STATE OF WASHINGTON August 2011

Intensively Monitored Watersheds: 2009 Fish Population Studies in the Hood Canal Stream Complex

by Clayton Kinsel and Mara Zimmerman

Washington Department of
FISH AND WILDLIFE
Fish Program
Science Division

FPA 11-06

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Acknowledgements

This work was funded by the Salmon Recovery Funding Board.

Data from the Hood Canal IMW project were collected by an experienced crew of technicians led by Mat Gillum. Eric Kummerow, Scott Walker and Karen Shields each brought their individual expertise, commitment, and enthusiasm to this project. They respond to the whim of the weather, tides and fishing schedules and have intimate knowledge of the watersheds, the fish, and fishing seasons. All field staff put in long hours, often at night during inclement weather, to ensure that traps continued to fish and that fish were handled and sampled in a gentle and timely fashion. Pete Topping provided logistical support related to trap installation and removal and expertise in trap design and function. Biologists from Weyerhauser and Washington Department of Ecology worked collaboratively to sample and mark coho parr. University of Washington has continuously provided access to the Big Beef property and research station since our long-term monitoring project began in 1978. Ryan Nauer and Ned Pittman (Habitat Program, WDFW) shared their knowledge of the watersheds and occasionally assisted with spawner surveys, parr surveys, and trap checks. Puget Sound Sampling Unit (WDFW) and the Skokomish Tribe worked cooperatively to sample the Area 12 chum and coho fisheries. Data retrieved from fishery sampling are used to calculate harvest rates of Big Beef Creek coho. Andy Weiss (WDFW) created the spawner distribution maps for this report. John Sneva (WDFW, adult coho) and Lance Campbell (WDFW, juvenile steelhead) determined fish ages from the collected scale samples. Thom Johnson (WDFW, Region 6 District Biologist) provided fishing regulation information and assisted with ESA permitting. The Hood Canal IMW project would not be possible without the support of Hood Canal landowners who grant access to the creeks and tribal fishermen who cooperate with harvest sampling efforts.

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Executive Summary

The Hood Canal Intensively Monitored Watersheds study includes four adjacent streams (Little Anderson, Big Beef, Seabeck, and Stavis creeks) that flow into the east side of Hood Canal. Coho salmon are the focal species for this study, although information on steelhead and chum are also collected. Objectives of fish population studies on the Hood Canal IMW streams are to (1) estimate abundance of coho parr and parr-to-smolt survival in all four creeks, (2) estimate juvenile production of coho and steelhead smolts in all four creeks, (3) compare timing of juvenile outmigration among watersheds, (4) determine escapement of coho and chum into Big Beef Creek, (5) describe spawning distribution and timing of coho salmon in all four creeks, and (6) estimate harvest rate and marine survival of Big Beef Creek coho.

Abundance and survival of coho parr were estimated using a mark-recapture approach. Parr were marked in selected stream reaches during surveys conducted in late July and early August. Marked coho were recaptured in downstream traps the following spring. For the 2007 brood year, parr abundance was highest in Big Beef Creek (N = 224,097, CV = 5.24%) and lowest in Seabeck (N = 7,541, CV = 10.15%) and Little Anderson (N = 9,123, CV = 12.02%) creeks. Coho parr abundance in Stavis Creek was estimated to be 29,727 (CV = 9.83%). Parr-to-smolt survival of the 2007 brood year was 19.26% in Big Beef Creek as compared to 11.58% in Little Anderson, 7.99% in Seabeck, and 11.33% in Stavis Creek.

Abundance of coho and steelhead smolts was estimated from fish captured in downstream traps operated between April and June. Downstream fan traps were operated on Big Beef Creek and fence weirs were operated on Little Anderson, Seabeck, and Stavis creeks. In 2009, coho smolt production was highest in Big Beef Creek (N = 45,398). Coho production was 1,101 smolts in Little Anderson Creek, 626 smolts in Seabeck, and 3,474 smolts in Stavis Creek. Steelhead smolt production was 1,005 in Big Beef Creek, 2 in Little Anderson, 21 in Seabeck, and 17 in Stavis Creek.

A total of 971 adult coho and 36 jack coho returned to the Big Beef Creek weir in 2009. Hatchery-origin coho represented 3.8% of the adult return and 8.3% of the jack return. Survival-to-return rate for jack coho was 0.08%. Marine survival of age-3 adult coho was 13.40%. Harvest rate of Big Beef Creek coho was 71.0% of the total run. Estimates of marine survival and harvest should be considered a lower bound due to unreported catch from some fisheries at the time of this report. Chum escapement to Big Beef Creek in 2009 included 132 summer chum and 370 fall chum. Seven adult steelhead (6 males, 1 female) were observed returning to Big Beef Creek in 2009, although this is likely an underestimate of escapement as a trap outage occurred in early January.

Introduction

IMW Project

In the past two decades, numerous salmon and steelhead populations in the Pacific Northwest have been listed under the Endangered Species Act. During this period, substantial resources have been invested in improving the condition of freshwater habitats. Little is known about whether and how salmon populations respond to habitat restoration efforts. In Washington State, Intensively Monitored Watersheds (IMW) program was established by selecting experimental watershed complexes where fish responses to habitat restoration would be measured. Salmonid abundance is measured at different life history stages in control and treatment streams prior to and following restoration activities. This study design, termed Before-After Control-Impact (BACI), distinguishes responses to restoration activities from responses to fluctuating environmental conditions (Downes et al. 2002; Roni et al. 2005).

Hood Canal IMW Stream Complex

This report focuses on salmonid abundances in the Hood Canal stream complex, which includes Little Anderson, Big Beef, Seabeck, and Stavis creeks (Figure 1). Land use surrounding Hood Canal watersheds ranges from urban and residential to protected and actively managed forest land. Stavis Creek is the control stream for which no treatments are planned. In Little Anderson Creek, lack of wood and off-channel habitat may be constraining salmonid production. The Little Anderson watershed was modified by replacing a culvert with a bridge on Northwest Anderson Hill Road in November 2002 and by placement of large woody debris in the lower reaches of the watershed in summer of 2007 and 2009. In Seabeck Creek, channel incision and sediment deposition may be reducing groundwater storage and exacerbating the effects of low summer flows on survival of juvenile salmon. In Big Beef Creek, predation in Lake Symington and channelization in the lower reaches of the creek are all likely to limit juvenile survival. Low escapement has the potential to limit freshwater production in all four creeks. Future habitat restoration in Big Beef and Seabeck creeks are in the planning phase.

This report presents methodology and results from the 2009 field season and is organized into three major sections: parr evaluation, smolt evaluation and adult evaluation. Coho (*Oncorhynchus kisutch*) are the focal species for the population abundance and survival estimates derived for these watersheds. When possible, abundance and life history information is also gathered for summer and fall chum salmon (*Oncorhynchus keta*), steelhead (*Oncorhynchus mykiss*) and coastal cutthroat trout (*Oncorhynchus clarki clarki*). Coho abundance in these creeks is estimated at three life history stages. Parr are collected by electrofishing and seining in index reaches during late summer. Smolts are captured in weirs operated during the spring. Adult escapement is enumerated at the Big Beef Creek weir. Spatial distribution and timing of spawning activity is summarized based on comprehensive spawner surveys on each of the four watersheds.

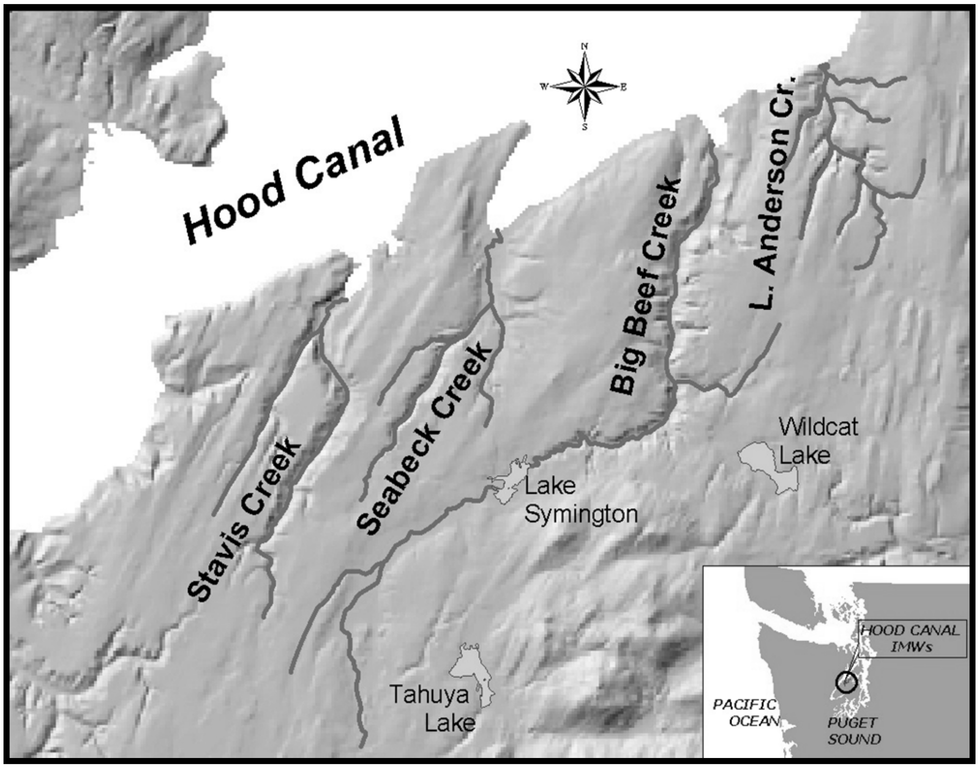


Figure 1.─Location of four IMW streams in Hood Canal: Little Anderson, Big Beef, Seabeck, and Stavis creeks.

Objectives of fish population studies on the Hood Canal IMW streams were to:

(1) Estimate abundance of coho parr and parr-to-smolt survival in all four creeks,
(2) Estimate juvenile production of coho and steelhead smolts in all four creeks,
(3) Compare timing of juvenile outmigration among watersheds,
(4) Determine escapement of coho, chum, and steelhead into Big Beef Creek,
(5) Describe spawning distribution and timing of coho salmon in all four creeks, and estimate harvest rate and marine survival of Big Beef Creek coho.

Hood Canal Parr Evaluation

Parr Methods

Fish Collection

Abundance of coho parr at the watershed scale was estimated using a mark-recapture study. Parr were captured and marked in late July and early August. The following spring, all smolts (marked and unmarked) were captured in weirs during the outmigration period. The incidence of marked fish among out-migrating smolts was used to back-calculate total watershed abundance of parr during the late summer months (Volkhardt et al. 2007). Recapture of marked fish also provided a measure of parr-to-smolt survival.

Coho and steelhead parr were collected by electrofishing and seining at index sample sites. Collection was completed in collaboration with Weyerhaeuser Company and Washington State Department of Ecology. At the outset of the IMW project, ten 50-meter index sites were selected in Little Anderson, Big Beef, Seabeck, and Stavis creeks using a spatially balanced probabilistic sample design (Figure 2). The same index reaches have been sampled annually since 2004. For each site, the goal was to collect and mark 100 fish of each species. When electrofishing yielded too few fish, adjacent areas were seined in order to increase the number of marked fish from that region of the watershed.

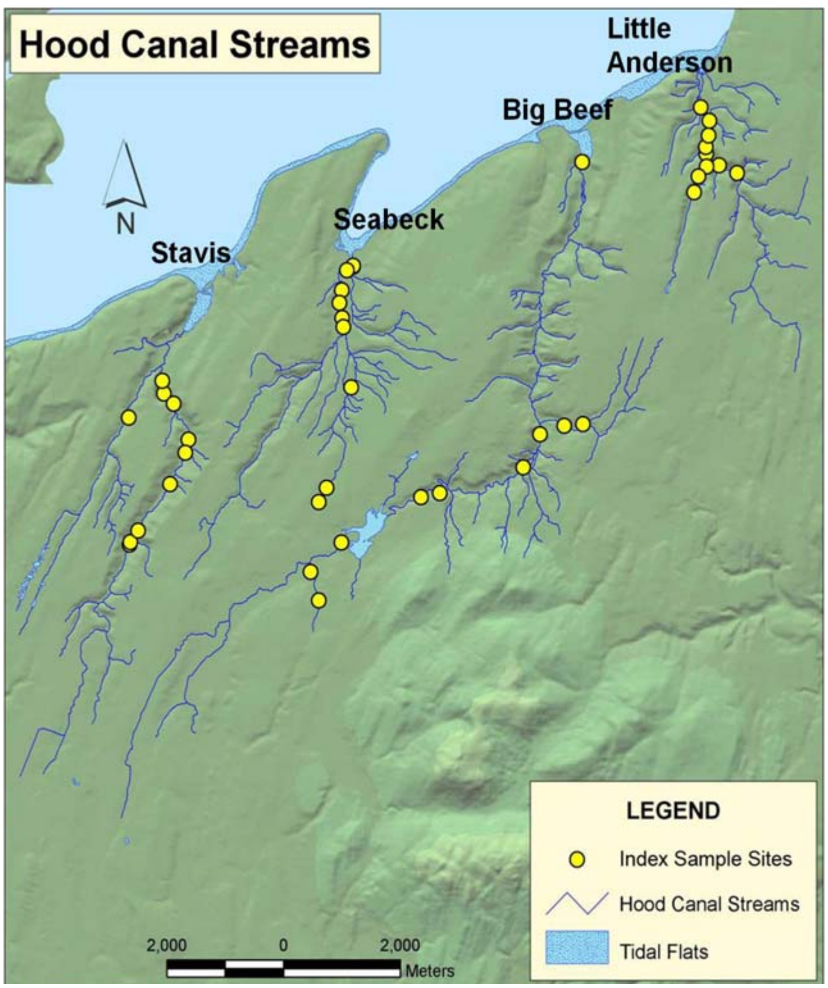


Figure 2─Index sample sites on Little Anderson, Big Beef, Seabeck, and Stavis creeks. Coho and steelhead parr are collected by electrofishing and seining at each site.

On all four creeks, coho parr were enumerated, measured (fork length, FL), weighed (mg), adipose fin clipped, and released. On Big Beef Creek, steelhead parr longer than 85-mm FL were PIT-tagged. Catches of steelhead on the other three creeks were not numerous enough to warrant mark and release. Steelhead parr longer than 85-mm FL were PIT tagged because this size class are 1+ age fish that will migrate downstream the following spring.

Marked coho and steelhead were recaptured in downstream weirs the following spring. Downstream migrating coho were inspected for adipose clips and steelhead were scanned for PIT tags. Additional information collected in the downstream weirs is provided in the Smolt Evaluation section.

Analysis

The length, weight, and condition of parr were summarized. Condition was described using Fulton's K index (Anderson and Neumann 1996). These metrics (*B)* were compared among the four watersheds using a Z-test (Zar 1999) and an α of 0.05.

Equation 1

$$K = (W / L^3) * 100{,}000$$

Equation 2

$$Z = \frac{(\overline{B}_1 - \overline{B}_2)}{\sqrt{V(B_1) + V(B_2)}}$$

Coho parr abundance was estimated by back-calculating abundance (Volkhardt et al. 2007) using a Petersen estimator with a Chapman modification (Seber 1973):

Equation 3

$$\hat{N} = \frac{(n_1 + 1)(n_2 + 1)}{(m_2 + 1)} - 1$$

where:

$\hat{N}$ = Estimated summer parr abundance,

n_1 = Number of parr marked and released (summer survey),

n_2 = Number of marked and unmarked smolts captured (downstream trap), and

m_2 = Number of marked fish recaptured (downstream trap).

Variance of the abundance estimate was (Seber 1973):

Equation 4

$$V(\hat{N}) = \frac{(n_1 + 1)(n_2 + 1)(n_1 - m_2)(n_2 - m_2)}{(m_2 + 1)^2 (m_2 + 2)} - 1$$

Parr to smolt survival ($\hat{S}$) was calculated for each stream as:

Equation 5

$$\hat{S} = \frac{m_2}{n_1}$$

This analysis was modified in years that fence weirs were blown out for a portion of the outmigration period. In this case, the number of recaptures ($\hat{m}_2$) was the sum of actual recaptures and those estimated for periods that the weir did not operate.

Estimated recaptures ($\hat{m}_i$) were the estimated catch for the outage period ($\hat{n}_i$) modified by the seasonal ratio of recaptures (m_2) to total (n_2) smolts caught in the downstream trap. The approach to estimated catch during the outage period is described in the Smolt Section of this report.

Equation 6

$$\hat{m}_i = \sum \hat{n}_i \frac{m_2}{n_2}$$

Parr Results

Summer 2009 Parr (Brood Year 2008)

In 2009, coho parr were marked in Big Beef (n_1 = 1,208), Seabeck (n_1 = 158), and Stavis (n_1 = 479) creeks (Table 1). In Little Anderson Creek, no zero-age coho were collected at any of the ten sampling sites. However, three 1+ coho were captured in Little Anderson. Of the three coho, one was already ad-marked, presumably a recapture of coho marked during the 2008 summer sampling. Samplers applied an adipose clip to the other two 1+ coho (n_1 = 2).

Average lengths for each watershed ranged from 60.5-mm FL (±7.1, 1 SD) to 84.7-mm FL (±10.3). Average weight ranged from 2.9 g (±1.2) to 7.1 g (±2.2). Average condition factor ranged from 1.12 (±0.07) to 1.19 (±0.08). Length, weight, and condition did not statistically differ among watersheds ($p > 0.05$, Table 2).

Steelhead parr were only caught in sufficient numbers to measure or tag in Big Beef Creek. In Big Beef Creek, steelhead lengths were bi-modal (Figure 2). The first peak in the size distribution was a combination of steelhead and cutthroat parr (trout less than 80-mm FL could not be identified to species). Steelhead 1+ parr had an average body length of 118.0 mm FL (±16.2), weight of 21.7 g (±8.4), and condition factor of 1.14 (±0.09). In 2009, a total of 72 steelhead parr were PIT-tagged.

Table 1.─Coho and steelhead parr marked in Hood Canal IMW streams in 2009. Coho were marked with an adipose clip. Steelhead were marked with PIT tags.

Stream	Date	Coho	Steelhead
Little Anderson	July 21 - August 4, 2009	2	n/a
Big Beef	July 20 - August 06, 2009	1,208	72
Seabeck	July 23 - July 28, 2009	158	n/a
Stavis	July 23 - August 5, 2009	479	n/a

Table 2.─Length (mm), weight (g), and Fulton condition factor (K) for coho and steelhead parr in Hood Canal IMW streams, summer 2009.

		Length		Weight		Condition		
Species	Stream	Mean	SD	Mean	SD	Mean	SD	Number Sampled
coho	Little Anderson	84.7	10.3	7.1	2.2	1.16	0.09	3
coho	Big Beef	60.5	7.1	2.9	1.2	1.19	0.08	441
coho	Seabeck	64.6	6.2	3.2	0.9	1.16	0.07	170
coho	Stavis	62.7	6.8	3.0	1.1	1.12	0.07	329
steelhead	Big Beef	118.0	16.2	21.7	8.4	1.14	0.09	33

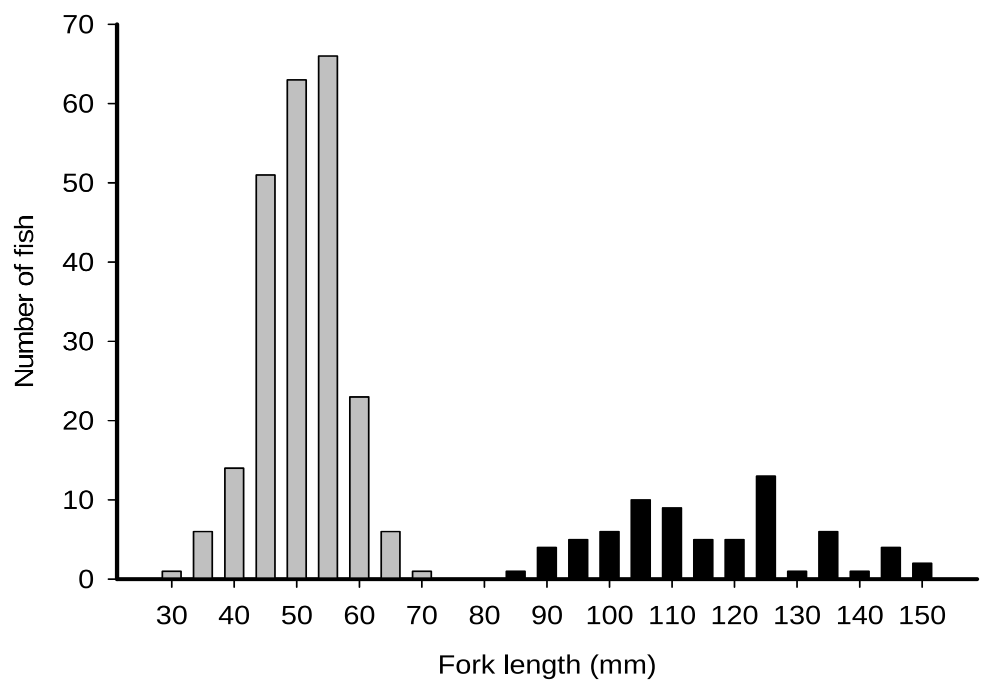


Figure 3.─Length distribution of steelhead (black bar) and trout parr (gray bar) captured during summer surveys on Hood Canal IMW streams, 2009. Trout less than 80-mm FL could not be identified to species and are classified as trout parr. Trout parr are a combination of steelhead and cutthroat.

Coho Parr Abundance and Survival (BY 2007)

Coho parr captured and marked in summer of 2008 (brood year 2007) were recaptured in downstream weirs in 2009. Summer parr abundance for BY 2007 was estimated to be 9,123 (*CV* = 12.02%) coho in Little Anderson Creek, 224,097 (*CV* = 5.24%) coho in Big Beef Creek, 7,541 (*CV* = 10.15%) coho in Seabeck Creek, and 29,727 (*CV* = 9.83%) coho in Stavis Creek (Table 3). Parr-to-smolt survival was highest in Big Beef Creek (19.26%) and lowest in Seabeck Creek (7.99%).

Table 3.─Coho summer parr abundance and parr-to-smolt survival in Hood Canal IMW streams (BY2007).

	Little Anderson	Big Beef	Seabeck	Stavis
Marked parr (n_1)	501	1,506	951	847
Total smolts (n_2)	1,035	43,272	609	3,119
Actual recaptures (m_2)	56	290	76	88
Parr abundance (N)	9,123	224,097	7,541	29,727
Abundance variance $V(N)$	1,202,342	137,842,017	585,633	8,537,989
Abundance 95% *C.I.*	2,149	23,012	1,500	5,727
Abundance *C.V.*	12.02%	5.24%	10.15%	9.83%
Actual+Estimated Recaptures ($\hat{m}_2$)	58	290	76	96
Survival ($\hat{S}$)	11.58%	19.26%	7.99%	11.33%

Recaptures of Tagged Steelhead

A total of 28 steelhead smolts caught in the 2009 downstream trap were recaptures of previously tagged fish (Table 4). Of these, 27 were tagged the previous summer (2008) and one had a PIT tag whose code origin could not be determined. The inability to identify the one code was likely due to a data recording error. This represents a recapture rate of 23.9% which was higher than the previous year's recapture rate of 9.0%.

Table 4.─Big Beef Creek steelhead tagged during summer parr sampling and recaptured as out-migrating smolts.

		Total Recaptures	
Tag Year	Total Tagged	2008	2009
Summer 2007	89	8	
Summer 2008	113		27

Parr Discussion

Variables Influencing Coho Parr Survival and Abundance

Abundance of coho parr for BY 2007 was lower than average for all creeks except Big Beef Creek. In Big Beef Creek, coho parr abundance for BY 2007 was 111% of the long-term average (Table 5). Coho parr abundance in Seabeck, Stavis, and Little Anderson creeks were just 42%, 48%, and 65% of long-term averages. Assuming that spawner abundances were correlated among the four creeks, these relative differences in parr abundance suggest that egg-to-parr survival differed among the creeks.

One possible explanation for differences in parr abundance is that the extreme December 2007 flood event had differential effects among these watersheds. This event occurred near the end of the coho spawning period and moved substantial amounts of substrate through each watershed. Scour and siltation occurring during egg incubation are known to have large impacts on egg-to-fry survival (Holtby and Healey 1986; Koski 1966). Under the same flow conditions, redds located in areas where substrate transport is substantial are expected to have higher mortality than those located where minimal substrate transport occurs. In comparison with the other three IMW watersheds, Big Beef Creek has a less confined stream channel, lower gradient reaches and more numerous wetlands. We hypothesize that access to more protected spawning areas in Big Beef Creek, as compared to Stavis, Seabeck, and Little Anderson creeks, may improve survival in Big Beef Creek during incubation flow events.

Table 5.─Summer parr abundance and parr-to-smolt survival for the 2007 brood year (BY) of coho compared to average values (BY 2003 to 2006) in Hood Canal IMW streams.

	Parr abundance ($\hat{N}$)		Parr-to-smolt survival ($\hat{S}$)	
Watershed	Average	BY 2007	Average	BY 2007
Little Anderson	13,917	9,123	10.20%	11.58%
Big Beef	201,353	224,097	15.65%	19.26%
Seabeck	17,926	7,541	10.24%	7.99%
Stavis	62,361	29,727	12.57%	11.33%

Parr-to-smolt survival is impacted by at least two seasonal factors – summer time low flows and winter time floods. Low flows during the summer months can decrease survival by limiting rearing habitat and are considered to be a major limiting factor for freshwater production of Puget Sound coho (Mathews and Olson 1980; Smoker 1955; Zillges 1977). Over-winter survival is the second factor that determines coho parr-to-smolt survival. Coho are known to redistribute during the winter months and their survival may be impacted by a series of variables that include channel complexity, high flow events, availability of refugia, and fish body size (Kinsel et al. 2009; Lawson et al. 2004; Quinn and Peterson 1996).

Parr-to-smolt survival for BY 2007 coho was near or above average in Little Anderson, Big Beef, and Stavis creeks but notably below average in Seabeck Creek (Table 5). The 2008 summer rearing conditions were favorable for the 2007 BY coho. Precipitation was above average, temperatures were below average, and stream flows on Big Beef Creek were very close to the 25-year average. The poor parr-to-smolt survival in Seabeck Creek was not consistent with favorable summer conditions. We hypothesize that localized conditions decreased parr-to-smolt survival in Seabeck for BY 2007 coho. Localized effects in this watershed included aggradation of the streambed and notable constriction of wetted habitat. During summer stream surveys in Seabeck Creek, we observed that a large portion of the stream bed was dry during the late summer and early fall months.

Among years, parr-to-smolt survival has ranged 25-fold among the four watersheds (Figure 4). Parr-to-smolt survival in Big Beef Creek has been consistently higher (with exception of one year) and less variable than the neighboring three watersheds. One explanation for this difference is that habitat and channel complexity on Big Beef Creek provides an optimal mix of pools for summer rearing and floodplain refuge for winter rearing. For example, parr-to-smolt survival corresponding to the December 2007 winter flood event was 15.2% in Big Beef Creek but ranged between 0.8 and 7.8% in the other three watersheds. These results support the idea that channel complexity and wetlands are important to maintain stable populations of juvenile coho.

The parr-to-smolt coho survival rates reported for the IMW study are notably lower than the 25.4 to 46.2% survival observed in 1990 and 1991 studies of Big Beef Creek coho (Quinn and Peterson 1996). Different survival rates between these studies may be partially explained by the time of year that the parr were marked. The Quinn and Peterson study marked coho in the month of October whereas the current study marked parr in late July and early August. Coho marked in October would have already survived the summer low flow bottleneck.

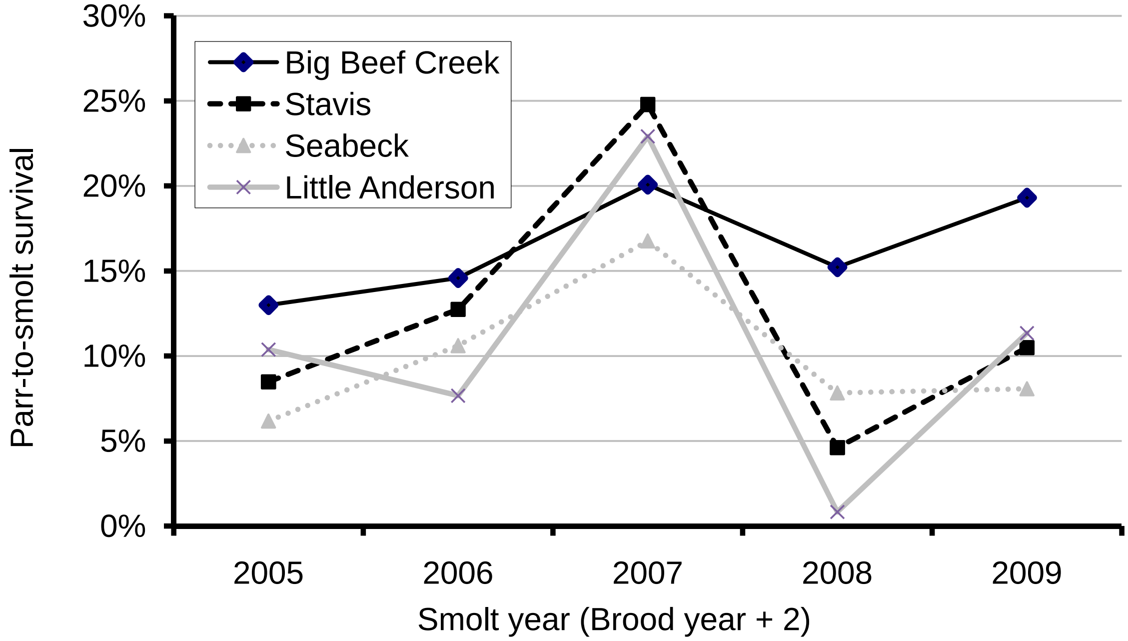


Figure 4.—Coho parr to smolt survival in Little Anderson, Big Beef, Seabeck and Stavis creeks for smolt years 2005-2009.

Assumptions for Coho Estimates

Validity of the abundance and survival estimates relies on assumptions that the system was closed between mark-release and recapture periods and that the estimated missed catch was accurate. The assumption that the system is closed is potentially problematic because of the long time period (8 months) between the release and recapture events. Dispersal rates among adjacent Hood Canal tributaries are unknown but are assumed to be minimal based on the salt water conditions connecting the watersheds. Emigration timing is assumed to occur during the April to June window in western Washington; however, fall outmigration events have been observed in some populations (Roni et al. 2008). Fall outmigration would not be documented in the Hood Canal watersheds as downstream traps do not operate during the winter months.

The abundance estimation method should be robust to violations of the closed system as long as marked and unmarked coho emigrate at the same rate. This assumption was likely met as the release of marked fish occurred throughout the watershed. However, emigration of juvenile coho will result in survival estimate that is biased low because undocumented emigrants are counted as mortalities. Therefore, the estimated survival is really an apparent survival and relies on the assumption that the majority of coho emigrate in the typical April to June window.

Trap outages in Little Anderson and Stavis creeks in 2009 resulted in an unknown number of marked coho that emigrated during the 3-day period (May 5 to 7). The estimation method assumed that the migration timing of marked and unmarked coho was comparable and that the linear interpolation method used to estimate missed catch during the outage was appropriate. Because few marked fish were estimated to have migrated during this period (2 marked coho in Little Anderson and 8 marked coho in Stavis), this estimation was not considered to have a major impact on the survival estimates.

Steelhead Parr-To-Smolt Survival

The recapture rates of tagged steelhead provided in this report should not be interpreted as parr-to-smolt survival rates. Estimates of steelhead parr-to-smolt survival are complicated by the extended period of freshwater residency for steelhead, as most juveniles spend two summers in freshwater prior to out-migration. The two-year summer rearing period is supported by the bimodal distribution of steelhead parr lengths and by the age distribution of steelhead smolts (described in Smolt Section of this report). The first peak is assumed to be parr that will reside in freshwater for another year and a half before emigrating to salt water. The second peak is assumed to be parr that will emigrate the follow spring. The juvenile steelhead tagged for survival estimates represented the second peak in the length distribution. Steelhead in the first peak (< 85-mm FL) are too small to tag and are difficult to distinguish from cutthroat trout. Evaluating steelhead parr-to-smolt survival is based on two assumptions currently under investigation. The first assumption is that all tagged steelhead migrate the following spring and do not hold in freshwater for an additional year. In support of this assumption, steelhead parr tagged in 2007 were recaptured as smolts in spring of 2008 and none were seen in spring of

2009. The second assumption is that the untagged size class of steelhead does not smolt the following year. This assumption will be tested by comparing the age distribution of tagged steelhead (recaptures) with that of untagged steelhead in the downstream trap. This comparison relies on age data which are presently unavailable and will be analyzed in subsequent years.

Hood Canal Smolt Evaluation

Smolt Methods

Fish Collection at Big Beef Creek

Downstream migrants at Big Beef Creek were collected with fan traps mounted to a permanent weir. Fan traps were placed into metal supports mounted to the concrete slab weir structure. The fans have folded, V-shape troughs, are oriented parallel to stream flow, and screen water through 14-gauge, perforated plates. Fan traps are set at different levels so that during low flow only the lowest trap operated. As stream flow increases, more fans are used. A flexible rubber sheet provides a fish-tight seal between the adjustable traps and the stationary weir support. Stop logs beneath the fans create an elevated pool necessary for trap operation. Fans are wider at the upper entrance and taper to a narrow downstream entrance. Downstream migrating fish are guided to a live box at the rear of the fan where they are removed and processed.

Fan traps were operated continuously between March 31 and June 10. Fish were collected and processed at least once during each 24-hour period. All downstream migrants were removed from the live box and enumerated. Steelhead out-migrants were divided into "smolt" and "parr" based on coloration of fish at time of capture. Steelhead "smolts" had faint or non-existing parr-marks, silvery coloration and black banding around their caudal fin. Steelhead "parr" are darker in coloration and have highly visible to faint parr marks. Although size was not the criteria used to distinguish these life stages, steelhead parr were generally smaller in size (usually < 125-mm FL) than steelhead smolts (usually > 125-mm FL). Some overlap exists between the categories, as some fish classified as parr were beginning to show some characteristics of pre-smolts and some very large migrants may still be dark in coloration. Juvenile steelhead were assigned to the most category (parr or smolt) with the closest resemblance.

A sub sample of coho and steelhead were measured (FL) each week. Average seasonal body size was estimated by weighting the mean length for a given week by the percent of the outmigration that occurred on that week. Scale and length data were collected from a sub sample of juvenile steelhead (up to three parr and three smolts per day). Freshwater age was determined from the scales by the WDFW Scale Lab. Out-migrant age composition was estimated by partitioning the total catch for a given week by the age composition measured for that week. Coded-wire tags were applied to coho smolts in good condition. Coded-wire tag codes and numbers of tagged fish were submitted to Pacific States Marine Fisheries Commission's (PSMFC) Regional Mark Processing Center (RMPC) database.

Downstream migrants from a pond adjacent to the weir were not trapped during the 2009 downstream migration. This pond is an outlet to spawning channels run by the University of Washington's Fisheries Research Institute (FRI) and circumvents the Big Beef Creek weir. Coho migration from the FRI ponds was estimated as described below.

Fish Collection at Little Anderson, Seabeck, and Stavis Creeks

Fence weirs were used to enumerate downstream migrants in Little Anderson, Seabeck, and Stavis creeks. Temporary fence weirs spanned the width of the stream and directed stream flow through a series of screened panels. Fence weirs were configured in a "V" shape with the apex pointing downstream. Wood-framed screen panels were covered with ½ x ½ -inch vinyl-coated steel mesh and held in place with metal fence posts and galvanized fencing wire. Woven nylon cloth was placed under the length of the weir to prevent erosion of the streambed. Gravel bags anchor the sheeting, support the screen panels, and stabilize the banks around the edges of the weir and live-box. A PVC pipe funneled migrating fish into the live box located downstream of the weir.

In all three creeks, fish were captured, enumerated, and released on a daily basis. A sub sample of coho were measured (FL) on a weekly basis. Seabeck Creek trap was installed 150 m above tidewater and was operated continuously between April 2 and June 11. Little Anderson Creek traps were installed 30 meters above tidewater and were operated between March 31 and June 11. The Little Anderson trap sites consist of two small traps, one on each of the two stream channels. One of these traps was undermined during a high flow event in early May and an unknown number of fish migrated passed the trap between May 5 and 7. Stavis Creek trap was installed approximately 500-meters upstream of the Stavis Bay Road Bridge and operated between March 31 and June 10. The Stavis trap was also compromised by high flows between May 5 and 7.

Analysis

Total coho smolt production was the sum of measured and estimated migration. Estimated migration includes "pre" and "post" season estimates, in-season estimates when the weirs were not operating properly, and migration through the FRI spawning channel and pond. Migration in the "pre" and "post" season periods are based on the average outmigration timing for coho smolts from four model years (1980, 1981, 1982, and 1984) at Big Beef Creek. During these model years, trapping was continuous between March 1 and June 30 and coho catch was zero at the outset and conclusion of trapping. On all four creeks, the timing model is used to extrapolate catch between the period of actual weir operation to these assumed start and end dates.

During the weir outage period on Little Anderson and Stavis creeks, missed catch ($\hat{n}_i$) and its associated variance [$V(\hat{n}_i)$] was calculated using average catch rates ($\overline{R}$) for the adjacent trapping periods and the number of hours (T_i) the weir did not operate (Equation 7, 8).

Equation 7

$$\hat{n}_i = \overline{R} * T_i$$

Equation 8

$$V(\hat{n}_i) = V(\overline{R}) * T_i^2$$

The proportion of coho smolts migrating through the FRI pond on Big Beef Creek was estimated using a pond-to-stream ratio of 2.26% applied to the total stream production estimate (actual catch summed with pre and post season estimates). This ratio is based on simultaneous measures of the stream and pond out migrants during the 1984-1986 and 1990 outmigration years.

Smolt Results

Coho Smolt Production

Coho production in Big Beef Creek was estimated to be 45,398 for BY 2007 (Table 6). This estimate included 910 smolts (2%) before trapping, 43,272 smolts (95.3%) during trapping, 213 (0.5%) smolts after trapping, and 1,003 smolts (2.2%) through the FRI pond trap. Big Beef coho smolts were produced by 659 females, 531 males, and 29 jacks released upstream of the weir in fall 2007. Juvenile productivity of BY 2007 was 69 smolts per female.

Coho production was estimated to be 1,101 smolts (CV = 1.5%) in Little Anderson Creek, 626 smolts in Seabeck Creek, and 3,474 (CV = 2.0%) smolts in Stavis Creek (Table 6). These estimates were based on in-season catches of 1,035, 609, and 3,119 coho smolts, respectively (Table 6).

Coho production was higher than the long-term average in Little Anderson and Big Beef creeks but lower than the long-term average in Seabeck and Stavis creeks (1993 to 2008 outmigration years, Figure 4).

Table 6.─Coho smolt production from Little Anderson, Big Beef, Seabeck, and Stavis creeks (BY 2007, out-migration year 2009). Stavis and Little Anderson production includes estimated catch and variance during periods when traps were damaged by high flows. Big Beef Creek estimate includes catch at main-stem trap and estimated catch at FRI pond trap. Estimates before and after trapping are based on a migration timing model from Big Beef Creek.

	Before Trapping	During Trapping			After Trapping	
Watershed	Estimated Migration	Measured Migration	Estimated Migration	Variance	Estimated Migration	Total Production
Little Anderson	23	1,035	38	46.91	5	1,101
Big Beef	910	43,272	[a]1,003	n/a	213	45,398
Seabeck	14	609	n/a	n/a	3	626
Stavis	71	3,119	267	788.38	17	3,474

[a]Estimated catch at FRI pond trap is derived using a 2.26 % pond-stream ratio established during 1984-1986 and 1990 trapping seasons.

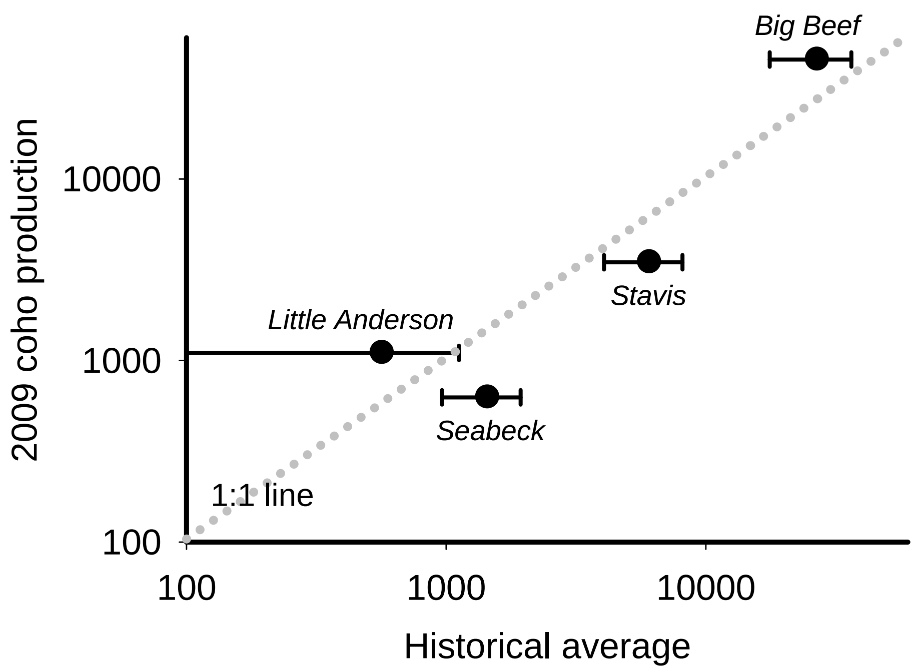


Figure 5.─Comparison of 2009 coho production in Hood Canal IMW streams with long-term average production. Long-term averages and standard deviations are calculated for outmigration years 1993 to 2008. Axes are on a log10 scale.

Migration Timing

All streams had a median coho migration within a 6-day period (Figure 6). Median migration dates ranged from May 9 (Seabeck Creek) to May 14 (Little Anderson Creek). Median migration dates were just 1-3 days later than long-term median migration dates for these populations (Figures 7*a,* 6*b,* 6*c,* and 6*d*).

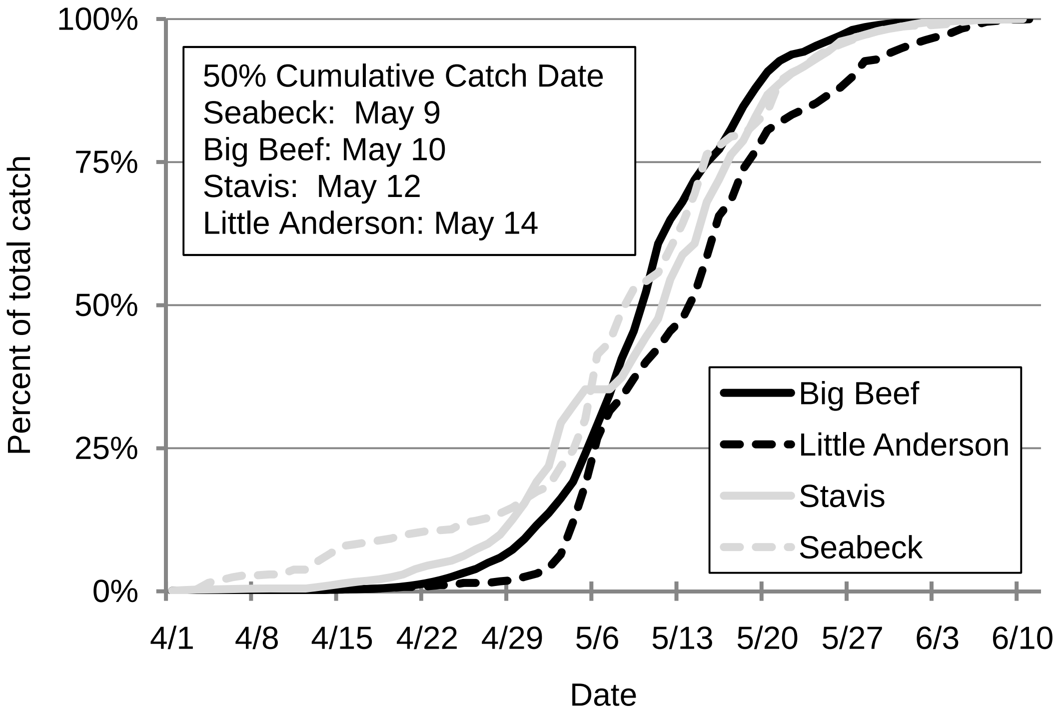
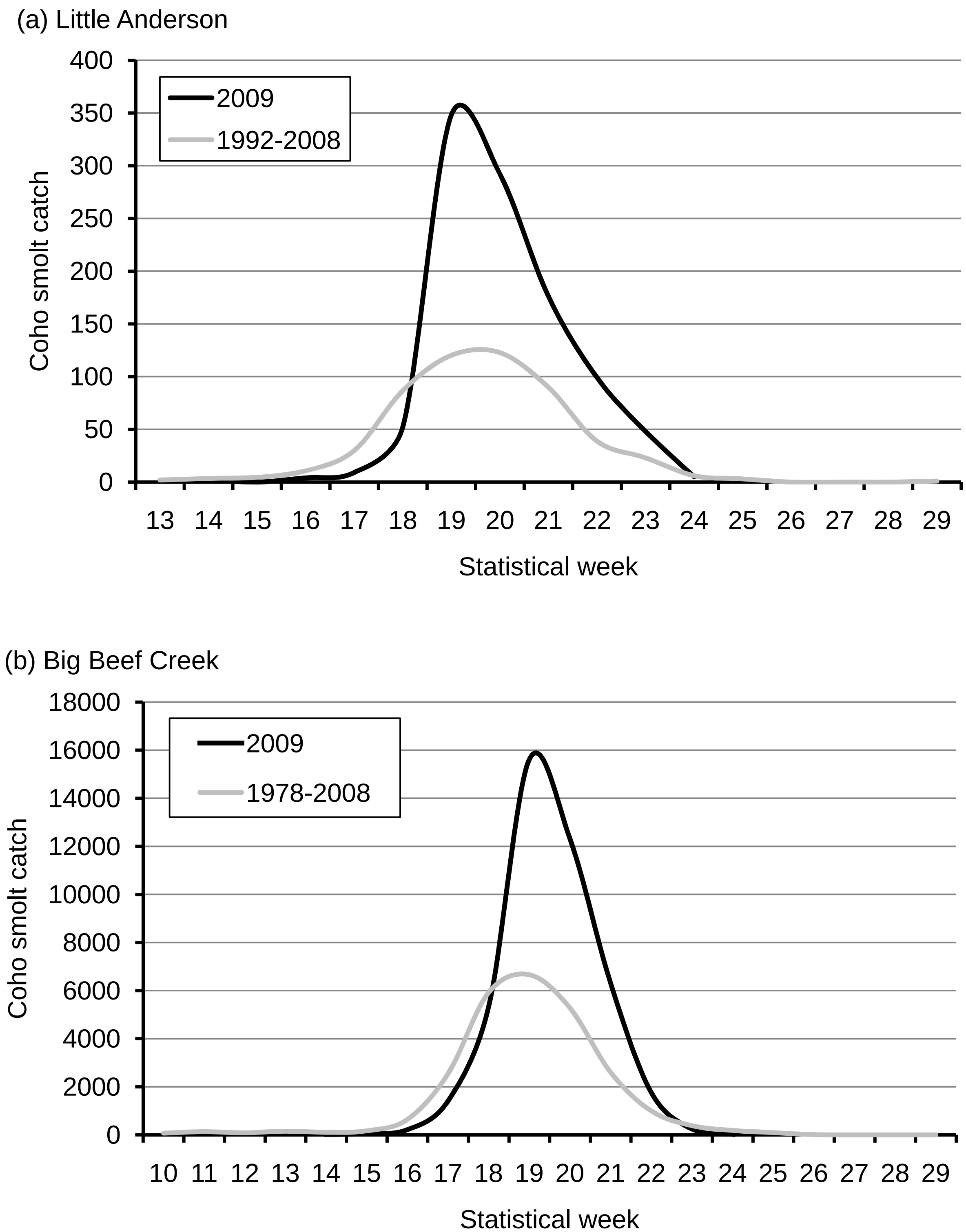
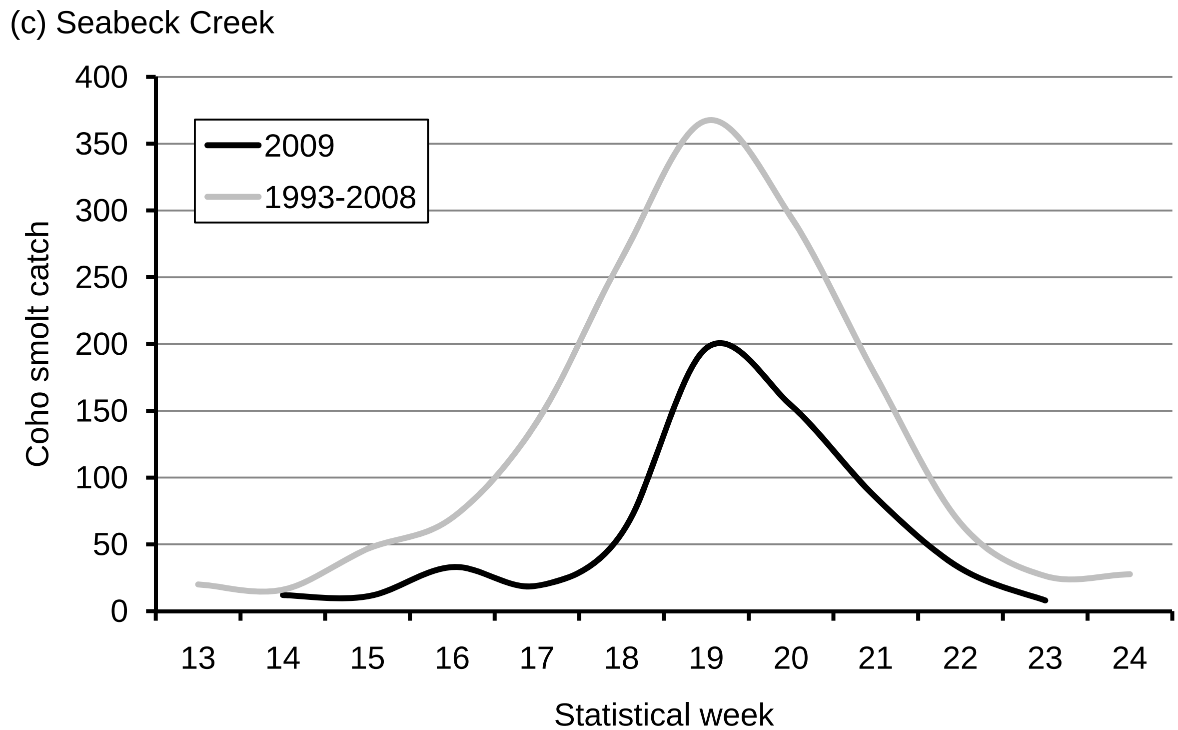


Figure 6.─Cumulative daily coho smolt migration at Big Beef, Little Anderson, Seabeck, and Stavis creeks during spring 2009.


(a) Little Anderson
400
350
300
250
200
150
100
50
0
Coho smolt catch
2009
1992-2008
13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
Statistical week
(b) Big Beef Creek
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Coho smolt catch
2009
1978-2008
10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
Statistical week



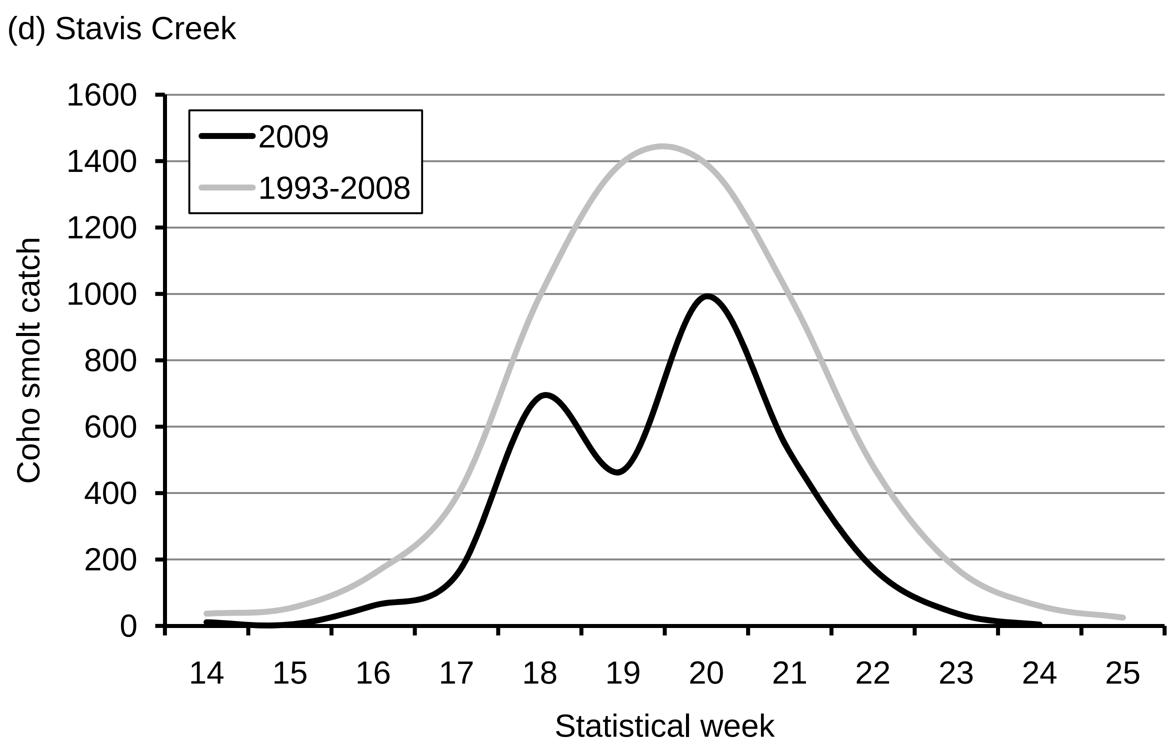


Figure 7.─Coho smolt catch by statistical week in 2009 compared with historical average catches for Little Anderson (a), Big Beef (b), Seabeck (c), and Stavis (d) creeks.

Body Size

Coho smolts emigrating from Big Beef Creek averaged 101.1-mm FL (±12.58 mm, ±1 standard deviation, SD, Appendix A-1). Average lengths of coho smolts in Little Anderson, Seabeck, and Stavis creeks were 101.6 mm (±8.09 mm SD), 95.5 mm (±8.37 mm SD), and 92.6 mm (±7.73mm SD) FL, respectively (Appendix A-2, A-3, and A-4).

Coho smolts in 2009 were shorter than historical lengths on Big Beef, Stavis and Seabeck creeks (Figure 8). In contrast, coho smolts in Little Anderson were longer than average in 2009. Seasonal differences in fork length were also observed to be consistent across the sampling season (Figure 9).

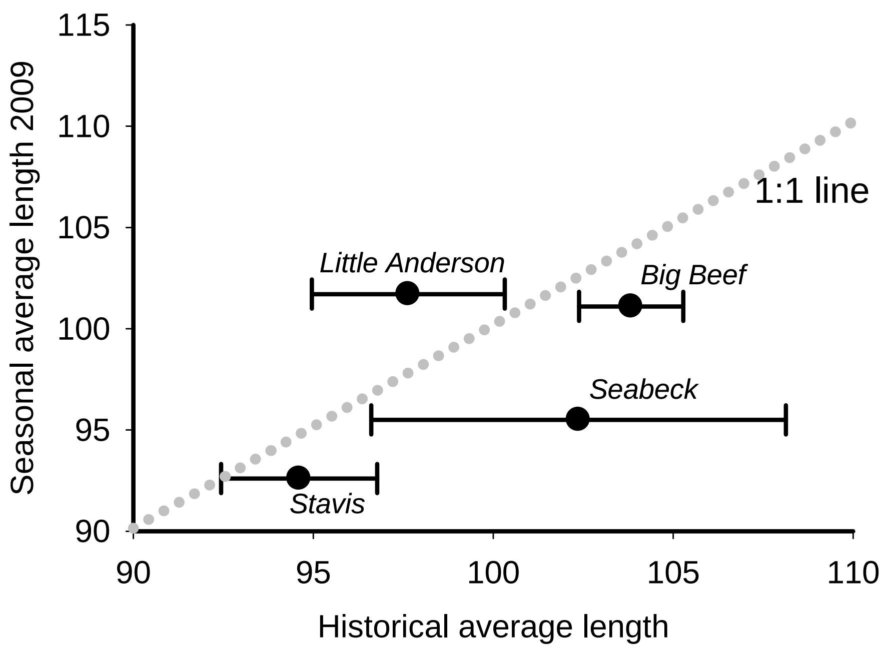
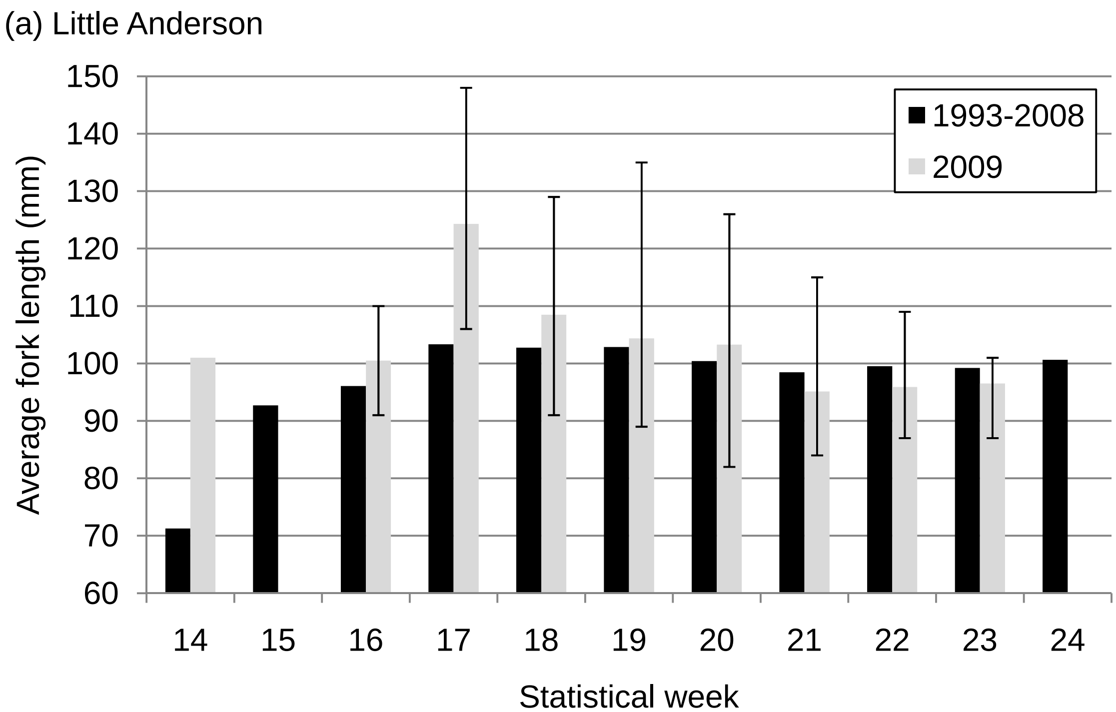
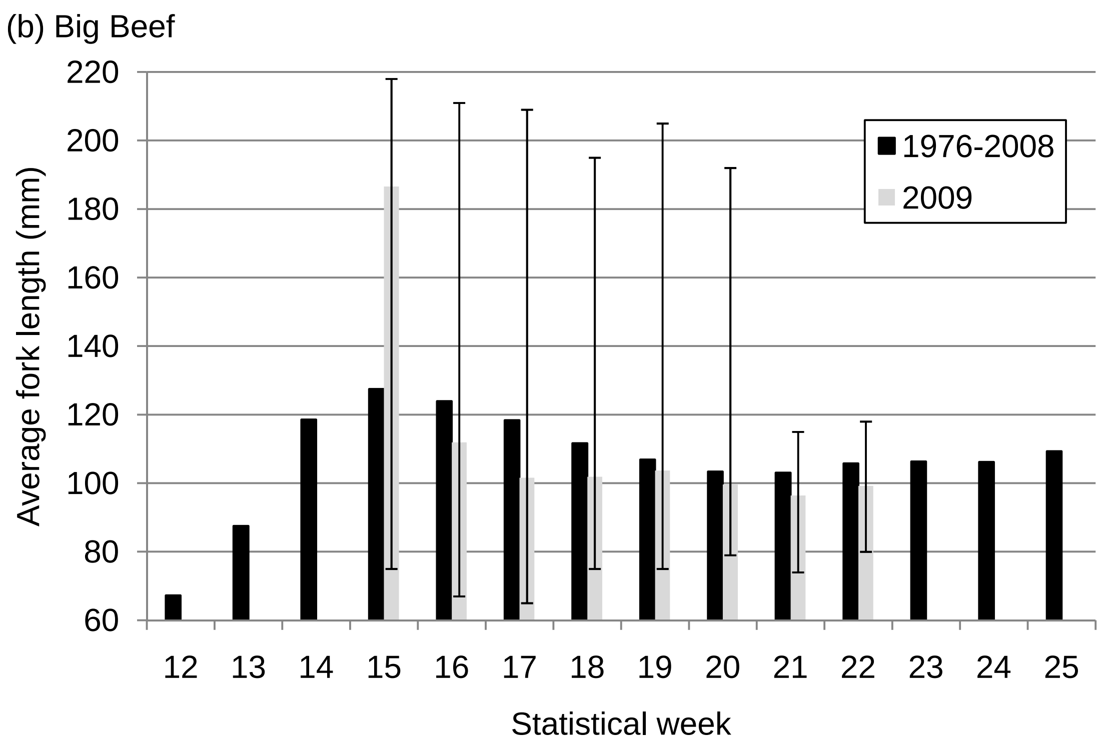
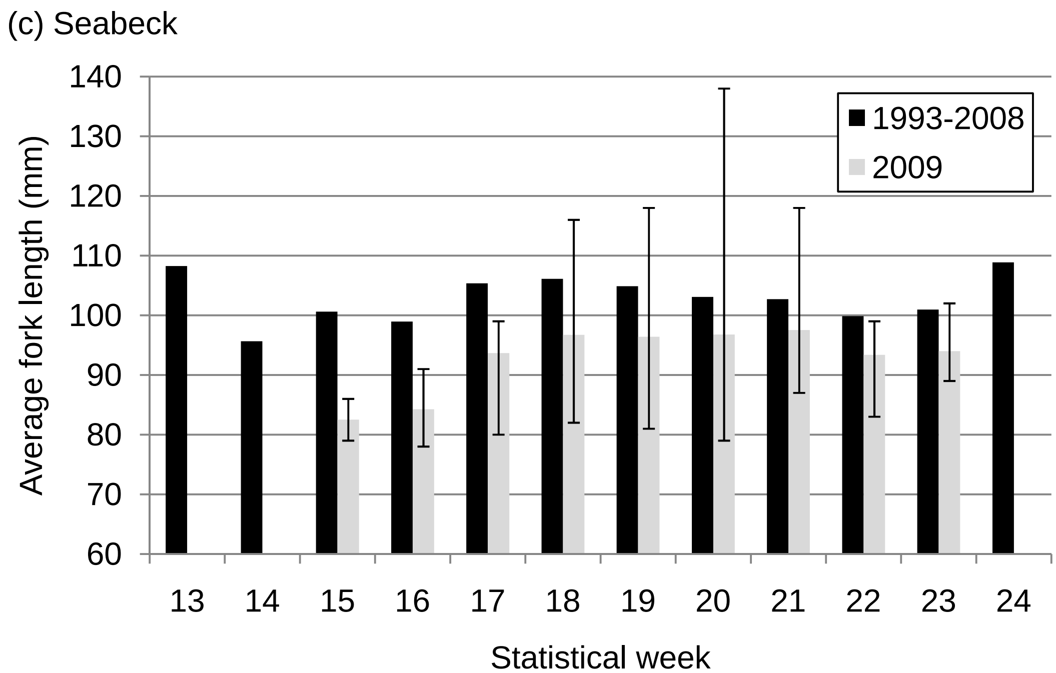


Figure 8.─Comparison of 2009 coho smolt lengths with historical average lengths in Hood Canal IMW streams. Historical averages and standard deviations are calculated for out-migration years 2003 to 2008.


(a) Little Anderson
Average fork length (mm)
150
140
130
120
110
100
90
80
70
60
14
15
16
17
18
19
20
21
22
23
24
Statistical week
1993-2008
2009


(b) Big Beef
Average fork length (mm)
220
200
180
160
140
120
100
80
60
12
13
14
15
16
17
18
19
20
21
22
23
24
25
Statistical week
1976-2008
2009



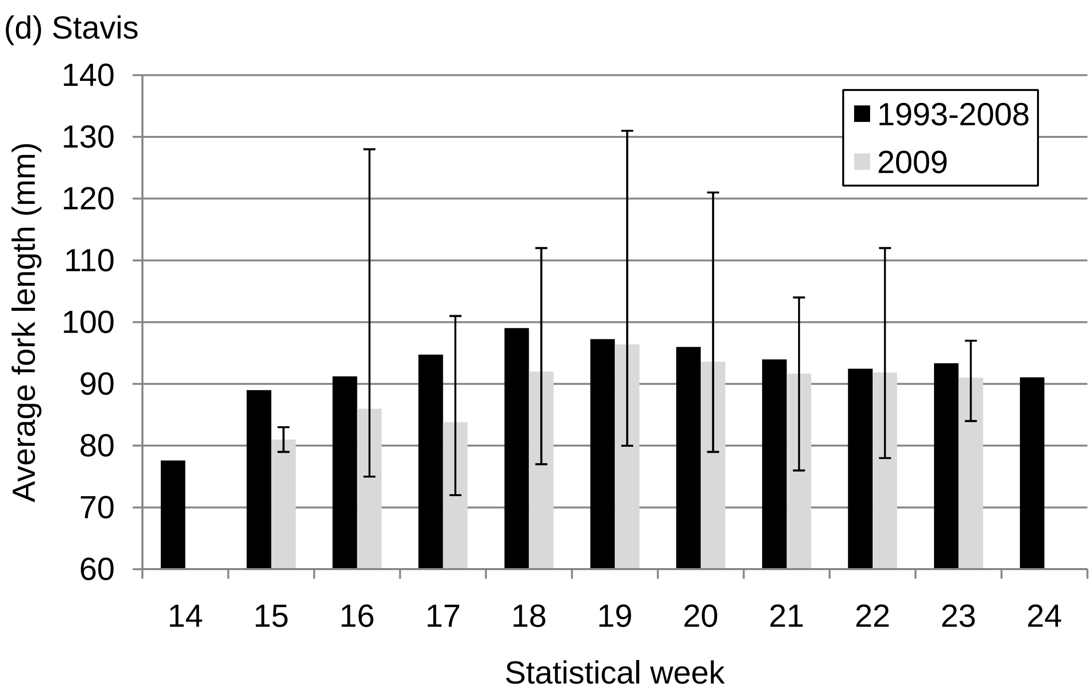


Figure 9.─Coho smolt fork lengths in 2009 compared to historical average fork lengths by statistical week for Little Anderson (a), Big Beef (b), Seabeck (c) and Stavis (d). Data are average fork length (mm) by statistical week. The 2009 data include minimum and maximum values.

Coded-Wire Tagging in Big Beef Creek

Coded-wire tags were applied to 38,547 Big Beef Creek coho smolts or an estimated 84.91% of the out-migration (Table 7). A portion of the coho smolts (*n* = 6,772) were not tagged for several reasons, including being captured when the tagging machine did not operate, in poor condition, escaped, too large or small for tagging, or recaptures from parr study. A small percentage (0.17%) of smolts died due to trapping, tagging, and sampling.

Four tag codes were applied to the Big Beef Creek coho smolts (Table 2-7). Use of multiple tag codes was intended to divide the outmigration into early, middle and late components. The early component of the migration (63-41/80) was tagged between April 15 and May 4. The middle component of the migration was tagged (63-45/94, 63-41/98) between May 5 and 15. The late component of the migration was tagged (63-44/64) between May 16 and June 1. Results from this tagging schedule will be used to distinguish survival of early and late migrating coho as jacks during the fall of 2009 and as adult coho in the fall of 2010.

Table 7.—Disposition of tagged and untagged coho smolts in Big Beef Creek, 2009.

Disposition	Number	Percent
63-41/80 (4/15 to 5/4)	7,792	17.16%
63-45/94 (5/5 to 5/9)	11,011	24.25%
63-41/98 (5/10 to 5/15)	10,924	24.06%
63-44/64 (5/16 to 6/1)	8,820	19.43%
Total tagged	38,547	84.91%
Before/after tagging	269	0.59%
Released untagged	2,433	5.36%
Poor condition	1,266	2.79%
Escaped during transfer	291	0.64%
Too small or large	97	0.21%
Ad-marked from parr survey	290	0.64%
Estimated untagged before/after trapping	1,123	2.47%
Estimated FRI pond	1,003	2.21%
Total untagged	6,772	14.92%
Trap mortality	66	0.15%
Sacrificed for tag placement	13	0.03%
Total mortality	79	0.17%
Total estimated migration	45,398	

Steelhead Production and Biological Sampling

Big Beef Creek steelhead production was 1,005 smolts. Production in Little Anderson, Seabeck, and Stavis creeks has been minimal yet present since trapping began in 1993. In 2009, a total of 2 smolts were caught in Little Anderson, 21 smolts in Seabeck, and 17 smolts in Stavis Creek (Table 9).

Steelhead smolt migration timing in Big Beef Creek was also similar compared to the long-term average (Figure 10). Steelhead smolt catch peaked on April 23, one day later than the historical average peak.

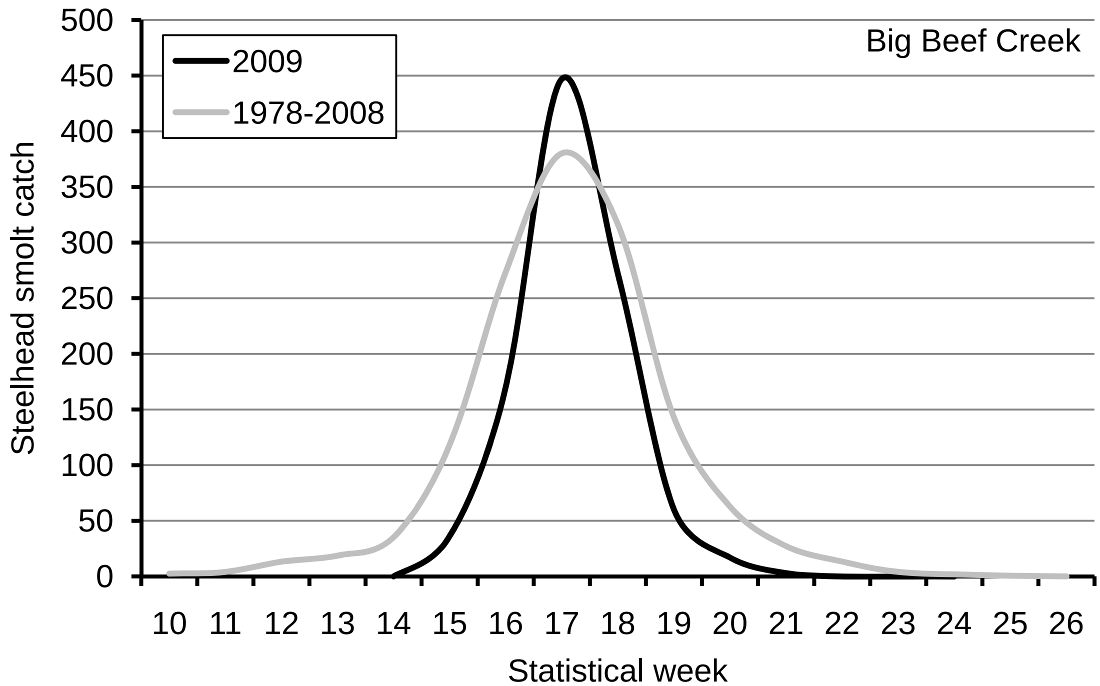


Figure 10.─Steelhead smolt catch by statistical week in 2009 compared to historical average (1978 to 2008) for Big Beef Creek.

Steelhead smolts emigrating from Big Beef Creek averaged 164.3-mm FL (±23.20 mm, ±1standard deviation); weekly averages ranged between 150.1-mm and 180.0-mm FL (Appendix A-5). Similar to coho, steelhead smolts in 2009 had average weekly fork lengths that were slightly shorter than the historical weekly averages from Big Beef Creek (Figure 11). Early steelhead migrants were longer than migrants captured later in the season (Figure 11).

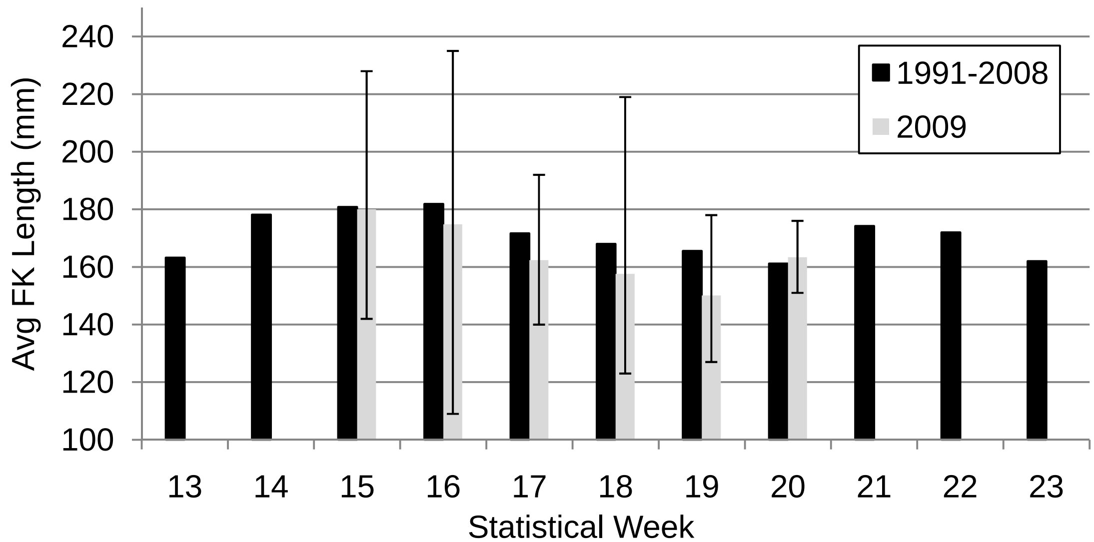


Figure 11.─Steelhead smolt fork lengths in 2009 compared to historical average (1991-2008) by statistical week. Data are average fork length (mm) by statistical week. The 2009 data includes minimum and maximum values.

Juvenile steelhead migrants identified as parr and smolts were present in all three age classes (Table 8). Of the 1,005 steelhead smolts in Big Beef Creek, 29% were age-1, 43% were age-2, and 28% were age-3 (Figure 12). Steelhead parr were primarily age-1 fish (80%), although a component were age-2 (19%) and age-3 fish (1%). The combination of age and length data showed that while average size increases with age there is also size overlap between all three age classes. Further study of adult age data from Big Beef steelhead will further determine which freshwater age classes are observed among returning adults.

Table 8.—Age and length disposition of juvenile steelhead migrants based on scale samples collected from Big Beef Creek downstream traps, 2009. Data for sampled fish in each age class include number of fish sampled, proportion life stage (parr or smolt), and fork length (mm).

Freshwater Age	# Sampled	% Parr	% Smolts	Fork length Min	Max	Avg	St. Dev.
Age 1	49	65.3%	34.7%	87	166	117.6	22.31
Age 2	51	17.6%	82.4%	106	210	155.2	26.12
Age 3	26	3.8%	96.2%	148	228	186.2	22.58
Unreadable	35	37.1%	62.9%	92	235	152.4	38.26
Totals	161			87	235	148.1	35.98

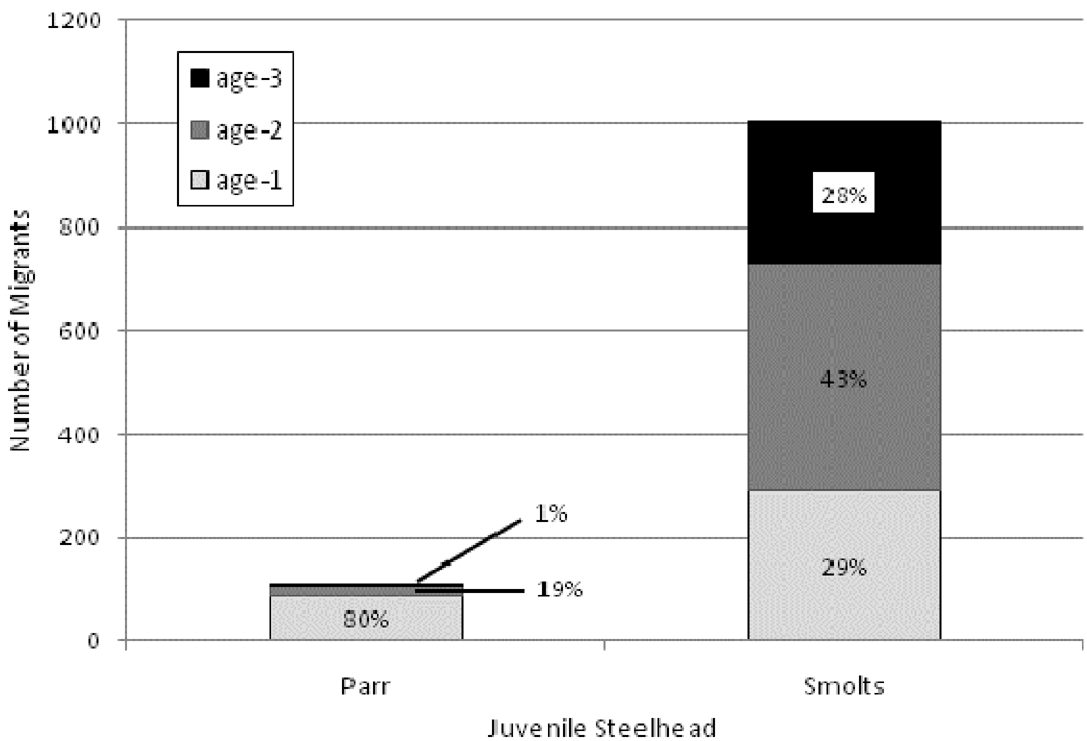


Figure 12.—Age composition of juvenile steelhead migrants from Big Beef Creek, 2009. Catch of age-1, 2, and 3 fish are shown for both parr and smolt migrants.

Other Salmonid Production

Other salmonids captured in the Hood Canal streams included trout parr (too small to distinguish cutthroat or steelhead origin), steelhead kelts, cutthroat smolts, cutthroat adults, chum fry, and coho fry (Table 9). Chinook fry were not caught in 2009 and have not been caught in these creeks since 2006.

Table 9.─Total salmonid catch in downstream traps on Little Anderson, Big Beef, Seabeck, and Stavis creeks during spring 2009.

	Total Catch			
Species/Age Class	Little Anderson	Big Beef	Seabeck	Stavis
Chum fry	0	77,137	0	0
Chinook fry	0	0	0	0
Coho fry	0	132	0	0
Coho smolts	1,035	43,272	609	3,119
Steelhead parr	0	108	0	0
Steelhead smolts	2	1,005	21	17
Steelhead adults	0	[b]4	0	[e]1
Cutthroat parr	251	394	409	395
Cutthroat smolts	403	649	356	981
Cutthroat adults	[a]3	[c]28	[d]7	[f]28

[a] 1 male and 2 females

[b] 2 males and 2 females

[c] 20 males and 8 females

[d] 7 males and 0 females

[e] 1 male

[f] 15 males and 13 females

Smolt Discussion

Coho Smolt Production

The Intensively Monitored Watrsheds program was established with a BACI study design to test whether habitat restoration will result in a population-level response. This design relies on selection of "reference" and "treatment" watersheds and assumes that common variables limit or enhance coho survival and cause synchrony in freshwater production of neighboring watersheds (Roni et al. 2005). Current results from the Hood Canal IMW watersheds demonstrate that coho production is correlated among watersheds across years (Figure 13). However, on any given year, local watershed conditions can have a large impact on coho production and that these factors may, in some cases, override regionally synchronous processes.

At least three conditions or events are hypothesized to impact coho smolt production in 2009 (BY 2007). These events were the culvert replacement on Little Anderson Creek, stream bed aggradations in Seabeck Creek, and the December 2007 flooding event. Replacement of an undersized culvert on NW Anderson Hill Road was completed in November 2002 and improved access to spawning habitat in portions of the creek above the culvert. Coho production in Little Anderson Creek (treatment watershed) was not synchronous with Stavis Creek (reference watershed) until after the culvert was replaced (Figure 12*a*). Little Anderson coho production has been synchronous with Stavis Creek since the 2005 outmigration (BY 2003). In 2009, coho production in Stavis and Little Anderson were moderate to low in comparison with other years. Smolt production on these watersheds was likely limited by survival during incubation (described below) as incubation conditions were harsh and rearing conditions during summer and overwinter parr life stages were generally favorable for coho from this brood year (BY2007).

In December of 2007, an extreme flooding event occurred midway through the coho spawning season. Over a 72-hour period (December 2 to 4), Kitsap County received an unprecedented 11.94 inches of precipitation which fell over an existing accumulation of snow. This event moved substantial amounts of substrate in the creeks in addition to being disastrous to roads and infrastructure in the region. Spawner surveys were conducted before and after the flooding event on all creeks except Little Anderson, which could not be accessed after the flood because roads became impassible. On Big Beef Creek, 85% of the coho redds (n = 152) recorded during spawner surveys were observed before the flood. On Seabeck and Stavis creeks, 38% (n = 13) and 46% (n = 26) of coho redds were observed before the flood respectively. Prior to the flooding event on Little Anderson Creek, just 1 redd was observed and just 18 adult coho and 2 jacks were passed above a picket weir operated near the mouth of the creek (Ned Pittman, WDFW Habitat Program, personal communication).

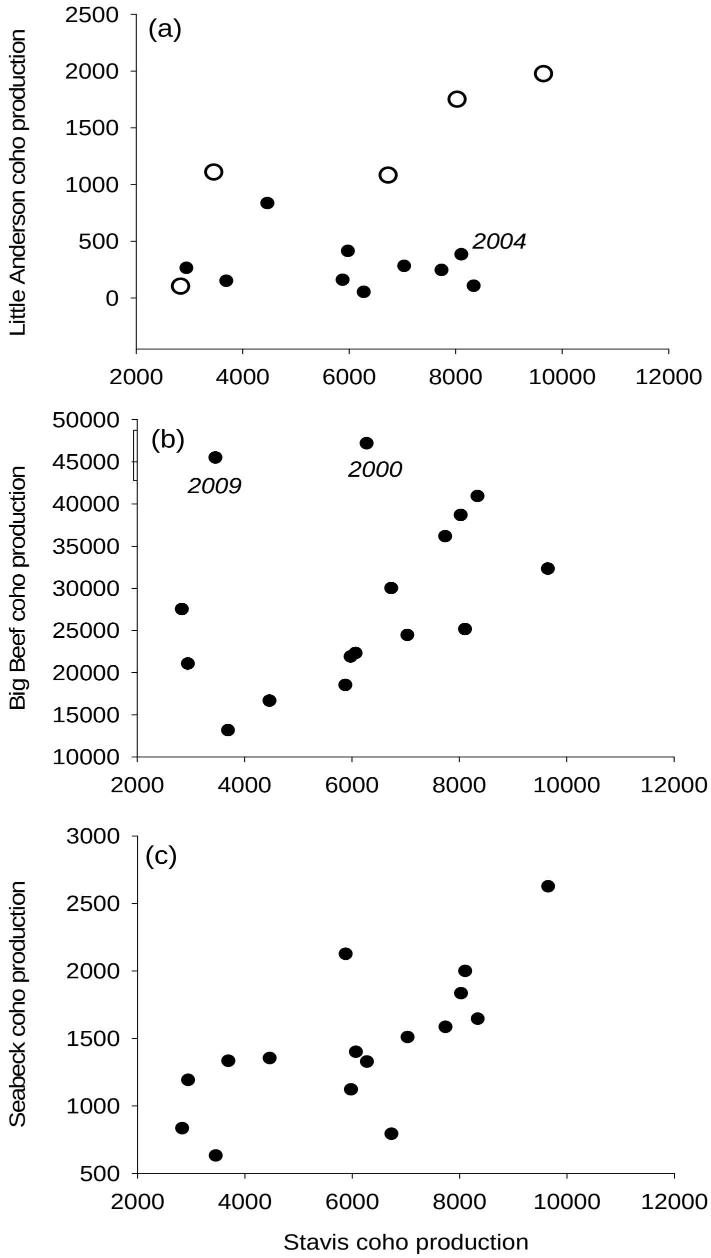


Figure 13.—Comparison of coho smolt production in "reference" watershed – Stavis Creek – to three "treatment" watersheds – Little Anderson (a), Big Beef (b), and Seabeck (c). Coho smolt production in Little Anderson Creek is shaded for out migration year 2004 and earlier (black circles) and 2005 and later (white circles). Out migration years 2000 and 2009 on Big Beef Creek are indicated because they are outliers to an otherwise good correlation between Stavis and Big Beef coho production.

The timing of the December 2007 flood was expected to negatively impact survival of incubating coho eggs in all watersheds (Devries 1997; Koski 1966; Montgomery et al. 1996) Although we did not directly measure survival during the intra-gravel period, summer parr abundance can be used as a proxy for this survival. Parr abundance is a result of the number of eggs deposited (i.e., number of spawners) and environmental limitations on survival from the egg to summer parr stage. Consistent with our expectations, summer parr abundances for BY2007 were well below historical averages in Little Anderson, Seabeck, and Stavis creeks (Table 10). However, in Big Beef Creek, coho parr abundance was above its long-term average. This suggests that the winter flooding event differentially affected incubation survival among these watersheds.

Big Beef Creek smolt production for BY 2007 was exceptionally high. This production resulted from above average parr abundance and parr-to-smolt survival (Table 10). As spawner abundances were moderate (659 females passed above Big Beef Creek weir), the above average parr abundance indicates that incubation survival of Big Beef coho was high despite the severe flood conditions. Portions of Big Beef Creek have a diverse network of unconfined channels and tributary habitats, especially in the upper portions of the watershed above Lake Symington. The availability of protected spawning areas in Big Beef, in comparison to the other three watersheds, may explain why the Big Beef population appears to have been buffered from the high incubation flows whereas coho populations in Little Anderson, Seabeck, and Stavis creeks were negatively impacted.

The 2009 coho production from Stavis Creek was just half of the historical average for this watershed (Table 10). This production was likely limited by survival during incubation but not summer or overwinter rearing flows. Stavis Creek lacks wide, unconfined channels and connected wetland and floodplain habitats that exist in Big Beef Creek. As a result, high flow events are hypothesized to have a greater impact in Stavis than Big Beef Creek. For BY2007, we hypothesize that coho redds in Stavis Creek were vulnerable to scour and suffocation similar to that observed in other coho populations (Holtby and Healey 1986; Koski 1966). Parr-to-smolt survival was comparable to the long-term average (Table 10) suggesting that lower than average smolt production was not the result of poor survival during the summer low flow period or the overwinter survival period.

The 2009 coho production in Seabeck Creek appeared to result from a multiplicative effect of low parr abundance and low parr-to-smolt survival (Table 10). Summer parr abundance for BY2007 was just one-third of the long-term average for Seabeck Creek, likely a result of scour-induced mortality during egg incubation. Parr-to-smolt survival was also notably low in Seabeck Creek, likely a result of limited summer rearing habitat. Although summer of 2008 had generally favorable rearing conditions for coho (i.e., cool and wet), stream surveys during the summer months indicated that much of the Seabeck Creek watershed was still dry. Stream bed aggradations and limited summer rearing habitats are becoming an increasing issue for this watershed. Degradation of rearing habitat has been correlated with declines in parr-to-smolt survival and coho smolt production on Seabeck Creek for the past three years (2007-2009 migration years). Dry portions throughout the creek confine coho rearing to the remaining pools and are likely serving as a key bottleneck to survival.

Table 10.─Summer parr abundance, parr-to-smolt survival, and smolt production for BY 2007 coho compared to average values (BY 2003- 2006) in Hood Canal IMW streams.

	Parr abundance ($\hat{N}$)		Parr-to-smolt survival (S)		Smolt production	
Watershed	Average	BY 2007	Average	BY 2007	Average	BY 2007
Little Anderson	13,917	9,123	10.20%	11.58%	1,221	1,102
Big Beef	201,353	228,783	15.65%	18.86%	32,214	45,392
Seabeck	17,926	7,541	10.24%	7.99%	1,542	626
Stavis	62,361	29,727	12.57%	11.33%	6,827	3,474

Assumptions for Coho Production

Coho production estimates rely on several assumptions including the accuracy of the migration timing model, the pond-to-stream migration ratio, and estimated migration during weir outage periods. The migration timing model has not been updated in more than two decades and should be re-evaluated in the near future. Upstream steelhead trapping, conducted in 2007 to 2009, has temporarily superseded any extensions of the downstream trapping season. However, the coho smolt migration is uni-modal during the trapping period and very little of the migration (< 5%) is estimated outside of the trap operation. As a result, the migration timing model did not have a large impact on the overall production estimate.

Coho migration through the spawning channels and FRI pond is another assumption based on historical data. The selected pond-to-stream ratio of 2.26% has been applied to all years that the pond trap does not operate. This ratio is based on concurrent measures of the stream and pond out-migrants during the 1984-1986 and 1990 outmigration years. Since these trap years, the pond-to-stream ratio has varied between 0.9 and 9.8% when measured. This ratio has not shown a trend over time; however, in order to test this assumption, both traps will periodically be operated simultaneously.

The blow out of Little Anderson and Stavis traps in 2009 occurred near the peak of the coho migration. This occurrence was problematic because the interpolation method applies a migration (i.e., catch) rate during the outage period based on the average of migration rates before and after the outage period. If the migration rates were higher during the outage period, production estimates from these creeks may be biased low. The Little Anderson trap site is composed of two small traps, but just one trap blew out during the high flow period. During the outage period, peak catch rates were observed in the trap that remained fishing. As with Little Anderson, the fence weir on Stavis was damaged by high flows during what may have been the peak of the coho migration. If peak migration occurred during our trap outage period, the 2009 production estimate from Stavis Creek is biased low.

Steelhead Smolt Production

Long term production of steelhead smolts from Big Beef Creek has been relatively consistent over time. Between 1978 and 2008, production has averaged 1,331 steelhead smolts with a low of 733 smolts and a high of 2,087 smolts. Our understanding of factors limiting steelhead production is currently evolving as our approach to studying their freshwater abundance and survival improves. Steelhead rear in freshwater for a period of one to three years resulting in a more complex age structure among migrants than that typically seen for coho. Diversity in the freshwater rearing period of steelhead increases the complexity of freshwater variables that limit steelhead production. Big Beef production during the spring of 2009 was 1,005 smolts, slightly lower than the long term average. Migration timing was also similar to the long term observed average timing. Average weekly fork lengths of steelhead smolts were consistently lower than historical averages, a result also observed for Big Beef coho. Variables that impact steelhead production by include competition for habitat and food resources with juvenile coho (2009 was the third largest coho production observed) and nutrient inputs from spawning adult chum and coho salmon (low number of chum and coho spawners during the fall of 2008). These variables may directly impact freshwater survival or indirectly impact marine survival by determining smolt lengths.

A more complete evaluation of Big Beef Creek steelhead will be made possible by several more years of parr-to-smolt survival data and smolt age structure. Parr-to-smolt survival study began in the summer of 2007 and, as such, just two years of data are currently available. The challenges of interpreting these data are discussed in the Parr Evaluation section. Further comparison of steelhead smolt age structure will allow production to be attributed to the proper brood year and will provide a more complete understanding of variability in smolt age structure.

Assumptions for Steelhead Production

Our estimates of steelhead production in Big Beef Creek assume that the majority of the downstream migration occurs between March and June and that steelhead smolts are accurately identified. Recent studies of Hood Canal steelhead and cutthroat populations indicate that the rate of steelhead and cutthroat hydridization in Big Beef Creek is unusually high (Barry Berijekian, NOAA, personal communication). As a result, the Big Beef steelhead production estimate more accurately represents both steelhead and steelhead-cutthroat hybrids of various ancestries. The implications of hybridization for the Big Beef Creek steelhead population are currently unknown.

Hood Canal Adult Evaluation

Adult Methods

Fish Collection at Big Beef Creek

The Big Beef Creek weir screens the entire stream flow through vertical picket sections with 25 mm openings. Fish moving upstream are trapped in a V-slot trap in the center of the weir. Weir operation begins in late August and continues through March. Coho and chum are caught between late August and January. Winter steelhead are caught between January and March. Steelhead data are collected as part of a collaborative effort with the Hood Canal Steelhead Enhancement Project led by the Northwest Fisheries Science Center's Manchester Research Station.

In fall of 2009, the weir and upstream trap began operation on August 26 and continued through March 18, 2010. Due to high flows, the Big Beef weir was pulled on November 19th at 1230 and reinstalled on November 24 at 0900. Fish were processed within 12 hours of entering the trap. All coho, chum and steelhead were removed from the trap and enumerated by species and sex. Tag status (coded-wire tag, CWT) and condition of coho were also recorded before being released upstream. Hatchery coho, identified by an adipose clip, were enumerated and sacrificed. No ad-marked coho were passed upstream of the weir. All chum and steelhead were passed upstream.

Coho age structure was validated from scale samples. A subsample of scales was collected from female coho and confirmed findings from previous years that female coho return to Big Beef as age-3 fish. Scales and body size were used to differentiate the two age classes of male coho. All males less than 35-cm FL were assumed to be jacks (age-2) and all males longer than 45-cm FL were assumed to be adult males (age-3). Periodic scale sampling over the last 30 years has supported this assumption. Coho males between 35 and 45-cm FL were assigned to age class based on scale samples.

Measurements of coho differed by size category. Female coho were measured at an 18.5% rate. Male coho between 35 and 45 cm FL were measured at a 100% rate. Males less than 35-cm FL (i.e., jacks) and longer than 45-cm FL (i.e., adult males) were measured at a 10.0% and 23.6% rate, respectively. Average lengths of jack and adult male coho were calculated by weighting the averages of each size class by the proportion of total fish representing that size class (< 35 cm and 35-45 cm for jacks, 35-45 cm and >45 cm for adult males).

Hatchery-origin coho arriving at the Big Beef Creek weir were identified based on mark status, CWT information, and scale patterns. The presence of CWTs was determined by scanning each coho with a portable electronic tag detector. All tags were retrieved from the snouts of all ad-marked coho in order to determine hatchery origin. A portion of the hatchery coho arriving at the Big Beef Creek weir are unmarked and are not distinguishable from wild coho. Therefore, unmarked hatchery fish are passed upstream of the weir with the wild fish. In order to determine the incidence of unmarked hatchery coho passed above the weir, scale samples were systematically collected from 20% of all returning coho with adipose fin intact. Banding patterns on the scales were examined by the WDFW scale lab and used to assign individual unmarked fish as wild or hatchery origin.

A small portion of unmarked tagged adult male (2.7%) and jack (11.5%) coho were sacrificed at the weir for tag recovery. Tags were also retrieved from the snouts of carcasses during spawner surveys as described below. Tag recoveries from unmarked coho verified the origin of these fish and provided a second measure of the incidence of unmarked hatchery coho.

Spawner Surveys

Spawner survey data are organized by segments and reaches identified in each watershed at the outset of the study in 2004. Segments were selected using the approach of the Northwest Indian Fisheries Commission's (NWIFC) Salmon and Steelhead Habitat Inventory and Assessment Project (http://access.nwifc.org/sshiap/framework.asp). Stream segments are of similar stream size, channel gradient, and valley confinement. Stream reaches, within each segment, are defined by reference points located at 100-meter intervals. Segment breaks and reference points are marked with flagging and aluminum tree tags and their location is recorded as latitude and longitude using a geographic positioning system unit.

Spawner surveys were conducted on all four watersheds a weekly basis between October 20, 2009 and January 7, 2010. Surveys cover 4.8 miles (7.7 km) of Little Anderson Creek, 11.2 miles (18.0 km) of Big Beef Creek, 6.4 miles (10.3 km) of Seabeck Creek, and 9.9 miles (16.0 km) of Stavis Creek. Early in the season, small tributaries were not surveyed because streams were dry and flow was too low to permit fish entry. Spawner surveys were conducted until coho spawning activity ended or until flows became too high to support entry by technicians. Surveys were not conducted during periods when turbidity, high stream flows, or snow accumulation resulted in unsafe conditions. Coho were the focus on the spawner surveys; however, incidental data were also collected for chum. During each survey, live salmon, carcasses, and new redds were enumerated by stream reach. New redds were flagged and numbered in order to avoid duplicate sampling in later surveys. Snouts were removed from all coho carcasses in order to mark the carcass as having been sampled and check for coded-wire tags.

Fisheries Sampling

Coho catches in all marine waters and terminal areas are monitored by a combination of WDFW and tribal staff. Coho in each sampled catch are enumerated, checked for adipose fin mark status (marked or unmarked), and electronically scanned for coded wire tag presence. CWT recoveries in the sampled catches are expanded using the ratio of sampled to total catch (G. Lensegrav, WDFW, personal communication). Recovery and expansion data are publically available through the RMPC coast-wide database (http://www.rmpc.org/).

Escapement Analysis

Coho escapement to Big Beef Creek was the census count from the weir partitioned into wild and hatchery-origin fish. Disposition of the coho return to the Big Beef Creek weir was totaled by mark status (unmarked or ad-marked), sex and age (females, adult males, and jacks) and by CWT tag status (tagged, untagged). This total included trap mortalities, fish found dead below the weir, and fish sacrificed for tag recovery. Disposition of coho passed above the weir was totaled by sex, age, and origin. Wild versus hatchery origin was estimated from mark status and the incidence of hatchery coho in the scale samples applied to the total unmarked return.

Coho escapements to Little Anderson, Seabeck, and Stavis creeks were estimated from smolt production in these creeks, survival to return estimates of Big Beef coho, and incidence of wild coho at the Big Beef Creek weir. This approach assumed that survival-to-return rates and the incidence of hatchery-origin spawners were similar among these watersheds and that dispersal among the watersheds was low.

Survival to return rate (SRR) of Big Beef Creek coho was estimated based on CWT returns of jacks and adults in 2009. Separate SRRs were calculated for jacks and adults after adjusting the corresponding smolt tag groups for tag retention (96.5% per D. Seiler and S. Neuhauser, WDFW unpub. data) and tagging survival (84% per Blankenship and Hanratty 1990). Survival to return was calculated as:

Equation 9

$$SRR_A = \frac{T_A}{adj(T_S)}$$

SRR_A = Adult survival-to-return, BY 2006 returning as adults in 2009,

T_A = Tagged coho returning as adults in 2009, and

$adj(T_S)$ = Wild smolts tagged in spring 2008, adjusted for tag-related retention and survival.

Equation 10

$$SRR_J = \frac{T_J}{adj(T_S)}$$

SRR_J = Jack survival-to-return, BY 2007 returning as jacks in 2009,

T_J = Tagged coho returning as jacks in 2009, and

$adj(T_S)$ = Wild smolts tagged in spring 2009, adjusted for tag-related retention and survival.

Total escapement in Little Anderson, Seabeck, and Stavis creeks was estimated from the smolt production in these watersheds and SRR and percent wild origin measured at Big Beef Creek:

Equation 11

$$\hat{E} = \frac{(S_{2008} * SRR_A)}{\%wild_A} + \frac{(S_{2009} * SRR_J)}{\%wild_J}$$

$\hat{E}$ = Coho escapement (wild and hatchery-origin) in fall 2009,

S_{2008} = Number of smolts in spring 2008 (BY 2006),

SRR_A = Survival-to-return of age-3 adult coho to Big Beef Creek (BY 2006),

S_{2009} = Number of smolts in spring 2009 (BY 2007), and

SRR_J = Survival-to-return of jack coho at Big Beef Creek, BY 2007.

$\%wild_J$ = Percentage of wild coho jacks at BBC weir in fall 2009,

$\%wild_J$ = Percentage of wild coho adults at the BBC weir in fall 2009.

Spawner Distribution Analysis

Coho redd data was summarized by stream reach. Spatial distribution of coho spawning in each watershed was depicted in a map with redd locations and densities (redds observed per reach). Temporal distribution of coho spawning in each watershed was reported as the total numbers of new redds and live coho by statistical week.

Marine Survival and Harvest Rate Analysis

Marine survival of Big Beef coho is based on the number of wild smolts with CWTs, CWT recoveries from the Big Beef Creek adult trap, and expanded CWT recoveries from coast-wide and terminal fisheries.

Coded-wire tag recoveries from the Big Beef Creek adult trap were estimated from the total unmarked CWT-positive coho adjusted for the incidence of Big Beef Creek origin fish in the CWT-positive return. A portion of the CWT-positive coho are sacrificed for tag recovery, the remainder are passed upstream to spawn. Although most of the recovered tags are typically of Big Beef Creek origin, a sub set are unmarked hatchery fish that stray to the Big Beef weir and mix with the wild tag group. The total estimated Big Beef tag return was:

Equation 12

$$T_{BBC} = \frac{RT_{BBC}}{RT_{TOT}} * T_{TOT}$$

T_{BBC} = Escapement of Big Beef Creek tagged coho at Big Beef weir,

RT_{BBC} = Recovered tags of Big Beef origin from unmarked coho at Big Beef weir,

RT_{TOT} = Total recovered tags from unmarked coho at Big Beef weir, and

T_{TOT} = Total unmarked, tagged coho at the Big Beef weir.

Marine survival (*MS*) was calculated separately for adult and jacks as they represented different tag groups. Marine survival for each tag group was calculated as:

Equation 13

$$MS = \frac{T_F + T_{BBC}}{adj(T_S)}$$

T_F = Fishery interceptions of tagged coho of Big Beef origin,

T_{BBC} = Return of Big Beef tagged coho to the Big Beef weir, and

$adj(T_S)$ = Adjusted number of tagged Big Beef smolts.

Harvest rate (*H*) of Big Beef Creek adult coho was the total coded-wire tags intercepted in fisheries divided by the sum of adult tagged coho in fisheries and escapement:

Equation 14

$$H = \frac{T_F}{T_F + T_{BBC}}$$

Adult Results

Disposition and Escapement of Big Beef Creek Coho

The Big Beef coho escapement reported herein is underestimated due to an unknown number of coho that migrated during the 5-day trap outage. A total of 971 adult coho (421 males, 550 females) and 36 jack coho were captured at the Big Beef Creek weir (Table 11). Thirty-seven adult coho (3.8%) and three jack coho (8.3%) were ad-marked. Twenty-one unmarked adult (2.2%) and 3 (9.1%) of the unmarked jack coho were sacrificed for CWT tag recovery. The remaining 913 unmarked adults (388 males, 525 females) and 30 jacks were released upstream.

Results from scale analysis and CWT recoveries suggested that all unmarked coho passed upstream of the Big Beef Creek weir were of wild origin. Scale samples from unmarked adult (*n = 211)* and jack coho (*n = 6*) were of wild origin (Table 12). Tag recoveries from adult coho at the weir (*n* = 19) and on the spawning grounds (*n* = 35) were of Big Beef Creek origin (Table 13). All tag recoveries from unmarked jacks (*n* = 3) were of Big Beef Creek origin.

Survival-to-Return of Big Beef Creek Coho

Survival-to-return of Big Beef Creek adult coho was 3.88% for brood year 2006. This rate was the tagged adult return (*n* = 778) divided by the adjusted tag group of 20,029 coho smolts tagged in spring 2008.

Jack return rate was 0.08% for brood year 2007. This rate was the tagged jack return (*n* = 26) divided by the adjusted tag group of 31,246 coho smolts tagged in spring 2009.

Escapement of Little Anderson, Seabeck, and Stavis Coho

Total 2009 escapement into Little Anderson was estimated to be 5 coho, 1 jack and 4 adults. Escapement into Seabeck Creek was estimated to be 34 coho, 1 jack and 33 adults. Escapement into Stavis Creek was estimated to be 118 coho, 3 jacks and 115 adults (Tables 14, 15). Total escapement incorporated a 96.2% incidence of wild adult coho and a 91.7% incidence of wild jack coho the Big Beef Creek weir.

Table 11.─Disposition of coho returning to Big Beef Creek weir, fall 2009. Unmarked and marked refers to the presence or absence of an adipose fin. Plus (+) or minus (-) signs indicate a positive or negative detection for a coded-wire tag.

	Unmarked										**Ad-marked**										**Total Coho**			
	Adults							**Jacks**			**Adults**							**Jacks**			**Adults**			**Jacks**
	Male			**Female**			**Total**				**Male**			**Female**			**Total**				**Male**	**Female**	**Total**	
Disposition	**+**	**-**	**Tot**	**+**	**-**	**Tot**		**+**	**-**	**Tot**	**+**	**-**	**Tot**	**+**	**-**	**Tot**		**+**	**-**	**Tot**				
Total Return	318	86	404	460	70	530	934	26	7	33	2	15	17	2	18	20	37	0	3	3	421	550	971	36
Trap Mortalities	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dead Below Weir	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UW Donations	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sacrificed	16	0	16	5	0	5	21	3	0	3	2	15	17	2	18	20	37	0	3	3	33	25	58	6
Total Upstream	302	86	388	455	70	525	913	23	7	30	0	0	0	0	0	0	0	0	0	0	388	525	913	30

Table 12.─Discrimination of wild versus hatchery origin of unmarked coho using scale samples. Scales were collected from a subsample of unmarked coho passed upstream of the Big Beef Creek weir, 2009.

Sex/Age group	Total return	Number sampled	Scale sample results: Unreadable	Scale sample results: Wild	Scale sample results: Hatchery	Total estimated: Wild	Total estimated: Hatchery
Males	404	113	2	111	0	40	0
Females	530	98	11	87	0	530	0
Total	934	211	13	198	0	934	0
Jacks	33	6	0	6	0	33	0

Table 13.—Coded-wire tag recoveries from coho returning to Big Beef Creek weir in 2009. Adults and jacks are reported separately by mark type.

Group	Tag Code	Origin	CWT Recoveries: Sacrificed at Trap	Donated to UW Hatchery Study	Stream Surveys/ Weir Recovery	Trap Mortality	Dead Below Weir	Total
Unmarked Adults	63-44/69	Big Beef	3	0	11	0	0	14
	63-45/97	Big Beef	16	0	24	0	0	40
	No tag	---	1	0	1	0	0	2
		Total	20	0	36	0	0	56
Ad-marked Adults	21-07/78	Port Gamble Pens	1	0	0	0	0	1
	18-58/56	Goldstream River BC	1	0	0	0	0	1
	No tag	---	2	0	0	0	0	2
		Total	4	0	0	0	0	4
Unmarked Jacks	63-41/80	Big Beef	3	0	0	0	0	3
	No tag	---	1	0	0	0	0	1
		Total	4	0	0	0	0	4
Ad-marked Jacks	---	Total	0	0	0	0	0	0

Table 14.—Estimated adult coho escapements into Little Anderson, Seabeck, and Stavis creeks in 2009. Calculations are based on smolt production (S) of the corresponding brood year, survival-to-return of adult coho (SRRA) to Big Beef Creek weir, and incidence of wild adult coho in Big Beef Creek escapement.

Watershed	S (BY 2006)	SRR_A	Wild adult escapement	% Wild coho	Total escapement
Little Anderson	96	3.88%	4	96.2%	4
Seabeck	828	3.88%	32	96.2%	33
Stavis	2,850	3.88%	111	96.2%	115
Total	3,774		147		152

Table 15.—Estimated jack coho escapements into Little Anderson, Seabeck, and Stavis creeks in 2009. Calculations are based on smolt production (S) of the corresponding brood year, survival-to-return of jack coho (SRRJ), and incidence of wild jack coho in Big Beef Creek escapement.

Watershed	S (BY 2007)	SRR_J	Wild jack escapement	% Wild coho	Total escapement
Little Anderson	1,101	0.08%	1	91.7%	1
Seabeck	626	0.08%	1	91.7%	1
Stavis	3,474	0.08%	3	91.7%	3
Total	5,201		4		5

Chum Escapement, Big Beef Creek

Chum salmon were caught between August 27 and November 30, 2009. Summer chum were designated as those migrating prior to October 15 and fall chum were designated as chum migrating on and after October 15. No chum salmon were caught between October 6 and 14, 2009. Peak catch of summer chum occurred on September 14 and peak catch of fall chum occurred on November 5 (Table 16).

A total of 502 adult chum returned to Big Beef Creek in 2009. This return included 132 summer chum and 370 fall chum (Table 17). The fall chum escapement estimate is likely an underestimate due to the 5-day outage of the Big Beef weir.

Table 16.─Numbers of summer and fall-run chum salmon caught by statistical week in the Big Beef Creek weir trap, 2009.

Statistical Week			Summer Chum			Fall Chum		
Begin	End	No.	Male	Female	Total	Male	Female	Total
24-Aug	30-Aug	35	4	1	5			
31-Aug	6-Sep	36	2	0	2			
7-Sep	13-Sep	37	17	9	26			
14-Sep	20-Sep	38	33	27	60			
21-Sep	27-Sep	39	14	11	25			
28-Sep	4-Oct	40	5	6	11			
5-Oct	11-Oct	41	2	1	3			
12-Oct	18-Oct	42	0	0	0	2	0	2
19-Oct	25-Oct	43				0	0	0
26-Oct	1-Nov	44				61	42	103
2-Nov	8-Nov	45				102	60	162
9-Nov	15-Nov	46				35	39	74
16-Nov	22-Nov	47				11	7	18
23-Nov	29-Nov	48				6	4	10
30-Nov	6-Dec	49				1	0	1
7-Dec	13-Dec	50				0	0	0
14-Dec	20-Dec	51				0	0	0
21-Dec	27-Dec	52				0	0	0
		Totals	77	55	132	218	152	370

Table 17.─Disposition of chum returning to Big Beef Creek weir, 2009.

	Disposition	Male	Female	Total	Percent
Summer chum	Unspawned, released upstream	77	55	132	100.0%
	Spawned below weir	0	0	0	0.0%
	Spawned, released upstream	0	0	0	0.0%
	Total summer chum	77	55	132	100.0%
Fall chum	Unspawned, released upstream	213	151	364	98.4%
	Spawned below weir	0	0	0	0.0%
	Spawned, released upstream	5	1	6	1.6%
	Released into UW ponds/spawning channel	0	0	0	0.0%
	Total fall chum	218	152	370	100.0%
Total		295	207	502	

Steelhead Escapement, Big Beef Creek

A total of 7 adult steelhead (6 males and 1 female) returned to Big Beef Creek in 2008-2009. The first adult steelhead was an unmarked male captured on November 7, 2008. The last observations were on February 24, 2009 when two unmarked males were captured. Steelhead escapement was likely an underestimate due to the trap outage that began on January 7, 2009. One steelhead was captured on January 7th before the weir was pulled and two were captured after the trap was reinstalled on January 9th. Average length of adult steelhead was 67.3 cm (range = 65-70 cm).

Coho Body Size

Fork lengths were measured for 113 adult males, 98 females, and 6 jack coho at the Big Beef Creek weir (Table 18). Adult male coho (average = 56.3-cm fork length, FL) were slightly shorter than female coho (average = 58.2-cm FL). Jack coho averaged 32.5-cm FL.

Table 18.─Average fork length (cm), range, standard deviation, and sample rate of unmarked coho at the Big Beef Creek weir, 2009.

Metric	Jacks < 35cm	Jacks 35-45cm	Adult males 35-45cm	Adult males > 45cm	Adult females
Average (cm)	32.0	38.0	41.9	57.1	58.2
Min (cm)	29	36	35	46	42
Max (cm)	34	40	45	73	71
St. Dev.	2.65	2.00	3.38	6.39	4.81
N	3	3	23	90	98
Sample rate	10.0%	100.0%	100.0%	23.6%	18.5%

Spatial Distribution of Coho Spawning

A total of 241 live coho, 81 carcasses, and 240 redds were observed during the spawner surveys. Most of the redd observations occurred in Big Beef and Stavis creeks (Table 19).

Coho redds were distributed throughout tributaries and main stem areas of Little Anderson, Big Beef, and Stavis creeks (Figure 14-18). On Big Beef Creek, 58.5% of the coho redds were observed upstream of Lake Symington. Thirty-three percent (*n* = 45) of all Big Beef Creek coho redds above the lake were found in a single tributary, Tributary 31 (also known as "Vine Maple tributary"). Coho redds on Seabeck Creek were concentrated in the lower main stem and Tributary 5, which flows into the lower end of Seabeck Creek. No coho redds were observed more than 2,417 meters upstream of the mouth of Seabeck Creek.

Table 19.─Live coho, coho carcasses, and coho redds observed during spawning ground surveys in the Hood Canal IMW streams, 2009.

			Carcasses				
Watershed	Survey dates	Live coho	Males	Females	Jacks	Not determined	Redds
Little Anderson	10/21-12/30	5	1	2	0	0	10
Big Beef	10/20-01/07	194	14	37	0	5	176
Seabeck	10/21-12/29	27	4	11	2	1	17
Stavis	10/26-12/30	15	1	3	0	0	37

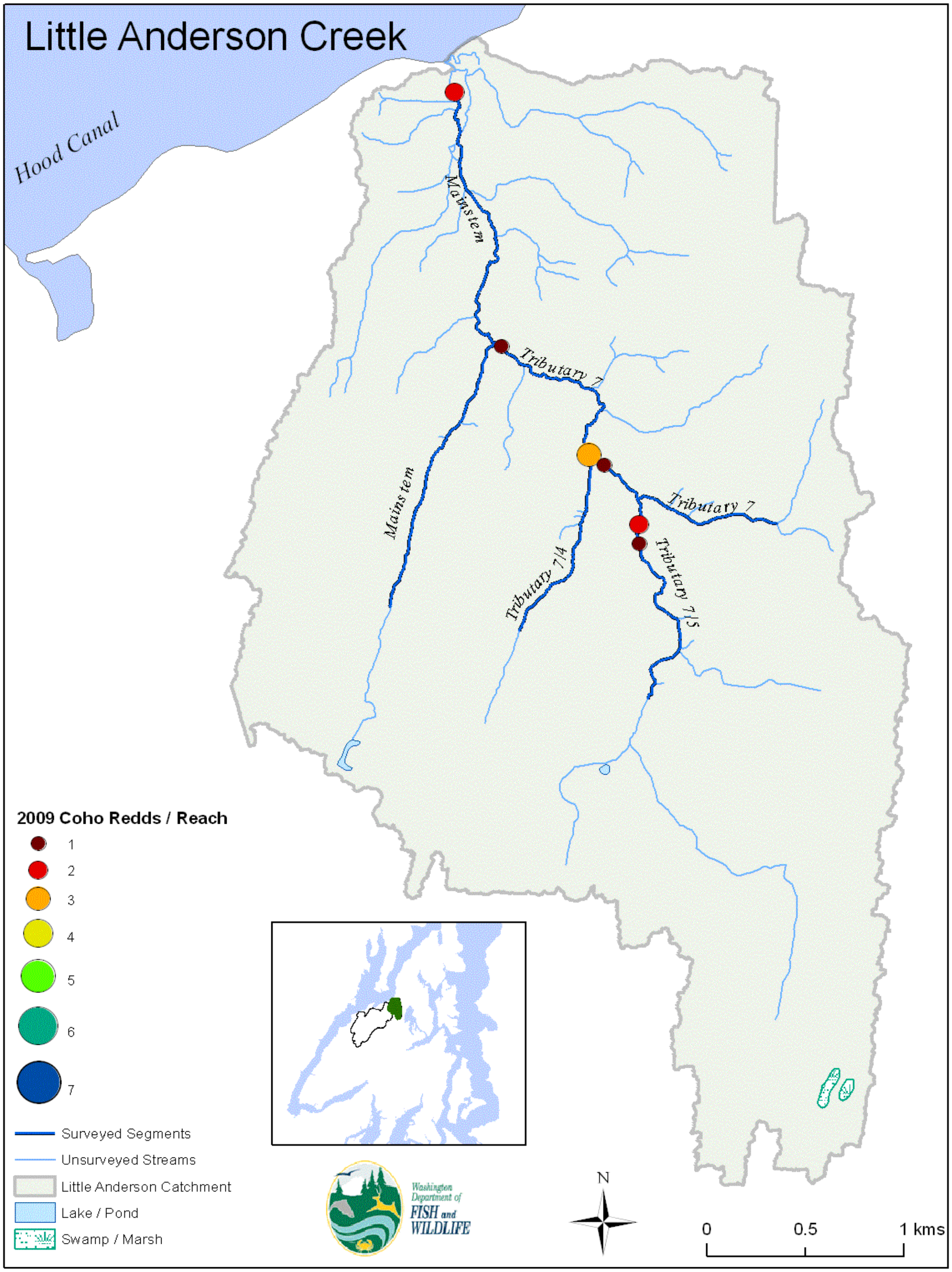


Figure 14.─Spatial distribution and density of coho redds in the Little Anderson Creek watershed, 2009.

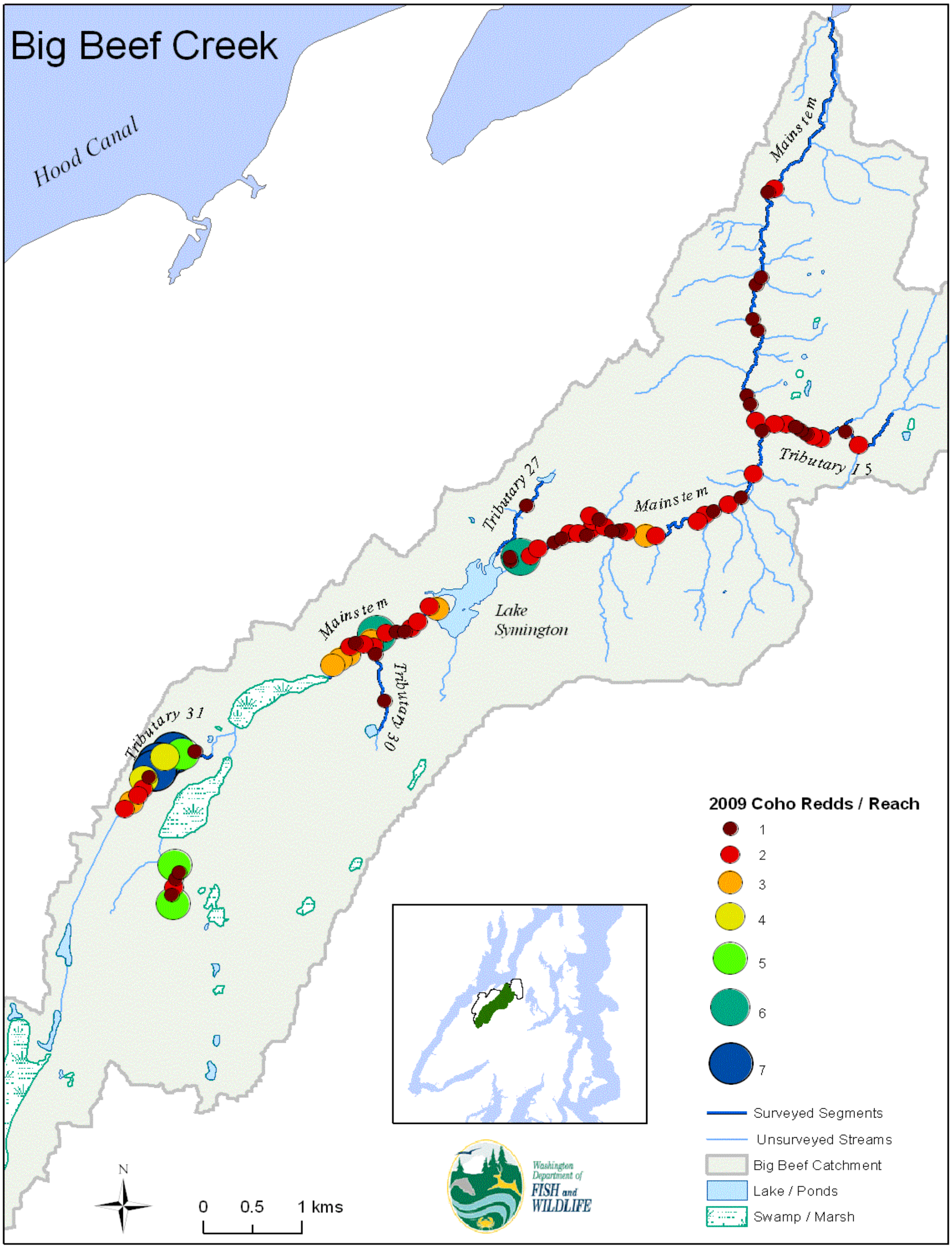


Figure 15.—Spatial distribution and density of coho redds in the Big Beef Creek watershed, 2009.

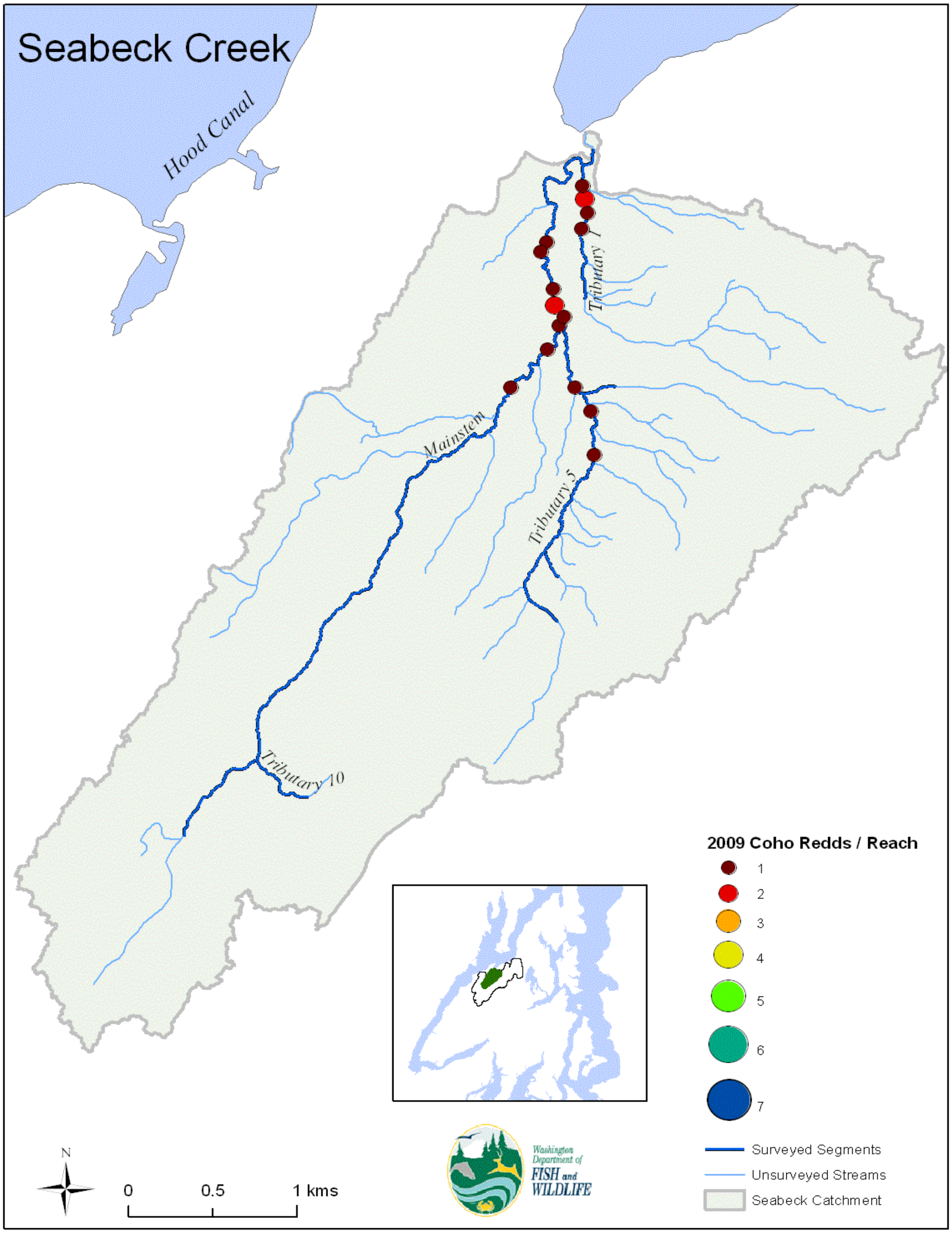


Figure 16.─Spatial distribution and density of coho redds in the Seabeck Creek watershed, 2009.

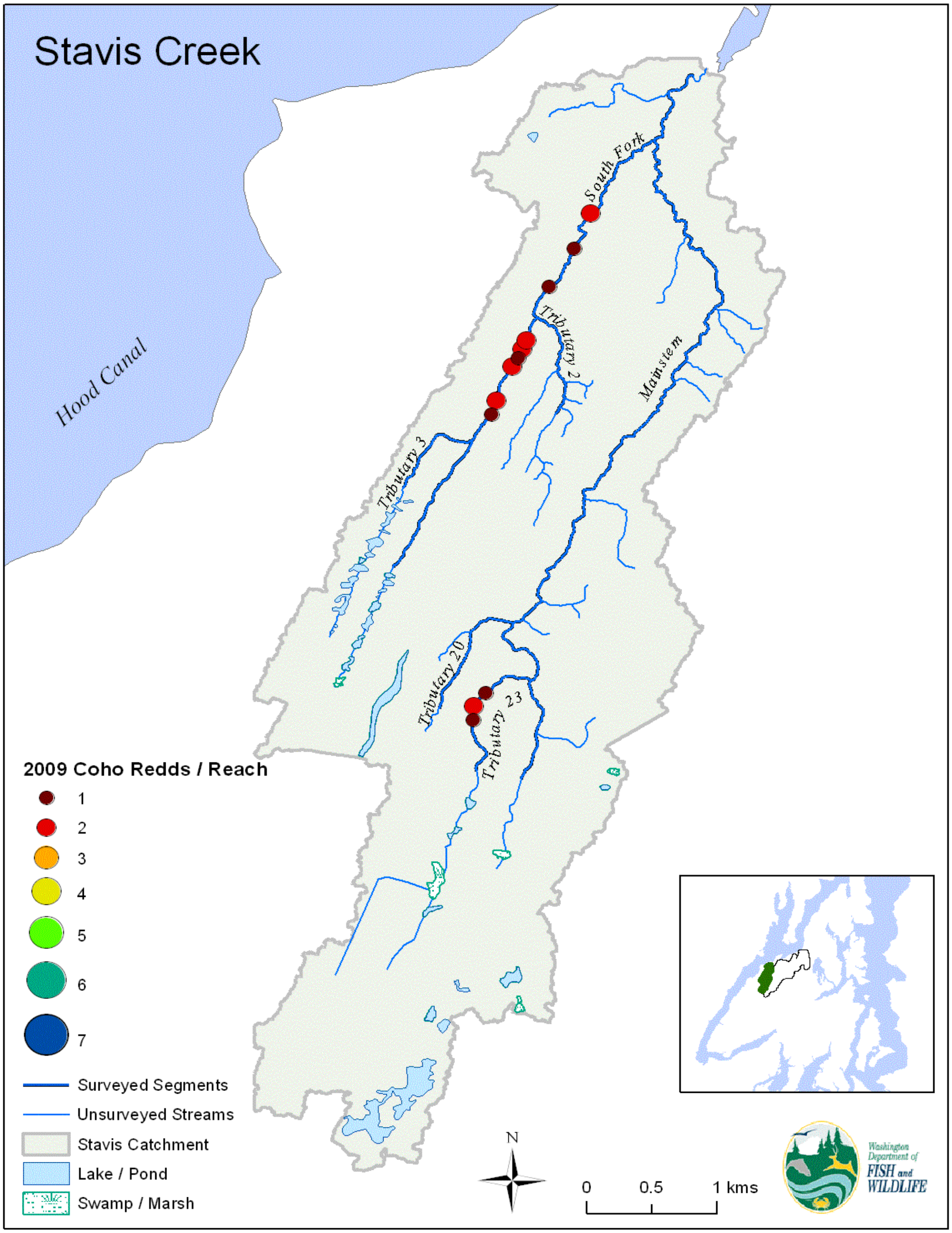


Figure 17.─Spatial distribution and density of coho redds in the Stavis Creek watershed, 2009.

Temporal Distribution of Coho Spawning

The first coho were detected on the Big Beef delta in mid-September. The first coho were captured at the Big Beef weir on October 5 and included unmarked (*n* = 9) and ad-marked (*n* = 2) adults. Large numbers of coho arrived at the weir following rain fall on October 16 that increased stream flow to 38 cfs (Figure 18). The total of 65% of all unmarked coho at the Big Beef Creek weir arrived during the period of increased flows between October 14th and 20th. The peak of daily coho catch occurred on October 17th (*n* = 285). The last observed unmarked adult coho was a single female captured on November 25th. November flows remained well above the long-term average and provided passage into tributary spawning habitats (Figure 19).

The first coho redds were observed between statistical week 43 (October 19-25, Big Beef Creek) and statistical week 46 (November 9 to 15, Seabeck Creek). On Big Beef Creek, new redd construction peaked during statistical week 49 (November 30 to December 6), 1 week after the peak live coho counts were recorded during spawner surveys (Figure 20*b*) and 7 weeks after peak catch at the weir (Figure 18). On Seabeck and Little Anderson creeks, new redd construction peaked during statistical week 49 (November 30 to December 6), 1 week after peak live counts were observed in these watersheds (Figure 20*a* and *c*). On Stavis Creek, peak observations of new redds and live coho occurred on the same week (statistical week 48, Figure 20*d*).

Harvest Rate

An estimated 1,905 tagged Big Beef coho (BY 2006) were intercepted in fisheries according to tag recoveries reported in the RMPC database by September 2010 (Table 21). Sixty-two percent of this harvest (*n* = 1,181) occurred in Marine Area 12 near the mouth of Big Beef Creek.

In the Marine Area 12 fishery, 98% of the unmarked tagged coho sampled were of Big Beef Creek origin (467/476 = 98.1%). This estimate was based on actual (non-expanded) tag recoveries from 476 unmarked and 24 ad-marked coho in the Marine Area 12 fishery (Table 20).

Tag recovery data correspond to a preliminary harvest rate of 71.0% of the total run (Table 21). The preliminary harvest rate represents a lower bound as no tags are currently reported for harvest in Puget Sound or ocean sport fisheries. A final estimate will be possible after all catch and tag expansion estimates are finalized in the Regional Mark Processing Center (RMPC) database (Regional Mark Information System online database).

Marine Survival

The preliminary marine survival estimate for adult coho (BY 2006) was 13.40%. This estimate was based on 1,905 fishery interceptions, 778 tagged adults returning to the weir, and an adjusted group of 20,029 smolts tagged in spring 2008 (Table 2-8). The preliminary marine survival estimate of 0.08% for jack coho (BY 2007) was based on zero reported fishery interceptions, 26 tagged jacks at the weir, and an adjusted group of 31,246 coho smolts tagged in spring 2009. Preliminary marine survival estimates are likely biased low because not all CWT recoveries from harvested coho are currently reported (as of Sept 1, 2010).

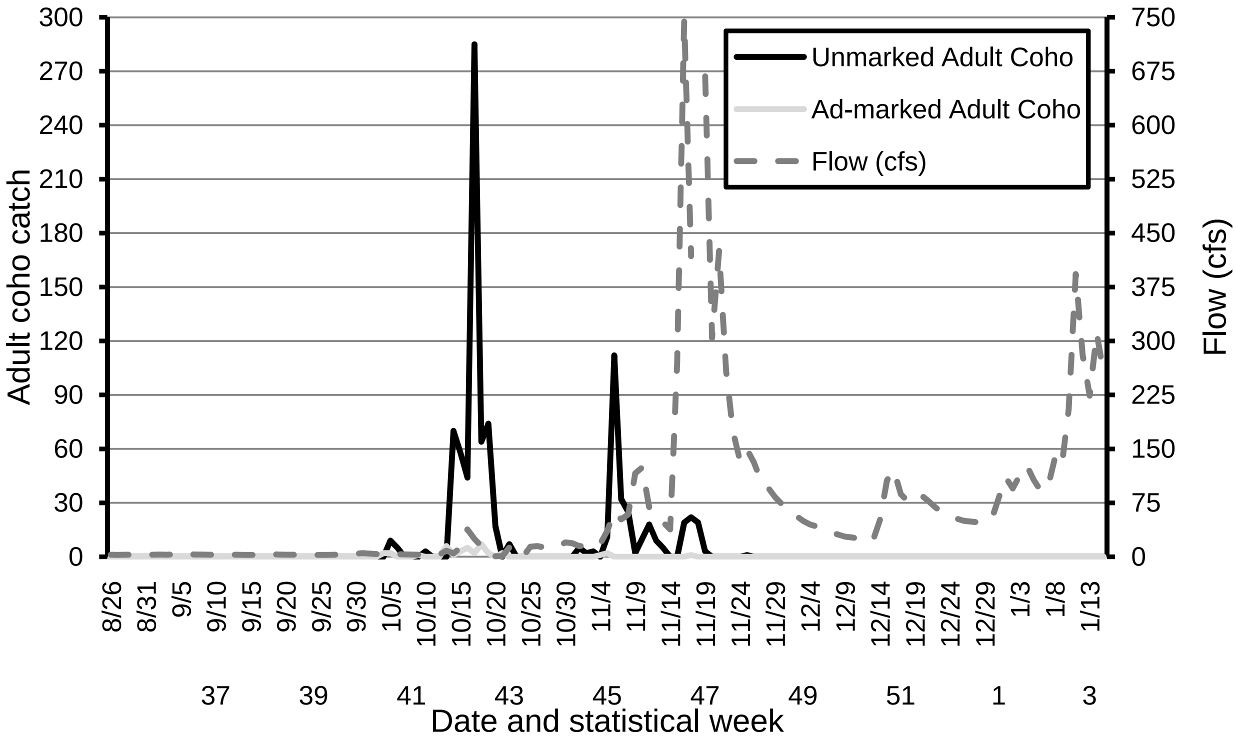


Figure 18.─Daily catch of unmarked and ad-marked coho spawners at the Big Beef Creek weir trap, fall 2009. Mean daily flow (cfs) was measured at USGS gauge #12069550.

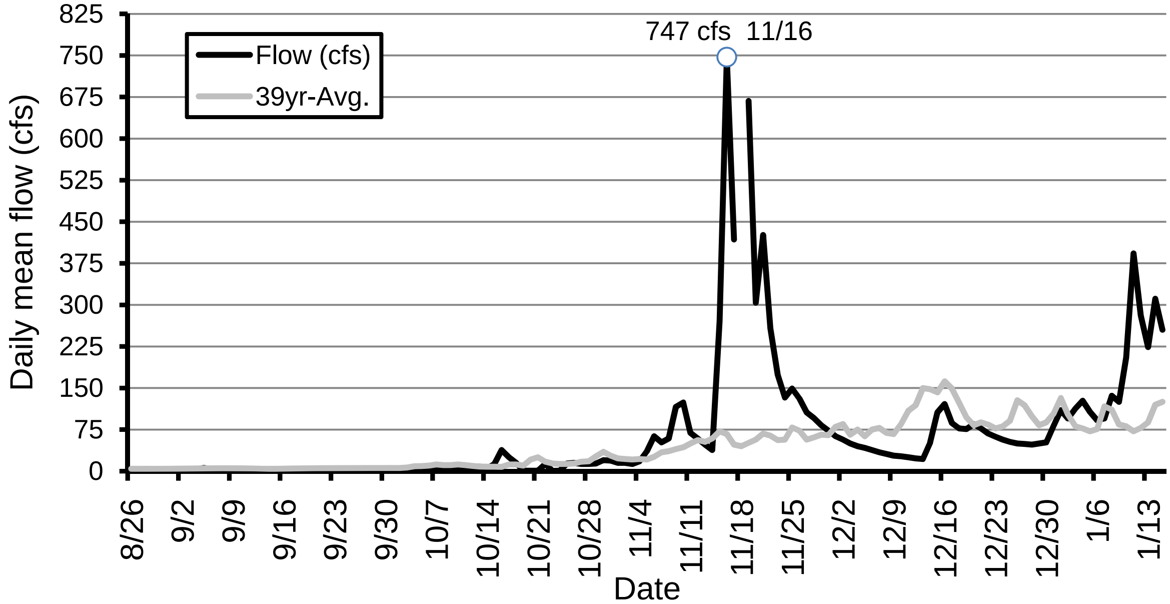


Figure 19.─Daily mean flow in 2009 and 39-year historical average at Big Beef Creek, USGS gauge#12069550.

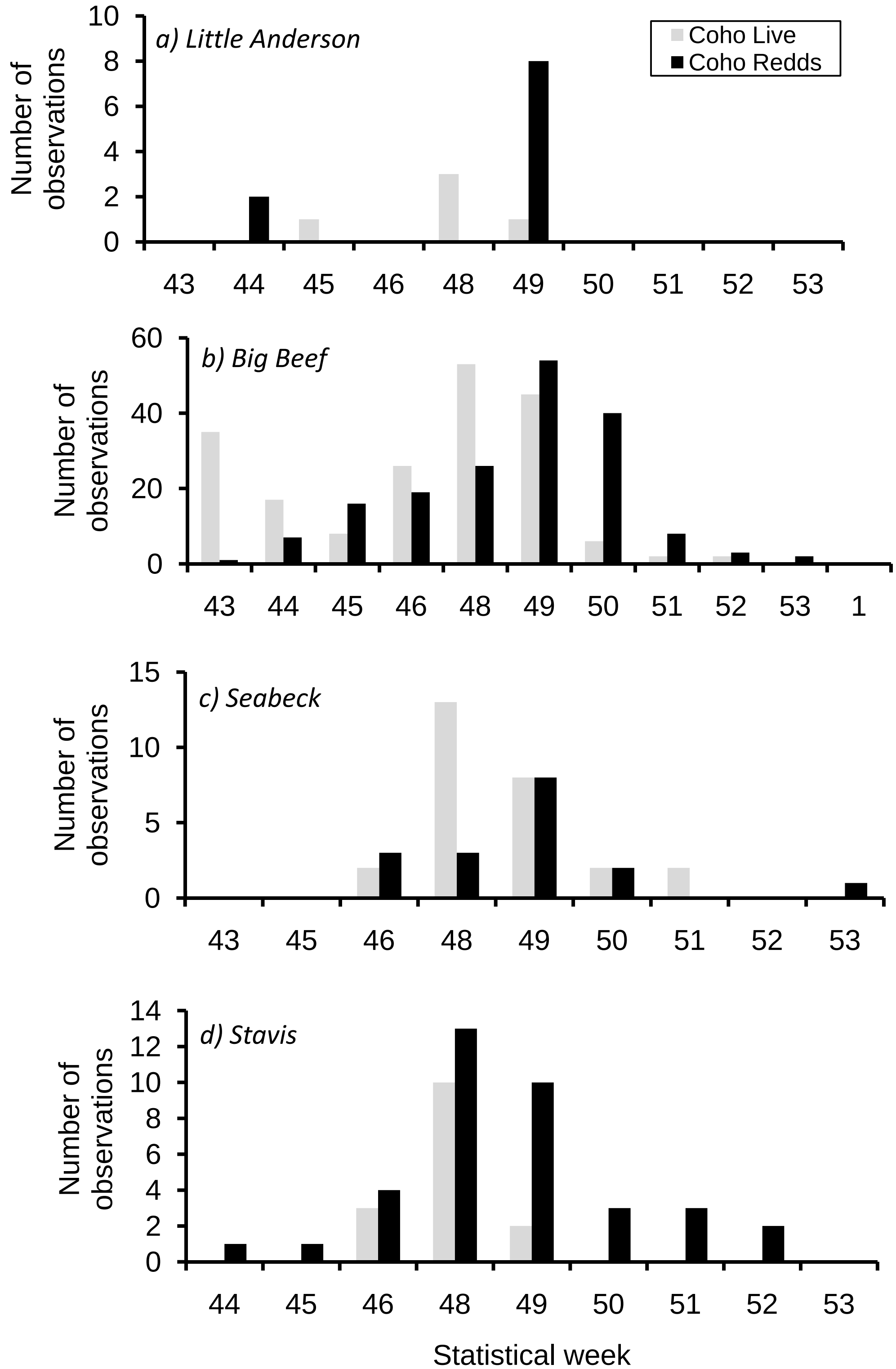


Figure 20.―Number of live coho (gray bars) and new coho redds (black bars) observed on Little Anderson (a), Big Beef (b), Seabeck (c), and Stavis (d) creeks by statistical week, 2009-2010.

Table 20.─Origin of coded-wire tags recoveries from the Hood Canal (Marine Area 12) treaty coho beach seine fishery, fall 2009.

Tag Code	Origin	#CWT Recoveries
63-44/69	Big Beef Adults (BY 2006)	121
63-45/97	Big Beef Adults (BY 2006)	346
05-39/72	Big Quilcene	2
05-39/74	Big Quilcene	2
05-39/78	Quilcene Bay Pens	7
18-58/57	Goldstream River (BC)	1
21-06/77	Skagit River	1
21-07/28	Port Gamble Bay Pens	12
63-36/92	Voight Creek	1
63-36/95	Lake Kapowsin	1
63-39/82	Peale Pass	1
63-41/67	Purdy Creek	2
63-41/68	Purdy Creek	3
Total		500

Table 21.—Marine survival of Big Beef Creek wild adult coho (2006 brood) based on the harvest and escapement of tagged wild adults during 2009 (Preliminary as of September 1, 2010).

	Area	Fishery Type	Tag Codes: 63-45/97 63-44/69
Harvest	Ocean (WA)	Troll (Treaty + Non-treaty)	45
Harvest	Puget Sound	Sport + Mixed Net/Seine (combined) [a]	1,860
Harvest	Estimated harvest of BBC tags[a]		1,905
Escapement	Big Beef Trap	Return of tagged wild coho to weir[b]	778
Escapement	Total escapement of BBC tags		778
	Total tagged run (Harvest + Escapement)		2,683
Summary	Total tagged smolts (tag codes 63-45/97, 63-44/69)		24,709
Summary	Adjusted tagged smolts[c]		20,029
Summary	Harvest rate (Total harvest of BBC tags/Total tagged run)		[d] 71.0%
Summary	Escapement rate (Total escapement of BBC tags/Total tagged run)		[e] 29.0%
Summary	Survival to return rate (Total tagged escapement/Adjusted tagged smolts)		3.88%
Summary	Marine survival (Total tagged run/Adjusted tagged smolts)		13.40%

[a] Preliminary estimate as of September 1, 2010. Numbers may increase once reporting is finalized in the PSMFC's Regional Mark Processing Center (RMPC) database.

[b] Estimated by expanding coded-wire tag sample results to total unmarked tagged adults returning to weir during the fall of 2009.

[c] Adjusted for the effect of trapping and tagging on survival (16%) and tag loss (3.5%).

[d] Preliminary harvest rate; currently biased low due to unreported catch data from fisheries.

[e] May be biased low due to tagged coho that passed the weir undetected during the 5-day trap outage.

Adult Discussion

Escapement Estimation

Unlike Big Beef Creek, the estimate of coho escapement on Little Anderson, Seabeck, and Stavis creeks do not benefit from a census weir. Therefore, two approaches were considered to derive escapement estimates for these creeks. The validity of these approaches was evaluated based on correlations between watershed estimates and Big Beef Creek weir counts, assuming that comparable ocean conditions and harvest rates resulted in generally correlated coho escapements among neighboring watersheds.

The first approach was based on cumulative observations of coho redds. Redd observations in all three neighboring watersheds were strongly correlated with Big Beef Creek census counts (Figure 21). If adopted, cumulative redd observations from the weekly spawner surveys could be used as an index of coho escapement. However, additional years with high coho returns are needed to validate the use of redd counts as this relationship was largely weighted by strong returns to all watersheds in 2004. Expansion of a redd-based escapement index to a total escapement, based on Big Beef redd-to-weir ratios, is not recommended. This expansion would assume comparable visibility among spawner surveys. However, Big Beef Creek is nearly three times the area and has considerably more wetland and marsh habitats than Little Anderson, Seabeck, and Stavis creeks. For this reason, the rate of redd detections is likely reduced during spawner surveys in Big Beef as compared to the neighboring watersheds.

The second approach was based on survival-to-return based estimates. Big Beef weir counts were strongly correlated with survival-to-return based estimates for Seabeck and Stavis creeks but not with Little Anderson (Figure 22). This suggests that the survival-to-return approach is not a good method for estimating for Little Anderson coho escapement. This conclusion was further supported by a *SRR* estimate in 2009 (n = 5, Table 14, 15) which was lower than the number of observed coho redds (n = 10, Table 19) and lower than the 16 adult adult coho captured a pipe weir in operated on Little Anderson Creek for a portion of the 2009 coho return by WDFW Habitat Program (Ned Pittman, WDFW, personal communication). Localized factors on Little Anderson Creek may explain this discrepancy. For example, Little Anderson smolt production was not correlated with neighboring tributaries until the NW Anderson Hill Road culvert was replaced in 2002 (Figure 13). Furthermore, the most popular fishing grounds in area 12 are just of the mouth of Little Anderson Creek. One consequence of this fishery may be disproportionately lower escapement rates into Little Anderson. As a result, the validity of survival-to-return based estimates for Little Anderson coho escapements is more uncertain that those of Seabeck and Stavis creeks.

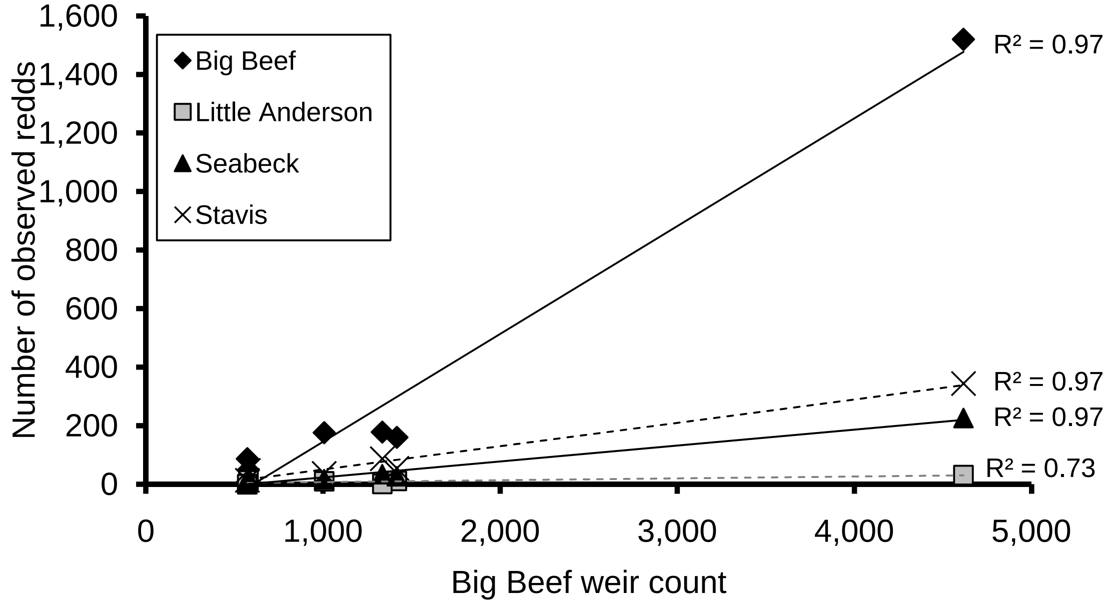


Figure 21.─Number of coho redds observerved on Big Beef, Little Anderson, Seabeck and Stavis creeks associated with Big Beef Creek coho census counts, 2004-2009.

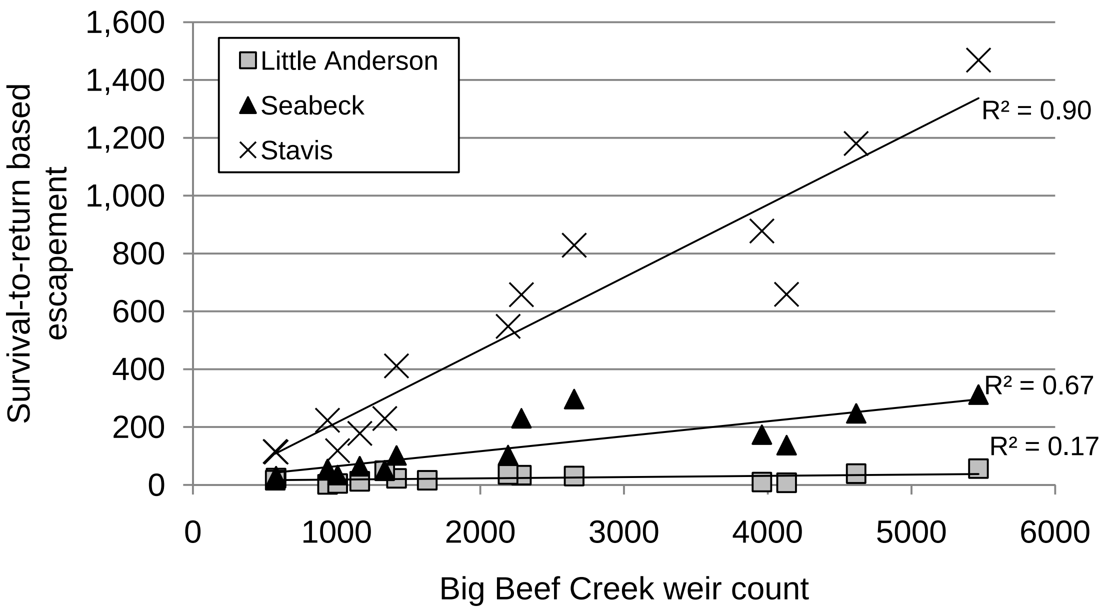


Figure 22.─Survival-to-return based coho escapement estimates for Little Anderson, Seabeck and Stavis Creeks associated with Big Beef Creek coho census counts, 1994-2009.

Escapement and Marine Survival

The 2009 escapement of Big Beef adult coho (n = 934) was 60.2% of the long-term average, 1978 to present (Figure 23). This escapement was the product of low smolt production (Kinsel et al. 2009) and low survival-to-return for the 2006 brood year. Although marine survival for the 2006 brood year (13.4%) was nearly comparable to the average historical rates (15.8%, Figure 24), a harvest rate of 71.0% dampened the effect of good ocean conditions and resulted in the lower than average escapement. Harvest rates of Big Beef coho have varied considerably from year to year. The maximum harvest rate of 91.5% in 1985 was more than 10 times the minimum harvest rate, estimated to be 8.2% in 2003. For the past five years, coho escapements have been well below the long-term average yet harvest rates have ranged between 64 and 85% (Figure 23).

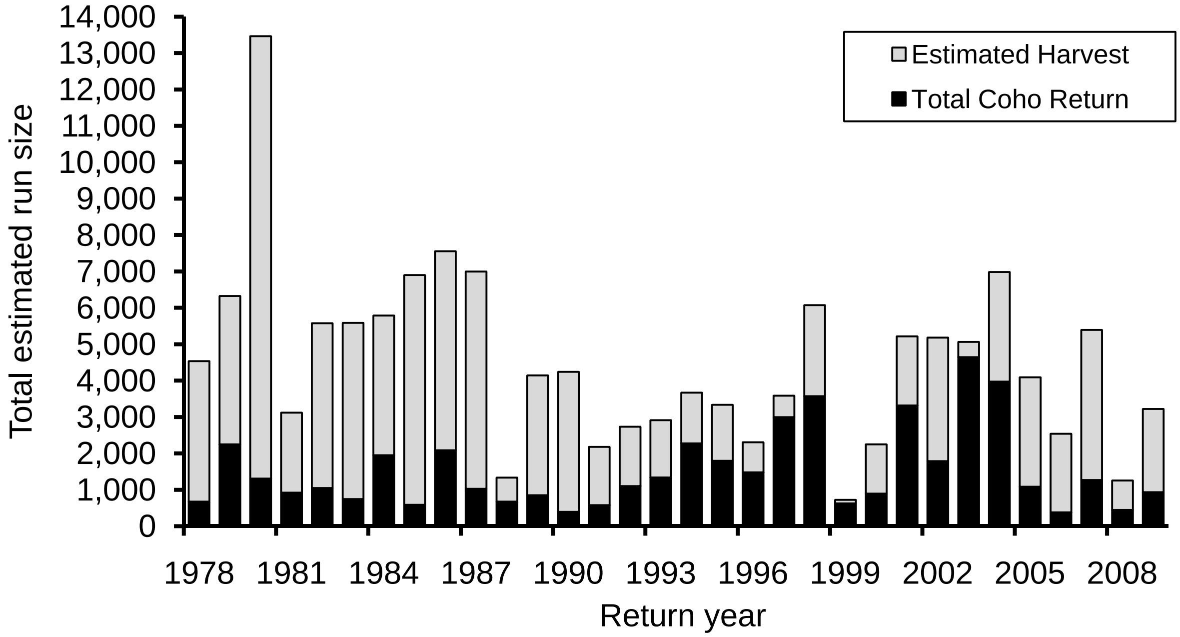


Figure 23.─Total estimated run size for Big Beef Creek adult coho partitioned into escapement and harvest, 1978 to 2009.

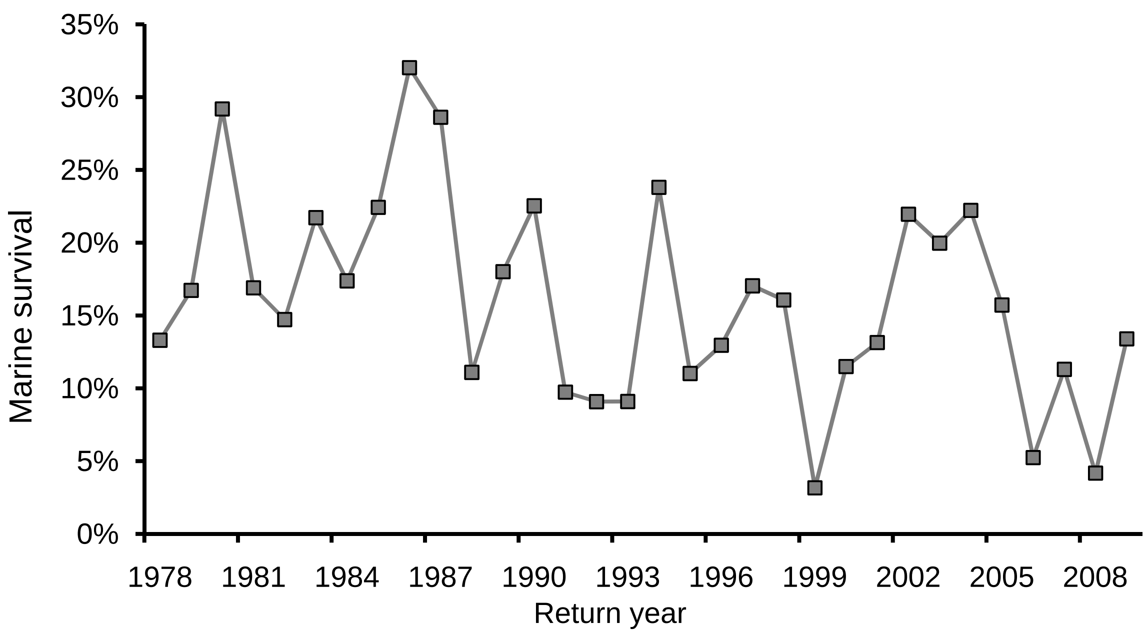


Figure 24.─Big Beef Creek coho marine survival by adult return year, 1978-2009.

Coho escapement was also below average in the other three IMW watersheds. In Seabeck Creek, the upper extent of coho spawning was the lowest observed since the inception of the IMW spawning surveys in 2004. For the last several years, low stream flows in Seabeck Creek have decreased the available spawning habitat and limited coho spawning to main stem areas low in the watershed. In 2009, coho migration into Seabeck Creek appeared to be hindered by low stream flow conditions throughout the spawning season. In the month of October 2009 many portions of this watershed were nearly dry. By early November, coho moved into the watershed in response to increased flows. However, early December was characterized by low flows and very cold temperatures. During this period, survey crews reported that some small tributaries were all “slush” and others were covered with 2-3 inches of ice. Portions of main stem Seabeck Creek were again de-watered during this cold snap.

Freshwater Production and Survival

Understanding the smolt-spawner relationship will be important for interpreting responses to habitat restoration. Detecting a response to habitat restoration does not require high levels of escapement but will require a known baseline relationship between adult spawners and juvenile productivity (juveniles per spawner). Tighter correlations in the baseline data will increase the ability to detect responses to habitat restoration.

The smolt and spawner data collected to date have shown that coho smolt production continues to increase with increased spawner abundance (Figure 25*a* to 28*a*). A logarithmic model fit to the smolt-spawner data was a better fit than either the linear model or the quadratic model. The logarithmic model indicates that smolt production continues to increase as more spawners enter the system but that the largest increases in freshwater production occur under the lowest escapements. A linear model would indicate density-independent smolt production and a quadratic model would indicate that freshwater production is maximized by a particular escapement. Although the logarithmic model was the best fit for the smolt and spawner data, about 50% of the variation in smolt production could not be explained by spawner abundance. This result indicates the importance of environmental variables such as spawning and rearing flows. Future work will identify the extent to which these environmental variables limit coho smolt production under baseline conditions in the IMW watersheds (i.e., pre-restoration). Habitat restoration actions should interact with these flow effects and reduce their impacts on coho survival.

In the Hood Canal IMW watersheds, juvenile productivity (smolts per adult spawner) is partially explained by spawner abundance. At low spawner abundance levels, smolts per spawner are higher than at high spawner abundance levels (Figure 25 to 28). Sixty-seven to eighty-four percent of the variation in juvenile productivity can be explained by estimated spawner abundance. A nonlinear power function fit to the spawner-smolt data from Big Beef Creek indicates that juvenile productivity increases when spawner abundance falls below 1,000 adults (Figure 26). Similar functions fit to data from Seabeck and Stavis creeks indicate that juvenile productivity increases when spawner abundance falls below 100 and 400 adults respectively (Figure 27 and 28). On Little Anderson Creek, the relationship between smolt survival and spawner abundance is only evident when spawner abundance is represented by redd observations (Figure 25). Issues related to survival-to-return based estimates for Little Anderson Creek are discussed above.

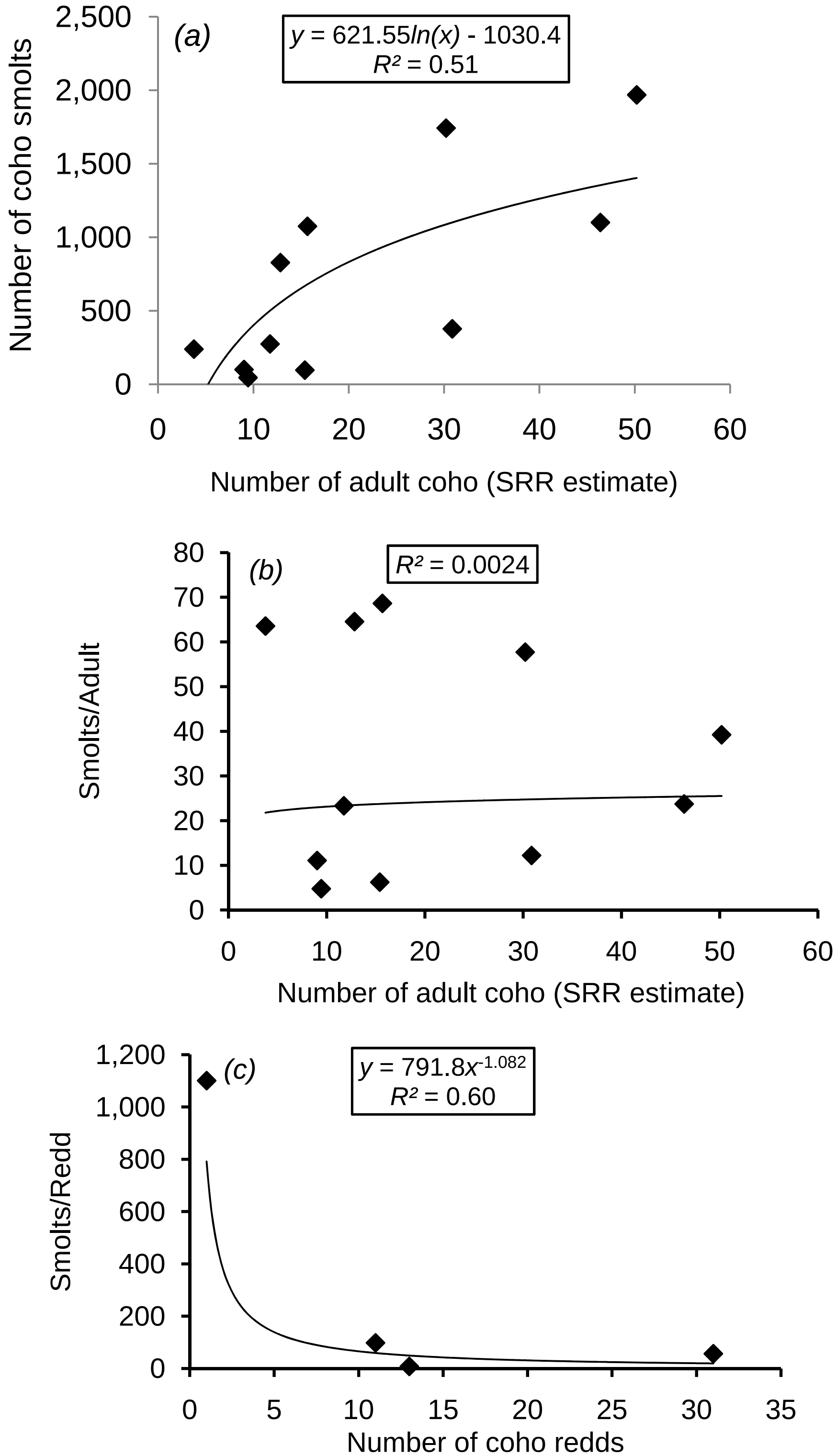


Figure 25.─Coho smolt production (a) and productivity (b, c) as a function of adult spawners on Little Anderson Creek. Adult spawners were estimated using the survival to return approach (a, b) for brood years 1994-2007 and the number of redds observed during weekly spawner surveys (c) for brood years 2004-2007.

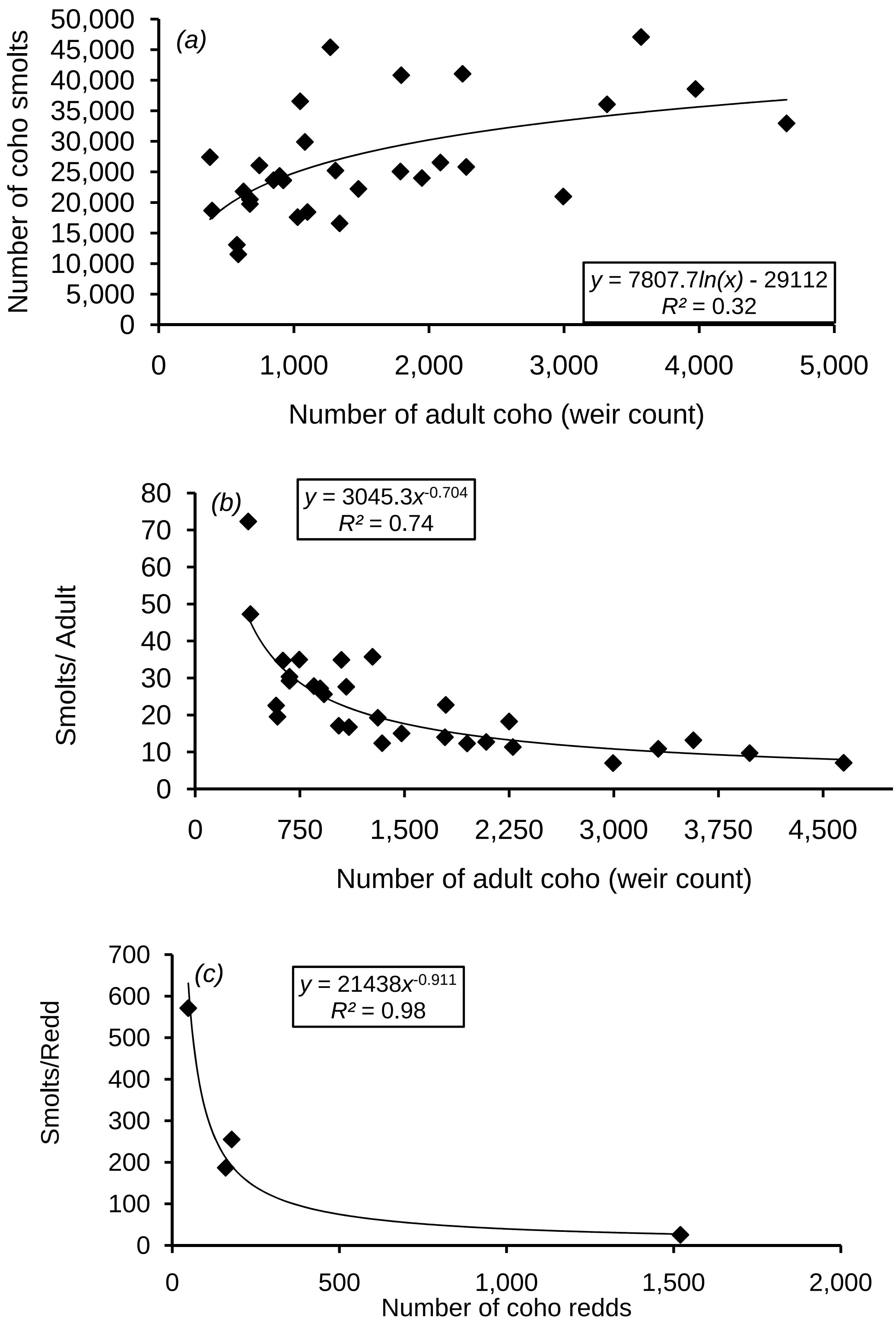


Figure 26.─Coho smolt production (a) and productivity (b, c) as a function of adult spawners on Big Beef Creek. Adult spawners were counted at the Big Beef weir (a, b) for brood years 1978-2007 and based on number of redds observed during weekly spawner surveys (c) for brood years 2004-2007.

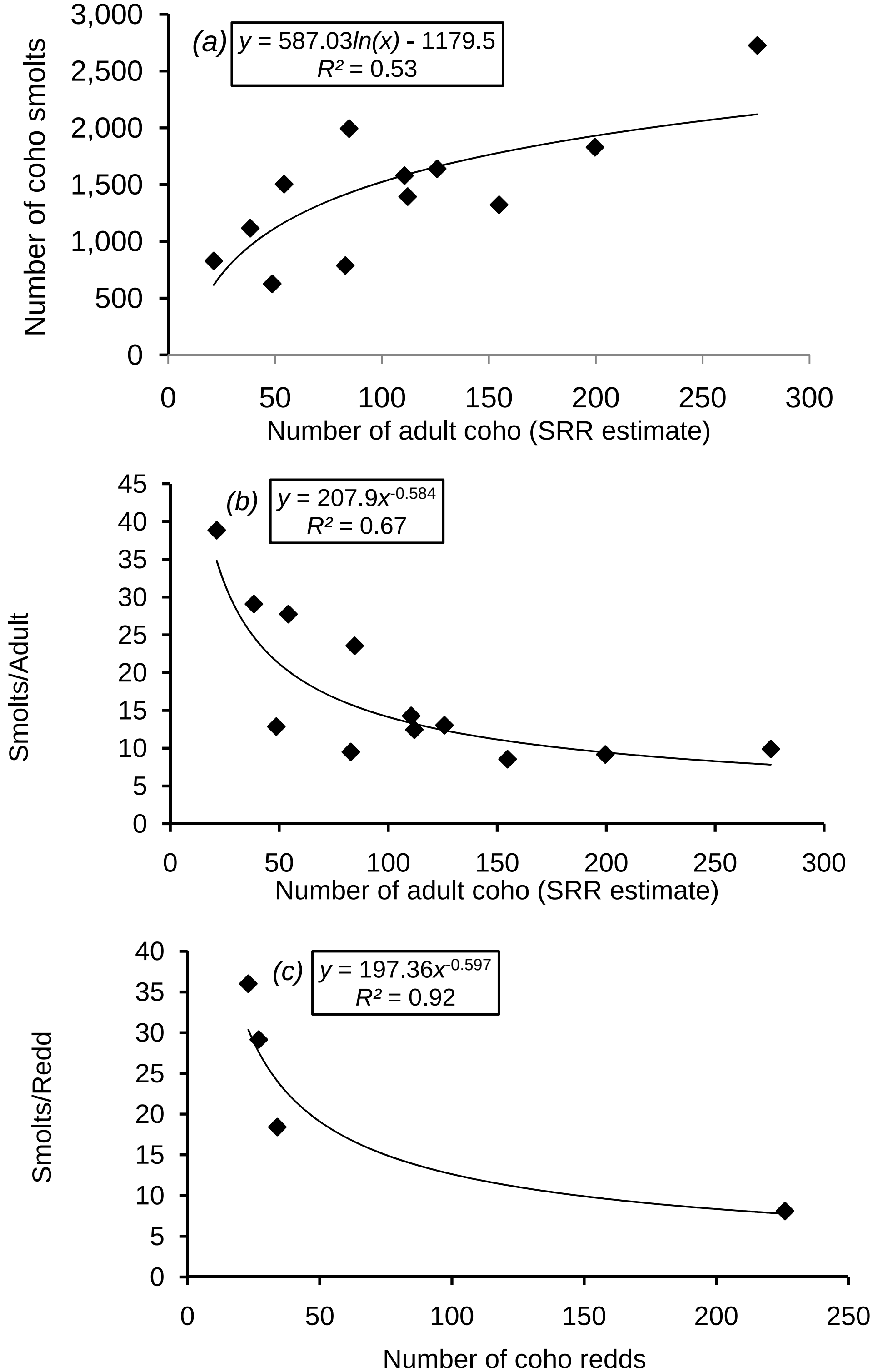


Figure 27.─Coho smolt production (a) and productivity (b, c) as a function of adult spawners on Seabeck Creek. Adult spawners were estimated using the survival to return approach (a, b) for brood years 1994-2007 and the number of redds observed during weekly spawner surveys (c) for brood years 2004-2007.

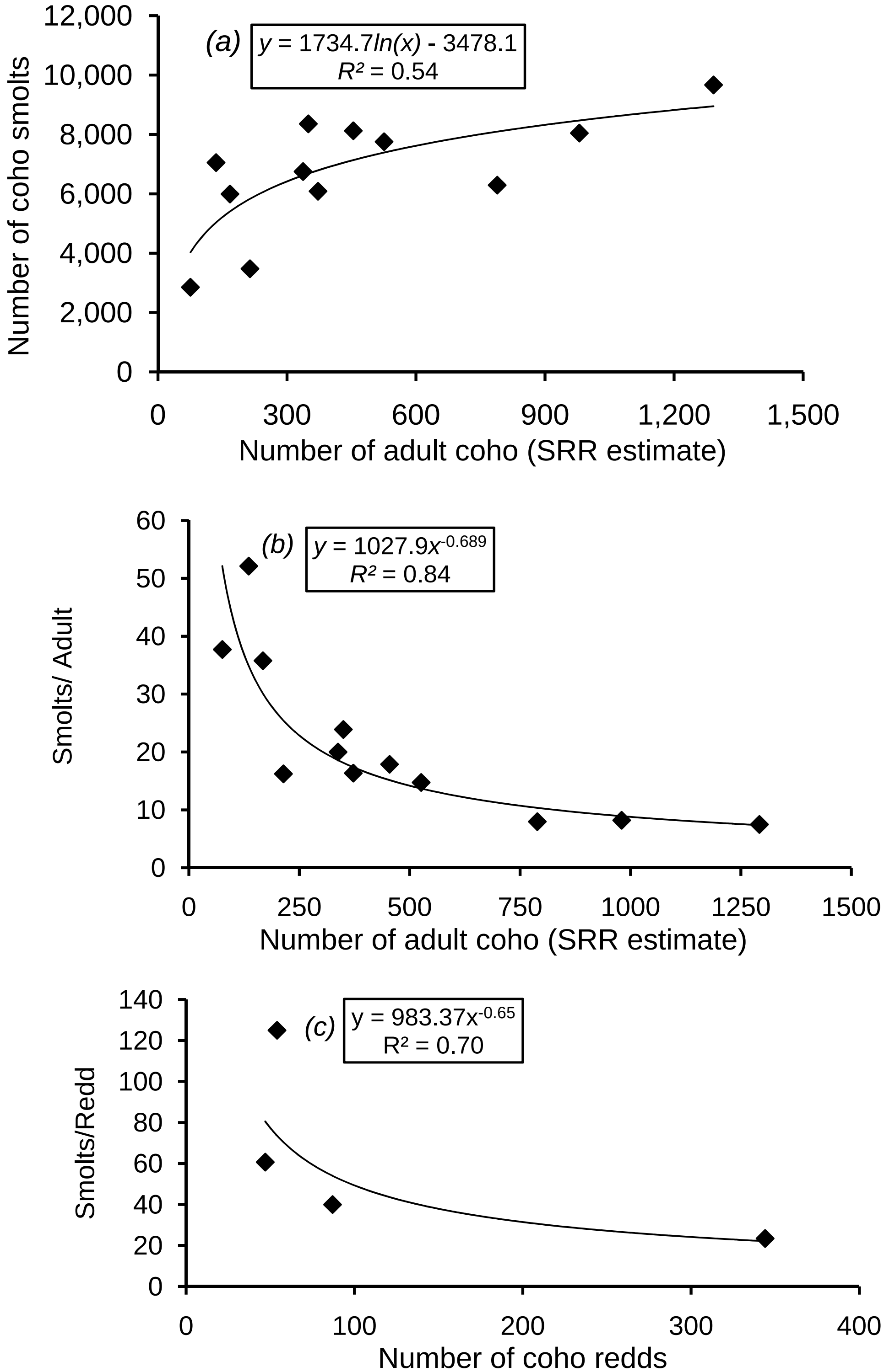


Figure 28.─Coho smolt production (a) and productivity (b, c) as a function of adult spawners on Stavis Creek. Adult spawners were estimated using the survival to return approach (a, b) for brood years 1994-2007 and the number of redds observed during weekly spawner surveys (c) for brood years 2004-2007.

Assumptions and Uncertainties

Because the weir on Big Beef Creek is a census count of adult salmon and steelhead, the escapement data for this watershed is among the best available in Puget Sound. However, the late November trap outage on Big Beef resulted in missed catch. In more than 30 years of study, the weir on Big Beef Creek has rarely been out during the coho migration period. Weir pickets were pulled on November 19, 2009 due to concerns that the stream might overflow its banks and cut a new course through existing facilities, as observed in the disastrous December 2007 flood event. Prior to the weir outage, the majority of coho and chum appear to have moved upstream due to adequate flows in mid October and early November. Just one additional coho was captured after the weir was reinstalled on November 24, 2009. Similarly, only 11 fall chum were captured after the trap was reinstalled. In past years, at least 95% of the coho migration occurring prior to November 19th when the weir fished continuously through large flow events in late October or early November. Therefore, the bias for coho and chum escapements due to the 2009 weir outage should not be very large in magnitude.

Survival-to-return escapement estimates for Little Anderson, Seabeck, and Stavis creeks were based on the assumptions that smolts return to their natal watershed to spawn. This assumption warrants further investigation. Returns to the Big Beef Creek weir and low recoveries of Big Beef CWTs among spawner carcasses from the other three creeks suggest a high degree of philopatry among coho populations but also indicate that some degree of dispersal may be occurring among creeks. Returns of tagged wild coho to the Big Beef Creek weir should have a similar incidence to the tag rate of the corresponding smolt release group. However, returning wild adult coho often have a lower incidence of CWTs than that estimated for the corresponding smolt release group. For example, in the 2004 brood year, the CWT incidence in coho smolts emigrating in 2006 was estimated to be 81.3% whereas the incidence of CWT in unmarked adult coho returning to the Big Beef Creek weir in 2007 was just 56.6% (719 of 1270). The tag rate of coho smolts was based on a total of 31,339 tagged and 5,250 untagged smolts were released in spring 2006 (2004 brood year), an adjusted tag group of 27,016 to account for tag loss (3.5%) and tagging-related mortality (16%), and an increase of 6,230 coho to the untagged group to account for tag loss. The unexplained reduction of CWT incidence (~25%) in this brood is an example of a year where reduction in CWT incidence is high. Over the long-term (1976-2006 brood years) the average difference in the CWT rate of emigrating smolts and returning adults is ~16%. Further understanding of this gap this will require additional investigation of Big Beef Creek coho parentage and of genetic exchange among coho populations in these Hood Canal tributaries.

Appendix A

Lengths of juvenile migrants in Hood Canal streams

APPENDIX A. Lengths of juvenile migrants in Hood Canal and Lower Columbia streams. Fork lengths (mm) by statistical week. Data are mean, standard deviation, range, and sample size. Sample rate is the percent sampled of the total number caught on a given statistical week. Seasonal values for mean and standard deviation are weighted by catch.

APPENDIX A-1.─Fork lengths (mm) of coho smolts in Big Beef Creek, 2009.

Statistical week	Begin	End	Mean	St. Dev.	Range Min	Range Max	Number sampled	Sample rate
15	4/6/2009	4/12/2009	186.6	43.00	75	218	9	20.0%
16	4/13/2009	4/19/2009	111.9	48.97	67	211	18	8.3%
17	4/20/2009	4/26/2009	101.6	27.19	65	209	54	3.8%
18	4/27/2009	5/3/2009	101.9	16.72	75	195	214	4.0%
19	5/4/2009	5/10/2009	103.7	14.04	75	205	332	2.1%
20	5/11/2009	5/17/2009	99.6	9.28	79	192	333	2.7%
21	5/18/2009	5/24/2009	96.4	8.72	74	115	122	1.9%
22	5/25/2009	5/31/2009	99.2	6.93	80	118	108	6.2%
23	6/1/2009	6/7/2009					0	0.0%
24	6/8/2009	6/14/2009	99.0	6.12	87	107	13	65.0%
		Seasonal	101.1	12.58	65	218	1203	2.8%

APPENDIX A-2.─Fork lengths (mm) of coho smolts in Little Anderson Creek, 2009.

Statistical week	Begin	End	Mean	St. Dev.	Range Min	Range Max	Number sampled	Sample rate
14	3/30/2009	4/5/2009	101.0		101	101	1	50.0%
15	4/6/2009	4/12/2009					0	0.0%
16	4/13/2009	4/19/2009	100.5	9.88	91	110	4	100.0%
17	4/20/2009	4/26/2009	119.3	9.34	89	136	9	100.0%
18	4/27/2009	5/3/2009	108.1	8.51	91	129	52	100.0%
19	5/4/2009	5/10/2009	104.3	8.32	89	135	72	20.7%
20	5/11/2009	5/17/2009	103.2	9.70	82	126	60	20.5%
21	5/18/2009	5/24/2009	95.2	6.59	84	115	45	25.6%
22	5/25/2009	5/31/2009	95.7	5.36	87	109	20	20.2%
23	6/1/2009	6/7/2009	98.5	7.27	87	101	8	16.7%
24	6/8/2009	6/14/2009					0	0.0%
		Seasonal	101.6	8.09	82	136	271	26.2%

APPENDIX A-3.—Fork lengths (mm) of coho smolts in Seabeck Creek, 2009.

Statistical week	Begin	End	Mean	St. Dev.	Range Min	Range Max	Number sampled	Sample rate
14	03/30/09	04/05/09					0	NA
15	04/06/09	04/12/09	82.5	4.95	79	86	2	18.2%
16	04/13/09	04/19/09	84.3	4.79	78	91	12	36.4%
17	04/20/09	04/26/09	93.7	7.45	80	99	6	31.6%
18	04/27/09	05/03/09	96.7	9.35	82	116	30	51.7%
19	05/04/09	05/10/09	96.4	8.71	81	118	51	25.9%
20	05/11/09	05/17/09	96.8	9.74	79	138	93	60.4%
21	05/18/09	05/24/09	97.5	8.07	87	118	21	24.7%
22	05/25/09	05/31/09	93.4	4.46	83	99	11	34.4%
23	06/01/09	06/07/09	94.0	7.00	89	102	3	37.5%
24	06/08/09	06/14/09					0	NA
		Seasonal	95.5	8.37	78	138	229	37.6%

APPENDIX A-4.—Fork lengths (mm) of coho smolts in Stavis Creek, 2009.

Statistical week	Begin	End	Mean	St. Dev.	Range Min	Range Max	Number sampled	Sample rate
14	03/30/09	04/05/09					0	NA
15	04/06/09	04/12/09	81.0	2.83	79	83	2	50.0%
16	04/13/09	04/19/09	86.0	13.71	75	128	13	21.3%
17	04/20/09	04/26/09	83.8	7.89	72	101	23	15.0%
18	04/27/09	05/03/09	92.0	8.19	77	112	74	10.7%
19	05/04/09	05/10/09	96.4	9.40	80	131	94	20.1%
20	05/11/09	05/17/09	93.6	7.05	79	121	144	14.5%
21	05/18/09	05/24/09	91.6	6.82	76	104	62	11.9%
22	05/25/09	05/31/09	91.8	6.37	78	112	61	35.1%
23	06/01/09	06/07/09	91.0	5.72	84	97	4	10.5%
24	06/08/09	06/14/09					0	NA
		Seasonal	92.6	7.73	72	131	477	15.3%

APPENDIX A-5.─Fork lengths (mm) of steelhead smolts in Big Beef Creek, 2009.

Statistical week	Begin	End	Mean	St. Dev.	Range Min	Range Max	Number sampled	Sample rate
14	03/30/09	04/05/09					0	NA
15	04/06/09	04/12/09	180.0	24.76	142	228	10	27.78%
16	04/13/09	04/19/09	174.8	27.64	109	235	27	15.88%
17	04/20/09	04/26/09	162.3	16.91	140	192	24	5.37%
18	04/27/09	05/03/09	157.6	20.37	123	219	31	11.40%
19	05/04/09	05/10/09	150.1	16.62	127	178	13	21.67%
20	05/11/09	05/17/09	163.3	12.50	151	176	3	17.65%
21	05/18/09	05/24/09					0	0.00%
22	05/25/09	05/31/09					0	NA
23	06/01/09	06/07/09					0	NA
24	06/08/09	06/14/09					0	NA
		Seasonal	164.3	23.20	109	235	108	10.7%

Appendix B

Statistical weeks and corresponding dates in 2009.

APPENDIX B. Statistical weeks and corresponding dates in 2009. Statistical weeks begin on Monday and end on Sunday of a given week. The first and last statistical week of each year is typically less than seven days.

Week Number		First Day (Monday)		Last Day (Sunday)		Statistical
1		01-Jan		04-Jan		January
2		05-Jan		11-Jan		January
3		12-Jan		18-Jan		January
4		19-Jan		25-Jan		January
5		26-Jan		01-Feb		January
6		02-Feb		08-Feb		February
7		09-Feb		15-Feb		February
8		16-Feb		22-Feb		February
9		23-Feb		01-Mar		February
10		02-Mar		08-Mar		March
11		09-Mar		15-Mar		March
12		16-Mar		22-Mar		March
13		23-Mar		29-Mar		March
14		30-Mar		05-Apr		March
15		06-Apr		12-Apr		April
16		13-Apr		19-Apr		April
17		20-Apr		26-Apr		April
18		27-Apr		03-May		April
19		04-May		10-May		May
20		11-May		17-May		May
21		18-May		24-May		May
22		25-May		31-May		May
23		01-Jun		07-Jun		June
24		08-Jun		14-Jun		June
25		15-Jun		21-Jun		June
26		22-Jun		28-Jun		June
27		29-Jun		05-Jul		June
28		06-Jul		12-Jul		July
29		13-Jul		19-Jul		July
30		20-Jul		26-Jul		July
31		27-Jul		02-Aug		July
32		03-Aug		09-Aug		August
33		10-Aug		16-Aug		August
34		17-Aug		23-Aug		August
35		24-Aug		30-Aug		August
36		31-Aug		06-Sep		August
37		07-Sep		13-Sep		September
38		14-Sep		20-Sep		September
39		21-Sep		27-Sep		September
40		28-Sep		04-Oct		September
41		05-Oct		11-Oct		October
42		12-Oct		18-Oct		October

Continued on next page.

APPENDIX B. continued.

Week Number		First Day (Monday)		Last Day (Sunday)		Statistical
43		19-Oct		25-Oct		October
44		26-Oct		01-Nov		October
45		02-Nov		08-Nov		November
46		09-Nov		15-Nov		November
47		16-Nov		22-Nov		November
48		23-Nov		29-Nov		November
49		30-Nov		06-Dec		November
50		07-Dec		13-Dec		December
51		14-Dec		20-Dec		December
52		21-Dec		27-Dec		December
53		28-Dec		31-Dec		December

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