Coho Life History in Tide Gated Lowland Coastal Streams
OWEB Grant 212-2044
Project Completion Report

Submitted by

Coos Watershed Association

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Project Summary

Coos Watershed Association's (CoosWA) coho Life Cycle Monitoring Project (LCM) is a continuation of a long-term monitoring study initiated in 2004 to examine coho salmon abundance, survival, life histories and habitat use in two tide gated coastal lowland streams, Larson and Palouse Creeks. Productive utilization of these remarkable habitat types is critical for the recovery and sustainability of Oregon Coastal coho. Specifically, this project developed, and adapted innovative mark recapture techniques using PIT tags to monitor the coho life cycle, further evaluated over-winter rearing strategies in relation to temporal and spatial habitat use and continued project effectiveness monitoring in these study streams. In addition, coho diet analyses were designed and conducted and will be analyzed in relation to seasonal and diurnal variations in environmental factors in order to assess proximal causes of habitat productivity.

Background

Study Area.

Palouse and Larson Creeks are two third order lowland streams that flow into Haynes inlet, the northern most portion of the estuary in Coos Bay, Oregon (Figure 1). Each stream is tide gated at its confluence with the Coos Bay estuary along the dike that supports North Bay Road. Palouse Creek is controlled by two top-hinged gates and Larson Creek has two side-hinged gates. Palouse Creek is 14.6 km long, and has a natural barrier to coho at river kilometer (RKm) 12.1. The Larson Creek mainstem is 12.9 km in length. The approximate catchment area of both sub-basins is 28 km^2 and the monthly streamflow averages less than 0.1 m^3/s during late summer to ≥19 m^3/s during winter bankfull events (CoosWA 2006).

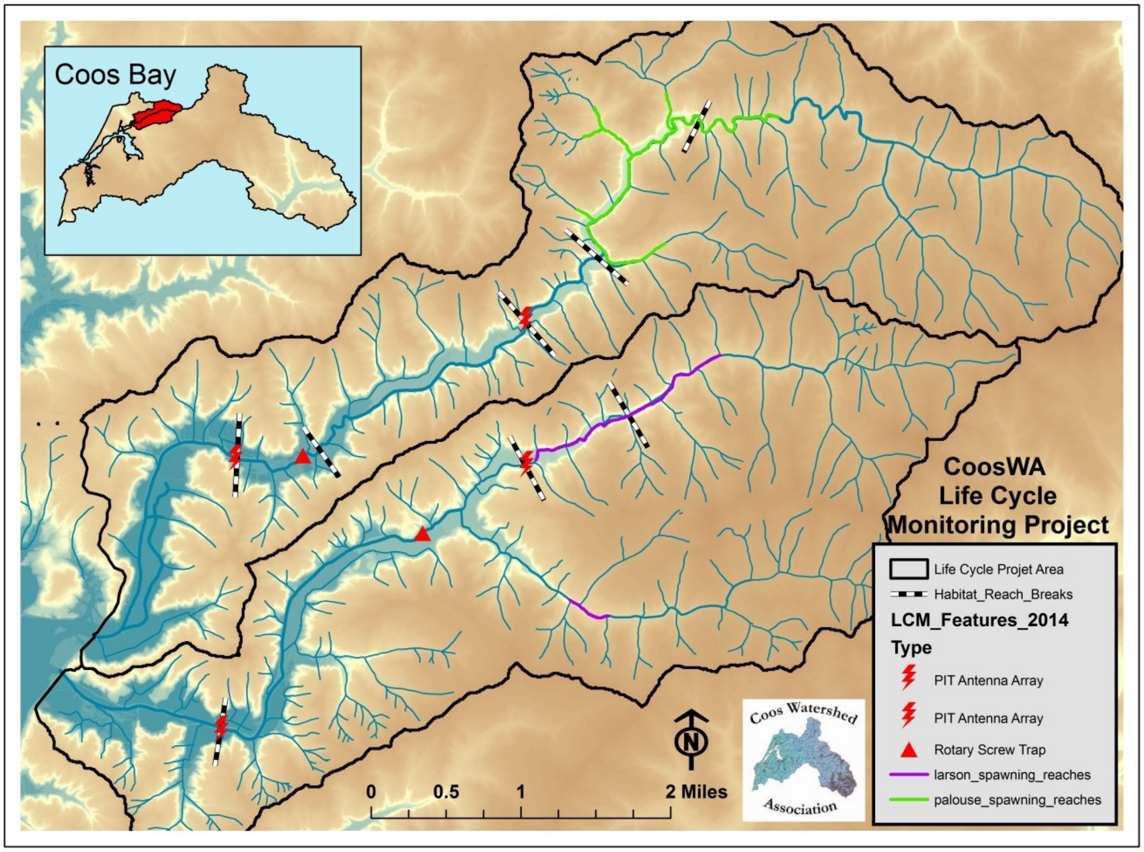


Figure 1. Coos Watershed Association Life Cycle Monitoring Project study area. Habitat reach breaks, PIT arrays, rotary screw traps, and spawning reaches (Palouse in green Larson in purple)

Tide Gate Research.

Coastal lowland streams such as Larson and Palouse Creeks are known to be productive juvenile coho salmon nursery areas as a result of a diversity of low to moderate gradient 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). Alteration of lowland areas is ubiquitous throughout the range of coho salmon due to diking, tide gating and landfill (Giannico and Souder 2005). Tide gates are commonly installed in coastal dikes to control the influence of tidal fluctuations on lowland areas, and typically affect stream hydrology and water quality conditions upstream of the gate by impounding streamflow during closed gate periods (i.e., high tidal cycles). These altered areas upstream of tide gates often experience increased temperature due to stagnant streamflow and highly variable levels of salinity resulting from tide gate seepage (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 ecology of salmonids in the reservoirs of these coastal lowland study streams is not well understood. Prey abundance and diversity in relation to tidal and salinity variation has been shown to be dynamic but seasonal and diurnal variation of consumption by coho has not been explicitly examined (Eaton 2010). The research focus of this this grant, OWEB 212-2044, was to further elucidate the effects of these habitat characteristics on juvenile coho ontogeny.

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 adult fish passage structures. Life Cycle Monitoring efforts conducted by CoosWA in Palouse and Larson subbasins is intended to broaden the scope of Oregon Plan projects by including tide gated lowland habitats that represent an important, yet indeterminate, component of coho production on the Oregon Coast.

Adult Spawner Recruits.

For the period of monitoring from 2004 – 2014 adult coho spawner populations in Palouse and Larson Creeks were sampled and monitored during spawning periods in late fall and winter using systematic spawner surveys conducted on seven-ten day rotations. Surveys in each sub-basin covered all known and accessible spawning areas. Sections of the Larson Creek mainstem and its main tributary, Sullivan Creek, were not surveyed due to lack of landowner access permission (Figure 1). Adult coho population sizes in the Palouse and Larson 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). All coho carcasses were categorized by gender and size (adult vs jack), measured and scanned for the presence of PIT tags during spawning surveys. No PIT tags were recovered from coho carcasses during the 2013 or 2014 spawning seasons.

Smolt Outmigration.

The abundance of coho smolt populations was estimated based on capture of downstream migrant fish at rotary screw traps (RST) operated on Palouse and Larson Creeks. The rotary screw traps were located downstream of most spawning and rearing areas 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 were also recorded using ODFW protocols. Fish captured each day at the Palouse and Larson screw traps were enumerated and a subsample of captured salmonids were measured for length and marked with a caudal fin clip. A maximum of 25 individuals of each salmonid species and age-class were measured, marked and released upstream of the screw trap.

Screw trap efficiency was calculated for each trap on a weekly basis and outmigrant smolt population estimates were calculated by extrapolating weekly captures totals based on weekly trap efficiency estimates. Variance and confidence intervals were calculated for yearly smolt population estimates using a bootstrap procedure with 1,000 iterations per calculation (Thedinga et al. 1994). 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 the surrounding days of operation.

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 total abundance estimates. The number and average fork length of female spawners was derived from sampled carcasses in 2014, and since few carcasses were observed in 2013, it was assumed that the male: female ratio was 1:1 and an average length obtained from cumulative years was used. An average female coho fecundity rate was applied to the estimated number of female coho to predict the total egg deposition in each stream. 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. A coho brood year represents the first year eggs are deposited during the winter spawning period by adult fish (e.g., 2012 brood year coho were derived from adult coho spawning during winter 2012-13, hatched in winter/spring 2013, and emigrated as age-1 smolts in spring 2014).

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. Previous (2008-2014) CoosWA PIT mark recapture methods used Full Duplex 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 severely reduce the detection probability of fish with these tags. 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 was confounded by the very poor recapture rate of these tags.

Half Duplex versions of transponders and readers allow for larger antennas (figure eight designs) and greater read ranges (approximating 23mm FDX tags). Conversion to this technology in 2015 will increase the efficacy of our 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. HDX tools provide for greater read ranges induced by higher voltages that will hopefully overcome a significant portion of the salt water attenuation of the read range in these and brackish estuary habitats. Four multiplexor HDX readers were purchased with this grant and will be deployed for the 2015 season. Development of snorkel wands and larger mobile antennas will expand the spatial scope and temporal frequency of habitats in which tagged fish can be quantitatively recaptured. Incorporating mobile passive recapture methods into the sampling design generates a more robust data set for survival analyses in programs, such as MARK, and a reference for calibration of sampling efficiencies across methods: rotary screw trap, seine, electrofish, etc (White and Burnham 1999).

Amendment 13 to the Pacific Marine Fishery Council's (PMFC) *Pacific Salmon Plan: Fishery Management Regime to Ensure Protection and Rebuilding of Oregon Coastal Natural Coho* (1999) sets harvest impacts on coastal coho using an adult spawning return model based on the brood year's jack returns the previous year. Recent technical revisions switched smolt-jack-adult survival metrics from Columbia River hatchery coho salmon to ODFW's Mill Creek life cycle site, in the Yaquina basin. Since 2010, in an effort to add additional sites to provide replication of natural origin coho jack returns, CoosWA sought to utilize the existing PIT arrays to recapture the tagged population of jacks and adults as they return to spawn (Table 1). Individual carcasses are also scanned to recapture tags during spawning surveys. Reported basin wide antenna efficiency of 99.97% in 2010, facilitated the recapture of 83 (140 total – 57 juveniles) PIT tagged adult or jack salmon returning to antenna arrays in Palouse creek (Table 2). In 2010 the mark-recapture estimate for the Palouse sub-basin was 1,027 coho. The estimate from traditional AUC (adjusted) methods from spawning surveys was 1,569 coho.

Table 1. PIT tagged juvenile coho by subbasin and brood year(Tagged), returns of adult and jack coho PIT tagged as juveniles (Returned), and the rate of return of PIT tagged juveniles(% Return).

Subbasin	Brood Year	Tagged (n)	Returned (n)	% Return
Larson Creek	2007	657	19	2.89%
	2008	620	3	0.48%
	2009	394	1	0.25%
	2010	655	4	0.61%
Palouse Creek	2007	1934	80	4.14%
	2008	3390	21	0.62%
	2009	1113	10	0.90%
	2010	291	3	1.03%

Table 2. Inter (red) and intra annual recaptures of CoosWA PIT juvenile coho (2009-2014).

	recapture year						
tag year	2009	2010	2011	2012	2013	2014	Total
2008	11						11
2009	1058	140					1198
2010		341					341
2011			38	3			41
2012				3			3
2013					75		75
2014						2	2
Total	1069	481	38	6	75	2	1671

Mark recapture estimates for 2010 were possible due to previous years tagging efforts (2008-09) which were much more substantial than subsequent years to date (Table 3). The range of PIT tagged juvenile coho needed to return a sample of jack salmon the following year was examined in order to quantify the number of coho smolts that need to be tagged in order to return a sufficient sample of PIT tagged jack salmon the following year. Power analysis based on ODFW Mill Creek LCM data dating back to 1998 suggests that smolt to jack ratios can be predicted based on PIT mark-recapture methods only in years with above average marine survival (Figure 2). Jack marine survival below the mean of 4% (green line) would on average require more than 5000 smolts to be tagged to return a sufficient recapture sample for statistically significant estimates greater than 50% of the time (power). However, as evidenced by previous

CoosWA tagging efforts (2008-9 brood years, Table 1) jack marine survival in the upper range (> 7%, red line) would require approximately 3000 smolts to be PIT tagged for a sufficient recapture sample for statistically significant estimates greater than 80% of the time. Years with high marine survival (≥ 10%, black line) 1500 tagged smolts would return a sufficient recapture sample for statistically significant estimates greater than 80% of the time. For the study period at Mill Creek Yaquina River, marine survival was >4.6% 5 of 16 years and <3.5% for 6 of the 16 years (Figure 3). Linear regression of jack returns based on number of coho PIT tagged (all size classes) validate these sample size projection with 14 tagged jacks predicted to return and be recaptured with a tagged sample of 4000 juveniles (Figure 4). Table 2 reveals the realized abundance and return rate of PIT tagged jack coho salmon to CoosWA study streams and the varying magnitude of the effects of marine survival.

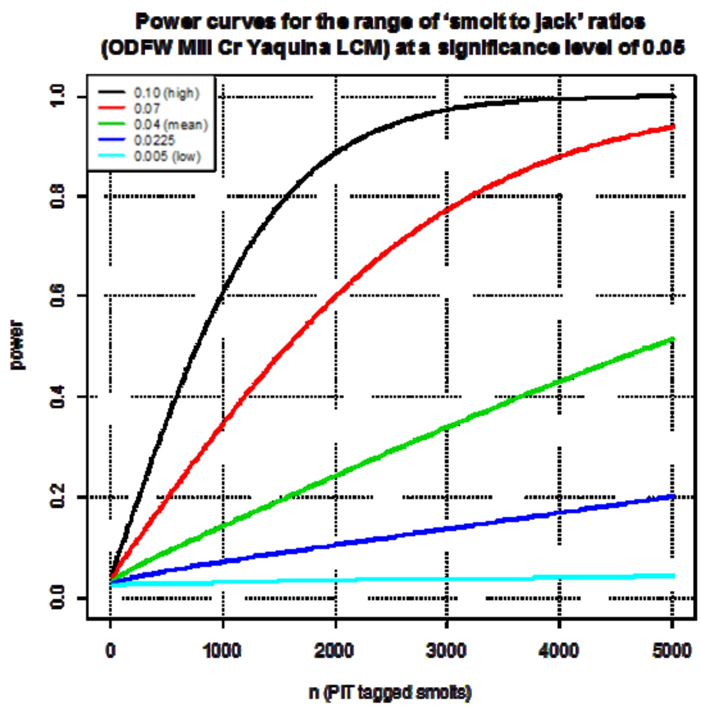


Figure 2. Power analysis of PIT tagged smolt to jack ratio. Colored power curves represent the range of smolt to jack ratios (marine survival) at ODFW Mill Creek Yaquina LCM site from 1998-2013 (see figure legend). Significance criterion (α, Type 1 error) is set at 0.05 conventionally and n is the predicted sample size of smolts that need to be PIT tagged to return a recaptured sample of PIT tagged jacks with the corresponding statistical power (1- β, Type 2 error).

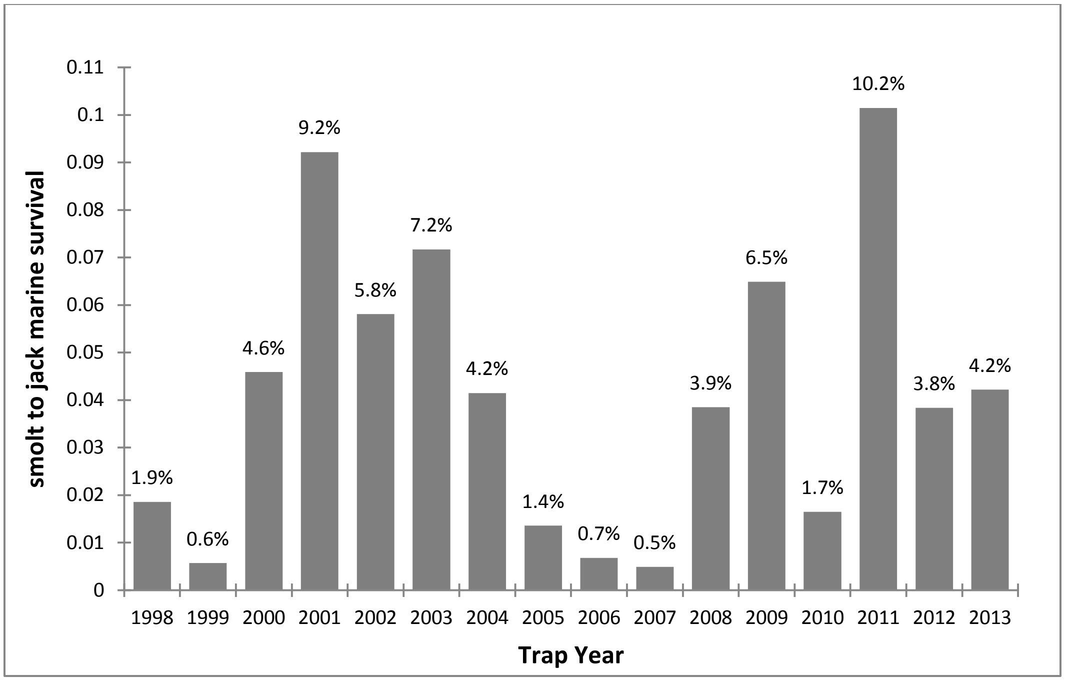


Figure 3 ODFW Mill Creek Yaquina LCM site smolt to jack ratio (marine survival) by trap year

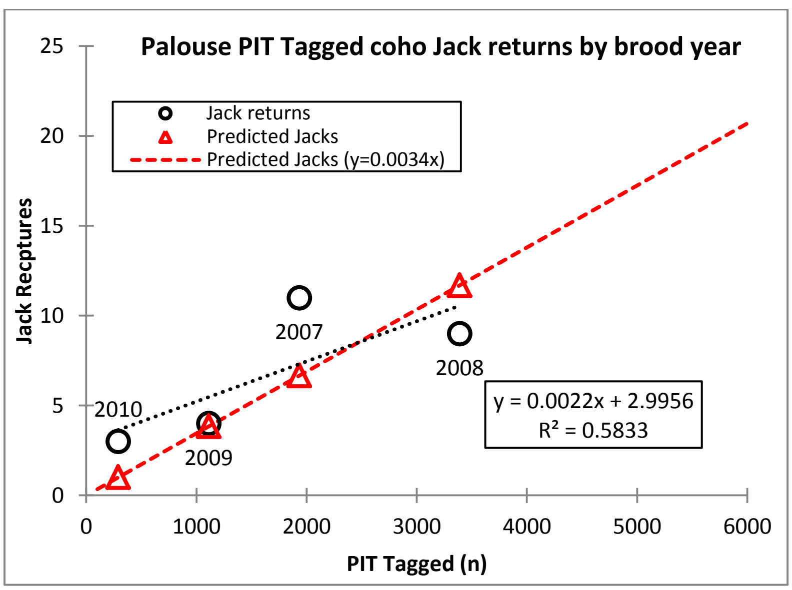


Figure 4. Jack recaptures of PIT tagged coho smolts in Palouse Creek by brood year. Jack recaptures (black circles with brood year) and linear regression of jack recaptures (black dotted line, black box) and predicted jack returns (red triangles) with linear regression forced through zero (red dashed line).

Reestablishing tagging efforts in the range of 3000 to 4000 coho per brood year such as was accomplished in 2008 and 2009 in conjunction with PIT array improvements described below will provide the dataset necessary for the high level of monitoring and analyses that will enhance coast wide ODFW efforts by providing juvenile and adult abundance and survival estimate calibration and specifically jack estimation validation.

Diet Analyses.

Previous studies of coho life history patterns in tide-gated systems of Coos Bay, Oregon (OWEB grants 207-238 and 210-2071) observed that a subset of juvenile coho, sub-yearling and yearling, opt to reside 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 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 disturbance as tidal pulses and fluctuations in seasonal freshwater input perpetually redistribute nutrients and sediments through the complex, dendritic layout of marshes and floodplains (Odum et al. 1995, Day et al. 2000).

Increases in coho growth rates, size, and overwinter survival rates were observed in early estuarine rearing individuals indicating that use of this habitat is an important life-history strategy to coho survival (Weybright 2011, Jones et al. 2014). Movement into this reach requires physiological trade-offs as individuals must adapt to increased salinities and successfully forage in waters that are often turbid. Despite the energetic demand of these trade-offs, increased growth rates in comparison to upstream counterparts 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. Using fish diet as a means to understand fitness and survival of early estuarine rearing juvenile coho will further characterize the complexity of early life history developmental strategies (Gray et al. 2002, Maier and Simenstad 2009, Daly et al. 2010).

Description

Juvenile trapping.

Rotary screw traps (RST) are passive-capture devices used for trapping fish moving downstream. The traps consist of a collection cone oriented to capture oncoming flow, an Archimedes screw that dampens the power of the water flow and transfers trapped fishes from the water stream into a live-box. The live-box retains the fish until they are processed, generally each morning. The rear wall of the live-box contains a cleaning drum that slowly rotates to remove small debris. Rotary screw traps (RST) have been a standard method for sampling salmonid smolts during outward migration. These devices capture an unknown proportion of the smolt population as they move downstream out of freshwater and into the estuary. A subset of captured fish are marked, fry are finclipped and smolts are PIT tagged, then released upstream of the

Rotary Screw Trap (RST). The proportion of tagged fish recaptured in the screw trap is an estimate of the trap capture efficiency (Macdonald and Smith 1980). The smolt migratory period has been consistent over the more than 15 years that ODFW and others have operated RSTs on the Oregon coast. A strong latitudinal gradient in coho smolt migration patterns trends toward later, shorter, and more predictable migrations with increasing latitude from California to Alaska. The populations of Oregon coast coho smolts share a regional freshwater emigration pattern despite latitudinal variability and stream types (Spence and Hall 2010). ODFW RSTs are minimally operated from early March through June with the peak of smolt emigration generally occurring in April (Miller and Sadro 2003). CoosWA has followed ODFW RST protocols, including progressive safety measures, since the inception of our trapping efforts in 2004. Recent ODFW database development will upgrade trap efficiency estimation to a Bayesian probabilistic method which will be incorporated into CoosWA methods for the 2015 trap season and applied to previous year's data at a future date (Eric Suring ODFW, personal communication).

Table 3. CoosWA PIT juvenile coho tagging efforts (2008-2014) by fork length of fish at capture.

	Tagging Year							
coho fork length (mm)	2008	2009	2010	2011	2012	2013	2014	Total
<60	498	1901	324	299	216	85		3323
60-70	435	1210	562	189	139	246	5	2786
70-80	375	513	371	98	103	95	4	1559
80-90	260	259	225	48	69	40	7	908
90-100	167	279	151	140	58	42	25	862
>100	226	802	113	292	74	52	68	1627
Total	1961	4964	1746	1066	659	560	109	11065

Rotary screw traps continuously monitor downstream movements of coho salmon subyearlings and smolts allowing for an estimate of outmigrants as well as a tagging location that is fixed but below spawning grounds where juveniles emerge. Tagging efforts were significantly curtailed due to the shift of emphasis to diet analysis.

Coho Field Study tagging and recapture efforts substantially contributed to the PIT tag dataset for the two years of work under this grant (Table 3). However, sample size of tagged fish since 2011have precluded any statistical mark recapture analysis.

Palouse Creek.

Marine survival for coho salmon in Palouse Creek is highly variable by brood year, with increasing peaks of 13% (2008), 15% (2010) and 18% (2013) bracketed by years of survival lower than 7% (2007, 2009, 2011 and 2012). Return years 2013 and 2014 have remained above 12% in marine survival (Figure 5b). Palouse Creek marine survival rates are also variable in comparison to other regional LCM sites, generally tracking the WF Smith ODFW site but peaking at much higher rates (Figure 7b). RST estimates for the 2012- 2014 seasons are highly questionable however due to the low capture rate (efficacy) at the RST (Figure 6 c and d). Decreasing capture rates, especially for smolts, resulted in less than 120 smolts captured at the Palouse RST in each of the last three years of this project. Coho smolt and fry abundance estimates for the grant period are at least an order of magnitude less than previous years (Figure 6c and d). The 95% confidence interval of the estimate of smolts for 2014 is very large and likely arbitrary due to the small sample size. These biases will also skew subsequent marine survival estimates as well. Palouse Creek coho freshwater survival rates more closely track other regional LCM sites (Figure 7a). The freshwater survival rate for coho salmon peaked in 2010 similarly to other sites but the magnitude of the peak was nearly double what was reported by ODFW for the WF Smith River LCM site (Figure 5 b and c).

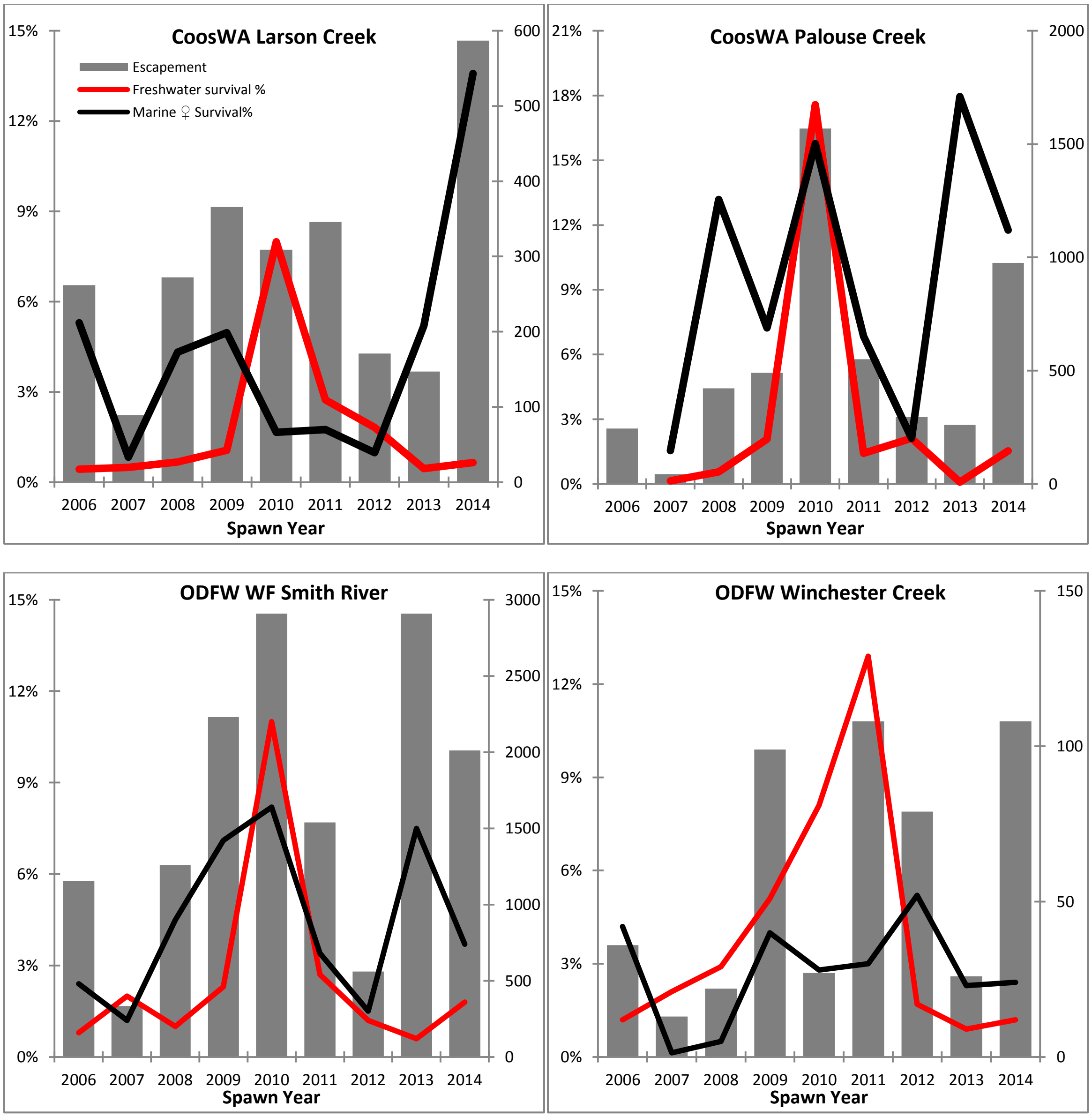


Figure 5a-d. Annual spawning escapement estimates (grey bars), freshwater survival (egg to smolt, red lines) estimates and marine survival estimates (smolt to adult, black lines) for four LCM sites in the Coos River watershed region from 2006-2014. Top two sites are operated by Coos Watershed Association and the bottom two by Oregon Dept. of Fish and Wildlife. Note varying scale on Y axes.

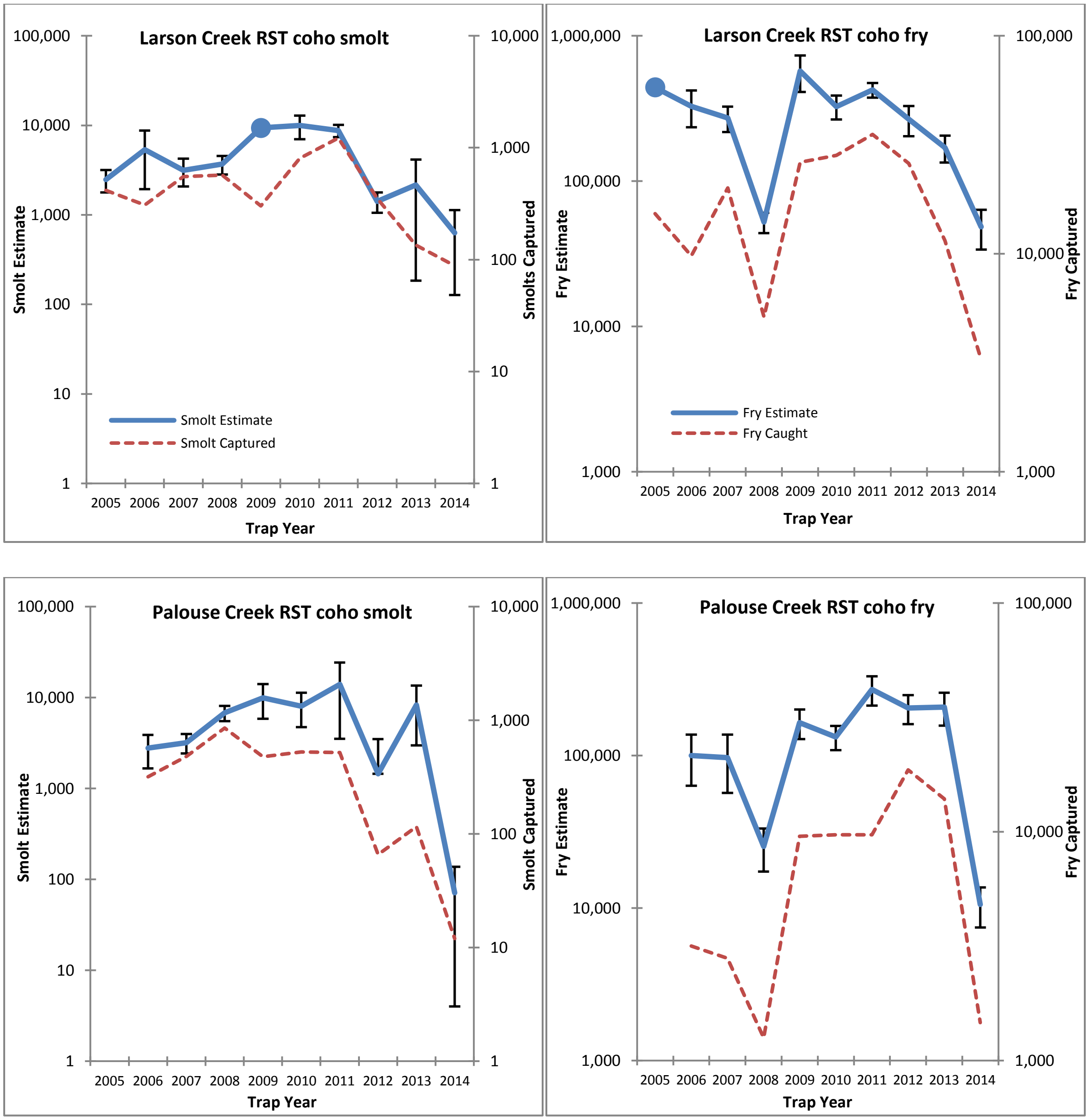
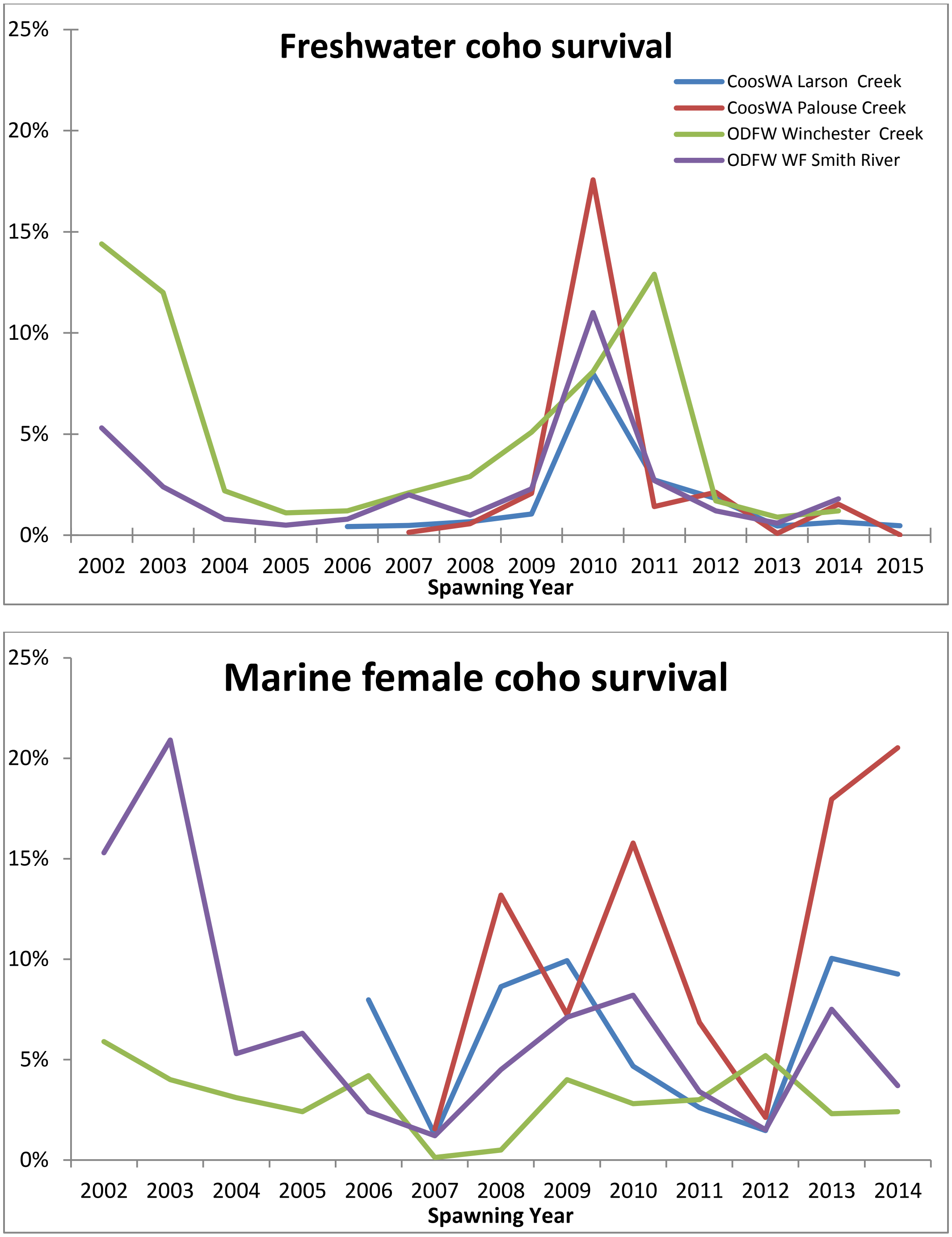


Figure 6a - d. 2005 through 2014 Larson and Palouse Creek rotary screw trap coho smolt and fry catch (dashed red line) and abundance estimates (solid blue lines) with 95% confidence intervals (black bars). Juvenile trapping was not initiated in Palouse Creek until 2006. Note variable log scale on y axes for scale.



Figures 7a and b. Survival estimates for four regional salmon Life Cycle Monitoring sites. Rotary screw trapping was initiated in 2006 for Larson Creek and 2007 for Palouse Creek. Freshwater survival is the ratio of eggs to smolts and marine survival the ratio of smolts to female adults for each brood year.

Larson Creek.

Marine survival rates for coho salmon in Larson Creek have been variable within the range of neighboring LCM sites (Figure 7b). Survival ranged between 1% and 10% at approximately 2 year intervals, generally tracking the trend at ODFW WF Smith River LCM site (Figure 5 a and c). Similarly to Palouse Creek, RST estimates for the 2012-2014 seasons are questionable due to low capture rate (efficacy) at the RST (Figure 6 a and b). Decreasing capture rates, especially for smolts, resulted in large 95% confidence intervals around the smolt estimates for 2013 and 2014. Smolt abundance estimates for the grant period are also an order of magnitude less than earlier years with larger sample sizes. Biases in these estimates will skew subsequent marine survival estimates. Freshwater survival rates more closely track the regional LCM sites (Figure 7a). The freshwater survival rate for coho salmon in Larson Creek peaked in 2010 similarly to other sites but variation reported by ODFW for the WF Smith River LCM site in other years was not captured at the Larson RST (Figure 5a and c; Figure 7a).

Diet analysis.

Identifying quality and quantity of macroinvertebrate community composition, both temporally and spatially, is a useful tool towards quantifying the capacity a habitat has to support juvenile salmonids. As existing tidal control structures need replacement, this knowledge will aid in restoration and mitigation efforts to create a habitat that best supports early estuarine life history strategies of juvenile coho salmon. Two questions will be examined: Does biomass of prey items in juvenile coho salmon diet differ between stream reaches of differing salinities within the stream-estuary ecotone? How does diet composition compare between stream reaches of differing salinities within the stream-estuary ecotone?

In addition to continued sampling in Palouse and Larson Creeks, Willanch Creek was also sampled due to accessibility and coho production. Each system was divided into three reaches: freshwater, brackish water, and bay. Brackish reaches were identified by the presence of a salinity wedge with a minimum measured salinity of 8 ppt. at depth. A distance buffer was placed between the reaches within each system to strengthen the assumption that fish captured within the reach are dietary representatives of the reach in which they were captured. Bay sites were located in either Haynes way, into which both Larson and Palouse Creeks drain, and Willanch Slough. Bay sites were only sampled at high tide to ensure high salinity levels.

Juvenile coho were sampled from each reach via seine net over the period of April 15 – July 3, 2014. Captured juvenile coho were anesthetized with tricane methanesulfonate (MS-222) and biological measurements of fork length (FL in mm) and weight (nearest 0.1 g) were recorded for each fish. Gastric lavage, commonly used for fish diet studies, was performed in the field on juvenile coho with a minimum FL of 65 mm (Hyslop 1980). A catheter was inserted through the mouth into the gastric cavity and a bottle containing water was used to gently flush the contents into a basin. The contents of the basin were poured through a coffee filter and the sample was preserved in 95% ethanol (EtOH) for laboratory analysis. Sampling continued until 20 lavage samples were procured from each reach.

The lavage samples are currently being sorted and enumerated at Oregon State University. Dietary data will be analyzed looking at the quality and quantity of prey. Prey items will be measured and through the use of linear regressions based on prey body length (mm), dry-weight biomass (mg) will be estimated (Benke et al. 1999). Niche overlap of dietary prey items will be analyzed using nonparametric multidimensional analysis with the hypothesis that there will be minimal overlap in dietary composition between different reaches (Marshall and Elliott 1997).

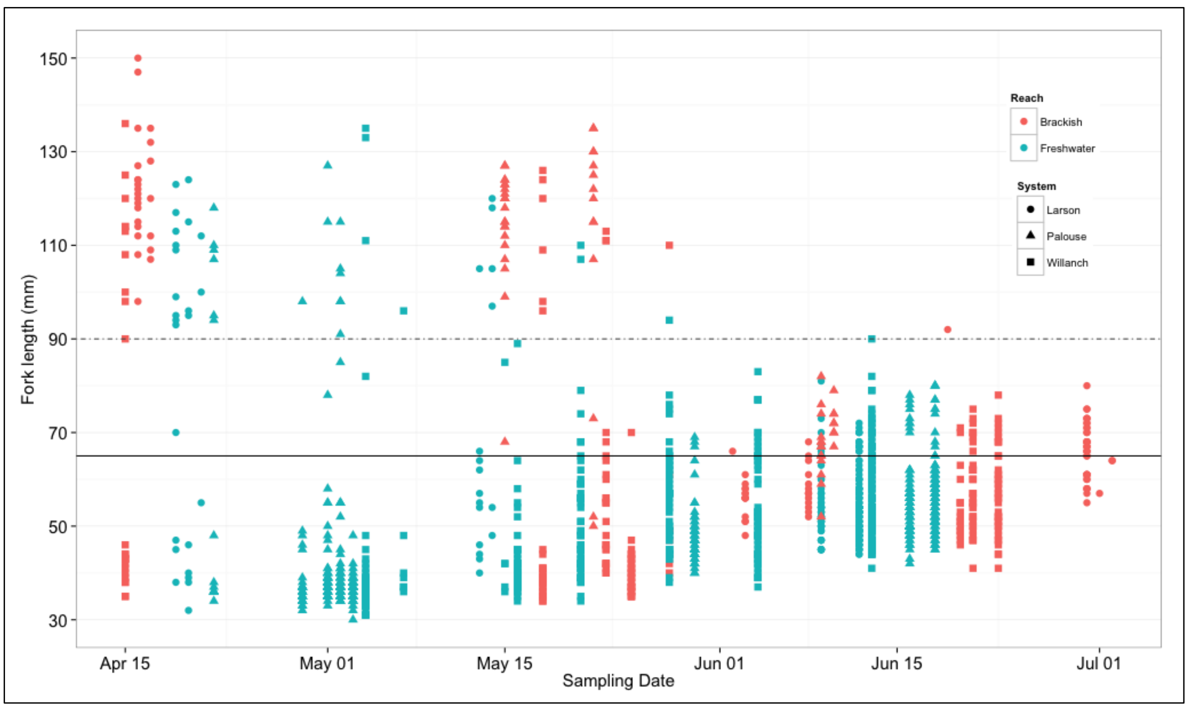


Figure 8. Fork length distribution of all juvenile coho captured from April 15 through July 7, 2014. Fish captured above the solid line underwent gastric lavage. Fish captured between the solid and dotted lines are age-0 fish. Fish captured above the dotted line are age-1 fish. Fish below the solid line are age-0 fish that did not undergo lavage.

Size Class	Reach	n	System	n	FL (mm)			
					Mean	SD	Min	Max
FL = 90+ (Age-1)	Freshwater	43	Willanch	8	109.5	16.96	90	135
			Larson	20	107	10.43	93	124
			Palouse	15	105.6	10.2	91	127
	Brackish	76	Willanch	20	111.8	11.54	90	136
			Larson	25	120.48	13.34	92	150
			Palouse	31	119.32	8.58	99	135
FL = 65 - 89 (Age-0)	Freshwater	104	Willanch	53	71.13	5.51	65	85
			Larson	25	68.4	3.49	65	81
			Palouse	26	73.81	4.98	65	85
	Brackish	73	Willanch	24	70.04	2.96	65	78
			Larson	28	69.39	3.69	65	80
			Palouse	21	70.71	4.64	65	82

Table 4. Sample size and fork length distribution of fish that underwent gastric lavage by reach and by system (subbasin) form April 15 through June 30, 2014.

Assessments of fork length distribution across the study sites indicate the presence of two size classes over the sampling period, which represents two age groups (Figure 8). Those with fork lengths of 90 mm and greater are considered emigrating age-1 (brood year 2013) juveniles while those with fork lengths less than 90 mm are age-0 (brood year 2014) juveniles (Groot et al. 1995, Quinn 2005). A total of 147 lavage samples were obtained across the freshwater reaches, 149 from the brackish reaches, and 9 from the bay locations (Table 4). Due to the low levels of capture at the bay locations, those samples have been removed from the study and are not included in the figures.

During the period of April 15 – May 15, 2014, the watershed experienced high increases in precipitation, which altered the salinity levels of the brackish reaches and caused high flow rates in the freshwater reaches. Brackish water sampling was postponed until the system had a chance to flush and stabilize. The majority of age-1 juveniles were caught before June 1, 2014 in each reach of each system (Figure 8) with the lowest catch occurring in the freshwater reach of Willanch Creek. This system experiences higher flow rates than Palouse and Larson Creeks, which resulted in decreased sampling effectiveness. Age-0 fish were also captured, but prior to May 13, the majority were smaller than 65 mm, which is the minimum fork length required for successful lavaging.

Graduate student Kailan Mackereth is currently processing lavage samples at Oregon State University. The projected completion date of this study is June 2015 and will result in the completion of a Master's thesis through Oregon State University.

Adult Spawner Estimates.

Adult coho salmon spawning has been monitored and estimated using Area under the Curve (AUC) methods in the Palouse and Larson sub-basins since 2003 and 2002, respectively. During the first four years of coho salmon spawner monitoring, estimates of coho spawner population abundance trended downward, the following three years showed progressively higher numbers. From 2010-2013 estimates declined and in 2014 the estimate was up again (Figure 9).

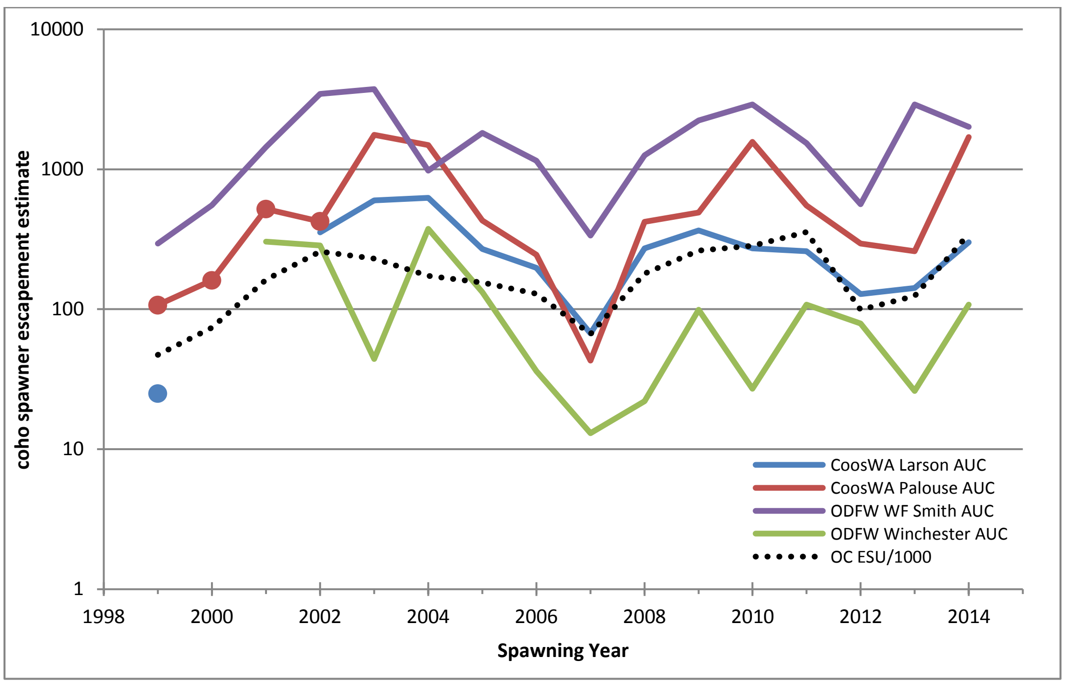


Figure 9. Adult coho spawner abundance at four regional LCM sites and for the Oregon Coast coho ESU since 1999. Lines indicate adjusted AUC estimates (ODFW method) and solid circles on lines indicate peak counts. Larson Creek was not surveyed 2000-2001 and Winchester Creek surveys were initiated in 2001.

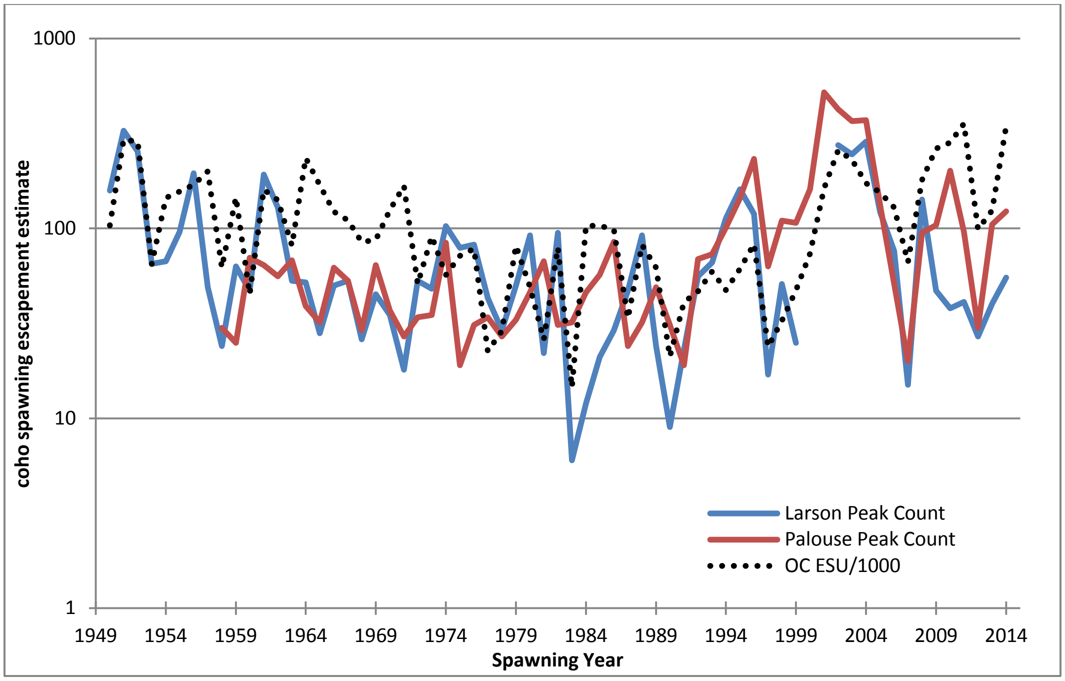


Figure 10. Peak coho counts (Adult+Jack+Dead) for standard ODFW Larson and Palouse Creek segments and the Oregon Coastal ESU naturally produced adult coho escapement estimate since 1950.

Previous surveys of standard segments for Palouse and Larson Creeks date back to 1950 (Figure 10). These estimates are peak counts (live+dead) of coho and generally track the trend of the recent more robust AUC surveys. Palouse Creek peak count of 105 coho in 2013 and 123 in 2014 were both above the mean of 91 and represent the 13th and 10th highest counts in 57 years (since1958). Larson Creek's peak count in 2013 (40) and 2014 (55) were both below the mean of 79 coho but similar to the median of 52 for the 63 years of surveys since 1950 (Figure 10). CoosWA has been denied survey access to portions of Larson Creek since 2008. Both denied segments, in the mainstem and in the tributary Sullivan Creek, are known to have some of the best spawning gravel in the Larson subbasin. Hence escapement estimates for Larson may be significantly lower than what is reported here.

Project Changes

The diet analysis research piece of this grant project was added in 2013 in order to further assess the growth and survival of juvenile coho in tidal habitats of lowland streams in the Coos Bay Estuary.

In December of 2013 Coos Watershed Association requested that remaining funding be used so that staff could continue field operations as outlined in the project application and also conduct diet analysis data collection through the summer of 2014. After that time data will be reviewed necessitating the extension December 2014. State and Federal take permits were amended to include the lavage sampling and shifted some take from freshwater habitats to the tidal and estuarine habitats.

CoosWA requested a budget amendment in April 2014. Funds were moved from Contracted Services to In-House Personnel to cover macro-invertebrate analysis work originally budgeted to be done by a contractor but will be done by a Coos WA employee (Kailan Mackereth). Funds from Supplies/Materials were moved to Equipment to purchase a portable FDX/HDX reader. The old reader was cumbersome and difficult to read. The new unit allowed CoosWA to begin using half-duplex tags as it reads both full-duplex and half-duplex PIT-tags.

Public Awareness

Over the period of this grant (212-2044 OWEB) two 11 month AmeriCorps intern positions have recruited a strong volunteer base from the Coos Bay community to participate in our project in addition to providing much of the sampling effort described above. Outreach to local schools including high schools and the community college, South Western Oregon Community College (SWOCC), also contributed to the work in this grant as well as the environmental awareness of the participants and their community. CoosWA project biologists and AmeriCorps members brought outreach for the LCM project to many Coos Bay festivals, events and meetings. The publication and dissemination of a recent case study of the Larson and Palouse subbasins has been an effective tool for sharing the results of our efforts with landowners in the context of the history of the area (Wright and Souder 2014).

Lessons Learned

Freshwater Survival metrics.

ODFW Western Oregon Rearing Project (WORP) analysis has suggested a density dependent relation between juvenile and parental coho abundance (Constable and Suring 2013). Figure 11 shows ODFW coastal coho ESU parr estimates from snorkel surveys and the female adults that produced them. Minto et al. (2008) described this inverse density-dependence for several species, both marine and freshwater, and suggested density-dependent mechanisms were fundamental to those patterns. Lobón-Cerviá (2014) found similar results in a brown trout population but determined that survival rates at progressive stages of ontogeny were entirely explained by environmental factors, including stream discharge and habitat depths. With the same patterns generated by two sets of opposing factors, density-dependence and environmental factors it is difficult to parse effects but the consistency of environmental patterns such as the Pacific Decadal Oscillation, suggests that survival rates and recruitment are largely determined by environmental factors for salmon populations (Losse et al. 2014).

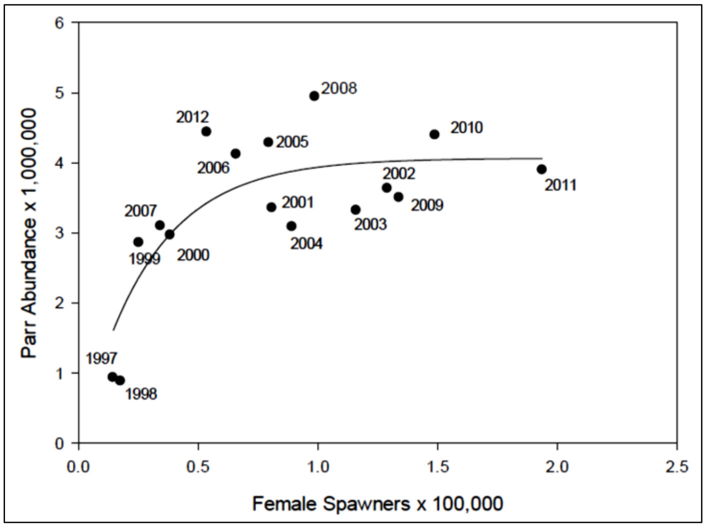
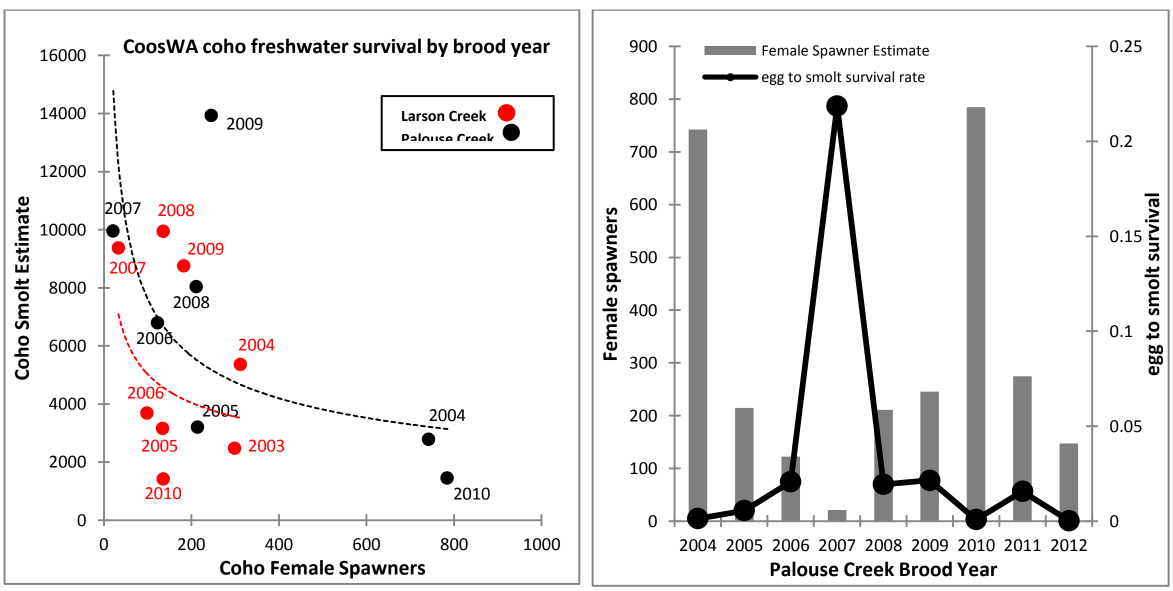


Figure 11. ODFW (Oregon Plan projects) spawner to parr relation by brood year. Female spawners (OASIS data) and parr abundance (WORP) are from annual Oregon coast wide ESU estimates.



Figures 12a-b. a. Relation of spawning escapement to smolt production (freshwater survival) by brood year. b. Palouse Creek female coho spawners and the survival rate to smolt stage for the eggs they produce.

Similar analyses of CoosWA monitoring data suggests an analogous inverse density-dependent relationship as described above (Figure 12a). Figure 12b also shows this negative relation between freshwater survival rate and number of female spawners that produced them in Palouse Creek. These consistent patterns of freshwater survival of coastal coho at both the ESU and subbasin level may reflect the generally stable environmental conditions for over summer rearing on the Oregon coast. However, 2014 was a very dry and hot summer and ODFW WORP parr snorkel counts, in the Mid-South Coast management area that includes Coos River watershed, do not reflect the trend seen in previous years (Ron Constable ODFW, personal communication). These life cycle metrics have emerged as critical for assessing and predicting coho population status in relation to correlated factors that affect freshwater survival.

Juvenile Trapping Issues.

Since 2011 RST efficacy and efficiency has become an acute problem. The chronic regional problems associated with placing infrastructure in streams of Tyee sandstone geology have been a constant struggle for both CoosWA and ODFW. Erosion is a continuous process in our study streams and is exacerbated by moderate to high flow events. Additional effort spent fyke netting around RSTs has had mixed results with generally only temporary improvements in trap efficiency. The accuracy and precision of juvenile coho population estimates reported in the ±95% confidence intervals is highly variable (Figure 6a-d). The range of this variability in the estimate is directly based on the mark recapture rates of fish at the RST. When capture rates are low, sample sizes may not accurately represent the population that final estimates model. When recapture rates are low, trap efficiencies are extrapolated across larger time periods and variability across time (i.e. flow conditions) is not accounted for. Individually, each of these issues can result in wider 95%CI bands (low precision) around the population estimates. When both are in effect, the accuracy of the estimate as a reflection of the population and the range of estimation are both highly questionable.

PIT tag effects and mortality.

National Oceanic and Atmospheric Administration (NOAA) fishery concerns with uncertainties in PIT tag effects, specifically survival and growth, on salmonids have led to an increase in the minimum fish fork length (FL) threshold from 60mm to 65mm for 12mm PIT tags (PIT Tag Steering Committee, Version 3.0, 2014). This is a conservative precautionary measure that will be further investigated to refine the standards based on current and future data analyses from across the range of salmonids including our study area. The Endangered Species Act and NOAA regulations state that scientific research must not operate to the disadvantage of the threatened species. NOAA's conclusion is that PIT tagging fish smaller than 65mm with 12mm tags is likely to cause unacceptable mortality rates for those fish.

Recent analyses of CoosWA coho PIT data and have not found a significant difference in apparent survival (recapture/tagged) for PIT tagged juvenile salmonids between 50 and 120mm. Table 5 lists the frequency of PIT tagged coho by size class and the number of recaptures for each size by method. Figure 13 illustrates these capture probabilities by fork length as a proxy for (apparent) survival for all coho PIT tagged by CoosWA since 2008. Recapture rates peak at 50% for fish between 75mm and 80mm in fork length (purple line). Passive (PIT antennas) recapture rates decline below this size class but active recapture rates are similar (~14%) for the smallest fish tagged. The size class in question (60mm -65mm FL) has a total recapture rate of 41.4% similar to the mean for all size classes of 39.9% (Figure 13). Figure 14 presents recapture probabilities (apparent survival) standardized at the mean recapture rate for all coho sizes (39.9%) set at 0%. Differences in probability of recapture from the mean are shown for both methods and totals.

Table 5. Frequency of PIT tagged coho and recaptures of PIT tagged coho from 2008- 2014 by fork length size class and recapture method. Active methods: seine, electrofishing, etc.; passive: fixed PIT antenna arrays. 'Both Recap' are individuals recaptured by both methods. Total recapture = ([active+passive]-both). 'All PIT coho' totals are sums of all size classes (n).

coho fork length size class (mm)	Total PIT tagged	Active Recap	Passive Recap	Both Recap	Total Recap
<50	389	56	39	8	87
50-55	1549	268	225	69	424
55-60	1365	217	274	71	420
60-65	1576	257	515	120	652
65-70	1205	195	490	98	587
70-75	903	128	390	74	444
75-80	648	71	303	44	330
80-85	468	36	203	22	217
85-90	432	28	186	17	197
90-95	375	11	145	6	150
95-100	378	17	148	10	155
100-105	405	21	146	12	155
105-110	366	22	141	13	150
110-115	363	13	149	11	151
115-120	231	7	110	5	112
120-125	198	6	86	3	89
>125	172	7	78	6	79
All PIT coho	11023	1360	3628	589	4399

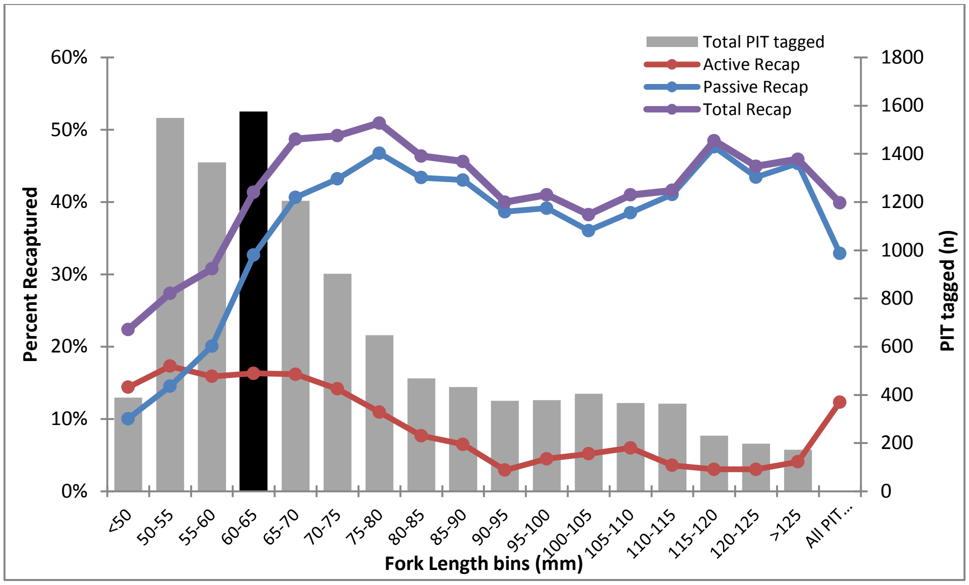


Figure 13. Total Coos WA PIT tagged coho (2008-2014) and recapture rates by fork length bin size and recapture method. Frequency of PIT tagged coho by fork length bin size (grey bars). Active and passive recapture rate (red and blue lines) and total recapture rate [=active+passive-both] (purple line) by fork length bin size. Note black bar, 60-65mm fork length bin that has been excluded from 12mm PIT tagging by NOAA. All PIT coho bin not displayed to preserve scale (see data in Table.).

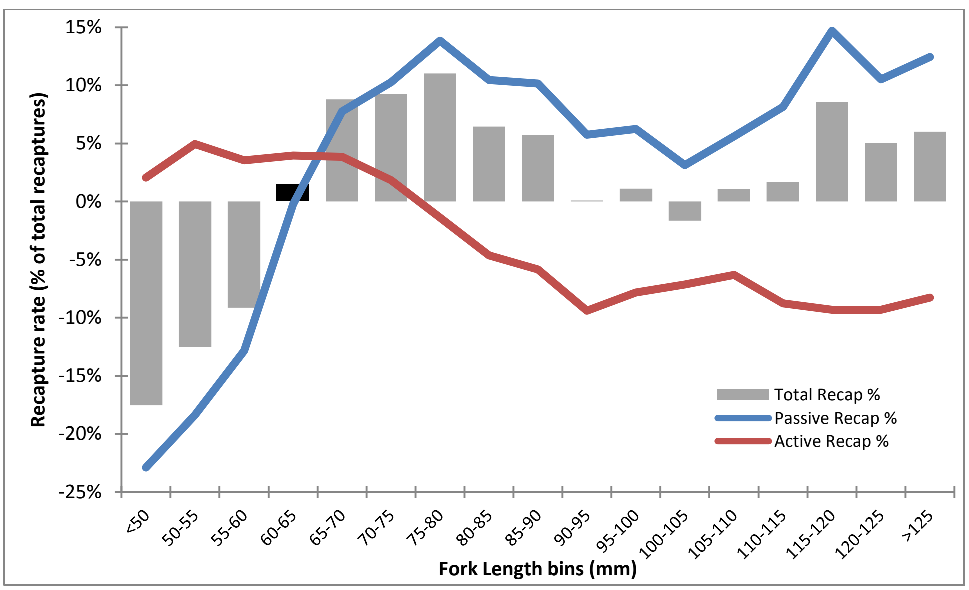


Figure 14. Standardized variation in recapture rates for CoosWA PIT tagged coho (2008-2014) by fork length (mm) at time of tagging. Bars represent the difference in mean recapture [= active + passive - both] rate for coho in a fork length bin from the mean recapture rate for all PIT tagged coho. 0% line on y axis is the standardized mean recapture rate (40%) for all PIT tagged coho (all sizes pooled). Difference in active and passive recapture rates (red and blue lines) from total recapture rate for each coho fork length bin. Note black bar, 60-65mm fork length bin that has been excluded from 12mm PIT tagging by NOAA.

The Integrated Status and Effectiveness Monitoring Program (ISEMP) report a similar trend for juvenile Chinook in the Entiat River in Washington State (Ward et al in prep, and personal communication). Survival probabilities (tagged/recaptured) peaked at about 85mm and decreased below this size. Differences in survival across sizes were not found to be significantly different both relative and absolute survival were estimated. ISEMP found that variability was explained by capture method and year of tagging more than fork length bin size. Modeled simulations by ISEMP of NOAA sample size restrictions did not affect subbasin scale survival estimates but did affect finer spatial and temporal scale survival estimates. Effects of 12mm PIT tags on mortality and growth of salmonids have generally been found to be negligible. Explicit research of tag effects on Brown trout (Salmo trutta) (Ombredane 1998) and Atlantic salmon (Salmo salar) (Gries 2002, Zydlewski et al 2003) showed tag retention rates are usually high (97% to 100%). Apparent survival rates for PIT tagged brown trout of 95% for fish ≥ 52 mm FL and 99% for fish ≥57 mm FL at time of tagging. No significant effect of tagging on growth (in both fork length and weight) was detected (Acoloas et. al. 2007).

Instantaneous growth, post tagging, in relation to days at large (recapture date-tag date) has been previously reported to range from 0 to 1.8 Ln g/day for coho in CoosWA study streams (Weybright 2010). Growth rates for all juvenile coho PIT tagged in the LCM study area since 2008 are presented in Figures 15 and 16 as a proxy for tagging/tag effects. Figure 15 suggests that the paradigm that smaller fish grow faster than larger fish is not altered by PIT tagging in our study sample although growth rate does increase with increasing days at large. All tagged coho at large less than 60 days (Figure 16) have very similar growth rates regardless of fork length class. Unlike post 60 days, growth rates appear to decline over the first 60 days post PIT tagging. High variability in fish at large less than 10 days is mainly attributable to measurement errors in the database.

NOAA PIT tag FL threshold restrictions have the potential to confound results from on-going research if detectability or survival rates vary between size classes that are not accounted for in tagging samples. Specifically, not PIT tagging salmon <65mm will likely result in non-representative population estimates of growth and survival. Protocol changes could impact estimates of other key parameters such as movement and growth. Ultimately, trend information could also be confounded by such proposed changes. Monitoring coho parr movements, growth and survival in the tidal areas of our LCM project could potentially be severely curtailed as coho on average do not grow to >65mm FL size till late in the season, generally October. Coho <65mm FL accounted for 47% of all coho PIT tagged by CoosWA since 2008.

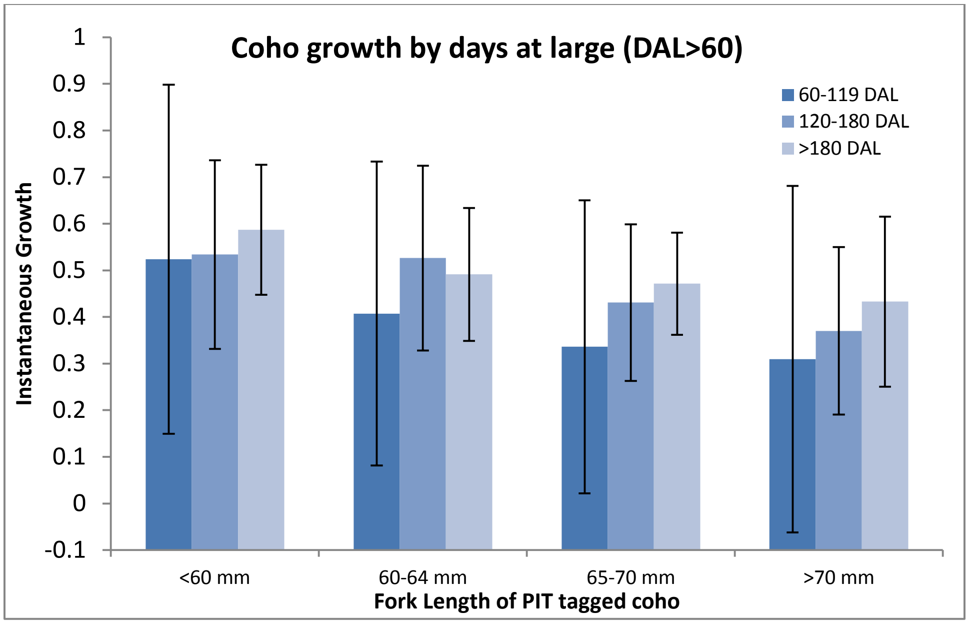


Figure 15. Coho instantaneous growth by fork length at tagging and greater than 60 days at large (DAL). Instantaneous growth (G) = $[100 \times (\log_e W2 - \log_e W1)(T2 - T1)^{-1}]$ where W1 is weight at capture (g), W2 is weight at recapture (g), and (T2 – T1) represents the number of days at large between tagging and recapture (DAL). Black bars are standard deviations, note minimum y axis.

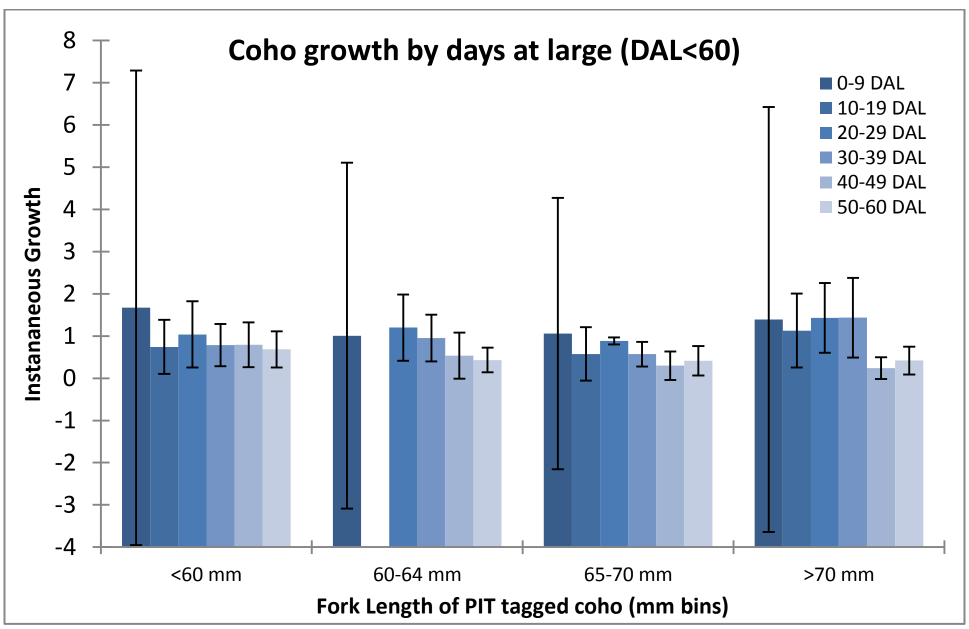


Figure 16. Coho instantaneous growth by fork length at tagging and less than 60 days at large (DAL). Instantaneous growth (G) = $[100 \times (\log_e W2 - \log_e W1)(T2 - T1)^{-1}]$ where W1 is weight at tagging (g), W2 is weight at recapture (g), and (T2 – T1) represents the number of days at large between tagging and recapture (DAL). Black bars are standard deviations, note y axis scale.

Another issue for tagging methods is rate of tag loss. PIT tag loss has been shown to be higher in smaller fish (57– 63mm) and when injection methods are used with up to 20% loss (Acoloas et al 2007, Baras et al 2000). However, Prentice at al 2000 and Dare 2003 found tag retention was high 90-99% for salmonids ranging from 55 to 100mm. PIT tagging efforts are often focused on migrating salmonids captured in situ, at fork lengths as small as 60 mm, during periods when water temperatures are elevated, and fish are released less than 24 h after tagging. These tagging conditions create stress from handling and anesthetizing juvenile salmon that has been estimated to take approximately 2 weeks to dissipate (Sharpe et al. 1998).

CoosWA is in communication with NOAA fisheries regulators and scientists and has agreed to follow the FL threshold restrictions for the 2015 season. The data in this report has been shared with State and Federal permitting agents. Our study proposal will be to PIT tag a subsample of 60mm - 65mm coho and assess their survival and growth. We hope to accomplish this by incorporating a resampling design that will more intensively recapture PIT tagged coho over shorter time intervals (<60 days) using mobile antennas and seining methods in order to elucidate the survival and growth rates of juvenile coho of all size classes.

Recommendations

LCM improvements.

ODFW has concurrently implemented duel monitoring methods at the Mill Creek Siletz LCM site. Prior PIT tagging efforts have yielded juvenile and jack recaptures this season following installation. Close communication with our ODFW collaborators will continue as we refine the antenna designs, hardware security and sustainability, and data management and analysis. Regional and coast wide efforts would benefit from an infrastructure similar to PIT Tag Information System (PTAGIS) in the Columbia Basin. As these efforts are expanded to other LCM sites integrated database collaboration would provide a measure of stray rates and other ESU scale population level life history information without any additional field work.

In order to better calibrate the efficacy of the RST in Palouse Creek CoosWA will (similarly to ODFW above) bracket the trap with 2 PIT antennas powered from a single reader. By leveraging the PIT mark recapture estimates against the customary RST efficiency estimates the efficiency of both methods can be calibrated in situ (Tattem et al 2013). Population level abundance estimates from RSTs have also been successfully calibrated by mark recapture estimates of population dynamics using PIT tags in Palouse Creek (Weybright 2011). Utilizing both methods will also support the capture probabilities of the new Bayesian estimators for RST capture efficiency by providing continuous monitoring data (PIT antenna arrays) that will operate when RSTs need to be removed during high flows or during periods of malfunction (cone not spinning).

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