Coho Life History in Tide Gated Lowland Coastal Streams 2014-2016

OWEB Grant 214-2031 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, adapts and advances a long-term monitoring study initiated in 2004 to explicitly examine coho salmon abundance, survival, life histories and habitat use in tide gated coastal lowland streams. Evidence from this project and across the range of coho strongly indicates that connectivity in diverse and dynamic tidal habitats provides alternative rearing pathways critical for the sustainability and recovery of Oregon Coastal (OC) coho stocks. Specifically, this project reestablished innovative PIT tag mark recapture techniques to monitor coho movements and migrations. Temporal and spatial components of over-winter rearing strategies, in relation to habitat use and project effectiveness monitoring, is the focus in these paired study streams. Notably, monitoring was shifted to Willanch Creek from Larson Creek. Juvenile coho diet analyses revealed seasonal and diurnal variation in foraging strategies between early migrating sub-yearlings and yearling smolts across their range in estuarine habitats. These results reveal the fundamental mechanisms that promote increased 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 OC coho populations.

Background

Much of the focus of stream restoration efforts has been in the upper reaches (spawning grounds) of salmon bearing streams. Awareness of tidal rearing by juvenile coho dates back to the 1980's (Hartman et al. 1982) and is now considered ubiquitous in coho populations in lowland tidally influenced streams (Koski 2009). This paradigm shift has raised new questions and challenges. Recent investigations under this project and others along the Oregon Coast and across the west coast of North America has found temporal and spatial patterns of instream and estuarine movements and migrations that promote growth through early ontogeny and survival in the freshwater, estuarine and marine environments of coho salmon. Utilizing tidal habitats for nutrient rich forage and stable over-winter shelter may be a critical life history strategy that has been obstructed through anthropomorphic channelization and simplification. These dikes, levees and tide gates are approaching the later stages of senescence and will require considerable maintenance in the near future. The convergence of these problems presents an opportunity to find solutions that benefit both salmon and landowners. Conversion of lowland habitats is pervasive and intense in the Coos River Estuary. Dikes and levees delineate pastures and structures that have been in use for many decades. Culverts and gates in the tidal zone are heavily impacted by the interaction of seasonally high flows and mixed semidiurnal tides. These structures work to inhibit brackish water from flooding pastures but may provide limited passage windows for anadromous and other migratory fish. Quantifying the spatial and temporal patterns of tidal rearing and the relative productivity of this life history strategy will inform restoration priorities in this challenging environment. Habitat connectivity is fundamentally essential for coho salmon. Opportunities to restore off channel tidal rearing habitats in ways that also promote pasture quality, for example where channel connectivity provides better field drainage, can be elusive. There is however, a growing awareness and agreement that these shared solutions can be the most sustainable and productive options.

Fish passage at tide gates is an enigmatic issue that has received little attention from federal and state fish regulatory agencies. Prior work in this project showed greater (downstream) migratory windows were available for salmon at a side door tide gate in relation to a classic top door design gate. The newest side door muted tide regulator (MTR) designs promise even greater fish passage and there is evidence they provide larger migratory windows (Figure 1). However, there is no explicit understanding of salmon temporal use and the environmental conditions present when passage is initiated. In order to more fully understand fish passage at tide gates previous efforts will need to be replicated at an MTR gate in order to evaluate fish passage in a comparative way.

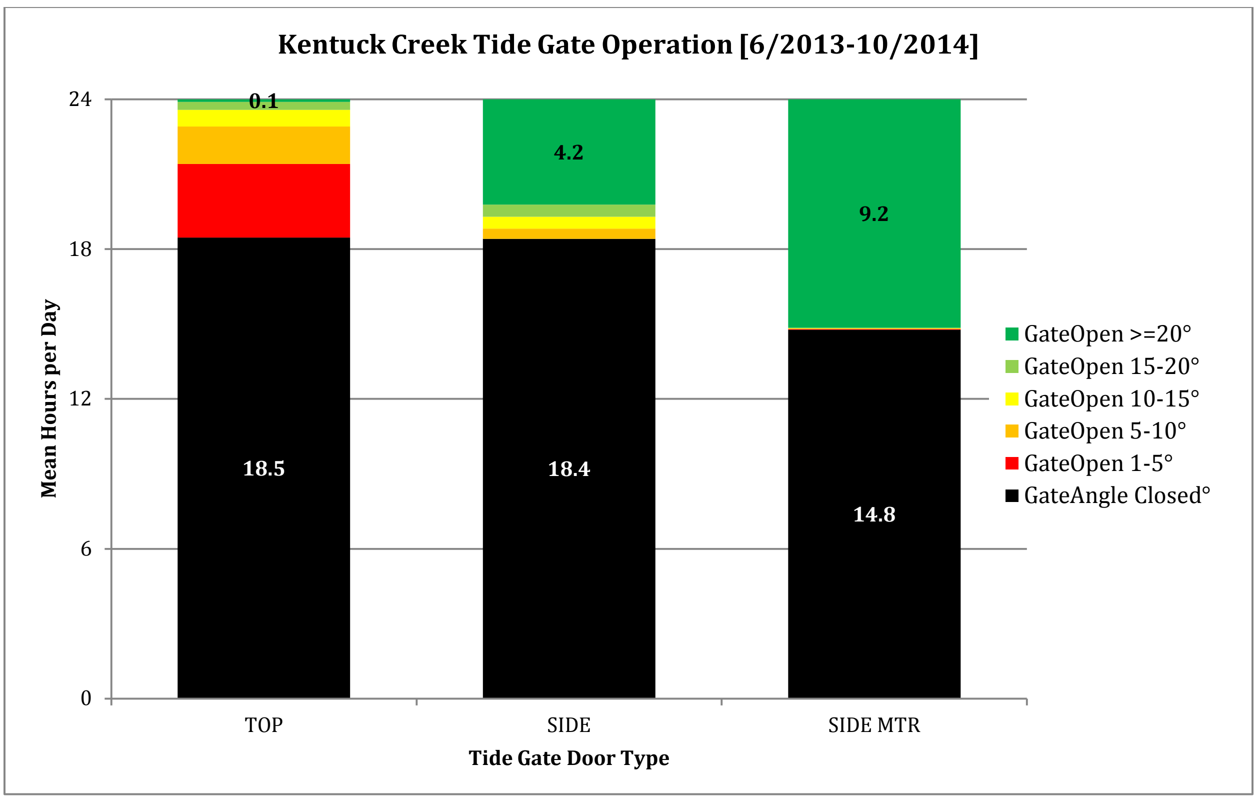


Figure 1. Mean hours per day that each gate door is open binned by range of angle opening

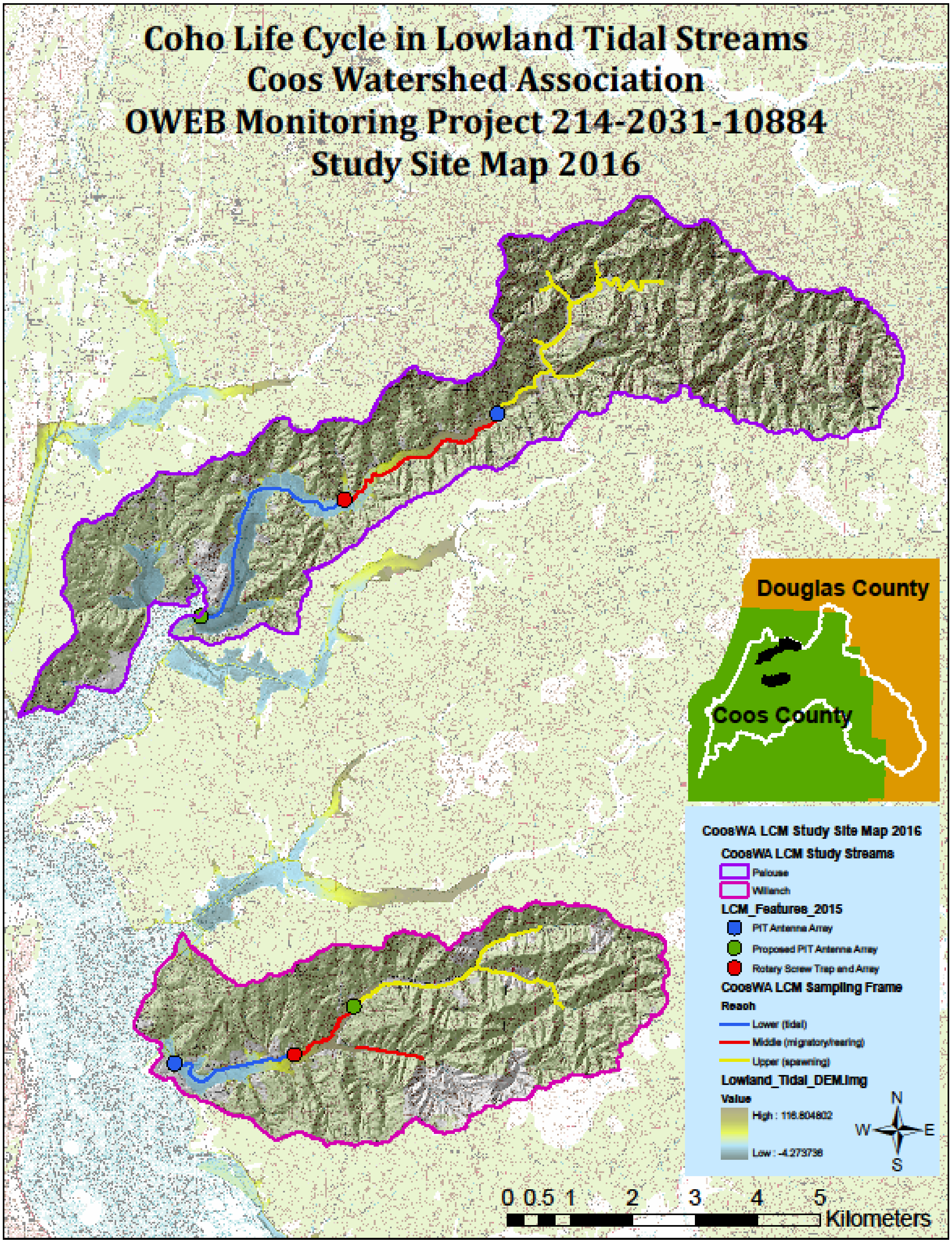


Figure 2. LCM study area

Study Area.

Palouse and Willanch Creeks are two third order lowland streams that flow into upper regions of the estuary in Coos Bay, Oregon (Figure 2). Each stream is tide gated at its confluence with the Coos Bay estuary under dikes that support roadways. Palouse Creek is controlled by two top-hinged gates and Willanch Creek has one side-hinged Muted Tide Regulator gate and one top hinged unregulated door. Palouse Creek is 14.6 km long, drains an area of 28 km^2, and has a natural barrier to coho at river kilometer (RKm) 12.1. The Willanch Creek mainstem is 9.7 km in length, drains an area of 22 km^2, and has no identified barrier to anadromous fish passage. Monthly streamflow averages less than 0.1 m^3/s during late summer to ≥19 m^3/s during winter bankfull flow events (CoosWA 2006).

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 diversity of low to moderate gradient and off channel stream habitats. These slow water habitats (i.e., pools, glides and ponded areas) provide critical nursery habitat for juvenile coho that can considerably increase juvenile coho salmon recruitment to marine environments (IMST 2002, Nordholm 2014). Human alteration of lowland areas is ubiquitous 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 used for agricultural production. Tide gates affect stream hydrology and water quality conditions upstream of the gate by impounding streamflow during closed gate periods (i.e., high tidal cycles). Areas upstream of tide gates often experience increased stream temperature due to stagnant flows and highly variable levels of salinity resulting from tide gate leaks that are common in older structures (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. The extent to which tide gates alter the trophic and migratory ecology of salmonids in coastal lowland streams is not fully understood but is of growing interest and concern as these structures senesce and fail. A focus of this grant, OWEB 214-2031, was to assess the effects of these structures on habitat characteristics and the consequences for juvenile coho ontogeny.

Beginning in the spring of 2016 a comprehensive suite of sensors was deployed at the Willanch Creek tide gate. These include gate angle sensors (previously at Kentuck Creek see above), pressure transducers (inside and outside the gate), a 5 parameter water quality sonde (outside the gate) and a HDX PIT/RFID antenna array. Datasets are still in separate databases and levels of quality assurance and check but the format and prototype was shown to be successful in detecting fish throughout most tidal stages. Preliminary analysis revealed poor detection at times when tide gate doors were completely shut, and when passage is precluded. Fall and winter flows will fully test the installation and provide evidence of any high velocity thresholds that may confound detection rates. Spring and fall are the recognized migratory peaks for juvenile salmon and tagging efforts at the juvenile trap in the middle reach of Willanch will provide for larger sample size of gate passage of tagged fish.

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 abundance and survival (Suring et al. 2012). These efforts were concurrent with spawning surveys conducted by the Oregon Adult Salmonid Inventory & Sampling (OASIS) project that used random and standard site selection to estimate abundance and trends of coho spawner escapement in the Oregon coastal ESU. Together, data from these efforts provide 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 is intended to broaden the scope of Oregon Plan projects by including tide gated lowland habitats that represent an important qualitative and quantitative component of coho population production on the Oregon Coast.

Adult Spawner Recruits.

Study streams are sampled and monitored during spawning periods in late fall and winter using systematic spawner 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 2014-2016 seasons. Surveys in each sub-basin covered all known and accessible spawning areas. Previous efforts in Larson Creek were hindered by lack of access to much of the main tributary, Sullivan Creek. 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 sub-basin (Jacobs and Nickelson 1998) (Figure 3). All coho carcasses were categorized by gender and size (adult vs jack), measured and finally scanned for the presence of PIT tags during spawning surveys.

Switching study streams to Willanch Creek from Larson does diminish the ability to track long term trends, however previous survey data from Willanch Creek does exist and tracks the trends found in both Larson and Palouse Creek (Figure 3). No PIT tags have been actively recovered from coho carcasses or passively detected at antennas during the 2013 - 2016 spawning seasons so no population estimates are available for comparison. 2015 was below average return year in our study streams and across the OC (Figure 4) any tagged fish would have been jacks. 2016 spawning year has just begun however and promises to be more productive.

The LCM study streams track the escapement trends a larger spatial scales at a log scale (Figure 4). Peak counts also closely track AUC estimates (Figure 5). These data suggest that modified survey protocols may be appropriate for escapement monitoring when other parameters are not in consideration.

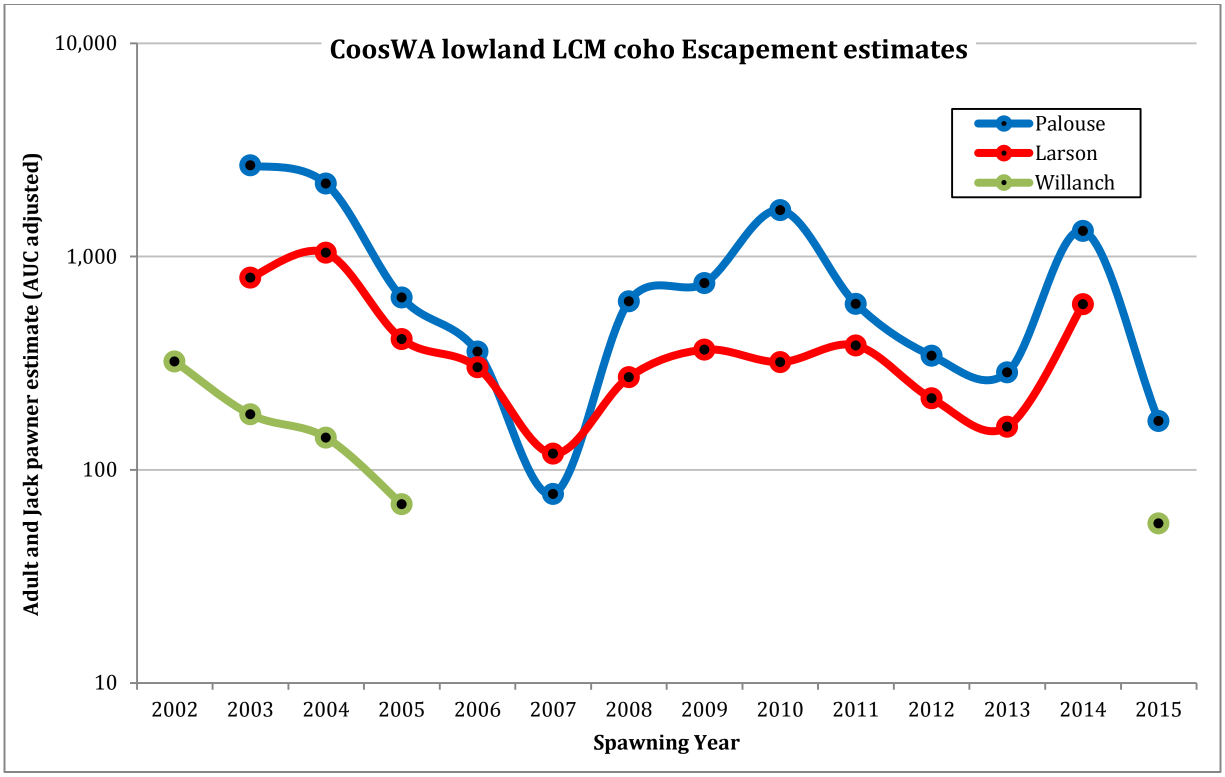


Figure 3. CoosWA LCM spawning coho population estimates in 3 study streams

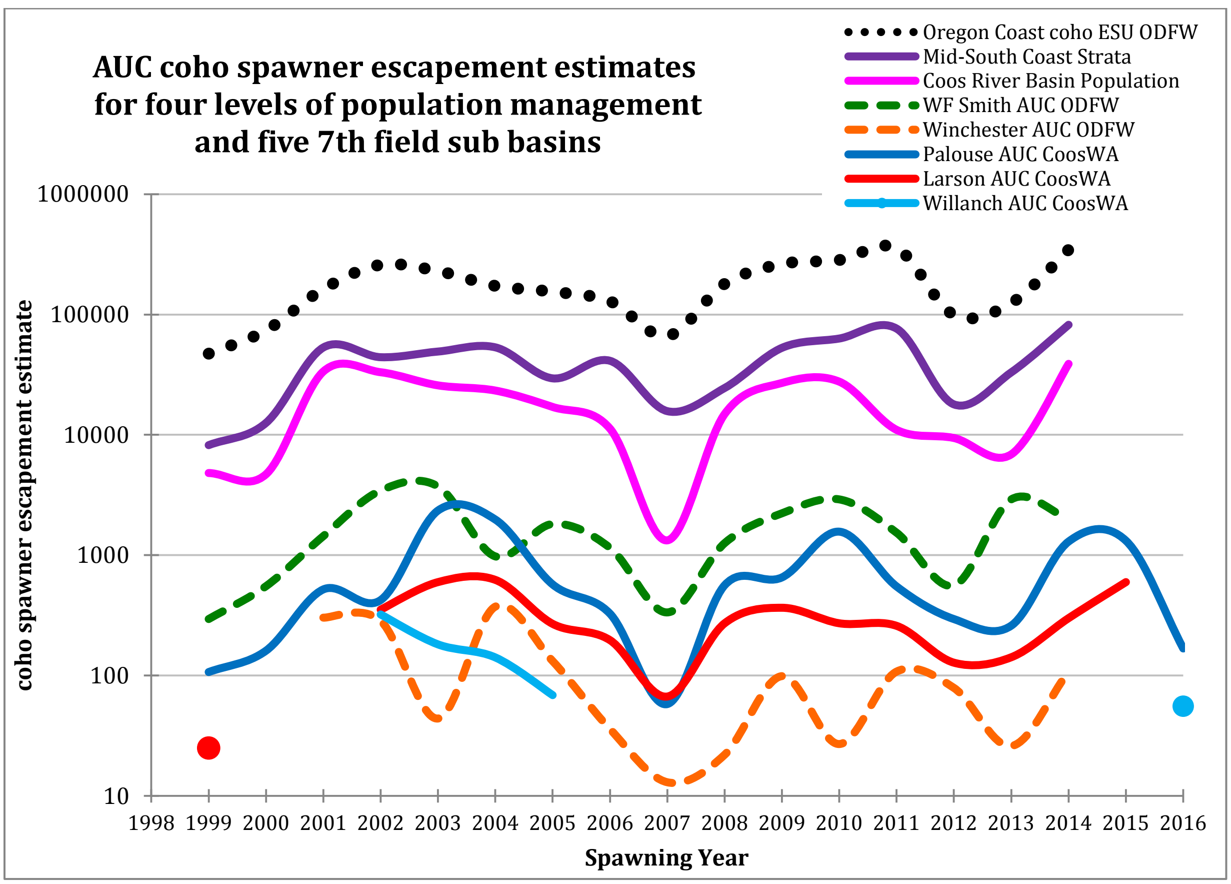


Figure 4. coho escapements estimates (AUC) for the Oregon Plan study period

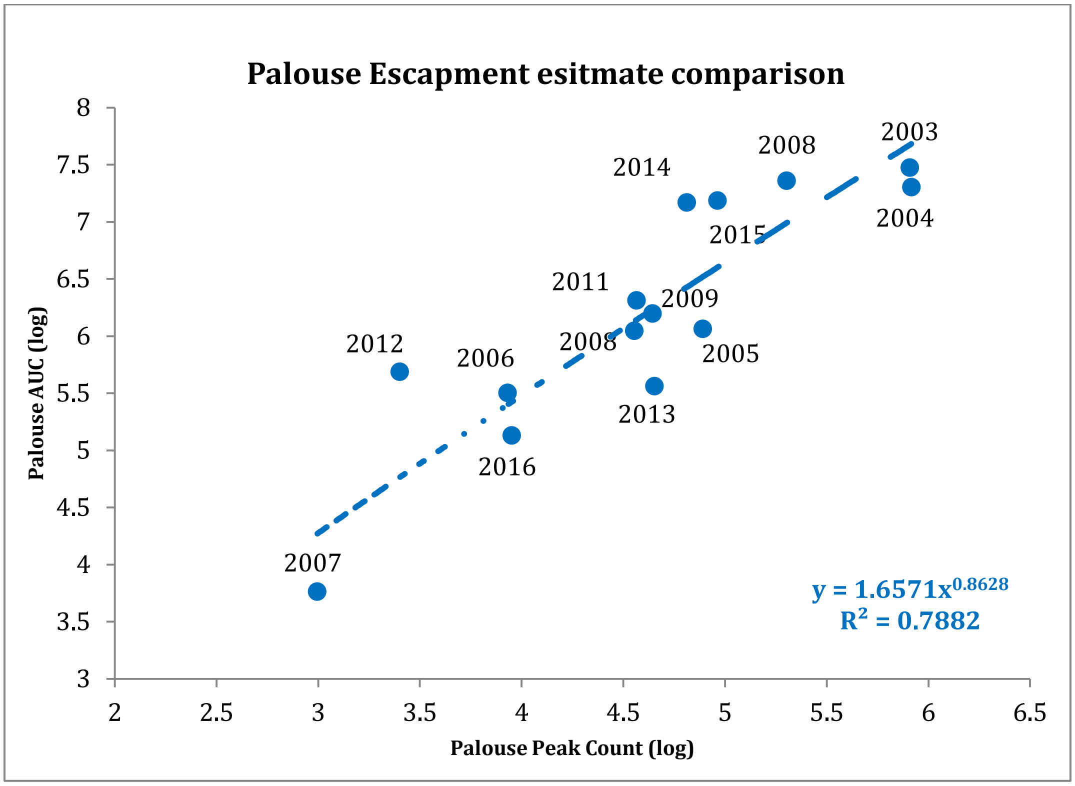


Figure 5. Escapement estimate method comparison

Historically, Pacific salmon species were thought to be influenced by the Pacific Decadal Oscillation (PDO), an indicator of ocean conditions, associated with El Niños (Figure 6). As the nature of El Niños has changed in the most recent decades, another phenomenon, the North Pacific Gyre Oscillation (NPGO) has been discovered to be a more important influence on population dynamics of west coast salmon populations since the 1980s (Kilduff et al 2015). Historic and contemporary peak counts of coho in Palouse Creek track these related climate trends (Figures 6 and 7). 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. Results of ongoing research suggests that coho marine survival is significantly and independently related to the dominant modes acting over the north Pacific region when the coho first enter the ocean and during the overwintering/spring period (Koslow 2002).

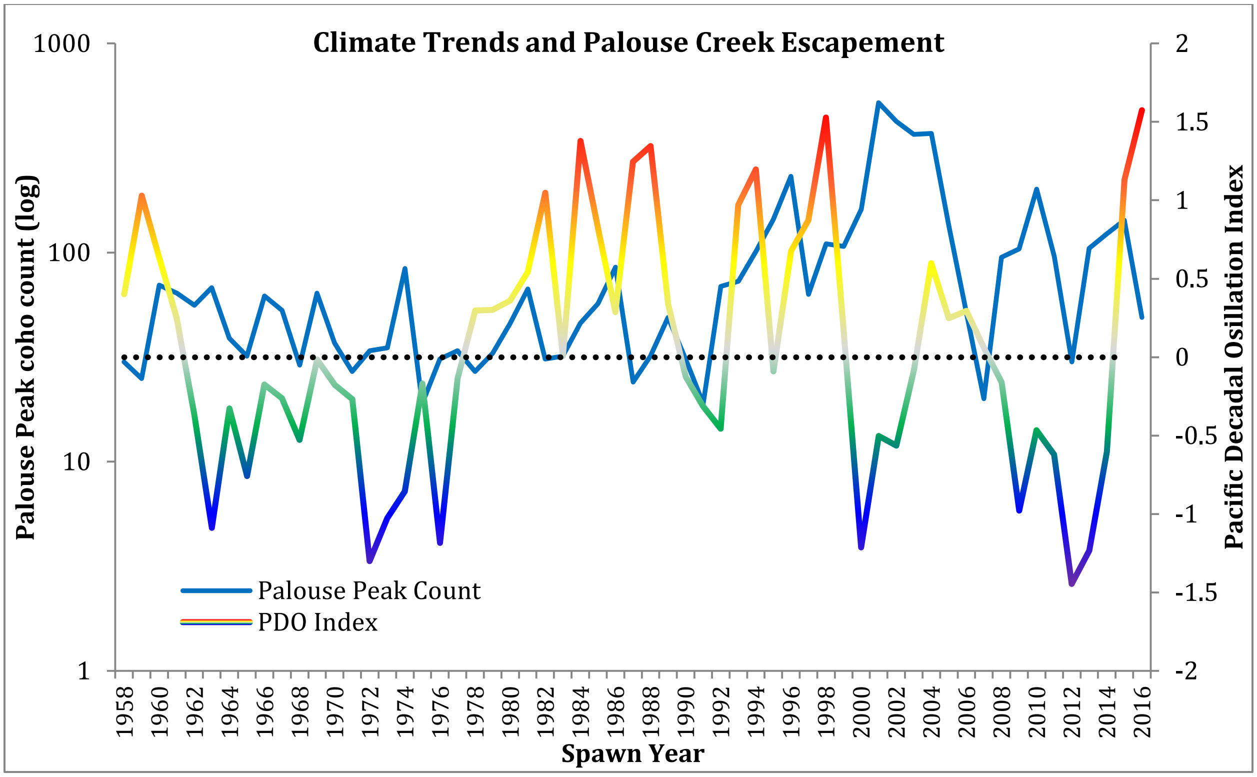


Figure 6. Palouse escapement and the PDO

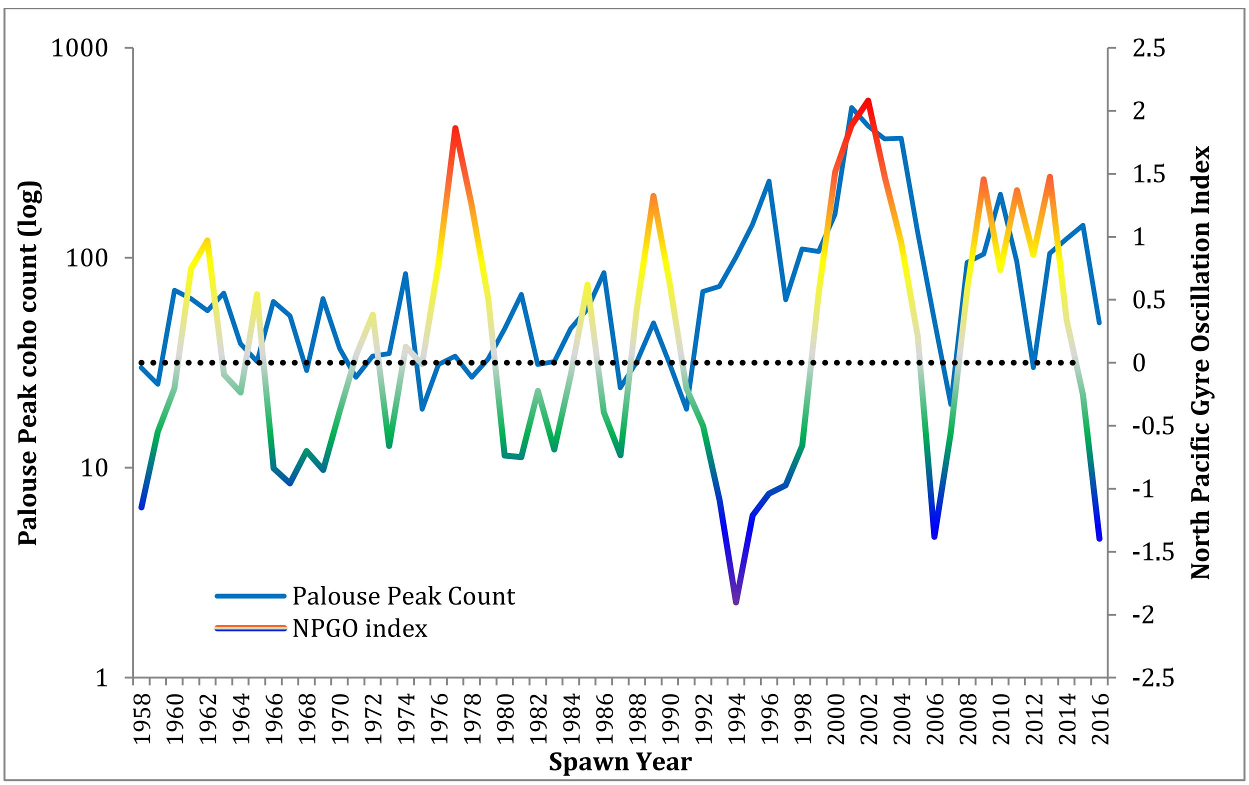
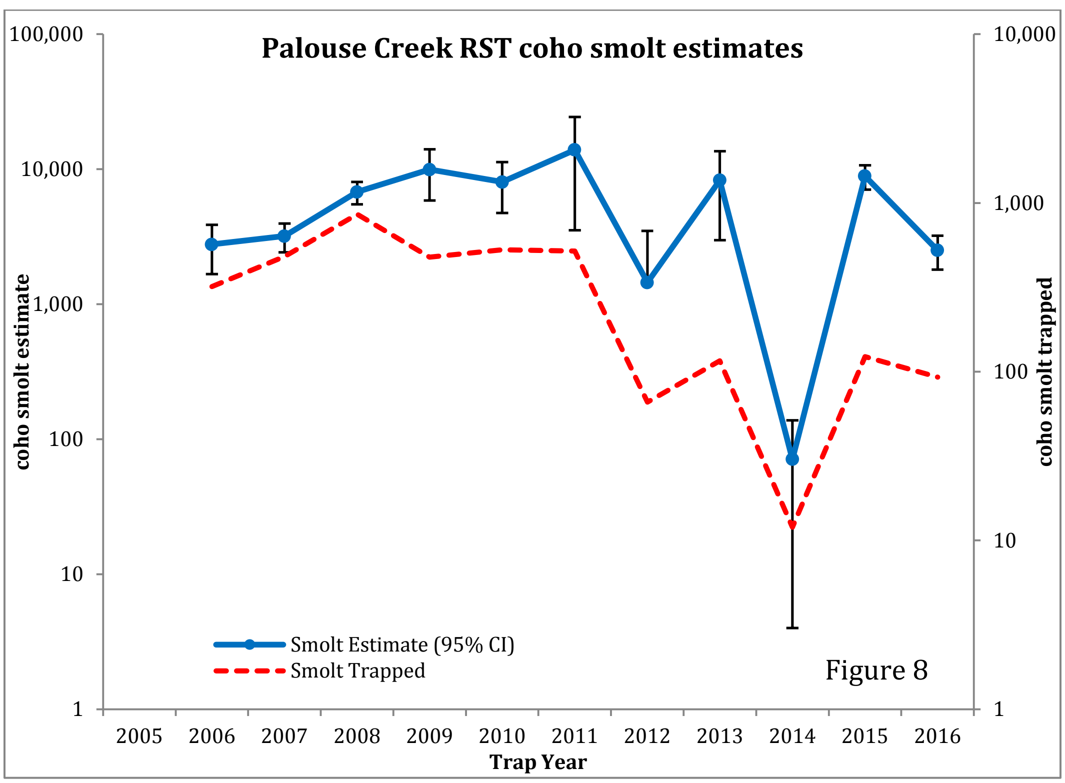


Figure 7. Palouse escapement and the NPGO

Smolt Outmigration.

Estimates of abundance of coho smolt populations are based on capture of downstream migrant fish at rotary screw traps (RST) operated on Palouse and Willanch Creeks. The rotary screw traps were located downstream of most 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 7 days and allowed for identification when recaptured. Smolt and parr salmonids >=65mm were PIT tagged and identified by 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.

RST efficiency was calculated for each trap on a weekly basis and seasonal outmigrant smolt population estimates were calculated by adjusting weekly captures 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 8 and 9). Screw trapping was suspended during high water events due to the danger posed to fish held in the trap. Catch estimates were calculated for days the trap did not operate by averaging catch from prior and subsequent days of operation.



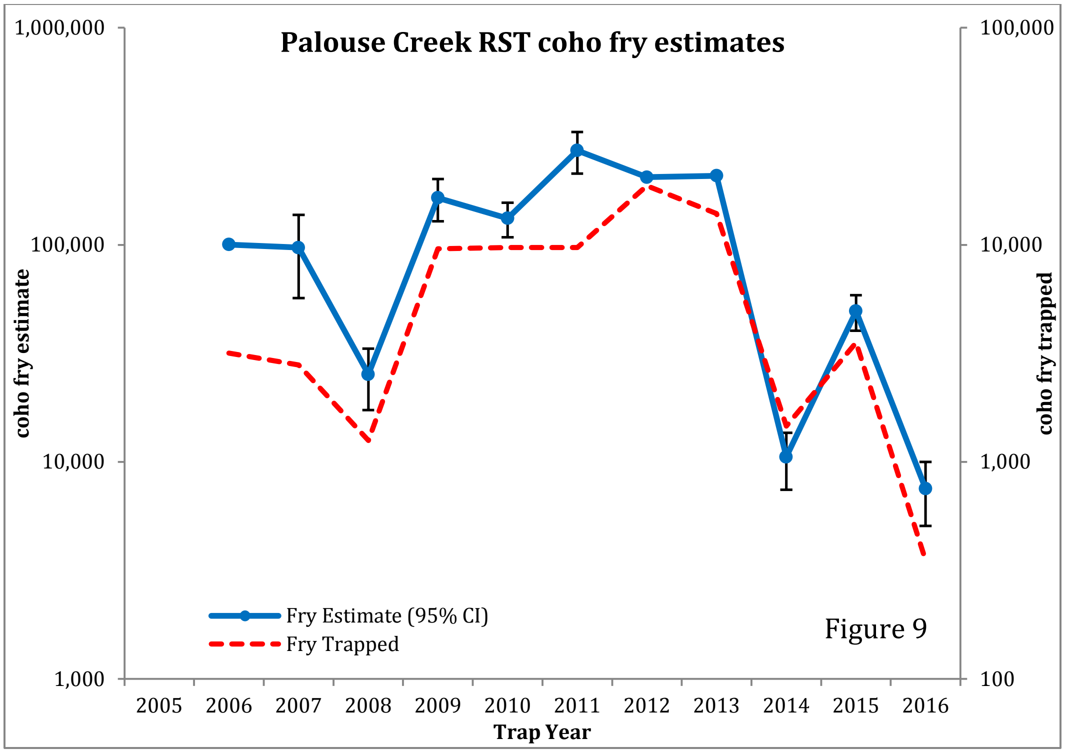


Figure 8-9. Palouse Creek rotary screw trap coho smolt and fry catch (dashed red line) and abundance estimates (solid blue lines) with 95% confidence intervals (black bars). Note variable log scale on y axes for scale

Both smolt and fry estimates for Palouse Creek were lower than 2015 and 2016, with the fry estimate being the lowest of the study period. Willanch Creek juvenile coho estimates were both higher in 2016 than in 2015. (Figure 9).

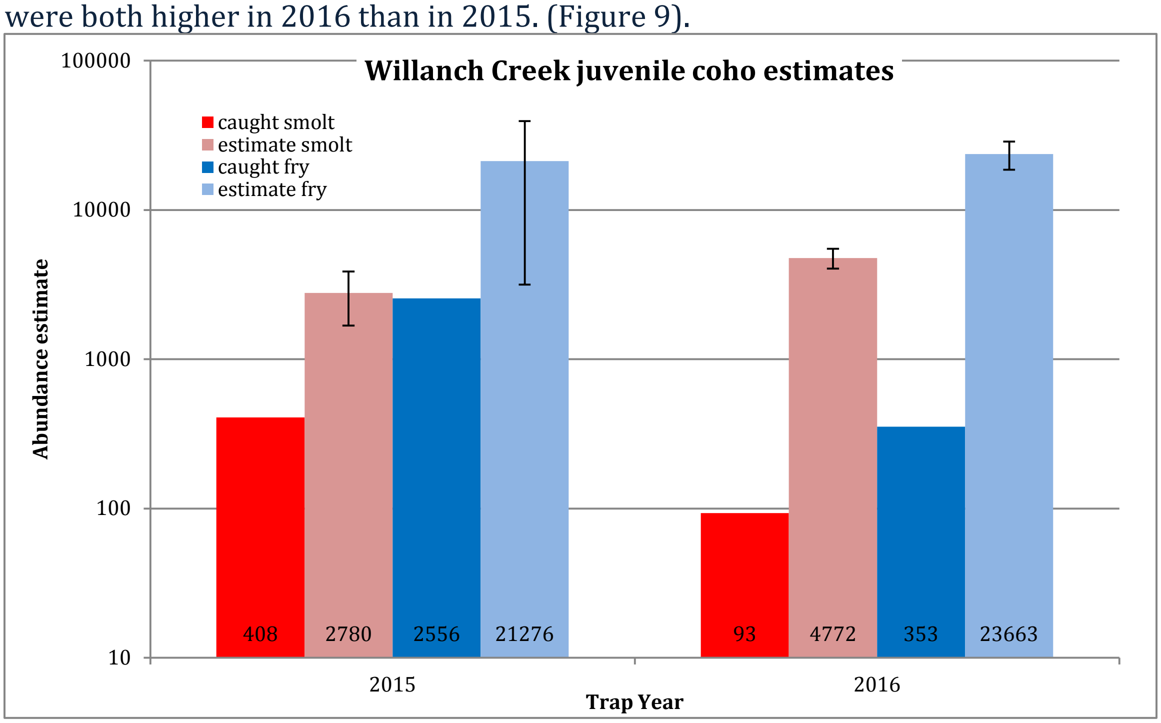


Figure 9. Willanch Creek juvenile coho population estimates

Freshwater and Marine Survival Estimates

Freshwater and marine coho survival rates were calculated for each brood year 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 were observed in 2015, it was assumed that the male: female ratio was 1:1 and an average length obtained from cumulative years was used. An annual average female coho fecundity rate was applied to the estimated number of female coho to predict the total egg deposition in each stream (Figure 10). 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 (Figure 11). A 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).

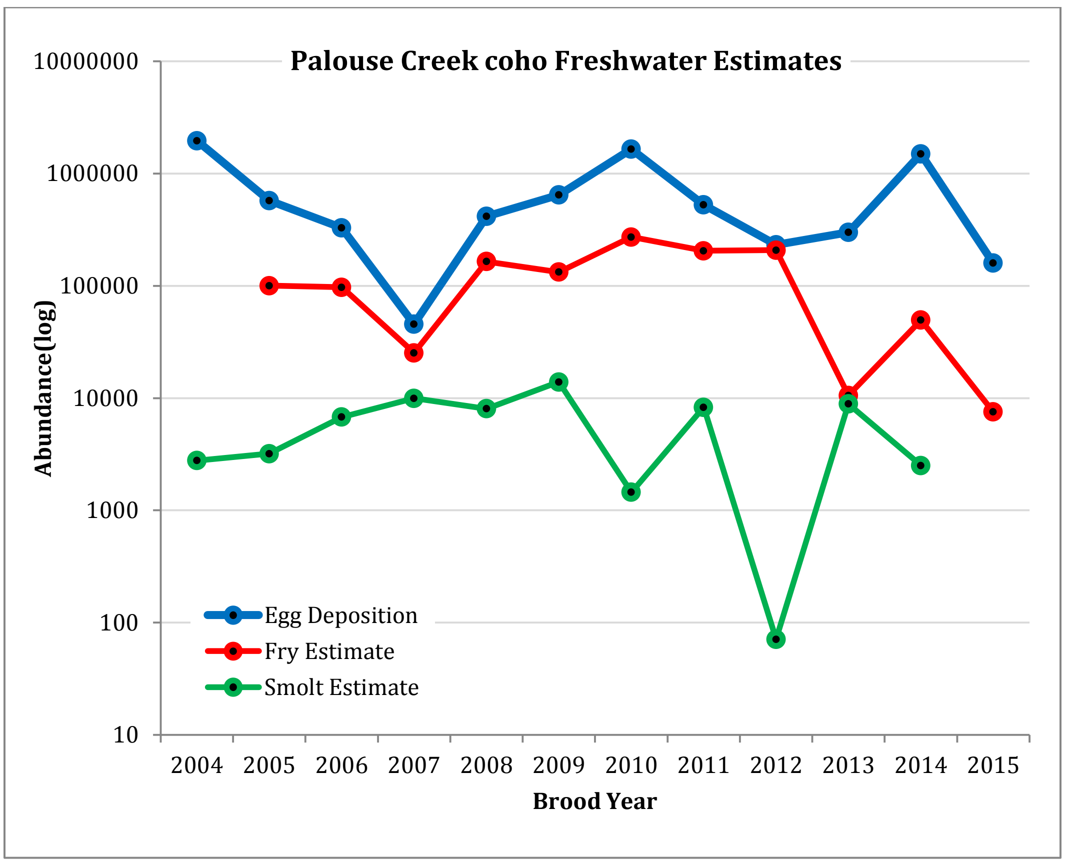


Figure 10. Abundance estimates through juvenile ontogeny for Palouse Creek coho salmon

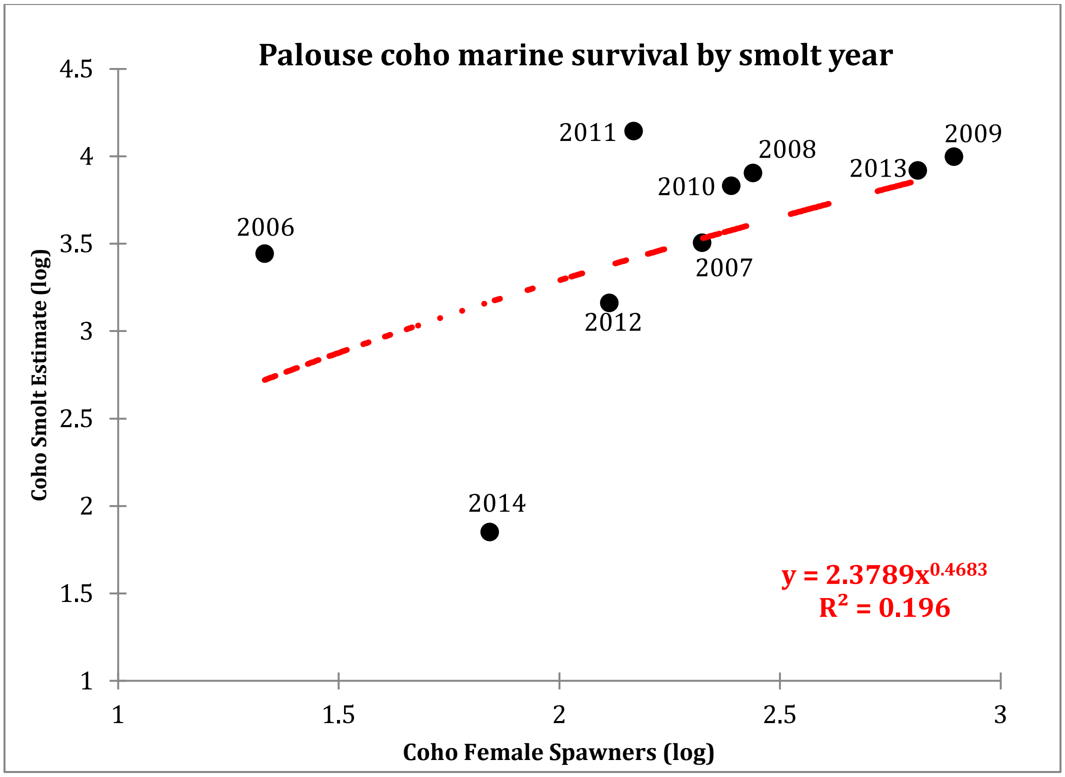


Figure 11. Marine survival by smolt year for Palouse Creek coho

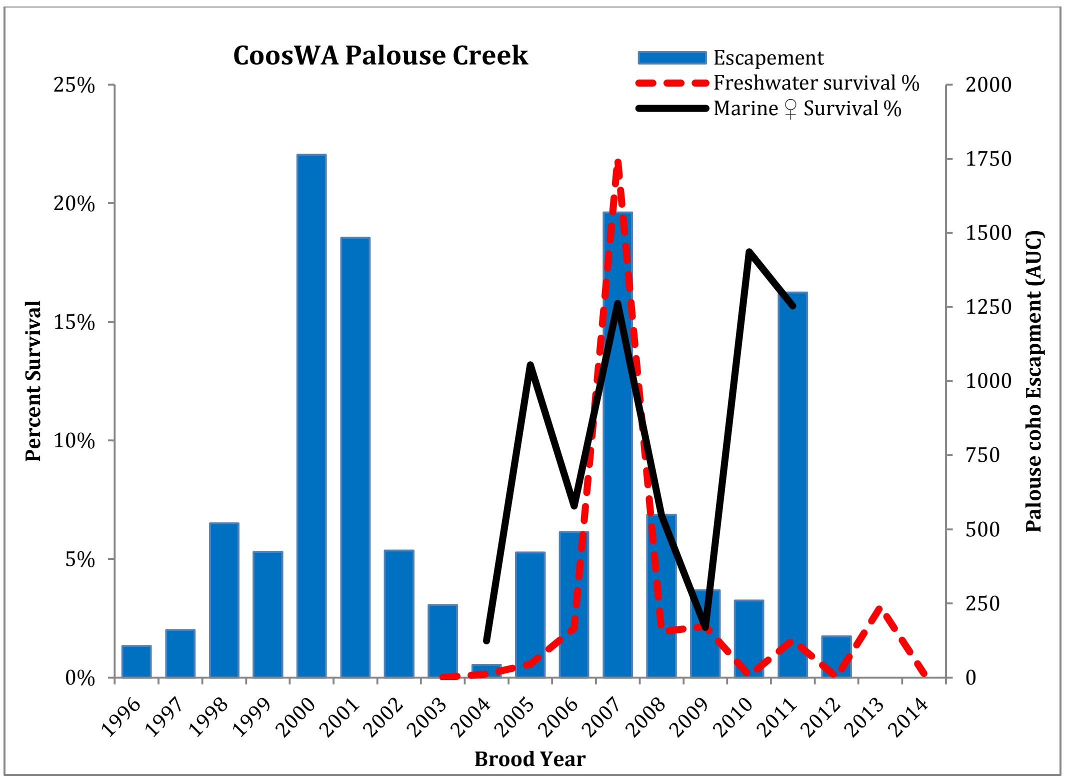


Figure 12. Annual spawning escapement estimates (blue bars), freshwater survival estimates (egg to smolt, red line) and marine survival estimates (smolt to adult, black line) for Palouse Creek. Note varying scale on Y axes.

PIT tagging

Detection and monitoring of fish movement in freshwater habitats using Passive Integrated Transponder (PIT) technology paired with mark recapture statistical analysis software 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 the ability to mark fish as small as 65 mm (fork length) with minimal effects on growth and survival (PTSC). Previous (2008-2014) CoosWA PIT mark recapture methods used Full Duplex (FDX) transponders and readers. The availability of smaller (8.5mm) tags permitted the tagging and recapture of smaller (48-60mm fork length) coho. Novel use of these 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. The lack of effective marking options and the highly dynamic tidal floodplain continues to be a primary challenge to rigorously investigate this phenomenon (Conrad et al. 2016).

The conversion to Half Duplex (HDX) transponders and readers has permitted the development of larger antennas (figure eight designs) and greater read ranges (approximating 23mm FDX tags). Conversion to this technology increases 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 expected 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 largely overcome the salt water attenuation of antenna amperage and read range. Development of snorkel wands and larger mobile antennas is still currently in development and will expand the spatial scope and temporal frequency of habitats in which tagged fish can be efficiently recaptured. Incorporating mobile passive recapture methods into the sampling design generates a more robust data set for 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 were installed in 2015 (Table1). Willanch Creek resights were not available until the spring of 2016. Active recapture, physical catch, rates for Palouse and Willanch Creek were 19% and 14%. These data provide for growth as well as survival estimates. HDX PIT capture and resight datasets from 2015 and 2016 have been through QA/QC and are being assimilated with prior FDX datasets into a unified Access relational database. This process will provide for comprehensive queries that will be analyzed for growth, survival, and movement patterns across time and space. A fuller analysis of the previous FDX mark recapture data set is now in review and publication is eminent. CoosWA will work closely with Dr. Guillermo Giannico and others at OSU Fish and Wildlife to both replicate these results for the full study period and further refine statistical strategies for the time series data at tide gates to address specific questions of interest.

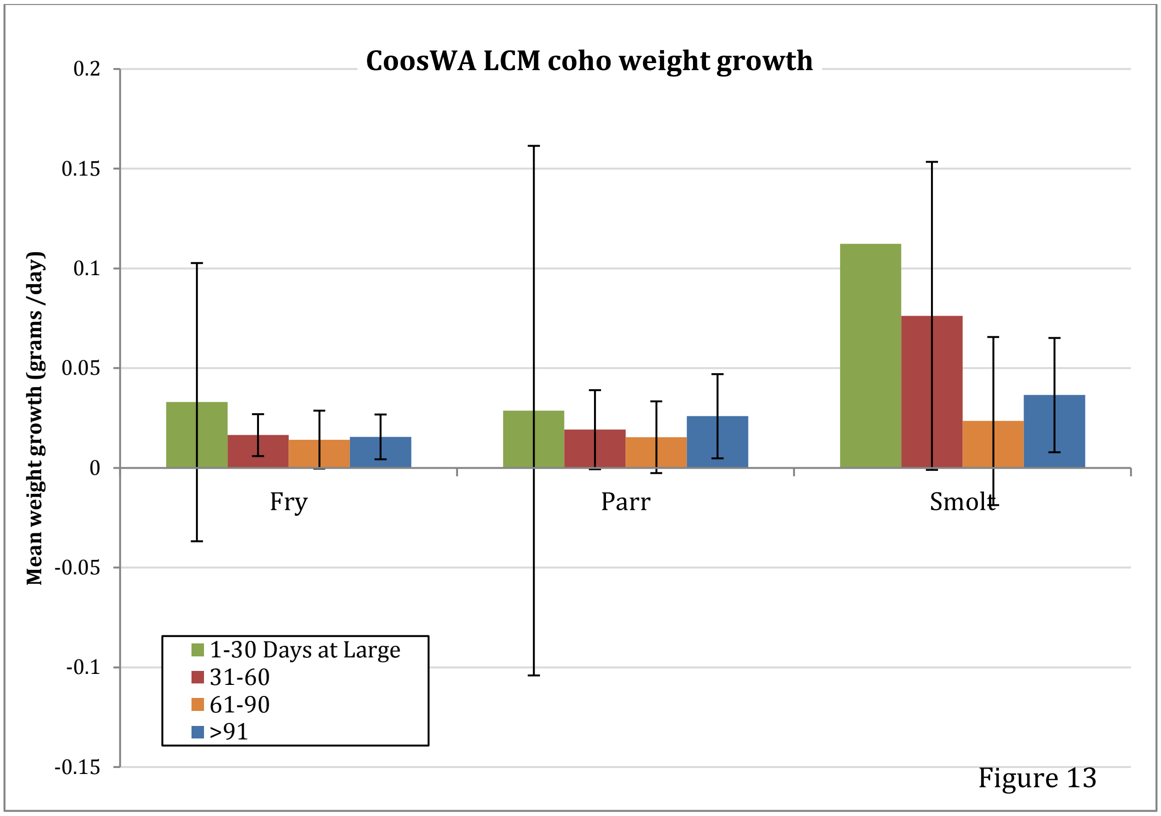
Coho growth analysis (Figures 13 and 14) indicate patterns observed elsewhere for PIT tagged salmon. Standard deviations of growth under 30 days at large (DAL) are highly variable directly related to the range of variation of error in measurements between samplers and the precision of instrumentation (0.1 g). Parr growth beyond the 30 day window shows a reduction then recovery of growth rates in both length and weight. These results closely match analogous growth and survival analysis done on Chinook salmon in the Entail River of Washington state (Ward et al. 2015). Fry data are solely from previous FDX efforts and smolt results are highly variable due to a greatly reduced sample size due to their inclination to emigrate to the estuary and ocean.

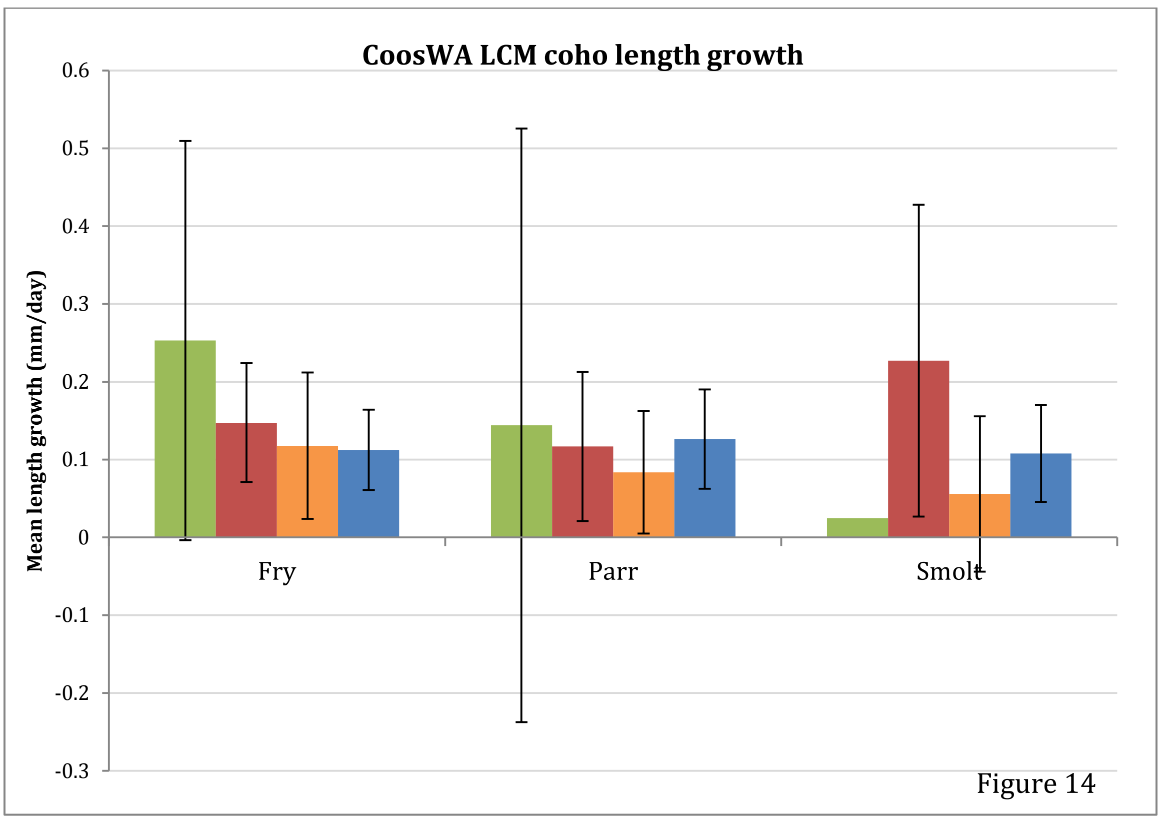
Stream Tagged	Species	Passive HDX Antenna Resight Location					Total	Resight %
		Palouse Reach 2	Palouse Reach 3	Willanch Reach 1	Willanch Reach 2	Not Resighted		
Palouse	COH	300	320			602	1169	53.0%
	CUTT	25	18			37	80	53.8%
	RBT	5	6			25	36	30.6%
Palouse Total		**330**	**344**			**664**	**1285**	**52.5%**
Willanch	COH	**4**	**2**	2	4	869	881	1.4%
	CUTT			2	7	483	492	1.8%
	RBT				9	186	195	4.6%
	CHI			1		2	3	33.3%
Willanch Total		**4**	**2**	**5**	**20**	**1540**	**1571**	**2.0%**
Larson	COH					41	41	0.0%
	CHI					1	1	0.0%
Larson Total						42	42	0.0%
Total		**334**	**346**	**5**	**20**	**2151**	**2856**	**24.7%**

Table 1

Stream Tagged	Species	Active Recapture Rate			Total	Recapture %
		Unknown*	Recap	Tag event		
Palouse	COH	2	235	939	1176	20.2%
	CUTT		6	56	62	9.7%
	RBT		1	34	35	2.9%
Palouse Total		**2**	**242**	**1029**	**1273**	**19.2%**
Willanch	COH	2	144	737	883	16.5%
	CUTT	2	43	304	349	12.9%
	RBT		16	156	172	9.3%
	CHI			3	3	0.0%
Willanch Total		**4**	**203**	**1200**	**1407**	**14.7%**
Larson	CHI			1	1	0.0%
	COH			41	41	0.0%
Larson Total				42	42	0.0%
Total		**6**	**445**	**2176**	**2722**	**16.6%**
		* possible tag loss				0.22%

Table 2





Figures 13 and 14. Growth in weight and length by life stage at 30 day intervals between initial capture and recapture (Days at Large)

Systematic integration of previous and current data sets will require further QA/QC by rectifying OSU datasets and dataframes with the HDX database. Merging FDX and HDX mark recapture databases will provide vital replication of previous efforts and attempt to further quantify the relative significance of tidal rearing on the productivity and sustainability of coho populations in tidally influenced streams. Results will inform restoration strategies for lowland tidal areas that have been identified as critical for these populations but present substantial challenges by their nature and construct.

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 through the complex, dendritic layout of marshes and floodplains (Odum et al. 1995, Day et al. 2000). Current conditions are largely simplified through channel straightening, dikes and gates that intentionally function to isolate floodplains from the stream channel.

Contemporary investigations into the proximal causal effects of increases in coho growth rates, size, and overwinter survival rates observed in early estuarine rearing individuals indicate 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). Further investigations of fish diet as a means to understand fitness and survival of early estuarine rearing juvenile coho will more fully characterize the complexity of early life history developmental strategies (Gray et al. 2002, Maier and Simenstad 2009, Daly et al. 2010).

Project Changes

The changes in this project from the original proposal resulted from several factors including change in personnel, change in study site, change in equipment prices, and change in sampling methodology.

As project manager, CoosWA Monitoring Coordinator began work shortly before the beginning of this project and after the proposal had been drafted and accepted. Proposed actions were largely based on replicating previous project efforts (OWEB grant 208-2098) in order to supplement datasets that have presented challenges in analysis. Sampling design for this iteration of the LCM project focused on two strategies, the first being to increase in season replication at sample sites in order to generate data for more robust growth and survival analysis, and to converge on a temporally and spatially balanced sample design that captured sufficient sample size and replication to produce a dataset that can provide growth, survival and migratory information at stream reach and population levels. In this effort reach designations were simplified and RST tagging efforts were expanded.

The switch to Willanch Creek from Larson Creek was necessitated by the denial of access by a primary landowner in the Larson Creek basin. Prior sampling in the stream reaches affected was limited to spring RST sampling and the lack of any seining sample effort is a major cause of the challenges in analysis previously mentioned above. Likewise the denial of access to the lower portions of Sullivan Creek in the Larson basin confounded spawning escapement estimates to an unknown degree. 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 and Larson Creeks track very closely, especially since AUC estimates have been added (2002). However, spawning surveys were conducted in Willanch Creek (2002-2005) following ODFW protocols with delineated reaches and segments that were replicated for this project in 2015. These years were relatively very productive and so provide a useful comparison for contemporary estimates. Additionally, ODFW conducted spawning surveys on two larger segments that together encompass the lower 3 Rkm (half of total) of the spawning area in Willanch Creek. These seven surveys were conducted in years prior (1995-2002) to CoosWA survey efforts (2002-2005) and therefore provide more historical data for trend analysis.

Increases in price for the HDX multiplexer readers and accumulation of unforeseen smaller expenses limited reader purchases to four. Originally six sites were expected to be setup with autonomous antenna arrays in order to replicate previous efforts and permit the use of closed population modeling and analysis. Previous stream reach delineation was based on habitat characteristics but was not spatially balanced within and between streams. HDX PIT antenna array placement for this project was selected to coincide with RST installations and delineate upper (spawning) middle (rearing/migration) and lower (tidal) reaches. Palouse Creek tide gate is both wide and deep and poses extreme challenges for antenna placement and durability (Bass 2010). Upper Willanch reaches are largely in corporate timber ownership and very shaded with riparian tree cover. These issues have thus far been impediments to deploying a third antenna array in each study stream.

<u>Public Awareness</u>

This biennium of the LCM project has produced a much closer working relationship with CoosWA outreach and education program. 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 solidify strong partnerships with South Western Community College's (SWOCC) new natural resource degree and

Oregon Institute of Marine Biology (OIMB) undergraduate programs. CoosWA's LCM project recruited two SWOCC students and two OIMB students for a total of six academic terms. 12 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 run time of adult and juvenile coho in order to expose community members to salmon in their environment. Although no specific media coverage was involved, CoosWA closely collaborates with local ODFW, SSNER, BLM and OIMB to coordinate community events and share resources to provide opportunity to explore the shared restoration and monitoring work in the Coos River Basin. Of note the LCM project cooperated with BLM and USFS to sponsor two AFS Hutton interns in the summer of 2015 and 2016. These high school students were fully immersed in the monitoring work of the 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.

Lessons Learned

Rebuilding the RFID mark-recapture infrastructure of the project was challenging and numerous unforeseen issues and expenses arose. Specifically the transition from FDX to HDX RFID technology required more testing and development effort than was anticipated in the proposal. These issues led to delays in deployment of antenna arrays and adjustments in situ. HDX PIT antenna designs and installations were developed from 10+ years of experience building in stream antennas and through collaboration with ODFW, OSU, and other groups including electricians and pipe fabricators in the Coos Bay area. Tidal reaches and especially tide gate structures experience a very dynamic range of environmental conditions that requires. Vandalism has not been a problem but a few items have been stolen at antenna sites. Implementing projects in locations with high public exposure requires these additional considerations.

Recommendations

Hiding, camouflaging, anchoring and locking equipment as solidly as possible adds expense and effort but should be explicitly included in proposals and budgets, especially when expensive equipment is utilized.

In as much as possible, monitoring infrastructure placed in the wetted channel of streams, especially in tidal areas, should be anchored with compensatory strength for durability through maximum high water events

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