. The Coquille Estuary has the potential to provide high quality winter and spring rearing habitat for coho, Chinook, steelhead, and Pacific lamprey in addition to many other species of fish and wildlife. Predominate land uses in the Coquille Estuary include private and public forested lands, agriculture, and urban areas.

The beginning of a significant uplift to winter and spring rearing habitat in the Coquille Valley began in 2017 with three working lands tide gate upgrades and habitat restoration projects (Figure 1). Traditional lumber, steel, and plywood tide gates were nearly all top-hinged heavy designs. Gate door openness times were limited and angle of door opening most often reflected outflow head pressures, which rarely developed more than 20˚ gate door angle of openness. Generally, the gravitational pull resulted in high outflow velocities and poor fish passage. This was combined with no ability to allow for tidal inflow, thus fish passage into tidal habitats was restricted to inadequate conditions on drain out cycles at low tide. All three tide gate upgrades encompass technology advancements that enhance fish passage relative to traditional top-hinge gates. Specifically, two of the sites (Seestrom and Cochran) incorporate a fully mechanical Muted Tidal Regulator (MTR), a device that allows for tidal inflow with the level set to a desired water elevation, whereupon the door closes. A third site (Winter Lake) incorporates electrically operated slide gates, which allows for fine-tuned gate door adjustments to provide for fish passage and water management. This structure has also included side-hinged aluminum tide gate doors rather than vertically hung top-hinged gates. Side-hinged gates open with very limited head differential and open to an angle of around 80˚. These combined advanced technologies allow for greater capacity of fish movement, since the duration and angle of door opening is substantially increased compared to the replaced structures. Furthermore, all three projects included habitat restoration actions that enhanced habitat connectivity to wetlands and productivity upstream of the new tide gates whether that be on the ODFW Coquille Valley Wildlife Management Area or on working ranch parcels. All Restoration consisted of newly constructed stream channels, riparian plantings and livestock exclusion fencing. A fourth tide gate upgrade project, Coaledo Tide Gate & Fish Passage Project, is scheduled to be completed in the summer of 2023. This tide gate services Beaver Creek and Beaver Slough and has been used, to this date, as a reference site.

The first tide gate upgrade and habitat restoration project, completed in 2017, the Cochran project is at River Mile (RM) 13.5. Cochran is relatively small in size with respect to both tide gate upgrade and habitat restoration; a 6.0’ diameter culvert and side-hinged tide gate was installed with MTR technology and 3,500’ of tidal channel was created, Figure 2. The second project, Winter Lake

Restoration, located at RM 20.4 was completed in 2018 and is unprecedented in size and complexity on the Oregon Coast. A structure containing seven new 8'x10' concrete box culverts and aluminum vertical slide style, electrically driven tide gates replaced the three failing old style vertical hinged wooden tide gates, Figure 3 - 4. The seven tide gates drain 1,761 acres and a berm network separates the floodplain into 3 hydrologically independent units up to elevation 6.5ft (Figure 1). Agriculture is the management focus of two units (Units 1 and 3; Figure 1) while fish and wildlife habitat is the management focus of Unit 2 owned mostly by ODFW. Construction developed 6.3 miles of new channel that was connected to historically present networks resulting in a total of 8.1 miles of channel. In addition, five tidal depressions, creating additional fish rearing area, were constructed in Unit 2 and are connected with new channels. The third project, Seestrom Tidelands Restoration (Seestrom), is a moderate-sized project completed in the summer of 2019 located at RM 14.3. The upgraded side-hinged MTR aluminum side-hinged tide gate drains 135 acres of land, which includes 11,500' of newly constructed tidal channel and 1.4 acres of tidal depressions, Figure 5).

The above three restoration projects are the core LCM restoration sites in the study. There are four other linked fish sampling locations in the study. The fourth sampling site, Beaver Slough (also referred to as Beaver Creek), is the reference site for LCM. Although Beaver Slough contains a tide gate, it is an old top-hinged wooden, leaky structure. There is a relatively, high degree of fish passage at this tide gate that apparently is facilitated by either an eroded pathway through the earthen fill surrounding the three corrugated metal 6.0ft culverts or rust degradation of the pipes. The relatively high density of juvenile coho captured upstream reflects the numbers of coho moving from downstream to upstream through the site. As discussed above, this tide gate is scheduled to be replaced in 2023. The fifth sampling site are the reaches of the mainstem of the Coquille River upstream of the LCM sites to the head of tide. The Coquille River reach tagging is important as it provides: 1) The opportunity to illuminate if coho juveniles migrating downstream are moving into only an individual wetland where the team captured them or multiple wetlands, and 2) the capture of riverine reared fish exhibiting differing body conditions prior to entering floodplain tidal wetlands. During the second year of monitoring a sixth sampling site was added to the project, Laverne Park, situated in the headwaters of the East Fork of the Coquille River. This site was added to increase the number of tagged juvenile coho in the Coquille River due to the difficulties of capturing sufficient numbers of coho in the mainstem Coquille River. To even further increase the number of tagged juvenile coho in the Coquille River, tagged coho were transferred from Beaver Slough to the mainstem Coquille River at Myrtle Point (Figure 1, RM 37.5).

Through a new partnership with the USFWS Bandon Marsh National Wildlife Refuge and additional grant funds (OWEB grant #222-2034-22290), an additional PIT antenna array will be installed in Fahy Creek of the Ni-les'tun Unit of Bandon Marsh National Wildlife Refuge (Figure 1). This PIT antenna will be the first within the LCM project that is on a non-tide gated channel and located low enough to be on the saltwater side of the estuary. Installation will occur in spring of 2023 and results will be incorporated into the third year's report.

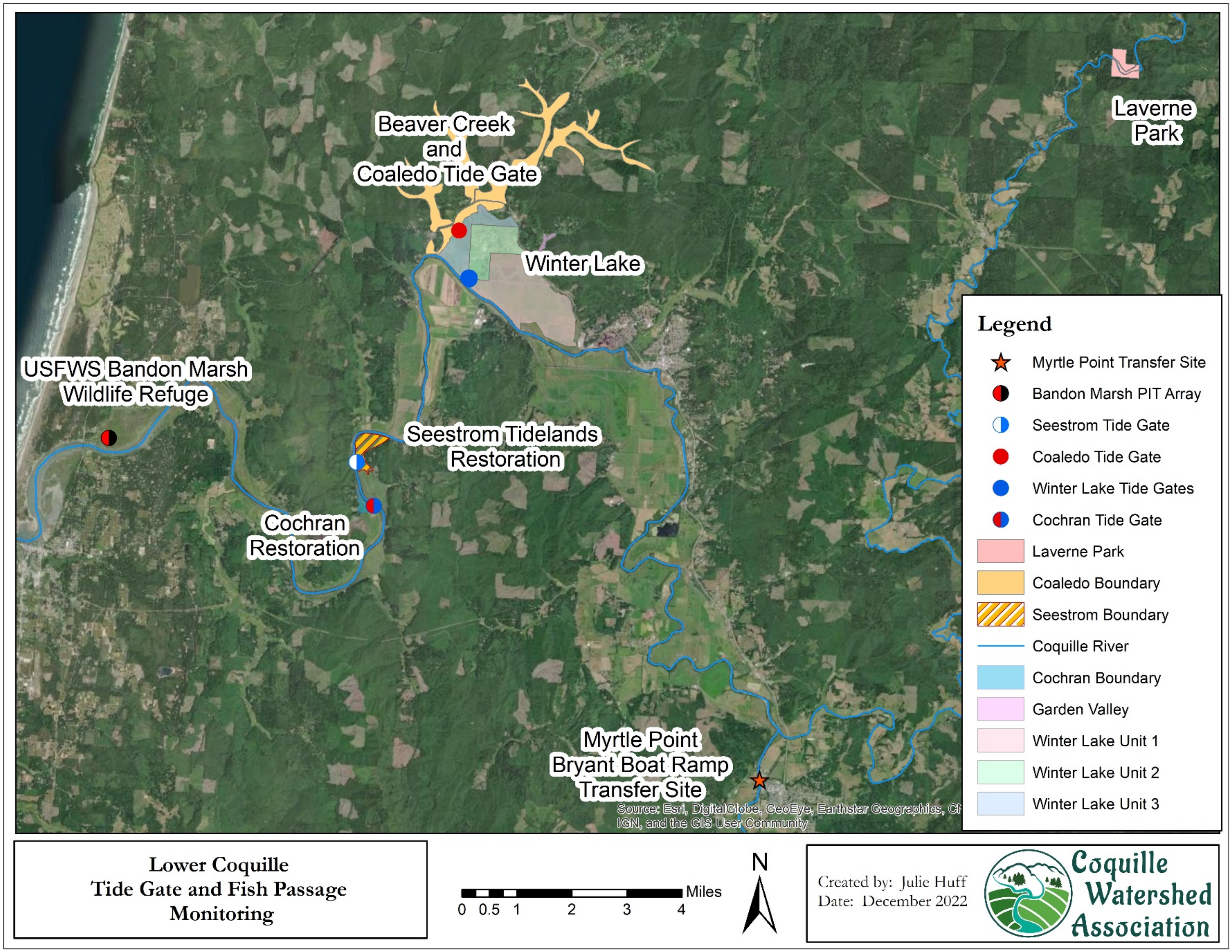

Figure 1. Lower Coquille Tide Gate and Fish Passage Monitoring location map.

Figure 2. A 6' diameter aluminum side-hinged MTR tide gate was installed at the Cochran project in 2017. The tide gate door is installed on the riverside of the culvert.

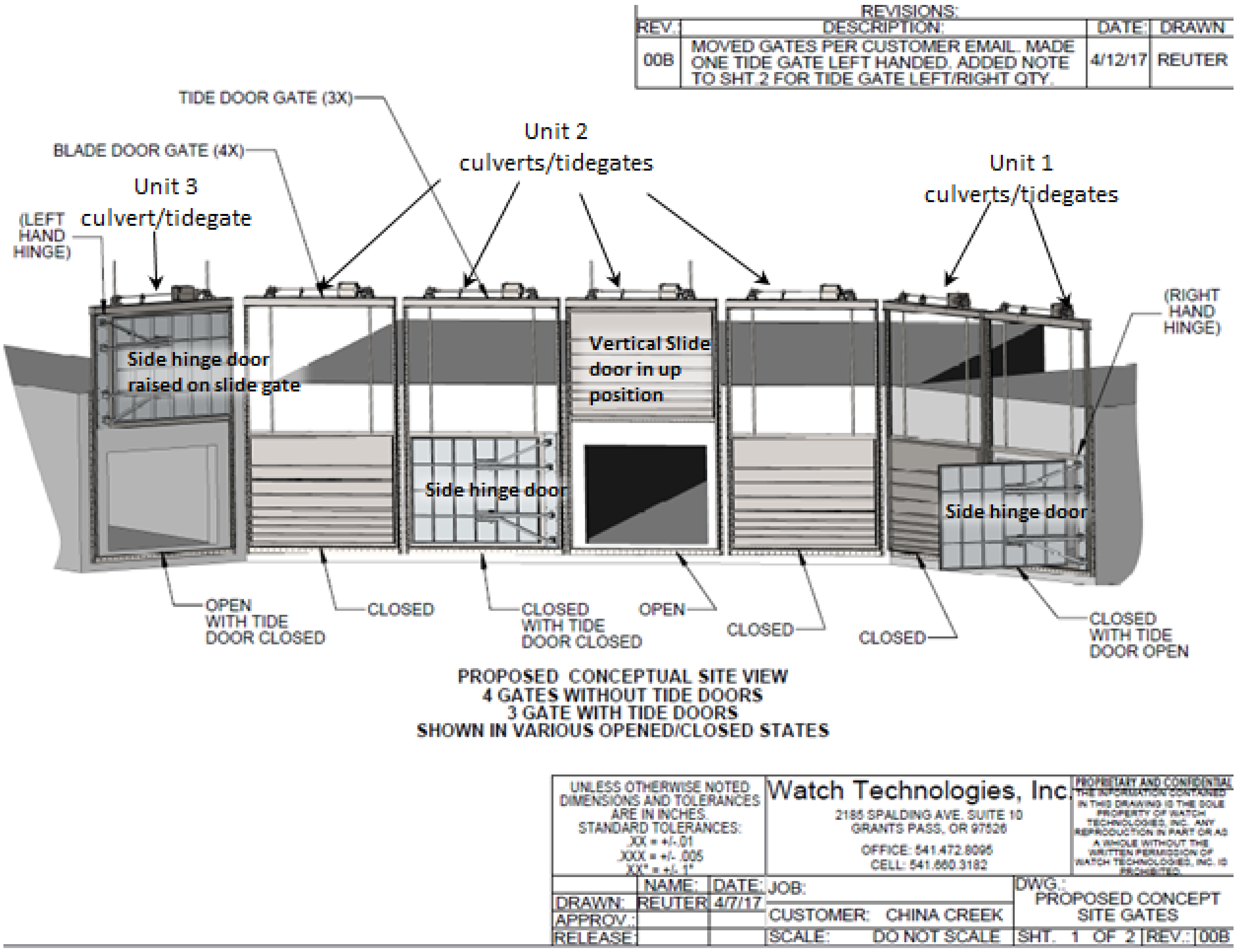

Figure 3. Winter Lake Project tide gate construction design drawing for box culverts and tide gates. Each Unit has one side-hinged tide gate door. Drawing depicts the river-side view of the tide gate structure.

Figure 4. Aerial view of the landward side of the Winter Lake tide gate structures during construction phase.

Figure 5. An 8'x8' aluminum side-hinged MTR tide gate was installed at the Seestrom project in 2019. The landward side of the MTR structure uses a counter weight to keep the tide gate door open during rising tides (left photo). The tide gate door is installed on the riverside of the concrete culvert (photo right).

4. Monitoring Questions

This monitoring project was designed to examine the effectiveness of several tide gate replacement projects at meeting their objectives and to assess how the collective uplift provided by these projects can promote recovery of coho salmon within the Oregon Coast Coho Salmon Evolutionarily Significant Unit. The primary goals for the project include improving understanding of juvenile coho use of tidal floodplains, understanding coho salmon response to the sizes, design, and operation of new tide gates and overall use of the restored habitats. The monitoring is intended to inform adaptive management of the sites while providing information to help improve effectiveness of future tide gate replacements and tidal habitat enhancement projects. To these ends, fish monitoring is focused on several questions related to the condition, growth, survival, and movement of juvenile coho salmon in off-channel tidally influenced habitats following tide gate replacement.

Condition

- Is overall body condition of juvenile coho reared in the tide gate project areas greater than riverine-reared coho?

Growth

- Are growth rates of juvenile coho reared in tide gate project areas greater than riverine-reared coho? Does overall size of restored habitat affect growth rate?

Survival

- Does survival increase for juvenile coho residing in tide gate projects compared to riverine-reared coho? Does survival vary with overall size of restored habitat?

Abundance & Density

- Are rearing densities dependent on overall size of restored habitat behind an upgraded tide gate?
- What are the general densities of juvenile coho during winter/spring months upstream of the various tide gate structures within the project area with differing designs and operation plans (Water Management Plans)?

Movement & Passage

- What is the residence time of juvenile coho in floodplain habitats upstream of redesigned, technologically advanced tide gates? Does residence time vary with overall size of restored habitat?
- What percentage of juvenile coho residing in the Coquille Estuary enter the restored project areas?
- Do juvenile coho enter more than one wetland restoration area during winter/spring downstream movements prior to entering the ocean?
- What are the fish passage effectiveness levels for the individual projects relating to water level and tide gate door operation?

5. Methods

The LCM program relies on Passive Integrated Transponder (PIT) technology and an expansive fish sampling effort to track juvenile coho throughout the freshwater estuary. The installation and operation of PIT antenna arrays are at the core of this study as they allow greater resolution of juvenile coho movement in both space and time due to the ability of PIT tagged fish to be individually identified. The arrays are attached directly to the landward (upstream) side of the tide gate culvert (Figure 6) whereas the tide gate door is installed on the river (downstream) side of the tide gate culvert. The tide gate culverts range in length from 50 feet at Winter Lake to 24 feet at Seestrom. PIT detections will denote when a juvenile coho is moving throughout the estuary but it will also identify approximately when passage of the tide gate has occurred. A total of 8 PIT antenna arrays have been installed; 4 on the Winter Lake tide gates, one on each of the Seestrom and Cochran tide gates and 2 on Beaver Slough 200 ft upstream of the tide gate. The PIT antennas are operated continuously throughout the 5-year project[2].

[2] During the second year of monitoring there were multiple instances of PIT array outages or extremely poor detection efficiencies. A table of operating dates during the 2021-2022 sampling season can be found in Appendix A.

Figure 6. Winter Lake Unit 2 PIT antenna array on tide gate culvert 2B and 2C. The pass thru (gray fiberglass structure) and sail (white sail in water) antenna are installed on the landward (upstream) side of the tide gate culvert whereas the tide gate doors are installed on the river (downstream) side of the tide gate culvert.

A. Fish Sampling

The LCM fish sampling occurs behind the tide gates in the restored habitat of all project sites and in the mainstem Coquille River. The main objective for fish sampling in the restored habitat behind the tide gates is to get data on species abundance, growth estimates, site density and residence times. The fish sampling season at project sites begins in December and runs through until water temperatures rise above 18℃ in May. A minimum of 6 sampling events will happen each season at Cochran and Seestrom with 8 events at Cochran and 12 events at Seestrom in 2022. Weekly fish sampling occurs at Beaver Slough and was proposed for Winter Lake Unit 2 but high water levels in Unit 2 caused inefficient trapping events. Therefore, Winter Lake Unit 2 tactics were altered and sampling events occur at dawn and dusk during peak abundance (as determined by coho caught at Beaver Slough) typically in March and April. With sampling not occurring in Winter Lake Unit 2 until mid-season there are low numbers of tagged coho on site. To counteract this, tagged coho are translocated from Beaver Slough to Winter Lake Unit 2 throughout the season.

The main objective for fish sampling in the mainstem Coquille River is to collect data on body condition of riverine coho and determine how many coho migrating down the Coquille River enter tide gates sites. It was proposed to beach seine the mainstem river throughout December and April but 2021 and 2022 resulted in low numbers of captured coho. To achieve tagging targets, juvenile coho may be captured a) in the Coquille River downstream from the tide gate structures and translocated upstream for release post-tagging, b) in the headwaters, higher up in the watershed (Laverne Park) or c) in Beaver Slough and translocated upstream for release post-tagging.

The primary method of capture for fish at Seestrom, Cochran and Beaver Slough are four foot diameter nylon hoop traps (Figure 7) with 25ft or 30ft leads. Traps were set using land or boat based methods in the thalweg of new and previously existing channels or canals with leads staked to both banks. Traps were mostly installed in sets of two. At Winter Lake, hoop traps were inefficient at capturing coho due to deeper channels allowing the coho to easily swim over the traps (Figure 8). Through trial and error, beach seining at dusk or dawn was deemed the most successful capture method and was utilized at Winter Lake in 2022 (Figure 9). Furthermore, Winter Lake is prone to flooding due to its location in the estuary and its low elevation, therefore during flood conditions a purse seine is used for sampling. Sampling in the mainstem Coquille River is accomplished using an 18.5ft North River boat and 126 ft beach seine while a small hand seine (6ft in height x 25ft in length) is used while wading in the small streams of the headwaters.

Ideally, fish sampling locations within a project area would be randomly selected throughout the entire project area. The Coquille River floodplain habitats are nuanced and a lot of consideration on capture sites and effective tactics has been implemented with the project. Water levels can increase up to 10ft overnight with heavy rain. Protection of fish from trap laydown mortality and the ineffectiveness of some tactics (seining) when the valley floor is fully flooded has dictated that capture sites be fishable at the greatest number of days possible. Each site has been chosen with specific criteria including: 1) the ability of the trap site to represent the habitat area in the immediate and general vicinity. The ability of known equipment to capture fish repeatedly throughout the sampling season. 3) The capacity to limit mortality of fish due to lay down or detachment of traps or high water levels preventing recovery of traps. 4) The capacity to conduct trapping and seining operations safely. For these reasons, sampling locations were mostly stationary. At Seestrom, Cochran, Winter Lake Unit 3 and Beaver Slough sampling sites were constant throughout the season (Figure 10 - 11). When seining methods are used at Winter Lake, the accessible locations, due to dry ground and riparian vegetation, are limited to just a few locations (Figure 10). Likewise, seining locations in the mainstem Coquille River are limited to locations where water levels, tide cycles and sandy bank exposure are available on the date of effort; therefore, each seining event is unique.

Although juvenile coho are the target species for monitoring, all fish species, native and non-native, are counted and recorded. The captured juvenile coho and are weighed to the nearest 0.1g and measured fork length to the nearest 1.0mm. All juvenile coho captured (measuring over 65mm) were tagged with Passive Integrated Transponders (PIT tagged). Records of each individual PIT tagged coho were kept to ensure analysis accounted for the transfer of fish from Beaver Slough to both Winter Lake Unit 2 and the Coquille River at Myrtle Point. In addition, body condition including parasite loading and PIT data was recorded for individual tagged fish in a digital form on Survey123. Length, weight, and overall body condition was also noted for lamprey and salmonids other than coho. All coho were scanned with a Biomark HPR Plus or Lite hand held PIT tag reader in order to detect recaptured fish that had been tagged during a trapping event on a previous day. Recaptures were measured, weighed and recorded in Survey123 for further analysis of body condition changes and mobility from where they were originally tagged. PIT tag data was scanned directly into Survey123 using a field tablet and the BluePiano app[3].

Figure 7. A 4' hoop trap with 25ft leads installed at the Cochran site. Hoop traps were used at most sampling sites in the 2020-2021 field season (left) but only at Cochran, Seestrom and Beaver Slough in the 2021-2022 season. During flood periods a purse seine was used to sample in the flooded project site of Winter Lake (right).

[3] Instructions on how to replicate this can be found at the 35 minute mark of the PNAMP ETIS Webinar from 2021.

Figure 8. High water levels at Winter Lake decreased trapping efficiencies when using the hoop traps due to juvenile coho swimming overtop the traps. The left photo shows Ivy Metzgus (CoqWA) and Morgan Davies (ODFW) in knee-deep water on the bank next to a sampling location. The right photo shows a marker buoy (circled in red) where the hoop trap leads are staked into the ground.

Figure 9. Dawn and dusk beach seining replaced hoop traps as the primary method of capturing juvenile coho at Winter Lake from March through the remainder of the season for 2022.

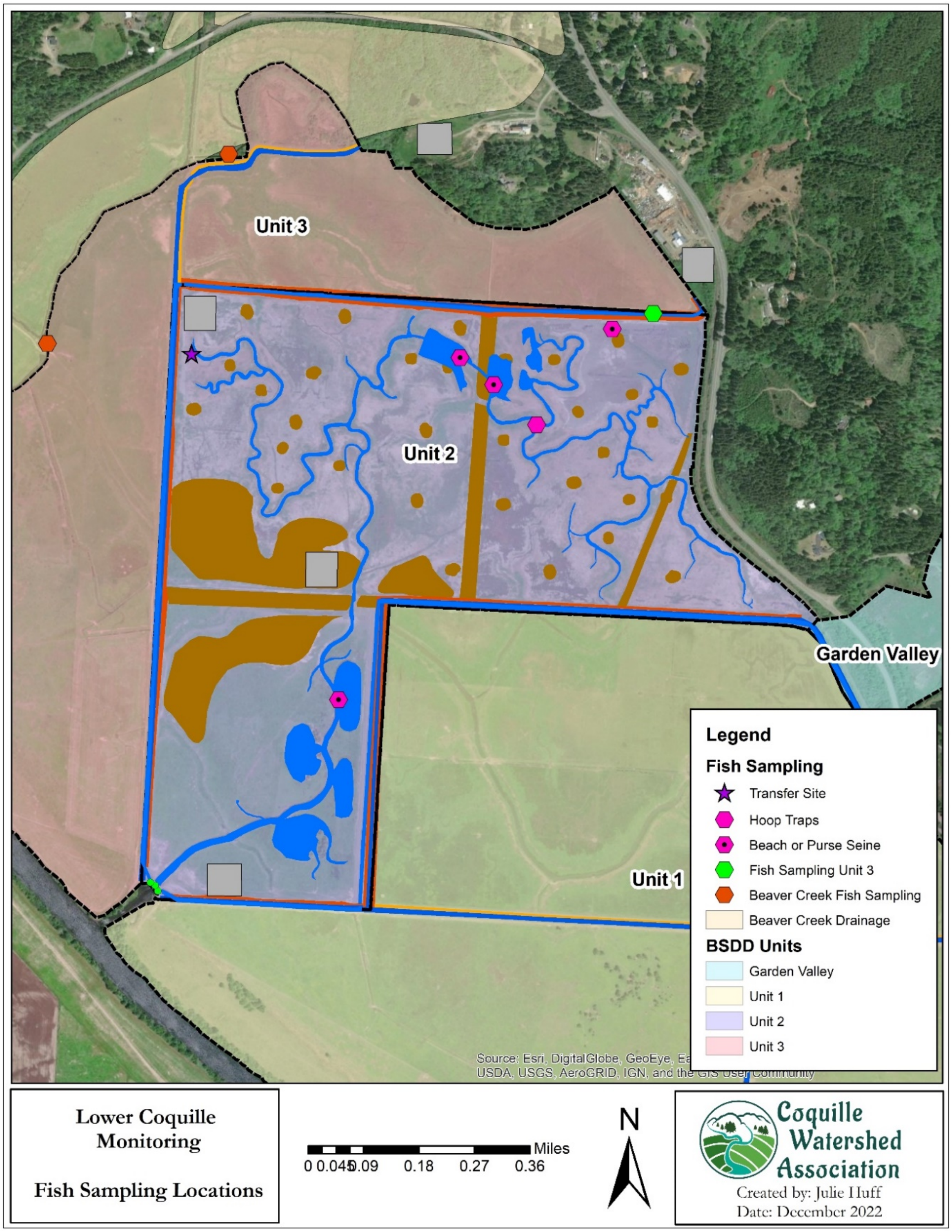

Figure 10. Sampling locations for the LCM site Winter Lake and Beaver Creek (Slough). Fish sampling in Unit 3 is a light pink hexagon, sampling in Beaver Slough is an orange hexagon and both stayed constant throughout the season. Fish sampling in Unit 2 are dark pink hexagons with the solid pink hexagon denoting hoop trap sites and the pink hexagon with a black dot denotes beach or purse seining sites. Due to the difficulties with sampling in the deep water of Unit 2, locations were chosen that had slightly higher ground.

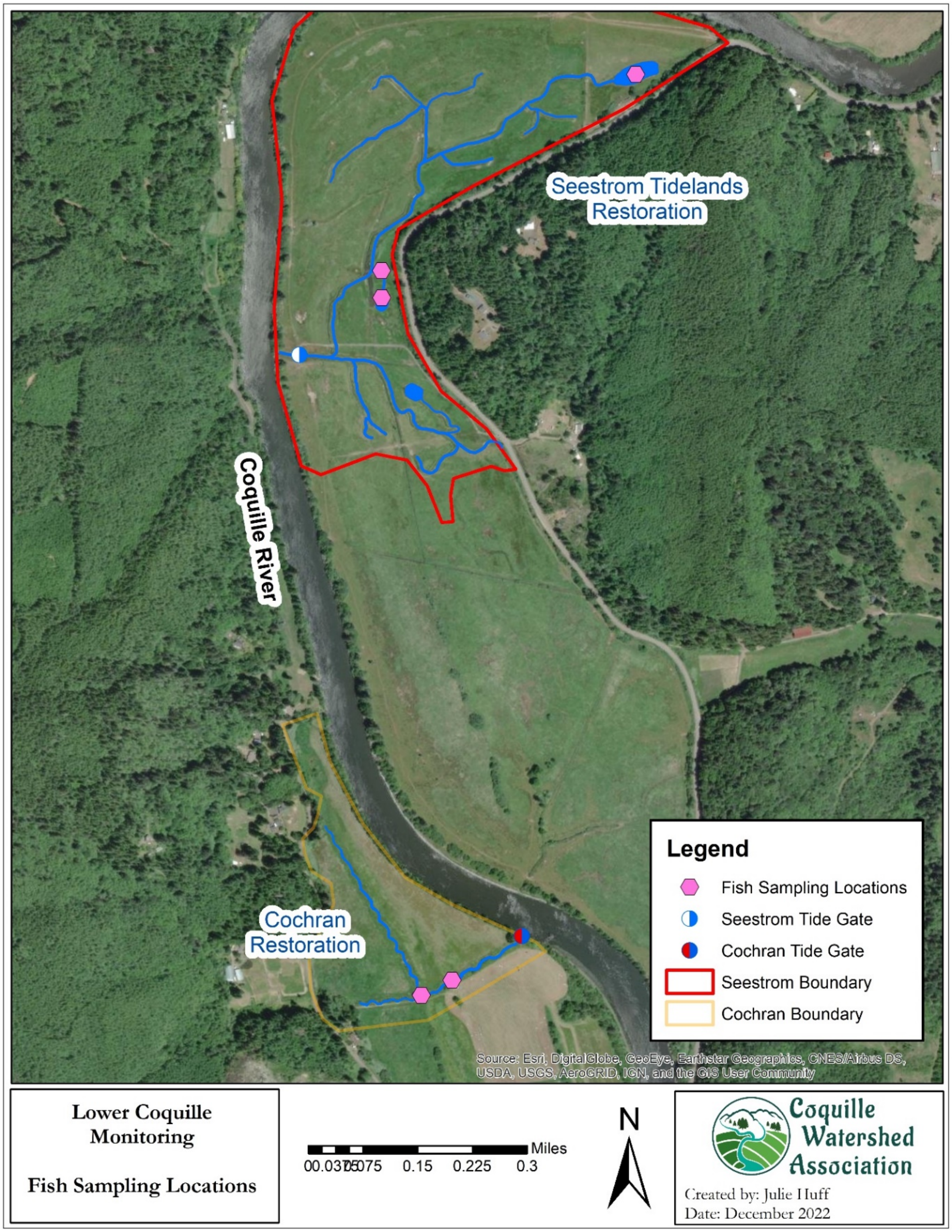

Figure 11. Sampling locations for LCM sites Seestrom and Cochran. At both locations, hoop traps were used throughout the season except the last sampling event when a beach seine was used.

6. Analytical Approach

A. Site Parameters

As part of the study, it is important to obtain information on water clarity, temperature, and water levels. Tide gate door management is just one of the factors that influence juvenile coho residence and movement throughout the estuary and affect these parameters due to the quantity of water exchanged. The site specific Water Management Plans specify interior water levels and tidal exchange of water at each site and are dependent on not only the tide gate operations, but also tidal and precipitation cycles, which in turn affect water quantity and quality factors. We monitored these influential site parameters such as temperature, conductivity and water level at all of the sites. Velocity meters are installed at Winter Lake and we obtained water velocity data for that site.

A suite of Onset aquatic data loggers were used for monitoring the site parameters, specifically, U24 conductivity loggers, U22 Pro v2 temperature loggers and U20 water level loggers. Each logger was set to 15-minute intervals and followed DEQ procedures for pre and post deployment calibration verifications. Furthermore, the data followed QA/QC standards as described in the Winter Lake Sampling and Analysis Plan approved by DEQ.

B. Species Abundance

Relative abundance of fish species in the four monitoring sites was determined by total individual counts of each species. Due to only seining and no hoop trapping at Winter Lake relative abundance was not fully representative of the monitoring across sites, thus we analyzed data accordingly with acknowledgement of this weakness.

C. Condition

Juvenile coho salmon were measured for length (fork length, mm) and weight (whole-body wet weight, g). A dimensionless body condition index was calculated from length and weight measurements as:

$$K = 10^5 \cdot (W/L^3) \qquad \text{(Eqn. 1),}$$

where K is Fulton's Condition Factor, W is whole-body wet weight (g), L is fork length (mm), and 10^5 is a scaling factor (Ricker 1975).

Weight-Length Relationships (WLR) at each location were assumed to follow:

$$W = aL^b \qquad \text{(Eqn. 2),}$$

where W is whole-body wet weight (g), L is fork length (cm), a is a constant intercept representing initial conditions, and b is the growth coefficient. The constants a and b were fit using least squares regression on the $\log_{10}$ transformed length and weight data as:

$$\log(W) = \log(a) + b \cdot \log(L) \qquad \text{(Eqn. 3).}$$

WLRs were calculated for each location with sufficient captures (Beaver Slough, Cochran, and Seestrom in 2021-22) with length and weight data pooled across all sampling dates. Data from sampling sites within locations were aggregated together; sites within locations were not analyzed separately. During the 2021-22 season, WLRs were not calculated for Winter Lake Units 1, 2 and 3 or the mainstem Coquille River due to low captures.

Length, weight, and condition factor data were evaluated for normality using the Shapiro-Wilk normality test (Shapiro & Wilk 1965) and for homogenous error variance using Bartlett's Test (Bartlett 1937a; 1937b). Logarithmic transformation failed to normalize distributions or to homogenize error variance for all locations in all months, so comparisons among locations were evaluated using the non-parametric one-way Kruskal-Wallis test (Kruskal & Wallis 1952). Significant results were followed by Dunn's method for post-hoc pairwise comparisons (Dunn 1964) with Bonferroni-adjusted p-values.[4] Regression coefficients for WLRs were compared using Analysis of Covariance (ANCOVA).

D. Growth

Instantaneous growth rates of recaptured PIT tagged fish were calculated assuming exponential growth as (Busacker et al. 1990):

$$g_L = [\text{Log}_e(L_2)\text{-Log}_e(L_1)]/\Delta t \qquad \text{(Eqn. 4), and}$$

$$g_W = [\text{Log}_e(w_2)\text{-Log}_e(w_1)]/\Delta t \qquad \text{(Eqn. 5)}$$

Where:

G_L = Growth Rate (Length), $mm{\cdot}d^{-1}$
G_W = Growth Rate (Weight), $g{\cdot}d^{-1}$
L_1 = Length at initial capture, mm
L_2 = Length at recapture, mm
w_1 = Weight at initial capture, g
w_2 = Weight at recapture, g
Δt = Time between capture and recapture, days

Specific growth rates, as a daily percent change in weight (G_w) or length (G_L), were calculated as:

$$G = 100(e^g\text{-}1) \qquad \text{(Eqn. 6),}$$

Where e is the base of natural logarithms and g is g_L or g_w for length and weight, respectively (Crane et al. 2019). These calculations were done for single-site coho, which were assumed to have been resident to their tagging locations for the duration of their time at large based on sampling recapture and antenna detection events.

Instantaneous growth rates were also calculated as the slope of the linear regression of mean $\log_e$-transformed lengths and weights of captured fish across sampling events. Specific growth rates then were calculated using equation 6. This approach assumes that captured fish were residents of their respective capture locations for the duration of the season (December – April). In both sampling seasons to-date, some PIT tagged fish were detected at antenna arrays in locations different from where they were tagged, and locations were not closed to immigration/emigration through the study

[4] The Bonferroni method is a means of reducing the probability of a Type I error (false positive significant result) when performing multiple comparisons. In this approach, the α threshold for significance is reduced as α* = α divided by the number of comparisons. The implication is that, for the suite of all comparisons, the significance threshold remains α.

period. Regression coefficients for growth rates (Length, Weight, K) were compared using Analysis of Covariance (ANCOVA).

E. Survival

Detection of tagged fish at a PIT antenna array reflects the joint probability of survival from tagging to detection and the probability of detection by the antenna array. Fish that are not detected at the antennas may be mortalities or fish that the antennas failed to detect. To separate those two "losses" of tagged fish, we intended to calculate detection efficiency of each antenna in the array as:

$$P_1 = N_1/(N_1+M_1) \qquad \text{(Eqn. 7),}$$

Where P_1 = Detection probability of antenna 1
N_1= Number of fish detected by antenna 1
M_1 = Number of fish missed by antenna 1 (number of fish that were detected at antenna 2 but not at antenna 1)

Equation 7 would also be used to calculate the detection efficiency of both antennas in the array, and the overall detection efficiency of the array, P, would be calculated as:

$$P = 1 - [(1-P_1) \cdot (1-P_2)] \qquad \text{(Eqn. 8).}$$

However, juvenile coho frequently staged near the antenna arrays making it unclear which fish-detection events should be considered fish-passage events (i.e., directional movement rather than milling near the array) for calculation of detection efficiency. In the present analysis, actual losses to mortality are not separated from apparent losses that are due to failure of the antenna arrays to detect tagged fish.

F. Movement and Passage Conditions

Assessment of movement and passage conditions is based on single site coho (detected only at their tagging location), mobile coho (detected at locations different from their tagging location, and translocated coho (fish intentionally transferred from their tagging location to a different location). In 2021, PIT-tagged juvenile coho were translocated from Beaver Slough into Winter Lake Unit 2 and into the mainstem Coquille River at Bryant Boat Ramp in Myrtle Point, Oregon (~17 river miles upstream from Winter Lake).

Residence times were assessed as post-tagging or post-arrival residence times at locations with PIT antenna arrays at the tide gates. For single site coho that were only detected at the location of tagging, the period of residence was calculated as the number of days between tagging and final detection at the tide gates. This calculation of residence time requires the assumption that these fish resided at their location of tagging prior to their final detection at the tide gate. This calculation was also used at Winter Lake Unit 2 for fish that were translocated there from Beaver Slough. For fish that were translocated to the mainstem Coquille River and fish that were detected at other locations prior to detection at a given antenna array, the period of residence was calculated as the time between the first and last detections at the tide gate antenna array. This calculation requires the assumption that these tagged fish did not leave and reenter the location undetected between the first and last detections.

Our current statistical approach to this question asks whether conditions used by tagged juvenile coho salmon to leave off-channel habitats are drawn from the same distribution as the conditions potentially available for use (i.e., when the tide gate doors were open). Two-sample Kolmogorov-Smirnov tests were used to assess whether the distribution of passage conditions (entering or exiting off-channel locations) used by juvenile coho differed from the distribution of conditions available when gates were open. The null hypothesis is that fish are using conditions that are a random sampling of available conditions; significant results indicate that the fish are using conditions that are a non-random subset of available conditions. Fish were excluded from the analysis if their tentative entrance or exit times were more than 15 minutes outside of periods when the gates were open. The following passage conditions were assessed: hour of day, hydraulic head (landward water level – seaward water level, meters), tidal bin[5] (categorical), velocity (meters·second^{-1}), upstream water level (i.e., water level on the landward side of the tide gate, meters), and rate of change of landward water level (centimeters·minute^{-1}).

7. Results

A. Site Parameters

Mean daily water temperature for all sites are provided in Figure 12. Similar to 2021, temperatures were similar until March when site temperatures diverged. Conductivity is a good measure for the salinity of water therefore conductivity is monitored throughout the winter and spring months. The mean daily conductivity for all sites are provided in Figure 13. During both the 2021 and 2022 field seasons salinity stayed within the freshwater range and will not be monitored in future years.

Maximum daily velocity for the Winter Lake units are provided in Figure 14. Velocity is a function of the differential height of the headwater and tailwater, therefore as the tide is falling velocity will increase to the magnitude of head differential until low tide is reached and then velocity will decrease as the remaining water in the site drains. The tide gate door closing is dependent on reaching equilibrium at the low tide as the rising tide eliminates the head differential. Maximum daily velocity typically represents the range of velocities experienced in the culvert of the tide gate structure over the course of the day. Velocities of Winter Lake – Unit 3 are bidirectional; positive velocities are outflow while negative velocities are inflow. Negative velocities (inflow) were not represented in the maximum daily velocity figure (Figure 14) for Winter Lake - Unit 3.

Although all project sites are situated in the Coquille Estuary, the river behaves differently whether high in the estuary at Winter Lake or lower in the estuary at Cochran. The Coquille River upstream of river mile 16.0 is slower to drainout following high water events than below river mile 16.0 due to streambank resistance and a geological feature. For these reasons, the Winter Lake tide gates behave

[5] Tidal bins were categorical classifications of tidal stage: 1 (Slack after Flood), 2 (Ebb), 3 (Slack before Ebb), 4 (Slack after Ebb), 5 (Flood), and 6 (Slack before Flood) (Appendix B).

as floodgates during short to moderately long periods in the winter and spring when storms cause the Coquille River to rise significantly and riverbank friction eliminates tidal signal (Figure 15, 16). Snowpack contribution to flows also have the effect of lengthening floodwater periods prior to when river levels drop and tidal effects reestablish. Even during typical tidal behavior, the dynamics of the Coquille River are different at each project site (Figure 16). Winter Lake is the site highest in the estuary and has a dampened tidal amplitude with minimal storm events (e.g. April 22) causing the river to rise significantly compared to the Cochran and Seestrom sites. Due to streambank resistance and a geological feature, as stated above, river elevations at low tide are also significantly higher above river mile 16.0 at Winter Lake than Seestrom and Cochran. The water management plan, these river dynamics and the elevation of the project site play a significant role in the duration that a tide gate door is open, as discussed below.

Fish passage through a tide gate is dependent on acceptable flow conditions but also the amount (% open) and duration that tide gate doors are open. The Cochran and Seestrom sites have side-hinge doors with a mechanical MTR that provides both inflow and outflow. The Winter Lake tide gates are electrical vertical slide gates with one gate per unit (Gate 1B, 2C and 3A) that has a second, side-hinged tide gate mounted on the outside of the vertical slide gate. These gates with both vertical slide and side hinged secondary tide gates are able to provide manual outflow through the side hinged gate and inflow through the vertical slide gate. If the slide gate is not open on the dual function gates then the side-hinge gates provide outflow only[6]. Water management plans dictate what water levels can be on the project sites behind tide gates and are agreed upon with the landowner before projects are implemented. Tide gate doors are adjusted so that water levels stay within the limits of the water management plans. Therefore, gate openness is highly dependent on water management plans and river levels. The Cochran site is the lowest site in the estuary and has one of the highest elevations; therefore, the tide gate door is open for significant periods throughout the winter and spring (Table 1). The Winter Lake project has large swaths of low elevation ground and is the highest site in the estuary, thus experiences higher river elevations at low tide. These factors result in both default and management actions that result in significant periods of time when tide gate doors are closed during the winter and spring (Table 1), as stated above. A monthly summary of gate openness of the side hinge gates at all sites show the range in gate openness (Table 1). The Winter Lake tide gates, as noted previously, rely on a motor driven adjustment of the electrical slide gates to allow incoming tide waters onto the project sites and are operated as summarized in Figure 17.

[6] For greater detail into how these gates function and are operated please refer to the Winter Lake Restoration Effectiveness Monitoring Report Year 3, 2021. https://drive.google.com/file/d/1EWPnLf34eEuXnEi22tH1vRCuN4BQP3Y7/view?usp=sharing

Table 1. Monthly duration of side-hinge tide gate door openness for Cochran, Seestrom, Winter Lake – Unit 1, Winter Lake – Unit 2 and Winter Lake – Unit 3. Both Cochran and Seestrom are manual mechanical MTR style tide gates that allow inflow and outflow. Inflow at Winter Lake is managed using the vertical slide gates (Figure 17). The side-hinged gates at Winter Lake are duplicative and only allow outflow.

Tide Gate Door Openness (side-hinge)	Cochran	Seestrom	Winter Lake, Unit 1	Winter Lake, Unit 2	Winter Lake, Unit 3
November	41%	63%	16%	13%	11%
December	89%	46%	12%	13%	6%
January	87%	58%	30%	27%	26%
February	100%	94%	26%	43%	47%
March	100%	70%	17%	26%	36%
April	98%	62%	11%	12%	22%
May	98%	61%	17%	6%	11%
June	83%	56%	13%	4%	10%

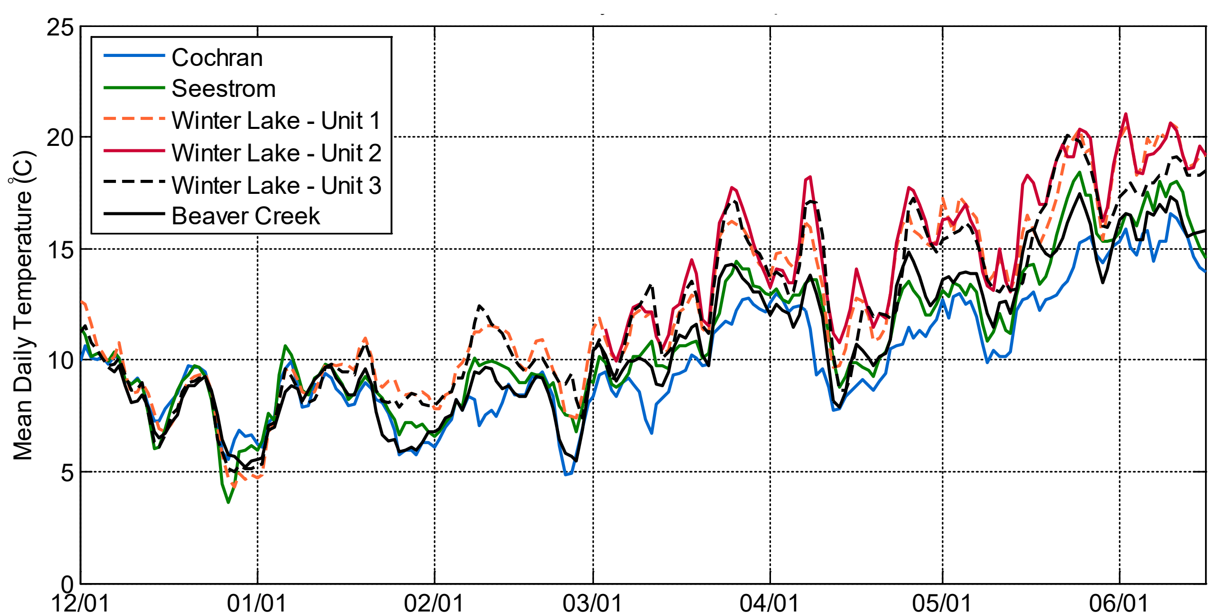

Figure 12. Mean daily water temperature at Cochran (blue), Seestrom (green), Winter Lake – Unit 1 (dashed orange), Winter Lake – Unit 2 (red), Winter Lake – Unit 3 (dashed black), Beaver Creek (black).

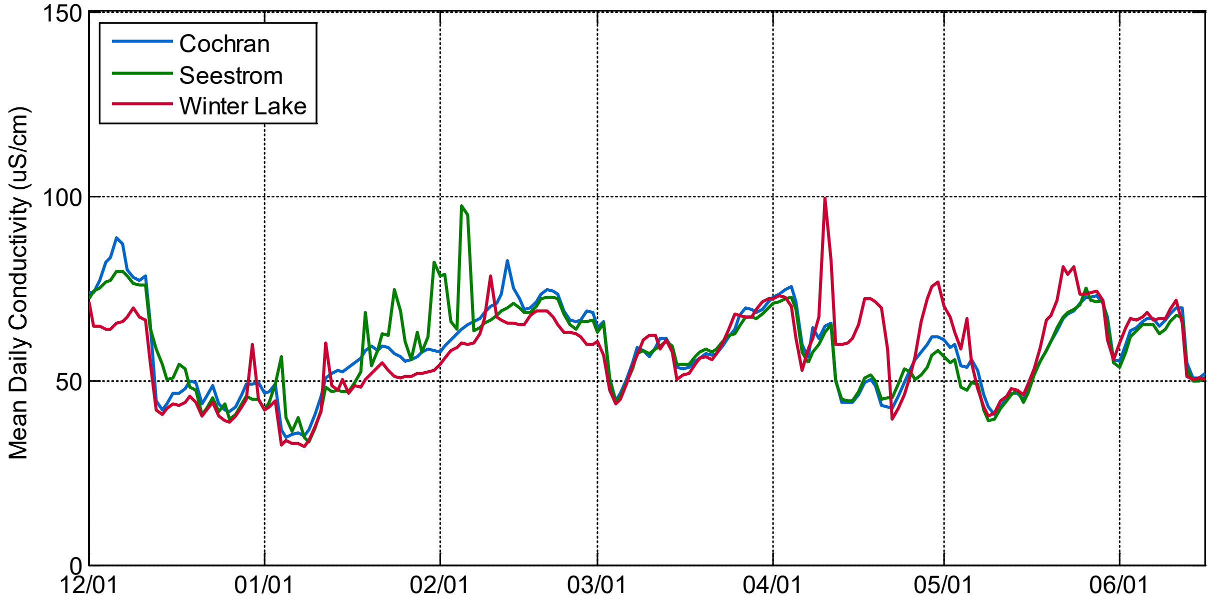

Figure 13. Mean daily conductivity (µS/cm) of the Coquille River at Cochran (blue), Seestrom (green), and Winter Lake (red).

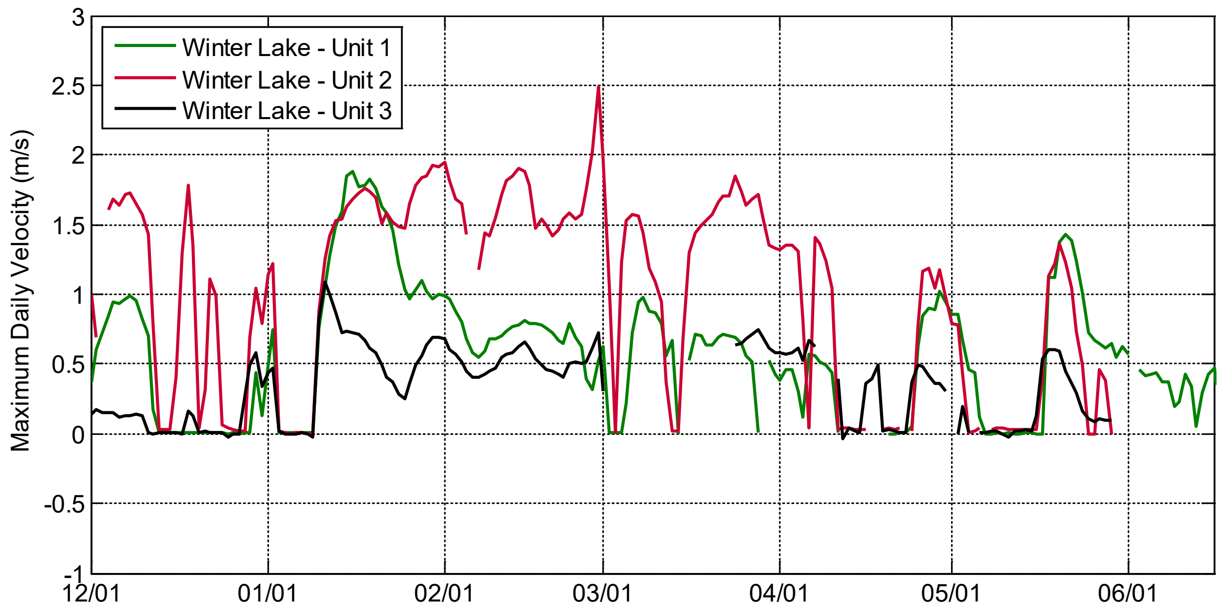

Figure 14. Maximum daily velocity (ft/s) at Winter Lake – Unit 1 (green), Winter Lake – Unit 2 (red), Winter Lake – Unit 3 (black). Maximum daily velocity is also representative of the daily range of velocities seen at the tide gate since velocity drops to zero when the tide gate door closes. Winter Lake – Unit 3(Gate 3A) experiences bi-directional flow, downstream flow is positive and upstream flow is negative. Velocity at Winter Lake – Unit 1 & 2 is from the culvert associated with Gate 1B and 2C, respectively, and experiences only downstream flow.

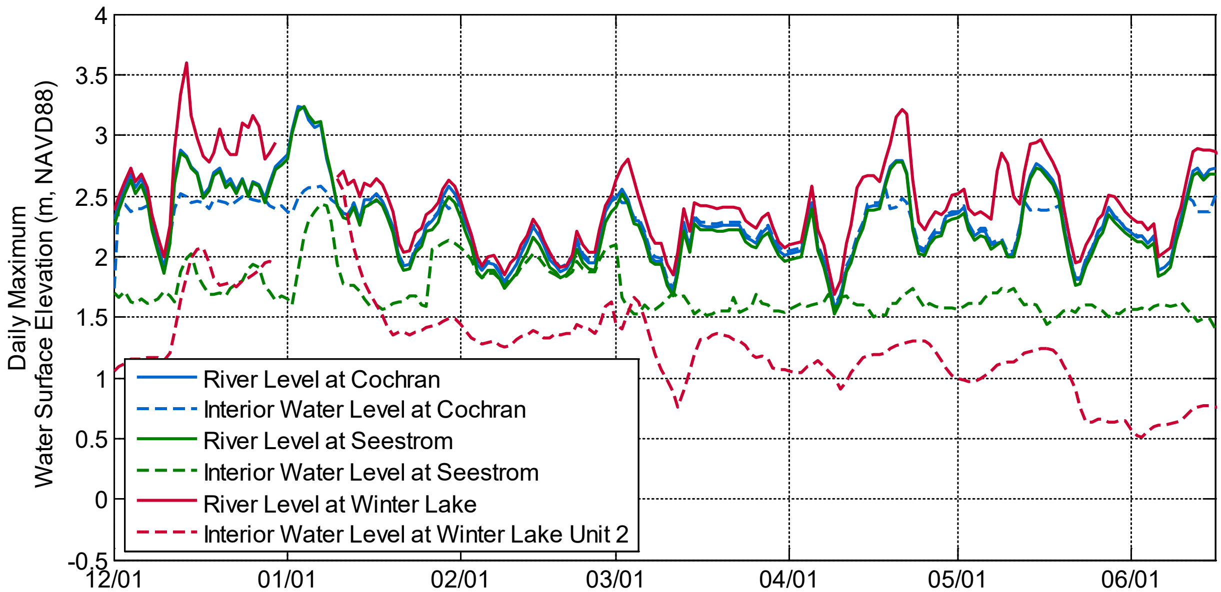

Figure 15. Daily maximum water surface elevations (m NAVD88) of the Coquille River at Cochran (blue), Seestrom (green), and Winter Lake (red) with their respect interior water levels represented as dashed lines. Winter Lake is positioned highest in the estuary and is influenced more by winter storm events than the other project sites.

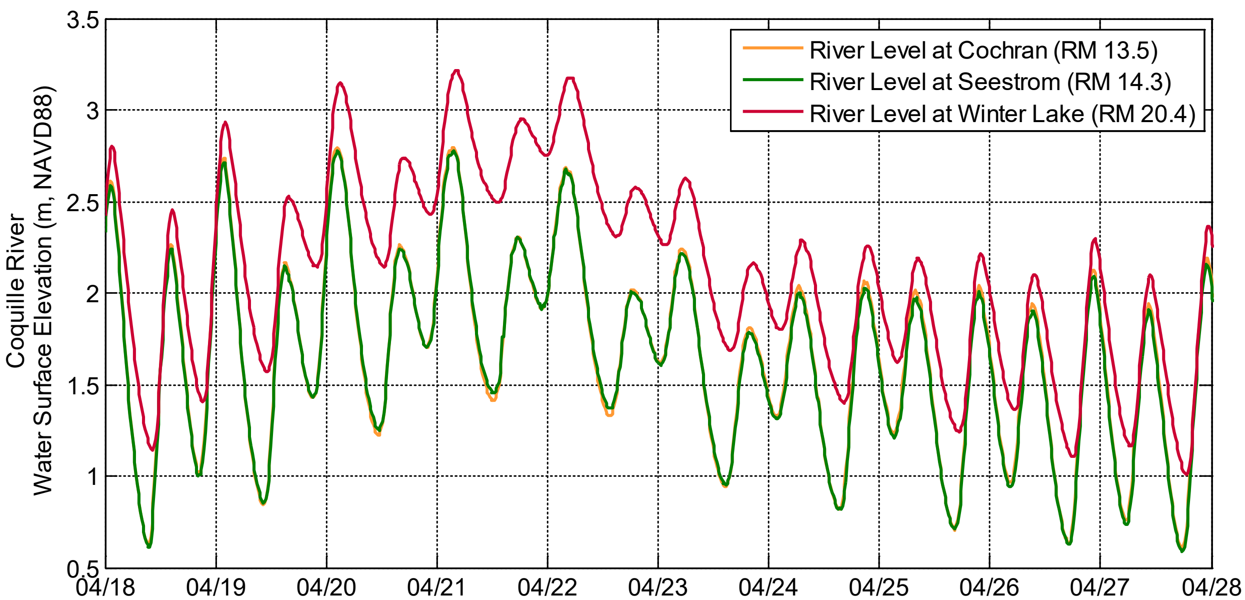

Figure 16. Water surface elevation of the Coquille River at the three project sites, Cochran (yellow), Seestrom (green) and Winter Lake (red). These sites are spread throughout the Coquille Estuary and have different tidal signals.

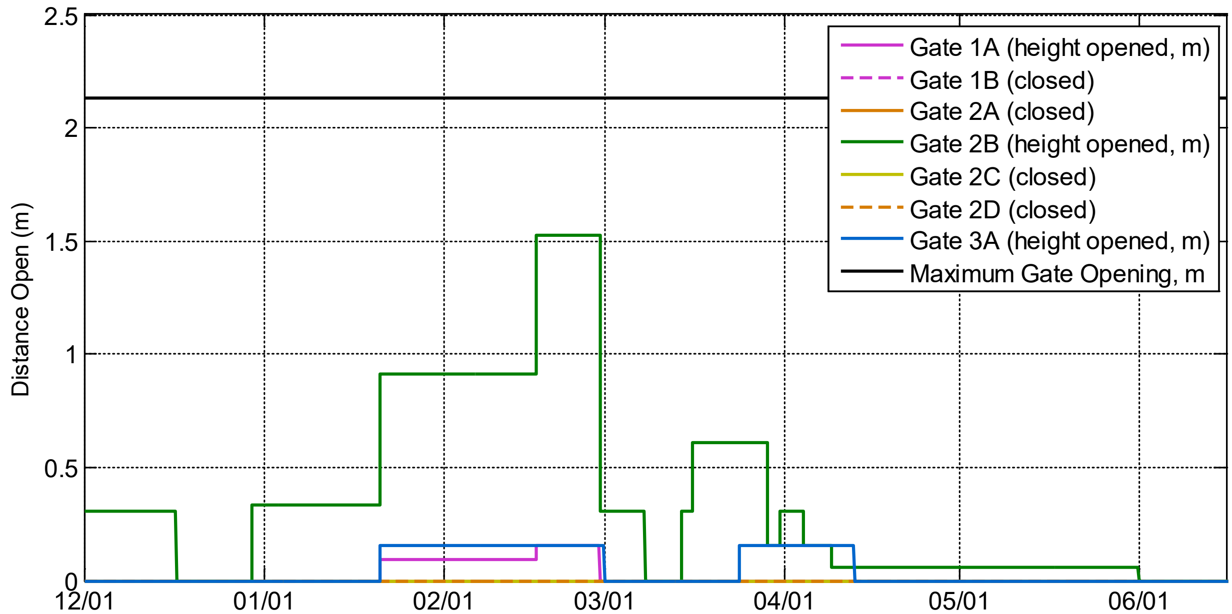

Figure 17. Distance open of vertical slide gates at the Winter Lake site for Unit 2 and 3. Gate 1B, 2C and 3A are dual function slide and side-hinge gates. The slide gate function of Gate 1B, 2A, 2C and 2D was not used during the monitoring season.

B. Species Abundance

Fish sampling in the Coquille Estuary was initiated in early December of 2021 and concluded for the season in mid-May of 2021 due to rising water temperatures and the need to meet NMFS PIT tagging and fish handling guidelines. A total of 1,973 pre-smolt coho juveniles were captured across all sites during the sampling season over a total of 57 sampling events with some days consisting of 2+ sampling events. There were 212 fewer coho captured in 2022 than 2021 even though there were an additional 14 sampling events in 2022. Actual coho abundance at the project sites in the Coquille follows the same trend as the Oregon Coast Coho salmon ESU Mid-South Coast stratum pre-smolt abundance estimates; 2021 pre-smolts, which correspond to LCM 2022 coho, are estimated to be 35% of the 2020 pre-smolt abundance (Figure 18). The largest numbers of coho captured was at the reference site, Beaver Slough (Table 2), which is similar to previous years of sampling at the site. Two hundred and eighty-seven juvenile coho were caught at Beaver Slough, PIT tagged and then translocated into the northwest corner of Winter Lake - Unit 2, while 412 tagged juvenile coho were translocated upstream into the mainstem Coquille River at Myrtle Point (Table 2).

A total of 22 other species of fish and aquatic organisms were captured in addition to coho, listed in Table 3. The most common non-native fish species captured at the LCM project sites are bullhead catfish *(Ameiurus nebulosus)*, bullfrog tadpoles (*Lithobates catesbeianus*), and bluegill *(Lepomis macrochirus)*. All are competing for food with coho juveniles while the large non-native fish are considered a potential predator on coho juveniles. Western brook lamprey (*Lampetra planeri*) and Pacific lamprey *(Entosphenus tridentata)* were captured only at the Seestrom project site (Table 3).

Fewer juvenile fall Chinook salmon were caught in 2022 than 2021, with the majority of juvenile fall Chinook caught at the Seestrom project site. During the planning phase of these restoration projects it was hypothesized juvenile fall Chinook would not use these restoration sites heavily, because they typically reside in larger channels,however, despite recent extreme low fall Chinook parental spawner abundance in the basin and by default meager total numbers of juveniles possible to be produced, we have observed direct and sought out use of tidal channels by juvenile fall Chinook suggesting tidal habitat importance to fall Chinook life-history success in the Coquille basin is very high.   Of the Chinook that were captured only 13 were large enough to be PIT tagged, with all of them being captured at the Seestrom site. Additionally, the last salmonid to be detected was a Chinook at the Seestrom site on June 17th.

Table 2. Fish sampling summary from the Dec 2021-May 2022 sampling season.

	Mainstem Sampling	Headwater Sampling (Laverne Park)	Cochran	Seestrom	Beaver Slough			Winter Lake	
					Released to site	Translocated to Unit 2	Translocated to Coquille River	Unit 2[1,2]	Unit 3
# of Sampling Events[3]	3	2	8	12	23	6	9	6	3
Total coho caught[4]	-	258	194	91	728	287	412	2	1
Total coho tagged[5]	-	81	168	83	526	255	399	2	1
Total Chinook caught	-	n/a	1	24	-	-	-	-	-

1 - No trapping was completed in Unit 1.

2 - Water levels were high during trapping events, causing low densities of coho and low trapping efficiency. See ODFW Winter Lake Volume Analysis for further information.

3 - Sampling events consisted of seining (beach or purse) and hoop traps. The number of hoop traps varied between 1 and 5, CPUE was not calculated for this chart.

4 - Includes recaptures

5 - Does not include recaptures

Table 3. Total species abundance for the Dec 2021-May 2022 fish-sampling season not including mainstem Coquille River sampling.

	Yearly Total	Winter Lake, Unit 3	Winter Lake, Unit 2	Cochran	Seestrom	Headwaters	Beaver Slough, Reference
Total Sampling Events	57[1]	3	6	8	12	2	23
Species (native)							
Coho[2]	1973	1	2	194	91	258	1427
Chinook	25	-	-	1	24	-	-
Cutthroat Trout	40	-	-	8	3	-	29
Lamprey (Western Brook)	2	-	-	-	2	-	-
Newts	364	-	-	81	70	-	213
Northwest Salamander	96	-	-	29	54	-	13
Pacific Lamprey	5	-	-	-	5	-	-
Red legged Frog	30	-	-	6	11	-	13
Sculpin sp.	823	-	7	328	476	-	12
Sucker	2	-	-	-	1	-	1
Three Spine Stickleback	4115	-	2	264	1831	-	2018
Tree frog	2	-	-	-	2	-	-
Unknown tadpole	398	-	26	-	17	-	355
Species (non-native)							
Black Crappie	99	40	1	-	5	-	53
Bluegill	335	46	162	2	61	-	64
Brown Bullhead	1891	194	29	2	186	-	1480
Bullfrog Adult	8	1	-	-	-	-	7
Bullfrog Tadpole	624	4	6	12	19	-	583
Crayfish sp.	302	3	12	4	86	-	197
Gambusia	34	1	-	2	27	-	4
Goldfish	162	-	-	-	103	-	59
Largemouth Bass	43	1	11	2	11	-	18
Yellow Perch	29	2	21	-	6	-	-

1 - 3 mainstem seining events occurred and did not capture any fish
2 - Includes recaptures

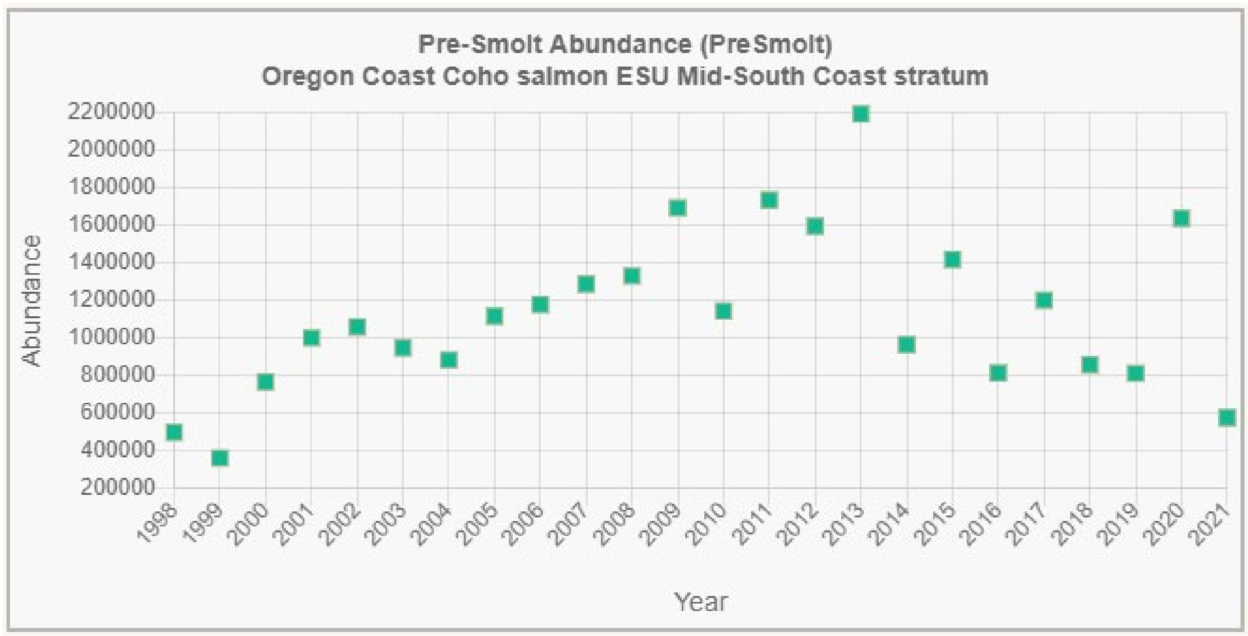

Figure 18. Pre-smolt abundance estimates for OR Coast Coho salmon ESU Mid-South Coast Stratum by year. Source: StreamNet. 2022. https://www.streamnet.org/data/hli/presmolt/?hli-id=30.

C. Condition

Mean lengths, weights, and condition factors for juvenile coho salmon by location and month of capture are provided in Table 4, Table 5, and Table 6, respectively. In 2020-21, Kruskal-Wallis tests indicated significant differences in mean lengths and weights among locations in each month and when data were pooled across all months (Table 7). Condition factor differed among locations in February, March, and April or when data were pooled across all months (Table 4). In 2021-22, we were only able to compare Beaver Slough, Cochran, and Seestrom due to insufficient captures in other locations and subsequent higher standard error. Kruskall-Wallis tests indicated significant differences in mean lengths and weights among sites in January, March, and April or when data were pooled across all months (Table 8). Mean condition factor differed significantly among locations in January through February or when data were pooled across all months (Table 8). Sample sizes were low in some months at some locations (See Table 4-Table 5). In the 2021-22 season, comparisons between fish rearing in off-channel areas and those captured in the mainstem Coquille River were not possible due to a lack of data from the mainstem during concurrent months. Mainstem data were available only for fish captured at Laverne Park in September and October of 2021.

Pairwise comparisons in 2020-21 suggested that, after starting the monitoring period at similar lengths, by April juvenile coho salmon in Beaver Slough and Winter Lake Unit 2 had grown significantly longer than their counterparts at Cochran, Seestrom, or in the mainstem Coquille River (Figure 19). The pattern was similar for weight, though pairwise comparisons could not clearly identify homogeneous groupings in April (Figure 20). In April, pairwise comparisons indicated that juvenile coho at Winter Lake Unit 2 were significantly heavier than those at Cochran, Seestrom, and in the mainstem Coquille River. Patterns were less pronounced for condition factor, where by April pairwise comparisons indicate three homogenous but overlapping groupings (Group A = Winter

Lake Unit 2, Cochran, and Seestrom; Group B = Cochran, Seestrom and Mainstem; Group C = Beaver Slough and Mainstem) (Figure 21).

In 2021-22, juvenile coho captured at Cochran tended to be smaller in length and weight than those captured at Beaver and Seestrom (Figure 22 & 23). As in 2020-21, patterns were more variable and less pronounced for condition factor, but this metric was lower at Beaver Slough late in the season (Figure 24). This was consistent with results in the previous season.

In 2020-21, there was little indication that slopes of WLRs differed among months within locations. Therefore, the 2021-22 WLRs were compared across locations using data aggregated across all sampling events (Table 6; Figure 25). When data were pooled, there were significant differences in the slopes of the WLRs among locations in 2020-21 (ANCOVA, $F = 5.96$, $df = 4, 1216$, $p = 0.0001$) and marginally significant differences in 2021-22 (ANCOVA, $F = 2.90$, $df = 2, 1580$, $p = 0.0553$). However, it is notable that the analysis in 2021-22 did not include Winter Lake Unit 2 or the mainstem Coquille River due to low to zero captures in those locations.

Table 4. Mean fork lengths (millimeters, ±95% CI) of juvenile coho salmon sampled in Beaver Slough, Winter Lake Unit 2, Winter Lake Unit 3, Cochran, Seestrom, and the mainstem Coquille River from December 2020 – April 2021 and December 2021 – May 2022. 'NA' indicates Not Applicable, where no juvenile coho salmon were sampled in the applicable month.

Year	Month	Beaver Slough		Winter Lake Unit 2		Winter Lake Unit 3		Cochran		Seestrom		Coquille R.	
		n	Fork Length (mm)	n	Fork Length (mm)	n	Fork Length (mm)	n	Fork Length (mm)	n	Fork Length (mm)	n	Fork Length (mm)
2020	Dec	22	72.6 (±2.7)	6	82.7 (±7.1)	0	NA	0	NA	58	82.2 (±3.5)	0	NA
2021	Jan	20	108.8 (±4.6)	6	106.5 (±10.1)	0	NA	70	87.6 (±2.4)	16	94.4 (±5.0)	0	NA
2021	Feb	23	112.2 (±4.4)	2	118.0 (±15. 7)	0	NA	88	99.1 (±2.2)	101	102.0 (±2.0)	0	NA
2021	Mar	411	130.5 (±0.9)	25	135.1 (±8.4)	1	185	0	NA	109	111.4 (±1.7)	0	NA
2021	Apr	137	131.8 (±1.7)	28	136.5 (±5.6)	0	NA	15	117.7 (±4.1)	59	117.1 (±3.5)	39	117.6 (±3.1)
2020-21	All	613	127.4 (±1.2)	67	127.9 (±5.7)	1	1.01	173	96.1 (±2.0)	343	103.9 (±1.7)	39	117.6 (±3.1)
2021	Dec	0	NA	0	NA	0	NA	2	87.5 (±10.8)	10	88.9 (±6.8)	0	NA
2022	Jan	180	108.6 (±1.7)	0	NA	0	NA	143	95.7 (±1.9)	25	103.7 (±2.7)	0	NA
2022	Feb	540	109.4 (±0.9)	0	NA	0	NA	5	97.6 (±14.7)	2	102.5 (±22.5)	0	NA
2022	Mar	366	122.4 (±1.2)	1	118	0	NA	17	114.9 (±8.4)	8	110.1 (±10.4)	0	NA
2022	Apr	182	141.7 (±2.2)	1	132	1	130	27	121.4 (±5.0)	34	137.9 (±5.5)	0	NA
2022	May	40	155.8 (±3.3)	0	NA	0	NA	0	NA	12	152.0 (±7.6)	0	NA
2021-22	All	1308	118.8 (±0.9)	2	125 (±13.7)	1	130	193	100.9 (±2.2)	91	121.7 (±5.1)	0	NA

Table 5. Mean whole-body wet weight (grams, ±95% CI) of juvenile coho salmon sampled in Beaver Slough, Winter Lake Unit 2, Winter Lake Unit 3, Cochran, Seestrom, and the mainstem Coquille River from December 2020 – April 2021 and December 2021 – May 2022. 'NA' indicates Not Applicable, where no juvenile coho salmon were sampled in the applicable month.

Year	Month	Beaver Slough		Winter Lake Unit 2		Winter Lake Unit 3		Cochran		Seestrom		Coquille R.	
		n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)
2020	Dec	22	4.3 (±0.4)	4	6.0 (±1.0)	0	NA	0	NA	58	7.4 (±1.2)	0	NA
2021	Jan	20	14.1 (±1.8)	6	15.0 (±4.5)	0	NA	69	7.6 (±0.6)	16	9.7 (±1.8)	0	NA
2021	Feb	23	16.6 (±2.0)	2	18.9 (±9.0)	0	NA	86	11.2 (±0.8)	99	12.0 (±0.7)	0	NA
2021	Mar	412	24.1 (±0.5)	23	32.2 (±5.4)	1	64	0	NA	109	15.6 (±0.7)	0	NA
2021	Apr	137	23.7 (±0.9)	28	30.2 (±3.2)	0	NA	15	19.3 (±2.2)	59	19.4 (±1.7)	39	17.7 (±1.4)
2020-21	All	614	22.7 (±0.5)	63	27.6 (±3.1)	1	1.01	170	10.5 (±0.7)	341	13.5 (±0.6)	39	17.7 (±1.4)
2021	Dec	0	NA	0	NA	0	NA	2	7.9 (±3.8)	10	8.4 (±2.7)	0	NA
2022	Jan	180	14.7 (±0.7)	0	NA	0	NA	142	10.4 (±0.7)	25	13.1 (±1.1)	0	NA
2022	Feb	541	14.4 (±0.4)	0	NA	0	NA	5	11.5 (±5.0)	2	11.9 (±6.3)	0	NA
2022	Mar	366	20.2 (±0.6)	1	20.9	0	NA	17	17.3 (±4.0)	8	15.5 (±4.1)	0	NA
2022	Apr	179	31.8 (±1.5)	1	29.0	1	22.6	27	21.1 (±2.6)	34	32.8 (±3.4)	0	NA
2022	May	40	41.4 (±2.5)	0	NA	0	NA	0	NA	12	41.0 (±5.5)	0	NA
2021-22	All	1305	19.3 (±0.5)	2	25.0 (±7.9)	1	1.03	193	12.5 (±0.9)	91	23.8 (±2.9)	0	NA

Table 6. Mean condition factor, K (±95% CI), of juvenile coho salmon sampled in Beaver Slough, Winter Lake Unit 2, Cochran, Seestrom, and the mainstem Coquille River from December 2020 – April 2021 and December 2021 – May 2022. 'NA' indicates Not Applicable, where no juvenile coho salmon were sampled in the applicable month.

Year	Month	Beaver Slough		Winter Lake Unit 2		Winter Lake Unit 3		Cochran		Seestrom		Coquille R.	
		n	K	n	K	n	K	n	K	n	K	n	K
2020	Dec	22	1.12 (±0.07)	4	0.96 (±0.28)	0	NA	0	NA	58	1.25 (±0.09)	0	NA
2021	Jan	20	1.08 (±0.03)	6	1.20 (±0.07)	0	NA	69	1.10 (±0.03)	16	1.11 (±0.06)	0	NA
2021	Feb	23	1.15 (±0.03)	2	1.12 (±0.10)	0	NA	86	1.11 (±0.02)	99	1.10 (±0.02)	0	NA
2021	Mar	411	1.07 (±0.01)	23	1.20 (±0.03)	1	1.01	0	NA	109	1.12 (±0.02)	0	NA
2021	Apr	137	1.02 (±0.01)	28	1.15 (±0.02)	0	NA	15	1.17 (±0.05)	59	1.15 (±0.02)	39	1.07 (±0.02)
2020-21	All	613	1.06 (±0.01)	63	1.16 (±0.03)	1	1.01	170	1.11 (±0.02)	341	1.14 (±0.02)	39	1.07 (±0.02)
2021	Dec	0	NA	0	NA	0	NA	2	1.14 (±0.15)	10	1.12 (±0.09)	0	NA
2022	Jan	179	1.11 (±0.01)	0	NA	0	NA	142	1.14 (±0.02)	25	1.16 (±0.03)	0	NA
2022	Feb	539	1.07 (±0.01)	0	NA	0	NA	5	1.17 (±0.04)	2	1.09 (±0.13)	0	NA
2022	Mar	366	1.07 (±0.01)	1	1.27	0	NA	16	1.09 (±0.05)	8	1.12 (±0.05)	0	NA
2022	Apr	179	1.08 (±0.01)	1	1.26	1	1.03	27	1.15 (±0.03)	34	1.23 (±0.04)	0	NA
2022	May	40	1.08 (±0.02)	0	NA	0	NA	0	NA	12	1.15 (±0.04)	0	NA
2021-22	All	1303	1.08 (±0.01)	2	1.27 (±0.01)	1	1.03	192	1.14 (±0.01)	91	1.17 (±0.02)	0	NA

Table 7. Results of Kruskal-Wallis tests (Kruskal-Wallis H Statistic, degrees of freedom, p-value) comparing fork lengths, weights, and condition factor among locations (Beaver Slough, Winter Lake Unit 2, Cochran, Seestrom, and Mainstem) by month and with data pooled across months during the 2020-21 season. Critical values are Chi-squared approximated at a=0.05 with k-1 degrees of freedom. Significant results are shown in bold.

Parameter	Month	H	df	p-value
Length	December[i]	12.74	2	**0.0017**
	January[ii]	45.07	3	**<0.0001**
	February[iii]	20.91	2	**<0.0001**
	March[iv]	184.43	2	**<0.0001**
	April[v]	94.30	4	**<0.0001**
	All Months	558.13	4	**<0.0001**
Weight	December[i]	18.81	2	**0.0001**
	January[ii]	45.57	3	**<0.0001**
	February[iii]	23.61	2	**<0.0001**
	March[iv]	175.76	2	**<0.0001**
	April[v]	69.48	4	**<0.0001**
	All Months	517.31	4	**<0.0001**
Condition Factor	December[i]	3.42	2	0.1811
	January[ii]	6.30	3	0.0979
	February[iii]	6.82	2	**0.0330**
	March[iv]	62.96	2	**<0.0001**
	April[v]	120.10	4	**<0.0001**
	All Months	142.36	4	**<0.0001**

[i]December includes only Beaver Slough, Seestrom, and Winter Lake Unit 2; Winter Lake Unit 2 had low sample size (n = 6 & 4 for length and weight & condition, respectively)
[ii]January includes Beaver Slough, Seestrom, Cochran, and Winter Lake Unit 2; Winter Lake Unit 2 had low sample size (n = 6).
[iii]February includes Beaver Slough, Seestrom, and Cochran; Winter Lake Unit 2 was not included due to low sample size (n = 2).
[iv]December includes only Beaver Slough, Seestrom, and Winter Lake Unit 2
[v]April includes all locations.

Table 8. Results of Kruskal-Wallis tests (Kruskal-Wallis H Statistic, degrees of freedom, p-value) comparing fork lengths, weights, and condition factor among locations (Beaver Slough, Cochran, and Seestrom) by month and with data pooled across months during the 2021-22 season. Critical values are Chi-squared approximated at a=0.05 with k-1 degrees of freedom. Significant results are shown in bold.

Parameter	Month	H	df	p-value
Length	December[i]	0.01	1	0.9137
	January	88.51	2	**<0.0001**
	February	3.56	2	0.1684
	March	8.37	2	**0.0153**
	April	35.35	2	**<0.0001**
	May[i]	0.47	1	0.4934
	All Months	169.69	2	**<0.0001**
Weight	December[i]	0.19	1	0.9137
	January	81.40	2	**<0.0001**
	February	2.76	2	0.2525
	March	7.27	2	**0.0263**
	April	30.00	2	**<0.0001**
	May[i]	0.06	1	0.8026
	All Months	144.41	2	**<0.0001**
Condition Factor	December[i]	0.05	1	0.8299
	January	13.82	2	**0.0010**
	February	9.00	2	**0.0111**
	March	10.50	2	**0.0052**
	April	58.40	2	**<0.0001**
	May[i]	7.97	1	**0.0048**
	All Months	162.287	2	**<0.0001**

[i]December includes only Cochran and Seestrom, and May includes only Beaver Slough and Seestrom.

Table 9. Weight-length relationship parameters for juvenile coho salmon sampled in December 2020 – April 2021 (Beaver Slough, Winter Lake Unit 2, Cochran, Seestrom, & mainstem Coquille River) and December 2021 – May 2022 (Beaver Slough, Cochran & Seestrom). Parameters were estimated from the linear relationship between $\log_{10}$ transformed values for weight (g) and length (cm).

Location	Year	n	r^2	p-value	a	b
Beaver Slough	2020-21	613	0.96	<0.0001	0.0150	2.86
	2021-22	1303	0.97	<0.0001	0.0101	3.02
Winter Lake Unit 2	2020-21	63	0.96	<0.0001	0.0095	3.08
	2021-22	2	NA	NA	NA	NA
Cochran	2020-21	170	0.93	<0.0001	0.0088	3.10
	2021-22	192	0.96	<0.0001	0.0133	2.93
Seestrom	2020-21	341	0.93	<0.0001	0.0162	2.84
	2021-22	91	0.98	<0.0001	0.0110	3.03
Mainstem Coquille R.	2020-21	39	0.93	<0.0001	0.0099	3.03
	2021-22	0	NA	NA	NA	NA

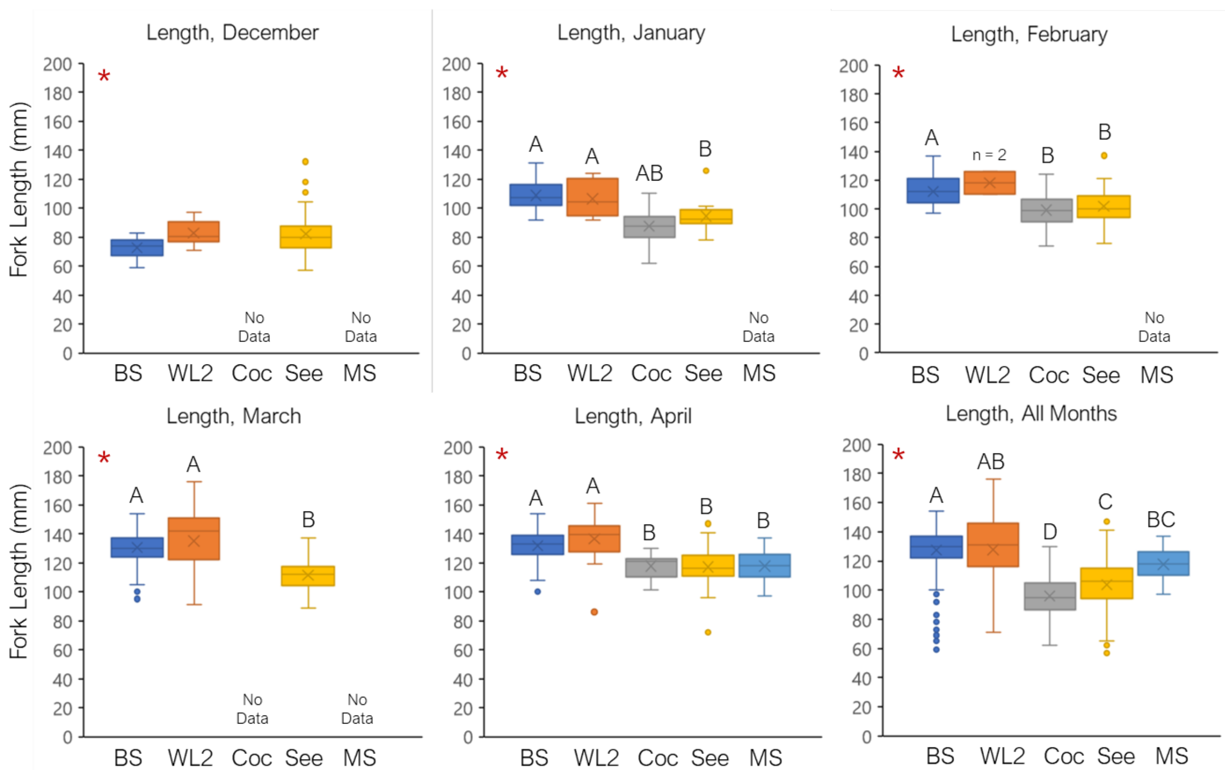

Figure 19. Box plots of fork length (mm) by month and pooled across months for Beaver Slough (BS), Winter Lake Unit 2 (WL2), Cochran (Coc), Seestrom (See) and the Mainstem Coquille River (MS) in the 2020-21 season. An asterisk (*) indicates significant Kruskall-Wallis tests. Letters (A, B, C) above boxes indicate homogenous groups identified through post-hoc pairwise comparisons with Bonferroni-adjusted p-values, p (p* = 0.017 in Dec, Feb, Mar; 0.008 in Jan; 0.005 in Apr & All Months). Winter Lake Unit 2 was not included in statistical analyses in February due to low sample size (n = 2). Post-hoc comparisons could not identify homogeneous groupings in December.*

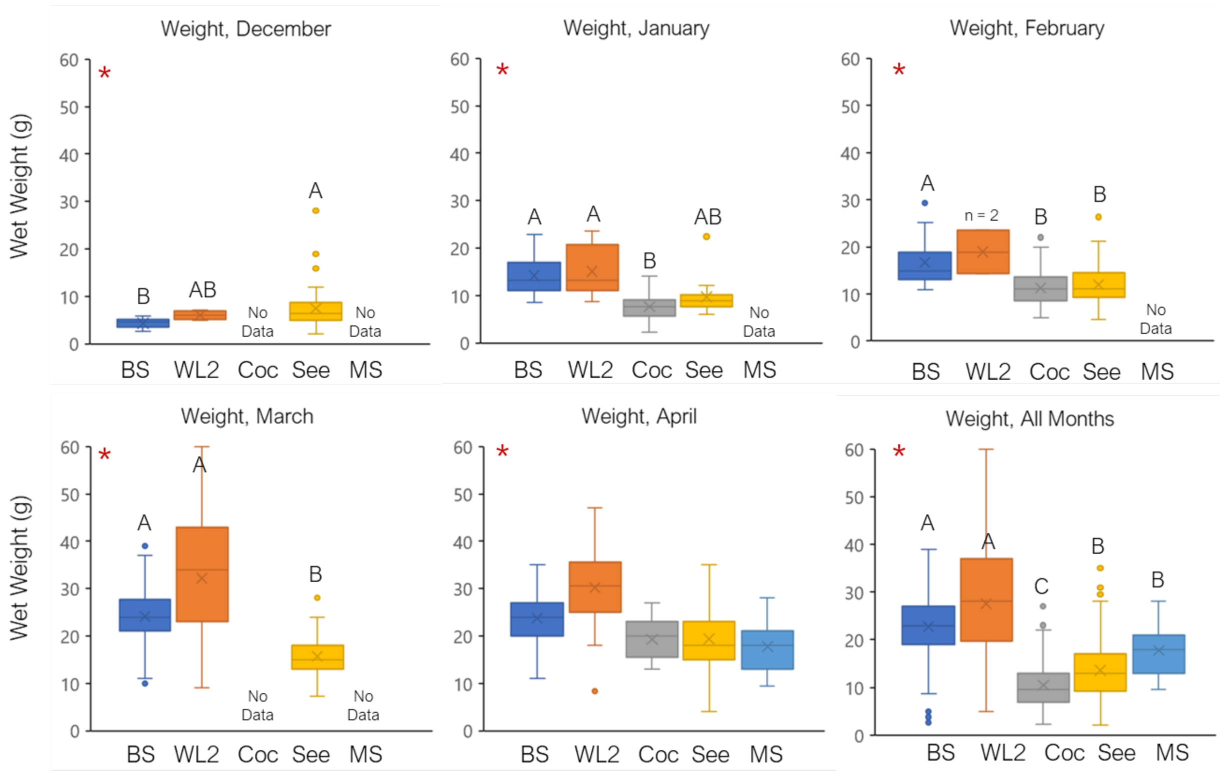

Figure 20. Box plots of whole-body wet weight (grams) by month and pooled across months for Beaver Slough (BS), Winter Lake Unit 2 (WL2), Cochran (Coc), Seestrom (See) and the Mainstem Coquille River (MS) in the 2020-21 season. An asterisk (*) indicates significant Kruskall-Wallis tests. Letters (A, B, C) above boxes indicate homogenous groups identified through post-hoc pairwise comparisons with Bonferroni-adjusted p-values, p (p* = 0.017 in Dec, Feb, Mar; 0.008 in Jan, & 0.005 in Apr & All Months). Winter Lake Unit 2 was not included in statistical analyses in February due to low sample size (n = 2). April post-hoc comparisons could not identify homogeneous groupings at p* = 0.005).*

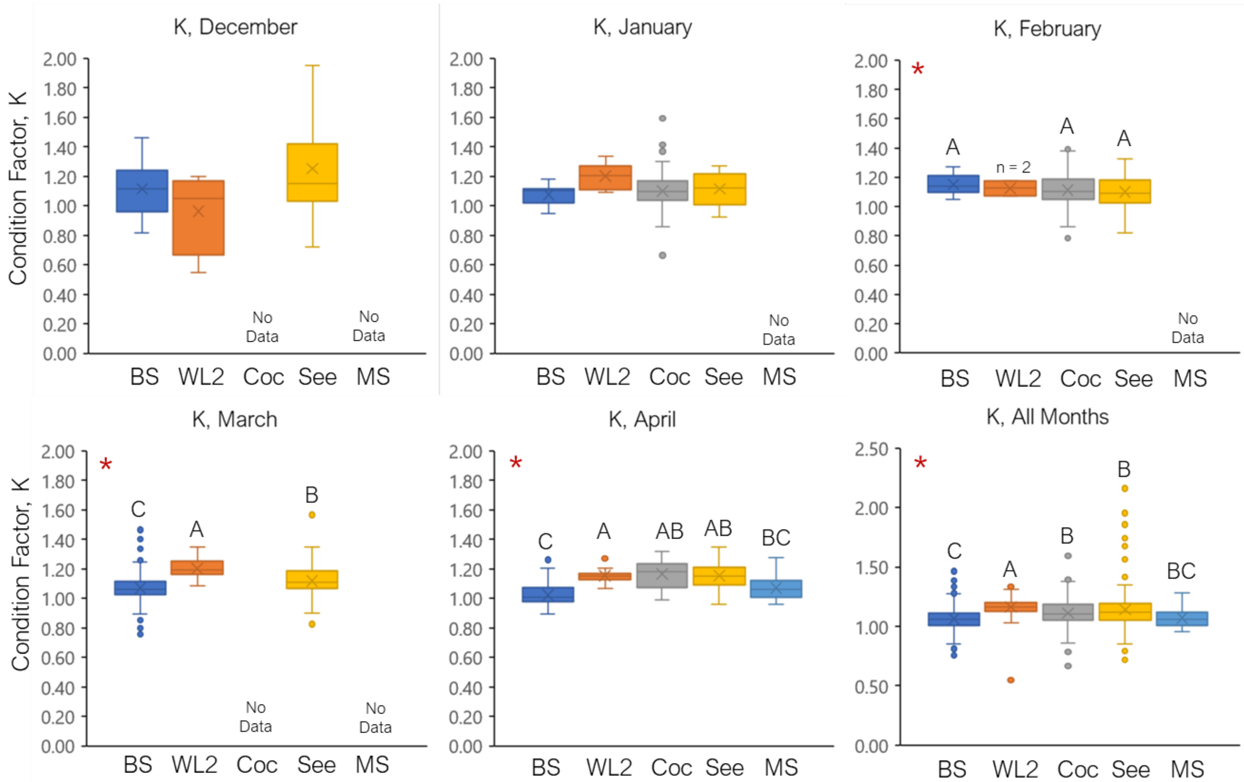

Figure 21. Box plots of Fulton's Condition Factor (K, nondimensional) by month and pooled across months for Beaver Slough (BS), Winter Lake Unit 2 (WL2), Cochran (Coc), Seestrom (See) and the Mainstem Coquille River (MS) in the 2020-21 season. An asterisk (*) indicates significant Kruskal-Wallis tests. Letters (A, B, C) above boxes indicate homogenous groups identified through post-hoc pairwise comparisons with Bonferroni-adjusted p-values, p (p* = 0.017 in Dec, Feb, Mar; 0.008 in Jan, & 0.005 in Apr & All Months). Winter Lake Unit 2 was not included in statistical analyses in February due to low sample size (n = 2); despite a significant Kruskal-Wallis Test in February, differences could not be discriminated with post-hoc comparisons at p* = 0.017.*

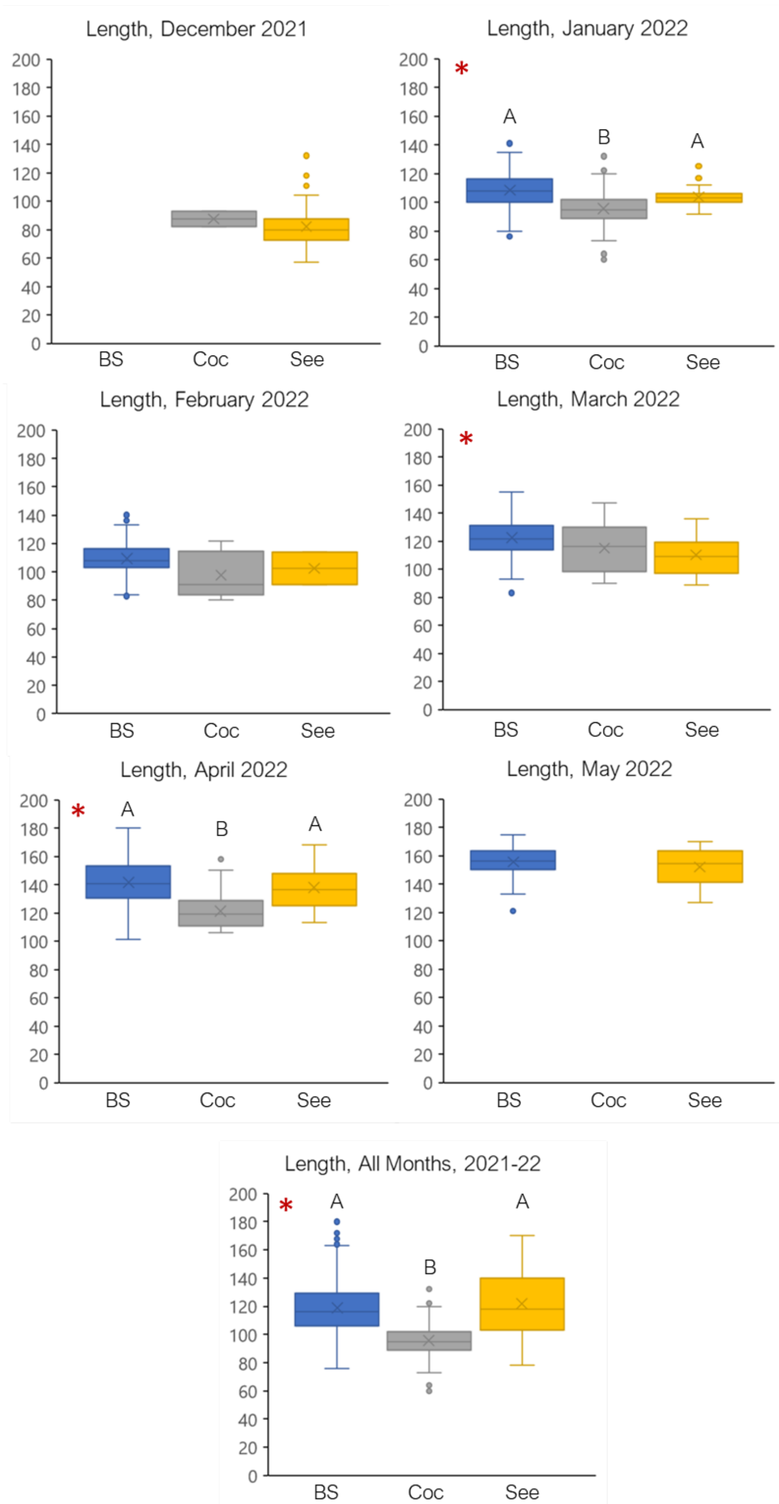

Figure 22. Box plots of fork length (mm) by month and pooled across months for Beaver Slough (BS), Cochran (Coc), and Seestrom (See) in the 2021-22 season. An asterisk (*) indicates significant Kruskall-Wallis tests. Letters (A, B) above boxes indicate homogenous groups identified through post-hoc pairwise comparisons with Bonferroni-adjusted p-values, p (p* = 0.05 in Dec, May; 0.017 in Jan-Apr & All Months). Post-hoc comparisons could not identify homogeneous groupings in March.*

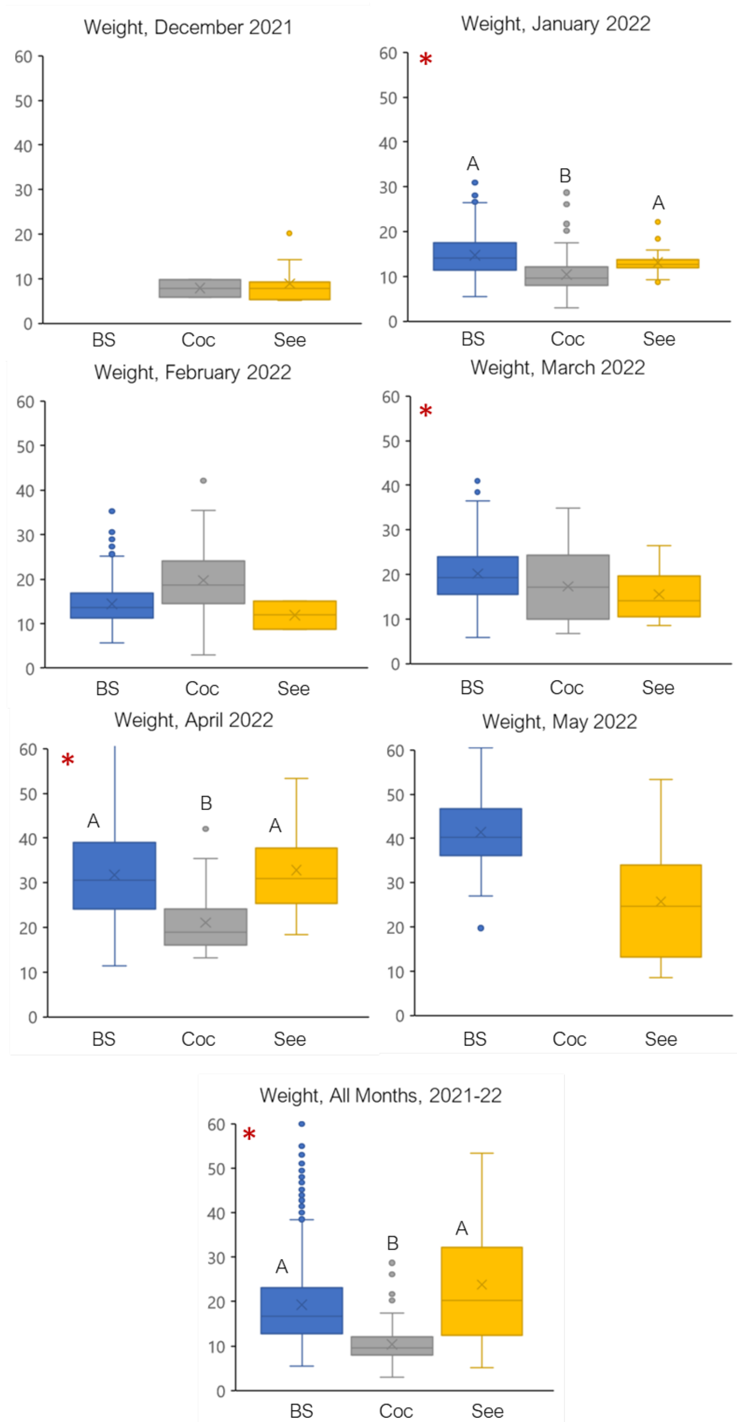

Figure 23. Box plots of whole-body wet weight (grams) by month and pooled across months for Beaver Slough (BS), Cochran (Coc), and Seestrom (See) in the 2021-22 season. An asterisk (*) indicates significant Kruskall-Wallis tests. Letters (A, B) above boxes indicate homogenous groups identified through post-hoc pairwise comparisons with Bonferroni-adjusted p-values, p (p* = 0.05 in Dec, May; 0.017 in Jan-Apr & All Months). Post-hoc comparisons could not identify homogeneous groupings in March.*

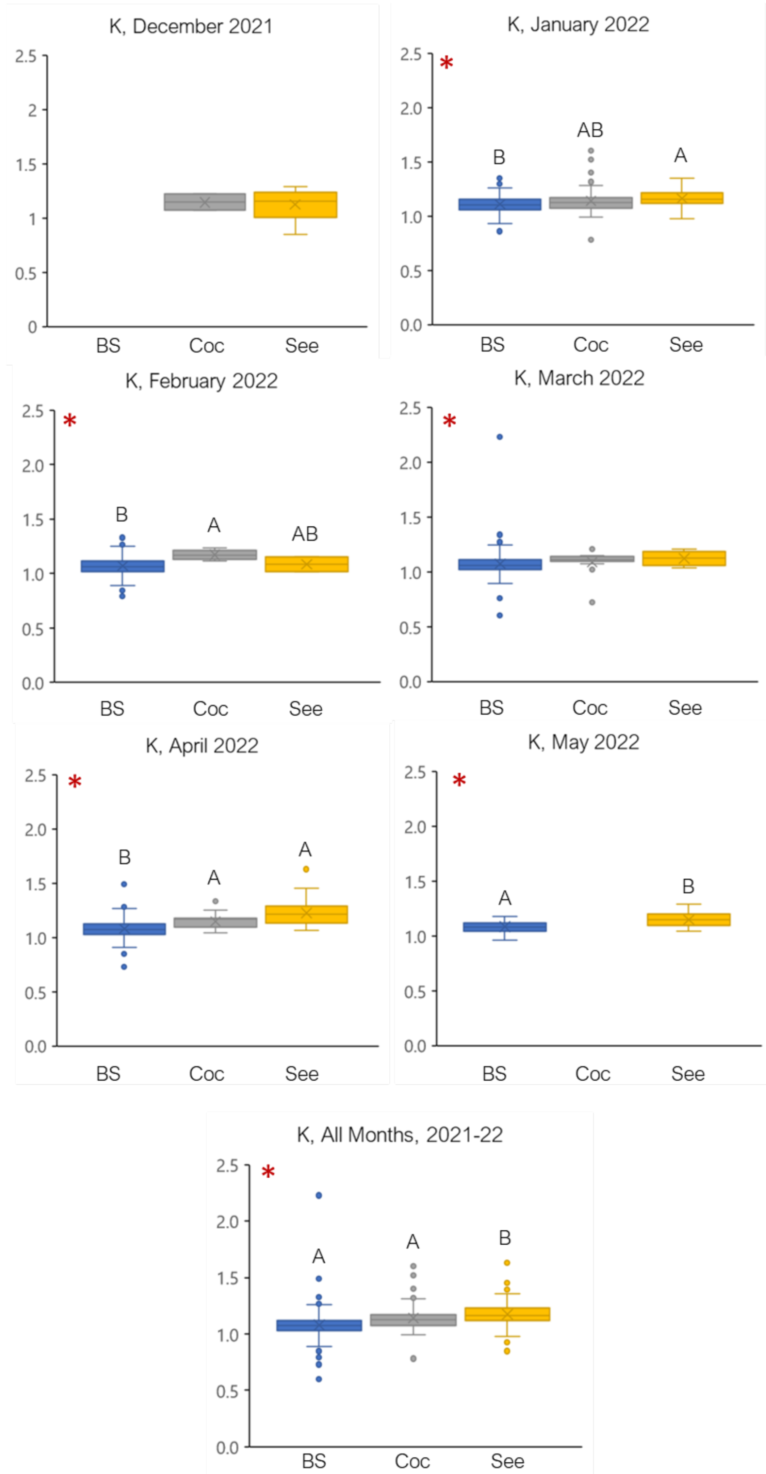

Figure 24. Box plots of Fulton's Condition Factor (K, nondimensional) by month and pooled across months for Beaver Slough (BS), Cochran (Coc), and Seestrom (See) in the 2021-22 season. An asterisk (*) indicates significant Kruskall-Wallis tests. Letters (A, B) above boxes indicate homogenous groups identified through post-hoc pairwise comparisons with Bonferroni-adjusted p-values, p (p* = 0.05 in Dec, May; 0.017 in Jan-Apr & All Months). Post-hoc comparisons could not identify homogeneous groupings in March.*

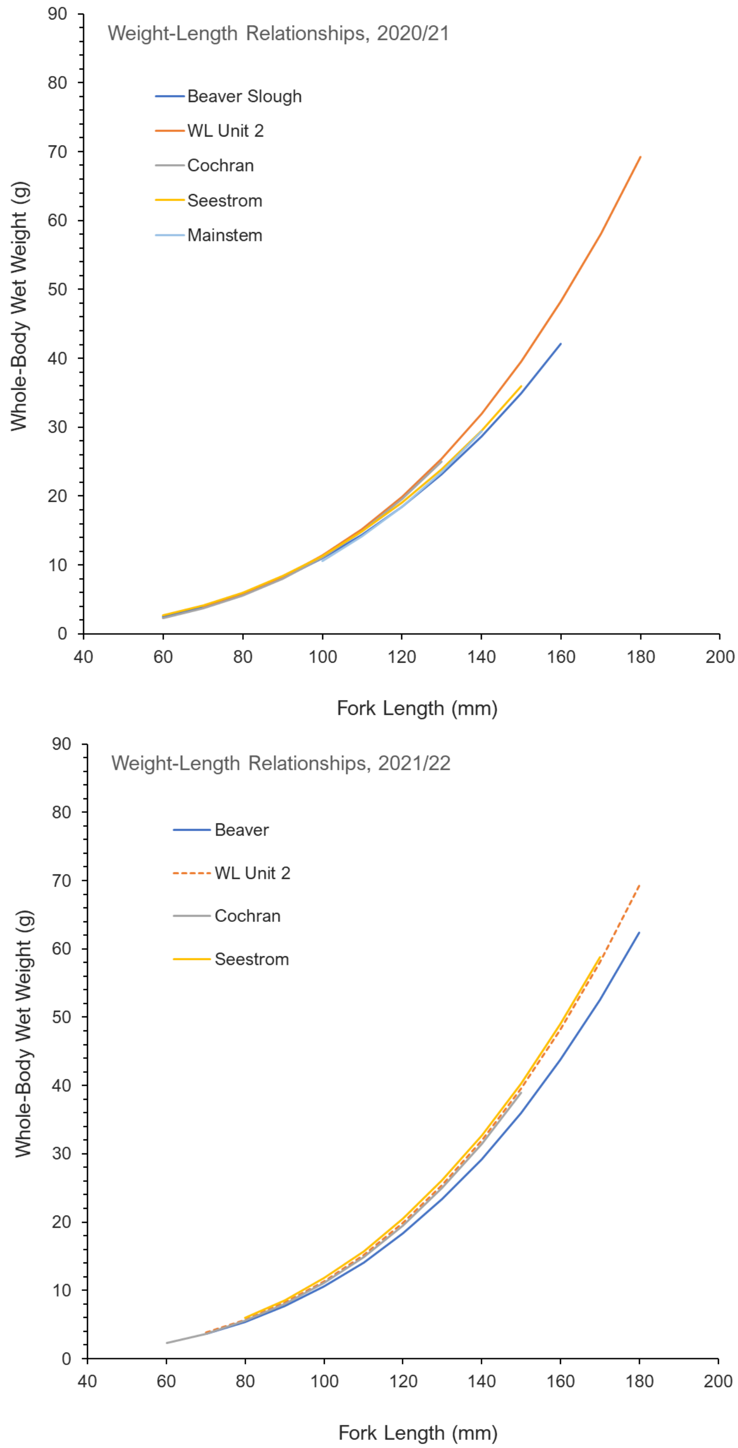

Figure 25. Weight-Length Relationships for juvenile coho salmon in Beaver Slough, Winter Lake Unit 2, Cochran, Seestrom, and the Mainstem Coquille River during the 2020-21 (upper panel) and 2021-22 seasons (lower panel). Data points are omitted for figure clarity. Curves span the length ranges observed at each site. The relationship was not generated for the mainstem or Winter Lake Unit 2 for the 2021-22 season due to insufficient captures. The 2020-21 curve for Unit 2 is shown as a dashed line for comparison in the 2021-22 figure (lower panel).

D. Growth

During the 2021-22 sampling season, 70 tagged fish were recaptured after their initial capture and tagging. Ten fish were recaptured twice after tagging and one was recaptured three times after tagging. This compares to 23 tagged fish recaptured during the 2020-21 season, when no fish were recaptured more than once.

In 2020-21, most recaptures occurred at the location of tagging. However, one fish was recaptured at Beaver Slough 50 days after its initial capture at the Cochran location. Recaptures at Winter Lake (n=4) included three fish that were initially captured in Beaver Slough but translocated into Winter Lake following tagging.[7] Observations were similar in 2021-22, when most recaptures also occurred at the same location as tagging or release (i.e., translocated fish in Winter Lake Unit 2). Exceptions were one fish initially tagged at Cochran but recaptured at Beaver Slough and relocated to Winter Lake Unit 2, two fish tagged at Beaver Slough, relocated to Winter Lake Unit 2, and recaptured at Beaver Slough, and 12 fish tagged at Beaver Slough, relocated to the mainstem, and recaptured at Beaver Slough. These capture histories are provided below:

3DD.003D35225C

- Captured and tagged on 1/19/22 at Beaver Slough; Relocated to mainstem at Bryant Boat Ramp, Myrtle Point RM 37.5
- Detected at Beaver Slough array on 1/26/22
- Detected the Beaver Slough array through 2/15/22
- Recaptured at Beaver Slough on 2/17/2022; Relocated to Winter Lake Unit 2
- Detected at Winter Lake Unit 3 array on 2/18/22

3DD.003D35222E

- Captured and tagged on 2/2/22 at Beaver Slough; relocated to mainstem at Bryant Boat Ramp, Myrtle Point RM 37.5
- Detected at Beaver Slough array on 2/6/2022
- Detected at Beaver Slough array on 2/25/22
- Recaptured at Beaver Slough on 3/2/22

3DD.003D35222F

- Captured and tagged on 2/2/22 at Beaver Slough; relocated to mainstem at Bryant Boat Ramp, Myrtle Point RM 37.5
- Detected at Beaver Slough array on 2/12/2022
- Recaptured at Beaver Slough on 3/2/22
- Near daily detection at Beaver Slough array through 3/21/22

3DD.003D3521FB

[7]After initially experiencing low capture numbers in Winter Lake Unit 2, some juvenile coho captured in Beaver Slough were tagged and translocated to Winter Lake for release. This practice was continued in 2021-22.

- Captured and tagged on 2/2/22 at Beaver Slough; relocated to mainstem at Bryant Boat Ramp, Myrtle Point RM 37.5
- Detected at Beaver Slough array on 3/4/22
- Recaptured on 3/16/22 at Beaver Slough; relocated again to mainstem at Bryant Boat Ramp, Myrtle Point RM 37.5

3DD.003D35221E

- Captured and tagged on 2/2/22 at Beaver Slough; relocated to mainstem at Bryant Boat Ramp, Myrtle Point RM 37.5
- Detected at Beaver Slough array on 2/19/22, detected for multiple days
- Recaptured on 3/23 at Beaver Slough. Last detect at tide gate on same day.

3DD.003E1AD3E1

- Captured and tagged on 2/2/22 at Beaver Slough; relocated to mainstem at Bryant Boat Ramp, Myrtle Point RM 37.5
- Detected at Beaver Slough array on 2/23/22; detected on multiple days
- Recaptured on 3/25/22 at Beaver Slough
- Detected at Beaver Slough array on 3/27/22

3DD.003E1AD600

- Captured and tagged on 3/10/22 at Beaver Slough; relocated to mainstem at Bryant Boat Ramp, Myrtle Point RM 37.5
- Detected t Beaver Slough array on 3/18/22
- Recaptured at Beaver Slough on 3/25/22; relocated to Winter Lake Unit 2

3DD.003E1AD542

- Captured and tagged on 3/23/22 at Beaver Slough; relocated to mainstem at Bryant Boat Ramp, Myrtle Point RM 37.5
- Detected at Beaver Slough array on 4/8/22; detected on multiple days
- Recaptured at Beaver Slough on 4/14/2022
- Detected at Beaver Slough array on 5/16/22

3DD.003E1AD52B

- Captured and tagged on 3/16/22 at Beaver Slough; relocated to mainstem at Bryant Boat Ramp, Myrtle Point RM 37.5
- Detected at Beaver Slough array on 3/30/22; detected on multiple days
- Recaptured on 4/14/22 at Beaver Slough
- Detected at Beaver Slough array on 5/10/2022

3DD.003E1AD5ED

- Captured and tagged on 3/10/22 at Beaver Slough; relocated to mainstem at Bryant Boat Ramp, Myrtle Point RM 37.5
- Detected at Beaver Slough array on 3/17/22; also detected on 4/5/2022

- Recaptured on 4/19/22 at Beaver Slough. No subsequent detections

3DD.003E1AD3E6

- Captured and tagged on 2/2/22 at Beaver Slough; relocated to mainstem at Bryant Boat Ramp, Myrtle Point RM 37.5
- Detected at Beaver Slough array on 2/11/22
- Recaptured at Beaver Slough on 4/28/22; relocated to Winter Lake Unit 2; no subsequent detections.

3DD.003D352223

- Captured and tagged on 2/2/22 at Beaver Slough; relocated to mainstem at Bryant Boat Ramp, Myrtle Point RM 37.5
- Recaptured at Beaver Slough on 5/3/22
- Detected at Beaver Slough array on 5/6/2022

3DD.003E1AD3AB

- Captured and tagged on 2/2/22 at Beaver Slough; relocated to Winter Lake Unit 2
- Detected at Beaver Slough array on 2/12/22; Detected on multiple days
- Recaptured at Beaver Slough on 5/3/22
- Detected at Beaver Slough array on 5/4/22

3DD.003E1AD39A

- Captured and tagged on 2/2/22 at Beaver Slough; relocated to Winter Lake Unit 2
- Detected at Beaver Slough array on 2/18/22; last detected at Beaver Slough on 3/2/22
- Recaptured on 3/16/22; relocated again to Winter Lake Unit 2.
- Detected at Winter Lake Unit 2 array on 3/26/22 and 3/28/22

3DD.003D3522F8

- Captured and tagged on 1/11/22 at Cochran
- Detected at Cochran array on 1/11/22 and 1/12/22
- Detected at Beaver Slough array on 3/2/22 and 3/3/22
- Recaptured at Beaver Slough on 3/16/22; relocated to Winter Lake Unit 2
- Detected at Winter Lake Unit 2 array on 3/26/22 and 3/28/22

Rates of growth calculated from single site recaptured individuals at Winter Lake Unit 2, Beaver Slough, Seestrom, and Cochran were similar to those inferred by regression of mean lengths and weights across sampling events in the first season (2020-21; Table 10). However, small sample sizes for recaptured individuals and, in some cases, relatively few successful capture events or low captures in some events limits the precision of estimates (Table 10). In 2022, rates of growth calculated from recaptured individuals differed more from estimates inferred by regression of mean lengths and weights across sampling seasons. The reason for these differences is not clear and will require further analysis (Table 10).

In the 2020-21 season, there were no significant differences in the slopes of growth regressions for length ($F = 0.96$, df 3, 25, $p = 0.4257$) or weight ($F = 1.00$, df 3, 24, $p = 0.1658$) among locations.

Results in the 2021-22 season were the same (length, F = 0.15, df 2, 30, p = 0.8619); weight (F = 0.16, df 2, 30, p = 0.8528).

Table 10. Growth in length (Δ length, %·d⁻¹) and weight (Δ length, %·d⁻¹) determined from the growth of tagged and recaptured individuals and inferred from the mean length or weight of fish captured at fish sampling events at each location. Confidence Intervals are shown in parentheses. Growth was not inferred from capture events at Winter Lake Unit 2 in 2021-22 due to low captures (n = 2).

Location	Season	Source	Δ length ($\%\cdot d^{-1}$)	Δ weight ($\%\cdot d^{-1}$)
Beaver Slough	2020-21	Inferred Growth (11 events)	0.41 (±0.16)	1.16 (±0.53)
		Recapture Growth (n = 3)	0.40 (±0.14)	1.25 (±0.39)
	2021-22	Inferred Growth (18 events)	0.31 (±0.08)	0.89 (±0.26)
		Recapture Growth (n = 68)	0.45 (±0.04)	1.77 (±0.21)
Winter Lake Unit 2	2020-21	Inferred Growth (13 events)	0.38 (±0.11)	1.20 (±0.33)
		Recaptures (n = 4)[i]	0.73 (±0.30)	2.67 (±1.43)
	2021-22	NA	NA	NA
		NA	NA	NA
Cochran	2020-21	Inferred Growth (4 events)	0.25 (±0.60)	0.78 (±0.14)
		Recaptures (n = 5)	0.51 (±0.04)	1.99 (±0.15)
	2021-22	Inferred Growth (8 events)	0.28 (±0.15)	0.82 (±0.41)
		Recaptures (n = 9)	0.71 (±0.13)	2.26 (±0.54)
Seestrom	2020-21	Inferred Growth (5 events)	0.29 (±0.14)	0.80 (±0.22)
		Recaptures (n = 8)	0.24 (±0.04)	1.64 (±0.51)
	2021-22	Inferred Growth (10 events)	0.31 (±0.12)	0.94 (±0.39)
		Recaptures (n = 4)ii	1.06 (±0.25)	2.90 (±0.95)

[i] 3 of 4 recaptures in WL Unit 2 were fish relocated from Beaver Slough.
[ii] 5 tagged coho were recaptured at Seestrom; one was not included in the analysis because it was recaptured after only one day at large.

E. Survival

Actual losses to mortality could not be separated from apparent losses due to the failure of the antenna arrays to detect some individuals. The percentage of tagged fish detected at antenna arrays will be considered minimum rates of survival until the detection efficiency of the antenna arrays can be determined. Regardless, a large proportion of tagged individuals were subsequently detected at the tide gates at Seestrom (2020-21 = 82%; 2020-22 = 88%), Cochran (2020-21 = 91%; 2021-22 = 88%), and Beaver Slough (2021-22 = 88%) (Table 11 & Table 12; Figure 26). The overall proportion of tagged fish subsequently detected at tide gate PIT antenna arrays was much lower at Winter Lake Unit 2 (2020-21 = 19%; 2021-22 = 17%) than at the other locations (Table 11 & 12; Figure 26). This lower detection proportion may be attributable to higher mortality in Winter Lake Unit 2, but is likely due to antenna outages and extremely low detection efficiency (Appendix A) at the Winter Lake Unit 2 PIT antenna array, or both. Estimates of detection probability at the Winter Lake Unit 2 location will be necessary to further assess this persistent discrepancy in detection proportions at Winter Lake relative to the other locations. These estimates are currently in progress.

Table 11. Time (days) elapsed from tagging to final detection (single site coho) and the percentage of tagged fish detected at the tide gate PIT tag antenna arrays by month and location in the 2020-21 sampling season. Note: PIT tag antenna array not installed at Beaver Slough until after 2020-2021 sample year.

	Month	Number Tagged	Time to Final Detection, Days		Percent of Tagged Fish Detected at Gate
			Avg ± 95% CI	Range	
Winter Lake Unit 2	December	5	NA	NA	0
	January	5	61 ± NA	NA	20
	February	2	NA	NA	0
	March	131[i]	22 ± 6	8 to 35	12
	April	77[i,ii]	10 ± 4	1 to 29	32
	May	0	NA	NA	NA
Cochran	December	0	NA	NA	NA
	January	48	11 ± 4	0 to 82	98
	February	76	4 ± 2	0 to 31	87
	March	0	NA	NA	NA
	April	15	4 ± 1	1 to 10	93
	May	0	NA	NA	NA
Seestrom	December	30	28 ± 10	0 to 74	67
	January	14	31 ± 11	12 to 57	79
	February	69	25 ± 5	1 to 70	90
	March	97	13 ± 3	1 to 47	76
	April	56	9 ± 2	1 to 31	89
	May	4[ii]	6 ± 7	1 to 15	100

[i]Fish tagged at Winter Lake in March and April include fish captured at Beaver Slough and relocated on the tagging date to Winter Lake Unit 2).

[ii]Fish tagged in May at Seestrom were juvenile Chinook salmon (n =4); fish tagged in April at Winter Lake Unit 2 include 21 Chinook salmon.

Table 12. Time (days) elapsed from tagging to final detection (single site coho) and the percentage of tagged fish detected at the tide gate PIT tag antenna arrays by month and location in the 2021-22 sampling season.

	Month	Number Tagged	Time to Final Detection, Days		Percent of Tagged Fish Detected at Gate
			Avg ± 95% CI	Range	
Winter Lake Unit 2[i]	December	0	NA	NA	NA
	January	53	7 ± 11	N/A	4
	February	109	30 ± 16	N/A	5
	March	50	12 ± 5	8 to 35	40
	April	45	11 ± 4	1 to 29	36
	May	0	NA	NA	NA
Beaver	December	0	NA	NA	NA
	January	47	65 ± 13	1 to 124	87
	February	298	48 ± 4	1 to 114	86
	March	108	41± 4	1 to 79	92
	April	64	28 ± 3	1 to 49	95
	May	13	7 ± 3	3 to 17	77
Cochran	December	2	5 ± 5	3 to 7	100
	January	138	7 ± 2	1 to 77	86
	February	4	11 ± 18	1 to 38	100
	March	15	18 ± 11	<1 to 56	100
	April	20	13 ± 7	1 to 45	95
	May	0	NA	NA	NA
Seestrom	December	9	58 ± 24	1 to 104	78
	January	21	24 ± 16	1 to 92	95
	February	2	39 ± 74	1 to 77	100
	March	8	33 ± 13	7 to 62	100
	April	32	9 ± 4	1 to 34	84
	May	11	2 ± 0.4	1 to 3	82

[i]Fish tagged at Winter Lake include fish captured at Beaver Slough and relocated on the tagging date to Winter Lake Unit 2.

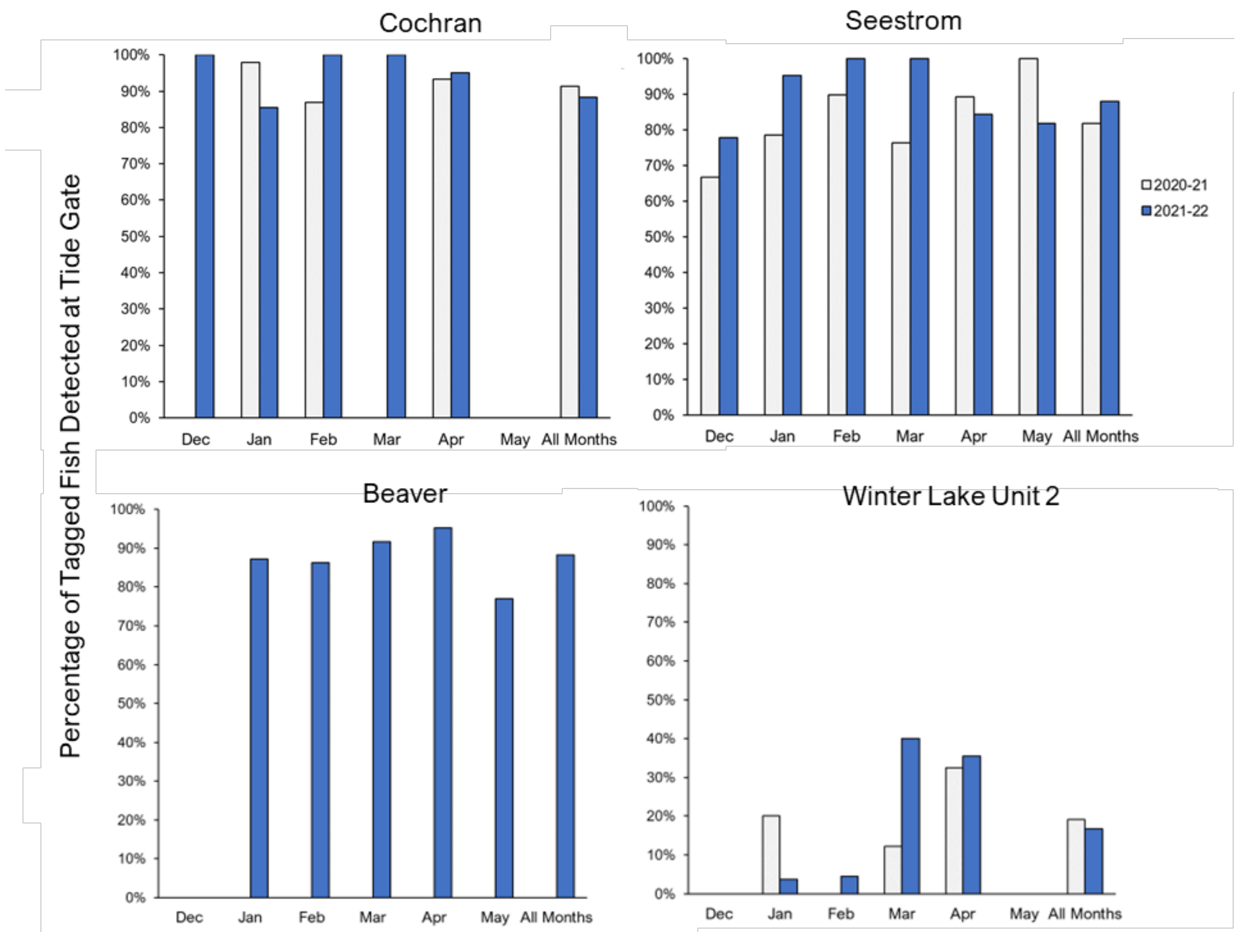

Figure 26. Percent of tagged fish detected at tide-gate antenna arrays by tagging month for each location in 2020-21 (gray bars; Cochran, Seestrom, Winter Lake Unit 2) and 2021-22 (blue bars; Cochran, Seestrom, Beaver, Winter Lake Unit 2). The antenna array at Beaver Slough was first operated during the 2021-22 season.

F. Movement and Passage

The following is a summary of tagging and detection data from the 2021-22 season (Figure 27) and depicts the affinity for coho to enter larger, lake like, habitats.

Early Season Tagging - Laverne Park

Eighty-one juvenile coho were tagged at Laverne Park in September and October 2021. Three of these fish (4%) were subsequently detected at antenna arrays at Winter Lake Unit 1 (n = 1) and Beaver Slough (n = 2). The first Laverne Park fish was detected entering Beaver Slough on 1/21/22, and it was detected multiple times through 5/4/2022. The other Laverne Park fish detected at Beaver Slough was first detected on 2/11/2022 and last detected at the Coaledo antenna array on 2/25/22. The fish detected at Winter Lake Unit 1 was first detected at that location on 2/12/22 and last detected on 2/18/2022.

Mainstem Translocations

Three hundred and ninety-nine juvenile coho were tagged and translocated from Beaver Slough to the mainstem Coquille River approximately 17 miles upstream from Winter Lake. Sixty-eight of these fish (17%) were eventually detected back at the Coaledo array at Beaver Slough. Nine of the returns to Beaver Slough also stopped at other sites prior to detection at Coaledo. Fourteen of the translocated fish were detected at Winter Lake Unit 1, two at Winter Lake Unit 2, thirty-two at Winter Lake Unit 3, and two at Seestrom. No fish translocated to the mainstem were detected at Cochran. Of the 117 coho detected after being released to the mainstem there was a large variation in how long it took for the coho to be detected again. The range in time was as little as 1.3 days for a coho to be detected 19 miles downstream at the Beaver Creek site to as long as 95 days for a coho to be detected at the Beaver Creek site (Table 13). This equates to a migration rate of less than 0.2 mi/d to 14.6 mi/d (Table 14).

Winter Lake Unit 1

Although no coho were tagged at Winter Lake Unit 1, 48 individuals, all coho, were detected at the Unit 1 PIT antenna array during the 2021-22 season. None were fish tagged in Unit 1. Five were originally tagged and released at Cochran, five at Seestrom, four at Beaver Slough and one in the mainstem Coquille River at Laverne Park. Fourteen of the coho detected at Unit 1 were fish that had been captured at Beaver Slough and translocated to the mainstem, and 19 were fish that had been translocated from Beaver Slough into Winter Lake Unit 2. One fish was detected in Unit 1 on two events that were interceded by detection at another location.

Winter Lake Unit 2

Only two coho were initially captured and tagged in Winter Lake Unit 2, but 287 juvenile coho were tagged and translocated from Beaver Slough to Unit 2. Fifty-three individuals, all coho, were detected at the Unit 2 PIT antenna array during the 2021-22 season. One was originally tagged and released in Unit 2, while six were originally tagged and released in Beaver Slough. Two of the coho detected at Unit 2 were fish that had been captured at Beaver Slough and translocated to the mainstem, and 44 were fish that had been translocated from Beaver Slough into Unit 2.

Winter Lake Unit 3

Only one juvenile coho was initially captured and tagged in Winter Lake Unit 3, but 68 individuals, all coho, were detected at the Unit 3 PIT antenna array during the 2021-22 season. One was originally tagged and released in Unit 3, while three were originally tagged and released at Cochran, one at Seestrom, and eight in Beaver Slough. Thirty-two of the coho detected at Unit 3 were fish that had been captured at Beaver Slough and translocated to the mainstem, and 44 were fish that had been translocated from Beaver Slough into Unit 2.

Cochran

One hundred and sixty-eight juvenile coho were tagged at Cochran, and 162 individuals, all coho, were detected at the Cochran PIT antenna array during the 2021-22 season. Of these, 158 were coho originally tagged and released at the Cochran location, while three were originally tagged and released at Seestrom and one at Beaver Slough. Two fish was detected at the Cochran array on two events that were interceded by detection at another location. No fish that were translocated from Beaver Slough into the mainstem or Unit 2 were detected at the Cochran array.

Seestrom

Eighty-three juvenile coho were tagged at Seestrom, and 108 coho were detected at the antenna array during the 2021-22 season. Of these, 73 were coho originally tagged and released at the Seestrom location, while 28 were originally tagged and released at the Cochran location, and three at Beaver Slough. Two were fish that had been translocated from Beaver Slough into the mainstem and two were fish that had been translocated from Beaver Slough to Unit 2. Three fish were detected at the Cochran array on two events that were interceded by detection at another location.

Thirteen juvenile Chinook salmon were tagged at Seestrom and eight were subsequently detected at the antenna array. All had been originally tagged and released at the Seestrom site. No tagged Chinook were detected at antenna arrays in other locations.

Beaver Slough

Five hundred and twenty-six juvenile coho were tagged and released at Beaver Slough, and 576 coho were detected at the antenna array during the 2021-22 season. Of these, 469 had been originally tagged and released in Beaver Slough, while three were originally tagged and released at Seestrom, seven at Cochran, and two in the mainstem at Laverne Park. Sixty-eight coho detected at the Beaver Slough array had been translocated from Beaver Slough to the mainstem and 27 had been translocated from Beaver Slough to Unit 2. Four coho were detected at the Cochran array on two events that were interceded by detection at another location. It is also notable that 27 of 287 (9.4%) juvenile coho translocated to Winter Lake Unit 2 were eventually detected back at the Beaver Slough array.

Post-tagging residence time for single site coho generally decreased through time at Beaver Slough, Seestrom, and Winter Lake Unit 2 in both 2020-21 and 2021-22. Short residence times calculated at Winter Lake in January are likely attributable to low sample size (n = 2) skewing results. Residence times at Cochran, the smallest location, tended to be relatively brief throughout both seasons, which might be attributable to a difference in site conditions. Residence times for single site coho tended to be longer in the larger, more complex habitats (Table 11 & 12; Figure 28).

In contrast to single site fish, the juvenile coho that traveled among sites or were detected after translocation to the mainstem, tended to have more variable and shorter residence times, on average. Many of these fish were detected for relatively brief detection events. There appears to be some tendency for these mobile fish to reside longer at Beaver Slough than other locations (Table 15). Most (87%) detection events of mobile fish at Beaver Slough involved fish that had been initially captured in Beaver Slough but translocated to Winter Lake Unit 2 or the mainstem Coquille River.

Residence times for the eight juvenile Chinook salmon tagged in April and May at Seestrom and detected at the antenna array ranged from 2 to 27 days (Avg = 10 ± 6 days).

Passage

Winter Lake Unit 1

We assessed passage at Winter Lake Unit 1 relative to hour of day, velocity, upstream (landward) water level, rate of change in landward water level, tidal bin, and hydraulic head (landward water level – seaward water level). The period for assessment was 1/1/2022 through 5/31/22, bracketing the first and final detections at this location. We tentatively assigned 49 entrance times and 24 exit times to juvenile coho at the Unit 1 tide gate. Thirteen tentative entrance times corresponded to times where the hinge gate was closed, and 11 of those detections occurred when the slide gate was open. Ten tentative exit times corresponded to times where the hinge gate was closed, but 5 of those occurred when the slide gate was open. Tentative entrance and exit times were excluded from the analyses if they occurred greater than 15 minutes before gate opening or after gate closure. The site was considered potentially passable if the hinge gate and/or the slide gate was open. This resulted in assessment of 47 entrance times and 19 exit times for juvenile coho at this location; 96% of tentative entrance times and 79% of tentative exit times occurred when passage was available (gate open).

There were significant differences in the distributions of conditions available and used for entry for hour of day, velocity, rate of change in landward water level, tidal bin, and hydraulic head in 2021-22 (Table 16). Fish appeared to prefer passage during evening and morning hours, and they tended to under-sample the highest rates of change in landward water level and tidal bin 2 (ebb). Instead, they tended to favor the slack periods before and after ebb (tidal bins 3 and 4), and flood (tidal bin 5) (Figure 29). Differences in available conditions for hydraulic head were driven by a preference for positive hydraulic head and under-sampling negative hydraulic head, and the fish appeared to under-sample the highest seaward and landward flow velocities (Fig. 10). There were no significant differences in the distribution of any passage covariates when available conditions were compared to conditions at exit (Table 16). These results may have been influenced by relatively low sample size for evaluating the distributions of potential covariates at exit times (n = 19).

Winter Lake Unit 2

We assessed passage at Winter Lake Unit 2 relative to hour of day, velocity, upstream (landward) water level, rate of change in landward water level, tidal bin, and hydraulic head. The period for assessment was 1/1/2022 through 5/31/22, bracketing the first and final detections at this location. We tentatively assigned nine entrance times and 50 exit times to juvenile coho at the Unit 2 tide gate. Five tentative entrance times corresponded to times where the hinge gate was closed, but 4 of those detections occurred when the slide gate was open. Thirty-two tentative exit times corresponded to times where the hinge gate was closed, but 30 of those occurred when the slide gate was open. Tentative entrance and exit times were excluded from the analyses if they occurred greater than 15 minutes before gate opening or after gate closure. The site was considered potentially passable if the hinge gate and/or the slide gate was open. This resulted in assessment of 8 entrance times and 48 exit times for juvenile coho at this location; 89% of tentative entrance times and 96% of tentative exit times occurred when passage was available (gate open).

We did not compare distributions of available conditions to distributions of conditions used for entrance in 2021-22 in Winter Lake Unit 2 due to low sample size (n = 8). However, there were significant differences in the distributions of conditions available and used for exit for velocity, landward water level, rate of change in landward water level, and hydraulic head in 2021-22 (Table 17). Despite the lack of a significant difference, the distribution of the hours used for exit suggest a preference for evening and morning hours, which was also observed in 2020-21 (Figure 30). Most exit events occurred during the ebb and flood tidal bins (2 and 5; Figure 30). Fish exiting Unit 2 tended to under-sample the highest landward water levels as well as the highest and lowest ends of the distributions of available hydraulic head and velocity (i.e., highest inflow and outflow velocities; Figure 30). The driver of differences in distributions of the rate of change in landward water level was not clear from visual comparison of distributions (Figure 30). Some of the differences in results between 2020-21 and 2021-22 are likely attributable to low sample size in 2020-21 (n = 17) due to low detection efficiencies and outages of the antenna (Appendix A). Furthermore, the low detection efficiencies and outages of the antennas could confound the results but misclassifying entries as exits. Future data will clarify the results.

Winter Lake Unit 3

We assessed passage at Winter Lake Unit 3 relative to hour of day, velocity, upstream (landward) water level, rate of change in landward water level, tidal bin, and hydraulic head. The period for assessment was 1/1/2022 through 5/31/2022, bracketing the first and final detections at this location. We tentatively assigned 68 entrance times and 55 exit times to juvenile coho at the Unit 3 tidegates. Twelve tentative entrance times corresponded to times where the hinge gate was closed, but 11 of those detections occurred when the slide gate was open. Fifteen tentative exit times corresponded to times where the hinge gate was closed, but 12 of those occurred when the slide gate was open. Tentative entrance and exit times were excluded from the analyses if they occurred greater than 15 minutes before gate opening or after gate closure. The site was considered potentially passable if the hinge gate and/or the slide gate was open. This resulted in assessment of 67 entrance times and 52 exit times for juvenile coho at this location; 95% of tentative entrance times and 99% of tentative exit times occurred when passage was available (gate open).

There were significant differences between the distributions of conditions available and used for entry times for hour of day, velocity, landward water level, rate of change in landward water level, tidal bin, and hydraulic head. Distributions of conditions available where significantly different from distributions of conditions used for exit for velocity, landward water level, rate of change in landward water level, and hydraulic head (Table 18).

At Unit 3, fish appeared to favor evening hours for passage, and differences in tidal bin distributions seem to be driven largely by a relative preference for bins 3 and 4 (slack periods before and after ebb) (Figure 31). The fish did not pass the gates at the highest water levels, and they under-sampled slightly positive rates of change in landward water levels. They tended to under-sample negative hydraulic head (landward flow) and oversample near-zero hydraulic head (consistent with passage during slack-water tidal bins), and they oversampled positive velocities (seaward flow) relative to negative velocities (landward flow; Figure 31). In this location, it is notable that seaward flow has appeared to be less turbulent than landward flow.

Cochran

We assessed passage at the Cochran tide gate relative to hour of day, upstream (landward) water level, rate of change in landward water level, tidal bin, and hydraulic head. The period for assessment was 12/1/2021 through 4/30/22, bracketing the first and final detections at this location. Velocity was not available in 2021-22, but velocity is likely related to hydraulic head. We tentatively assigned six entrance times and 164 exit times to juvenile coho at the Cochran tide gate. All tentative entrance and exit times occurred when passage was available (gate open), so no tentative passage times were excluded from the analyses.

Due to low sample size for entrance events (n = 6), we only assessed exit conditions relative to available conditions at Cochran in 2021-22. Results were largely consistent with the previous year (Table 19). There were significant differences between the distributions of conditions available and used for exit for hour of day, landward water level, rate of change in landward water level, and hydraulic head. Fish tended to prefer passage in morning and evening hours and during tidal bins 2 and 5 (ebb and flood). At Cochran, the fish preferred the middle of the distribution of upstream water levels, and they under-sampled the lowest landward water levels, which at this site result in a near complete drain of the landward habitat. They under-sampled the tails of the distribution of available rates of change in landward water levels, favoring slightly positive rates of change. They also tended to prefer the relatively low hydraulic head, which is likely to be consistent with relatively lower velocities (Figure 32).

Seestrom

We assessed passage at the Seestrom tide gate relative to hour of day, upstream (landward) water level, rate of change in landward water level, tidal bin, and hydraulic head. Velocity was not available in 2021-22, but velocity is likely related to hydraulic head. The period for assessment was 12/1/2021 through 5/31/22, bracketing the first and final detections at this location. We tentatively assigned 39 entrance times and 143 exit times to juvenile coho at the Seestrom tide gate. Tentative entrance and exit times were then excluded from the analyses if they occurred greater than 15 minutes before gate opening or after gate closure. This resulted in assessment of 37 entrance times and 129 exit times for juvenile coho at this location; 95% of tentative entrance times and 90% of tentative exit times occurred when passage was available (gate open).

Results at Seestrom were similar to those in the previous year. There were significant differences between the distributions of conditions available and used for entry times for hour of day and hydraulic head. Distributions of conditions available where significantly different from distributions of conditions used for exit for hour of day and landward water level (Table 20). As with most other sites, the hour of day used for passage followed a bimodal distribution favoring morning and evening hours (Figure 33). Fish entering Seestrom appeared to over-sample the higher end of the distribution of hydraulic head, and exiting fish tended to have a distribution of landward water levels that was skewed more toward the higher end of the distribution than available conditions (Figure 33).

Of the eight juvenile Chinook detected exiting the Seestrom location, 6 were detected on the ebb tide (tidal bin 2), one during the slack after ebb (tidal bin 3), and one during the flooding period (tidal bin 5). Seven of these fish were last detected during the morning hours (~3-8am), and one was last detected in the early evening (~5:30pm). Seven of the ten were last detected at hydraulic heads of ~0.03 to 0.06 meters. One juvenile Chinook was last detected at the array at a negative hydraulic head when the gate was closed. Although sample size was low, the juvenile Chinook tagged at the Seestrom location seemed to behave similarly to the coho with respect to gate passage (*cf.* Figure 33).

Beaver Slough

In 2021-22, we did not have data to indicate when the Coaledo gate at Beaver Slough was open or closed, so we have not assessed whether there are statistically significant differences in conditions available for passage and used for passage. Additionally, the PIT antenna arrays are installed ~200' upstream of the tide gate in the active channel; therefore, site conditions at passage are inferred to be similar to when detection occurred at the PIT antenna. Water levels also were available for only a portion of the season (landward ca. 2/17/22 and seaward ca. 3/9/2022), and water level data are relative elevations because the logger cables broke at undetermined times. We tentatively assigned 110 entrance times and 570 exit times to juvenile coho at the Coaledo tide gate, but we were not able to confirm whether these tentative passage times coincided with an open gate.

As with many other locations, juvenile coho tended to pass the gate in a bimodal distribution favoring morning and evening hours over mid-day timing (Figure 34). Passage occurred predominantly during ebb tides (tidal bin 2), though tidal bin classification was available only after early March. Passage also tended to favor low to negative change in landward water level, consistent with passage during seaward flows on ebbing tides (Figure 34). The preference for a negative hydraulic head would be consistent with a preference for landward flow, but calculation of hydraulic head may have been influenced by breakage of the pressure transducer cables.

Table 13. Days at large for coho translocated to the mainstem Coquille River at Myrtle Point and detected at a single location after translocation.

Days at Large	Number of Fish
0-5	30
5-10	21
10-15	17
15-20	15
20-35	11
35-95	10

Table 14. Migration rate for coho translocated to the mainstem Coquille River at Myrtle Point and detected at a single location after translocation.

Mi/Day	Number of Fish
0-2	56
2-4	25
4-6	18
6-8	2
8-10	1
10-12	1
14-16	1
TOTAL	104

Table 15. Time (days) elapsed from first to last detection by event and month for mobile coho, including fish translocated to the mainstem in the 2020-21 sampling season. Month is the start of the detection event (assumed entrance to the off channel habitat location).

	Month	Number of Events	Time to Final Detection, Days	
			Avg ± 95% CI	Range
Winter Lake Unit 1	December	0	NA	NA
	January	24	13 ± 11	0 to 115
	February	23	8 ± 8	0 to 83
	March	1	0	NA
	April	0	NA	NA
	May	1	1.1	NA
Winter Lake Unit 2	December	0	NA	NA
	January	2	0	NA
	February	0	NA	NA
	March	5	1 ± 1	0 to 3
	April	2	<1	0 to 0.5
	May	0	NA	NA
Winter Lake Unit 3	December	0	NA	NA
	January	10	15 ± 12	0 to 57
	February	46	12 ± 5	0 to 62
	March	10	7 ± 8	0 to 36
	April	2	41 ± 0.6	40 to 41
	May	0	NA	NA
Beaver	December	0	NA	NA
	January	16	41 ± 19	0.1 to 121
	February	45	35 ± 9	0 to 105
	March	36	33 ± 8	0 to 72
	April	1	0	NA
	May	6	2 ± 3	0 to 9
Cochran	December	0	NA	NA
	January	2	0	NA
	February	3	16 ± 32	<1 to 49
	March	1	NA	NA
	April	0	NA	NA
	May	0	NA	NA
Seestrom	December	0	NA	NA
	January	17	11 ± 10	0 to 90
	February	15	9 ± 8	0 to 48
	March	4	12 ± 22	0 to 45
	April	1	<1	NA
	May	1	<1	NA

Table 16. Winter Lake Unit 1. Kolmogorov-Smirnov results (K-S D Statistic and p value) comparing the distribution of conditions when passage was available (gates open) to conditions for detections assigned as entry or exit through the tide gate in 2020-21 and 2021-22. Parameters assessed were hour of day, velocity, upstream (landward) water level, rate of change of upstream water level, tidal bin, and hydraulic head (upstream – downstream water level). Detections were included in analyses only if they occurred when gates were open. Number of entrance and exit events are shown in parentheses.

Parameter	2020-21		2021-22	
	Entry	Exit	Entry (n =47)	Exit (n = 19)
Hour of Day	NA	NA	D = 0.2357, p **= 0.0112**	D = 0.1590, p **=** 0.7549
Velocity	NA	NA	D = 0.3898, p **< 0.0001**	D = 0.2390, p **=** 0.2877
US Water Level	NA	NA	D = 0.1951, p **=** 0.0575	D = 0.2382, p **=** 0.2604
Δ US Water Level	NA	NA	D = 0.2564, p **= 0.0043**	D = 0.1738, p **=** 0.6501
Tidal Bin	NA	NA	D = 0.2670, p **= 0.0026**	D = 0.1176, p **=** 0.9650
Hydraulic Head	NA	NA	D = 0.3748, p **< 0.0001**	D = 0.2146, p **=** 0.3803

Table 17. Winter Lake Unit 2. Kolmogorov-Smirnov results (K-S D Statistic and p value) comparing the distribution of conditions when passage was available (gates open) to conditions for detections assigned as entry or exit through the tide gate in 2020-21 and 2021-22. Parameters assessed were hour of day, velocity, upstream (landward) water level, rate of change of upstream water level, tidal bin, and hydraulic head (upstream – downstream water level). Detections were included in analyses only if they occurred when gates were open. Number of entrance and exit events are shown in parentheses.

Parameter	2020-21		2021-22	
	Entry	Exit (n = 17)	Entry	Exit (n = 48)
Hour of Day	NA	D = 0.3505, p **= 0.0345**	NA	D = 0.1274, p = 0.4192
Velocity	NA	D = 0.2900, p **=** 0.1242	NA	D = 0.2059, p **= 0.0377**
US Water Level	NA	D = 0.1823, p **=** 0.6420	NA	D = 0.2701, p **= 0.0019**
Δ US Water Level	NA	D = 0.2083, p **=** 0.4701	NA	D = 0.1982, p **= 0.0467**
Tidal Bin	NA	D = 0.1475, p **=** 0.8648	NA	D = 0.1276, p **=** 0.4176
Hydraulic Head	NA	D = 0.2672, p **=** 0.1886	NA	D = 0.3911, p **< 0.0001**

Table 18. Winter Lake Unit 3. Kolmogorov-Smirnov results (K-S D Statistic and p value) comparing the distribution of conditions when passage was available (gates open) to conditions for detections assigned as entry or exit through the tide gate in 2020-21 and 2021-22. Parameters assessed were hour of day, velocity, upstream (landward) water level, rate of change of upstream water level, tidal bin, and hydraulic head (upstream – downstream water level). Detections were included in analyses only if they occurred when gates were open. Number of entrance and exit events are shown in parentheses.

Parameter	2020-21		2021-22	
	Entry	Exit	Entry (n = 67)	Exit (n = 52)
Hour of Day	NA	NA	D = 0.3898, p **< 0.0001**	D = 0.1556, p **=** 0.1641
Velocity	NA	NA	D = 0.4738, p **< 0.0001**	D = 0.2839, **p = 0.0011**
US Water Level	NA	NA	D = 0.4982, p **< 0.0001**	D = 0.2460, **p = 0.0039**
Δ US Water Level	NA	NA	D = 0.4568, p **< 0.0001**	D = 0.4284, p **< 0.0001**
Tidal Bin	NA	NA	D = 0.2255, p **= 0.0023**	D = 0.1221, p **=** 0.4248
Hydraulic Head	NA	NA	D = 0.6769, p **< 0.0001**	D = 0.4849, p **< 0.0001**

Table 19. Cochran. Kolmogorov-Smirnov results (K-S D Statistic and p value) comparing the distribution of conditions when passage was available (gates open) to conditions for detections assigned as entry or exit through the tide gate in 2020-21 and 2021-22. Parameters assessed were hour of day, upstream (landward) water level, rate of change of upstream water level, tidal bin, and hydraulic head (upstream – downstream water level). Detections were included in analyses only if they occurred when gates were open. Velocity was not measured at Cochran. Number of entrance and exit events are shown in parentheses.

Parameter	2020-21		2021-22	
	Entry	Exit (n = 120)	Entry	Exit (n = 164)
Hour of Day	NA	D = 0.2647, p **< 0.0001**	NA	D = 0.1176, p **= 0.0227**
Velocity	NA	NA	NA	NA
US Water Level	NA	D = 0.3177, p **< 0.0001**	NA	D = 0.2235, p **< 0.0001**
Δ US Water Level	NA	D = 0.2422, p **< 0.0001**	NA	D = 0.1669, p = **0.0002**
Tidal Bin	NA	D = 0.2128, p **< 0.0001**	NA	D = 0.9082, p = 0.1380
Hydraulic Head	NA	D = 0.2472, p **< 0.0001**	NA	D = 0.4341, p **< 0.0001**

Table 20. Seestrom. Kolmogorov-Smirnov results (K-S D Statistic and p value) comparing the distribution of conditions when passage was available (gates open) to conditions for detections assigned as entry or exit through the tide gate in 2020-21 and 2021-22. Parameters assessed were hour of day, velocity, upstream (landward) water level, rate of change of upstream water level, tidal bin, and hydraulic head (upstream – downstream water level). Detections were included in analyses only if they occurred when gates were open. Velocity was not measured at Seestrom in 2021-22. Number of entrance and exit events are shown in parentheses.

Parameter	2020-21		2021-22	
	Entry	Exit (n = 214)	Entry (n = 37)	Exit (n = 129)
Hour of Day	NA	D = 0.3322, p **< 0.0001**	D = 0.2600, p = **0.0156**	D = 0.3239, p **< 0.0001**
Velocity	NA	D = 0.0894, p = 0.1045	NA	NA
US Water Level	NA	D = 0.1034, p = **0.0230**	D = 0.1544, p = 0.3592	D = 0.1434, p = **0.0106**
Δ US Water Level	NA	D = 0.0635, p = 0.3683	D = 0.1326, p = 0.5531	D = 0.1056, p = 0.1162
Tidal Bin	NA	D = 0.0927, p = 0.0549	D = 0.0303, p = 1.0000	D = 0.0954, p = 0.1952
Hydraulic Head	NA	D = 0.2300, p **< 0.0001**	D = 0.2558, p = **0.0183**	D = 0.0994, p = 0.1607

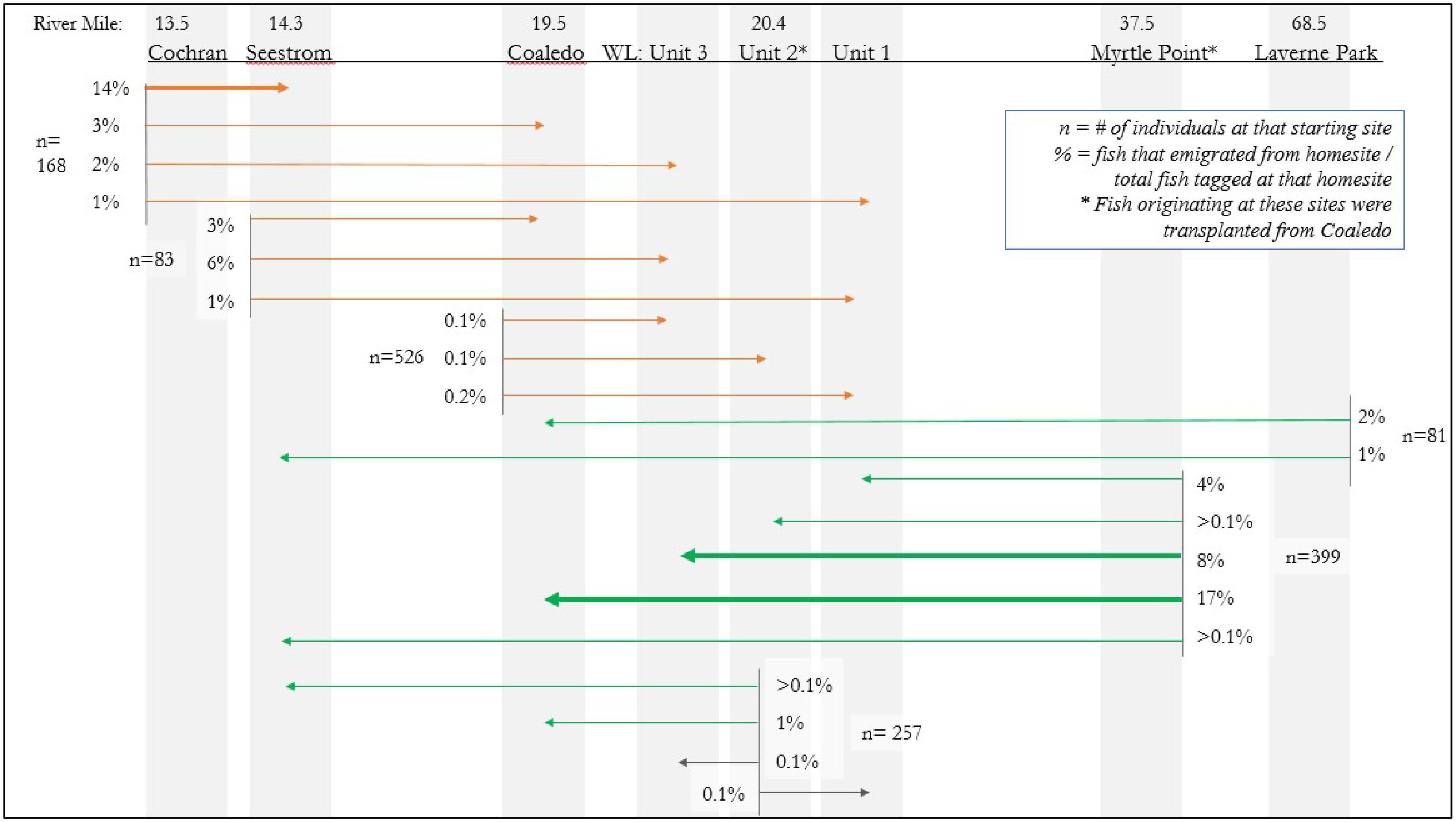

Figure 27. Coho movement depicted throughout the Coquille Estuary. There was significant migration from site to site by tagged coho throughout all project sites.

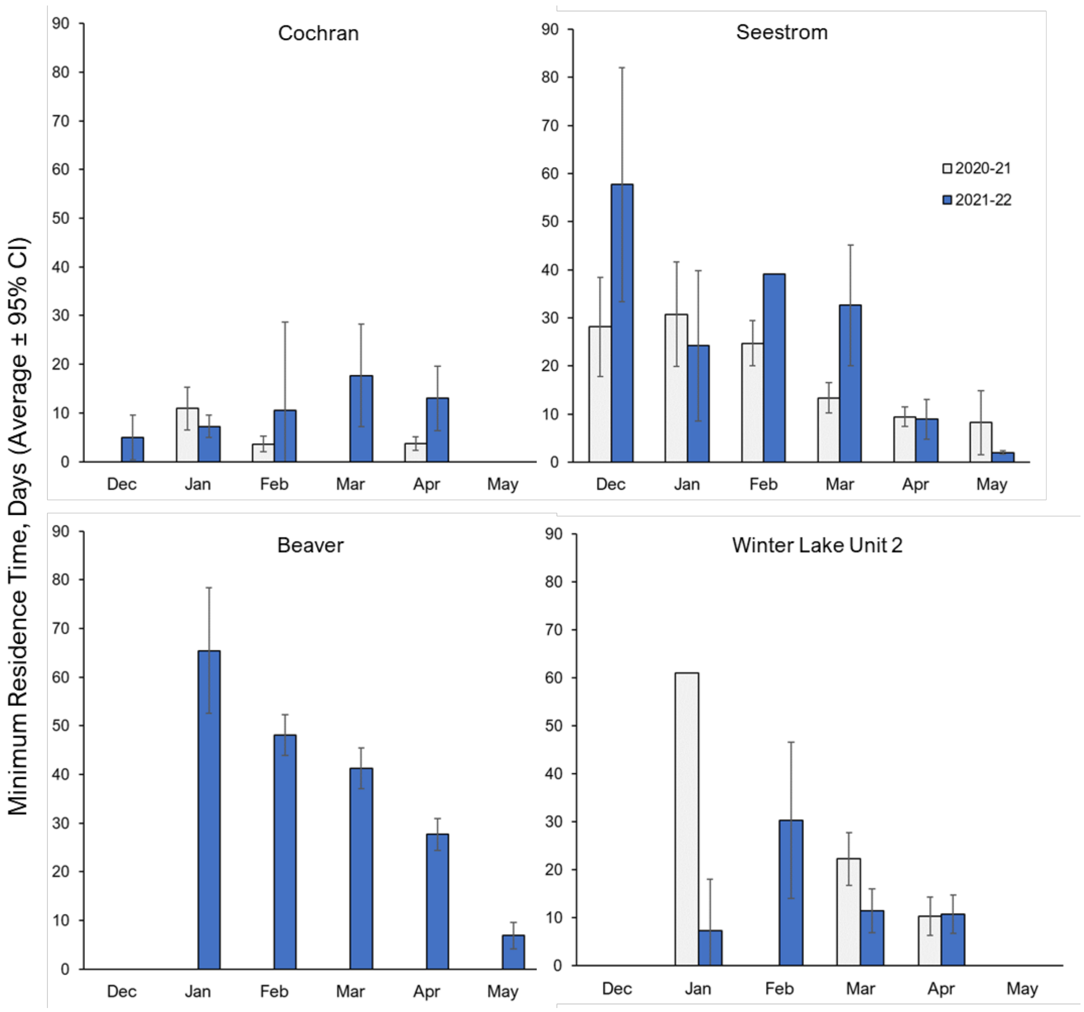

Figure 28. Minimum residence time (days from tagging until final detection at tide gate arrays), Average ±95% Confidence Intervals in 2020-21 (gray bars; Cochran, Seestrom, Winter Lake Unit 2) and 2021-22 (blue bars; Cochran, Seestrom, Beaver, Winter Lake Unit 2). The antenna array at Beaver Slough was first operated during the 2021-22 season. Months indicate month of initial capture and tagging.

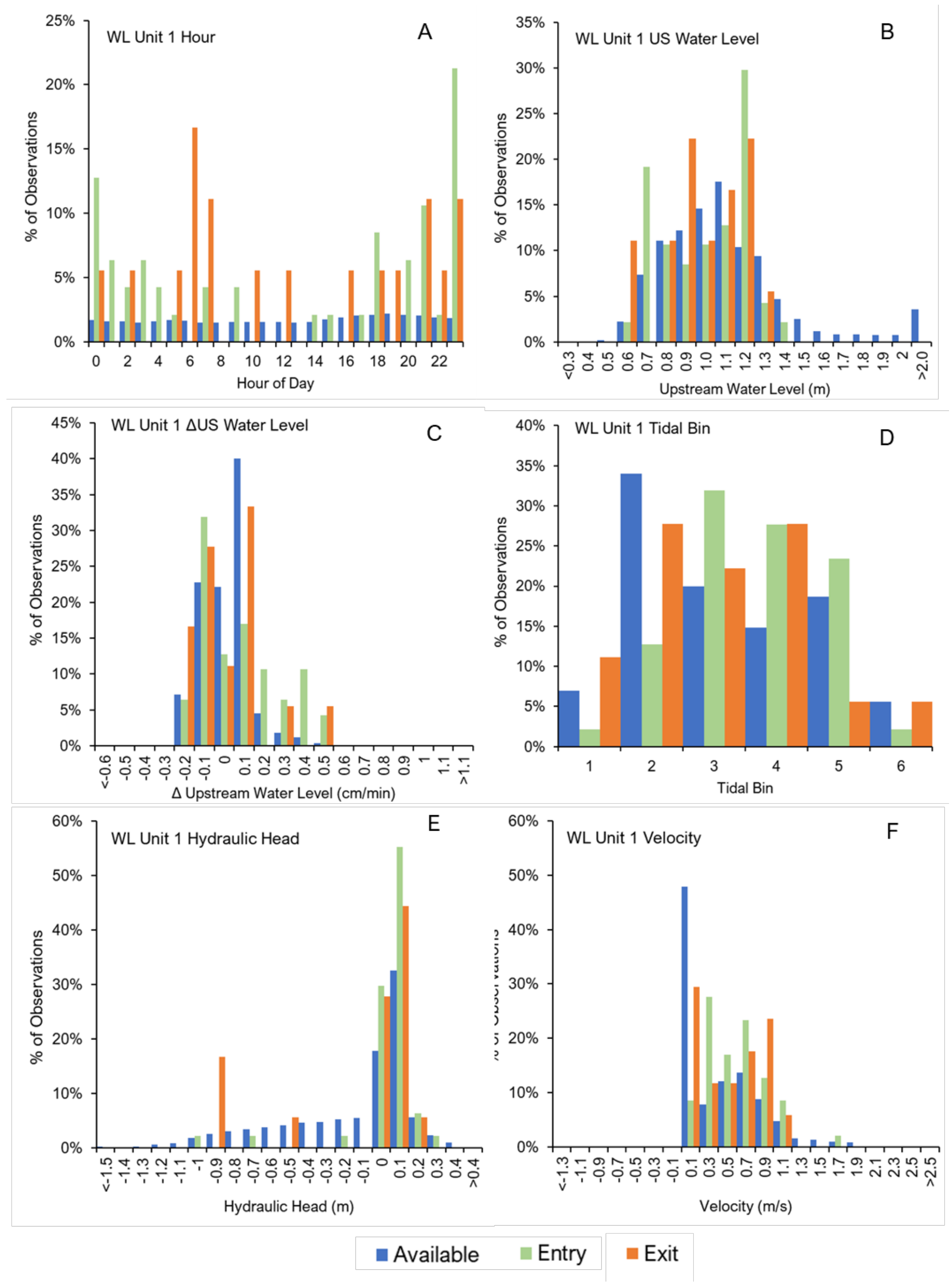

Figure 29. Winter Lake Unit 1. Frequency distributions for available (gates open, blue) and used for entry (green) and exit (orange) for hour of day (panel A), upstream (landward) water level (panel B), rate of change of upstream (landward) water level (Panel C), tidal bin (Panel D), hydraulic head (US-DS Water Level, Panel E), and velocity (Panel F). Tidal bins are 1 (Slack after Flood), 2 (Ebb), 3 (Slack before Ebb), 4 (Slack after Ebb), 5 (Flood), and 6 (Slack before Flood).

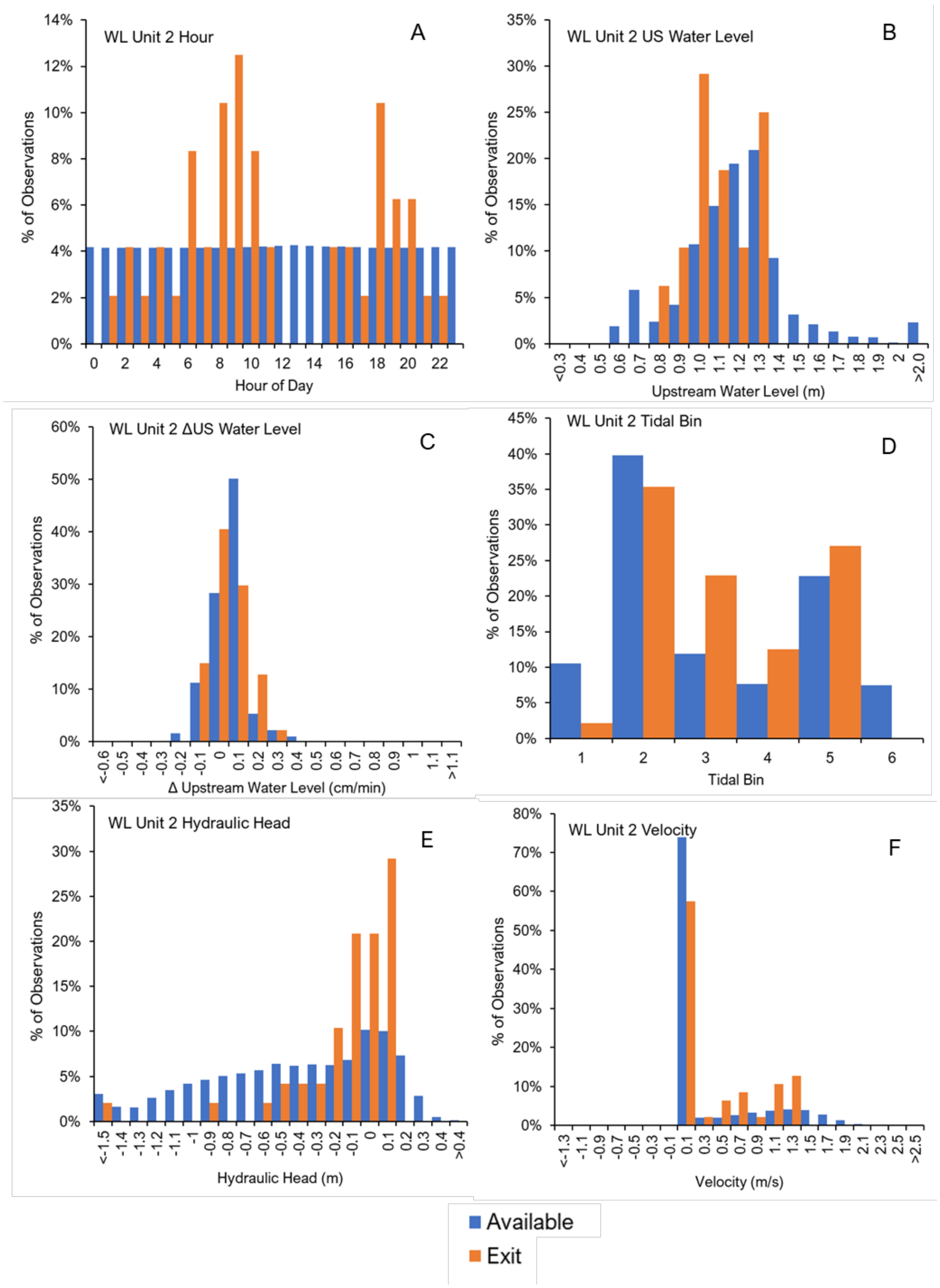

Figure 30. Winter Lake Unit 2. Frequency distributions for available (gates open, blue) and used for entry (green) and exit (orange) for hour of day (panel A), upstream (landward) water level (panel B), rate of change of upstream (landward) water level (Panel C)

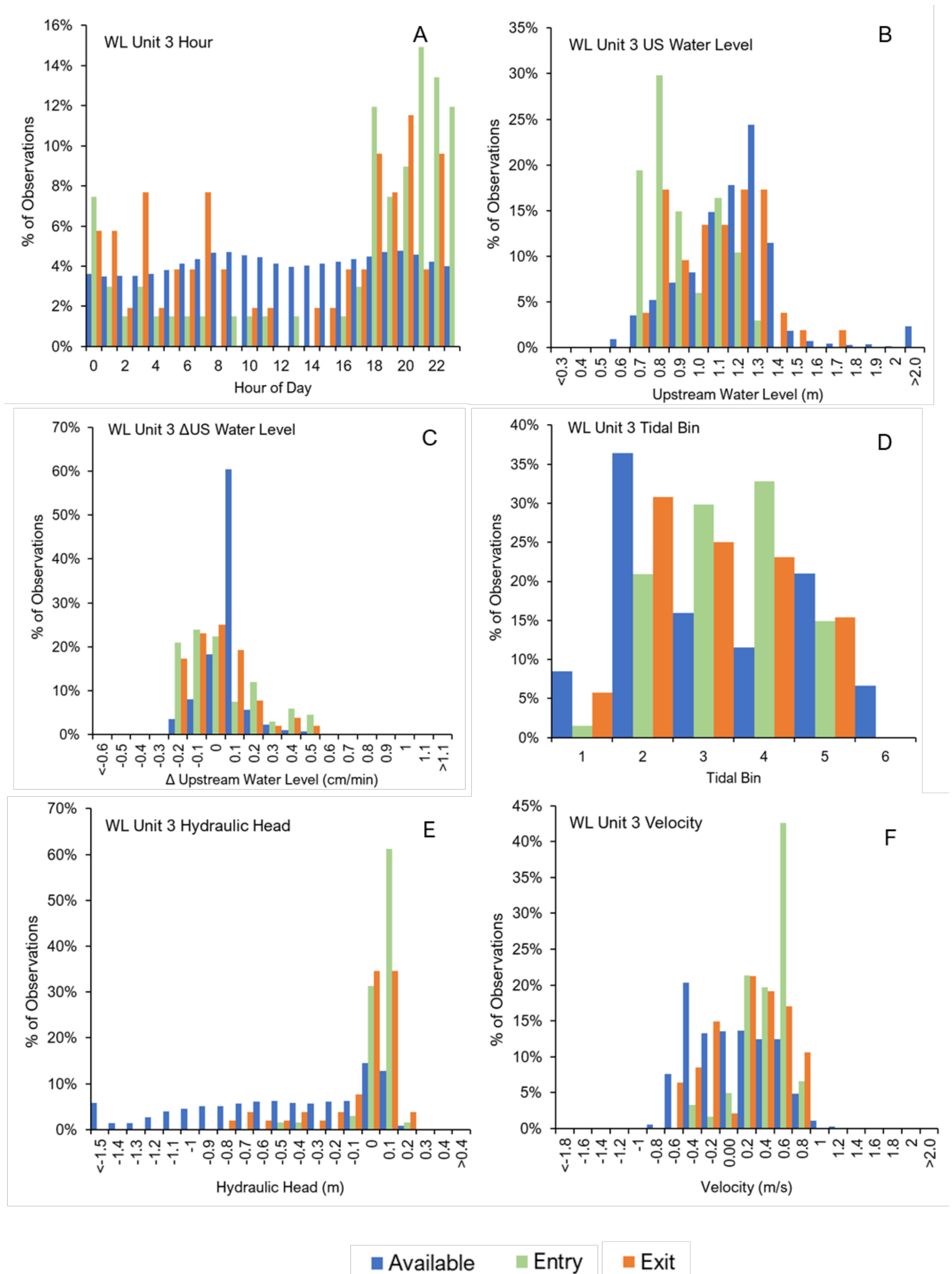

Figure 31. Winter Lake Unit 3. Frequency distributions for available (gates open, blue) and used for entry (green) and exit (orange) for hour of day (panel A), upstream (landward) water level (panel B), rate of change of upstream (landward water level (Panel C), tidal bin (Panel D), hydraulic head (US-DS Water Level, Panel E), and velocity (Panel F). Tidal bins are 1 (Slack after Flood), 2 (Ebb), 3 (Slack before Ebb), 4 (Slack after Ebb), 5 (Flood), and 6 (Slack before Flood).

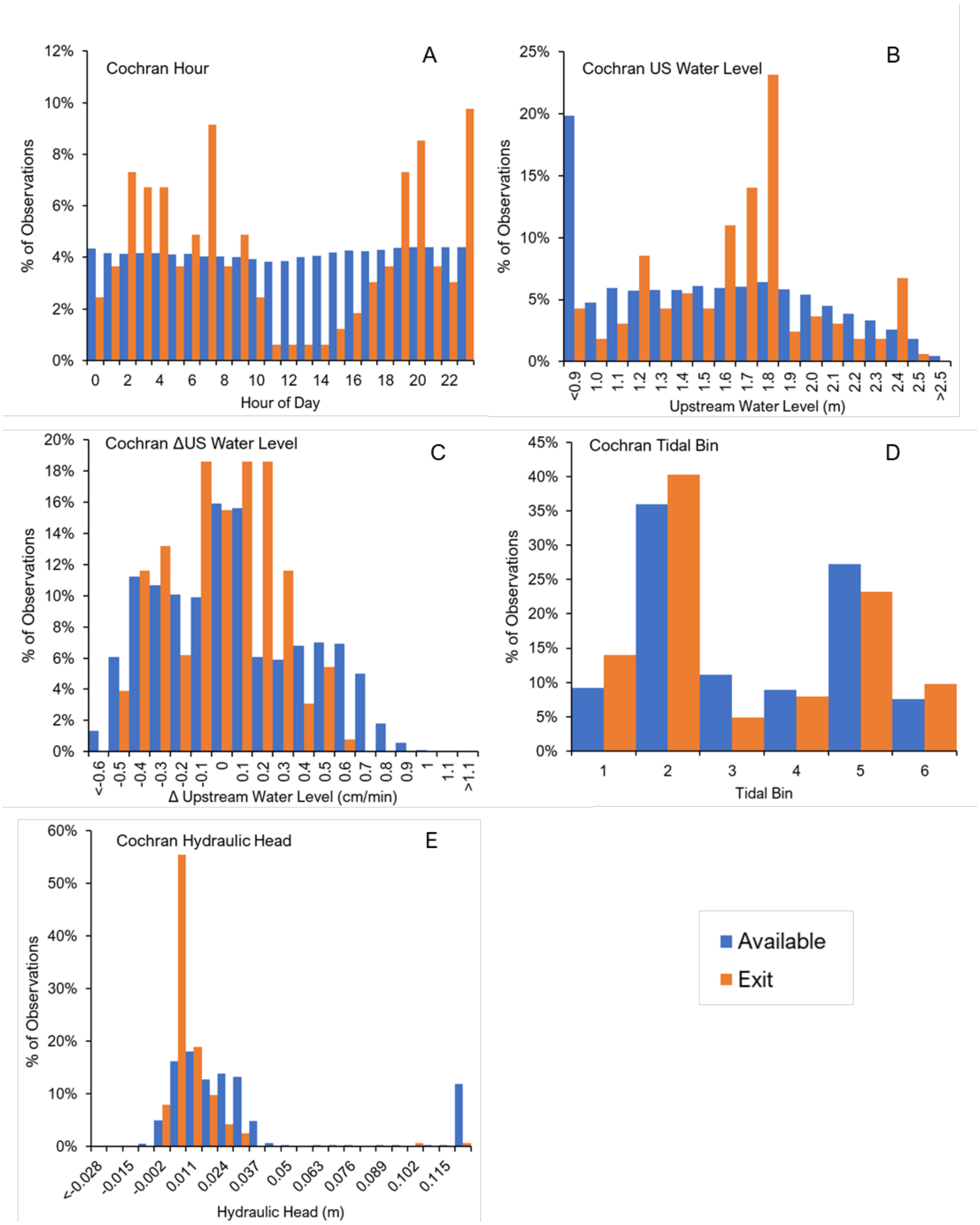

Figure 32. Cochran. Frequency distributions for available (gates open, blue) and used for entry (green) and exit (orange) for hour of day (panel A), upstream (landward) water level (panel B), rate of change of upstream (landward) water level (Panel C), tidal bin (Panel D), and hydraulic head (US-DS Water Level, Panel E). Tidal bins are 1 (Slack after Flood), 2 (Ebb), 3 (Slack before Ebb), 4 (Slack after Ebb), 5 (Flood), and 6 (Slack before Flood).

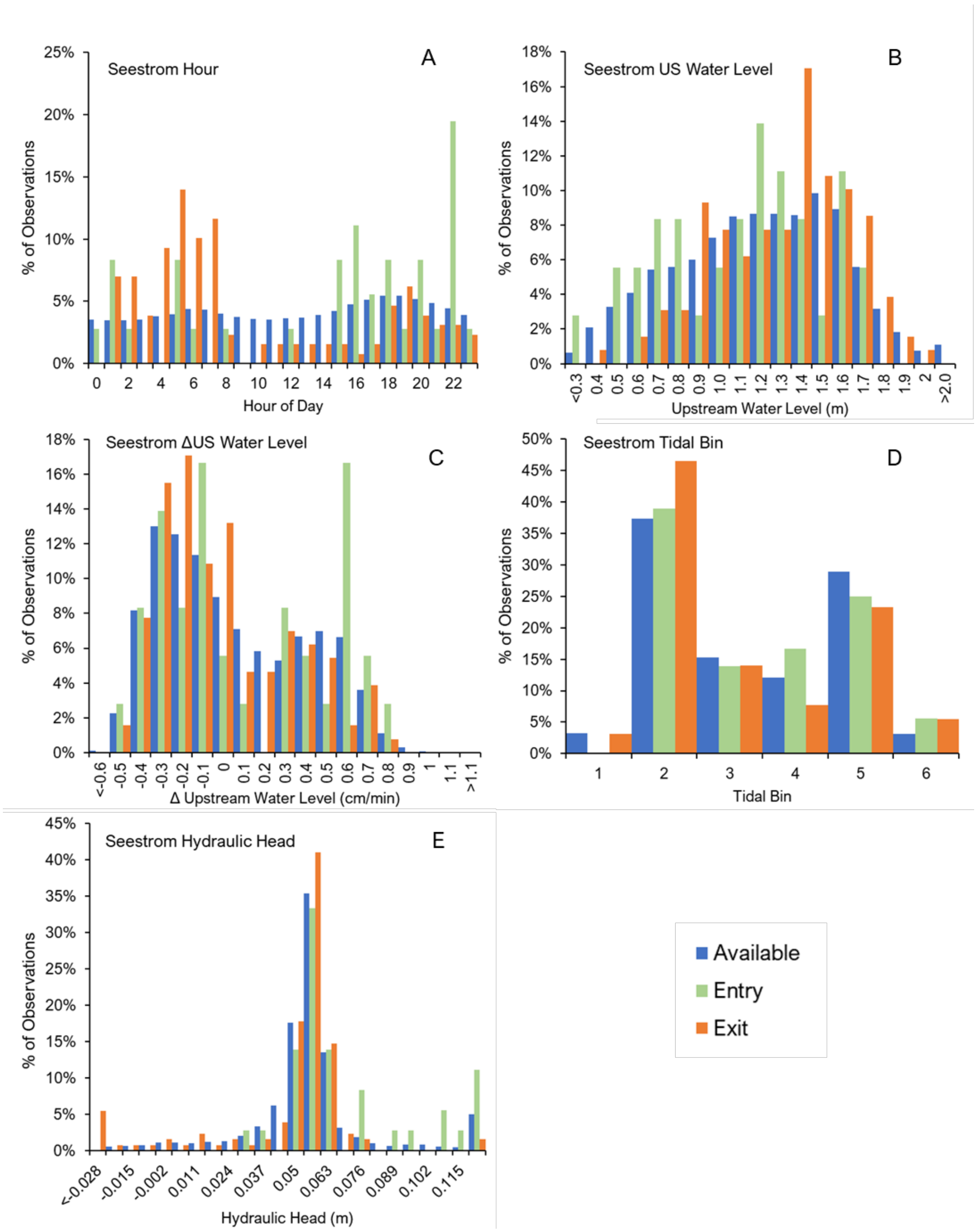

Figure 33. Seestrom. Frequency distributions for available (gates open, blue) and used for entry (green) and exit (orange) for hour of day (panel A), upstream (landward) water level (panel B), rate of change of upstream (landward) water level (Panel C), tidal bin (Panel D), hydraulic head (US-DS Water Level, Panel E), and velocity (Panel F). Tidal bins are 1 (Slack after Flood), 2 (Ebb), 3 (Slack before Ebb), 4 (Slack after Ebb), 5 (Flood), and 6 (Slack before Flood).

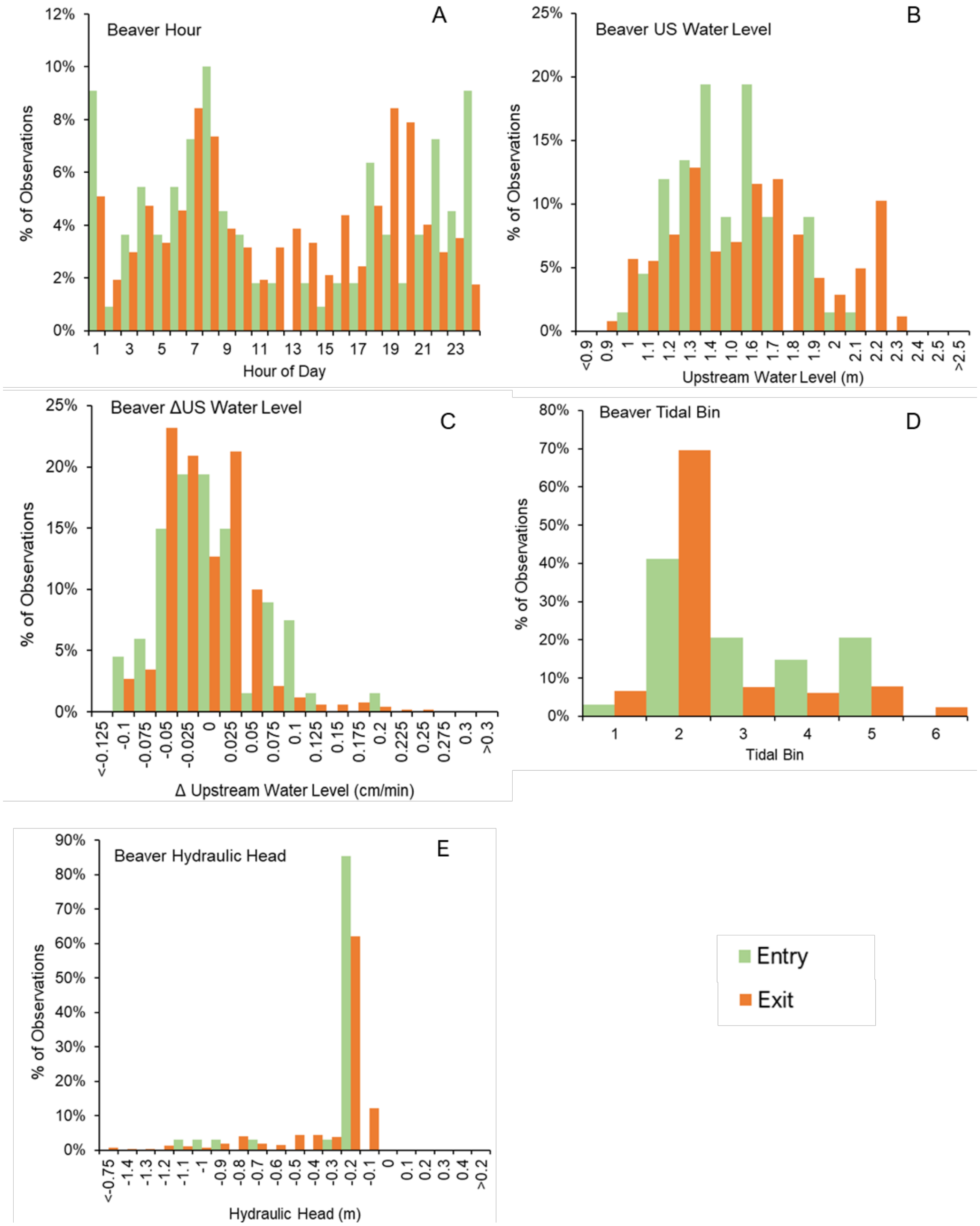

Figure 34. Beaver Slough. Frequency distributions for conditions during entry (green) and exit (orange) for hour of day (panel A), upstream (landward) water level (panel B), rate of change of upstream (landward) water level (Panel C), tidal bin (Panel D), and hydraulic head (US-DS Water Level, Panel E). Tidal bins are 1 (Slack after Flood), 2 (Ebb), 3 (Slack before Ebb), 4 (Slack after Ebb), 5 (Flood), and 6 (Slack before Flood).

8. Discussion

A. Condition

Is overall body condition of juvenile coho reared in the tide gate project areas greater than riverine-reared coho?

In the 2020-21 sampling season, we were able to compare length, weight, and condition factor between off-channel locations and the mainstem river near the end of the winter rearing period. In that assessment, juvenile coho salmon captured at Winter Lake Unit 2 were significantly longer, heavier, and more robust in body condition than juvenile coho captured in the mainstem Coquille River. Juvenile coho salmon captured at Beaver Slough also approached the end of winter rearing longer and heavier than those captured in the mainstem, but condition factors were similar. Juvenile coho captured late in the season at the Cochran and Seestrom locations were similar in length, weight, and condition to fish captured in April in the mainstem (Table 4-6; Figure 19- 21). High weights relative to length at Winter Lake Unit 2 can also be seen in weight-length relationships from the 2020-21 season (Figure 25).

In the 2021-22 sampling season, this question could not be further addressed because no juvenile coho salmon were captured in the mainstem, except for fish captured and tagged at Laverne Park early in the season (September & October). However, there were similarities in the results for the sites with available data (Winter Lake Unit 2, Seestrom, Cochran, Beaver Slough) (cf. Figure 19 - 24).

The mean lengths of juvenile coho captured in April at Beaver Slough (2020-21 = 131.8 ± 1.7 mm; 2021-22 = 141.7 ± 2.2 mm) and Winter Lake Unit 2 (2020-21 = 136.5 ± 5.6 mm; 2021-22 = 132 mm[8]) are similar to those observed for out-migrating coho salmon at the Mill Creek life cycle monitoring site in the Yaquina basin (Avg. = 130.7 mm from 1997 through 2014). This site tends to have larger out-migrants and often-higher marine survival rates relative to other life cycle monitoring sites within the Oregon Coast Coho ESU (Suring et al. 2015). April lengths at Seestrom during the 2021-22 season were also relatively large (137.9 ± 5.5mm; Table 4).

The similarities in length, weight, and condition among the two smaller off-channel locations (Cochran and Seestrom) and the mainstem Coquille River may reflect greater exchange of fish in these locations with the mainstem (i.e., shorter residence times and higher mobility for juvenile coho using the smaller off-channel locations). However, it is notable that fish at Seestrom in 2021-22 were substantially longer and heavier by the end of season than in 2020-21 (Table 4 - 6). Higher weights and condition in Winter Lake Unit 2 may be attributable to differences in resource availability and/or fish densities between these locations.

In both sampling seasons, comparisons of condition-related metrics has been limited due to differential capture success among locations. Continued adaptive adjustments to sampling approaches and the aggregation with data collected in future sampling years should continue to improve our ability to discriminate the size and condition of juvenile coho salmon in the various off-channel and mainstem locations. However, the analytical approach currently applied also may be overly conservative. The Bonferroni adjustment we applied to post-hoc pairwise comparisons can

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[8] Only one juvenile coho was captured in Winter Lake Unit 2 in April during the 2021-22 season.

substantially inflate Type II error rates, and the decision to apply the adjustment is neither straightforward nor routinely applied in a consistent manner (Cabin & Mitchell 2000). As additional data are collected, the decision to apply this adjustment may be reconsidered.

B. Growth

Are growth rates of juvenile coho reared in tide gate project areas greater than riverine-reared coho? Does overall size of restored habitat affect growth rate?

In both sampling seasons, we have not recaptured any of the juvenile coho salmon tagged in the mainstem, and there have not been multiple successful capture events in the mainstem. Therefore, we have not been able to determine growth rates from recaptures or infer growth rates for juvenile coho salmon in the mainstem Coquille River. However, the larger sizes near the end of the winter rearing period at some of the off-channel locations suggest that juvenile coho rearing in these areas likely grow at faster rates assuming the fish enter the monitoring period (late December) at similar sizes.

There were no statistically significant differences in growth rates (length or weight) among off-channel locations in either 2020-21 or 2021-22 when growth was inferred from successive capture events. Continued adaptation of capture effort/methods and continued data collection will help to identify the differences in growth rates among sites that seem apparent in the differential progression of lengths and weights through the winter period (Figure 19 and Figure 24).

C. Survival

Does survival increase for juvenile coho residing in tide gate projects compared to riverine-reared coho? Does survival vary with overall size of restored habitat?

As with growth (above), we intended to approach these questions using mark-recapture methods that were precluded by low recaptures. Survival from tagging to final detection at the Seestrom and Cochran tide gates appears to be relatively high given that overall >80% of tagged individuals in both the 2020-21 and 2021-22 seasons were subsequently detected at the tide gates after some time at large (Table 11 & 12; Figure 26). Similarly, almost 90% of juvenile coho tagged at Beaver Slough were subsequently detected at the Beaver Slough PIT array in 2021-22, the first year of operation at that location (Table 12; Figure 26). Lower proportions of tagged fish detected at the tide gates in Winter Lake Unit 2 in both sampling seasons (Table 11 & 12; Figure 26) may be attributable to lower rates of survival, lower detection efficiency, or both. Survival to final detection will be further resolved as we determined detection efficiencies for each tide gate antenna array. Estimates of detection efficiency will allow us to account for apparent losses (losses attributable to a failure to detect, not realized losses due to mortality) in estimates of survival. We are continuing to develop a rule set to formalize the discrimination of fish-passage events from fish-detection events (e.g., Connolly et al. 2008).

D. Abundance/Density

Are rearing densities dependent on overall size of restored habitat behind an upgraded tide gate?

We intended to address questions of abundance and rearing densities using abundances estimated through mark-recapture approaches. Limited recaptures so far have precluded this approach. We will continue to pursue these methods as adaptation of capture effort and methods increases the number of fish tagged and recaptured.

What are the general densities of juvenile coho during winter/spring months upstream of the various tide gate structures within the project area with differing designs and operation plans (Water Management Plans)?

We are currently exploring methods for juvenile coho abundance estimates that fully utilize fish capture and resight data and reduce violations of assumptions. With additional data, results will be more robust in accuracy and precision. We plan to report on these monitoring questions in the next reporting iteration.

E. Movement & Passage

What is the residence time of juvenile coho in floodplain habitats upstream of a fully redesigned and technologically advanced tide gate? Does residence time vary with overall size of restored habitat?

Residence times determined through this work are residence times from tagging to final detection at tide gate PIT antenna arrays for fish detected only at their tagging location (single site coho) or event residence times from first detection to last detection for fish detected at multiple locations. These are not comprehensive residence times because we do not know how long the fish resided at the tagging location prior to tagging. These estimates may be considered as minimum residence times that are specific to the time of tagging.

Despite these limitations, our current estimates of residence time do provide for comparisons among locations if they are compared at similar points during the winter rearing period. There appears to be a general trend of longer post-detection rearing earlier in the season progressing to shorter residence times later in the period, except for at the smallest site (Cochran) where residence times are typically relatively brief (Table 11 & 12; Figure 28). In 2020-21, post-tagging residence seemed to be longer in the largest habitat (Winter Lake Unit 2) and shorter in the smallest habitat (Cochran) (Table 12; Figure 28). Results in 2021-22 also depicted longer residence times in larger, more complex off channel locations, but low captures in some months led to high uncertainty in estimates in some months at some locations (e.g., Winter Lake Unit 2 (Figure 28).

In the 2021-22 season, we were also able to evaluate residence times of mobile or translocated coho from entrance to exit of a location. Many of these fish were detected for relatively brief periods, particularly at some sites (e.g., Winter Lake Unit 2), but it is notable that residence times tended to be longer at Beaver Slough (Table 13). There appears to be a propensity for mobile and translocated fish to favor the larger, more complex locations (i.e., Winter Lake Units & Beaver Slough). Recapture histories of translocated fish suggest homing of Beaver Slough fish back to that rearing location, but it is not yet clear whether the tendency to return to Beaver Slough reflects a fidelity to that site or simply attraction to favorable off channel conditions.

What percentage of juvenile coho residing in the Coquille Estuary enter the restored project areas?

We did not capture juvenile coho in the mainstem Coquille River until late in the season in 2020-21, and no juvenile coho were captured in the mainstem in 2021-22 except for early-season tagging at Laverne Park. We will continue to explore this question as we learn more about the proportion of juvenile coho in the mainstem that use restored project areas for winter rearing habitat. However, it is notable that in the 2021-22 sampling season, 3 of 81 fish (4 %) tagged at Laverne Park (~49 miles upstream from Winter Lake) early in the season were subsequently detected at the Coaledo and Winter Lake Unit 1 PIT arrays later in the season. One hundred and four of 399 fish (26%) tagged at Beaver Slough and subsequently relocated to the mainstem approximately 17 river miles upstream from Winter Lake were subsequently detected at tide gate PIT arrays at Seestrom, Coaledo, and Winter Lake Units 1, 2 and 3).

Do juvenile coho enter more than one wetland restoration area during the winter and spring downstream movements prior to entering the ocean?

Of the 970 coho that were detected at least once after tagging, 230 coho (24%) were detected at multiple sites throughout the winter and spring, indicating they are highly mobile in the Coquille Estuary. This cohort of multi-site coho demonstrate the need for an estuary wide restoration approach and that a single large restoration project would not solely fill the need of off-channel estuary habitat in the winter and spring.

What are the water level and tide gate door operation preferences of juvenile coho for movement through tidegates?

Despite some differences among locations, in general the tagged juvenile coho in this study tend to prefer passage at morning and evening hours relative to mid-day and ebbing tidal flow or slack on, before or after ebbing flow, and this is reflected in a tendency to pass the gates at positive hydraulic heads (higher landward than seaward water levels). Where velocity data are available, the fish also seem to select for intermediate velocities, avoiding the tails of velocity distributions (highest seaward and/or landward flows). Although data during 2021-22 on juvenile Chinook are limited to low numbers at the Seestrom location, there were not striking differences relative to our observations for juvenile coho. We are continuing to evaluate potential velocity thresholds and use of covariates like hydraulic head as surrogates for velocity when and where we lack velocity data. We also plan to continue to evaluate the interplay of the hinge gates and slide gates at the Winter Lake complex, where there were detections classified as entries or exits when hinge gates were closed but slide gates were open.

9. Conclusion

The Lower Coquille Monitoring program has shown that the three tide gate upgrade and habitat restoration projects are highly used by juvenile coho salmon during the winter and spring rearing period of both sampling seasons. In concurrence with the 2020-2021 sampling season, the Winter Lake project sees the longest residence time of juvenile coho while simultaneously producing coho that are in similarly robust condition to the highly active and successful off-channel habitat of the reference site, Beaver Slough. In the 2021-2022 the coho captured at the Seestrom site were also larger. This more robust condition could improve marine survival, as coho in similar condition at the Mill Creek life cycle monitoring site tend to have greater marine survival than other sites within the Oregon Coast coho ESU (Suring *et al.* 2015). The 2021-2022 sampling season showed extensive us of multiple sites by tagged coho. This indicates that multiple off-channel habitats are needed throughout the estuary to satisfy the over-winter rearing needs of coho in the Coquille Watershed. More knowledge is being amassed about the site condition preferences of coho during tide gate passage events. At most sites passage is preferred during morning and evening hours along with ebbing tidal flow or slack on, before or after ebbing flow. Additional knowledge will be gathered from the accumulation of data over the next two years such as population estimates at project sites, added clarity of patterns of important passage parameters during in and out-migration and comparisons of body condition metrics and growth rates.

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11. Appendices

A. PIT Antenna Operation

Table 21. Table of PIT antenna operation dates for the 2021-2022 field season.

Winter Lake								Seestrom		Cochran		Coaledo	
Unit 1		Unit 2[1]				Unit 3							
Gate 1A pass thru	Gate 1AB Sail	Gate 2B pass thru[2]	Gate 2B pass thru	Gate 2C pass Thru	Gate 2C pass thru[3]	Gate 3A sail	Gate 3A pass thru	Antenna 1	Antenna 2	Antenna 1	Antenna 2	Antenna 1	Antenna 2
12/1-12/12	12/1-12/12	12/1-12/12	12/1-12/12	12/1-12/12	12/1-12/12	12/1-12/12	1/28-6/18	12/1-6/18	12/1-6/18	12/1-6/18	12/1-6/18	12/1-6/18	12/1-6/18
12/22-6/18		12/22-2/17	12/22-2/11	12/22-1/18	12/22-2/11	1/28-6/18							
		3/4-4/11	2/17-6/18	1/20-6/18	2/17-6/18								
		4/17-5/10											
		5/16-6/18											

1 - All Winter Lake Unit 2 antennas had extermly poor detection efficiency from an undertermined time early in the season until 3/14 when the antennas were replaced.

2 - The sail antennas became non-functional and the second pass thru antenna of Gate 2B was used for the 2021-2022 season

3 - The sail antennas became non-functional and the second pass thru antenna of Gate 2C was used for the 2021-2022 season

B. Tidal Bin

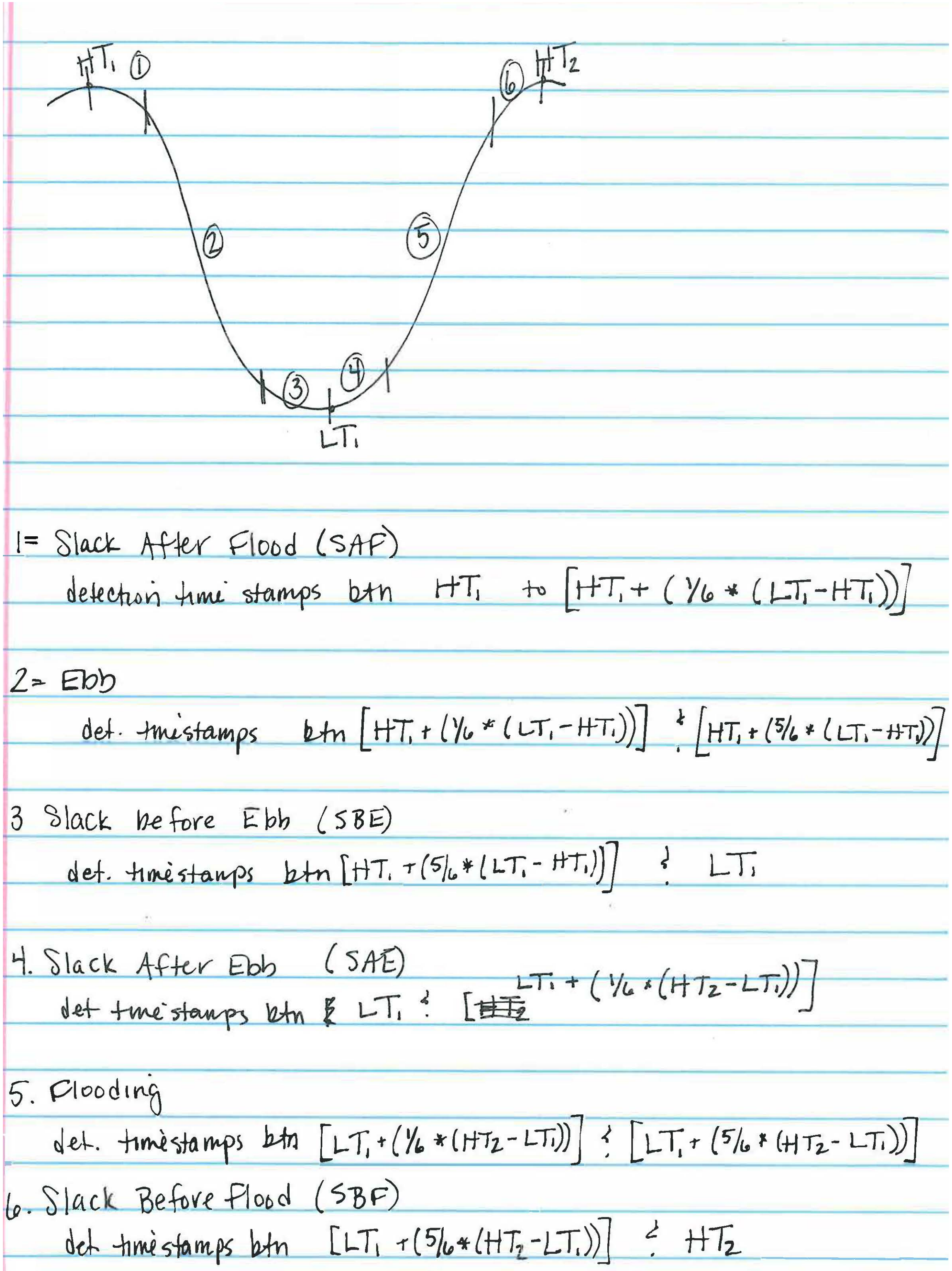

Figure 35. A schematic of how tidal bins were calculated for the Lower Coquille Monitoring project.