Study Plan for the Strait of Juan de Fuca Intensively Monitored Watershed

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Executive Summary

The Strait of Juan de Fuca (Straits) Intensively Monitored Watershed was initiated in 2004 to test the population-scale response of Steelhead Trout (*Oncorhynchus mykiss*) and Coho Salmon (*O. kisutch*) to habitat restoration. These streams were chosen to take advantage of the Lower Elwha Klallam Tribe's ongoing fish and habitat monitoring. The Straits IMW includes two treatment watersheds, East Twin River and Deep Creek, and one control watershed, West Twin River. Restoration treatments completed include LWD placement, road decommissioning, fish passage improvements, off-channel habitat creation/reconnection, and riparian planting. Monitoring of physical habitat and Coho and Steelhead parr densities began in 2004 using the Environmental Protection Agency's EMAP site selection and sampling protocols. Smolt and adult monitoring predates the IMW program, and began as early as 1998 in Deep Creek. Preliminary results suggest some small improvements in pool habitat and small increases in Coho and Steelhead adults in East Twin and Coho adults in Deep Creek, relative to West Twin.

Studies of Coho parr, PIT-tagged in August, reveal that large numbers (average across all streams and years of 70%) are leaving these streams in the fall/winter at six to nine months age. Marine survival of these fall migrants is low (approximately one-fifth that of spring smolts) compared to spring migrants, and fall migrants comprised 32% of the returning PIT-tagged adults. Fish that migrated in the spring tended to be larger at the time of tagging (August) than fall migrants, but returning adults of both groups were of similar size at tagging and tended to be the largest individuals. Four common Coho life history types were identified; 0+ fall smolts that returned after 12 months at sea, 0+ Fall smolts that spent 24 months at sea, 1+ spring smolts that spent 6 months at sea, and 1+ spring smolts that spent 18 months at sea.

PIT-tagged Steelhead parr were observed leaving freshwater as fall/winter and spring migrants at Age 0 through Age 3 but returning adults were all Age 1+ migrants and most of these were spring migrants.

While these preliminary results are encouraging, most of the habitat restoration was only recently completed and it will take several years for the habitat and, in turn, fish populations to respond. Monitoring for two to three generations (six to nine years for Coho) is needed to confirm that these initial trends are the result of restoration actions implemented in East Twin and Deep Creek. However, if substantive changes are not seen in the next two years, we should consider additional treatments, including:

- Salmon carcass analogs in East Twin River and
- Targeting overwinter habitat restoration in Deep Creek.

Based on the data collected to date, both options have the potential to increase the number of outmigrating Coho smolts and marine survival rates of Coho Salmon.

Introduction

Despite hundreds of millions of dollars invested in habitat and watershed restoration in the Pacific Northwest every year, many questions exist about their success. Most monitoring and evaluation to date has focused on reach-scale response to restoration (Roni et al. 2008). While many of these reach or project-scale efforts have shown localized reach-scale improvements in fish habitat and juvenile fish density (e.g., Cederholm et al. 1997; Roni and Quinn 2001; Morley et al. 2005; Roni et al. 2005) little information exists on the population or watershed-scale response to restoration activities. To address this pressing need, the Intensively Monitored Watershed (IMW) program was developed to evaluate the efficacy of habitat restoration in increasing salmon production at a watershed scale (Bilby et al. 2005). The basic premise of the IMW program is that the complex relationships controlling salmon response to habitat conditions are best understood by intensive monitoring of physical, chemical and biological parameters in selected treatment and control watersheds.

East Twin River, West Twin River, and Deep Creek were included in the SRFB's IMW program in 2004 taking advantage of the fish (Lower Elwha Klallam Tribe, Northwest Fisheries Science Center, and WDFW) and habitat (Lower Elwha Klallam Tribe) monitoring programs already in place. We've supplemented the existing monitoring and encouraged additional restoration activities in order to evaluate the response of fish and fish habitat to restoration.

In this report, we update the 2007 study plan (Ehinger et al. 2007) and provide preliminary results from the Strait of Juan de Fuca IMW complex. The IMW program has been funded by the Salmon Recover Funding Board (SRFB) since 2004. There are two other IMW complexes in western Washington focusing on Coho Salmon (*Oncorhynchus kisutch*), and Steelhead (*O. mykiss*) Trout, the Hood Canal and Lower Columbia complexes (Figure 1).

Study Area

The Straits IMW is composed of three watersheds: West Twin River, East Twin River, and Deep Creek; (48°10'00 N, 123°55'00 W). The watersheds range in area from 34 to 45 km^2 with elevation ranging from approximately 915 m in the headwaters to sea level (Table 1). Precipitation averages 190 cm per year and occurs primarily between October and May as rain with occasional brief snowfalls (ONF 2002).

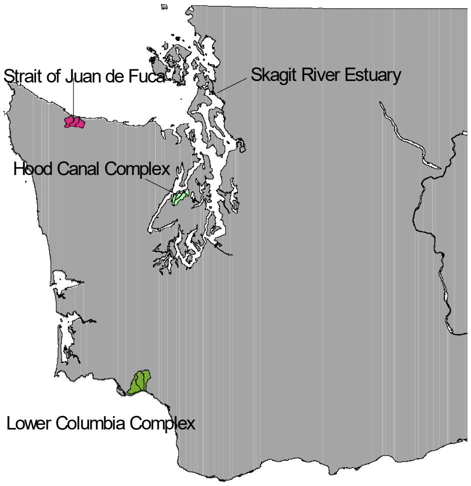


Figure 1. Locations of the four SRFB-funded IMW complexes: Strait of Juan de Fuca, Hood Canal, Lower Columbia, and Skagit Estuary.

Table 1. Characteristics of three Strait of Juan de Fuca IMW watersheds.

	East Twin River	West Twin River	Deep Creek
Drainage area (km^2)	36.2	33.9	44.0
Geology	Quaternary alluvium, Pleistocene continental glacial drift, Tertiary marine, Tertiary volcanic		
Ownership	28.4% Private, 71.6% Public		
Total stream length (km)	89.7	92.8	103.8
Mean precipitation	190 cm		

These watersheds are underlain by volcanic rocks of the Crescent Formation, marine sedimentary rocks, and glacial deposits. The oldest rocks (the Crescent Formation) are at higher elevations, while the youngest, the marine sedimentary rocks, are at the lower end of the watershed. Glacial deposits occupy lower valley margins and valley floors toward the upper part of the watershed, and throughout broad terrace areas in the lower parts of the watershed. Recent alluvium is found locally adjacent to higher-order channels, especially at the lower end of the watershed. The area of the watershed underlain by the Crescent Formation is steep and dissected with generally shallow soils. Landslides and resulting debris torrents are most common in this area of the three watersheds. The marine sedimentary rocks include a mixture of siltstones, sandstones, mudstones and conglomerates. Most mass wasting on this geology is associated with steep converging topography and over-steepened channel margin slopes. The low strength, fine-grained nature of these rocks contributes to the generation of fine sediment in these watersheds. Glacial deposits occupy valley bottoms, toe slope areas, and terraces in the lower part of the watershed. Typically these are relatively thick deposits on gentle slopes and not particularly susceptible to erosion. Exceptions exist where streams have incised deeply into these deposits, leaving high banks of relatively weak materials, and forming small inner gorge structures that are susceptible to, and in part created through, erosion and/or mass wasting. Glaciolacustrine clay overlying dense glacial till is found in some areas along the lower Deep Creek inner gorge and the upper part of the East Fork of the East Twin River, a condition susceptible to deep-seated mass wasting.

The primary land use within these watersheds for the last 100 years has been forestry (ONF 2002; Bilby et al. 2005). All three watersheds have a history of intensive logging, beginning in the early 20th century, fire, instream salvage and intentional large woody debris (LWD) removal. As a result, much of the instream wood that historically created pools and regulated the movement of sediment and organic matter in these watersheds has been lost. Wood loss contributed to channel incision at some sites, isolating the floodplain and reducing access to off-channel habitats. In the headwaters of these drainages, mid-slope roads were constructed in the 1970’s and 1980’s to access stands of old-growth timber on very steep slopes. Shallow, rapid landslides generated from clearcuts and roads have degraded fish habitat and water quality. For example, during a large storm event in November of 1990, landslide debris dammed several locations in Deep Creek and generated a very large dam-break flood. This event traveled from the headwaters to the estuary and caused widespread damage (scour, sedimentation, redistribution of LWD, loss of pools). Since the early 1990’s the rate of landsliding has been greatly reduced in the complex (pers. comm., Mike McHenry). This is partially attributable to the near complete elimination of logging on U.S.D.A. Forest Service ownership under current management guidelines and the large scale road decommissioning projects. Almost the entire USFS 3040 road system, which generated a large percentage of the shallow rapid landslides has been decommissioned.

Early-succession forest stages occupy 27.3 percent of the watershed, mostly on private land while mid-succession stages cover 60.8 percent of the watershed. Late-succession stands cover 11.0 percent of the watershed, mostly on National Forest land. Only 0.8 percent of the watershed is not forest, primarily wetlands and waterbodies. There are few residences in the three watersheds with no agricultural or urban development. The three watersheds are almost completely owned by U.S.D.A. Forest Service, Washington Department of Natural Resources, and two private forestry companies. Because of the relatively young age of recently harvested timber, very little new timber harvest is expected on private and state-owned lands in the complex over the next decade. Moreover, a large proportion of federal lands in Deep Creek are managed as late-successional reserves under the Northwest Forest Plan with very limited, if any, harvest expected in the near-term. Finally, any new harvest on private lands will be regulated under the state's Forest Practices Rules (based on the Forest and Fish Agreement) which requires buffers along all fish-bearing streams, most non fish-bearing perennial streams, as well as buffers on unstable slopes. Taken together, we are confident that the response to instream habitat restoration will not be directly affected by forest management activities.

Fish species present in the three basins include Coho Salmon, Steelhead/rainbow trout, Cutthroat trout *O. clarki*, Chum Salmon *O. keta*, Pacific Lamprey *Lampetra tridentata*, Western Brook lamprey *L. richardsoni*, Torrent sculpin *Cottus rhotheus* and Reticulate sculpin *C. perplexus*. Coho Salmon and other anadromous fishes are found below river kilometer (RM) 5.8 on East Twin, approximately RK 6.3 on the West Twin, and RK 7.1 on Deep Creek (ONF 2002) (Figure 2). Historical accounts mention Chinook salmon (*Oncorhynchus tshawytscha*) in these watersheds but it is unclear whether these were the results of WDFW hatchery outplants in the 1970's or a natural population. Chinook salmon have not been observed in recent years. Only Coho salmon and Steelhead are included in the analyses.

Due to chronically low escapements, no terminal salmon fisheries are currently conducted in the watersheds. Tribal fisheries for winter Steelhead have been closed in these streams since 1990. The East Twin River is currently closed to sport Steelhead fishing, and all wild Steelhead must be released by anglers on Deep Creek and the West Twin River. No hatchery supplementation occurs in the study streams. The status of salmon and steelhead stocks, based upon the most two recent stock reviews, is summarized below (Table 2).

The Pacific Fisheries Management Council review of the status of Coho populations in the Strait of Juan de Fuca region concluded that none of the 48 independent drainages in this region supported healthy Coho stocks (PFMC 1997). The study concluded that Strait of Juan de Fuca Coho populations as a whole are negatively impacted by low freshwater survival, low marine survival rates and high marine interception rates.

Historic fish monitoring

Sporadic spawning ground surveys by WDFW (then Washington Department of Fisheries) in Deep Creek from 1950-1970 reported counts as high as 206 fish per kilometer. Repeated surveys of index areas have been conducted in Deep Creek and Sadie Creek (East Twin tributary) since 1984 by WDFW. These index areas provide an indication of temporal trends, but cannot be reliably expanded into an estimate of watershed-level spawner abundance. The Deep Creek index reach (river mile 0.0-1.3 /km 0.0-2.1), was established primarily to assess Chum Salmon population trends, however the Chum Salmon population crashed following the 1990 landslide event and has not recovered. Significant efforts have been made since 1997 to improve estimates of spawning salmon abundance in Deep Creek and East Twin and West Twin rivers. A stratified random sampling system of available habitat types was initiated in 1997. This new system enables estimation of individual watershed escapement. Coho escapement to individual watersheds has been consistent with Deep Creek supporting the highest number of spawning Coho followed by West Twin then East Twin River.

The status of winter Steelhead was considered healthy in the early 1990's as a result of higher escapement to the Pysht River (WDF, 1993; Table 2). Formal Steelhead escapement surveys were only initiated in 1995, limiting the ability to determine long-term trends in watershed escapement. Winter Steelhead adults enter the watershed beginning in December and continue through May. Spawning occurs in February through early June. The stock is currently managed for wild production and no hatchery fish have been released in these streams since the early 1980's.

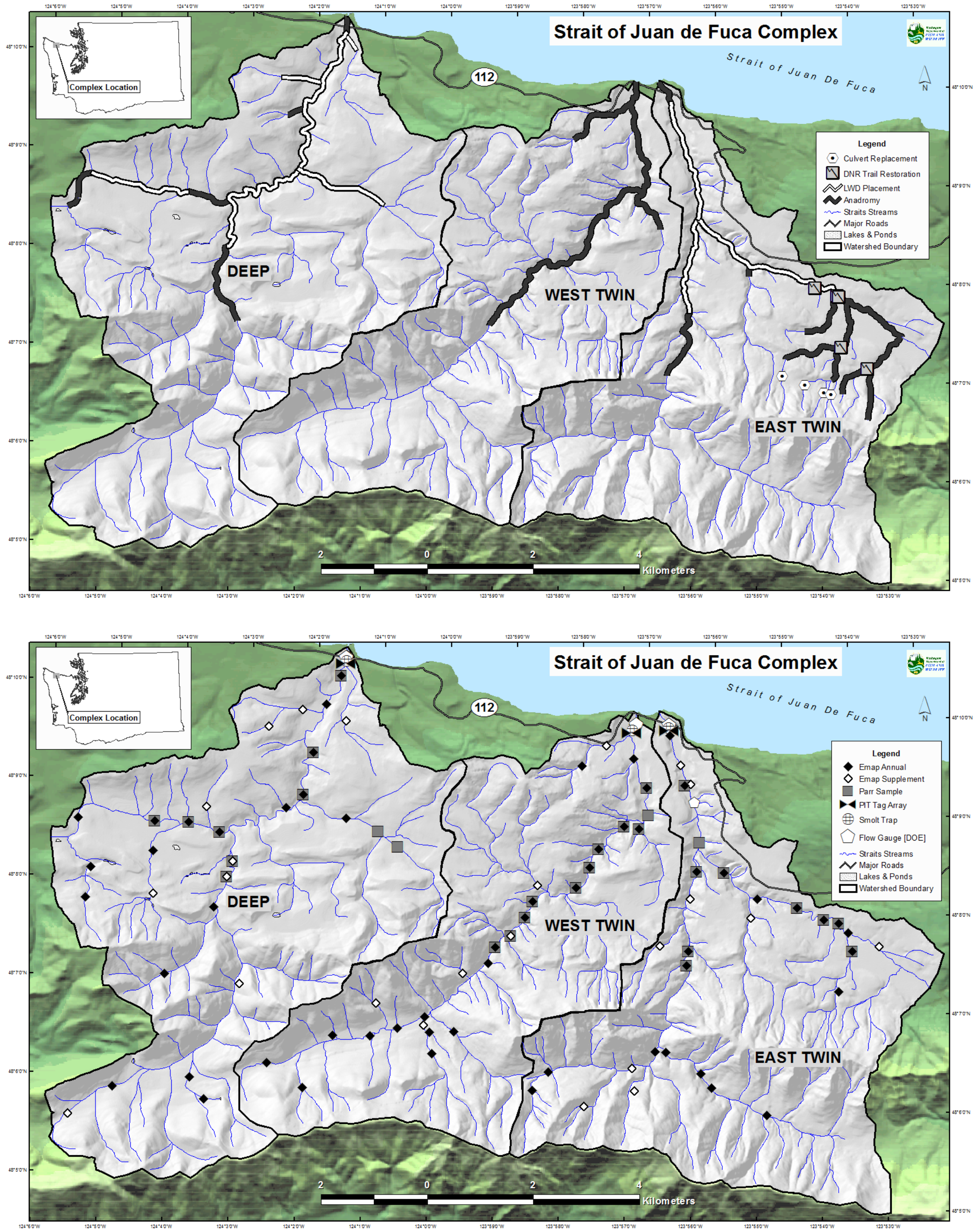


Figure 2. Maps of the study watersheds showing extent of restoration, anadromous fish limits (Top), and locations of monitoring activities (Bottom).

Table 2. Status of salmonid stocks in the Deep/Twins Watershed.

				Stock status	
Species	**Race**	**Production**	**Stock origin**	**(WDF et al. 1993)**	**(McHenry et al. 1996)**
Chum	Fall	Wild	Native	Healthy	Critical
Coho	Fall	Wild	Mixed	Depressed	Stable
Steelhead	Winter	Wild	Unresolved	Healthy	Depressed

Restoration treatments

A watershed assessment completed in 2002 (ONF, 2002) indicated there were low levels of large-woody debris, loss of floodplain habitat and overwinter habitat, young riparian stand conditions, and high levels of mass wasting. Mass wasting originating from logging roads on federal land was addressed immediately but it required nearly two decades to secure the cooperation and funding to retire the most problematic roads. Instream restoration measures implemented through 2014 were designed to increase channel complexity and reconnect floodplain and off-channel habitat through the addition of LWD in East Twin River and Deep Creek. Approximately 3.4 million dollars was spent on restoration in the two streams during our study period (Table 3; Figure 2). Restoration treatments were initiated in Deep Creek and East Twin River in 1998 and 2002, respectively, but the vast majority has been done since 2006. Restoration has focused on the anadromous portion of both treatment streams. However, the anadromous portion comprises only 16% of the total stream network in each stream. Additionally, both streams have anadromous reaches that were not treated because they were geomorphically unsuitable (e.g. too steep or confined). Achieving watershed scale restoration treatments has been challenging. Early LWD projects suffered from a lack of knowledge at the time of implementation as to the size of LWD needed and installation techniques. In some cases projects were underdesigned (e.g. pieces to small). As a result, restoration has been iterative in some reaches and has taken longer than expected to achieve the desired spatial scale.

Access to the stream is difficult. Recent LWD projects have used helicopters to place accumulations of LWD at several hundred meter intervals along the treated length of stream channel. The intent is to incorporate naturally-generated LWD pieces into existing, functional, habitat-forming logjams. The result is that density of LWD in our restoration projects is probably lower than in a typical LWD project where ground-based equipment can be used and the length of stream treated is much shorter.

Table 3. Summary of restoration measures implemented in Deep Creek and East Twin River (RK-river kilometer).

Deep Creek

Year	Amount	Description
1997	$280,000	First large-scale restoration in watershed. Replaced undersized culvert on Gibson Creek with railcar bridge; placed LWD in Gibson Creek (RK 0.2-0.6); Placed LWD in upper Deep (RK 4.2-5.6) at 54 locations: off channel complex constructed at RK 1.4.
1998	$300,000	LWD in mainstem Deep (RK 0.3-4). Initial treatments low profile log and rock structures.
2005	$300,000	10 logjams mainstem Deep (RK 0.3-2.1)
2007-10	$200,000	Helicopter LWD in EF Deep (60 pieces) and 105 key pieces in mainstem Deep (RK 0.3-1.9) and 200 pieces in the WF Deep (RK 0.8.-2.7)
2009-11	$400,000	USFS 3040 road decommissioning
2012	$100,000	Helicopter LWD in upper Deep (RK 4.8-5.5)
2013	$100,000	Helicopter LWD in upper Deep (RK 4.0-4.8)
2014-15	$120,000	Helicopter LWD in upper Deep (RK 2.7-3.2)
Total	$1,800,000	

East Twin River

Year	Amount	Description
2000	$50,000	E. Twin OC Pond/Riparian Planting 0.5 mile
2002-06	$850,000	Helicopter placement ETwin (32 keys)/Sadie(75 logs): Ground based treatments 1.3 K km reach (30 keys and logs); ground based treatments (RK 0.4-1.7) 15 logjams (30 keys/60 logs); ORV access blocked to Sadie and logjam constructed at Powerlines; riparian plantings 2.7 KM
2007	$500,000	Culvert corrections headwaters of Sadie Creek (4 tributaries)
2009-10	$120,000	USFS 3040 road treatments
2011	$100,000	Helicopter placement to Susie (20 keys) and lower East Twin (RK 0.5-1.9) 25 Keys/120 Logs)
Total	$1,600,000	

Expected Restoration Results

Using habitat restoration data from East Twin River and Deep Creek and following methods described in Roni et al. (2010), we estimated the average change in Coho Salmon parr and smolt densities for the large wood placement and flood plain restoration completed to date. We then used these numbers in a Monte Carlo simulation to predict changes in fish numbers in each treatment watershed given the extent of restoration completed and assuming no change in parr to smolt survival (Table 4). Restoration of habitat in Deep Creek is expected to result in an increase of 2684 Coho smolts, a 24% increase in mean annual production. The change in East Twin River Coho smolt production was calculated at 1855 smolts, an increase of 22% over the mean. These increases are expected no sooner than one or more generations following completion of restoration actions, depending upon the habitat response. Power analyses done using Coho smolt production data from Hood Canal and the Lower Columbia indicate that a change in mean smolt production of 23-34% is detectable with 12 years of post-restoration monitoring in Hood Canal (IMW SOC, 2007) and 43-55% change in the Lower Columbia complex using a BACI design (Zimmerman, et al. 2012).

Table 4. Estimated response of habitat restoration on Coho smolt production in Deep Creek and East Twin River were based on published values.

Stream	**Wood placement**			**Off channel habitat**		**Total smolts/yr**	**% of mean**
	meters restored	**parr produced**	**smolts produced (estimated)**	**m^2 habitat restored**	**smolts produced (estimated)**		
Deep Creek	5632	3147	1187	4046	1497	**2,684**	**24%**
East Twin R.	6437	3597	1357	1347	498	**1,855**	**22%**

Goals and Hypotheses

The goals of the IMW program's Coho/Steelhead complexes are to determine:

1) Whether freshwater habitat restoration can produce a change in production of outmigrant Coho Salmon and Steelhead Trout?
2) What features or processes influenced by the habitat improvements caused the increased production or lack thereof?
3) Are the beneficial effects of habitat improvement maintained over time?

The first goal is addressed by measuring smolt/outmigrant production in each treatment basin relative to the reference basin in that complex. However, addressing the first goal may not provide information about the cause of any increase in outmigrant production. Thus, the second and third goals are critical if the results of the IMW effort are to be useful to local restoration advocates to prioritize restoration projects within and among watersheds. However, the data required for questions two and three are more complicated to measure, requiring assessment of the fish populations at various stages during freshwater rearing over a period of years as the restoration is implemented. The basic set of monitoring variables described below will provide basin-wide estimates of spawner abundance, parr-to-smolt survival, smolt production, and several common habitat metrics. These data are the foundation of the monitoring efforts and will be supplemented with additional research to better identify causal mechanisms.

The specific hypotheses to be tested (questions to be answered) are listed below.

1. Restoration results in a measurable increase in basin wide habitat quality in the treatment watersheds (East Twin and Deep Creek) compared to control watershed (West Twin).
2. Restoration results in a measurable increase in Coho and Steelhead smolt (outmigrant) production in treatment watersheds compared to control watershed.
3. Restoration results in a measurable increase in Coho and Steelhead parr production and/or growth in treatment watersheds compared to control watershed.
4. Restoration results in a measurable increase in Coho and Steelhead parr to smolt survival in treatment compared to control watershed.
5. Restoration results in a measurable reduction in number of fall Coho migrants in treatment watersheds compared to control watershed.
6. Restoration results in a measurable increase in smolt to adult survival for Coho and Steelhead in treatment watersheds compared to control watershed.

Methods

Experimental Design

Initially, the IMW program recommended using a before-after control-impact (BACI) design in the Coho/Steelhead complexes (Seiler, et al., 2002). However, collecting several years of pre-project data was not possible in the Straits and early restoration efforts began on the two treatment watersheds at the same time or slightly before (Deep Creek) baseline habitat monitoring. Therefore, we use an intensive post-treatment design (Hicks et al. 1991; Roni et al. 2005) to examine differences in the trends in fish metrics through time and among treatment and control watersheds. Rather than comparing the difference in habitat conditions and fish abundance before and after restoration, the temporal trends are compared between the treatment and control watersheds following treatment. Thus it is important that the control watershed is closely correlated with the treatment watershed, which is the case for most metrics in these streams.

The BACI design may be used at smaller spatial scales and for questions best addressed at a reach scale. Questions that can be addressed at this finer scale include life-history specific biological responses or physical habitat responses to management actions. Reference sites for some reach-level projects are within the basin designated for treatment. These reference sites consist of a reach in close proximity and comparable in initial habitat condition to the treated section of channel.

West Twin River will not receive any restoration projects and will serve as a statistical control basin. The design requires sufficient influence over land management to ensure that reference sites, at all spatial scales, remain untreated through the duration of the study. We expect other activities will occur in some of the reference watersheds (e.g., forest management) as well as the treatment watersheds. We have very limited ability to control these activities. However, forest harvest will be limited in area (much of the federal land is in late seral stage reserves and on much of the private lands the timber stands are too young for harvest) and the regulations on state and private lands are much more restrictive that during the previous harvests. Therefore, we do not believe these actions will compromise the integrity of the study.

Habitat monitoring

Habitat is sampled for two purposes using two designs. First, we employ a Before-After study design to estimate the smaller-scale (>1 km but less than the entire watershed) effects of a suite of restoration projects on physical habitat (Table 5). The anadromous length of each stream was divided into segments following TFW protocols (Pleus, et al. 1998). Each segment was monitored at least once prior to restoration and at intervals following restoration actions in that segment (1992, 1995, 1997, and 2009, and 2013) following TFW (Pleus, et al. 1999; Schuett-

Hames, et al. 1999) as restoration progressed. Although this monitoring is much larger scale than the typical project effectiveness monitoring, it is well-suited to the Straits IMW complex because our LWD projects tend to be larger in scale.

Second, in 2004 we began a watershed-scale stream habitat monitoring effort using a sampling plan and field methods adapted from the U.S. EPA, Environmental Monitoring and Assessment Program (EMAP, http://www.epa.gov/emap). Sampling locations were identified from the fish-bearing stream network using a random, spatially-balanced design that was stratified by stream order (Strahler 1957; Stevens and Olsen 2004) (Figure 2). This allows statistically valid descriptions and comparisons of many habitat metrics over time and across watersheds. Based on an analysis of data in 2006, the total number of sites was doubled to a minimum of 20 per stream per year and the location of some sites were changed in 2007 to ensure all were located in fish-bearing reaches.

These habitat surveys follow EMAP protocols, which consist of measures and counts made at and between 21 equally spaced cross-sections at each site. Cross-sections are positioned along a length of stream that is the longer of either 40 bankfull widths or 300 m. Substrate, LWD, habitat type, bankfull width, and depth are collected at each transect (see Crawford 2008a,b,c for details on methods). The following metrics were calculated for each site and then averaged among all sites sampled to provide an annual index of watershed condition: counts of LWD in bankfull channel, mean thalweg depth, proportion of pools, percent fines (sediment <2mm), and median particle size (D50).

Krueger, et al. (2012) provides summary statistics of the EMAP habitat metrics collected through 2011. Given that much of the restoration was only recently completed, the data record is too short for a meaningful analysis of habitat change due to restoration and is not presented here. However, two important points are:

1) The three watersheds tracked each other (i.e. are well correlated) through time for most habitat parameters suggesting that West Twin River will be a useful reference stream in the analysis.
2) EMAP sampling included all fish-bearing reaches and is likely to be less sensitive to the effects of habitat restoration than is the TFW monitoring, which encompassed only the anadromous stream length, where most of the habitat restoration is concentrated.

Flow & Water Quality

Flow and water quality (dissolved oxygen, temperature, turbidity) are monitored continuously by stream gauges located at the mouth of each stream (Figure 2). Mean daily flows averaged 39, 41 and 52 cubic feet per second (cfs) in East Twin, West Twin, and Deep Creek respectively. Stream temperature averaged approximately 8°C in all three streams, ranging from 0 to 19°C. While temperatures were near optimal for salmonids for both summer and winter, high flow events in fall and winter are suspected to impact overwinter survival and egg incubation in the three study streams. To examine the effect of high flow events, we calculated the number of flow events from September to May that exceeded 100 cfs for each study stream for each year. We then examined whether the number of days of flows greater than 100 cfs each year was correlated with annual estimates of overwinter survival, parr abundance and smolt production. The 100 cfs value was selected for this exploratory analysis because it is a moderately high flow event.

Fish monitoring

Juvenile abundance – Single pass electrofishing was conducted at up to 10 of the EMAP habitat sites in each watershed to estimate juvenile fish abundance and mark (PIT tag) juvenile Coho and Steelhead to determine overwinter survival (Figure 2). The same sites were sampled each year. Electrofishing occurred in August and early September each year. A 50 to 75 meter reach at each site was isolated with block nets and a single downstream pass was made to provide an index of fish numbers at those sites. Three-pass electrofishing was conducted in one to five reaches in each stream each year. Population estimates based on three-pass electrofishing were calculated using Carle and Strub (1978). A simple linear regression was developed between population estimates using single-pass electrofishing vs. three-pass electrofishing. This was used to adjust abundance estimates of juvenile Coho, Steelhead parr (>60mm) and Steelhead fry (<60mm) in reaches were only single pass electrofishing was conducted. Total wetted area of each reach was calculated by wetted width and length measurements taken during electrofishing of each reach. The number of fish per square meter at all sites sampled in each watershed was averaged to produce a single index of parr abundance for each watershed and year.

Each captured fish was anesthetized, identified to species, measured, and weighed. Beginning in 2005, all juvenile Coho larger than 55 mm and juvenile Steelhead greater than 60 mm were marked with PIT tags in East and West Twin. PIT tagging in Deep Creek commenced in 2009. To increase the total number of juvenile Coho Salmon PIT-tagged, additional multiple-pass electrofishing was conducted in three to five additional, deliberately-selected reaches in East Twin and West Twin from 2005 till present and from 2009 till present in Deep Creek. Fish tagged in these additional reaches are included in estimates of overwinter survival, but were not used as an index of abundance.

Smolts and Adults – Smolt production for each watershed has been estimated since 1998 in Deep Creek and since 2001 in East Twin and West Twin by the Lower Elwha Klallam Tribe using fence weir type smolt traps. The traps are located in the lower mainstem of each stream (Figure 2) and operated during spring smolt outmigration period, late April to mid-June. The traps include a channel spanning weir that forces all smolts into a trap box. Although the vast majority of smolts are captured, trap efficiency estimates are made periodically to correct for any fish that may slip through the weir during high flows.

Coho and Steelhead adult/redd surveys are conducted by the LEKT and WDFW throughout the spawning season in the major spawning areas in all three streams. These numbers are converted to total spawners using the area under the curve (AUC) method.

PIT tag methods – Stationary multiplex PIT tag readers were installed 300 to 500 m above tidewater in the East Twin and West Twin rivers in 2004 and in Deep Creek in 2009. To maximize our probability of detecting PIT tagged fish, each reader includes two antenna arrays each composed of three antennae that spanned the stream under most flows (see Roni et al. 2012 for a detailed description). This configuration allows for the detection of PIT-tagged fish emigrating from the watersheds to the marine environment and the estimation of overwinter survival of PIT-tagged Coho. Outmigration timing and survival for tagged Steelhead is much more complicated because Steelhead may smolt at ages one to four, which makes it difficult to distinguish among age classes and returning adults.

For each stream and year, survival from tagging in August and September to out-migration is estimated in two steps. First, we calculate the total number of tagged juvenile Coho that out-migrate each month based on the last detection date from September through June. Then we correct those numbers based on the PIT tag reader efficiency. Because each PIT tag reader included two antenna arrays in each stream, we use the combined efficiency of both arrays (Zydlewski et al. 2006; see Roni et al. 2012 for details).

The combined efficiency was used to correct monthly rates of detection and survival for each stream. Annual survival from tagging to out-migration was calculated by summing the total monthly-corrected detections by the total number of fish tagged that year. We examined each tagging cohort separately from 1 September to 30 June because all tagged fish were last detected during this period, few or no fish emigrated in July and August, and we detected no two-year old juvenile Coho. In addition, we classified Coho as fall/winter (fall/winter) migrants if they emigrated before 1 February and spring migrants if they emigrated from 1 February through 30 June. The peak spring migration typically took place during April or May, with few fish emigrating before March or after mid-June. We calculated the proportion of fall/winter migrants by dividing the number of fall/winter (corrected for efficiency) by the total number of migrants detected (corrected for efficiency).

Using a combination of PIT tagged Coho detected and undetected in the smolt trap, we also estimate the total summer parr population in the watershed. Coho smolt to adult survival was calculated for each brood year as the proportion of tagged smolts that returned approximately 18 months later. Smolts per spawner for Coho was estimated by dividing the total number of smolts produced by the estimated number of spawning adults two years prior.

Steelhead have a more complex life history. We describe outmigration timing and adult returns in this document. A detailed analysis is currently underway (Hall, et al. in prep).

Table 5. Summary of data collected and the number of years collected, by stream and organization. LEKT = Lower Elwha Klallam Tribe, WDFW = Washington Department of Fish and Wildlife, NOAA = NOAA Northwest Fisheries Science Center, DOE = Department of Ecology, WEYCO = Weyerhaeuser Company.

	Years of data collection		
	East Twin	West Twin	Deep Creek
Habitat			
TFW (LEKT)	2002, 2007, 2013	2004, 2011	1992, 1995, 1997, 2003, 2009, 2012
EMAP (WDFW)	2004 to Present	2004 to Present	2004 to Present
Flow, Temp., WQ (DOE)	2004 to Present	2004 to Present	2004 to Present
Temp, DO (LEKT)	1998, 2007 summer temps		1996, 1999, 2000, 2005 summer temps
Fish			
Adults (LEKT, WDFW)	2000 to present	2000 to present	2000 to present
Summer parr (Weyco, WDFW, DOE)	2004 to present	2004 to present	2004 to present
Smolts (LEKT)	2002 to present	2002 to present	1998 to present
PIT tagging (NOAA,LEKT, WEYCO)	2004 to present	2005 to present	2009 to present

Statistical analysis

The TFW habitat data from East Twin and Deep Creek were analyzed using one-way ANOVA or a t-test comparing habitat conditions at different times as restoration was implemented. We examine trends over time for all fish variables with two types of analysis. First, we examined the trends for each river and parameter through time using simple linear regression. Second, to examine the "restoration response" we calculated the difference between treatment and control pairs (East Twin minus West Twin and Deep Creek minus West Twin) for each parameter and year. We then used simple linear regression to examine whether there was a detectable positive (or negative) temporal response in the parameter of interest. A $P<0.10$ level of significance was used for all statistical tests.

Results

Habitat

We expected that the addition of LWD to Deep Creek would result in a decrease in the width:depth ratio and an increase in the percentage of pool habitat. In Deep Creek, there was a significant ($P<0.05$) decrease in width:depth ratio after restoration in all stream segments (Figure 3). However, the percent pool habitat increased significantly only in the Lower segment, while the response was variable and decreased the Middle and Upper segments, respectively. Although LWD volume increased substantially in East Twin River, no significant response was seen in width:depth ratio or in percent pool habitat between 2002 and 2007 (the most recent dataset available at this time).

Temporal Trends in Fish

Trends over time in mean summer parr density were not significant for Coho parr, Steelhead parr or trout fry in any of the study streams (Table 6). Total summer Coho parr populations, estimated from PIT-tag mark-recapture estimates, show no significant trend in East Twin, but a decreasing trend through time in West Twin. There were too few data to analyze from Deep Creek where PIT-tagging began in 2009.

Mean spring Coho smolt production is higher in Deep Creek, 12,327, compared to 8,027 and 5547 in East Twin and West Twin, respectively. Coho smolt production, measured at the smolt trap, showed no significant trend in West Twin and Deep Creek, but a slight negative trend in East Twin (Figure 4). Steelhead smolt production is much lower with mean values of 1,730, 837, and 969 in Deep Creek, East Twin, and West Twin, respectively, and displayed a negative trend through time in all three streams (Figure 5; Table 6).

Average Coho escapement is 292, 257, and 277 in Deep Creek, East Twin, and West Twin, respectively. Trends in Coho adult abundance were not significant in Deep Creek, but showed a negative trend through time in East Twin and West Twin (Figure 4). Average Steelhead escapement was 127, 67, and 81 in Deep Creek, East Twin, and West Twin, respectively. Adult Steelhead returns showed a significant negative trend for all three streams (Figure 5), which is consistent with observations of other streams in the region.

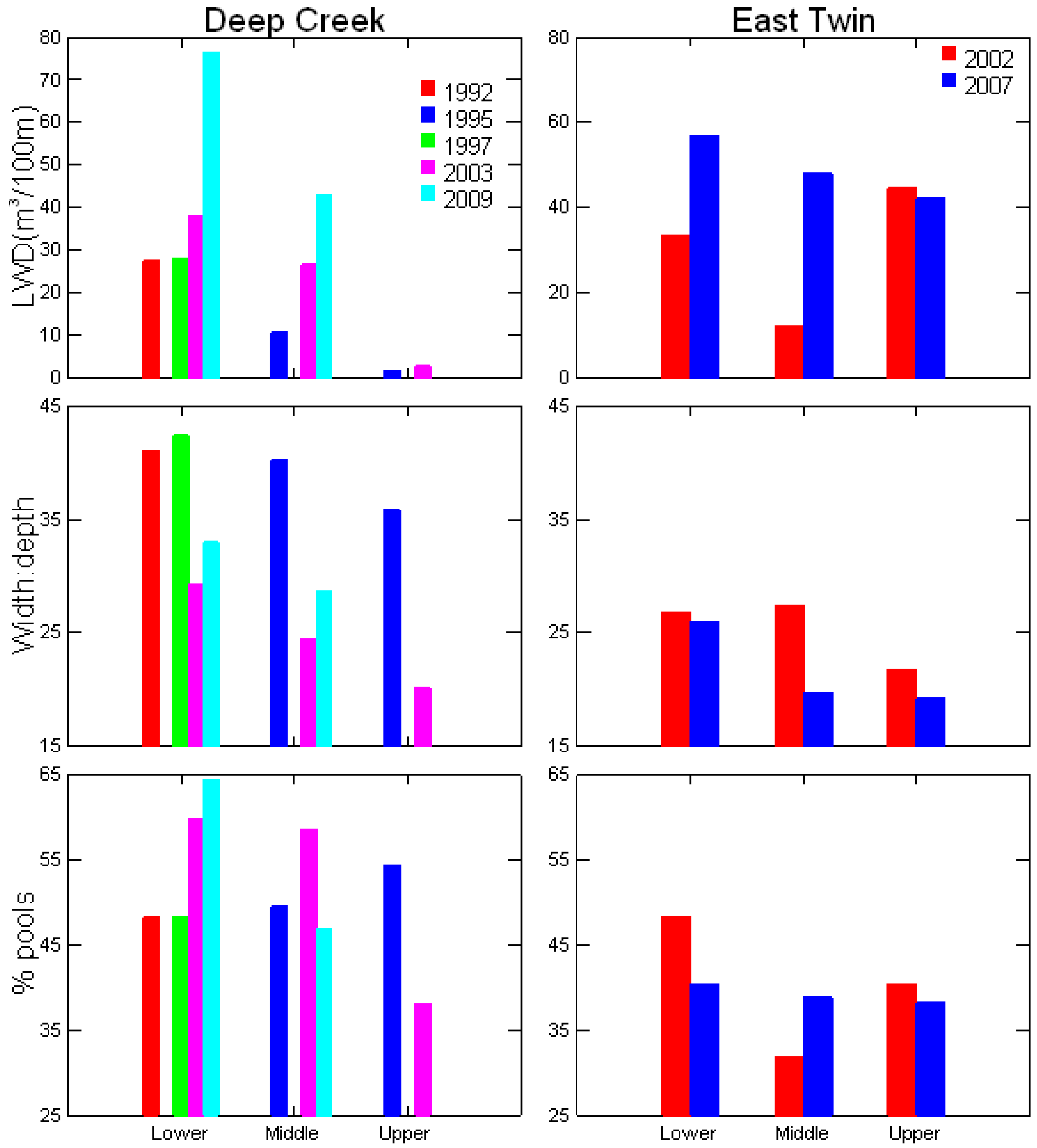
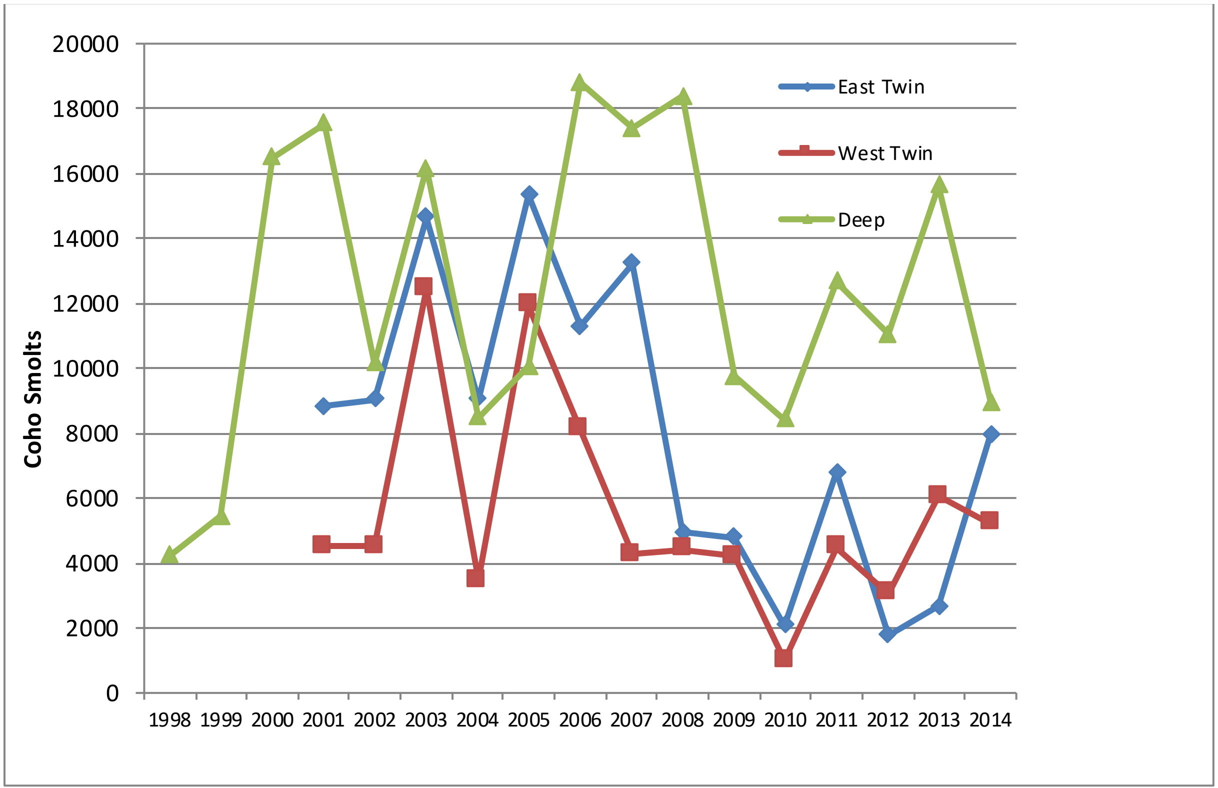


Figure 3. Trends in LWD, width:depth ratio, and % pool habitat by stream segment for Deep Creek and East Twin River. In Lower Deep Creek width:depth ratio decreased and the % pool habitat increased after LWD was added. In Middle Deep Creek, the response to LWD was variable. Width:depth ratio decreased significantly, but % pool habitat response was variable. In East Twin River, LWD addition to the Lower and Middle segments showed mixed response in the Lower segment and improvements in both width:depth ratio and % pool habitat in the Middle segment, although none of the changes were significant, based on the latest available data. No restoration was done in the Upper segment during this time.

Coho smolt-to-adult survival, based on spring smolt outmigration, showed a negative trend in Deep Creek but no trend in East Twin or West Twin. Overwinter survival in West Twin showed a weak positive trend (Table 6). We also examined spring smolts produced per adult spawner. This represents the productivity of the population. Coho smolts produced per spawner showed no significant trend (Table 6) in any of the streams. No trend in smolts per spawner was apparent for Steelhead, but Steelhead smolt at ages one to four years, making calculation of the number of smolts per spawners extremely difficult.

No correlation was detected between the number of high flow events (>100 cfs) and fish abundance or survival for any life stage ($p > 0.50$).



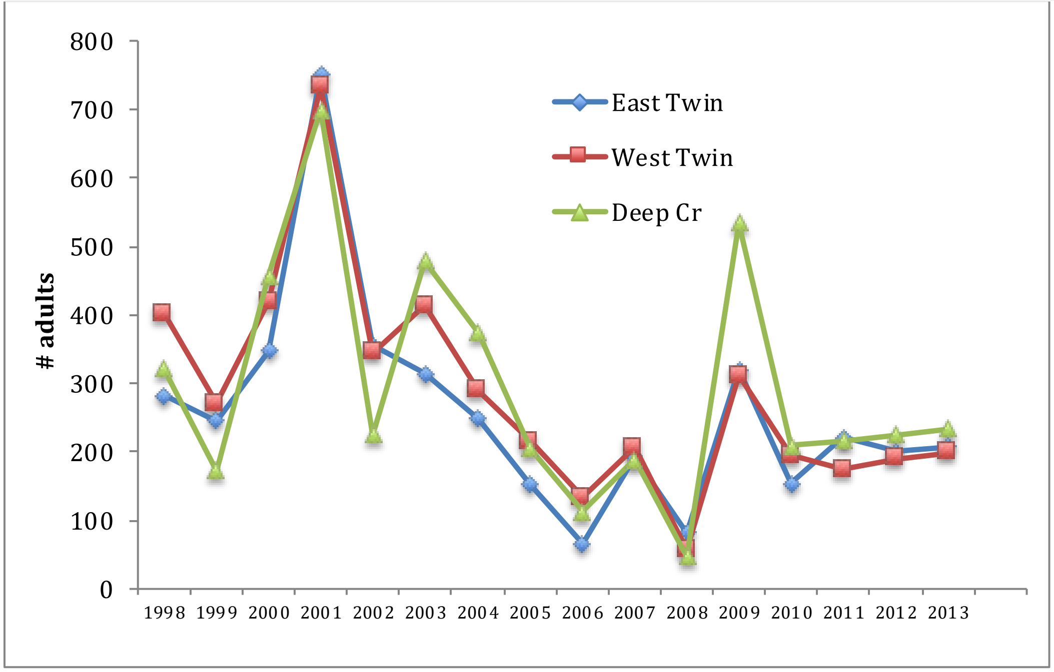


Figure 4. Coho smolts spring outmigration (top) and adult (bottom) estimates for each of three watersheds through study period.

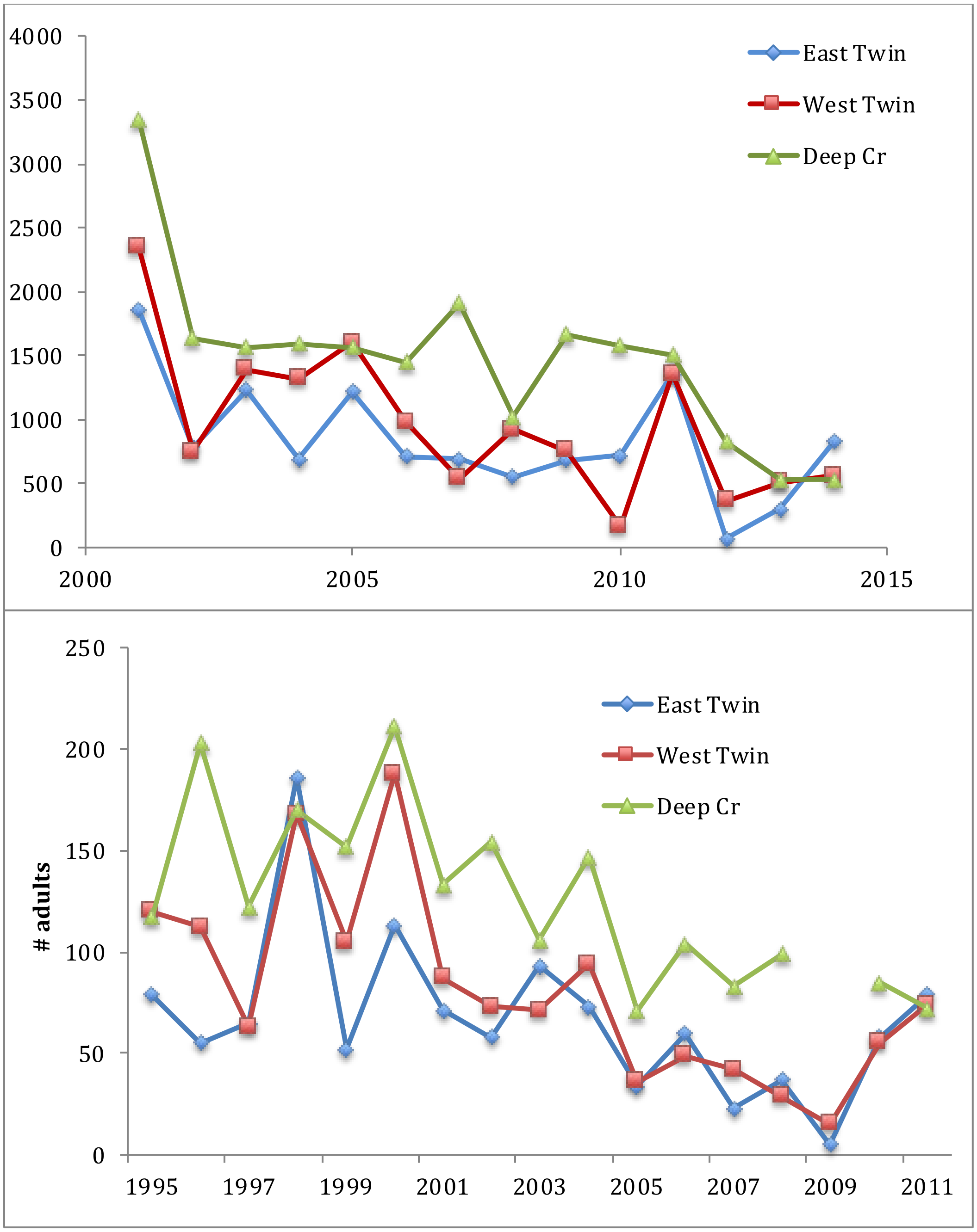


Figure 5. Steelhead smolt (top) and adult abundance (bottom) for three study watersheds.

Table 6. P-values for the regression analysis for trends in key parameters through time for each stream are shown. Direction of the trend, positive (+) or negative (-), and r^2 values are reported only for significant relationships ($p < 0.10$).

Metric	East Twin	West Twin	Deep Creek
Coho parr densities	0.57	0.83	0.89
Steelhead parr densities	0.24	0.25	0.64
Trout fry densities	0.20	0.57	0.26
Coho parr population	0.37	**0.07, (-) r^2 = 0.43**	0.74
Coho smolt production	**0.02, (-) r^2 = 0.42**	0.16	0.50
Steelhead smolt production	**0.07, (-) r^2 = 0.23**	**0.03, (-) r^2 = 0.34**	**0.01, (-) r2 = 0.55**
Adult Coho	**0.07, (-)r^2 = 0.17**	**0.02, (-) r^2 = 0.31**	0.20
Adult Steelhead	**0.08, (-) r^2 = 0.14**	**0.004, (-) r^2 = 0.40**	**0.003 , (-) r^2 =0.44**
Coho overwinter survival	.54	**.04, (+) r^2 = 0.50**	NA
Coho - Smolt to adult survival	**0.05; (+) r^2=.27**	0.66	**0.06, (-) r^2= 0.19**
Coho smolts/spawner	0.99	0.61	0.32

Treatment-Control Pairs

When we looked at the difference between treatment and control watershed pairs, no trend in restoration response was detected for either watershed pair (East Twin vs. West or Deep Cr vs. East Twin) in juvenile fish densities (Coho parr, Steelhead parr, trout fry), Steelhead smolt production, Coho overwinter survival, or Coho smolt to adult survival (Table 7). Positive trends were detected for Steelhead adults and Coho adults in East Twin and adult Coho in Deep Creek (Table 6). Similarly Coho smolts per spawner showed an increasing trend through time in Deep Creek, but not for East Twin. Coho smolt production in East Twin declined relative to West Twin.

Table 7. Results of regression analysis of difference between treatment and control watershed pairs for key metrics. Shown are the regression P-value and for P<0.10 the trend direction and r^2 value.

Metric	East -West Twin	Deep Cr-West Twin
Coho parr densities	0.45	0.96
Steelhead parr densities	0.35	0.27
Trout fry densities	0.38	0.97
Coho smolt production	**0.03, (-) r^2= 0.28**	0.92
Steelhead smolt production	0.12	0.393
Adult Coho	**0.02, (+) r^2=0.27**	**0.05, (+) r^2=0.19**
Adult Steelhead	**0.05, (+) r^2=0.18**	0.77
Coho overwinter survival	0.322	NA
Coho smolt to adult survival	0.11	0.40
Coho smolts per adult	0.64	**0.02, (+) r^2 = 0.50**

PIT Tagging Results

Our initial studies in East Twin and West Twin rivers documented very large numbers of Coho parr emigrating into the marine environment in the fall (Figure 6). This pattern does not appear to be related to higher fall stream flow or water temperature and the pattern is very similar in all three streams and among years. The size of fish at tagging (in August) appears to be a major factor determining whether a fish migrates to sea in fall/winter or spring and whether it survives to return as an adult. First, those fish never detected (presumed mortality) or those detected emigrating in the fall are smaller at tagging than those detected outmigrating in the spring as smolts (Figure 7). Although the mean length of fall/winter and spring migrants may vary among years, spring migrants are consistently larger at the time of tagging in all three streams and in all years (Table 8). In addition, those tagged fish that return as adults are substantially larger at tagging than those that do not return, regardless of whether they leave the stream as fall/winter or spring migrants. Figure 7 shows the mean fork length of over 26,000 parr tagged in all streams and in all years combined. Mean fork length at tagging of returning spawners was similar for fall/winter and spring migrants and was substantially larger than the mean of all spring migrants or all fall migrants. Overwinter survival, based on PIT tagging, shows similar pattern among all three streams (Table 9). However, marine survival of spring migrants was approximately five fold higher than for fall migrants over all years (Figure 8).

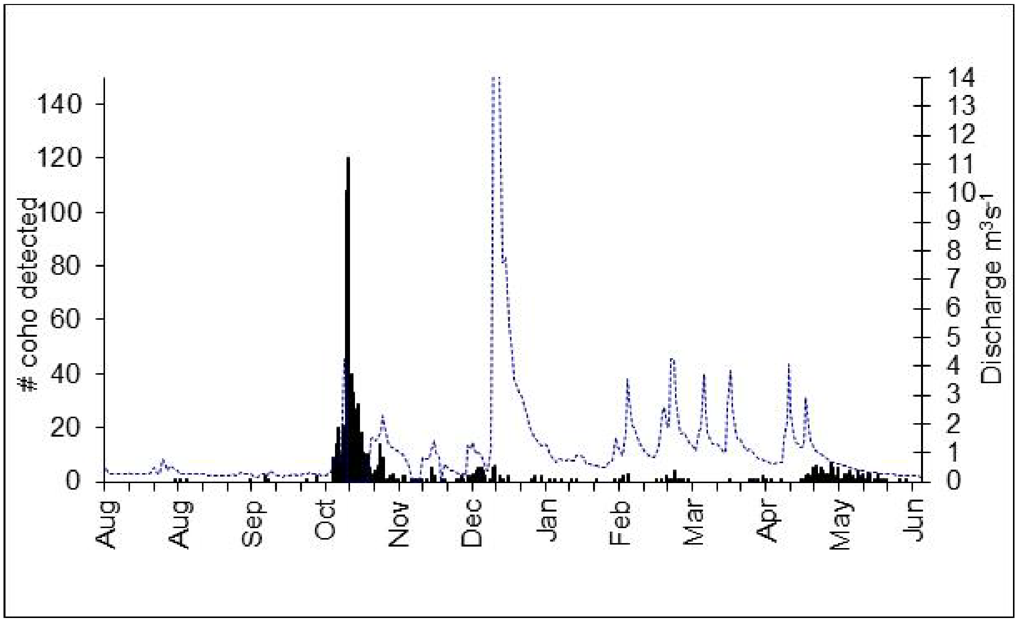


Figure 6. Example of typical migration pattern for PIT tagged juvenile Coho observed in all years and all three study streams. Dashed line represents stream discharge, black bars are number of Coho detected emigrating past PIT tag reader each day. This example is for fish tagged in summer of 2008 in West Twin River but the pattern was consistent among streams and years.

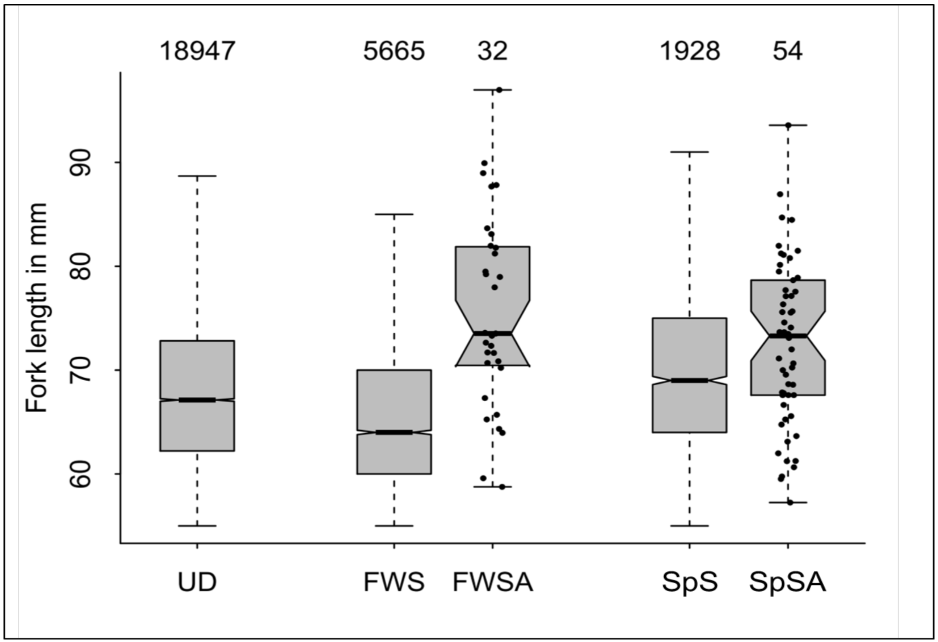


Figure 7. Box and whisker plot showing fork length at tagging for juvenile Coho that were never detected (UD), detected as fall/winter smolts (FWS), detected as adult returns from fall/winter smolts (FWSA), detected as spring smolts (SpS), and detected as adults returns from spring smolts (SpSA). There were too few tagged adults to evaluate differences among the three streams (From Bennett et al. 2014).

Table 8. Coho parr length at tagging (in mm) of fall/winter versus spring outmigrants in East Twin River, West Twin River, and Deep Creek. Note that the relative difference between fall/winter and spring migrants is consistent, although the absolute length varies among years.

		East Twin	West Twin	Deep Creek
2005/2006	Fall	63.6 (n = 500)	62.6 (n = 222)	
	Spring	67.2 (n = 378)	67 (n = 541)	
2006/2007	Fall	63 (n = 647)	63.3 (n = 248)	
	Spring	67.2 (n = 125)	67.5 (n = 198)	
2007/2008	Fall	71.9 (n = 312)	71.3 (n = 150)	
	Spring	73.4 (n = 233)	72.2 (n = 192)	
2008/2009	Fall	62.8 (n = 587)	65.9 (n = 600)	
	Spring	66.4 (n = 181)	67.9 (n = 265)	
2009/2010	Fall	76.2 (n = 257)	78.1 (n = 15)	-
	Spring	78.7 (n = 76)	83.3 (n = 54)	72.4 (n = 9)
2010/2011	Fall	64 (n = 479)	64.8 (n = 515)	62.2 (n=214)
	Spring	66.8 (n = 48)	67.3 (n = 61)	68.3 (n = 120)
2011/2012	Fall	65.2 (n=423)	67.6 (n=224)	64.1 (n=112)
	Spring	65.9 (n=101)	68.4 (n=95)	64.4 (n=113)
2012/2013	Fall	66.8 (n=337)	66.7 (n = 275)	64.1 (n=266)
	Spring	67.8 (n = 97)	68.6 (n = 91)	67.7 (n= 210)
2013/2014	Fall	62.4 (n = 464)	62 (n = 190)	61.5 (n = 128)
	Spring	65.7 (n = 74)	64.2 (n = 54)	64.6 (n = 94)

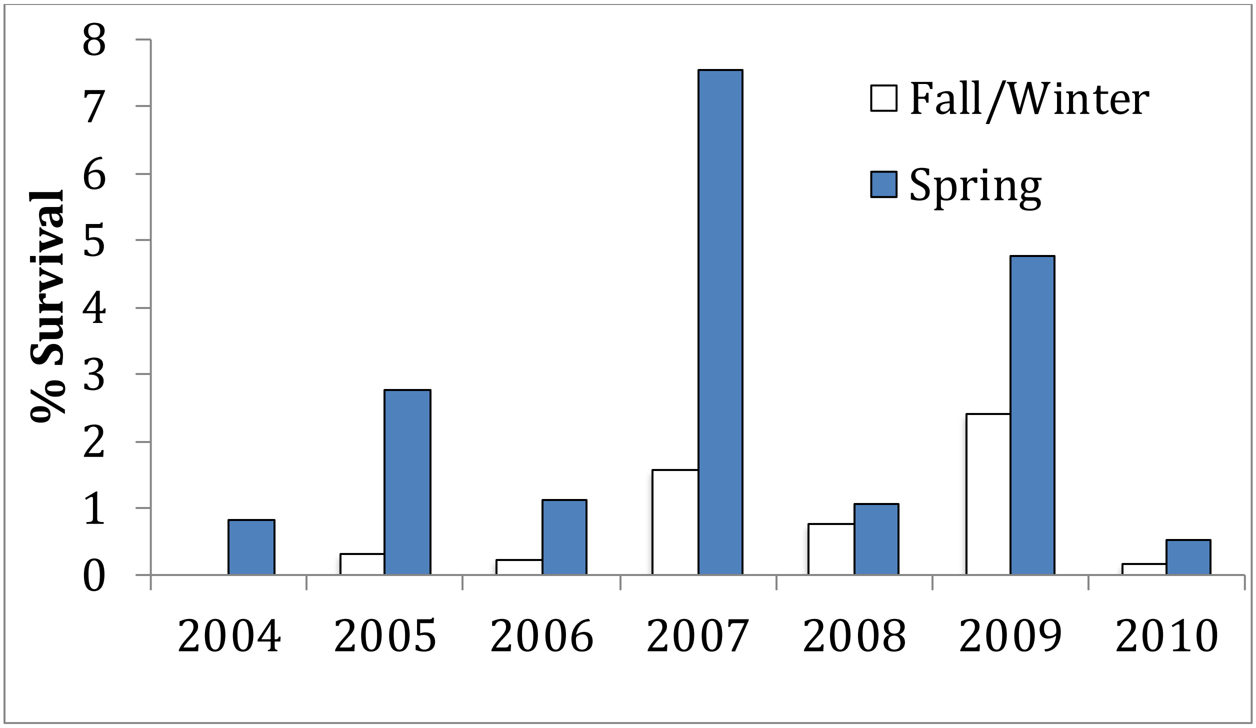


Figure 8. Marine survival of PIT-tagged Coho was consistently higher for Spring migrants.

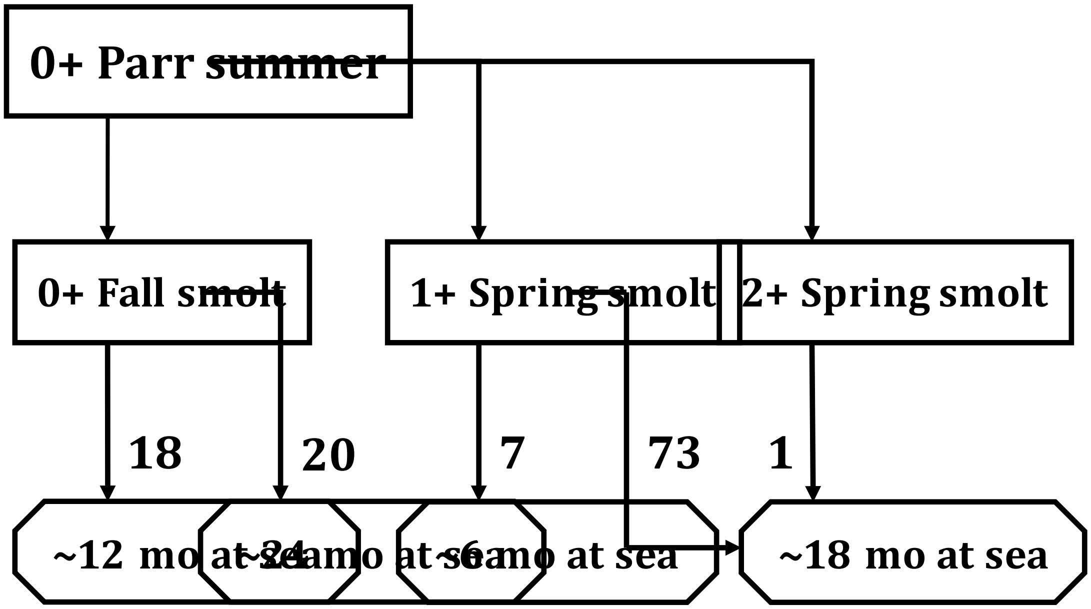


Figure 9. At least five Coho salmon life history strategies have been identified. Although most PIT-tagged adults were spring outmigrants, 32% were fall/winter migrants. Of these fall/winter migrants, 18 of 38 returned after only 12 months at sea.

Table 9. Survival of juvenile Coho in East and West Twin Rivers and Deep Creek from tagging to fall migration, spring migration, and for all Coho migrants.

Tagging year	Outmigration Season	Number detected	Tagged	Survival	Overall survival	Corrected survival
East Twin						
2005	Fall 05	500	3,117	0.16	0.28	0.30
2005	Spring 06	378	3,117	0.12		
2006	Fall 06	647	2,509	0.26	0.31	0.34
2006	Spring 07	125	2,509	0.05		
2007	Fall 07	312	1,627	0.19	0.33	0.35
2007	Spring 08	233	1,627	0.14		
2008	Fall 08	587	2,298	0.26	0.33	0.36
2008	Spring 09	181	2,298	0.08		
2009	Fall 09	257	622	0.41	0.54	0.56
2009	Spring 10	76	622	0.12		
2010	Fall 10	479	1,425	0.34	0.37	0.38
2010	Spring 11	48	1,425	0.03		
2011	Fall 11	423	1,717	0.25	0.31	0.33
2011	Spring 12	101	1,717	0.06		
2012	Fall 12	337	901	0.37	0.48	0.49
2012	Spring 13	97	901	0.11		
2013	Fall 12	464	1,812	0.26	0.30	0.31
2013	Spring 13	74	1,812	0.04		
Average					**0.35**	**0.38**
West Twin						
2005	Fall 05	222	3,032	0.07	0.25	0.35
2005	Spring 06	541	3,032	0.18		
2006	Fall 06	271	2,496	0.11	0.19	0.29
2006	Spring 07	198	2,496	0.08		
2007	Fall 07	150	1,285	0.12	0.27	0.27
2007	Spring 08	192	1,285	0.15		
2008	Fall 08	600	2,270	0.26	0.38	0.40
2008	Spring 09	265	2,270	0.12		
2009	Fall 09	15	162	0.09	0.43	0.43
2009	Spring 10	54	162	0.33		
2010	Fall 10	515	1,077	0.48	0.53	0.55
2010	Spring 11	61	1,077	0.06		
2011	Fall 11	224	724	0.31	0.44	0.45
2011	Spring 12	95	724	0.13		
2012	Fall 12	275	708	0.39	0.52	0.53
2012	Spring 13	91	708	0.13		
2013	Fall 13	190	1,306	0.15	0.20	0.20
2013	Spring 14	54	1,306	0.04		
Average					**0.36**	**0.39**
Deep Creek						
2009	Fall 09	19	142	0.13	0.19	0.20
2009	Spring 10	8	142	0.06		
2010	Fall 10	214	1,377	0.16	0.24	0.26
2010	Spring 11	120	1,377	0.09		
2011	Fall 11	112	1,075	0.10	0.21	0.23
2011	Spring 12	113	1,075	0.11		
2012	Fall 12	266	1,598	0.17	0.30	0.31
2012	Spring 13	210	1,598	0.13		
2013	Fall 13	128	1,794	0.07	0.13	0.14
2013	Spring 14	94	1,794	0.05		
Average					**0.21**	**.023**

While previous studies have indicated that Coho that emigrate as fry or parr do not contribute to the adult population, our limited data on adult returns suggest that they do. Nearly 32% (38 of 119 adults) of PIT-tagged adult returns were from fall/winter migrants (Figure 9) (Bennett, et al. 2014). Of these returning fall/winter migrants 47% returned after only 12 months at sea compared to only 9% of the spring migrants.

Tagged Steelhead parr outmigration patterns were quite complex. We were able to reconstruct detection histories for complete juvenile cohorts from age-0 tagged fish from tagging years 2005 – 2011 in East Twin and West Twin. From these fish, a total of 21.7% (2,607/12,037) of age-0 tagged fish were detected as migrants on the stationary PIT readers (Table 10). The number of migrants observed expressing each sequential age and seasonal migration timing group followed an exponential decay function (exponential regression: $R^2 = 0.96$, $p < 0.001$), with most migrants expressing an age-0 fall timing (58.9%) and decreasing exponentially with 22.3% age-1 spring, 9.9% age-1 fall, 6.1% age-2 spring, 2.1% age-2 fall, 0.5% age-3 spring, and 0.1% age-3 fall migrants (Figure 10). We also observed an increasing trend in the proportion of tagged fish that were detected as migrants as age at tagging increased, with 21.7% (2,607/12,037) becoming migrants for age-0 tagged fish, 29.9% (1,414/4,725) for age-1 tagged fish, and 37.1% (219/591) for age-2 tagged fish (Table 10).

Table 10. Proportions of Age-0 cohort of tagged Steelhead classified as non-migrants and migration timing.

			Age-0 tagged fish		
River	Tag Year	Tagged	Non-Migrant	age-0 Migrant	age-1+ Migrant
ET	2005	816	83%	7%	9%
	2006	840	86%	7%	7%
	2007	1655	73%	16%	11%
	2008	818	80%	14%	6%
	2009	1097	65%	24%	11%
	2010	564	77%	17%	6%
	2011	451	78%	16%	5%
WT	2005	1013	89%	4%	8%
	2006	977	81%	8%	12%
	2007	1316	80%	10%	10%
	2008	635	74%	19%	7%
	2009	916	79%	9%	11%
	2010	566	75%	18%	7%
	2011	373	81%	14%	5%

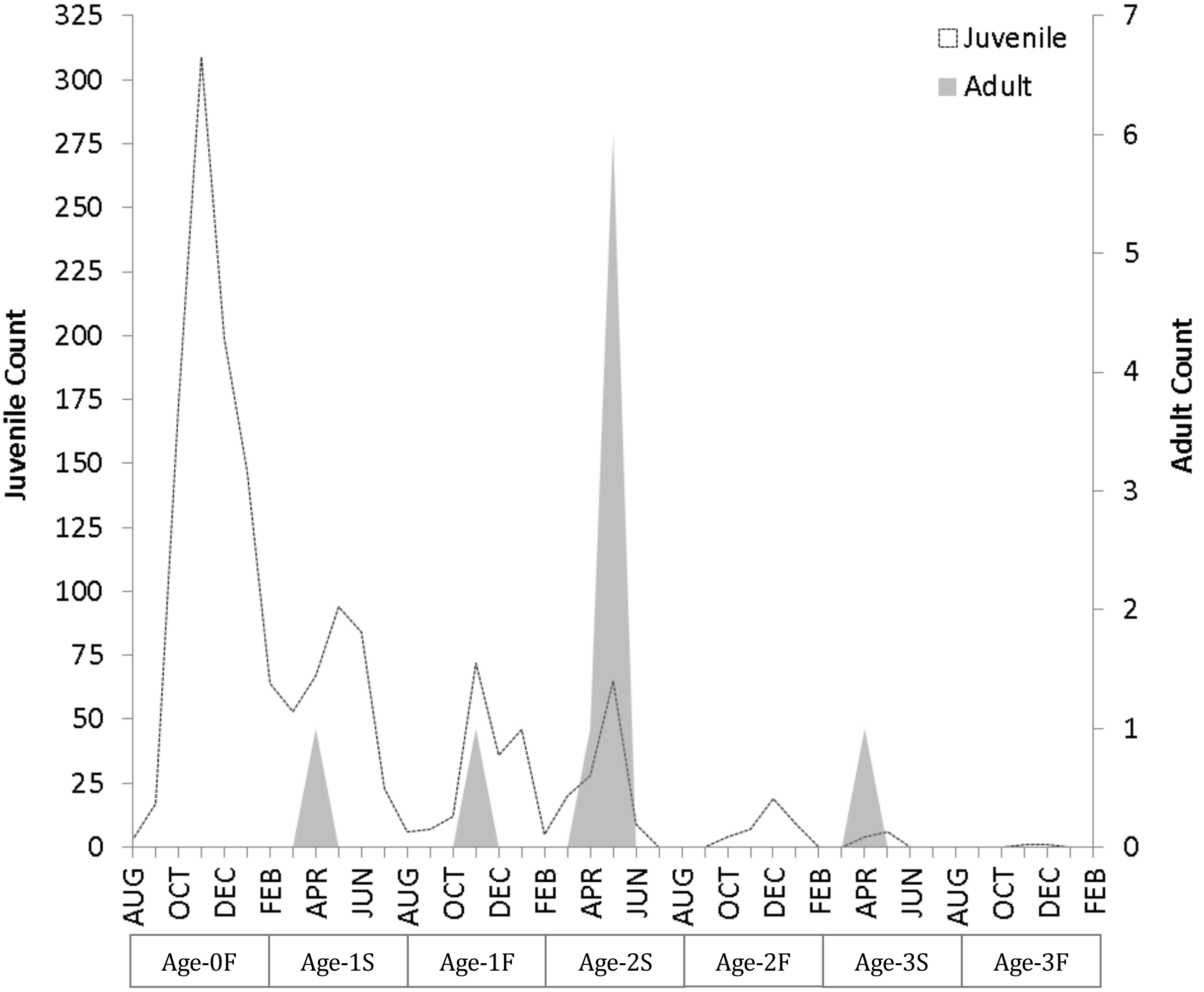


Figure 10. Counts of juvenile migrants by month of migration and count of returning adults produced from each month and age migrant group with river and tagging year pooled. Only age-0 tagged fish from tagging years 2005 – 2008 were included in this plot, as these are the only cohorts from which complete adult migration windows could be reconstructed from the stationary PIT tag reader array data series assuming a maximum total adult age of six years. Juvenile migrant life history types as determined from peaks in migrant timings are labeled below the months showing age (Age-0, Age-1, Age-2, and Age-3) and season (F = fall and S = spring) at juvenile migration. Adult counts are overlaid on the secondary axis showing the age and month at which the adult left the river as a juvenile.

Juveniles were also detected leaving the river in the summer at age-1 to rear in the ocean, then returning to the river to overwinter before migrating to the ocean in the following spring as an age-2 spring migrant. This half-pounder life history (see Hodge et al. 2014) was observed in only 0.2% (20/12,037) of age-0 tagged fish from 2005 – 2011, with approximately half coming from each river. We also observed fish that moved between rivers through the ocean as juveniles, although these fish represent only 0.8% (102/12,037) of the fish tagged at age-0 between 2005 and 2011. The frequency of movement from tagging river to non-tagging river was three times higher among fish tagged in East Twin, with 1.2% (75/6,241) of the fish tagged in East Twin moving to West Twin as compared to 0.4% (27/5,796) of West Twin tagged fish moving to East Twin. The proportions of fish moving from each river by age at migration between rivers were relatively comparable between rivers with most of movements occurring at age-0 or age-1 (48 and 44%, respectively) and relatively few fish moving at age-2 (8%). We also observed fish moving back into their tagging river after switching rivers. Among fish tagged in West Twin that moved to East Twin, 14.8% (4/27) returned to West Twin after the initial emigration. In contrast, only one fish out of the seventy-five fish observed moving from East Twin to West Twin returned to the tagging river after the initial emigration. However, this individual subsequently returned back to West Twin where it remained until migrating out to the ocean. Among the fish detected moving between rivers as juveniles, median time between detections was 65.8 hours with a minimum 1.9 hours. Based on the distance between stream mouths in Strait of Juan de Fuca (~500m) and the location of the stationary PIT readers, the median travel speed for fish moving from East to West Twin River was approximately 25 meters per hour (< 0.01 m/s) with a maximum speed of approximately 790 meters per hour (0.22 m/s).

A total of 37 adult returns were detected from all tagging years and a variety of adult life histories were observed among these adults, with variations in the number of years spent in the ocean, season of return to the river, and repeat spawning. Detection histories indicate that all adults migrated from the river at age-1 or older (age-1+) with no adults having migrated at age-0. The maximum total adult age observed was six years, with age-1 migrants returning after one to three years in the ocean (age 1.1, 1.2, and 1.3), age-2 migrants spending one to four years in the ocean (age 2.1, 2.2, 2.3, and 2.4), and age-3 migrants returning after one or two years in the ocean (age 3.1 and 3.2). Both winter and spring returns of adult Steelhead were observed, and both semelparous and iteroparous life histories were observed. Repeat spawning was only observed among age-2 migrants, with the first return occurring after one or two years in the ocean and the second return occurring one year after the first return. Given a maximum total age of six years, the life history diversity observed from all tagging years as described above can only be used to determine the presence of different life histories in the population. To determine the relative prevalence of life histories, we only considered age-0 tagged fish from tagging years 2005 – 2008 for which we could reconstruct complete cohorts. From these fish, a total of ten adults were observed with most adults having an age-2 spring juvenile life history. However, some adult life history strategies observed in the full data series were absent among this complete cohort data series. Therefore, small sample sizes among our complete cohort limits our ability to quantify the relative frequencies of different life history types given that known life histories in these populations are missing from our complete cohort data series. However, both the full data series and complete cohort reconstructions indicate that age 2.2 and 3.2 life histories with a spring juvenile migrant timing are the most commonly expressed Steelhead life histories in these populations among returning adults.

Discussion

Initially, restoration was guided by watershed analysis (ONF 2002). Actions completed so far range from the very long-term (planting conifers in hardwood-dominated riparian zones), to the mid-term (decommission of failure-prone forest roads), to the placement of instream LWD jams to retain naturally recruited wood and provide habitat complexity in the short-term. The effects of riparian plantings won't be seen for decades, but the effects of the decommissioning of the 3040 road, completed in 2010 and 2011 in East Twin and Deep Creek, respectively, and the extensive LWD projects completed in 2011 and 2014 in East Twin and Deep Creek, respectively, should be seen within the next few years.

In spite of the short time since restoration, some significant improvements in width:depth ratio and percent pool habitat were seen in Deep Creek. The response in East Twin River was mixed and non-significant in either of the treated segments as of the 2007 sampling data. Habitat data collected in 2013 are undergoing review and will be available by late-2015 for analysis.

In terms of absolute numbers, Coho and Steelhead smolt and adult population numbers are low in all three streams (Table 6) and this complicates the analysis. The trend analyses suggest that Steelhead adult returns and smolt production continue to decline in absolute numbers in all three streams (Table 6). Coho adults declined in two of the three streams and smolts declined in one of the three. The response of several fish metrics in East Twin and Deep Creek, when corrected for the control (West Twin), were more encouraging. These suggest that, relative to West Twin, Steelhead adults and Coho adults are increasing in East Twin (Figure 9) and Coho adult returns are increasing in Deep Creek (Figure 10). In addition, the number of Coho smolts produced per adult is increasing over time in Deep Creek. However, Coho smolt production declined over the same period in East Twin.

Our PIT tagging studies are providing important information with which to measure the effect of restoration but also to help guide future restoration efforts. So far we have identified four common Coho life history strategies based on the how much time they spend in freshwater, fall/winter vs. spring migrants, and whether they spend one or two years in saltwater. An important question is whether migration timing is a response to freshwater conditions (e.g. limited overwinter habitat or food) or a genetic predisposition (i.e. a life history strategy). If Coho fall migrants are being forced out due to limited habitat, then providing overwinter habitat could cause a shift toward spring migration. Higher marine survival rates seen in spring migrants should translate into more returning adults. If fall migration is simply another life history strategy, then providing additional food in the form of salmon carcass analogs could increase the growth rates. The PIT-tagged adults tend to be larger parr when tagged, so larger parr may increase the number of returning adults, regardless of when they emigrate.

Steelhead migration timing is more complex but it is clear that most tagged Steelhead parr leave freshwater as Age 0 fall migrants. Although only 37 tagged adults have been detected so far, all have been Age 1+ migrants. Given the complexity of their lifecycle, it’s too early to know how restoration may affect their numbers or migration timing.

Recommendations

While these preliminary results are encouraging, most of the restoration work was just recently completed and it will take several years for the habitat to respond and for fish to respond to those changes. In addition, low marine survival experienced throughout study translates into low adult populations that are vulnerable to stochastic events.

Simulation modeling suggests that a large proportion of a stream network may need to be restored to be confident in effecting a fish response (Roni et al. 2010). Although restoration projects have been implemented across much of the current anadromous zone of East Twin and Deep Creek, the IMW monitoring has identified additional restoration strategies targeted toward specific life history types. We believe the IMW program must continue to actively restore habitat and adapt our restoration strategy as we better understand how fish are responding in these streams.

We recommend that we:

- Consider distributing salmon carcass analogs in East Twin River in 2017 to test whether this affects Coho growth, migration timing, and survival.
- Consider projects that would increase overwinter habitat restoration in lower Deep Creek.
- PIT tag additional outmigrating Coho and Steelhead parr in October and November, 2015 to obtain more precise estimates of marine survival in all three streams.

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