Coho Life History in Tide Gated Lowland Coastal Streams 2016-2018

OWEB Grant 231-2031 Project Completion Report

Submitted by

Coos Watershed Association

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Project Summary

Coos Watershed Association's (CoosWA) coho life history in tide gated lowland coastal streams, a life cycle monitoring (LCM) project, examines the ecology of tidal rearing for coho in the Coos River Basin. This project has adapted to and advanced the recent paradigm shift in juvenile coho life histories, rearing and foraging strategies, growth, survival, migrations, and sub-basin level population productivity in the tidal zone. Temporal and spatial components of coho over-winter rearing strategies, in relation to habitat use and project effectiveness monitoring, is the monitoring focus in the paired study streams of Palouse and Willanch Creeks. Project results further reveal the fundamental mechanisms that promote juvenile coho growth and survival in the estuarine ecotone. In conjunction with prior and current data, results highlight the critical importance of these diverse habitats for recovering viable and resilient Oregon Coast coho populations.

Background

Historically, stream restoration efforts have focused on upper stream reaches of salmon bearing streams where both spawning and rearing coho were assumed to predominately reside. Awareness of tidal zone rearing by juvenile coho dates back to the 1980's (Hartman et al. 1982) and is now considered ubiquitous for coho populations in lowland tidally influenced streams (Koski 2009). This paradigm shift has raised new questions and challenges due to the temporal and spatial dynamics of the tidal zone. Recent results from this project and others along the Oregon Coast and across the west coast of North America have found that juvenile coho demonstrate patterns of freshwater and estuarine movements and migrations that promote growth through early ontogeny and smoltification and survival in both the freshwater and marine environments. Utilizing nutrient rich marine forage and complex off-channel refuge in tidal slough habitats may be a critical life history strategy that has been reduced through anthropomorphic channelization, simplification and obstructions. Dikes, levees and tide gates were constructed to create agricultural pasture from marsh platform habitats and isolate them from the tidal and salt water influence. The built environment of the tidal zone is very old, in a late stage of senescence and will require considerable maintenance in the near future. The convergence of these problems presents a considerable threat to road infrastructure in particular however, these shared problems present an opportunity to find solutions that benefit salmon, landowners, and the general public. Dikes levees, culverts and tide gates in the tidal zone are heavily impacted by the interaction of seasonally high flows and mixed semidiurnal tides with the underlying sandstone geology. This networked built environment inhibits brackish water from flooding pastures by design, but likewise blocks or provides only limited migratory passage and access to off channel rearing habitat for anadromous and other migratory fish. Quantifying the spatial and temporal patterns of coho tidal rearing and the relative resiliency and productivity of this life history strategy will inform restoration priorities and practices in the challenging tidal environment. Habitat connectivity is fundamentally essential for coho salmon particularly in the estuarine and freshwater juvenile life stages. Opportunities to restore fish passage and off channel tidal rearing habitats in ways that also promote pasture quality exist, but have been elusive. There is however, a growing shared awareness and understanding that these collectively beneficial solutions are the most sustainable and productive options for restoring ecological, economic and social function in lowland tidal environments.

Fish movements and migrations through passage structures are perplexing issues that have largely been treated as a hydrologic engineering issue based on a limited number of controlled studies of swimming performance (Silva et al 2017). This project has previously shown greater (downstream) migratory windows were available for salmon at a side door tide gate in relation to a classic top door design gate (Bass 2010). Newer side door muted tide regulator (MTR) tide gate designs provide even greater fish passage windows. However, there is great uncertainty surrounding salmon behaviors around tide gates in relation to tidal stages and concurrent environmental conditions. Results of this grant will provides innovative data to compare and contrast salmon movements around MTR tide gates with previous project results from top and side door tide gates (Bass 2010).

Study Area.

Palouse and Willanch Creeks are two, third order, lowland (estuary confluence) streams in the upper regions of the estuary in Coos Bay, Oregon (Figure 1). Each stream is tide gated at its confluence with the Coos Bay estuary through levees that support public roadways. Palouse Creek is controlled by two wooden top-hinged tide gates and Willanch Creek has two aluminum gates, one side-hinged Muted Tide Regulator gate and one top hinged unregulated door. Palouse Creek is 14.6 km long, drains a watershed area of 28 km2, and has a natural upstream barrier to coho at river kilometer (RKm) 12.1. Willanch Creek is 9.7 km in length, drains a watershed area of 22 km2, and has no identified barrier to anadromous fish passage. For both study streams, stream flow averages less than 0.1m3/s during late summer and up to ≥19 m3/s during winter bankfull stream flow events (CoosWA 2006).

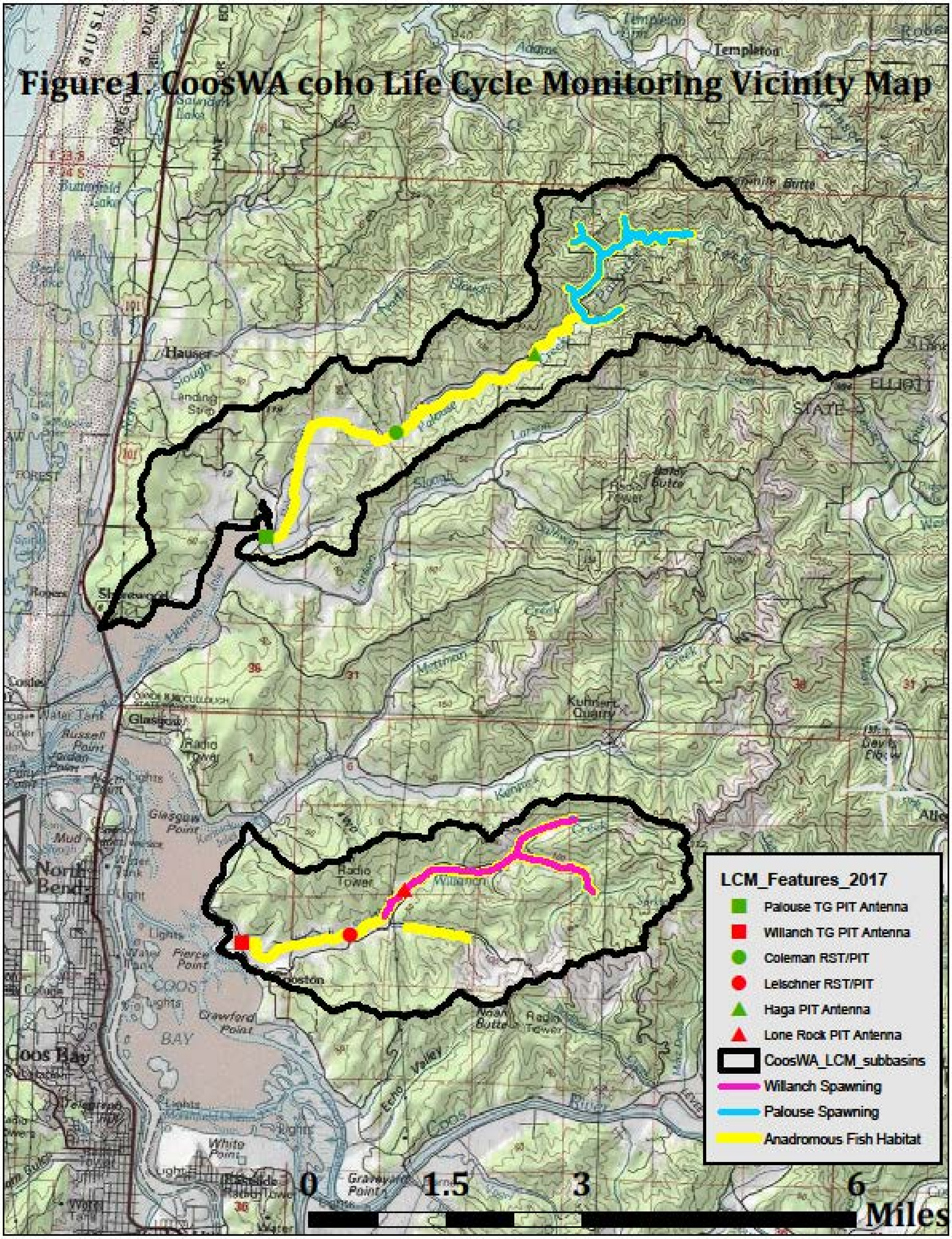

Figure 1. Study Area

Tide Gate Research.

Coastal lowland streams such as Willanch and Palouse Creeks are known to be productive juvenile coho salmon nursery areas as a result of a relatively high abundance and diversity of low to moderate gradient and off channel stream habitats. These slow water habitats (i.e., pools, glides and ponded areas) provide refuge habitat and marine sourced forage for juvenile coho that can considerably increase juvenile coho salmon recruitment to marine environments (IMST 2002, Nordholm 2014, MacKereth 2016). Human alteration of lowland areas is prevalent throughout the range of coho salmon, principally: diking, tide gating and associated landfill (Giannico and Souder 2005). Tide gates were commonly installed in dikes to control tidal fluctuations of salt water inundation in lowland areas converted for use of agricultural production. Tide gates alter stream hydrology and water quality conditions upstream of the gate by impounding water during closed gate periods (i.e., high tidal cycles) (Souder et al 2018). Areas upstream of tide gates often experience seasonally increased stream temperature due to stagnant flows and variable levels of salinity resulting from leakage that is common in older tide gate structures (Giannico and Souder 2005, Bass 2010). CoosWA LCM project has demonstrated that coho utilizing these habitats in late spring and early summer months grow faster than juveniles that remain in the upper spawning reaches (MacKereth 2016). The extent to which the altered environment around tide gates effects the ecology of salmonids in coastal lowland streams is not fully understood, but is of growing interest and concern as these structures deteriorate and fail.

Beginning in the spring of 2016 a comprehensive suite of sensors was deployed at the Willanch Creek tide gate. These include tide gate angle sensors, pressure transducers (upstream and downstream of tide gates), a HDX PIT/RFID antenna array, and a period of data from a 5 parameter water quality sonde (downstream of the tide gate). Notably, we installed an ADCP water velocity meter in the MTR side of the split tide box. Uniquely we captured a full annual tidal cycle of water velocities. This variable is important because fish passage guidelines and culvert sizing for replacement is largely dependent on water velocity thresholds based on juvenile fish swimming performance (NOAA 2011). In 2018, Souder and Giannico described the monitoring methods used at Willanch Creek tide gate and suggested that collecting in situ water velocity measurements is critical in order to suitably assess fish passage conditions before and after tide gate replacements. This full suite of water conditions and fish behavioral data is unique for tide gate monitoring. Notably, Art Bass is currently working with Guillermo Giannico to reanalyze and publish his 2010 thesis research which focused on tide gate fish passage data from the original lowland LCM project efforts in 2008 (Bass 2010). CoosWA is also concurrently collaborating to replicate their data formatting methods in order to quantify and comparatively assess Willanch tide gate fish passage to their forthcoming results from Larson and Palouse. Results for these specific will be available in the next biennium of the lowland LCM project.

Population Monitoring.

Beginning in 1997, coho salmon Life Cycle Monitoring efforts were implemented as part of the Oregon Plan for Salmon and Watersheds by Oregon Department of Fish and Wildlife (ODFW) in seven coastal subbasins on the Oregon coast to monitor fish population abundance and survival (Suring et al. 2012). These on–going efforts are concurrent with spawning surveys conducted by the ODFW Oregon Adult Salmonid Inventory & Sampling (OASIS) project which uses random site selection to estimate abundance, and coastal ODFW districts that use standard sites to track long term trends of coho spawner escapement in the Oregon coastal ESU. Together, data from these efforts provides valuable information for managers regarding salmon abundance and survival trends, and spatial and temporal variation in salmon production among Oregon coastal subbasins. ODFW Life Cycle Monitoring sites are located primarily in upland settings at sites with constructed adult fish passage structures. Life Cycle Monitoring efforts conducted by CoosWA in Palouse and Willanch subbasins and previously in Larson Creek are intended to diversify the scope of Oregon Plan projects by including tide gated lowland study sites that represent an important qualitative and quantitative component of coho population production on the Oregon Coast. Oregon Plan LCM data and OSU research from these CoosWA study streams since 2003 have generally corroborated regional ODFW juvenile and adult coho salmon monitoring while providing significant contributions to the awareness, understanding and paradigm shift of coho rearing in tidal slough habitats.

Adult Spawner Recruits [Escapement].

Study streams are sampled and monitored during spawning periods from late fall through winter (generally mid October-early February) using systematic salmon spawning surveys conducted on seven to ten day rotations. Palouse Creek has been surveyed every season since 2004 and Willanch Creek for the 2002-2005 and 2014-2018 seasons. Surveys in each sub-basin covered all known and accessible spawning areas (Figure 1). Previous escapement estimation efforts in Larson Creek were hindered by lack of access to much of a productive tributary, Sullivan Creek. This project biennium, adult coho population sizes in the Palouse and Willanch sub-basins were calculated using area-under-the-curve (AUC) calculations based on the number of fish observed in each segment and totaled for the sub-basin (Jacobs and Nickelson 1998) (Figure 2). All coho carcasses were categorized by gender and size (adult or jack), and measured and scanned for the presence of unique PIT tags during spawning surveys. Coho salmon escapement was very low for the 2016-17 period and carcass recovery was extremely low, with no PIT tagged adult salmon recovered over the study period of this grant.

Switching study streams to Willanch Creek from Larson may somewhat diminish the ability to track long term trends, however contemporary and previous seasonal spawning survey results from Willanch Creek tracks the trends found in both Larson and Palouse Creek (Figure 2). Resights (PIT antenna array detections) of returning PIT tagged adult salmon are small in number and are likely anecdotal to spawning survey numbers. This data will be further examined to determine any comparable reference between data sources for escapement estimates. Escapement AUC estimates for 2016 and 2017 seasons were the lowest yet observed in Willanch Creek and the fourth and second lowest in Palouse over the 14 year study period (Figure 2).

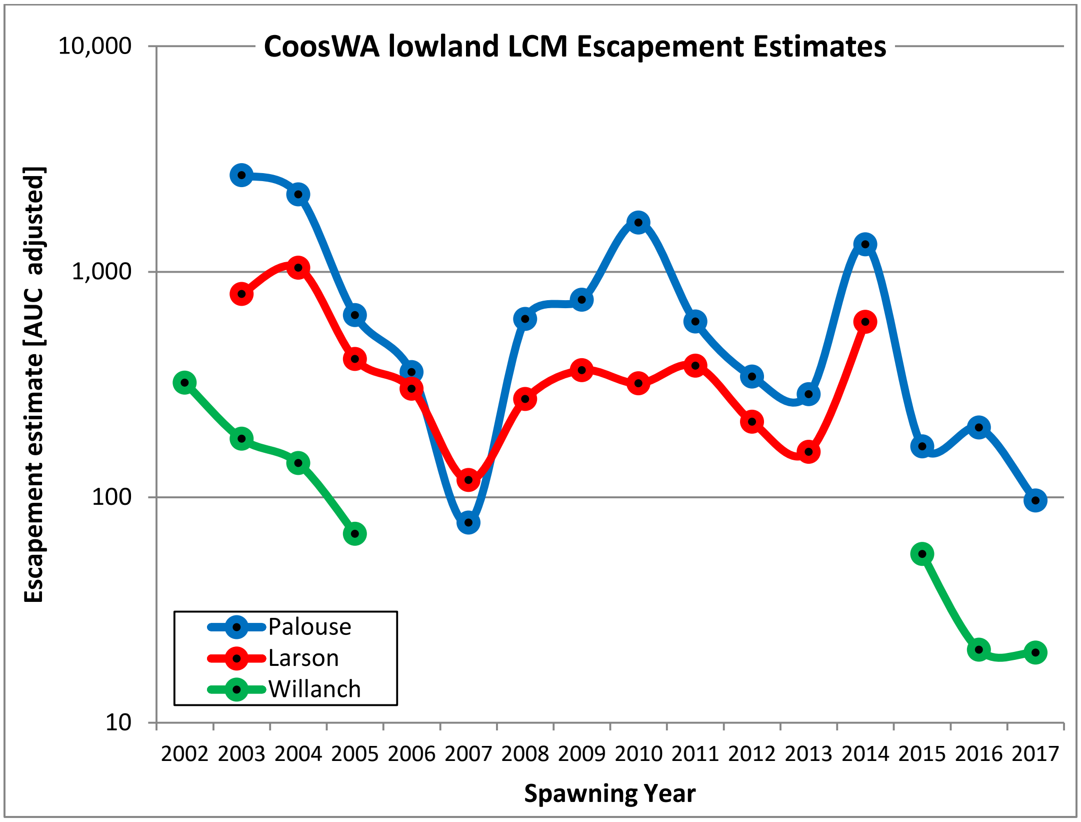

Figure 2. CoosWA lowland LCM sub basin escapement estimates

CoosWA's LCM study streams track escapement trends on larger spatial scales (Figure 3). Projected at orders of magnitude across four spatial scales, coho escapement generally tracks cohorts at the ESU, strata, basin and subbasin levels. Of note are increases in the early 2000's and the sharp decline in 2007 and rebound in 2014. The general synchronization of escapement trends at local, regional and coast wide scales suggests marine survival is a strong component of relatively recent temporal variability in population productivity. More uncertain is the magnitude of the role of marine survival in the historical declines of coho salmon populations in relation to reductions in freshwater survival and the potential of watershed restoration to restore productivity at various scales.

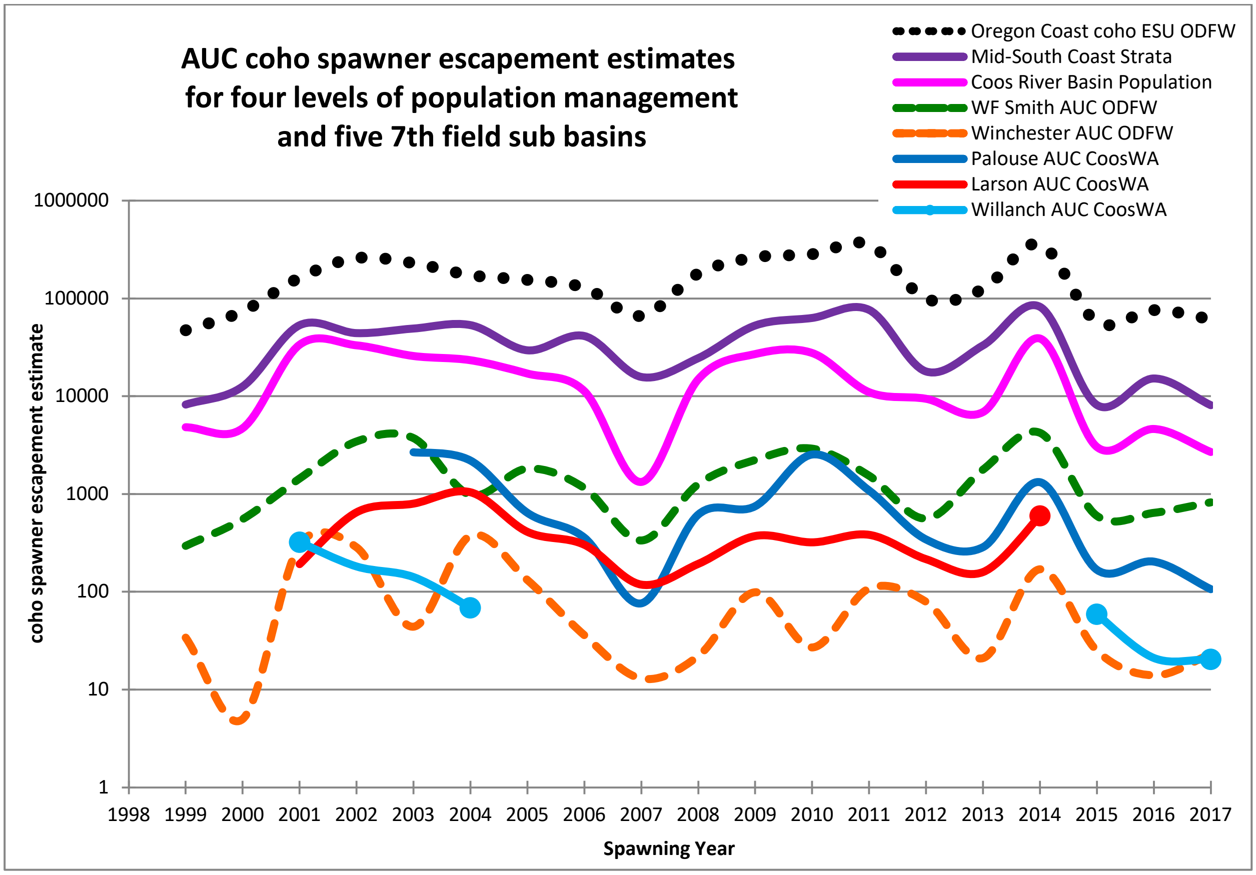

Figure 3. Oregon Coast coho escapement estimates for the Oregon Plan study period

Smolt Outmigration.

Estimates of the abundance of coho smolt populations are based on the capture of downstream migrant fish at rotary screw traps (RST) operated on Palouse and Willanch Creeks. The rotary screw traps were located downstream of freshwater spawning and rearing areas (at or near upper tidal influence zone) in each stream to maximize the opportunity to capture downstream migrant smolts (Figure 1). RST sampling efforts targeted coho smolts, however, coho fry, steelhead and cutthroat trout and lamprey sp. were also sampled using ODFW LCM project protocols (ODFW). Fish captured each day at the Palouse and Willanch screw traps were enumerated and a subsample of salmonid fry (<=55mm) were measured for length and soaked in a Bizmark Brown Y dilution that darkened the fish for about seven days and allowed for identification when recaptured. Smolt and parr salmonids >=65mm were PIT tagged and identified by a handheld reader or at fixed antenna sites (See below). All tagged and marked individuals were released upstream of the screw trap in order to calculate an estimate of trapping efficiency required for abundance estimates by life stage.

RST efficiency was calculated for each trap on a weekly basis and seasonal outmigrant smolt population estimates were calculated by adjusting weekly capture totals based on weekly trap efficiency estimates. Variance and confidence intervals were calculated for yearly coho smolt and fry population estimates using a bootstrap procedure with 1,000 iterations per calculation (Thedinga et al. 1994) (Figure 4-7). Screw trapping was suspended during high water events due to the danger posed to fish held in the trap and operational safety. Catch estimates were calculated for days the trap did not operate by averaging catch from prior and subsequent days of operation.

Palouse Creek trap efficiency was low for 2018, but estimates for both smolt and fry were larger for 2018 than in 2017. Productivity results for both life stages were among the lowest of the study period dating back to 2006. Likewise Willanch Creek productivity remained low for the brood years 2017 and 2018. Smolt productivity in Willanch Creek has however shown a steady upward trend based on calculated estimates. Larger 95% confidence intervals generally result from lower catch related to lower trap efficiency and smaller marked sample size (Figures 4 and 6).

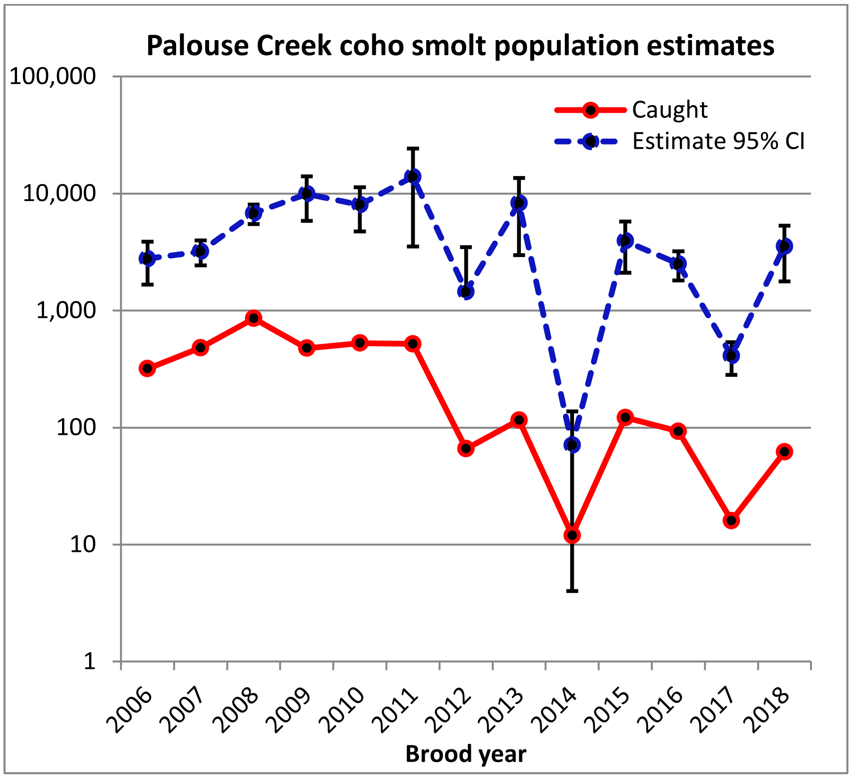

Figure 4. Palouse coho smolt cohort catch and estimates

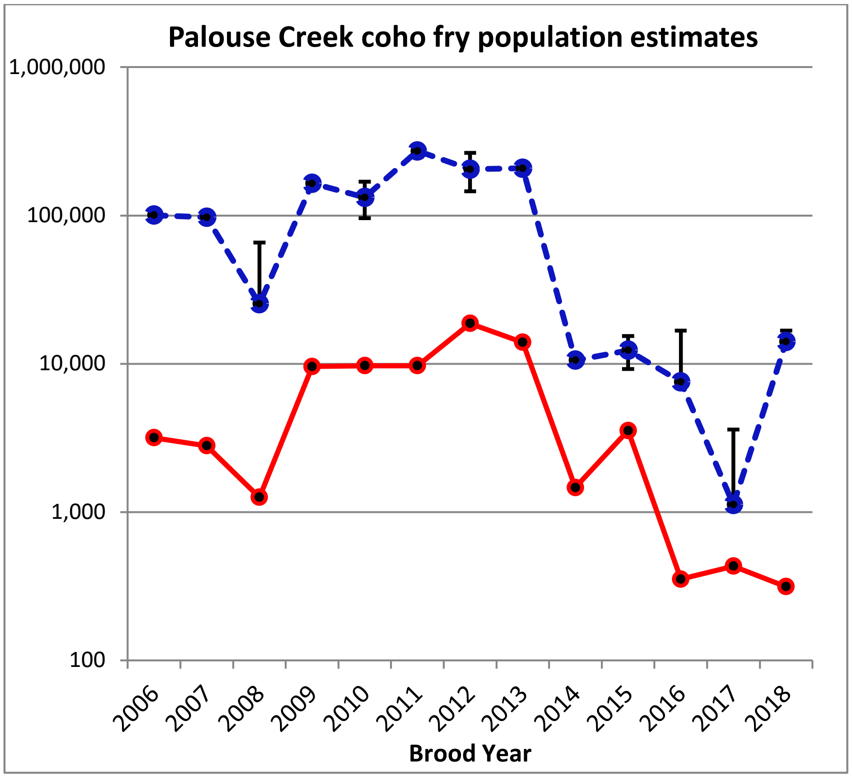

Figure 5. Palouse coho fry cohort catch and estimates

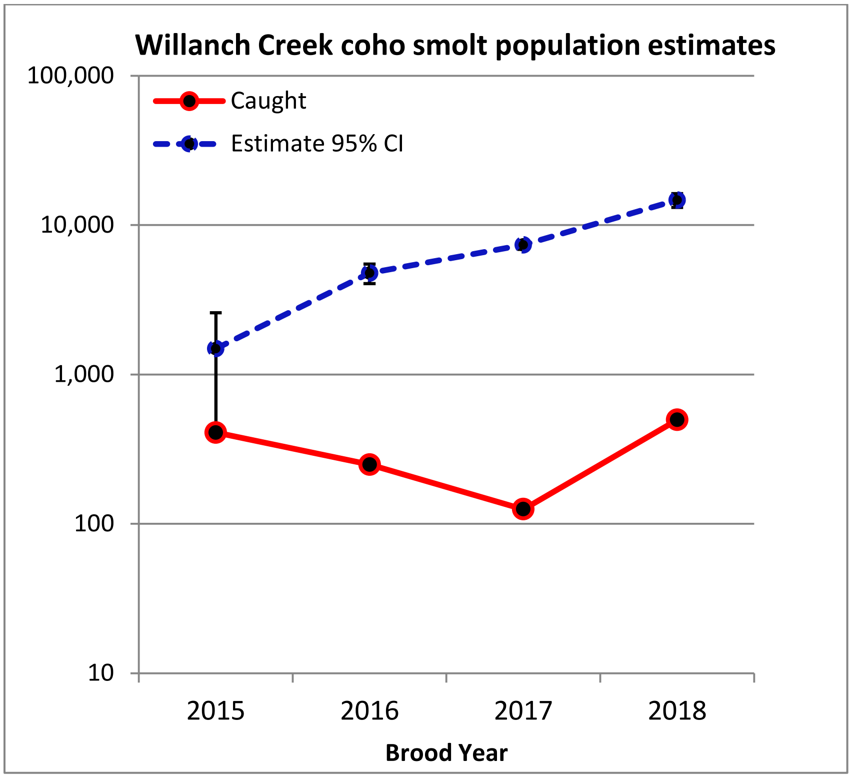

Figure 6. Willanch coho smolt cohort catch and estimates

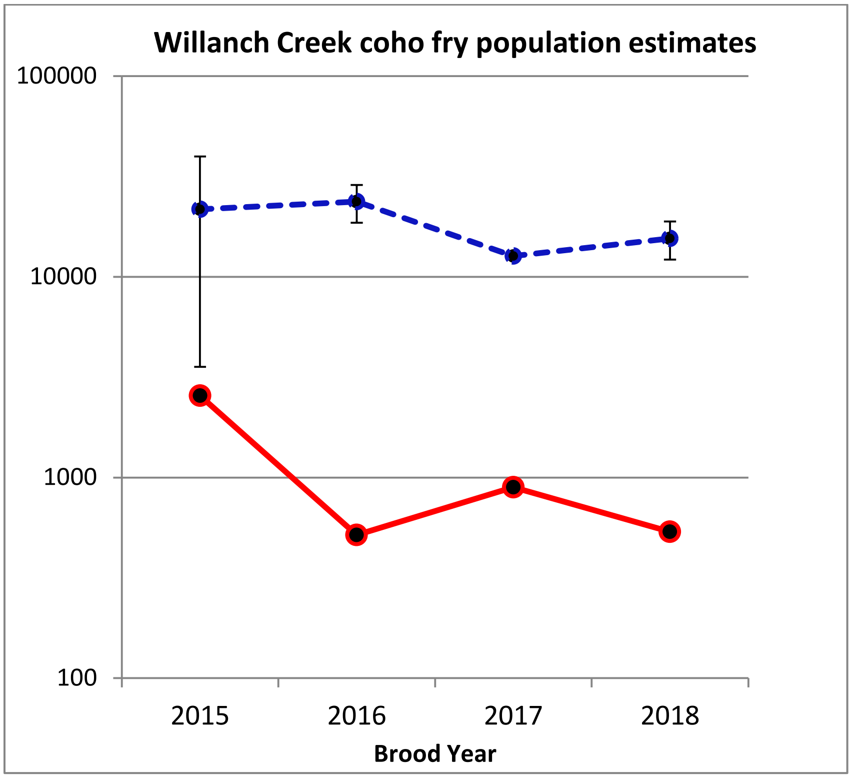

Figure 7. Willanch coho fry cohort catch and estimates

Freshwater and Marine Survival Estimates.

Freshwater and marine coho survival rates were calculated for coho cohorts based on estimates of egg deposition, emigrant smolt population size, and the total number of adult coho spawners. Total egg deposition for each brood year was estimated based on coho spawner counts and annual mean size of female spawners. The number and average fork length of female spawners was derived from sampled carcasses in 2014, and since few carcasses have been observed since 2015, it was assumed that the male: female ratio was 1:1 and the average length obtained from cumulative years was used. An annual average female coho fecundity rate (egg deposition) was applied to the estimated number of female coho to predict the total egg deposition in each stream (Figure 8). The coho freshwater survival rate was calculated as the number of smolts having survived to outmigration divided by the estimated total number of eggs deposited. Marine survival was calculated as the proportion of coho adults that returned to each stream from the estimated total number of emigrant smolts of that cohort (Figures 9-11). Coho brood year represents the first year eggs are deposited during the winter spawning period by adult fish (e.g., 2014 brood year coho were derived from adult coho spawning during winter 2014-15, hatched in winter/spring 2015, and emigrated as age-1 smolts in spring 2016).

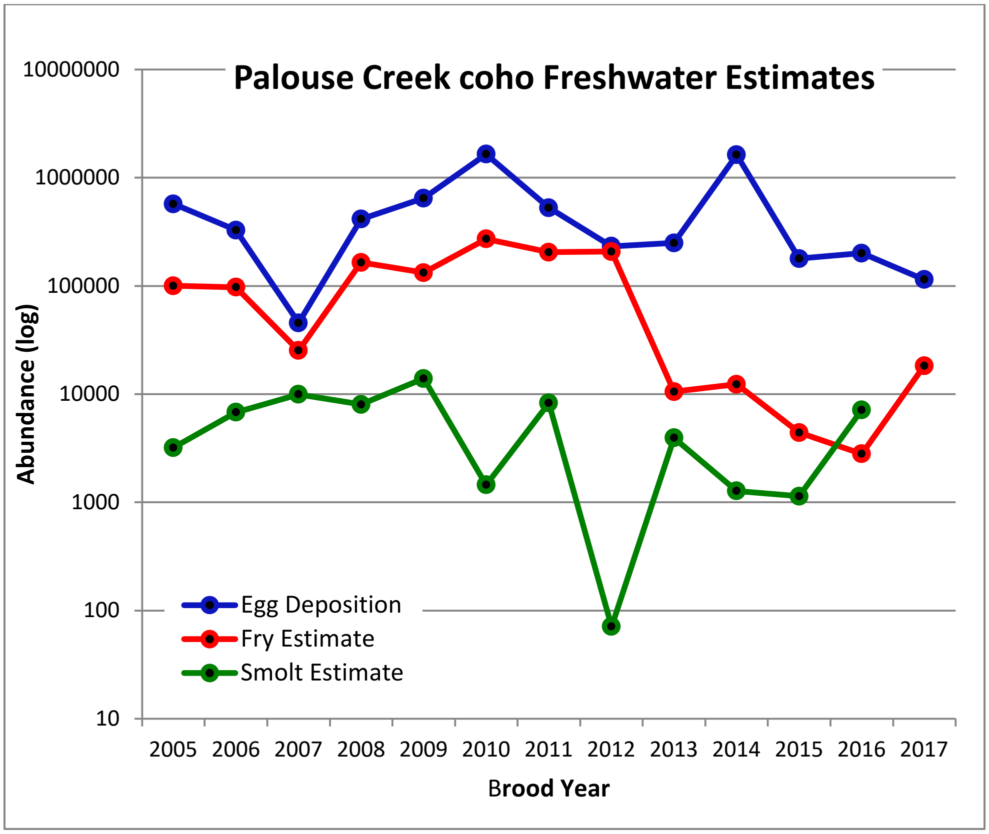

Figure 8. Palouse Creek freshwater life stage estimates

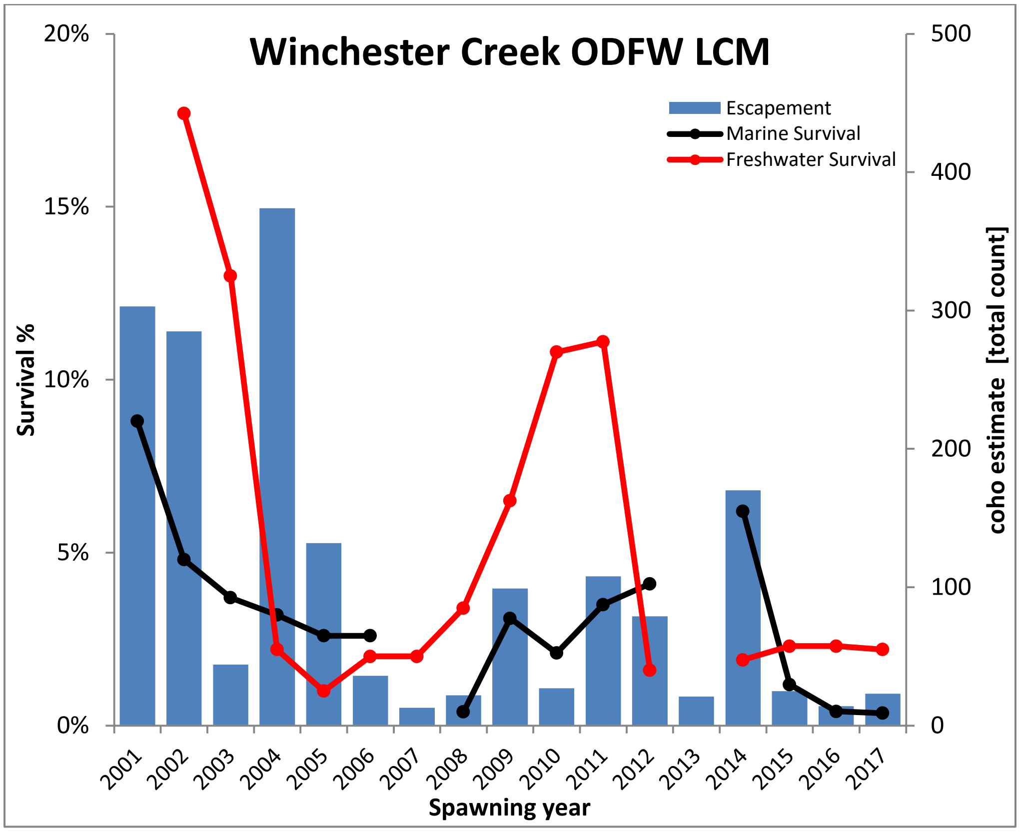

Figure 9. Winchester Creek [ODFW} LCM estimates

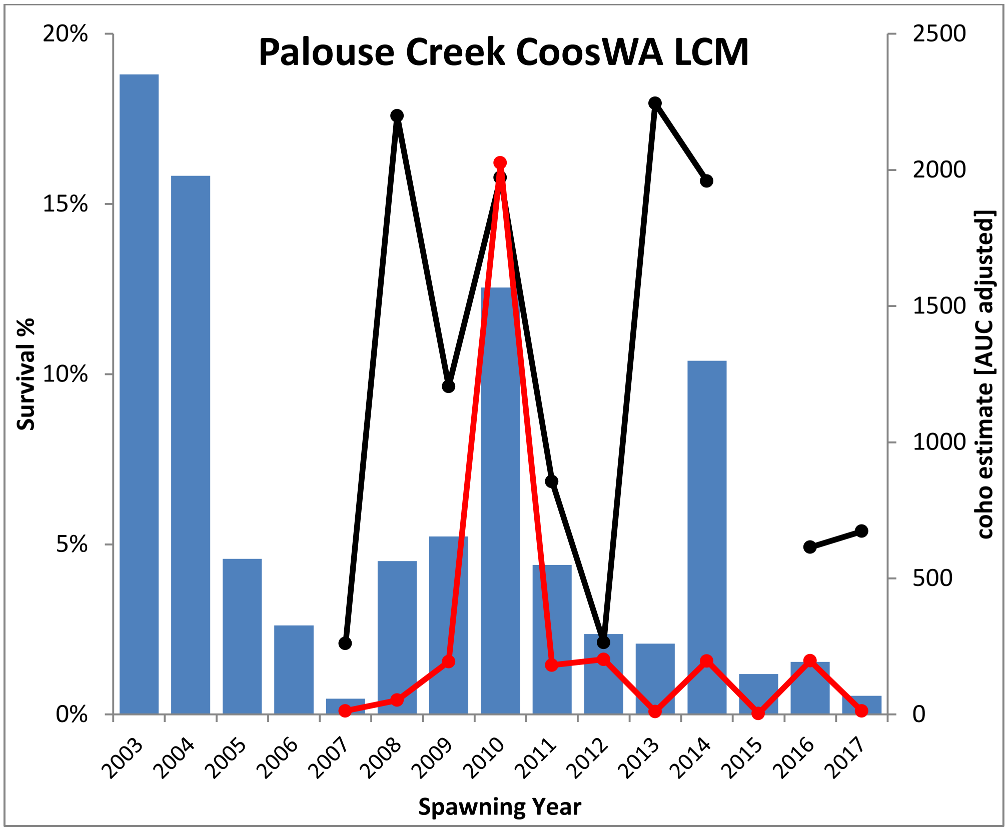

Figure 10. Palouse Creek [CoosWA} LCM estimates

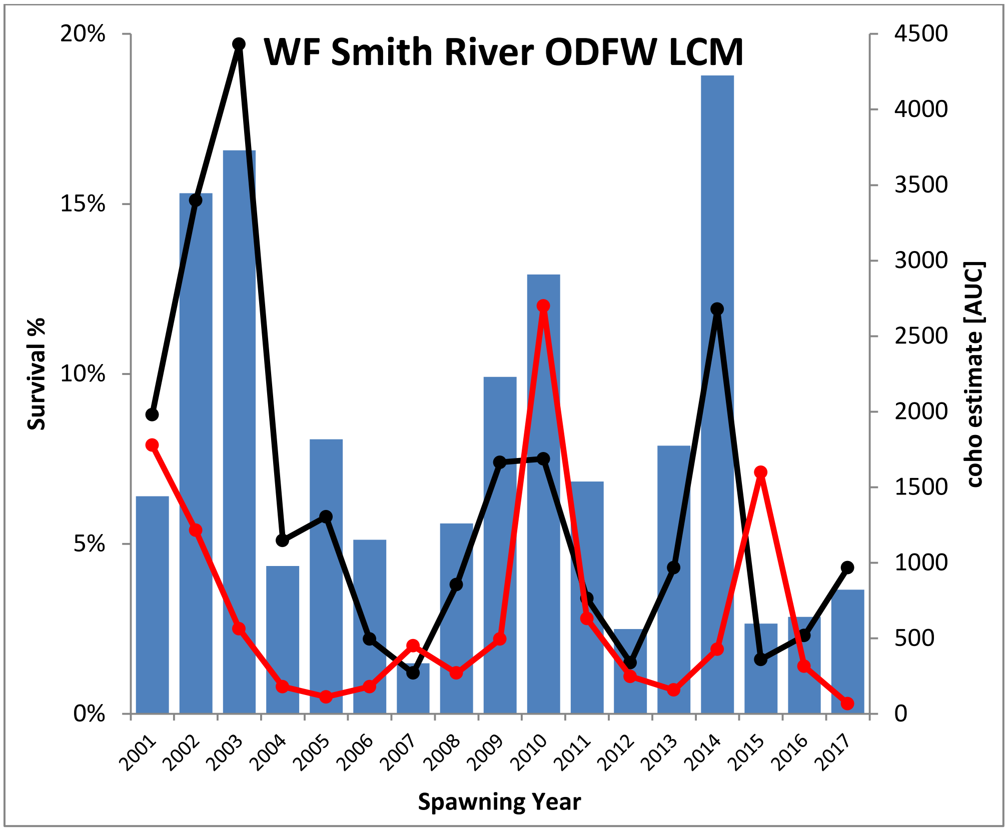

Figure 11. WF Smith River [ODFW} LCM estimates

Evidence of strong marine influence on salmon populations is apparent in the trends of the Pacific Decadal Oscillation (PDO), an indicator of ocean conditions, associated with El Niño seasons (Figure 12). As El Niño cycles have changed in recent decades, another phenomenon, the North Pacific Gyre Oscillation (NPGO) shown in Figure 13 has revealed an even more accurate indication of population dynamics of west coast salmon populations since the 1980s (Kilduff et al 2015). Mean marine survival estimates of the three south coast regional coho LCM sub basin populations (Figures 9-11) track these related climate trends (Figures 12 and 13). Other significant marine variables that effect marine survival of salmon include: strong upwelling; cool sea surface temperature (SST); strong wind mixing; a deep and weakly stratified mixed layer; and low coastal sea levels associated with strong transport of the California Current. Evolving paradigms indicate these variables interact dynamically to distinguish dominant modes of variability in nutrient availability and subsequently biological productivity in the near shore environment in late spring and early summer (May-Sept) when coho smolts are entering the marine environment (Koslow 2002). There are numerous interactive variables, many with high uncertainty in the marine environment and coast-wide freshwater landscape and aquatic habitat issues that should not be discounted.

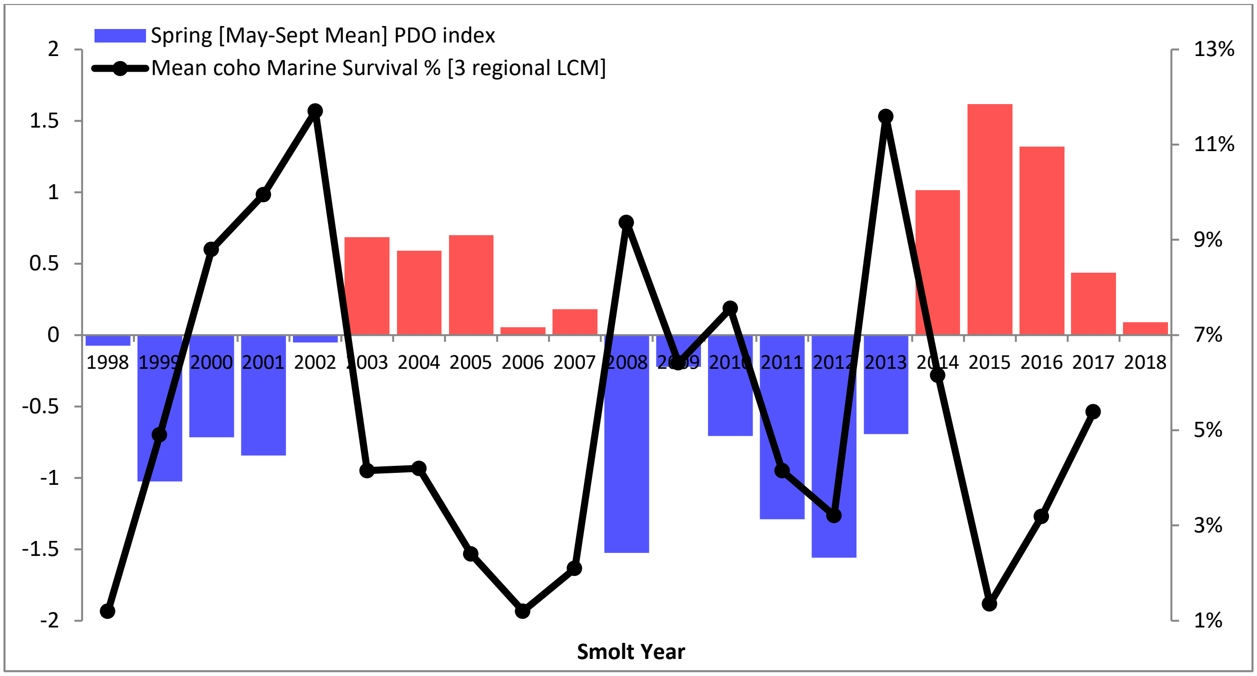

Figure 12. Mean coho marine survival of 3 regional LCM sites in relation to PDO index

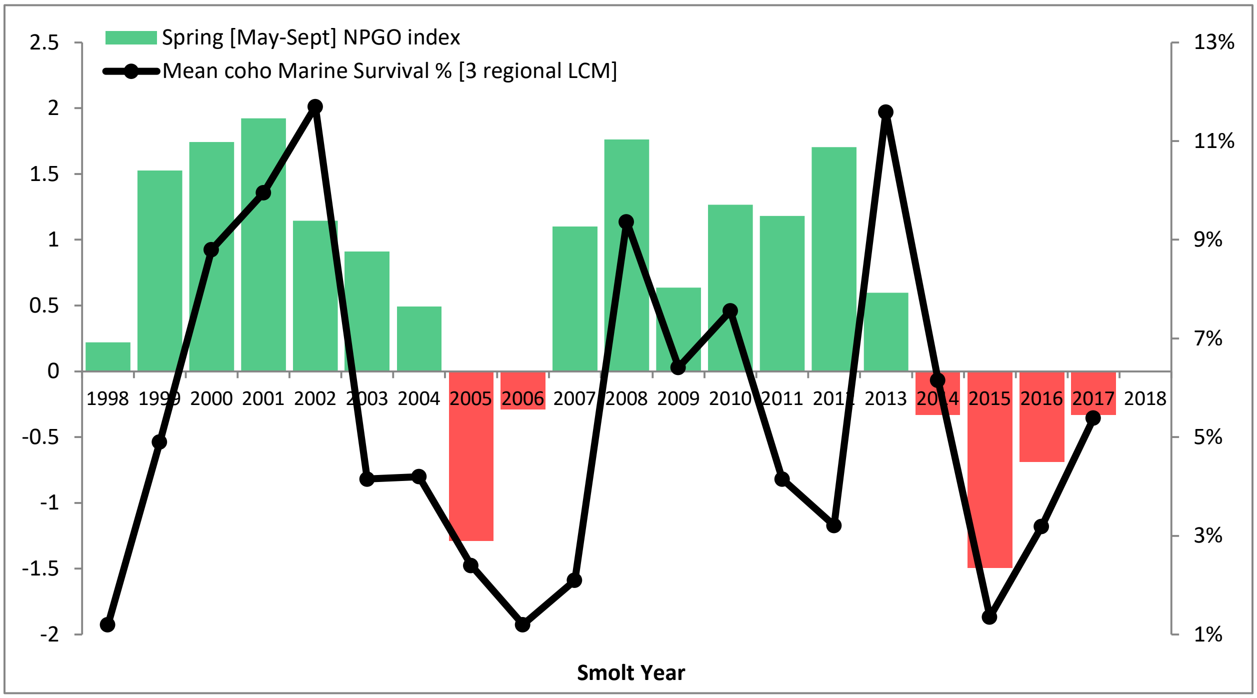

Figure 13. Mean coho marine survival of 3 regional LCM sites in relation to NPGO index

PIT tagging.

Detection and monitoring of fish movement in freshwater habitats using Passive Integrated Transponder (PIT) technology is a putative method for the estimation and modeling of salmonid population dynamics (Zydlewski et al 2003). Passive Integrated Transponder (PIT) tags are uniquely identifiable 12mm tags that provide researchers with the ability to mark fish as small as 65 mm (fork length) with minimal effects on growth and survival (PTSC 2014). Previous (2008-2014) CoosWA PIT mark recapture methods used Full Duplex (FDX) transponders and readers. Notably, the availability of smaller (8.5mm) FDX tags permitted tagging and recapture of smaller (48-60mm fork length) coho. This projects novel use of these smaller tags in estuarine environments revealed that the reduced read range of the smaller tag and the salt water attenuation of PIT antenna detection fields combined to critically degrade the detection probability of fish with these tags. This confounded the ability to effectively monitor the movements and migrations of the sub-smolt coho population and quantitatively assess the freshwater survival of this critical phase of development. Previously, sub 65mm coho tagged with 8mm tags were actively recaptured and provide significant sample size for growth analysis. Figure 14 shows the increase in error of mean growth rates as sample size decreases and fish length increases. The current lack of effective unique marking options and the highly dynamic environment of the tidal floodplain remains a primary challenge to rigorously investigating coho ecology at this life stage (Conrad et al. 2016).

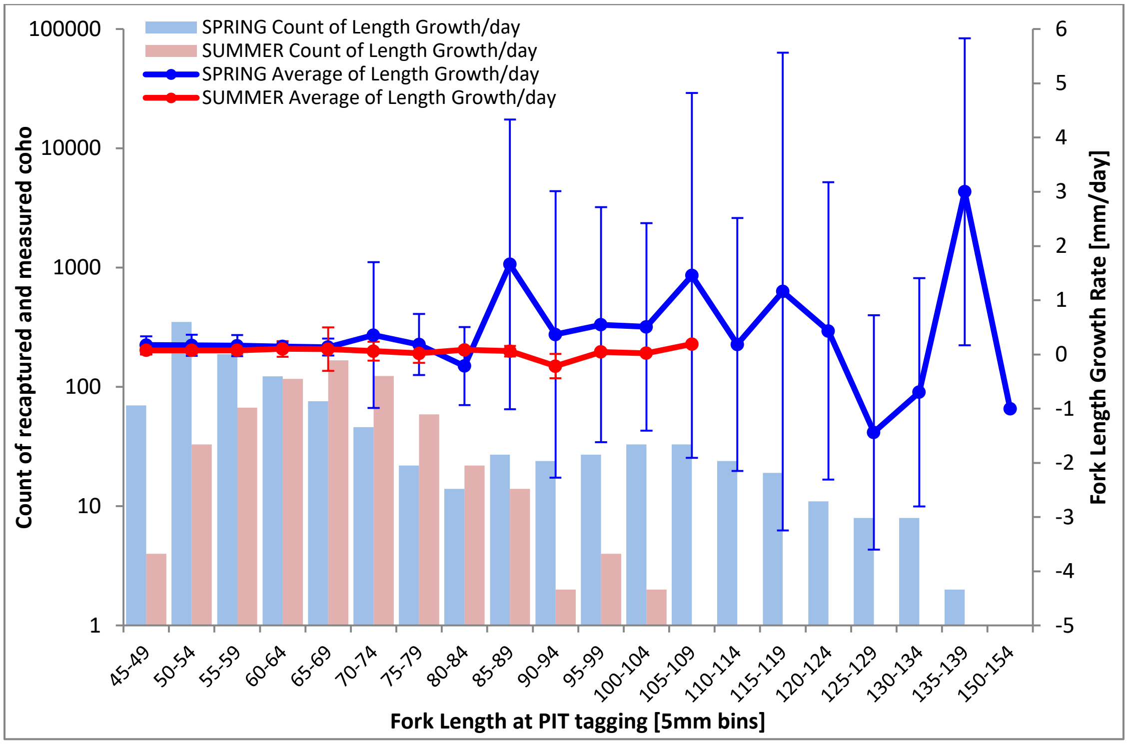

Figure 14. CoosWA LCM coho growth rates by season and size [length] class

The conversion to Half Duplex (HDX) transponders and readers has permitted the development of larger more robust antennas (figure eight designs) with greater read ranges (approximating 23mm FDX tags). Conversion to this technology increased the efficacy of monitoring efforts by capturing most or all of the water volume in the streams, even at high flow when fish movements are assumed to increase, both volitionally and involuntarily. In brackish water at tide gate installations, HDX tools provide for greater read ranges induced by higher voltages (up to 24V) and have been able to largely overcome the salt water attenuation of antenna amperage and read range in the Willanch Creek tide gate PIT array. Development of snorkel wands and larger mobile antennas is still currently in development, with temporal and spatial data logging capacity. Prototype mobile readers were developed this biennium and a robust field tested form factor will enable efficient resighting throughout all stream reaches. Incorporating mobile passive recapture methods into the sample design generates a more robust and balanced data set, particularly for freshwater survival analyses, and an accessible reference for calibration of sampling efficiencies across methods (rotary screw trap, seine, electrofish, etc). Resighting, passive recapture of tagged fish at antenna arrays, was common at Palouse Creek where HDX arrays have run continuously, outside of short outages since 2015 (Table1). Willanch Creek resights have operated since spring 2016.
Diurnal patterns were observed for coho 'MOVEMENT' defined as unique consecutive detections of a unique fish at both antennas in an array (Figure 15). Movements through the

Palouse Creek array overwhelmingly occurred in the mean annual dark half of the diurnal cycle, particularly in the 19th hour. Willanch Creek RST/PIT array is located 200 meters closer to the release point for tagged fish. This may explain the 'MOVEMENT' activity at that site immediately after the 12th hour, after tagged fish were generally released. Further data management and analysis are current topics of discussion with Guillermo Giannico, Jarod Weybright, Art Bass, and CoosWA staff. This conversation focuses on defining explicit questions, assessing the current data for evidence to answer these questions, and how to refine methods if current efforts do not provide sufficient data.

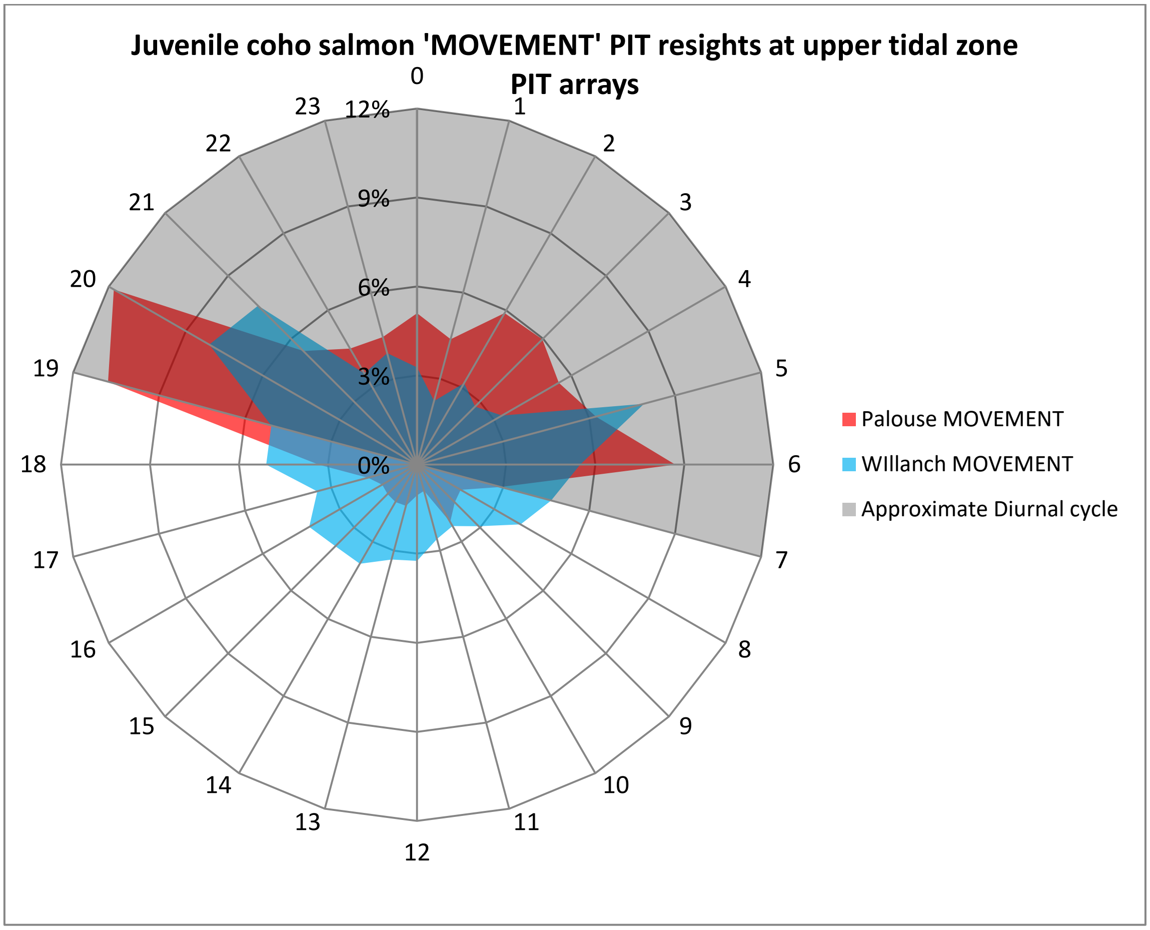

Figure 15. CoosWA LCM coho diurnal movements at RST/PIT arrays

Coho growth (Figures 16 and 17) in length and weight indicate patterns observed elsewhere for PIT tagged salmon. Calculated growth rates under 14 days at large (DAL) are highly variable. This is directly related to the range of variation of error in measurements between samplers and the precision of instrumentation (0.1 g). Growth beyond the 30 day window shows a reduction, then recovery of growth rates in both length and weight. Further analysis of PIT recapture data will parse out life stage and stream reach variables to assess juvenile coho growth in the manner of Weybright and Giannico 2017.

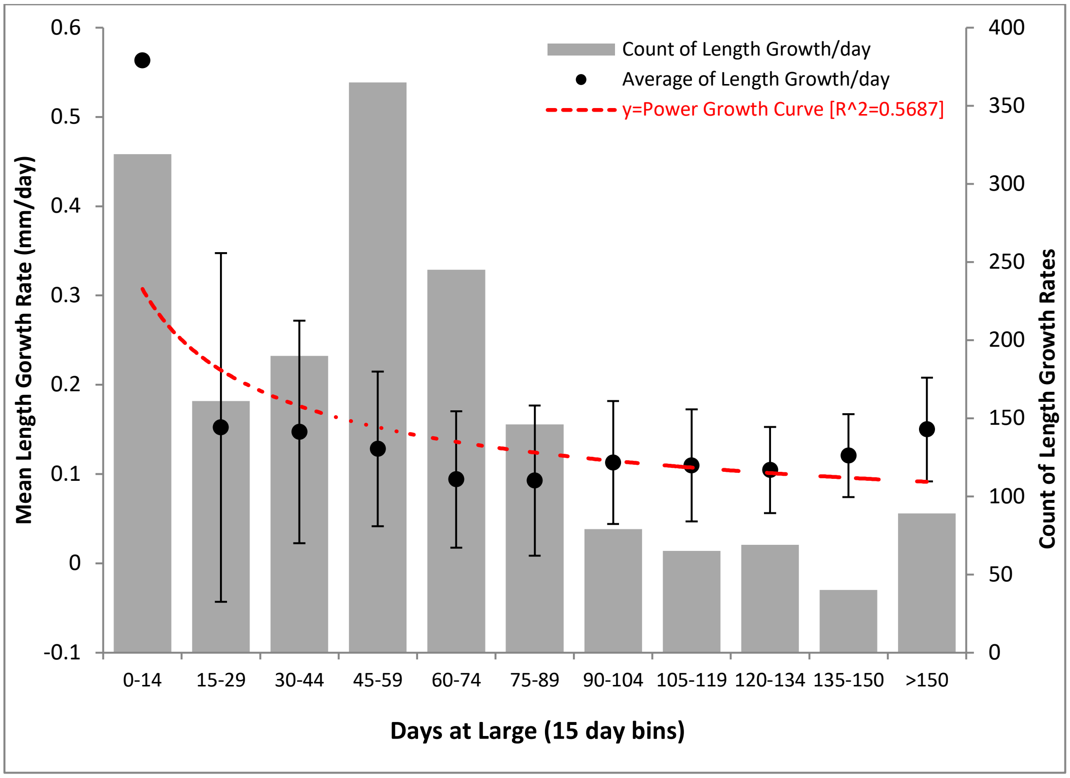

Figure 16. CoosWA LCM coho length growth rates [grams/day]

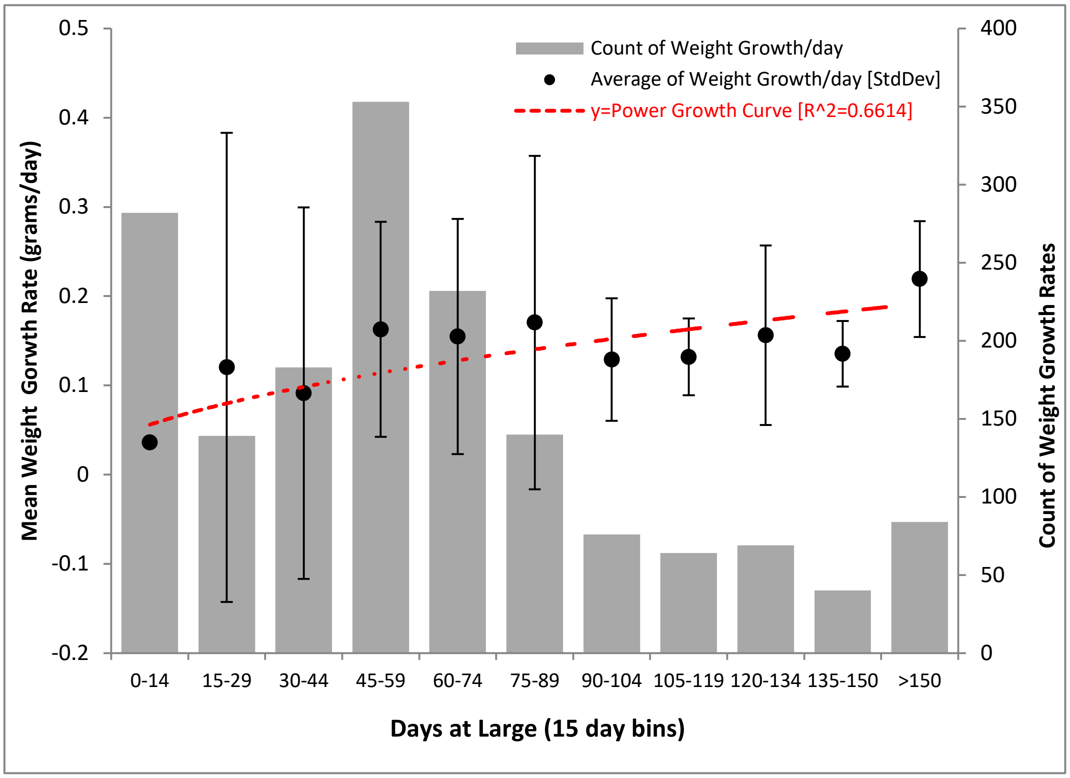

Figure 17. CoosWA LCM coho weight growth rates [mm/day]

CoosWA and OSU are in process rectifying previous FDX PIT tag and current HDX PIT tag data sets in order to conduct an analysis similar to Weybright and Giannico 2017. The 10 year study period captures a range of variability that will be challenging to differentiate. Further attributing population level changes to individual restoration efforts will likely be equally confounding.

Diet Analyses.

Previous studies of coho life history patterns in tide-gated systems of Coos Bay, Oregon (OWEB grants 207-238 and 210-2071) and elsewhere (Jones et al 2014) observed that a subset of juvenile coho, both sub-yearling and yearling, volitionally or reluctantly end up residing in the stream-estuary ecotone during winter and spring (Crombie 1996, Bass 2010, Weybright 2011, Nordholm 2014). The stream-estuary ecotone is the aquatic habitat that extends from the upstream head of tide and downstream to where the stream channel converges with estuarine mudflats (Miller and Sadro 2003). This includes off-channel habitats such as tidal channels, seasonal floodplains, and fringing emergent marshes. In an unaltered state, this dynamic system is driven by disturbances as daily tidal pulse and seasonal freshwater fluctuations perpetually redistribute nutrients and sediments throughout the complex, dendritic layout of marshes and floodplains (Odum et al. 1995, Day et al. 2000). Current conditions are severely simplified through channel straightening, dikes and gates that intentionally function to isolate floodplains from the stream channel.

The results of this projects diet analysis, and other contemporary investigations into the proximal causal effects of increases in coho growth rates, size, and overwinter survival rates in early estuarine rearing individuals, indicates that use of this habitat is an important life-history strategy for coho survival at the individual and population level (Weybright 2011, Jones et al. 2014, and Mackereth 2016). Movement into these tidal reaches requires physiological trade-offs as individuals must adapt to increased salinities and successfully forage in waters that are often turbid and hydrodynamic while avoiding a different suite of predators. Despite the energetic demand of these trade-offs, increased growth rates in comparison to upstream freshwater rearing cohorts indicate that there may be an energetic benefit in the form of either increased prey quality and/or quantity associated with the stream-estuary ecotone (Mackereth 2016).

The ubiquity of tide gates, drainage ditches, dikes, levees, etc. in lowland tidal basins restrict these life cycle pathways in ways that may affect coho productivity at the population level. Further investigations of fish diet as a means to understand fitness and survival of early estuarine rearing juvenile coho will more fully characterize the spatial and temporal complexities of coho early life history developmental strategies (Gray et al. 2002, Maier and Simenstad 2009, Daly et al. 2010).

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Project Changes.

Project (OWEB 231-2031) efforts did not change substantially from the original proposal but significant additions were incorporated. Installation of PIT antenna arrays, environmental and operational sensors at Willanch Creek tide gate provide a reference and 'close' the tagged population by framing the tidal slough zone with antenna detection arrays and replicates the work of Bass 2010 at a Muted tide regulated tide gate. Additional effort and resources were allocated to monitoring water level and temperatures at a finer scale throughout both study streams. Water level and temperature monitoring will provide context for the conditions of habitat types and categories in relation to migratory movements.

Intensive monitoring at Willanch Creek MTR tide gate has produced a dataset that is outside of the scope of this report and the original project proposal. CoosWA is communicating with collaborators to find expertise and resources to rigorously analyze this dataset. This will be in relation to forthcoming more rigorous analysis of Art Bass's fish passage research at Palouse and Larson Creeks tide gates (Bass 2010).

CoosWA LCM project attempts to be flexible and adapt to rapidly growing information about coho tidal rearing. Causal relationships between restoration efforts and coho population parameters are exceptionally elusive and complex, especially across multiple projects and across time and space. The amount and history of restoration in Palouse Creek for example likely confounds any trends that can be identified in coho population demographics and abundance. A major disadvantage of switching from Larson to Willanch Creek was the loss of the long-term ODFW standard spawning dataset in the upper reach. However, escapement estimate trends for Palouse, Larson and Willanch Creeks track very closely, especially since AUC estimates have been added (2002). Fortuitously, spawning surveys were conducted in Willanch Creek (2002-2005) using ODFW protocols with delineated reaches and segments that were replicated for this project from the 2015 through 2017 spawning seasons and are still underway. The early 2000's been relatively productive and therefore provide a constructive baseline and context for comparison with contemporary local and regional estimates.

Public Awareness.

This biennium of the LCM project has solidified a close working relationship with CoosWA outreach and education programs. This biennium the LCM project had two AmeriCorps interns who provided essential survey and sample efforts as well as significant data management and exploratory analyses. AmeriCorps interns also helped expand partnerships with South Western Community College's (SWOCC) natural resource degree and Oregon Institute of Marine Biology (OIMB) undergraduate programs. CoosWA's LCM project recruited four SWOCC students and two OIMB students for a total of seven academic terms. Ten community volunteers also contributed varying levels of effort that, in total, was indispensable to the efforts and results of this LCM project.

This project also collaborated with several of CoosWA's education programs and provided hands-on, stream-side fish sampling and survey experience for dozens of Coos Bay and North Bend high school students across all reaches of the study streams. Students participated in collection, handling and tagging fish in different habitats and with various methods. Several specific events targeted the peak migratory periods of adult and juvenile coho in order to expose more community members to salmon in their environment.

Although no specific media coverage was involved, CoosWA closely collaborates with local ODFW, SSNER, BLM and OIMB staff to coordinate community events and share resources to provide opportunities to explore the shared restoration and monitoring work occurring in the Coos Basin. Of special note, the LCM project again cooperated with BLM and USFS to sponsor four AFS Hutton interns in the summer of 2017 and 2018. These local high school students were fully immersed in the monitoring work of the LCM project and were essential to summer sampling and tagging efforts. CoosWA's Monitoring Coordinator twice presented at SWOCC natural resource classes sharing background and results of coho monitoring and the link between salmon and their habitats. Monitoring Coordinator presented at Oregon AFS conferences in both 2017 and 2018, made possible by funding in grant 231-2031.

Lessons Learned.

Seasonal tidal rearing of coho in the coastal range is an emerging paradigm that has been identified in populations across the lowland range of this ESA listed species. The long term monitoring of the CoosWA lowland LCM project has shown that tidal rearing is a significant component of the coho population diversity and productivity in our study streams. Coho use these habitats in seasonal patterns that provide both increased quality of forage and refuge from high flows promoting growth and survival. Finally, coho that utilize this strategy return to spawn at a higher rate than those that rear exclusively in freshwater, i.e. higher marine survival (Nordholm 2014). CoosWA LCM project methods and results provide a uniquely comprehensive understanding of this phenomenon and highlight the significance that restoring these habitats may have for coho population level productivity, resiliency and sustainability.

The highly altered and managed conditions of lowland reaches present enormous challenges for restoration prioritization, implementation and effectiveness monitoring. This project provides crucial replication of previous monitoring efforts required to access the effects of completed restoration projects and predict the benefit of future efforts. Mark-Recapture models rely on spatial references for delineating movements and migrations through time. Assumption of a closed population mark recapture model (explicitly defining immigration and emigration from a study area) requires antenna arrays at the tide gates, although open population models do exist. IN addition to model selection, datasets need to be standardized across methods and all study years in order to be unified into a dataframe for rigorous statistical analysis.

The addition of a technical assistant will provide critical capacity to replace lost effort especially in field management of antenna arrays and traps. Ongoing collaborations with ODFW at local, regional and state levels will continue to improve methods and efficiencies for both CoosWA and ODFW LCM efforts.