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Intensively Monitored Watersheds: 2008 Fish Population Studies in the Hood Canal and Lower Columbia Stream Complexes

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Hood Canal

Data for 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 responded 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 and Mike Ackley provided logistical support related to trap installation and removal and expertise in trap design and function. Kelly Kiyohara edited earlier versions of this report. 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) 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. Thom Johnson (WDFW, Region 6 District Biologist) provided with 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 the harvest sampling efforts.

Lower Columbia

Juvenile migrant data were collected by Steve Wolthausen, Brad Allen, and Nathan Miller. Coho parr sampling was conducted by Steve Wolthausen and Clayton Kinsel. Coho spawner surveys were conducted by Steve Wolthausen, Brad Allen, Nathan Miller, and TJ Monaghan. Chinook spawner surveys were conducted by Jeff Fisher, Brad Swift, and Paul Lodholz. Steelhead spawner surveys were conducted by Kathy Mai, Lisa Rasmusan, Paul Lodholz, Sierra Franks, Nathan Woodard, Ann Stephenson, Paul Dunlap, and Josua Holowatz. Installation of the Abernathy weir and juvenile traps was completed with the assistance of Mike Ackley, Clayton Kinsel, and Pete Topping. Kelly Kiyohara edited earlier versions of the report. Biologists from Weyerhauser and Washington Department of Ecology worked collaboratively to sample and mark coho parr. John Holmes (USFWS) provided biological data from adult coho captures at the Abernathy Fish Technology Center weir. USFWS provided office space for field staff and storage space for trapping equipment. Access to the upper watershed of Germany Creek is provided by Sierra Pacific lumber company. The Lower Columbia IMW project would not be possible without the cooperation of local residents who grant access to the creeks.

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Chapter 1. Introduction to Intensively Monitored Watersheds 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) were selected as experimental watersheds where fish responses to habitat restoration would be measured. Salmonid abundances at different life history stages are measured 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). This report focuses on salmonid abundances in two stream complexes – one in Hood Canal and one in the lower Columbia River.

The Hood Canal stream complex includes Little Anderson, Big Beef, Seabeck, and Stavis creeks (Figure 1-1). Land use surrounding Hood Canal watersheds ranges from urban and residential to almost entirely forest covered. 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. 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 salmonid production. Low escapement has potential to limit production in all creeks. Future habitat restoration in Big Beef and Seabeck creeks are in the planning phase.

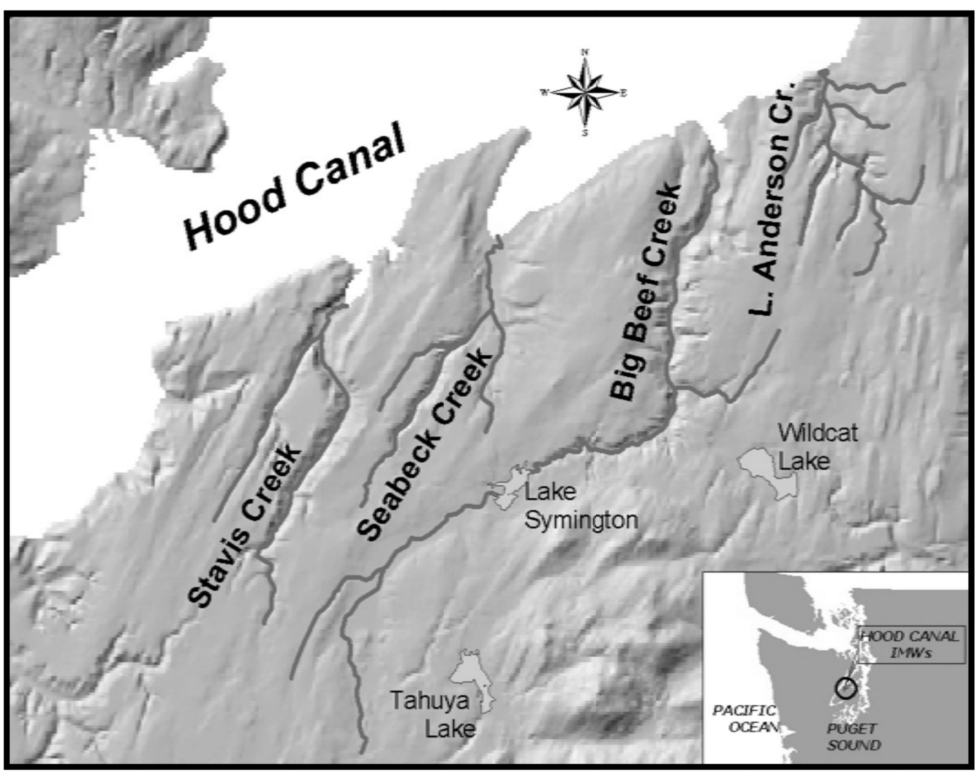


FIGURE 1-1─Location of four IMW streams in Hood Canal: Little Anderson, Big Beef, Seabeck, and Stavis creeks.

The lower Columbia stream complex includes Mill, Abernathy, and Germany creeks (Figure 1-2). Land use in the lower Columbia is dominated by commercial forestry. In this stream complex, Mill Creek has been designated the control stream. Abernathy and Germany are designated as treatment streams. Lack of wood in the channels, reduced off-channel habitat, and altered sediment delivery and transport are all factors likely to be impacting salmonid production. A restoration plan that identifies and prioritizes multiple projects has been developed for the Lower Columbia Fish Recovery Board.

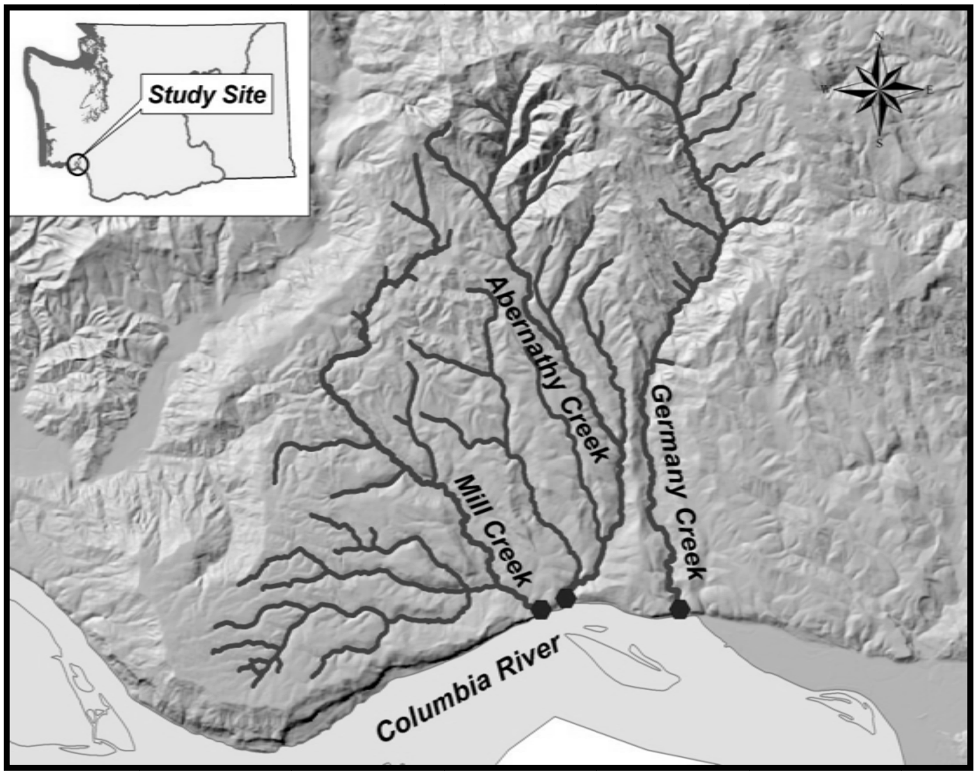


FIGURE 1-2.─Location of three IMW streams in the Lower Columbia: Mill, Abernathy, and Germany creeks. Circles at the mouth of each stream represent the downstream migrant trapping location.

Salmonid population studies in the Hood Canal and lower Columbia stream complexes are conducted annually by the Washington Department of Fish and Wildlife. This report presents methodology and results from the 2008 field season. In each watershed, coho (*Oncorhynchus kisutch*) abundance was estimated at three life stages – parr, smolt, and spawner. Parr are subyearling juvenile salmon that survive from the egg stage through the summer low flow period. Parr are sampled at index reaches in each creek. Smolts are yearling juvenile salmon in process of leaving freshwater habitat for the marine environment. Smolts are captured in traps at the mouth of the river. Spawners are salmon returning to the river from the ocean. Spawners are captured at weirs in Big Beef (Hood Canal) and Abernathy (lower Columbia) creeks. Coho spawner distributions are evaluated from surveys conducted in all study streams. Smolt and adult abundances are also reported for steelhead (*Oncorhynchus mykiss*) and chum (*Oncorhynchus keta*) in Hood Canal stream complex and Chinook (*Oncorhynchus tschawytscha*) and steelhead in lower Columbia.

This report is organized into three chapters that summarize results from the 2008 field season. Chapter 1 is an Introduction to the IMW project. Chapter 2 includes parr, smolt, and spawner results from the Hood Canal stream complex. Chapter 3 includes parr, smolt, and spawner results from the Lower Columbia stream complex. Executive summaries for each stream complex are found at the beginning of the chapter.

Chapter 2. Hood Canal Stream Complex

Executive Summary

The Intensively Monitored Watersheds project 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 in these watersheds, 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, chum, and steelhead 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 2006 brood year, parr abundance was highest in Big Beef Creek (N = 171,430, CV = 7.2%) and lowest in Seabeck (N = 10,319, CV = 10.3%) and Little Anderson (N = 11,209, CV = 43.6%) creeks. Coho parr abundance in Stavis Creek was estimated to be 59,664 (CV = 11.4%). Overwinter survival of the 2006 brood year was 15.2% in Big Beef Creek as compared to 0.8% in Little Anderson, 7.8% in Seabeck, and 4.6% 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 2008, coho smolt production was highest in Big Beef Creek (N = 27,416). Coho production was 96 smolts in Little Anderson Creek, 828 smolts in Seabeck, and 2,850 smolts in Stavis Creek. Steelhead smolt production was 925 in Big Beef Creek, 7 in Little Anderson, 17 in Seabeck, and 14 in Stavis Creek.

A total of 451 adult coho and 122 jack coho returned to the Big Beef Creek weir in 2008. Hatchery-origin coho represented 1.1% of the adult return and 9.0% of the jack return. Survival-to-return rate for jack coho was 0.47%. Marine survival of age-3 adult coho was 4.13%. Harvest rate of Big Beef Creek coho was 64.2% 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 2008 included 709 summer chum and 472 fall chum. Steelhead escaepment was not determine in 2008 because a large winter flood compromised weir integrity during the steelhead spawning period.

Introduction

The Hood Canal IMW stream complex flows into the east side of Hood Canal from the western Kitsap Pensinsula. Natural-origin salmonids in these streams include coho salmon, chum, cutthroat trout, and steelhead. Chum are represented by a summer and fall run. Summer chum were extirpated from Big Beef Creek by the late 1980s and then reintroduced from a Quilcene River broodstock (brood year 1996 to 2004).

Coho 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 other species. Coho abundance in these creeks are 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 outmigration period. 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.

Long-term coho population data have been collected at a permanent weir on Big Beef Creek and the temporary fence weirs on Little Anderson, Seabeck, and Stavis creeks. The Big Beef Creek weir screens the entire creek flow and captures both upstream and downstream migrants. This weir is located at the University of Washington Research Station at Big Beef Creek and was modified by WDFW in 1978 and again in 1986 in order to improve capture of migrating salmonids. Fence weirs, operated during the coho downstream migration period, are used to measure migrants on Little Anderson (initiated 1992), Seabeck (1993), and Stavis (1993) creeks. When operated effectively, these weirs capture 100% of downstream migrating coho.

Harvest rate and marine survival of Big Beef Creek coho are estimated by coded-wire tagging smolts migrating downstream and recovering coded-wire tags from fisheries interceptions and from spawners returning to the weir. Historically, a substantial portion of coho harvest occurred outside Hood Canal (e.g., Vancouver Island Troll Fishery, Washington Troll and Sport Fisheries). In recent years, fisheries outside Hood Canal have been constrained by weak-stock management and the listing of many salmonid species under the Endangered Species Act. As a result, the Hood Canal treaty net fisheries (Terminal Area 12) have increasingly contributed to the fishing impacts on wild Big Beef Creek coho. The Area 12 coho and chum fisheries, centered in the Big Beef Creek region of the canal, extends as far north as Lone Rock and as far south as Stavis Bay.

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, chum, and steelhead 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.

Hood Canal Parr Evaluation

Authors: Clayton Kinsel and Mara Zimmerman

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 smolts migrating downstream 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 overwinter survival.

Coho and steelhead parr were collected by electroshocking in 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 randomly chosen in Little Anderson, Big Beef, Seabeck, and Stavis creeks using a spatially balanced probabilistic sample design (Figure 2-1). The same ten index reaches in each watershed have been sampled consistently since the project began in 2004. In order to increase the number of marked fish, areas adjacent to many sites were also sampled using a stick seine.

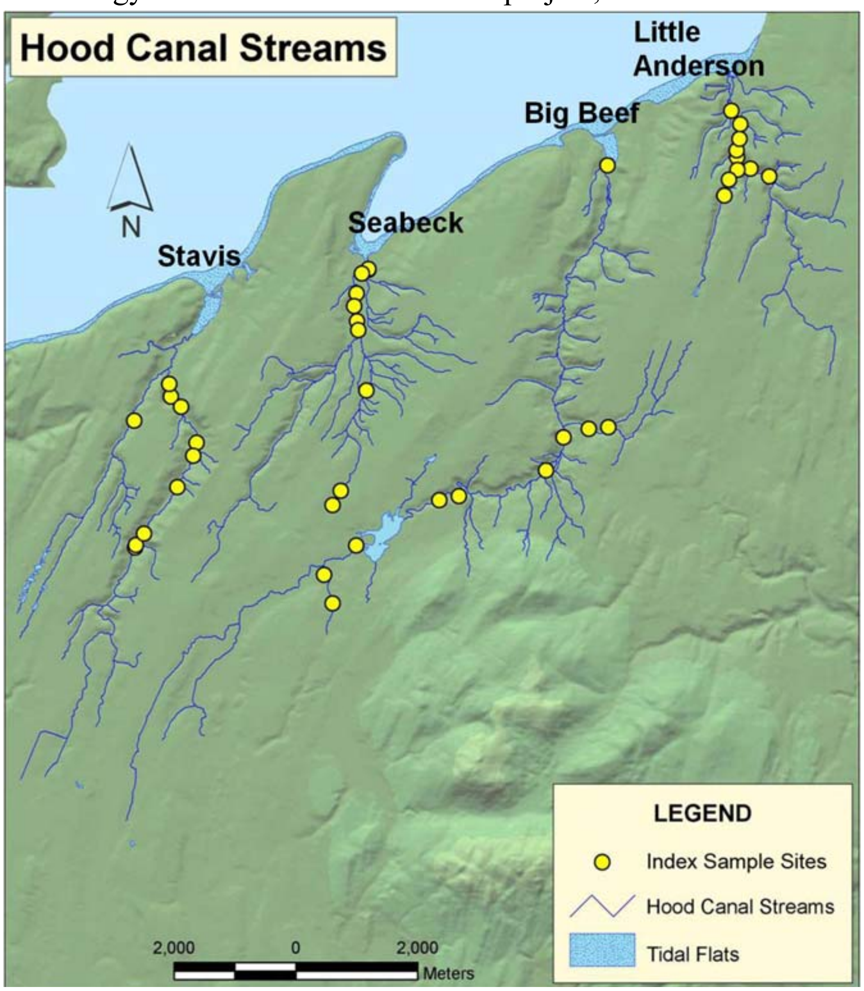


FIGURE 2-1—Index sample sites on Little Anderson, Big Beef, Seabeck, and Stavis creeks. Coho and steelhead parr are collected by electrofishing and seining at each site.

On all four creeks, coho parr were enumerated, measured (fork length, FL), 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 substantial enough to form a mark group. Steelhead parr longer than 85 mm were PIT tagged because this size class is likely to be 1 year olds that will migrate downstream the following spring. This assumption will be tested in subsequent years of the study.

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 at the downstream weirs is provided in the Smolt Evaluation section.

Analysis

Coho parr abundance was estimated using a Petersen estimator with a Chapman modification (Seber 1973):

Equation 2-1

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

where:

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

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

n_2 = Number of smolts captured in second sample (downstream trap), and

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

Variance of the abundance estimate was (Seber 1973):

Equation 2-2

$$V(\hat{N}) = \frac{(n_1+1)(n2+1)(n_1-m_2)(n_2-m_2)}{(m_2+1)^2(m_2+2)} - 1$$

Overwinter survival ($\hat{S}$) was:

Equation 2-3

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

Confidence intervals and coefficient of variation associated with abundance were calculated from the variance (Appendix B, Equation B-1, B-2).

Results

Coho parr marked in 2008 represent the parr life history stage of the 2007 brood year (BY). In 2008, coho parr were marked and released in Little Anderson (n_1 = 501), Big Beef (n_1 = 1,506), Seabeck (n_1 = 951), and Stavis (n_1 = 847) creeks (Table 2-1). In addition, a total of 113 steelhead parr were PIT-tagged in Big Beef Creek. Summer parr abundance for BY 2007 coho will be calculated based on recaptures of marked coho in downstream weirs in spring of 2009.

TABLE 2-1.—Coho and steelhead parr marked in Hood Canal IMW streams in 2008. Coho were marked with an adipose clip. Steelhead were marked with PIT tags.

Date	Stream	Coho	Steelhead
July 22 -August 6, 2008	Little Anderson	501	n/a
July 21-August 12, 2008	Big Beef	1,506	113
July 24 -August 1, 2008	Seabeck	951	n/a
July 29 -August 1, 2008	Stavis	847	n/a

Summer parr abundance for BY 2006 was calculated from coho marked as parr in summer of 2007 and recaptured in the downstream weirs in spring of 2008 (Table 2-2). Summer parr abundance for the 2006 brood year was estimated to be 11,209 (*CV* = 43.6%) coho in Little Anderson Creek, 171,430 (*CV* = 7.2%) coho in Big Beef Creek, 10,319 (*CV* = 10.3%) coho in Seabeck Creek, and 59,664 (*CV* = 11.4%) coho in Stavis Creek. Overwinter survival was highest in Big Beef Creek (15.2%) and lowest in Little Anderson Creek (0.8%).

TABLE 2-2.—Summer parr abundance and overwinter survival of coho in Hood Canal IMW streams (2006 brood year). Estimates are based on marked parr (n_1, summer 2007), recaptures of marked smolts (m_2, spring 2008), and total capture of smolts (n_2, spring 2008). Mark and recapture information is used to estimate summer parr abundance (*N*) and overwinter survival (*S*). Variance, confidence intervals (*C.I.*), and coefficient of variation (*C.V.*) are reported for the abundance estimate.

	Little Anderson	Big Beef	Seabeck	Stavis
Marked parr (n_1)	476	1,050	994	1,515
Total smolts (n_2)	93	26,097	808	2,754
Recaptures (m_2)	3	159	77	69
Parr abundance (*N*)	11,209	171,430	10,319	59,664
Abundance variance *V(N)*	23,859,420	153,800,692	1,122,643	46,609,984
Abundance 95% *C.I.*	9,574	24,307	2,077	13,381
Abundance *C.V.*	43.60%	7.20%	10.30%	11.40%
Survival (*S*)	0.80%	15.20%	7.80%	4.60%

Discussion

Coho parr abundance for BY 2006 was lower than the average abundance measured for the previous three brood years in all four watersheds (Table 2-3). The largest difference occurred in Seabeck Creek, where parr abundance of BY 2006 was just 50.4% of average parr abundance. Parr abundance in Little Anderson, Big Beef, and Stavis creeks were 75.6%, 81.1%, and 94.3% of their average values. Low parr abundances in Seabeck may be due to low flows during the summer rearing and fall spawning periods. Aggradation of the streambed in Seabeck Creek has resulted in increasing portions of the watershed being dry from early summer through the fall. Lack of spawning and rearing habitats likely has a negative impact on spawning distribution and egg to parr survival in Seabeck and may explain low parr abundances for BY 2006.

TABLE 2-3.─Summer parr abundance and overwinter survival for the 2006 brood year (BY) of coho compared to average values of the 2003, 2004, and 2005 brood years in Hood Canal IMW streams.

	Parr abundance ($\hat{N}$)		Overwinter survival (*S*)	
Watershed	Average	BY 2006	Average	BY 2006
Little Anderson	14,819	11,209	13.7%	0.8%
Big Beef	211,327	171,430	15.9%	15.2%
Seabeck	20,462	10,319	11.2%	7.8%
Stavis	63,259	59,664	15.3%	4.6%

In Big Beef Creek, overwinter survival of BY 2006 coho was comparable to average survival in previous years. However, overwinter survival of BY 2006 coho in Little Anderson, Seabeck, and Stavis creeks were notably lower than previous years. Low survival may have resulted from a large storm event in early December of 2007. This storm occurred during the overwinter rearing period and involved record flooding on all four IMW watersheds. Little Anderson, Seabeck, and Stavis creeks have minimal channel complexity and little off-channel habitat when compared to Big Beef Creek. Channel complexity and off-channel habitat can provide refuge for juvenile coho during high flow events. Minimal availability of refuge areas in Little Anderson, Seabeck, and Stavis creeks may have decreased overwinter survival of juvenile coho in these three watersheds.

Hood Canal Smolt Evaluation

Authors: Clayton Kinsel and Mara Zimmerman

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 a 14-gauge, perforated plate. Fan traps are set at different levels so that during low flow only the lowest trap operated. As stream flow increases, more fans are activated. 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 April 1 and June 6. Fish were collected and processed at least once each 24-hour period. All downstream migrants were removed from the live box and enumerated. Coded-wire tags were applied to coho smolts in good condition. Coded-wire tag codes and associated numbers of fish were submitted to Pacific States Marine Fisheries Commission's (PSMFC) Regional Mark Processing Center (RMPC) database. Each week, a random sample of coho were measured (fork length, FL).

Downstream migrants from a pond adjacent to the weir were collected in a trap at the downstream end of the pond. This pond, an outlet to the University of Washington's Fisheries Research Institute (FRI) spawning channels, circumvents the Big Beef Creek weir. In years when the pond trap is not fished (i.e., trap left open), the proportion of fish migrating through the pond is estimated with a pond:stream ratio of 2.26%. This ratio is based on 1984-1986 and 1990 outmigration years.

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 or box flume delivered migrating fish into the live box located downstream of the weir.

Seabeck Creek trap was installed 150 m above tidewater and was operated continuously between March 28 and June 5. Little Anderson Creek trap was installed 30 meters above tidewater and was operated continuously between April 1 and June 5. Stavis Creek trap was installed approximately 500-meters upstream of the Stavis Bay Road Bridge and operated between April 4 and June 6. Fish were enumerated and released from fence traps on a daily basis. A random sample of coho were measured (FL) on a weekly basis.

Analysis

On each creek, total coho smolt production was the measured migration combined with an estimated "pre" and "post" season migration. A small portion of coho are assumed to have migrated prior or subsequent to the trapping period; migration in the "pre" and "post" season periods are based on average timing of downstream coho migrations in 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. Migration timing from the model years predicted the proportion of the downstream migration occuring on a given day. For the 2008 trapping season, these proportions were applied to days between March 1 and June 30 when the weir did not operate. At Big Beef Creek, the timing model was applied to all smolts, including those migrating through the FRI spawning channel and ponds. This approach assumes that the entire migration occurs between March 1 and June 30.

Smolt abundance and body size have varied greatly over the long-term data set collected for these watersheds. Therefore, we tested the hypothesis that density-dependent interactions would limit the growth of coho juveniles in high production years. An ANCOVA model examined the relationship between average fork length and smolt production while accounting for differences in fork length among creeks. Fork length was the response variable in this analysis. Watershed was the explanatory variable and percent of maximum production was the covariate. Percent maximum production (annual smolt production/maximum smolt production) standardized the range of smolt production numbers across watersheds. Pair-wise comparisons between watersheds used estimated marginal means that accounted for variation in body lengths explained by production.

Results

Coho Smolt Production

A total of 26,097 coho smolts were caught in the Big Beef Creek weir trap (Table 2-4). An additional 529 coho smolts were caught in the FRI pond trap, 1.97% of the catch in the main-stem trap. Total estimated production for BY 2006 coho in Big Beef Creek was 27,416 (Table 2-5). The production estimate included 551 smolts (2.0%) estimated prior to trapping, 26,626 smolts (97.1%) during trapping, and 239 (0.9%) smolts subsequent to trapping Coho smolts in in Big Beef Creek were produced from 238 females, 171 males, and 120 jacks released upstream of the weir in fall 2006. Juvenile productivity of the 2006 brood year was 115 smolts per female.

A total of 93, 808, and 2,754 coho smolts were caught in the Little Anderson, Seabeck, and Stavis creek traps, respectively (Table 2-4). These catches were expanded to total production estimates of 96 smolts for Little Anderson, 828 smolts for Seabeck Creek, and 2,850 smolts for Stavis Creek (Table 2-5).

Other Salmonids

In Big Beef Creek, downstream migrant salmonids included 925 steelhead smolts, 683 cutthroat smolts, 513 trout parr, 22,194 chum fry, and 221 coho fry (Table 2-4). Nineteen cutthroat adults (10 males and 9 females) but no steelhead kelts were caught in the downstream weir. Little Anderson, Seabeck, and Stavis produced a combined total of 1,710 cutthroat smolts but very few steelhead. A total of 7, 17, and 14 steelhead smolts were captured at Little Anderson, Sea beck, and Stavis creeks, respectively.

TABLE 2-4.—Total catch of downstream migrant salmonids at Little Anderson, Big Beef, Seabeck, and Stavis creeks during spring 2008.

Species/Age Class	Total Catch			
	Little Anderson	Big Beef	Seabeck	Stavis
Coho smolts	93	26,097	808	2,754
Coho fry	0	221	0	0
Chum fry	0	22,194	0	0
Chinook fry	0	0	0	0
Steelhead parr	1	240	1	2
Cutthroat parr	452	273	149	205
Steelhead adults	0	0	0	0
Steelhead smolts	7	925	17	14
Cutthroat adults	[a]8	[b]19	[c]12	[d]46
Cutthroat smolts	544	683	188	978

[a] Includes 3 males and 5 females.
[b] Includes 10 males and 9 females.
[c] Includes 7 males and 5 females.
[d] Includes 24 males and 22 females.

TABLE 2-5.—Total estimated coho smolt production for the 2006 brood year (2008 outmigration year) in Little Anderson, Big Beef, Seabeck, and Stavis creeks. Big Beef Creek estimate includes catch at main-stem trap and FRI pond trap. Estimates before and after trapping are based on downstream migration timing averaged over four model years at Big Beef Creek (1980-1982, 1984).

Watershed	Before Trapping		During Trapping	After Trapping		Total Estimated Production
	Dates	Estimated Migration	Measured Migration	Dates	Estimated Migration	
Little Anderson	3/1 to 4/1	2	93	6/5 to 6/30	1	96
Big Beef	3/1 to 4/1	551	26,626	6/6 to 6/30	239	27,416
Seabeck	3/1 to 3/28	12	808	6/5 to 6/30	8	828
Stavis	3/1 to 4/4	71	2,754	6/9 to 6/30	25	2,850

Migration Timing

Big Beef Creek reached fifty percent cumulative migration on May 13, 2008. Median migration dates for coho in Seabeck, Little Anderson and Stavis creeks ranged from two to seven days after Big Beef Creek (Figure 2-2). Peak migration was later than average on all four creeks (Figure 2-3). On Big Beef Creek, average peaks for daily coho smolt catches occur around May 2, compared to May 15 in 2008 (Figure 2-3*a*). Similar delays of nearly two weeks were observed for Stavis (Figure 2-3*b*), Seabeck (Figure 2-3*c*) and Little Anderson (Figure 2-3*d*) creeks.

Steelhead smolt migration in Big Beef Creek was also delayed when compared to the long-term average (Figure 2-4). Steelhead smolt catch peaked on April 29, a week later than the historical average peak.

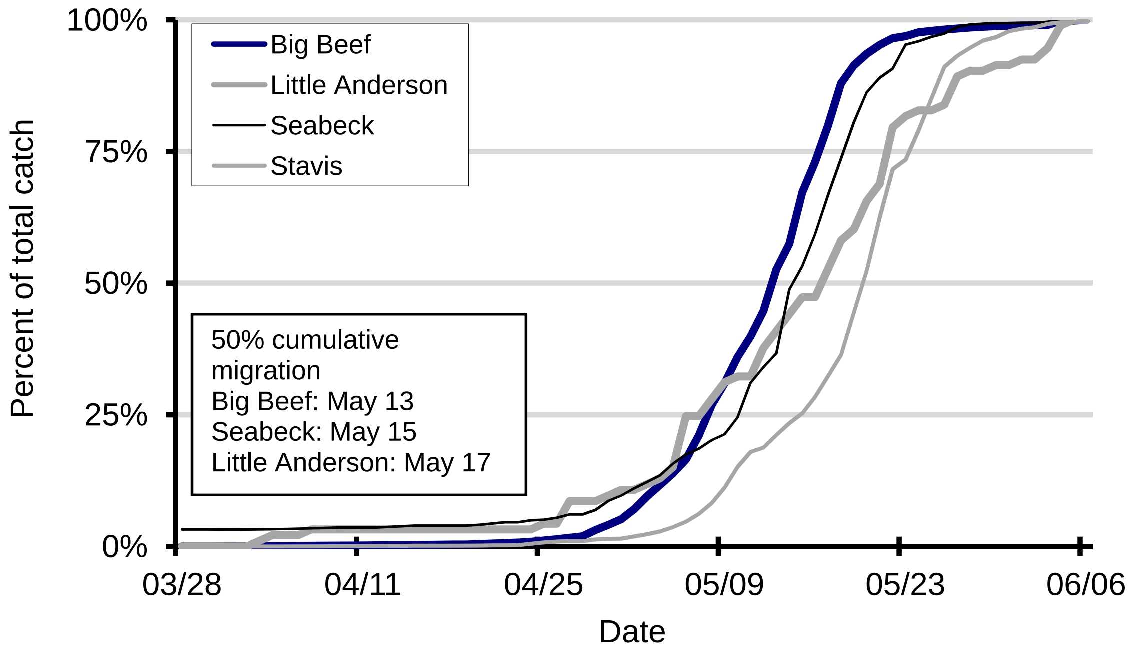
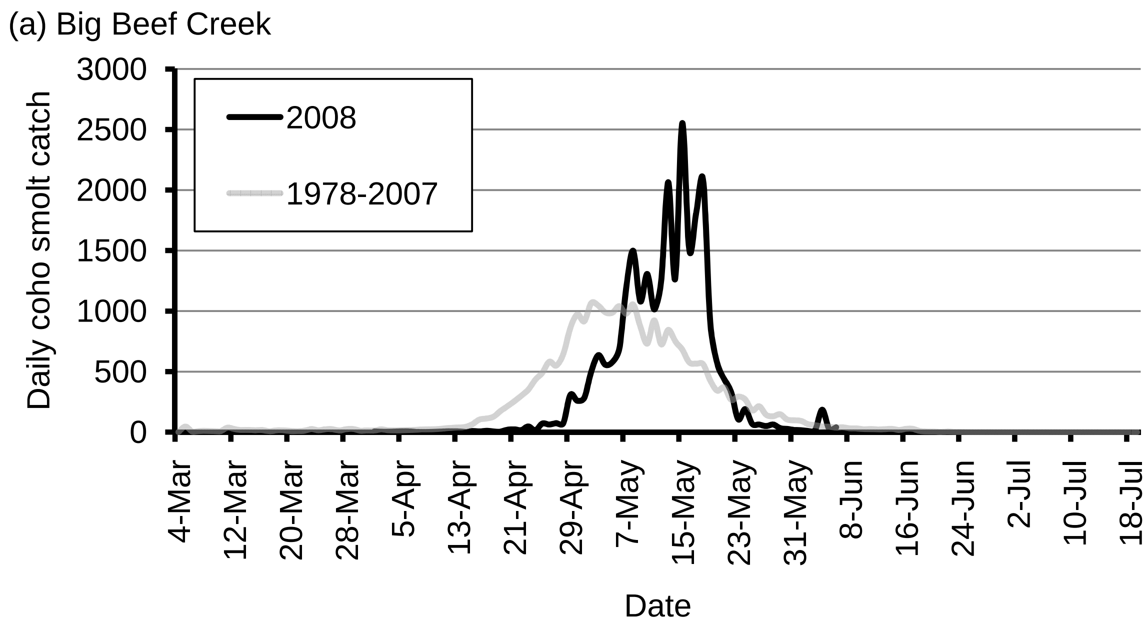
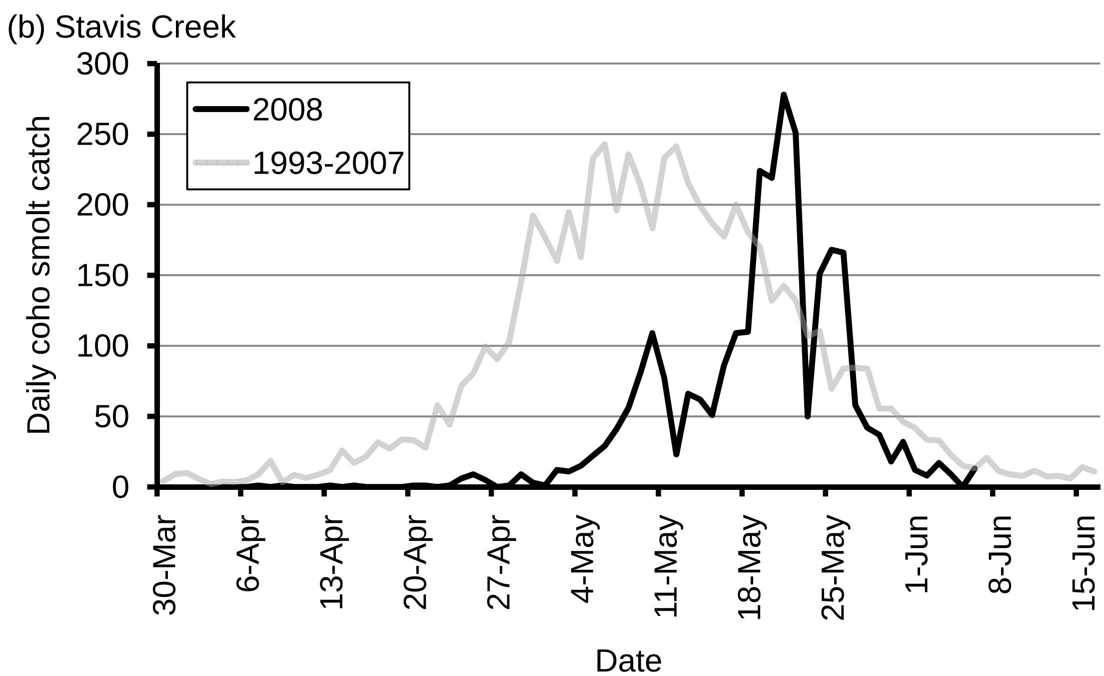
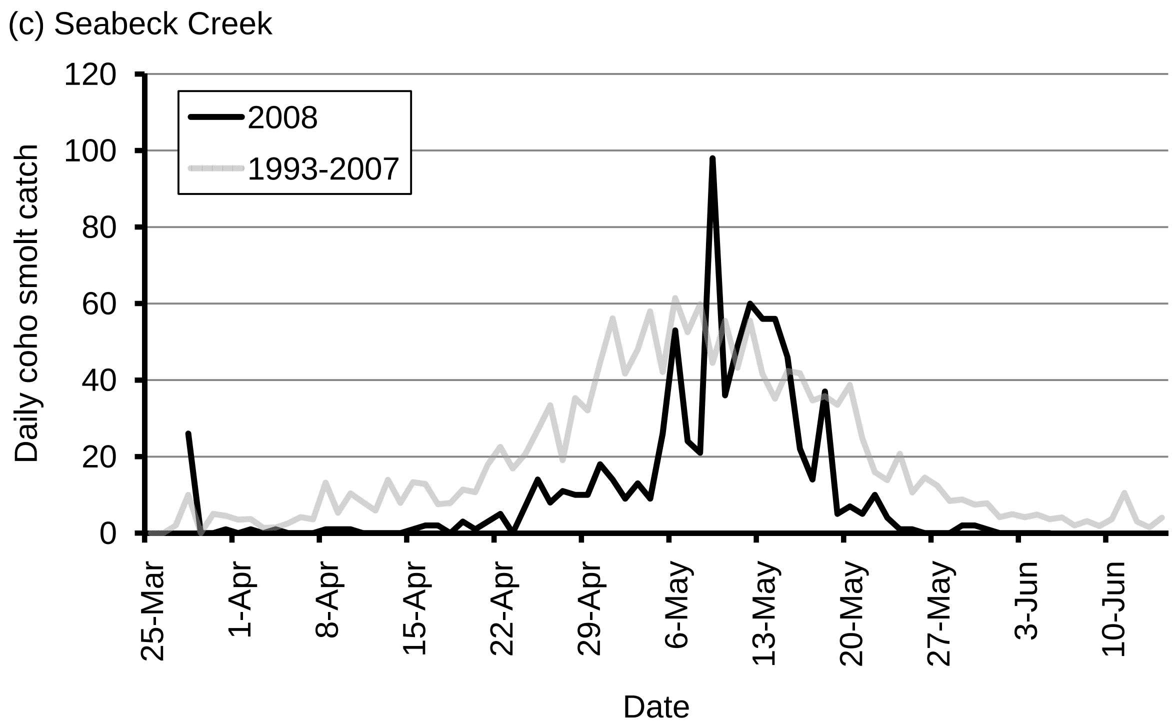


FIGURE 2-2.—Cumulative coho smolt migration at Big Beef, Little Anderson, Seabeck, and Stavis creeks during spring 2008.


(a) Big Beef Creek
Daily coho smolt catch
3000
2500
2000
1500
1000
500
0
2008
1978-2007
4-Mar
12-Mar
20-Mar
28-Mar
5-Apr
13-Apr
21-Apr
29-Apr
7-May
15-May
23-May
31-May
8-Jun
16-Jun
24-Jun
2-Jul
10-Jul
18-Jul
Date


(b) Stavis Creek
Daily coho smolt catch
300
250
200
150
100
50
0
2008
1993-2007
30-Mar
6-Apr
13-Apr
20-Apr
27-Apr
4-May
11-May
18-May
25-May
1-Jun
8-Jun
15-Jun
Date



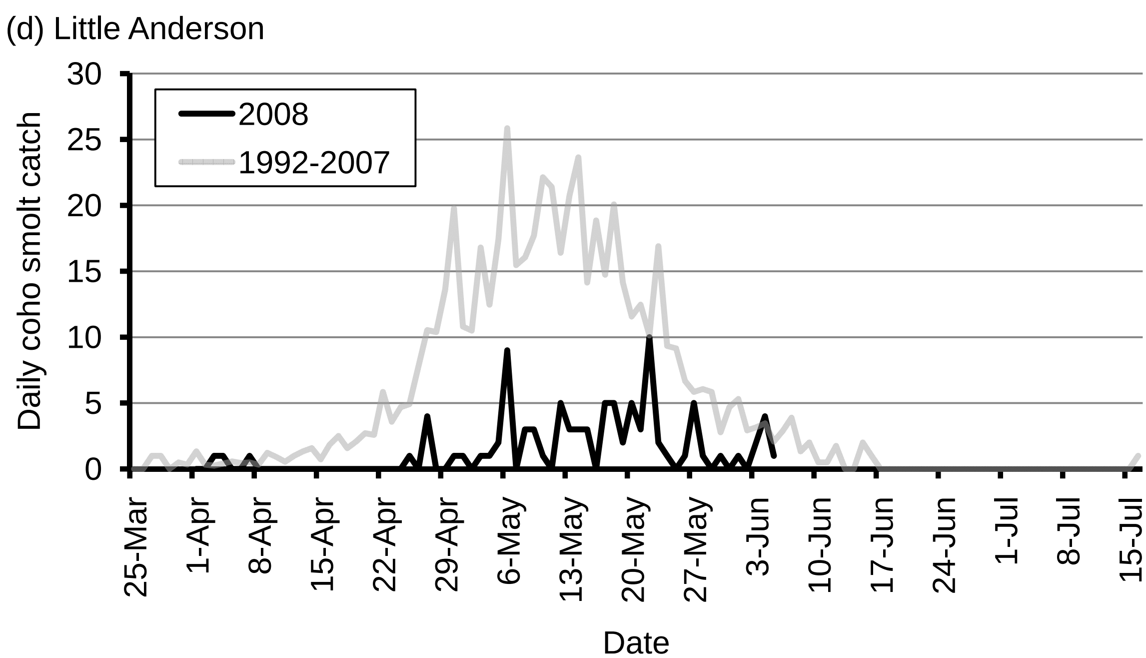


FIGURE 2-3.—Daily coho smolt catch in 2008 compared with historical average catches for Big Beef (*a*), Stavis (*b*), Seabeck (*c*), and Little Anderson (*d*) creeks.

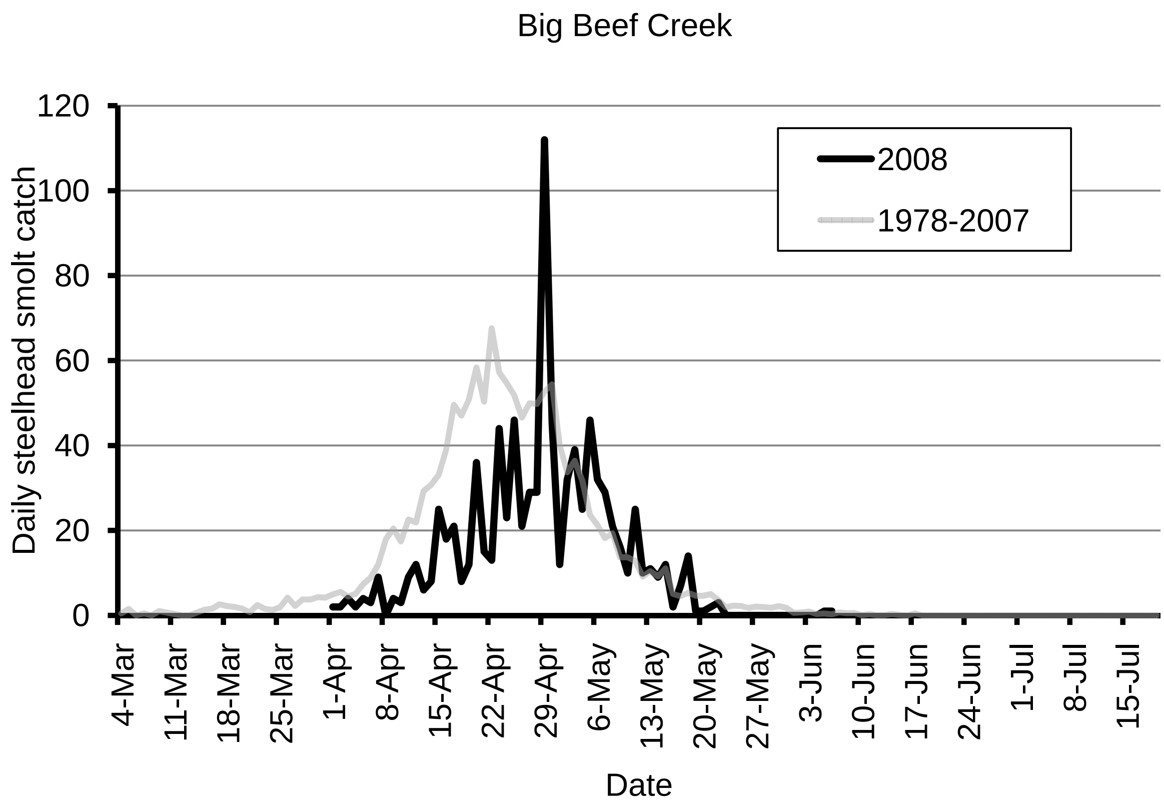


FIGURE 2-4.─ Daily steelhead smolt catch in 2008 compared to historical average (1978 to 2007) for Big Beef Creek.

Coded-Wire Tagging in Big Beef Creek

Coded-wire tags were applied to 24,709 coho smolts in Big Beef Creek (Table 2-6). This corresponds to an estimated tagging rate of 90.13% of all coho smolts. Remaining coho smolts (1,347) were released untagged because they were captured before or after tagging was operational, were in poor condition, escaped, or were too large or small for tagging. A small percentage (0.15%) of smolts died due to trapping, tagging and sampling.

Two tag codes were applied to the Big Beef Creek coho smolts (63-44/69 and 63-45/97). Use of two codes was intended to divide the outmigration into an early and late period. However, the delayed migration timing disrupted plans to split the two codes evenly across the season. The early component of the migration (n = 4,024 coho smolts) was tagged with code 63-44/69. May 7th was selected to switch the tag code (63-45/97) because this is the average median migration date for Big Beef Creek. A total of 17,547 coho smolts were tagged with code 63-45/97, depleting this spool of wire. Therefore, tag code 63-44/69 was reinitiated on May 18 in order to complete tagging of the remainder of coho smolts (n = 3,138). As a result, tag codes from 2008 downstream migration can not be used to distinguish survival of early and late migrating coho.

TABLE 2-6.─Disposition of tagged and untagged coho smolts in Big Beef Creek, 2008.

Disposition	Number	Percent
63-44/69 (4/22 to 5/6)	4,024	14.68%
63-45/97 (5/7 to 5/18)	17,547	64.00%
63-44/69 (5/18 to 6/4)	3,138	11.45%
Total tagged	24,709	90.13%
FRI pond	529	1.93%
Before/after tagging	450	1.64%
Poor condition	590	2.15%
Escaped during transfer	130	0.47%
Too small or large	18	0.07%
Ad-marked from parr survey	159	0.58%
Estimated untagged before/after trapping	790	2.88%
Total untagged catch	2,666	9.72%
Trap mortality	30	0.11%
Sacrificed for tag placement	11	0.04%
Total mortality	41	0.15%
Total estimated migration	27,416	

Body Size of Coho Smolts

Coho smolts emigrating from Big Beef Creek averaged 105.3-mm FL (±10.36 mm, ±1standard deviation); weekly averages ranged between 95.7 mm and 130.6-mm FL (Appendix C-1). Average lengths of coho smolts in Little Anderson, Seabeck, and Stavis creeks were 93.8 mm (±2.7mm), 104.3 mm (±9.5mm), and 96.0 mm (±7.6mm) FL, respectively (Appendix C-2, C-3, and C-4).

In all creeks, coho smolts were shorter in high production than low production years (production effect: $F_{1,64} = 10.9$, $p = 0.002$; Figure 2-5). This result did not differ among creeks (production by creek interaction: $F_{3,64} = 0.85$, $p = 0.5$). However, coho fork lengths were consistently different among creeks (creek effect: $F_{3,64} = 7.5$, $p < 0.001$). Coho in Big Beef Creek were longer than any other creek (pair-wise comparison with Bonferroni correction, $p < 0.002$). Coho smolts in Seabeck Creek were longer than those from Seabeck or Stavis creeks ($p < 0.005$). Coho lengths did not differ between Seabeck and Stavis creeks ($p = 0.7$).

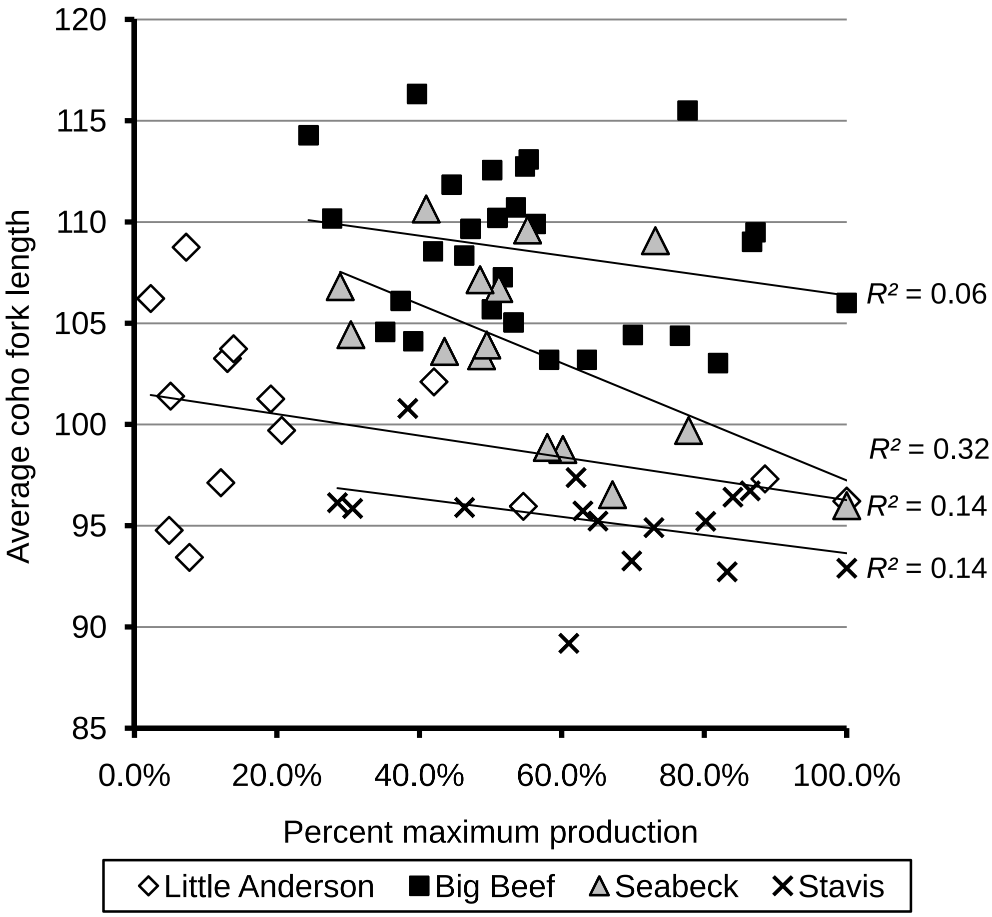


FIGURE 2-5─Coho fork length as a function of annual smolt production for Little Anderson, Big Beef, Seabeck, and Stavis creeks. Smolt production is represented as percent maximum production of each creek. Each data point represents a single year of data from a given watershed.

Discussion

Low escapement, winter flooding, and cool spring temperatures were all likely to impact smolt production of BY 2006 coho in the Hood Canal IMW streams. In 2006, Big Beef Creek spawner escapement was exceptionally low, 379 adults and 120 jacks. A total of 238 females were passed upstream of the weir. This compares with an average of 824 females passed upstream each year between 1982 and 2005. Juvenile productivity of the 2006 brood year (115 smolts/female) was almost three times the average productivity (average = 44 smolts/female) observed for this watershed.

Juvenile productivity is a measure of juvenile survival to smolt stage. Survival to the smolt stage can be influenced by many variables including density-dependent competition. When long-term data from Big Beef Creek are combined, an inverse relationship exists between the number of coho smolts per female and the number of female spawners (Figure 2-6). One explanation for this result is that increased juvenile survival under low escapement results from minimal competition during the river rearing period. In addition to survival, juvenile growth was also a density-dependent function (Figure 2-5). In concert, these results suggest that watershed carrying capacities of these streams limit juvenile coho production with respect to survival and growth. These type of density-dependent responses highlight the importance achieving adequate escapement when evaluating response of coho populations to restoration activities.

Low overwinter survival of juvenile coho was an important variable contributing to poor smolt production in Little Anderson, Seabeck, and Stavis creeks for the 2006 brood year. As discussed in the Parr Evaluation section, a large flood event in early December 2007 was likely to have decreased overwinter survival. If overwinter survival in Stavis Creek had been average (15%), total smolt production (~9,000 smolts) would have been slightly higher than average for this watershed (Table 2-7). Similarly, if overwinter survival in Little Anderson Creek had been closer to average (13.7%), total smolt production from this watershed would have been comparable (~1,500 smolts) to average. However, in Seabeck Creek, overwinter survival can only partially explain low smolt production of the 2006 brood year. Average overwinter survival (11.2%) in Seabeck would have produced ~1100 smolts, just 63% of the observed average. Limited rearing and spawning habitats in Seabeck Creek, discussed in the Parr Evaluation section, were likely additional variables contributing to low coho smolt production of the 2006 brood year in this creek.

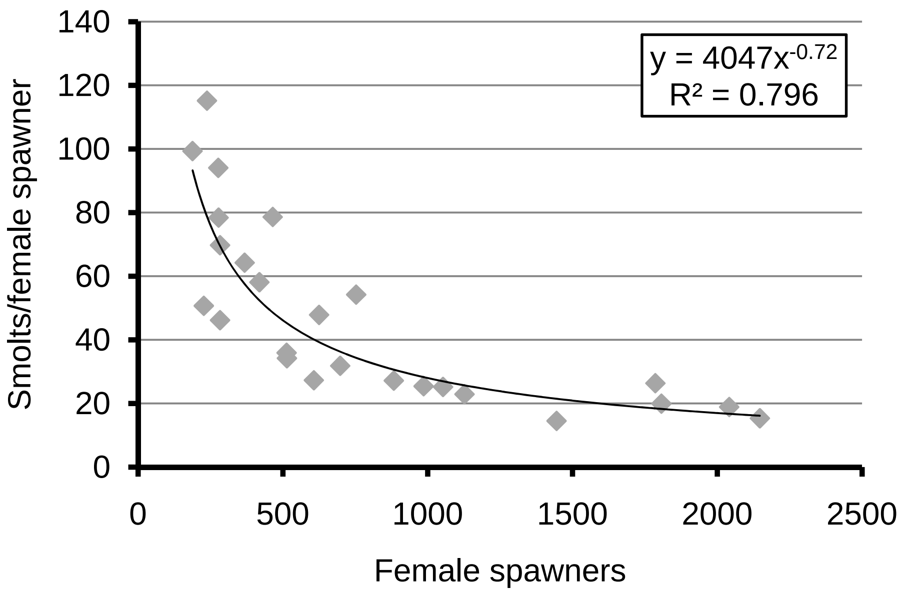


FIGURE 2-6.—Juvenile productivity of coho as a function of female spawners in Big Beef Creek, BY 1982-2006.

TABLE 2-7.—Summer parr abundance, overwinter survival, and smolt production for BY 2006 coho compared to average values (BY 2003, 2004, and 2005) in Hood Canal IMW streams.

	Parr abundance ($\hat{N}$)		Overwinter survival (S)		Smolt production	
Watershed	Average	BY 2006	Average	BY 2006	Average	BY 2006
Little Anderson	14,819	11,209	13.7%	0.8%	1,596	96
Big Beef	211,327	171,430	15.9%	15.2%	33,570	27,416
Seabeck	20,462	10,319	11.2%	7.8%	1,745	828
Stavis	63,259	59,664	15.3%	4.6%	8,153	2,850

Spring temperatures may be an important variable contributing to migration timing of coho smolts. Following the December 2007 flood event, spring of 2008 was one of the coolest on record for the Pacific northwest. Compared to average from previous years, downstream migrations were delayed for coho on all four creeks as well as for steelhead smolts on Big Beef Creek. Consequences of variable downstream migration timing are unknown; however, timing of entry into marine waters is likely to impact interactions with food resources and predators in Hood Canal. Future comparisons of the survival of early and late-migrating smolts may provide further insight into this issue.

Hood Canal Adult Evaluation

Authors: Clayton Kinsel and Mara Zimmerman

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. Upstream migrating adults are trapped in a V-slot trap in the center of the weir. The Big Beef Creek adult weir is operated between late August and March. Coho and chum are trapped between late August and January. Adult steelhead were added to the trapping operations in 2006 and are trapped January through March. Steelhead are being studied as part of a collaborative effort with the Hood Canal Steelhead Enhancement Project led by NOAA fisheries.

The weir and upstream trap was operated continuously beginning on August 22, 2008. The last coho was captured on January 9, 2009. Fish were processed within 12 hours of entering the trap. All upstream coho and chum migrants were removed from the trap and enumerated by species and sex. Scale samples were collected in order to age coho. Tag status (CWT) and condition 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 arriving in the trap were passed upstream. Adult steelhead were not trapped in 2008 due to the flood event in December 2007. This flooding disabled the weir during the steelhead migration period.

Male and female coho were distinguished from each other based on body shape and presence (male) or absence (female) of an extended upper jaw (i.e., kype). All males less than 35-cm FL were assumed to be jacks and all males longer than 45-cm FL were assumed to be adult males. Periodic scale sampling conducted over the last 30 years has supported this assumption. Scale samples were collected from all coho males between 35 and 45 cm in order to determine whether they were jacks or adults. Jacks are 2-year old males that return after approximately 6 months in the ocean. Adults are 3-year old males that return after approximately 1.5 years in the ocean. Adult males and jacks between 35 and 45 cm FL were measured at a 100% rate whereas jacks less than 35-cm FL and adult males longer than 45-cm FL were measured at an 8.9% and 20.4% rate, respectively. In order to calculate average jack and adult male lengths, average lengths for the two size groups (<35 cm and 35-45 cm for jacks, 35-45 cm and >45 cm for adult males) were weighted by proportion measured in each size group.

Hatchery coho arriving at the Big Beef Creek weir were identified based on mark status, CWT information, and scale patterns. All coho were scanned with a portable electronic tag detector for the presence of coded-wire tags. Adipose-marked hatchery coho with CWTs were sacrificed as described above. CWT information was retrieved from adipose-marked coho in order to determine hatchery origin. In addition to hatchery coho readily identified by their adipose clip, a portion of hatchery coho in Hood Canal are also unmarked. Because these coho can not be visually discriminated from wild coho, they are passed upstream of the weir. In order to determine the incidence of 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 used to assign individual fish as wild or hatchery origin.

A subsample of umarked adult coho (1.2%) and unmarked jack coho (16.8%) were also sacrificed at the weir for tag recovery. Coded-wire tags were also retrieved from carcasses during spawner surveys as described below. CWT recoveries from unmarked coho at the weir and from carcasses on the spawning grounds verified whether returning coho were of Big Beef origin and provided a second measure of the incidence of unmarked hatchery coho.

Spawner Surveys

Spawner surveys were conducted during the upstream migration and spawning period for coho on Little Anderson, Big Beef, Seabeck, and Stavis creeks. In order to provide a spatial reference for the survey information, segments were identified in each watershed. At the outset of the IMW project, each of the four watersheds were divided into stream segments of similar stream size, channel gradient, and valley confinement. Within stream segments, shorter stream reaches were defined by reference points located at 100-meter intervals. Segment breaks and reference points were marked with flagging and aluminum tree tags as well as with a GPS latitude and longitude. This segmentation approach was a joint effort by the WDFW and Northwest Indian Fisheries Commission (NWIFC) Salmon and Steelhead Habitat Inventory and Assessment Project (SSHIAP).

Spawner surveys were conducted on a weekly basis between October 21, 2008 and January 16, 2009. Spawner surveys were conducted on 4.4 miles (7.1 km) of Little Anderson Creek, 10.8 miles (17.4 km) of Big Beef Creek, 6.2 miles (10 km) of Seabeck Creek, and 9.5 miles (15.3 km) of Stavis Creek. Small tributaries were not surveyed early in the season when streams were dry and flow was too low to permit fish entry. Spawner surveys continued in all streams 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. While coho were the focus on the spawner surveys, incidental data were also collected for chum. Counts of live salmon, carcasses, and redds were enumerated by species and referenced to the nearest segment and reference point. Redds were flagged and numbered in order to avoid double counting. Snouts were removed from all coho carcasses and checked for coded-wire tags. Snout removal also marked the carcass as having been sampled.

Fisheries Sampling

Coho catches in the Area 12 treaty net fisheries near Big Beef Creek were monitored on a daily basis between September 18 and November 20, 2008. WDFW staff traveled by boat throughout the open fishing area and requested permission to examine the landed catch of tribal fishers. For each sampled catch, coho were enumerated, checked for adipose fin mark status (marked or unmarked), and electronically scanned for coded wire tag presence. When permission was granted by the fisherman, snouts were removed from coho with CWTs to determine the incidence of Big Beef Creek coho among the catch.

Escapement Analysis

Coho spawners arriving in fall of 2008 and early winter of 2009 were BY 2005 (adults) and BY 2006 (jacks). Collectively, these returns will be the parents of the 2008 brood year of coho. Coho escapement in Big Beef Creek was the enumeration of all coho passed above the weir. Coho escapements into Little Anderson, Seabeck, and Stavis creeks were calculated 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.

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

Survival to return rate (SRR) of Big Beef Creek coho was estimated based on CWT returns of jacks and adults in 2008. Separate SRRs were calculated for jacks and adults after adjusting the smolt tag groups for tag retention (96.5% per D. Seiler and S. Newhauser, WDFW unpubl. data) and tagging survival (84%) (84% per Blankenship and Hanratty 1990). Survival to return was calculated as:

Equation 2-4

$$AS = \frac{AR}{m_{adj}}$$

AS = Adult survival-to-return, BY 2005 returning as adults in 2008,

AR = Tagged coho returning as adults in 2008, and

m_{adj} = Adjusted number of wild smolts tagged in spring 2007.

Equation 2-5

$$JS = \frac{JR}{m_{adj}}$$

JS = Jack survival-to-return, BY 2006 returning as jacks in 2008,

JR = Tagged coho returning as jacks in 2008, and

m_{adj} = Adjusted number of wild smolts tagged in spring 2008.

Total wild coho escapement in Little Anderson, Seabeck, and Stavis creeks was estimated from survival to return of jacks and adults measured in Big Beef Creek applied to the associated wild smolt production in each watershed:

Equation 2-6

$$\hat{E}_{wild} = P_{BY2005} * AS_{BY2005} + P_{BY2006} * JS_{BY2006}$$

$\hat{E}_{wild}$ = Escapement of wild coho estimated for Little Anderson, Seabeck or Stavis creeks, 2008,

P_{BY2005} = Smolt production (BY 2005) from Stavis, Seabeck or Little Anderson, spring 2007,

AS_{BY2005} = Survival-to-return of age-3 adult coho to Big Beef Creek, BY 2005,

P_{BY2006} = Smolt production (BY 2006) from Stavis, Seabeck or Little Anderson, spring 2008, and

JS_{BY2006} = Survival-to-return of jack coho to at Big Beef Creek, BY 2006.

Total coho escapement into Little Anderson, Seabeck, and Stavis creeks has a wild and hatchery component as no barrier prevents hatchery coho from moving upstream to spawn in these watersheds. Therefore, total coho escapement was estimated from wild escapement in each watershed divided by the incidence of wild coho returns to Big Beef Creek:

Equation 2-7

$$\hat{E}_{Total\,2008} = \frac{\hat{E}_{wild\,2008}}{\%wild_{BBC2008}}$$

$\hat{E}_{Total\,2008}$ = Coho escapement estimated for Stavis, Seabeck or Little Anderson creeks in 2008, and

$\%wild_{BBC2008}$ = Percentage of wild to total coho arriving at BBC weir in 2008.

Spawner Distribution Analysis

Spatial distribution of coho redds in each watershed was represented by the number of redds within each 100-m reach (50-m upstream or downstream from each reference point). The number of redds associated with each reference point was mapped in order to show areas of high and low spawner densities.

Temporal distribution of coho redds was examined by plotting the total numbers of new redds per km surveyed each statistical week in each watershed.

Escapement, Harvest, and Marine Survival Analysis

The fate of coho smolts tagged at Big Beef Creek was described with respect to escapement, harvest, and marine survival. Jack and adult escapement rates (survival to return) are described above. Harvest rate of Big Beef Creek coho in brood year *i* was the total coded-wire tags intercepted in fisheries divided by the sum of tagged coho in fisheries and escapement:

Equation 2-8

$$H_i = \frac{F_i}{F_i + E_i}$$

H_i = Harvest rate of adult coho (BY 2005) returning in 2008,

F_i = Fishery interceptions of tagged adult coho in 2008, and

E_i = Tagged coho returning as adults in 2008.

Fishery interceptions were extracted from the Regional Mark Processing Center (RMPC) database maintained by the Pacific States Marine Fisheries Commission. Coded wire tag recoveries reported to the RMPC database are expanded based on proportion of fisheries sampled. Fishery interception data from RMPC included sampling of net fisheries in Terminal Area 12.

Marine survival of jack coho was equivalent to survival to return of jack coho (*JS*) because jacks are too small to recruit into the fishery. Marine survival of adult coho in brood year *i* was calculated as:

Equation 2-9

$$MS_i = \frac{F_i + E_i}{P_i}$$

MS_i = Marine survival of adult coho (BY 2005),

F_i = Fishery interceptions of tagged adult coho in 2008,

E_i = Tagged coho returning as adults in 2008, and

P_i = Adjusted number of wild smolts tagged in spring 2007.

Results

Disposition and Escapement of Big Beef Creek Coho

A total of 451 adult coho (229 males, 222 females) and 122 jack coho were captured at the Big Beef Creek weir. Five (1%) of adult coho and 11 (9%) of jack coho were ad-marked and sacrificed at the weir. Four of the unmarked adult (1%) and 16 (13%) of the unmarked jack coho were sacrificed for CWT tag recovery at the weir. The remaining 441 unmarked adults (221 males, 220 females) and 95 jacks were released upstream (Table 2-8).

Scale analysis and CWT recovery results both suggested that all unmarked coho passed upstream of the Big Beef Creek weir were of wild origin. Scale samples from unmarked adult (*n = 89)* and jack coho (*n* = *39*) indicated a wild origin (Table 2-9). CWT recoveries from adult coho at the weir (*n* = 4) and on the spawning grounds (*n* = 7) were of Big Beef Creek origin (Table 2-10). Similarly, CWT recoveries from unmarked jacks (*n* = 17) were of Big Beef Creek origin.

TABLE 2-8.—Disposition of coho returning to Big Beef Creek weir, fall 2008. Unmarked and marked refers to the presence or absence of an adipose fin. Plus sign (+) indicates a positive detection for a CWT. Minus sign (-) indicates that no CWT was detected.

	Unmarked										**Ad-marked**										**Total Coho**			
	Adults										**Adults**										**Adults**			
	Male			**Female**			**Total**	**Jacks**			**Male**			**Female**			**Total**	**Jacks**			**Male**	**Female**	**Total**	**Jacks**
Disposition	**+**	**-**	**Tot**	**+**	**-**	**Tot**		**+**	**-**	**Tot**	**+**	**-**	**Tot**	**+**	**-**	**Tot**		**+**	**-**	**Tot**				
Total Return	157	68	225	164	57	221	446	95	16	111	0	4	4	0	1	1	5	1	10	11	229	222	451	122
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	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	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	3	0	3	1	0	1	4	16	0	16	0	4	4	0	1	1	5	1	10	11	7	2	9	27
Total Upstream	154	67	221	163	57	220	441	79	16	94	0	0	0	0	0	0	0	0	0	0	221	220	441	95

TABLE 2-9.—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, 2008.

Sex/Age group	Total return	Number sampled	Scale sample results			Total estimated	
			Unreadable	Wild	Hatchery	Wild	Hatchery
Males	225	57	1	56	0	225	0
Females	221	35	1	34	0	221	0
Total Adults	446	91	2	89	0	446	0
Jacks	111	39	0	39	0	111	0

TABLE 2-10.─Coded-wire tag recoveries from adult coho (BY 2005) and jack coho (BY 2006) that returned to the Big Beef Creek weir in 2008. Unmarked and adipose-marked coho are reported separately.

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	63-39/99	Big Beef	2	0	2	0	0	4
	63-40/64	Big Beef	2	0	5	0	0	7
	63-40/65	Big Beef	0	0	0	0	0	0
	No tag		0	0	0	0	0	0
		Total	4	0	7	0	0	11
Ad-marked adults			0	0	0	0	0	0
		Total	0	0	0	0	0	0
Unmarked jacks	63-44/69	Big Beef	14	0	0	0	0	14
	63-45/97	Big Beef	3	0	0	0	0	3
	No tag		0	0	0	0	0	0
		Total	17	0	0	0	0	17
Ad-marked jacks	21-07/28	Port Gamble Pens	1	0	0	0	0	1
		Total	1	0	0	0	0	1

Survival-to-Return of Big Beef Creek Coho

Survival-to-return of adult coho (BY 2005) was 1.48%. This rate was the tagged adult return (n = 321) divided by the adjusted tag group of 21,715 coho smolts released in spring 2007. Jack return rate (BY 2006) was 0.47%. This rate was the tagged jack return (n = 95) divided by the adjusted tag group of 24,709 coho smolts released in spring 2008.

Escapement of Little Anderson, Seabeck, and Stavis Coho

Total 2008 escapements into Little Anderson, Seabeck, and Stavis creeks were estimated to be 17, 16, and 117 coho, respectively (Table 2-11). Total escapement incorporated a 97.21% incidence of wild coho at the Big Beef Creek weir.

TABLE 2-11.─Estimated coho escapements into Little Anderson, Seabeck, and Stavis creeks in 2008.

Watershed	Smolt production (BY 2005)	Adult SRR @ Big Beef	Wild adult escapement	Smolt production (BY 2006)	Jack SRR @ Big Beef	Wild jack escapement	Proportion wild coho in Big Beef escapement	Total escapement
Little Anderson	1,075	1.48%	16	96	0.47%	0	97.21%	17
Seabeck	787	1.48%	12	828	0.47%	4	97.21%	16
Stavis	6,749	1.48%	100	2,850	0.47%	14	97.21%	117
Total	8,611		128	3,774		18		150

Escapement of Big Beef Creek Chum

A total of 1,181 adult chum returned to Big Beef Creek in 2008. This return included 709 summer chum and 472 fall chum (Table 2-12). Chum were caught between August 25 and December 8 with peak catches in mid-September and again in mid-November (Table 2-13). A distinct break between the two runs occurred between October 9 to 16, 2008; during this period no chum were caught. Summer chum were designated as those migrating prior to October 15 and fall-run chum were designated as chum migrating after October 15.

TABLE 2-12.—Disposition of chum returning to Big Beef Creek weir, 2008.

	Disposition	Male	Female	Total	Percent
Summer chum	Released upstream unspawned	407	300	707	99.7%
	Spawned below weir	0	2	2	0.3%
	Spawned released upstream	0	0	0	0.0%
	Total summer chum	407	302	709	100.0%
Fall chum	Released upstream unspawned	285	167	452	95.8%
	Spawned below weir	5	3	8	1.7%
	Spawned released upstream	1	3	4	0.8%
	Released into UW ponds/spawning channel	3	5	8	1.7%
	Total fall chum	294	178	472	100.0%
	Total	701	480	1,181	

TABLE 2-13.—Numbers of summer and fall-run chum salmon caught by statistical week in the Big Beef Creek weir trap, 2008.

Statistical week			Summer chum			Fall chum		
Begin	End	No.	Male	Female	Total	Male	Female	Total
Aug-17	Aug-23	34	0	0	0			
Aug-24	Aug-30	35	50	25	75			
Aug-31	Sept-6	36	71	36	107			
Sept-7	Sept-13	37	113	79	192			
Sept-14	Sept-20	38	92	64	156			
Sept-21	Sept-27	39	66	76	142			
Sept-28	Oct-4	40	10	18	28			
Oct-5	Oct-11	41	5	4	9			
Oct-12	Oct-18	42	0	0	0	2	2	4
Oct-19	Oct-25	43				14	6	20
Oct-26	Nov-1	44				43	24	67
Nov-2	Nov-8	45				93	41	134
Nov-9	Nov-15	46				82	62	144
Nov-16	Nov-22	47				46	33	79
Nov-23	Nov-29	48				8	5	13
Nov-30	Dec-6	49				6	4	10
Dec-7	Dec-13	50				0	1	1
Dec-14	Dec-20	51				0	0	0
Dec-21	Dec-27	52				0	0	0
Dec-28	Jan-3	53				0	0	0
Jan-4	Jan-10	1				0	0	0
Jan-11	Jan-17	2				0	0	0
		Total	407	302	709	294	178	472

Coho Body Size

Fork lengths were measured for 57 adult males, 34 females, and 29 jack coho at the Big Beef Creek weir (Table 2-14). Adult male coho (average = 61.2-cm FL) were longer than jack coho (average = 33.4-cm FL) but comparable to female coho (average = 62.8-cm FL).

TABLE 2-14.—Average fork length (cm), range, standard deviation (S.D.), and sample rate of unmarked coho spawners in Big Beef Creek, 2008.

	Jacks < 35cm	Jacks 35-45cm	Adult males 35-45cm	Adult males > 45cm	Adult females
Average (cm)	31.9	37.4	42.5	62.2	62.8
Min (cm)	30	35	39	46	50
Max (cm)	34	44	45	77	71
S.D.	1.35	2.14	1.92	8.02	4.85
N	7	32	11	46	35
Sample rate	8.9%	100.0%	100.0%	20.4%	15.8%

Spatial Distribution of Coho Spawning

A total of 271 live coho, 25 carcasses, and 104 redds were observed on the four IMW streams; most of the observations occurred in Big Beef and Stavis Creek (Table 2-15).

TABLE 2-15.—Live coho, coho carcasses, and coho redds observed during spawning ground surveys in the Hood Canal IMW streams, 2008.

Watershed	Survey dates	Live coho	Carcasses				Redds
			Males	Females	Jacks	Not determined	
Little Anderson	10/22-01/15	0	0	0	0	0	0
Big Beef	10/24-01/15	194	14	6	0	1	87
Seabeck	10/21-01/16	2	0	2	0	0	4
Stavis	10/21-01/12	75	1	0	0	1	13

Spatial distribution of coho redds in Big Beef and Stavis creeks were comparable to previous seasons (Figure 2-7, 2-8). In 2008, 59.8% of the coho redds were observed upstream of Lake Symington on Big Beef Creek. Lack of spawners was evident during surveys of Little Anderson and Seabeck creeks. On Seabeck Creek, 3 of the 4 redds were within the same 100 meter section just below the confluence between tributary 5 and the main stem. The one redd on Seabeck Creek that was observed upstream of this confluence occurred earlier in the season when flows increased for a brief period of time (Figure 2-9). Flows upstream of this confluence remained too low for coho migration and spawning throughout the season. Surveys on Little Anderson did not locate any live coho, carcasses, or redds in 2008.

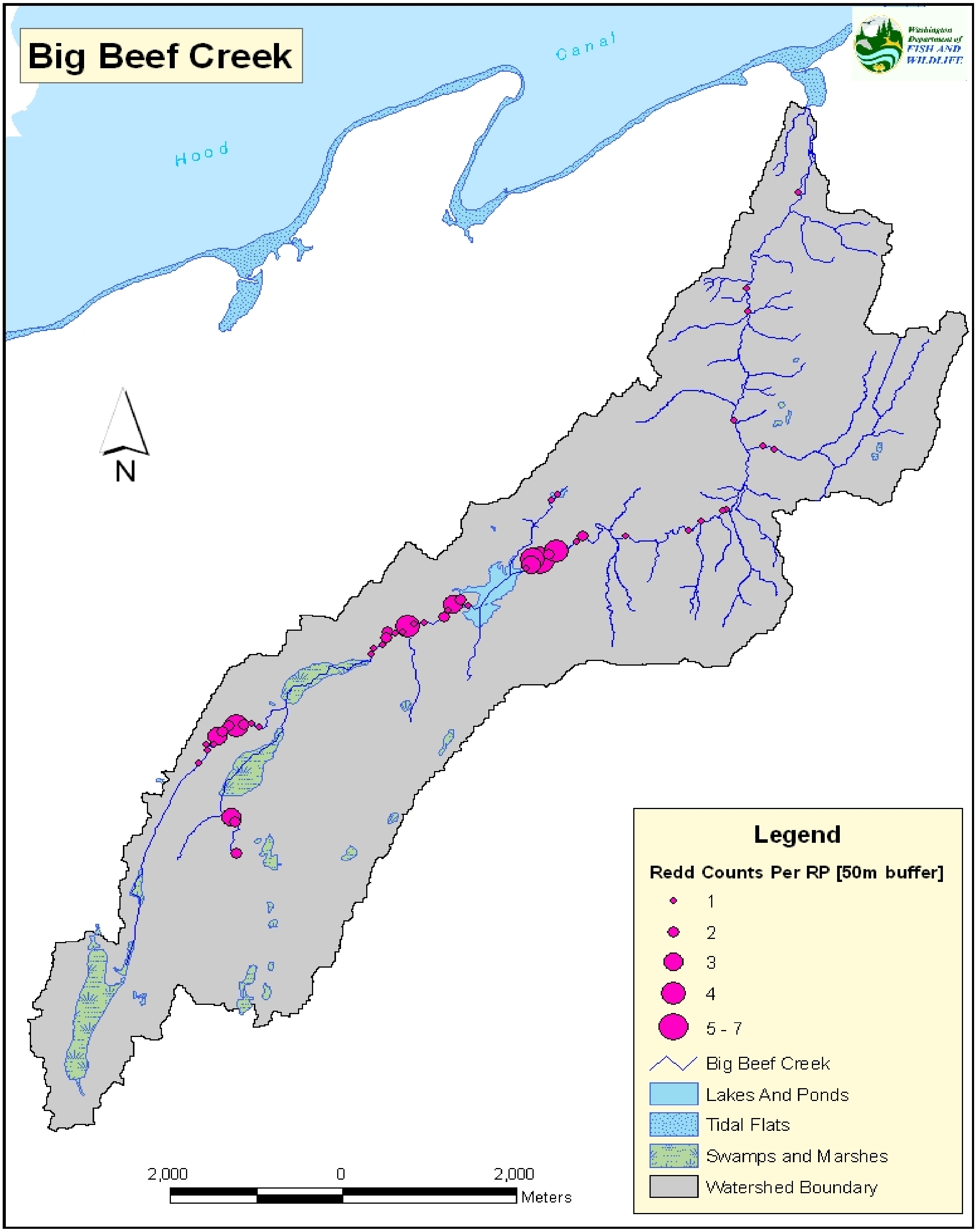


FIGURE 2-7. —Spatial distribution and density of coho redds in the Big Beef Creek watershed, 2008.

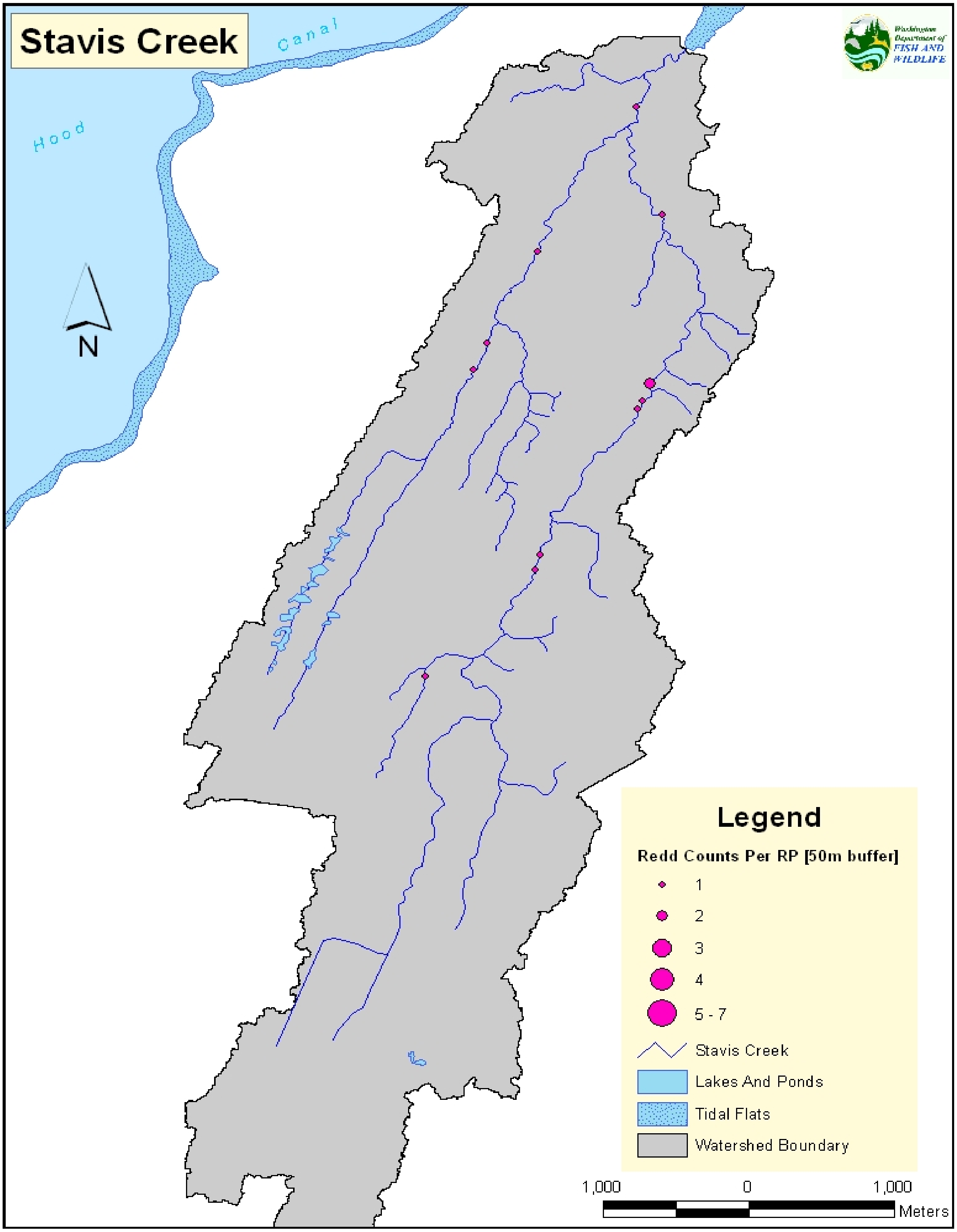


FIGURE 2-8. —Spatial distribution and density of coho redds in the Stavis Creek watershed, 2008.

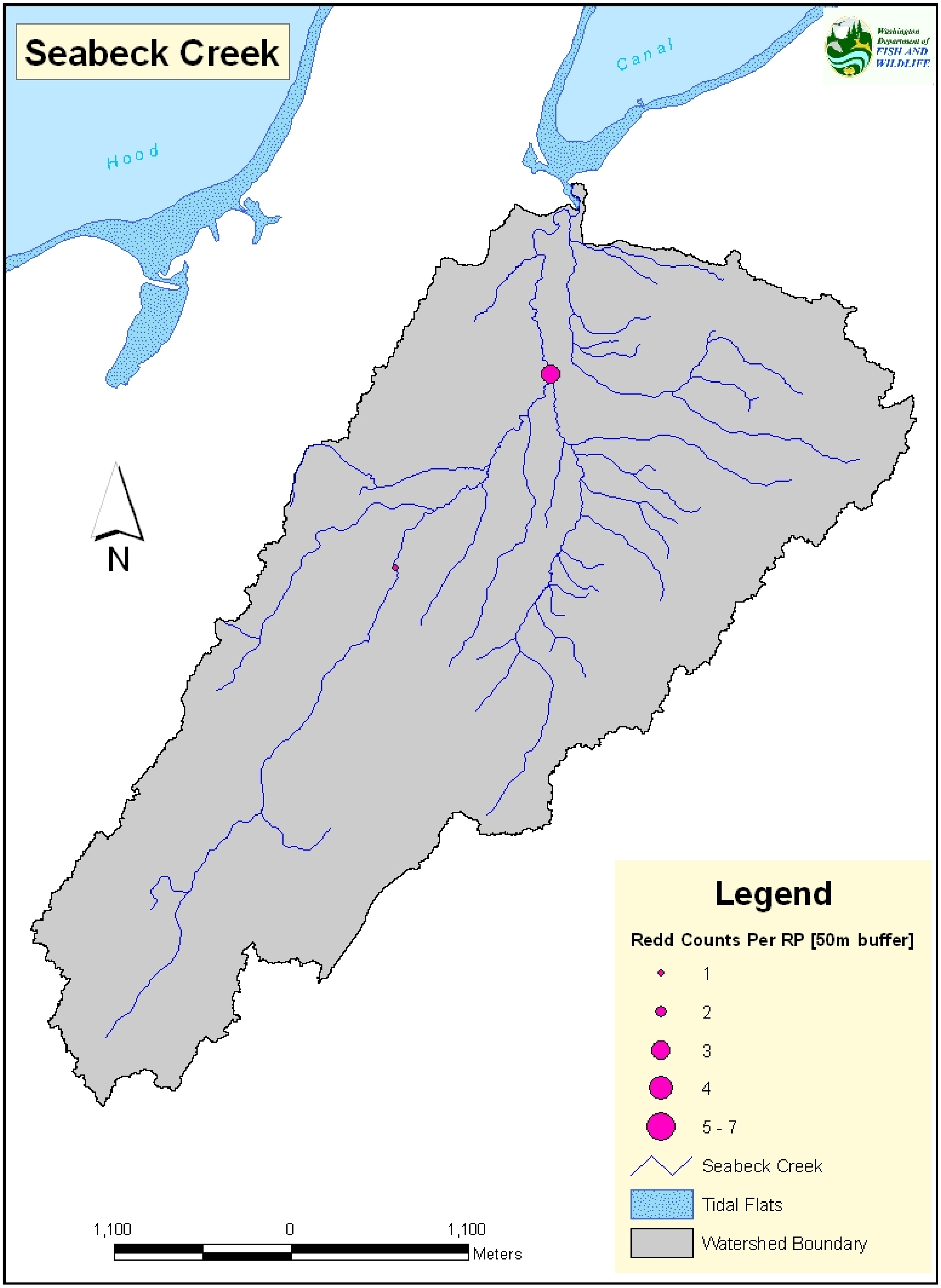


FIGURE 2-9. —Spatial distribution and density of coho redds in the Seabeck Creek watershed, 2008.

Temporal Distribution of Coho Spawning

Flows during the fall of 2008 differed notably from long-term average flows during the spawning period (Figure 2-10). This difference is relevant as flow events are often correlated with the movement of coho spawners into the creeks and upstream.

Very few adult coho were observed on the Big Beef delta through September. The first adult coho captured at the Big Beef Creek weir was a hatchery ad-marked male captured and sacrificed on September 5. Wild unmarked coho (n = 12) were first captured and passed upstream on October 4, after a rain storm raised the level of Big Beef Creek 3-4 inches (Figure 2-10). Eighty-one percent of the coho migration into Big Beef Creek occurred during the high flow period between November 1st and 15th. After this period, flows quickly dropped off and remained well below the long-term average until late December. The last returning unmarked adult coho (n = 3) were captured on January 9, 2009.

The first coho redd on Seabeck Creek was observed on statistical week 45 (Appendix D; November 4 to 10). Coho redds on Stavis and Big Beef creeks were first observed on statistical week 46 (November 11 to 17). New redd deposition on Big Beef Creek peaked during statistical week 47 (November 18 to 24), 2-3 weeks after the peak count (November 4) was observed at the weir (Figure 2-11 and 2-12). New redd deposition on Stavis Creek peaked during statistical week 49 (December 2 to 8), two weeks later than Big Beef (Figure 2-13).

Spawning in Seabeck Creek was minimal and associated with the rainfall event in early November and a later rainfall and snowmelt event in January that raised flows in the creek (Figure 2-14). Seabeck had either no or little flow in many critical areas. No spawning activity was observed for six statistical weeks (47-52) that typically represent the coho spawning season.

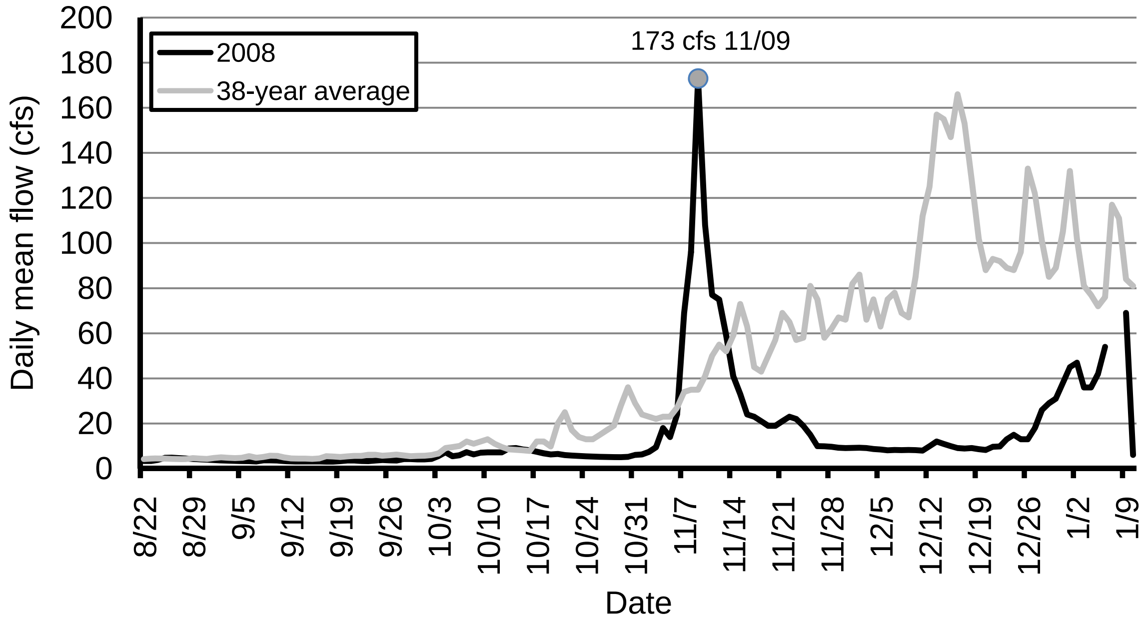


FIGURE 2-10.—Daily mean flow in 2008 and 38-year historical average at Big Beef Creek, USGS gauge#12069550.

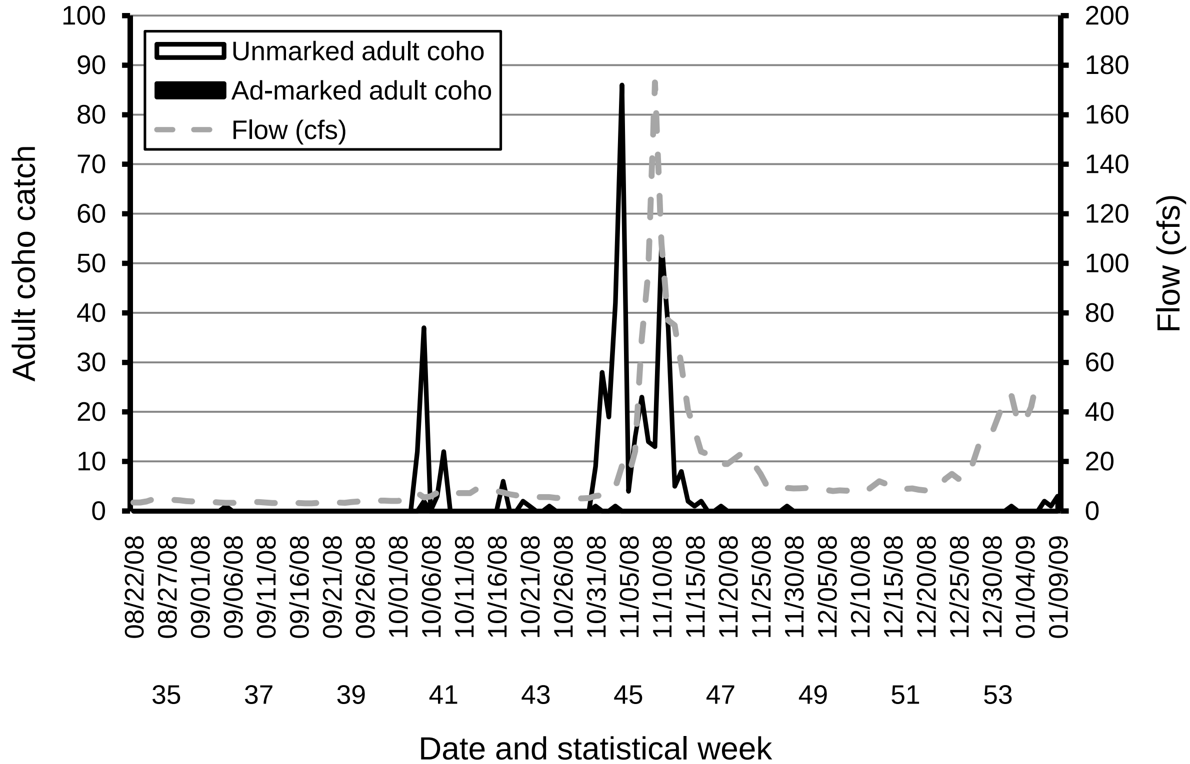


FIGURE 2-11.─Daily catch of unmarked and ad-marked coho spawners at the Big Beef Creek weir trap during the fall migration (2008). Mean daily flow (cfs) was measured at USGS gauge#12069550.

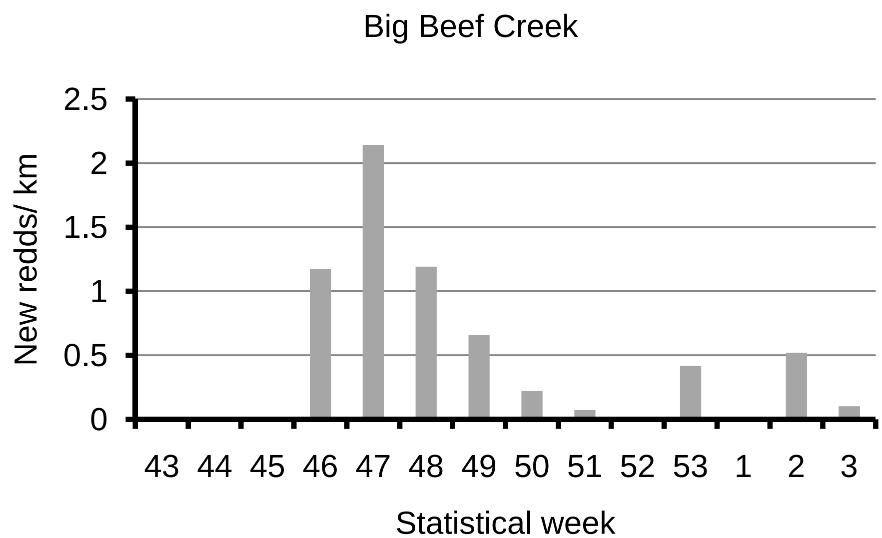


FIGURE 2-12.─Density of new coho redds per surveyed stream length on Big Beef Creek, statistical week 43 (2008) to statistical week 3 (2009).

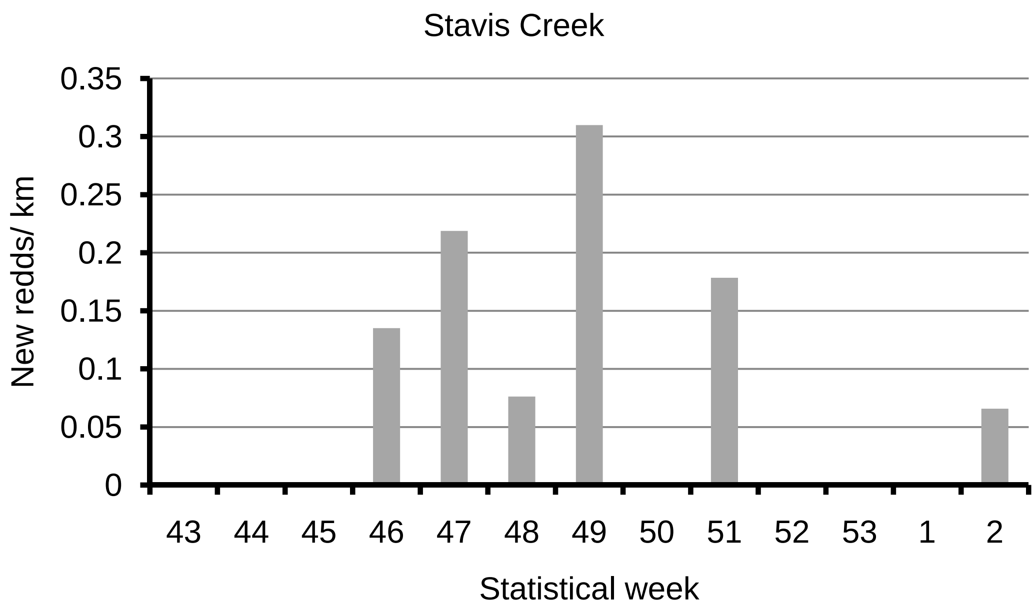


FIGURE 2-13.—Density of new coho redds per surveyed stream length on Stavis Creek, statistical week 43 (2008) to statistical week 2 (2009).

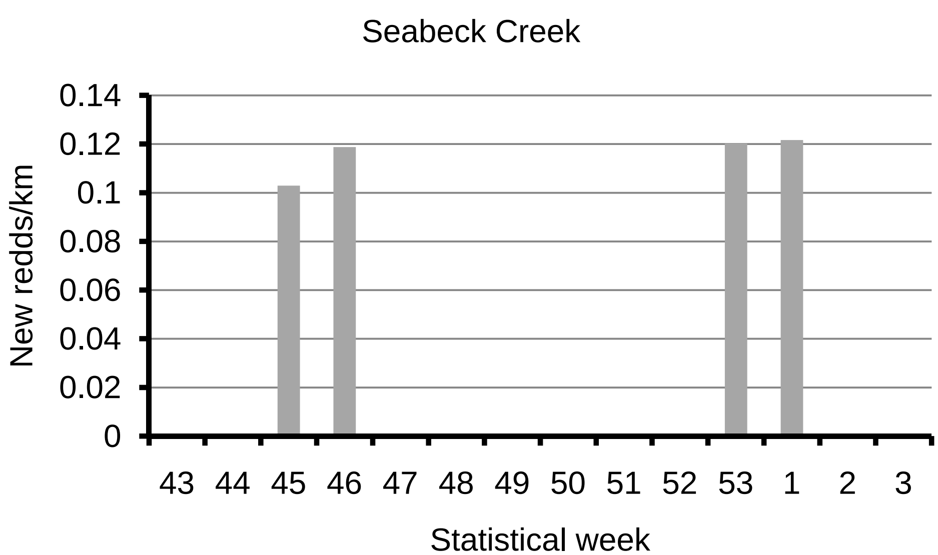


FIGURE 2-14.—Density of new coho redds per surveyed stream length by statistical week on Seabeck Creek, statistical week 43 (2008) to statistical week 3 (2009).

Harvest Rate.

The terminal net fishery in Marine Area 12 was open from September to late November in 2008. In this fishery, a total of 265 unmarked and 3 ad-marked coho contained CWTs (Table 2-16). Coded-wire tags from unmarked coho were all of Big Beef origin.

As of June 2009, an estimated 576 tagged Big Beef coho (BY 2005) were captured in Puget Sound and ocean sport fisheries and mixed net/seine fisheries (Table 2-17). This corresponds to a preliminary harvest rate of 64.2% of the total run. The preliminary harvest rate represents a lower bound as no tags are currently reported for harvest in Puget Sound and 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).

TABLE 2-16.─Coded-wire tags recoveries from the Hood Canal (Area 12) treaty coho beach seine fishery, fall 2008.

Tag Code	Origin	#CWT Recoveries
63-39/99	Big Beef adults (BY 2005)	112
63-40/64	Big Beef adults (BY 2005)	108
63-40/65	Big Beef adults (BY 2005)	42
63-44/69	Big Beef jacks (BY 2006)	2
63-45/97	Big Beef jacks (BY 2006)	1
21-06/73	Port Gamble Bay Pens	1
63-36/69	George Adams Hatchery	1
	Total	267

Marine Survival

A preliminary marine survival estimate of 4.13% for adult coho (BY 2005) is based on 576 fishery interceptions, 321 tagged adults returning to the weir, and an adjusted tag group of 21,715 smolts in spring 2007 (Table 2-16). The preliminary marine survival estimate is likely biased low because not all CWT recoveries from harvested coho are currently reported (as of June 8, 2009).

TABLE 2-17.─Marine survival of Big Beef Creek wild adult coho (2005 brood) based on the harvest and escapement of tagged wild adults during 2008 (Preliminary as of June 8, 2009).

	Area	Fishery Type	BBC tags in the adult coho return (2005 Brood) Tag Codes: 63-39/99 63-40/64 63-40/65
Harvest	Ocean (WA)	Troll (Treaty + Non-treaty)	27
	Puget Sound	Sport + Mixed Net/Seine (combined) [a]	549
		Estimated harvest of BBC tags[a]	576
Escapement	Big Beef Creek Trap	Return of wild coho tags to trap[b]	321
		Estimated escapement of BBC tags	321
		Total run (Harvest + Escapement)	897
Summary	Total tagged smolts (tag codes 63-39/99, 63-40/64, 63-40/65)		26,789
	Adjusted tagged smolts[c]		21,715
	Harvest rate (Total harvest/Total run)		[d] 64.2%
	Escapement rate (Total escapement/Total run)		35.8%
	Survival to return rate (Total escapement/total adjusted tagged smolts)		1.47%
	Marine survival (Total run/Total adjusted smolts tagged)		4.13%

[a] Preliminary estimate as of June 8, 2009. 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 2008.

[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.

Discussion

Preliminary tag recovery results for BY2006 Big Beef Creek coho indicate that this brood year has had the smallest run size and the second lowest escapement observed since 1978 (Figure 2-15). Of note, the last three cohorts of wild Big Beef Creek coho have experienced three of the four lowest marine survival rates measured for this population. Low marine survival coupled with a high harvest rate has reduced escapement to low levels for three consecutive brood years. While a harvest rate of 64% is not uncommon in coho fisheries, the effect of this harvest rate is substantial when applied to the small run of coho returning to Big Beef Creek in 2008.

Adequate escapements of Big Beef Creek coho are necessary to maximize smolt production from this system. Maximum smolt production is defined by the carrying capacity of the watershed and the environmental variables that limit survival in a given year. When Big Beef Creek coho escapement exceeded approximately 450 female spawners, smolt production has ranged from to 16,574 to 47,087 and is weakly correlated with the number of spawners (Figure 2-16). At these higher escapement levels, variation in smolt production is better explained by spawning and rearing flows (WDFW unpubl. data). However, in years where escapement at Big Beef Creek has been lower than 450 female spawners, production has never exceeded 30,000 smolts. This suggests that smolt production in these years has been limited by fewer eggs laid in the gravel. Low smolt production has the potential to depress run sizes in future years, especially when coupled with low marine survival conditions. Furthermore, low escapement jeopardizes the ability to measure response to habitat restoration. The IMW project seeks to measure whether the carrying capacity of each watershed (measured as smolt production) increases in response to habitat restoration efforts. A change in carrying capacity can only be measured under adequate escapement levels that assure that smolt production of each watershed is currently at carrying capacity.

Flows during the spawning period impact escapement and early life history of coho in several ways. In 2008, stream flows were very low through the peak spawning period, making fish entry into the smaller creeks (Little Anderson and Seabeck) virtually impossible. Coho migration into Seabeck was hindered by low stream flow conditions throughout the month of December with large parts of the stream being dry or reduced to just a trickle. Low flows during the spawning period may decrease availability of spawning habitat and limit coho spawning to main-stem areas low in the watershed. Low flows may also result in redd dewatering and poor egg survival if high flow events, such as that occurring in early November 2008, are followed by major reductions in water level. Extended periods of low flow also prolong coho residence in the canal and their vulnerability to terminal area fisheries. As observed at the Big Beef Creek weir in 2008, coho often arrive during the first major flow event.

Escapement estimates for Little Anderson, Seabeck, and Stavis creeks were low and in agreement with spawner survey observations. Spawner surveys returned many fewer redds than the estimated female escapement, an expected result as redds detectability is typically less than 100%. Coho redd detection is particularly problematic for making escapement estimates as coho spawning occurs during periods where flows and inclement weather decrease access to and visibility of spawning substrate.

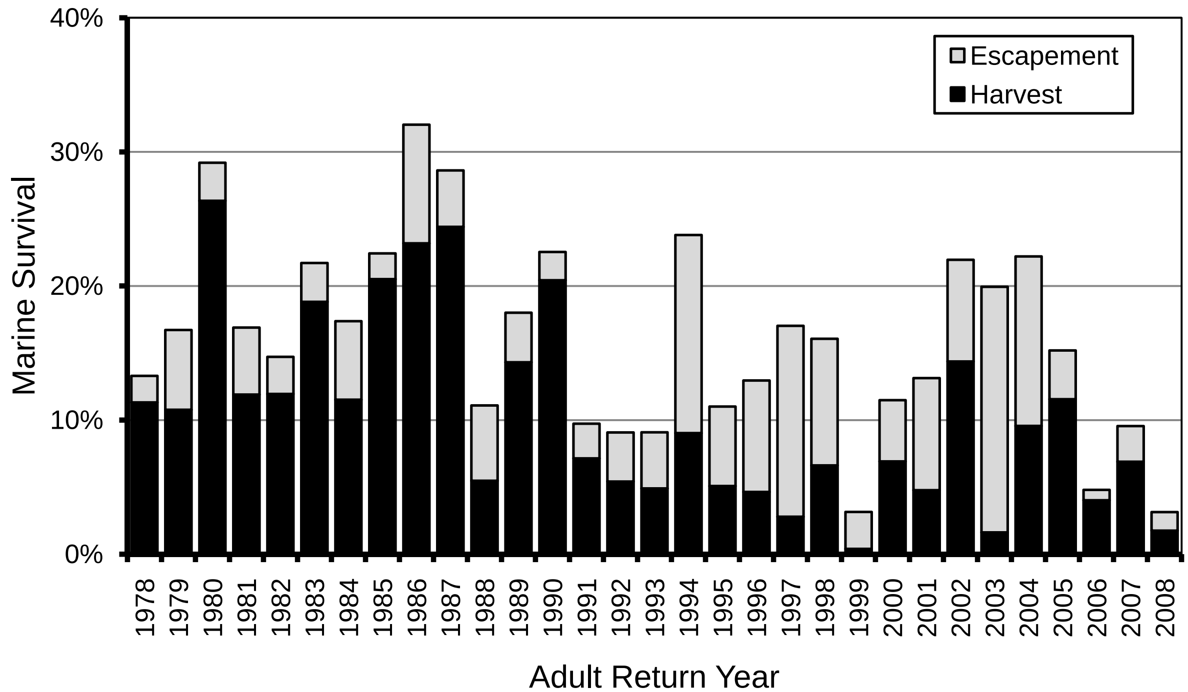


FIGURE 2-15.—Marine survival of adult coho from Big Beef Creek by return year, 1978 to 2008. Marine survival is partitioned into two components – harvest and escapement – that describe the fate of adult coho.

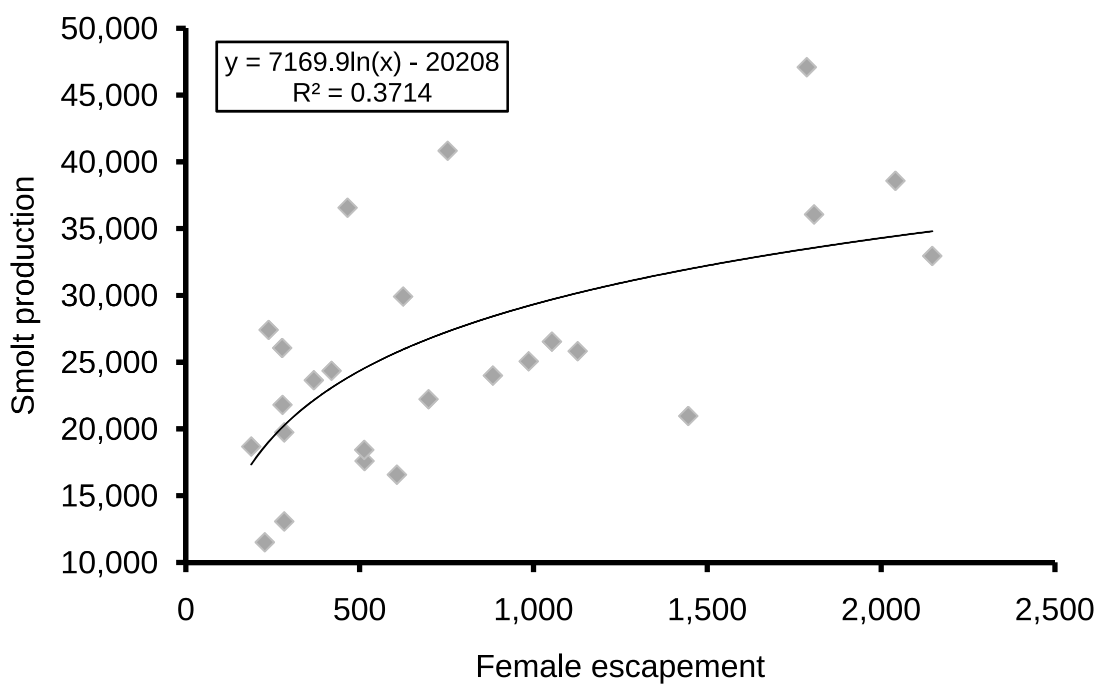


FIGURE 2-16.—Coho smolt production associated with female escapement to Big Beef Creek weir (BY 1982-2006).

Assumptions

Survival-to-return escapement estimates for Little Anderson, Seabeck, and Stavis creeks were based on two major assumptions – (1) smolt production estimates are correct and (2) smolts return to their natal watershed to spawn. Smolt production estimates would be inaccurate (assumption #1) if the Big Beef Creek timing model were incorrect. As catches of coho were nearly zero at the beginning and ending of the trapping season and 96.6% -97.6% of the total estimates occurred during the trapped period, use of the existing Big Beef Creek timing model is unlikely to cause large inaccuracies in smolt production estimates. Smolt production estimates would also be inaccurate (assumption #1) if a major component of the Big Beef Creek downstream migration occurred outside the March to June time window. This is a possibility in some years. A small portion of juvenile coho are caught as fry in the downstream trap and some juvenile coho are also observed to be rearing in the Big Beef Creek estuary (downstream of the weir) during the fall. If these coho remain below the weir until smolting, smolt production from Big Beef Creek would be underestimated and survival-to-return overestimated.

In comparison to smolt production, the return of smolts to their natal watershed (assumption #2) is a more problematic assumption that warrants further investigation. Dispersal of spawners among creeks remains to be studied. 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. However, returns to the Big Beef Creek weir also indicate that some degree of dispersal among creeks may be occurring. Each year, a portion of CWT coho returning to the Big Beef Creek weir are unmarked. If dispersal to nonnatal creeks is minimal among returning spawners, CWT returns of wild coho to the Big Beef Creek weir should have a similar incidence to CWTs in the corresponding smolt release group. However, returning wild adult coho often have a lower incidence of CWTs than the corresponding smolt release group. For example, the actual CWT incidence of coho smolts in the 2005 brood year was 87.6%. This calculation is based on a total of 26,789 unmarked tagged and 2,140 unmarked untagged smolts were released in spring 2007 (2005 brood year), an adjusted tag group of 21,715 to account for tag loss (3.5%) and tagging-related mortality (16%), and an increased non-tagged group to 3,078 to absorb the tag loss. This compares with a 71.2% (317 of 441) incidence of CWTs in the unmarked adult coho returning to the Big Beef Creek weir in 2008. The unexplained reduction of CWT incidence (~16%) in this brood year will require further understanding of coho dispersal among the Hood Canal tributaries.

Chapter 3. Lower Columbia stream complex

Executive Summary

The Intensively Monitored Watersheds project includes three adjacent streams (Mill, Abernathy, and Germany creeks) along the north bank of the lower Columbia River. Chinook and coho salmon and steelhead trout are the focal species for study in these watersheds. Objectives of fish population studies on the Lower Columbia IMW streams were to (1) estimate parr abundance parr-to-smolt survival of coho, (2) estimate juvenile production of Chinook, coho, and steelhead, (3) compare timing of juvenile outmigration among watersheds, (4) estimate escapement of coho, Chinook, and steelhead in all three creeks, and (5) describe spawning distribution and timing of coho, Chinook, and steelhead.

Parr abundance and over-winter survival estimates were based on a mark-recapture study design. Coho parr were captured and marked during August and September surveys in selected stream reaches. Marked fish were recaptured in downstream traps the following spring. Smolt production was estimated from screw traps operated near the mouth of each creek between February 7 and June 23, 2008. Production was estimated using a time-stratified mark-recapture study design. Chinook and steelhead spawner abundance was estimated from spawner surveys of each creek. Coho spawner abundance was estimated from a mark-recapture study on Abernathy Creek.

Chinook salmon abundance was estimated at two life stages – juvenile and adult. For the 2008 outmigration (brood year 2007), juvenile production of Chinook salmon was highest in Mill Creek (N = 29,995, CV = 9.8%) and lowest in Abernathy Creek (N = 10,780, CV = 13.5%). Juvenile production in Germany Creek was estimated to be 17,644 (CV = 6.9%). The 2008 Chinook escapement was estimated to be 206 adults (95% *C.I.* 183-229) in Mill Creek, 85 adults (95% *C.I.* 44-121) in Abernathy Creek, and 444 adults (95% *C.I.* 416-473) in Germany Creek.

Coho salmon abundance was estimated at three life stages – parr, smolt, and adult. Parr abundance (2006 brood year) was highest in Germany Creek (N = 183,535, CV = 26.5%) and lowest in Mill Creek (N = 69,628, CV = 20.6%). Parr abundance in Abernathy Creek was 161,069 coho (CV = 35.1%). Over-winter survival in Abernathy (2.8%) and Germany (1.8%) creeks was lower than in Mill Creek (14.4%). Coho smolt production for the 2006 brood year (2008 outmigration) was estimated to be 10,930 (CV = 4.6%) in Mill Creek, 5,699 (CV = 6.6%) in Abernathy Creek, and 3,982 (CV = 3.6%) in Germany Creek. Coho escapement into Abernathy Creek was estimated to be 513 adults and 182 jacks in the fall of 2008. Survival-to-return rate to Abernathy Creek was 0.37% for jack coho (brood year 2006) and 1.85% for adult coho (brood year 2005). Hatchery-origin coho represented 43.9% of the adult escapement and 73.1% of the jack escapement.

Steelhead abundance was estimated at two life stages – smolt and adult. Steelhead production has been consistently highest in Germany Creek. For the 2008 outmigration, smolt abundance of steelhead was 1,256 (CV = 7.5%) in Mill Creek, 1,192 (CV = 15.1%) in Abernathy Creek, and 3,769 (CV = 4.6%) in Germany Creek. The 2008 escapement of adult steelhead was lowest in Mill Creek (N = 38) and comparable in Abernathy (N = 248) and Germany (N = 244) creeks.

Introduction

Mill, Abernathy and Germany creeks are second order tributaries located in Cowlitz and Wahkiakum counties (Figure 1-2). These creeks flow into the Columbia River west of Longview, Washington at river mile (RM) 53.8, 54.2, and 56.2, respectively. Salmonid species in these creeks include "tule" fall Chinook salmon (Marshall et al. 1995), coho salmon, cutthroat trout, and winter-run steelhead (LCFRB 2004; Myers et al. 2006). Chum salmon are also observed in low numbers.

For each listed species, populations in these three watersheds are classified as a single population (LCFRB 2004). Chinook, chum, and coho populations in these watersheds listed as "threatened" under the Endangered Species Act. Chinook and coho are considered part of the Coastal Major Population Group for Lower Columbia Evolutionary Significant Unit (ESU). Chum are part of the Coastal Major Population Group for the Columbia River chum ESU. Winter-run steelhead in Mill, Abernathy, and Germany creeks are considered part of the Southwest Washington distinct population segment (DPS) defined by NOAA (http://www.nwr.noaa.gov/ESA-Salmon-Listings/Salmon-Populations/Steelhead/Index.cfm).

Hatchery salmonids have been historically released into these watersheds to provide additional harvest opportunities. In recent years, hatchery planting activities in the lower Columbia region have been eliminated or reduced in response to funding reductions and concern about negative interactions with natural-origin salmonids. On Germany and Mill creeks, a limited hatchery program for winter-run steelhead and coho salmon was discontinued in the late 1990s. Hatchery winter-run steelhead planted in many LCR tributaries were derived from Chambers Creek steelhead, a winter-run population native to lower Puget Sound. Hatchery summer-run steelhead plants are of Skamania stock, originally derived from a mix of North Fork Washougal and Klickitat River summer-run steelhead (Crawford 1979). The spawning time for both hatchery stocks has been advanced so that the majority of spawning occurs between December and February (Crawford 1979) and hatchery summer steelhead timing has recently been advanced further. While neither hatchery stock was directly planted into Mill, Abernathy or Germany creeks, stray hatchery steelhead are known to enter Abernathy Creek (USFWS 2005, 2006, 2007, 2008) and are assumed to enter Mill and Germany creeks.

On Abernathy Creek, annual hatchery plants of fall Chinook and winter-run steelhead were discontinued in 1999. Analysis of allozyme frequencies from Abernathy Creek Chinook show this population is genetically different from other Columbia River Chinook populations except for Kalama River Chinook (Myers et al. 2006). Until 1999, fall Chinook were released into Abernathy Creek from the hatchery located at RM 3, now the U.S. Fish and Wildlife Service (USFWS) Abernathy Fish Technology Center (AFTC). The Abernathy hatchery program was initiated from Spring Creek "tule" fall Chinook salmon, a population originating from the White Salmon River. Genetic composition in these watersheds may still show influence from this population or from the other hatchery populations, which consistently spawn in these basins. These include salmon from the Elochoman, Big Creek, and Kalama Falls hatcheries (Jenkins 2006). The Abernathy Fish Technology Center (AFTC) currently implements a winter-run steelhead brood stock program as part of an ongoing reproductive success study (USFWS 2005). Initial brood stock for this program was derived from juvenile *O. mykiss* collected in Abernathy Creek. The spawn timing of progeny from this program overlaps with wild winter-run steelhead (USFWS 2005). All steelhead from this program are marked with an adipose fin clip.

Anadromous salmonids have access to most of the habitat in these basins with the exception of Abernathy Creek, where a natural falls at RM 3.5 was a likely barrier to all but winter-run steelhead. In the 1950s, the falls on Abernathy was laddered and provided upstream access for anadromous salmonids. An electric weir is currently operated by the AFTC near RM 3. When the weir is in operation, adult fish moving upstream are diverted into holding ponds at the AFTC. Captured fish are subsequently moved upstream of the falls.

Chinook, coho, and steelhead are the focal species for population abundance and survival estimates derived for these watersheds. Abundances of coho are estimated at three life stages (parr, smolt, spawner); abundance of Chinook and steelhead are estimated at two life stages (smolt, spawner). Coho parr are collected by electrofishing and seining in index reaches during late summer. Juvenile outmigrants of all species are captured in screw traps operated near the mouth of the creek during the outmigration period.

Adult escapement is estimated using combinations of weirs on Abernathy Creek and spawner surveys on all three creeks. Coho escapement is estimated using a mark-recapture study conducted between October and January in Abernathy Creek. Coho escapement in Mill and Germany Creek is estimated suing survival to return for Abernathy coho applied to the corresponding smolt production in Mill and Germany. Adult abundance of steelhead is estimated from redd surveys, due to the difficulties of observing adult winter-run steelhead in freshwater (Freymond and Foley 1986). Wild winter-run steelhead populations in the Lower Columbia River (LCR) typically begin spawning in early March and continue through late May/early June. Steelhead redds constructed prior to late February are likely from hatchery steelhead. Redd surveys were focused on the wild steelhead spawning time frame only, as natural spawning of stray hatchery steelhead was beyond the scope of this project. Distribution and abundance of tule fall Chinook spawners was estimated using a combination of carcass tagging and Area-Under-the-Curve (AUC) methodologies.

Objectives of fish population studies on the Lower Columbia IMW streams were to:

(1) Estimate parr abundance and parr-to-smolt survival of coho,

(2) Estimate juvenile production of Chinook, coho, and steelhead,

(3) Compare timing of juvenile outmigration among watersheds,

(4) Estimate escapement of coho, Chinook, and steelhead in all three creeks, and

(5) Describe spawning distribution and timing of coho, Chinook, and steelhead.

Lower Columbia Parr Evaluation

Authors: Pat Hanratty and Mara Zimmerman

Methods

Fish Collection

Abundance of coho parr at the watershed scale was estimated using a mark-recapture study. Parr were captured and tagged with passive integrated transponder (PIT) tags in late August and early September. During the outmigration period the following spring, a portion of the outmigration (tagged and untagged) were captured in screw traps. Incidence of tagged fish among total captured smolts was used to back-calculate the total watershed abundance of parr. Recapture of marked fish also provided a measure of overwinter survival.

Coho and steelhead parr were collected by electroshocking 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 randomly chosen on Mill, Abernathy and Germany creeks using a spatially balanced probabilistic sample design (Figure 3-1). The same ten index reaches in each watershed have been sampled consistently since the project began in 2004. In order to increase the number of marked fish, areas adjacent to many sites were also sampled using a stick seine.

On all three creeks, coho parr were enumerated, measured (fork length, FL), tagged, and released. PIT tags were applied to coho parr longer than 55-mm FL. PIT tags used in this study were 12.50mm by 2.07mm (134.2kHz ISO, 0.1020g). PIT-tagged coho were recaptured in downstream migrant screw traps the following spring. Downstream migrating coho were electronically scanned with an ISO Compatible RFID Portable Reader. Additional information collected at the downstream traps is provided in the Smolt Evaluation section.

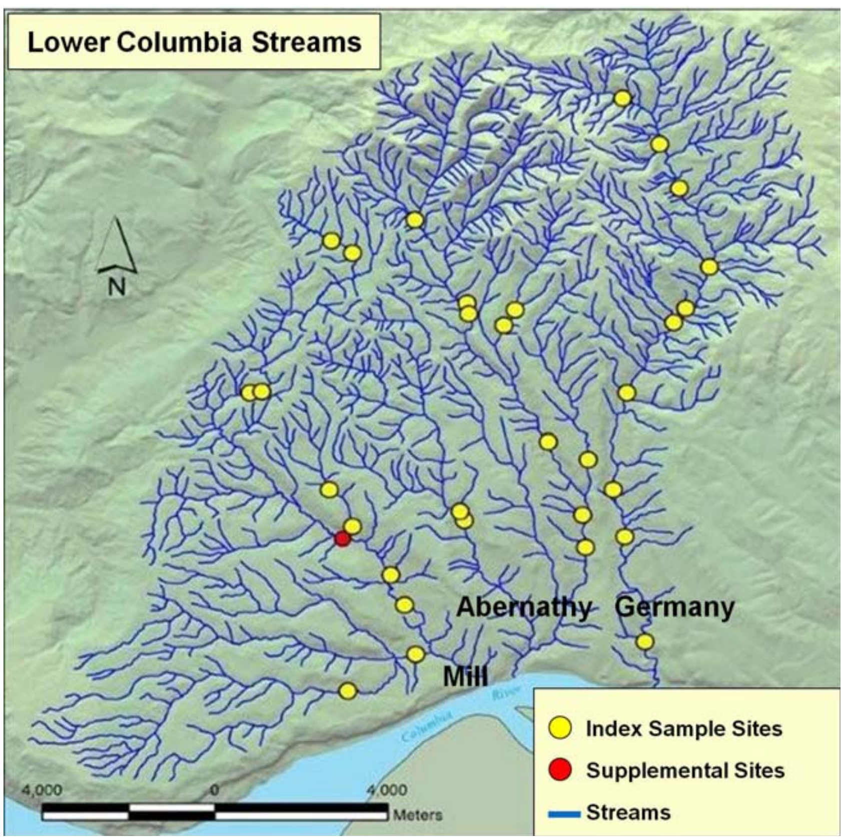


FIGURE 3-1.—Index sample sites on Mill, Abernathy, and Germany creeks. Coho parr are collected by electrofishing and seining at each site.

Analysis

Coho parr abundance was based on the number of parr tagged with PIT tags (n_1) during electrofishing and seine surveys, coho smolt catches in the screw trap (n_2), and tagged coho smolts recaptured (m_2) in the screw trap. Abundance was estimated using a back-calculation approach and the Petersen estimator with a Chapman modification (Seber 1973):

Equation 3-1

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

where:

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

n_1 = Number of parr tagged and released during summer surveys,

n_2 = Total smolts captured in downstream migrant traps, and

m_2 = Number of tagged fish recaptured in downstream migrant traps.

Variance of the abundance estimate was (Seber 1973):

Equation 3-2

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

Overwinter survival ($\hat{S}$) was:

Equation 3-3

$$\hat{S} = \frac{r_{\exp}}{n_1}$$

Recaptures of tagged fish were expanded (r_{exp}) because the downstream traps only catch a portion of the outmigration. Expansions were summed for the *n* efficiency strata (*j*) identified for downstream traps. Additional information on efficiency strata is provided in the Smolt Evaluation section. Expanded recapture of tagged fish was:

Equation 3-4

$$r_{\exp} = \sum_{j=1}^{j=n} \frac{m_{2j}}{e_j}$$

m_{2j} = Recaptures of taggeded fish in downstream trap during in strata *j,* and

e_i = Efficiency of downstream trap during strata *j.*

Confidence intervals and coefficient of variation associated with abundance were calculated from the variance (Appendix B, Equation B-1, B-2).

Results

During summer 2008, coho parr were captured, tagged, and released in Mill (n_1 = 368), Abernathy (n_1 = 1,001), and Germany (n_1 = 1,000) creeks. PIT tag codes associated with these releases were entered into the PTAGIS database (PIT Tag Information System for the Columbia River Basin, http://www.ptagis.org/). Coho parr tagged in 2008 represent the parr stage of the 2007 brood year. Summer parr abundance for the 2007 brood year will be calculated based on recaptures of PIT-tagged coho in downstream traps in spring of 2009.

Summer parr abundance for the 2006 brood year was calculated from coho tagged as parr in summer of 2007 and recaptured in the downstream traps in spring of 2008. Summer parr abundance for the 2006 brood year was estimated to be 69,628 (CV = 20.6%) coho in Mill Creek, 161,069 (CV = 35.1%) coho in Abernathy Creek, 183,535 (CV = 26.5%) (Table 3-1) coho in Germany Creek.

In order to estimate overwinter survival, recaptures were expanded to 51 coho on Mill Creek, 28 coho on Abernathy Creek, and 18 coho on Germany Creek (Table 3-2). Overwinter survival in Mill Creek (14.0%) was five to seven times greater than that in Abernathy (3.0%) and Germany (2.0%) creeks (Table 3-3).

TABLE 3-1.─ Summer parr abundance of coho in Lower Columbia IMW streams (2006 brood year). Estimates are based on the tag group of PIT-tagged parr (n_1, summer 2007), recaptures of PIT-tagged smolts (m_2, spring 2008), and total capture of smolts (n_2, spring 2008). Mark and recapture information is used to estimate summer parr abundance ($\hat{N}$). Variance, confidence intervals (C.I.), and coefficient of variation ($C.V.$) are reported for the abundance estimate.

Parameter	Mill	Abernathy	Germany
Tagged parr (n_1)	351	1,003	1,040
Total smolts captured (n_2)	4,153	1,122	2,291
Recaptures of tagged smolts (m_2)	20	6	12
Parr abundance (N)	69,628	161,069	183,535
Abundance variance $V(N)$	206,177,506	3,200,270,991	2,362,588,263
Abundance 95% C.I.	28,143	110,879	95,269
Abundance C.V.	20.6%	35.1%	26.5%

TABLE 3-2.—Expanded recaptures (r_{exp}) of marked coho in Lower Columbia IMW streams (2006 brood year). Recaptures (m_2) were expanded based on trap efficiency (e) for each strata.

Watershed	Strata	Begin	End	m_2	e	r_{exp}
Mill	1	02/07/08	04/16/08	5	14.2%	35.18
	2	04/17/08	05/09/08	6	69.6%	8.61
	3	05/10/08	05/12/08	0	56.7%	0.00
	4	05/13/08	05/18/08	5	72.8%	6.87
	5	05/19/08	06/01/08	3	55.8%	5.38
	6	06/02/08	06/03/08	0	18.4%	0.00
	7	06/04/08	06/23/08	1	44.2%	2.26
			Total	20	---	50.67
Abernathy	1	02/07/08	04/15/08	1	10.5%	9.50
	2	04/16/08	05/05/08	0	11.5%	0.00
	3	05/06/08	05/19/08	2	36.9%	5.42
	4	05/20/08	06/22/08	3	23.4%	12.84
			Total	6	---	27.76
Germany	1	02/07/08	04/14/08	1	20.0%	5.00
	2	04/15/08	05/12/08	1	48.9%	2.05
	3	05/13/08	05/18/08	3	72.5%	4.14
	4	05/19/08	05/21/08	1	49.5%	2.02
	5	05/22/08	05/30/08	4	78.6%	5.09
	6	05/31/08	06/03/08	1	58.0%	1.73
	7	06/04/08	06/07/08	1	83.1%	1.20
	8	06/08/08	06/22/08	0	28.4%	0.00
			Total	12	---	18.29

TABLE 3-3.—Overwinter survival (S) of coho in Mill, Abernathy, and Germany creeks (2006 brood year). Overwinter survival was the expanded recaptures (r_{exp}) divided by the total tagged fish that were released (n_1).

Watershed	r_{exp}	n_1	S
Mill	51	351	14.4%
Abernathy	28	1,003	2.8%
Germany	18	1,040	1.8%

Discussion

For BY 2006 coho, late summer parr abundance in Mill Creek was less than half that of Abernathy and Germany creeks. This difference in the estimates was also reflected in the low capture rates of parr in Mill Creek. Low encounter rates resulted in just 351 coho parr being tagged in Mill Creek in the summer of 2007, although the goal is to tag at least 1,000 parr in each creek. Parr abundance in Mill Creek may have been limited by lower escapement in 2006. The number of coho redds observed during fall spawner surveys in Mill Creek (n = 6) was 50% of those observed in Germany (n = 12) and 14% of those observed in Abernathy Cr. (n = 42).

Overwinter survival of the BY 2006 coho was notably lower in Abernathy and Germany creeks than Mill Creek. Low survival may have resulted from a large storm event in early December of 2007. This storm occurred during the overwinter rearing period and involved record flooding on all three watersheds. Abernathy and Germany creeks are steeper in gradient than Mill Creek, with minimal channel complexity and little off-channel habitat. In Mill Creek, channel complexity and off-channel habitat can provide refuge for juvenile coho during high flow events. In Abernathy and Germany Creeks, steeper gradients combined with low summer flows may displace parr out of the upper reaches. Displacement of parr into lower reaches of the stream in late summer makes them susceptible to premature entry into the Columbia River during high winter flows. Physiological stress associated with displacement, combined with the uncertain rearing conditions downstream (i.e., predation), is likely to result in low survival.

Assumptions

The mark-recapture approach used to derive abundance and survival estimates was based on six assumptions (Hayes et al. 2007). Violation of an assumption has potential to bias estimates derived from the mark-recapture study. Consideration of assumptions and the accuracy of abundance and survival estimates are discussed below.

Assumption 1. Population is geographically closed and no immigration or emigration has occurred. This assumption would be violated if juvenile coho moved into or out of a creek between the mark period (early September) and the recapture period (January through June). Coho emigration between September and January would be unusual; however, the large winter flooding event in December 2007 may have involuntarily swept juvenile coho into the Columbia River. In addition, fall emigration of juvenile coho is observed on East and West Twin creeks, tributaries to the Straits of Juan de Fuca (Roni et al. 2008). Parr abundance estimates should not be impacted by emigration because these estimates rely on the relative (not absolute) numbers of tagged to untagged fish caught in the screw traps. Survival estimates reported here are underestimated if early emigration occurred and the early emigrants survived at a similar rate as the typical emigrants. Immigration of juvenile coho between September and January is unlikely. PIT tag recoveries at the screw trap support the assumption that coho migration among neighboring creeks is minimal to none.

Assumption 2. Population is demographically closed with no births or deaths. This assumption would be violated if additional recruitment occurs into a cohort or if a portion of the cohort dies. While the birth component of this assumption is met, the back-calculation approach to estimating abundance clearly violates the death component. Mortality is expected between tagging and recapture periods and should not produce a biased abundance estimate unless the mortality rate differs between marked and unmarked fish. Differential mortality is discussed under assumption 6 below.

Assumption 3. No marks are lost or missed. This assumption would be violated if individual fish lose PIT tags, PIT tags are not detected from fish captured in the downstream traps, or emigrating smolts with PIT tags are not caught in the downstream trap. Tag loss and mortality associated with PIT tagging of juvenile salmon has been shown to be minimal (1-2%) between the parr and smolt life history stage (Knudsen et al. 2009; Prentice et al. 1994) and should not violate this assumption. Detection of tagged fish in the downstream trap is likely accurate as hand-held detectors are operated by experienced field staff who thoroughly scan each fish.

However, some tagged fish are missing during emigration because the downstream traps are partial capture. Missed tags due to partial-capture traps should not bias the abundance estimate unless the trap affinity of tagged versus untagged fish differs. Differential behavior of tagged and untagged fish is discussed under assumption 4 below. Missed tags due to partial-capture traps will underestimate overwinter survival. In order to account for this bias, recapture rates were expanded by trap efficiency.

Assumption 4. Marking does not change fish behavior or vulnerability to capture. This assumption would be violated if tagged coho were recaptured at a different rate than untagged coho. If tagged coho are more prone to capture than untagged coho, parr abundance will be underestimated. If tagged coho are less prone to capture than untagged coho, parr abundance will be overestimated. The catchability of tagged versus untagged coho is not known.

Assumption 5. Marked fish mix at random with unmarked fish. This assumption would be violated if tagged fish migrated at a different time or with a different spatial distribution (with respect to the trap) than untagged fish. Given the widespread and random spatial distribution of the sample sites where coho were marked and the length of time between mark and recapture, adequate mixing of tagged and untagged fish is likely to occur. Differential behavior of tagged and untagged coho has the potential to bias recapture estimates and is discussed in assumption 4 above.

Assumption 6. All animals have an equal probability of capture that does not change over time. This assumption is violated if the recapture of tagged versus untagged fish varies over time. This assumption is met by stratifying recapture rates by trap efficiency when expanding recaptures missed by the partial-capture traps. This assumption is also violated if mortality rates differ between tagged and untagged fish. Mortality and tag loss of PIT tagged salmon appears to be minimal (1-2%) for pre-smolt Chinook and coho but substantial (13.2% – 59.1%) for the smolt to adult transition for both species (Knudsen et al. 2009; Prentice et al. 1994). Coho parr tagged in the Lower Columbia tributaries were substantially shorter than pre-smolt Chinook (yearling fish, >100-mm FL; Knudsen et al. 2009) and juvenile coho (>110-mmFL; Prentice et al. 1994) where tag-related mortalities were previously measured. In addition, coho parr in the Lower Columbia tributaries were tagged during the summer low flow period, an environmentally stressful time during the coho life history. If tagged fish have a higher mortality rate than untagged fish, recapture rates will be low, parr abundance overestimated, and overwinter survival will be underestimated. Potential bias created by tag loss or tag-related mortality is expected to be similar among watersheds and not affect relative differences observed.

Lower Columbia Smolt Evaluation

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Methods

Trap Operation

Rotary screw traps (5-ft or 1.5-m diameter) were operated near the mouth of Mill, Abernathy, and Germany creeks (Figure 1-2). Trap operations began in early February and continued through late June, when catches of all migrants declined to nearly zero. In mid-April, panels were added to each trap in order to increase efficiency. The trap position was moved slightly upstream into the flow and removable 8-foot (2.4-m) plywood or screened weir panels were installed above the trap. Panels were angled upstream to each bank. Panels direct more flow into the trap, increase screw rotation speed and improve overall capture efficiency. Capture efficiencies are particular important for the larger yearling fish (i.e., coho and steelhead) that begin their migration in mid-April. Yearling migrants have greater ability to behaviorally avoid the trap structure than the smaller subyearling migrants (i.e., Chinook).

In Mill Creek, the screw trap was installed at river mile 0.3 (RKm 0.5) and operated between 1630 on February 7 and 0830 on June 23. Panels were added on April 16. The trap fished a total of 3,109.5 hours over 138 days and was nonoperational on three occasions for a total of 170.5 hours. The Mill Creek trap did not operate between February 8 and 10 (40.5 hours) due to very high flows. The trap also did not operate between May 28-29 (35 hours) and June 16-19 (95 hours) due to high numbers of peamouth (*Mylocheilus caurinus*) migrating above the trap to spawn above the trap.

In Abernathy Creek, the screw trap was installed at river mile 0.4 (RKm 0.64) and operated between 1530 on February 7, 2008 and 0900 on June 22, 2008. Panels were added on April 15 and again on April 29. The Abernathy trap fished a total of 3,168 hours over 137 days and was nonoperational on five occasions for a total of 89.5 hours. The Abernathy Creek trap did not operate between February 8 and 9 (23.5 hours), May 16 (7.5 hours), May 29-30 (34.5 hours), May 31 (9 hours), and June 15-16 (14.5 hours).

In Germany Creek, the screw trap was installed at river mile 0.3 (RKm 0.5) and operated between 1400 on February 7, 2008 and 1000 on June 22, 2008. Panels were added on April 13. The Germany trap fished a total of 3,133 hours over 137 days and was nonoperational on five occasions for a total of 127 hours. The Germany Creek trap did not operate between February 8-9 (23.5 hours), May 16 (20 hours), May 30 (7.5 hours), June 1-2 (27 hours), and June 17-19 (49 hours).

Fish Collection

Each trap was checked at least twice daily. Juvenile fish were netted from the holding box into dishpans, anesthetized with tricaine-methane-sulfonate (MS 222), classified to species, and hand counted. Each fish was examined externally and scanned for tags that would indicate its status as a recapture from an efficiency trial (described below) or from the parr study (see Lower Columbia Parr Evaluation). Coho were electronically scanned for PIT tags using an ISO

Compatible RFID Portable Reader. Chinook, coho, steelhead, and cutthroat smolts were randomly sampled for size (fork length).

Multiple trap efficiency trials were conducted throughout the season for Chinook, coho, and steelhead. Steelhead efficiencies were used as a surrogate for cutthroat. Chinook were marked with Bismarck brown dye and coho and steelhead were marked with small fin clips. Fin clips were applied to either the caudal or pelvic fins and were rotated at the start of a new efficiency trial. Mark groups were released when catch was sufficient (*N* > 10). In Abernathy Creek, efficiency trials for steelhead were conducted with both natural-origin and hatchery-origin steelhead caught in the trap. Hatchery-origin steelhead were from the Abernathy Fish Technology Center (AFTC) operated by the United States Fish and Wildlife Service. All hatchery steelhead released by the AFTC were adipose clipped. These included two groups, one with coded-wire tags and one with PIT tags. Hatchery- origin steelhead were scanned for tags using a CWT detector and a PIT tag reader.

Coho smolts were coded-wire tagged in Mill and Germany Creeks and PIT tagged in Abernathy Creek. Coded-wire tags will be used to estimate harvest rate and PIT tags will be used to estimate survival to return rate.

Analysis

Production was the abundance of juvenile downstream migrants. Abundance was estimated using a single-trap, time-stratified mark-recapture approach. The general approach was to (1) calculate total catch, (2) group efficiency trials into strata (3) calculate abundance for each strata, (4) extrapolate migration prior to and post trapping, and (5) calculate total production.

(1) Calculate total catch. Total catch ($\hat{n}_2$) was the actual catch (c) summed with missed catch ($\hat{c}$) during periods of trap outages. Missed catch for a given period i was estimated as:

Equation 3-5

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

where:

$\overline{R}$ = Mean catch rate (fish/hour) from adjacent fished periods, and

T_i = time (hours) during missed fishing period i.

Variance associated with $\hat{n}_2$ was equivalent to that of the estimated catch ($\hat{c}$) as actual catch had no variance. Variance of total catch was estimated as:

Equation 3-6

$$Var(\hat{n}_2) = Var(\hat{c}) = T_i^2 * Var(\overline{R})$$

<u>(2) Group efficiency trials into strata</u>. A G-test (Sokal and Rohlf 1981)was used to determine whether adjacent efficiency trials were statistically different. Of the marked fish (n_1) released in each efficiency trial, a portion are recaptured (m_2) and a portion are not seen (n_1-m_2). If the seen:unseen [m_2:(n_1-m_2)] ratio differs between trials, the trial periods were considered as separate strata. However, if the ratio did not differ between trials, the two trials were pooled by into a single strata. A G-test determined whether adjacent efficiency trials were statistically

different. The α-level was corrected for multiple comparisons using a Bonferonni correction [α = 0.05/(T-1)] where T was the number of trials. Trials that did not differ were pooled and the pooled group compared to the next adjacent efficiency trial. Trials that did differ were held separately. Pooling of time-adjacent efficiency trials continued iteratively until the m_2:(n_1-m_2) ratio differed between time-adjacent trials. Once a significant difference is identified, the pooled trials are assigned to one strata and the significantly different trial is the beginning of the next strata.

<u>(3) Calculate abundance for each strata</u>. Abundance for a given strata *j* was calculated from total maiden catch ($\hat{n}_2$), marked fish released in that strata (n_1), marked fish recaptured in that strata (m_2). Abundance was estimated with a Peterson estimator with a Chapman correction (Seber 1973).

Equation 3-7

$$\hat{N}_j = \frac{(\hat{n}_{2j}+1)(n_{1j}+1)}{(m_{2j}+1)}$$

Variance associated with the Peterson estimator was modified to account for variance of the estimated catch during trap outages (derivation in Appendix A):

Equation 3-8

$$V(\hat{N}_j) = Var(\hat{n}_{2j})\left(\frac{(n_{1j}+1)(n_{1j}*m_{2j}+3n_{1j}+2)}{(m_{2j}+1)^2(m_{2j}+2)}\right)+\left(\frac{(n_{1j}+1)(n_{1j}-m_{2j})*\hat{n}_{1j}*(\hat{n}_{1j}+m_{2j}+1)}{(m_{2j}+1)^2*(m_{2j}+2)}\right)$$

<u>(4) Extrapolate migration prior to and post trapping</u>. A portion of the outmigration occurred outside the period of trap operation. Modality of the trap catches suggested that this migration was minimal. Pre- and post-trapping migration were estimated using linear extrapolation:

Equation 3-9

$$\hat{N}_{before} = \frac{\sum \hat{N}_i}{n}*\left(\frac{t}{2}\right)^2$$

Variance of the extrapolation was estimated as:

Equation 3-10

$$Var(\hat{N}_{before}) = \left(\frac{\sum\left(\hat{N}_i-\overline{N}\right)^2}{n(n-1)}+\frac{\sum Var(\hat{N}_i)}{n}\right)*\left(\frac{t^2}{2}\right)$$

where:

$\hat{N}_i$ = Migration estimate for the first days of actual trapping,

$\overline{N}$ = Average daily migration for the first/last days of actual trapping,

n = Number of daily migration estimated using in the estimate, and

t = Number of days between start/end of migration and the first/last day of trapping.

(5) Calculate total production. Total production was the sum of extrapolated migration and stratified abundance estimates:

Equation 3-11

$$\hat{N} = \hat{N}_{before} + \sum_{j=1}^{j=n} \hat{N}_j + \hat{N}_{after}$$

Total variance was the sum of extrapolated migration variances and stratified abundance variances. Confidence intervals and coefficient of variation associated with abundances were calculated from the variance (Appendix B, Equation B-1, B-2).

Results - Chinook

Production

In Mill Creek, 4,708 juvenile Chinook were captured. Missed catch was estimated to be 6 Chinook through the three outage periods, resulting in a total estimated catch of 4,714 juvenile Chinook (Table 3-4). Fifteen efficiency trials were conducted between February 21 and April 15, 2008. Marked juvenile Chinook (M = 965) were released in efficiency trials ranging between 21 and 170 fish. No efficiency trials occurred between April 17 and the end of June due to low catch rates. Efficiency trials were grouped into four strata that ranged between 14% and 45% efficiency. The fourth strata represented the period for which no actual efficiency data were collected. In the absence of actual efficiency data, migration for this strata was estimated by applying 2006 Germany Creek efficiency data to the 2008 Mill Creek catch between April 17th and June 23. Germany Creek 2006 efficiency data were applied because they were from a similar time frame and trapping conditions to the Mill Creek 2008 data. Measured production was estimated to be 29,464 juvenile Chinook (Table 3-4). Assuming the start and end of the outmigration were January 1 and July 31, an additional 531 juvenile Chinook migrated before (N = 497) and after (N = 34) the trapping period. Total production was estimated to be 29,995 juvenile Chinook (CV = 9.8%, Table 3-7).

In Abernathy Creek, 1,713 juvenile Chinook were captured. Missed catch was estimated to be 2 Chinook through the 5 outage periods, resulting in a total estimated catch of 1,715 juvenile Chinook (Table 3-5). Seven efficiency trials were conducted between February 29 and March 31, 2008. Marked juvenile Chinook (M = 307) were released in efficiency trials ranging between 39 and 63 fish. No efficiency trials occurred between April 1 and the end of June due to low catch rates. Efficiency trials were grouped into two strata that had efficiencies of 12% and 43%. The second strata represented the period after paneling, for which no efficiency data were available. Migration for this period was estimated using an adjusted coho efficiency. Coho recaptures in Abernathy Creek were adjusted using a Chinook to coho efficiency ratio when trials for the two species were conducted simultaneously in 2007. Measured production was estimated to be 10,771 juvenile Chinook (Table 3-5). Assuming the start and end of the outmigration were January 1 and July 31, an additional nine juvenile Chinook migrated before (N = 0) and after (N = 9) the trapping period. Total production was estimated to be 10,780 juvenile Chinook (CV = 13.5%, Table 3-7).

In Germany Creek, 3,917 juvenile Chinook were captured. Missed catch was estimated to be 60 Chinook through the five outage periods, resulting in a total estimated catch of 3,977 juvenile Chinook (Table 3-6). Fifteen efficiency trials were conducted between February 16 and March 30, 2008. Marked juvenile Chinook (M = 945) were released in efficiency trials ranging between 22 and 165 fish. No efficiency trials occurred in April through June due to low catch rates. Efficiency trials were grouped into five strata that ranged between 13% and 62% efficiency. The fifth strata represented the period for which no efficiency data existed. Migration for this period was estimated by applying 2006 Germany Creek efficiency data to the 2008 Germany Creek catch. Germany Creek 2006 efficiency data were applied because they were from a similar time frame and trapping conditions to those in 2008. Measured production was estimated to be 17,047 juvenile Chinook (Table 3-6). Assuming the start and end of the outmigration to be January 1 and July 31, an additional 597 fish migrated before (N = 547) and after (N = 50) the trapping period. Total production was estimated to be 17,644 juvenile Chinook (CV = 6.9%, Table 3-7).

TABLE 3-4.─Efficiency strata for juvenile Chinook outmigration in Mill Creek, 2008.

Strata	Dates		Total Catch	Variance	Marks		Migration	
j	Start	End	C_j	$V(C_j)$	M_j	R_j	N_j	$V(N_j)$
1	02/07/08	03/17/08	1,488	0.98	520	72	10,626	1,374,865
2	03/18/08	03/25/08	569	0.00	255	60	2,391	77,567
3	03/26/08	04/16/08	2,415	0.00	190	28	15,911	7,238,515
4	04/17/08	06/23/08	242	1.55	200	90	536	2,346
		Total	4,714	2.54	1,165	250	29,464	8,693,293

TABLE 3-5. ─Efficiency strata for juvenile Chinook outmigration in Abernathy Creek, 2008.

Strata	Dates		Total Catch	Variance	Marks		Migration	
j	Start	End	C_j	$V(C_j)$	M_j	R_j	N_j	$V(N_j)$
1	02/07/08	4/15/08	1,130	0.00	307	36	9,414	2,115,837
2	04/16/08	6/22/08	585	0.65	856	369	1,357	4,603
		Total	1,715	0.65	1163	405	10,771	2,120,440

TABLE 3-6. ─Efficiency strata for juvenile Chinook outmigration in Germany Creek, 2008.

Strata	Dates		Total Catch	Variance	Marks		Migration	
j	Start	End	C_j	$V(C_j)$	M_j	R_j	N_j	$V(N_j)$
1	02/07/08	03/12/08	799	18.06	253	65	3,078	113,352
2	03/13/08	03/14/08	352	0.00	157	55	995	12,948
3	03/15/08	03/30/08	1,094	0.00	420	56	8,087	1,023,996
4	03/31/08	04/13/08	985	0.00	115	30	3,689	320,873
5	04/14/08	06/22/08	747	32.00	84	52	1,199	10,799
		Total	3,977	50.07	1,029	258	17,047	1,481,969

TABLE 3-7.—Production of juvenile Chinook in Mill, Abernathy, and Germany creeks, 2008.

Watershed	Production	Low 95% C.I.	High 95% C.I.	CV
Mill	29,995	24,216	35,775	9.80%
Abernathy	10,780	7,926	13,634	13.50%
Germany	17,644	15,255	20,033	6.90%

Body Size

In Mill Creek, captured Chinook ranged between 32 and 81-mm FL (*n* = 144, Appendix C-5). During the majority of the migration (February through April), weekly average lengths were consistently between 34-mm and 39-mm FL (Figure 3-2*a*). In May and June, weekly average lengths of captured Chinook increased from 50-mm FL on statistical week 20 to 62-mm FL on statistical week 26.

In Abernathy Creek, juvenile Chinook ranged between 34 and 78-mm FL (*n* = 141, Appendix C-6). During the majority of the migration (through mid-May), weekly average lengths were consistently between 35-mm and 39-mm FL (Figure 3-2*b*). In late May and June, captured Chinook were notably longer; weekly average lengths increased from 43-mm to 65-mm FL during this period.

In Germany Creek, juvenile Chinook ranged between 33 and 95-mm FL (*n* = 233, Appendix C-7*)*. Weekly average lengths ranged between 35 and 39-mm FL through April (Figure 3-2*c*). In May and June, average weekly lengths increased from 49 to 63-mm FL.

Migration Timing

In Mill Creek, the first juvenile Chinook was caught on February 10, 2008. Peak migration occurred between statistical week 11 and 15 (March 10-April 13, Figure 3-3*a*). After this period, outmigrant abundance steadily declined. The median outmigration date was March 28, 2008 (Figure 3-4).

In Abernathy Creek, catch of juvenile Chinook was zero through most of February. On the last two days of February, 43 and 17 fish were caught, respectively. The outmigration of juvenile Chinook peaked on statistical week 14 (March 31–April 6) and then declined rapidly through statistical week 19 (May 12–18, Figure 3-3*b*). The median migration date of juvenile Chinook was April 1 (Figure 3-4).

In Germany Creek, 11 juvenile Chinook were captured over the first 26.5 hours of trapping (prior to the outage). Outmigrant abundance remained low through the end of statistical week 8 (February 24). Peak migration occurred on statistical week 12 (March 17-23, Figure 3-3*c*). A second smaller peak occurred between statistical weeks 21 and 23. The median migration date for juvenile Chinook was March 22 on Germany Creek (Figure 3-4).

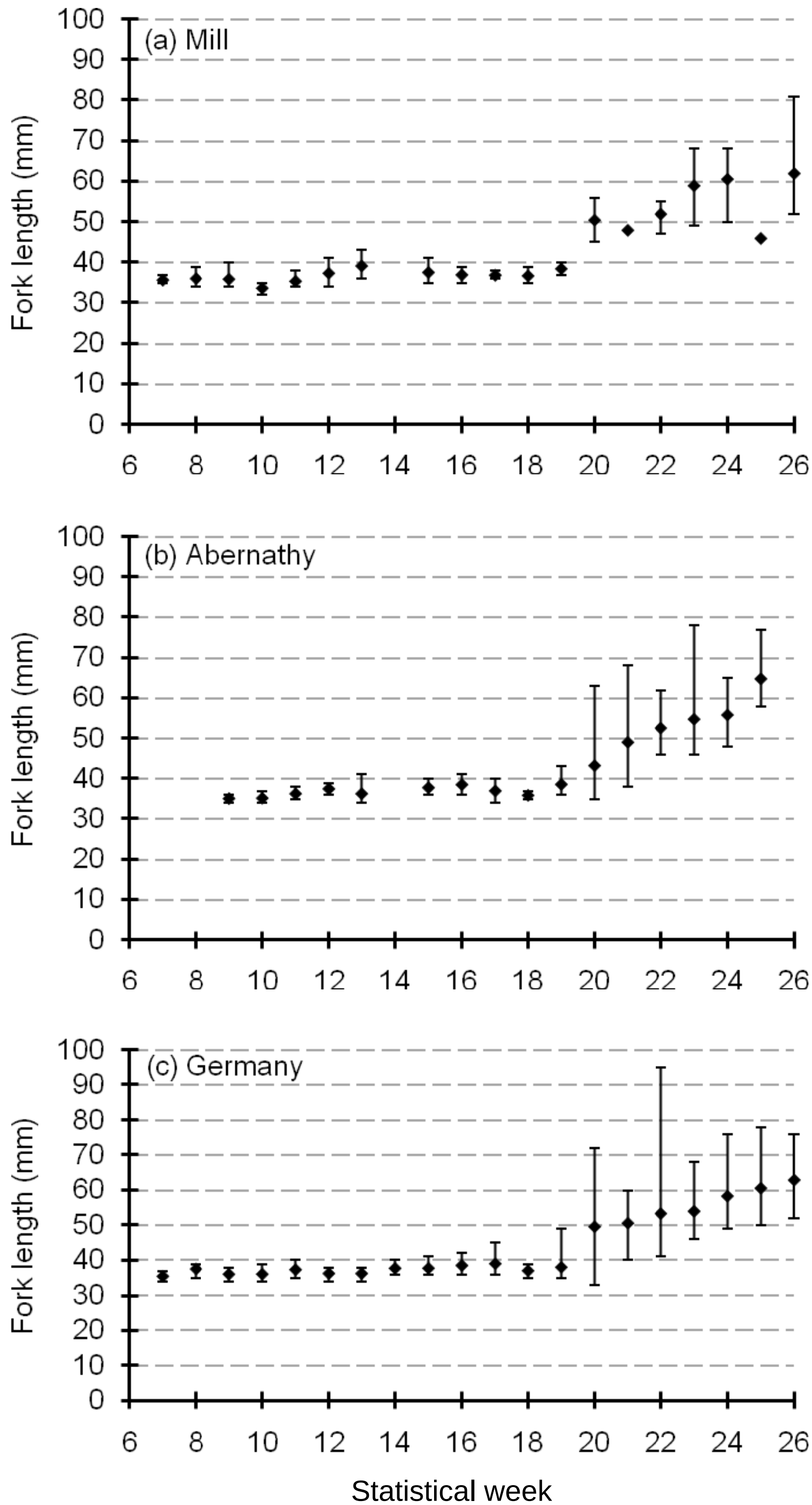

FIGURE 3-2. ─Lengths of juvenile Chinook migrants captured on Mill (*a*), Abernathy (*b*), and Germany (*c*) creeks, 2008. Data are mean, minimum, and maximum fork lengths (mm) by statistical week.

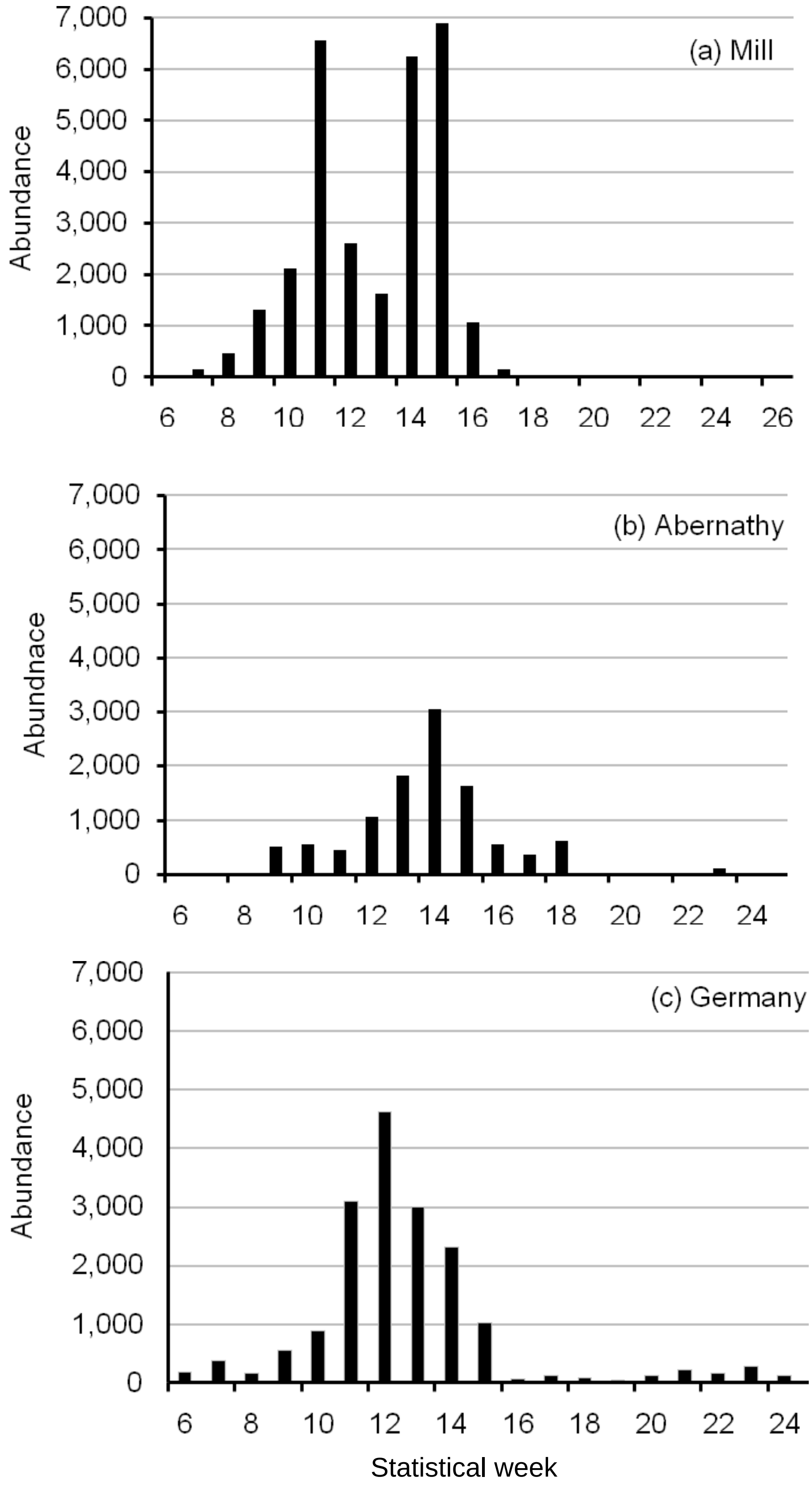

FIGURE 3-3.─Migration timing of juvenile Chinook in Mill (*a*), Abernathy (*b*), and Germany (*c*) creeks, 2008. Data are estimated outmigrant abundances by statistical week.

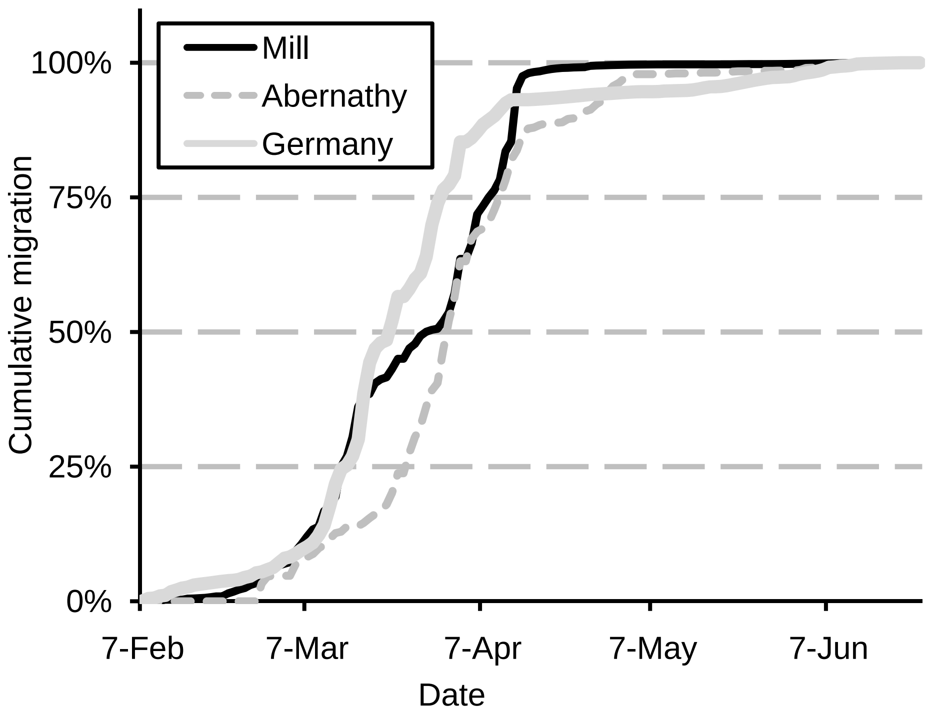

FIGURE 3-4. —Cumulative migration of juvenile Chinook in Mill, Abernathy, and Germany creeks, 2008. Data are percent of cumulative migration on a daily basis.

Results – Coho

Production

In Mill Creek, 4,153 coho smolts were captured and 2,532 (61%) of these were coded-wire tagged (tagcode 63-45/85). Missed catch was estimated to be 232 coho smolts during the three trap outage periods, resulting in a total estimated catch of 4,385 coho (Table 3-8). Twenty-four efficiency trials were conducted between February 11 and June 21, 2008. Marked coho smolts (M = 2,155) were released in efficiency trials ranging between 9 and 197 fish. Efficiency trials were grouped into seven strata with efficiencies between 14% and 73%. Measured production was estimated to be 9,781 coho smolts (Table 3-8). Assuming the start and end date of the outmigration were January 1 and July 31, an additional 1,149 smolts migrated before (N = 807) and after (N = 342) the trapping period. Total production was estimated to be 10,930 coho smolts (CV = 4.6%, Table 3-11).

In Abernathy Creek, 1,122 coho smolts were captured and 1,038 (92.5%) of these were PIT tagged. Missed catch was estimated to be 72 coho smolts during the five trap outage periods, resulting in a total estimated catch of 1,194 coho (Table 3-9). Fourteen efficiency trials were conducted between February 10 and June 8, 2008. Marked coho smolts (M = 875) were released in efficiency trials ranging from 7 to 104 smolts. Efficiency trials were grouped into four strata with efficiencies between 10% and 37%. Measured production was estimated to be 4,699 coho smolts (Table 3-9). Assuming the start and end dates of the outmigration were January 1 and

July 31, an additional 1,000 smolts migrated before (*N* = 984) and after (*N* = 16) the trapping period. Total production was estimated to be 5,699 coho smolts (*CV* = *6.6*%, Table 3-11).

In Germany Creek, 2,291 coho smolts were captured and 2,078 (90.7%) of these were coded-wire tagged (tagcode 63-45/84). Missed catch was estimated to be 185 coho smolts during the five trap outage periods, resulting in a total estimated catch of 2,476 coho (Table 3-10). Twenty-one efficiency trials were conducted between February 22 and June 12, 2008. Marked coho smolts (*M* = 958) were released above the trap in efficiency trials ranging from 5 to 95 smolts. Efficiency trials were grouped into eight strata that ranged between 20% and 83% efficiency. Measured production was estimated to be 3,867 smolts (Table 3-10). Assuming the start and end dates of the outmigration were January 1 and July 31, an additional 115 smolts migrated before (*N* = *93*) and after (*N* = 22) the trapping period. Total production was estimated to be 3,982 coho smolts (*CV* = 3.6%, Table 3-11).

TABLE 3-8. ─Efficiency strata for coho smolts in Mill Creek, 2008.

Strata	Dates		Total Catch	Variance	Marks		Migration	
j	Start	End	C_j	$V(C_j)$	M_j	R_j	N_j	$V(N_j)$
1	02/07/08	04/16/08	381	4	197	28	2,607	207,351
2	04/17/08	05/09/08	762	0	537	374	1,094	1,437
3	05/10/08	05/12/08	249	0	150	85	438	1,272
4	05/13/08	05/18/08	733	0	290	211	1,007	1,663
5	05/19/08	06/01/08	1,415	825	450	251	2,533	15,824
6	06/02/08	06/03/08	66	0	76	14	343	7,089
7	06/04/08	06/23/08	779	125	455	201	1,760	11,327
		Total	4,385	954	2,155	1,164	9,781	245,964

TABLE 3-9. ─Efficiency strata for coho smolts in Abernathy Creek, 2008.

Strata	Dates		Total Catch	Variance	Marks		Migration	
j	Start	End	C_j	$V(C_j)$	M_j	R_j	N_j	$V(N_j)$
1	02/07/08	04/15/08	72	0.3	19	2	486	51,016
2	04/16/08	05/05/08	67	0.0	52	6	514	30,836
3	05/06/08	05/19/08	508	13.7	393	145	1,373	10,460
4	05/20/08	06/22/08	547	32.7	411	96	2,327	50,175
		Total	1,194	47	875	249	4,699	142,486

TABLE 3-10. ─Efficiency strata for coho smolts in Germany Creek, 2008.

Strata	Dates		Total Catch	Variance	Marks		Migration	
j	Start	End	C_j	$V(C_j)$	M_j	R_j	N_j	$V(N_j)$
1	02/07/08	04/14/08	59	0.10	5	1	179	7,199
2	04/15/08	05/12/08	233	0.00	176	86	475	1,783
3	05/13/08	05/18/08	527	119.27	120	87	725	2,104
4	05/19/08	05/21/08	226	0.00	95	47	453	2,528
5	05/22/08	05/30/08	974	4.85	290	228	1,238	1,761
6	05/31/08	06/03/08	196	495.42	88	51	336	2,580
7	06/04/08	06/07/08	196	0.00	89	74	235	168
8	06/08/08	06/22/08	65	0.16	95	27	225	1,738
		Total	2,476	619.79	958	601	3,867	19,859

TABLE 3-11. ─Production of coho smolts in Mill, Abernathy, and Germany creeks, 2008. Production includes pre- and post-season extrapolations and in-season estimates.

Watershed	Production	Low 95% C.I.	High 95% C.I.	CV
Mill	10,930	9,954	11,906	4.6%
Abernathy	5,699	4,958	6,439	6.6%
Germany	3,982	3,704	4,259	3.6%

Body Size

In Mill Creek, coho smolts ranged from 65 to 185-mm FL (n = 405, Appendix C-8); weekly average lengths ranged between 78 and 112-mm FL and increased over time (Figure 3-5*a*). In Abernathy Creek, coho smolts ranged from 51 to 165-mm FL (n = 1,070, Appendix C-9). Weekly average lengths ranged between 74 and 117-mm FL, increased through mid-May (Figure 3-5*b*). In Germany Creek, coho smolts ranged from 66 to 154-mm FL (n = 177, Appendix C-10) with weekly average lengths ranging between 80 and 121-mm FL. The 151-mm FL coho smolt captured in early February and appeared to be age 2+. Similar to Abernathy Creek, coho lengths in Germany Creek increased through mid-May (Figure 3-5*c*).

Migration Timing

In Mill Creek, coho outmigration began around statistical week 11 or 12 (March 17-23). Migration steadily increased in early May and peaked during statistical week 23 (June 2-8). Migration declined to near zero by the last week of trapping (Figure 3-6*a*). The median migration date for coho smolts in Mill Creek was May 15 (Figure 3-7).

In Abernathy Creek, migration of coho was minimal until statistical week 18 (April 28-May 4). Migration peaked on statistical week 21 (May 19-25) and declined to nearly zero by the last week of trapping (Figure 3-6*b*). The median migration date for coho smolts in Abernathy Creek was May 18 (Figure 3-7).

In Germany Creek, coho smolt outmigration was nearly zero until statistical week 18 (April 28). Migration peaked on statistical week 21 (May 19-25) and declined to nearly zero by the last week of trapping (Figure 3-6*c*). The median migration date of coho smolts in Germany Creek was May 21 (Figure 3-7).

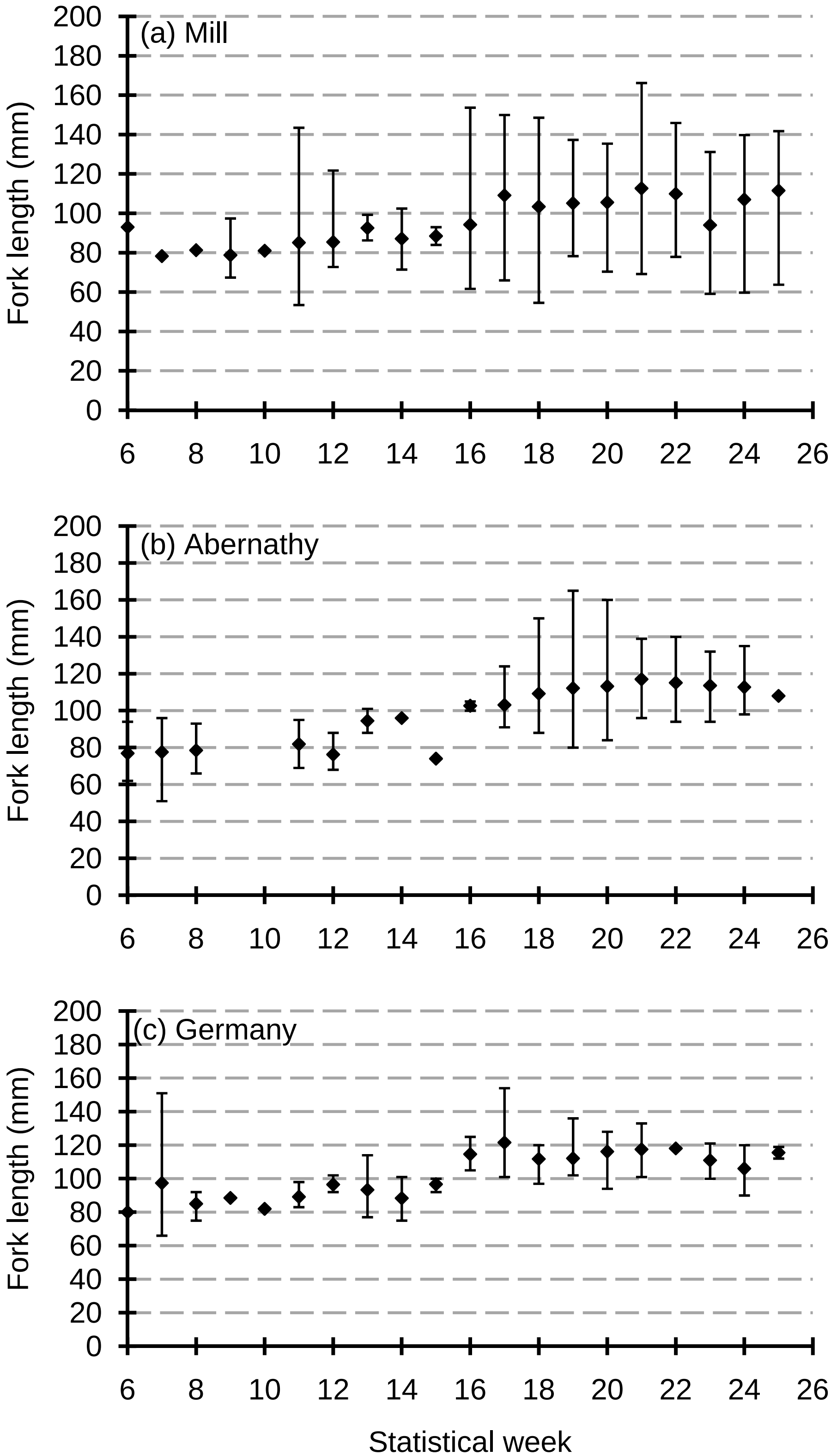

FIGURE 3-5. —Lengths of coho smolt migrants captured on Mill (*a*), Abernathy (*b*), and Germany (*c*) creeks, 2008. Data are mean, minimum, and maximum fork lengths (mm) by statistical week.

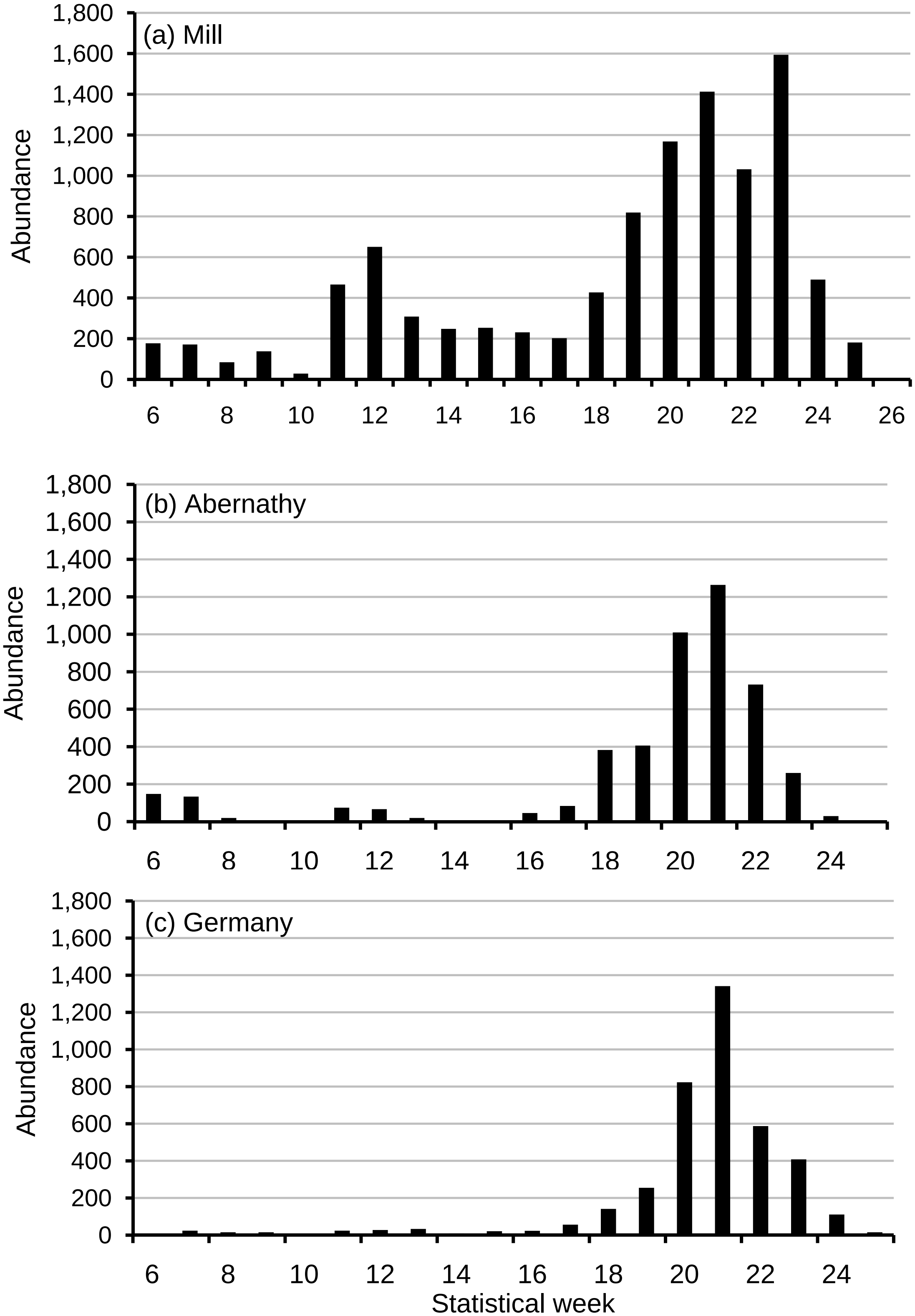

FIGURE 3-6. —Migration timing of coho smolt outmigration in Mill (*a*), Abernathy (*b*), and Germany (*c*) creeks, 2008. Data are abundance estimates by statistical week.

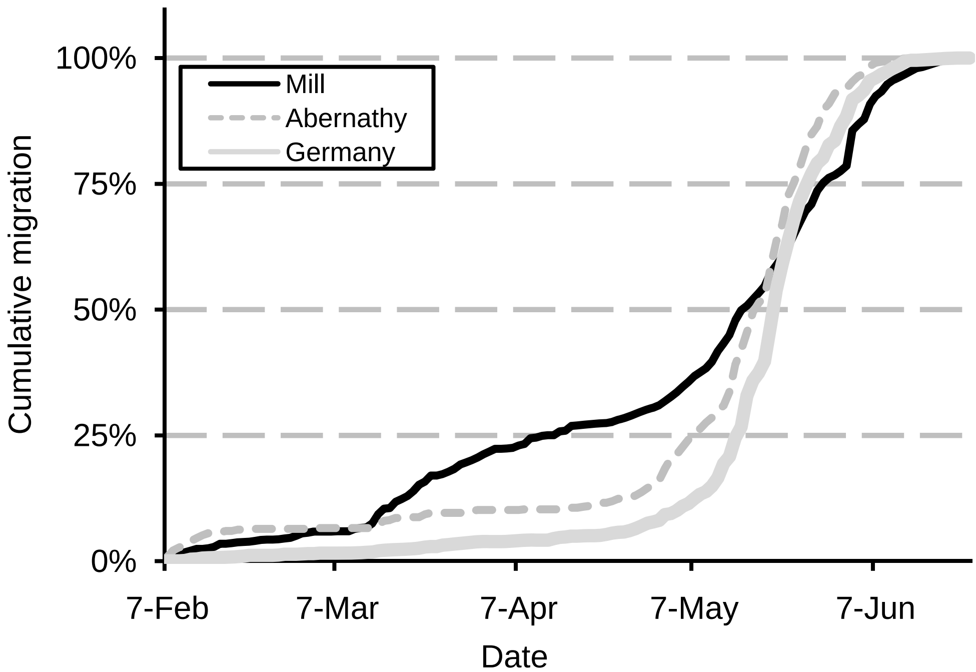

FIGURE 3-7. ─Cumulative migration of coho smolts in Mill, Abernathy, and Germany creeks, 2008. Data are percent of cumulative migration on a daily basis.

Results – Steelhead and cutthroat

Production

In Mill Creek, 441 steelhead smolts and 281 cutthroat smolts were captured. Missed catch during the three trap outage periods was estimated to be 5 steelhead and 29 cutthroat, resulting in a total estimated catch of 446 steelhead (Table 3-12) and 310 cutthroat. Efficiency trials for steelhead were applied to both steelhead and cutthroat catches. Marked steelhead smolts (M = 355) were released in 11 efficiency trials ranging between 15 and 60 fish. Efficiency trials were grouped into two strata with efficiencies between 10% and 39%. The first strata represented a period that no steelhead mark groups were released due to low catch numbers. For this period, steelhead marks and recaptures were based on coho efficiencies. For this calculation, coho recaptures were adjusted (downward) by the ratio of steelhead to coho efficiencies when the two species were caught simultaneously later in the season. Measured production was estimated to be 1,247 steelhead (Table 3-12) and 1,008 cutthroat. Assuming the start and end dates of the outmigration were January 1 and July 31, an additional 9 steelhead and 172 cutthroat smolts migrated before and after the trapping period. Total production was estimated to be 1,256 steelhead (CV = 7.5%, Table 3-15) and 1,180 cutthroat (CV = 8.4%).

In Abernathy Creek, 142 natural-origin steelhead smolts and 37 cutthroat smolts were captured. In addition to natural-origin steelhead, 1,208 hatchery- origin steelhead were captured. Of the hatchery steelhead, 1,151 scanned negative and 57 scanned positive for PIT tags. Missed catch during the five trap outage periods was estimated to be seven steelhead and one cutthroat, resulting in a total estimated catch of 149 natural-origin steelhead (Table 3-13) and 38 cutthroat. Efficiency trials were conducted with a combination of natural-origin and hatchery-origin steelhead in order to increase the size of release groups. Marked steelhead smolts (*M* = 347) were released in five efficiency trials ranging between 19 and 168 fish. Efficiency trials were grouped into two strata with efficiencies between 5% and 13%. The first strata represented a period that no steelhead mark groups were released due to low catch numbers. For this period, steelhead marks and recaptures were based on coho efficiencies. For this calculation, coho recaptures were adjusted (downward) by the ratio of steelhead to coho efficiencies when the two species were caught simultaneously later in the season. Measured production was estimated to be 1,192 natural-origin steelhead (Table 3-13) and 310 cutthroat. Assuming the start and end dates of the outmigration were January 1 and July 31, no additional steelhead and cutthroat smolts migrated before and after the trapping period. Total production was estimated to be 1,192 steelhead (*CV* = 15.1%, Table 3-15) and 310 cutthroat (*CV* = 19.3%,).

In Germany Creek, 1,723 steelhead smolts and 92 cutthroat smolts were captured. Missed catch during the five trap outage periods was estimated to be 137 steelhead and eight cutthroat, resulting in a total estimated catch of 1,860 steelhead (Table 3-14) and 100 cutthroat. Efficiency trials conducted with steelhead were applied to steelhead and cutthroat catches. Marked steelhead smolts (*M* = 1,005) were released in 19 efficiency trials ranging between 34 and 100 fish. Efficiency trials were grouped into eight strata with efficiencies between 20% and 67%. The first strata (prior to April 16) represented a period that no steelhead mark groups were released due to low catch numbers. For this period, steelhead marks and recaptures were based on coho efficiencies. For this calculation, coho recaptures were adjusted (downward) by the ratio of steelhead to coho efficiencies when the two species were caught simultaneously later in the season. Measured production was estimated to be 3,769 steelhead (Table 3-14) and 177 cutthroat. Assuming the start and end dates of the outmigration were January 1 and July 31, no additional steelhead and seven cutthroat smolts migrated before and after the trapping period. Total production was estimated to be 3,769 steelhead (*CV* = 4.6%, Table 3-15) and 184 cutthroat (*CV* = 7.4%).

TABLE 3-12. ─Efficiency strata for steelhead smolts in Mill Creek, 2008.

Strata	Dates		Total catch	Variance	Marks		Migration	
j	Start	End	C_j	$V(C_j)$	M_j	R_j	N_j	$V(N_j)$
1	02/07/08	04/16/08	14	0.00	197	20	139	1,739
2	04/17/08	06/23/08	432	5.45	355	138	1108	7,081
		Total	446	5.45	552	158	1247	8,820

TABLE 3-13. ─Efficiency strata for natural-origin steelhead smolts in Abernathy Creek, 2008.

Strata	Dates		Total Catch	Variance	Marks		Migration	
j	Start	End	C_j	$V(C_j)$	M_j	R_j	N_j	$V(N_j)$
1	02/07/08	04/15/08	8	0.0	19	1	95	2,832
2	04/16/08	06/22/08	141	1.6	347	44	1,097	29,787
		Total	149	2	366	45	1,192	32,619

TABLE 3-14. ─Efficiency strata for steelhead smolts in Germany Creek, 2008.

Strata	Dates		Total catch	Variance	Marks		Migration	
j	Start	End	C_j	$V(C_j)$	M_j	R_j	N_j	$V(N_j)$
1	02/07/08	04/15/08	7	0.00	5	1	25	167
2	04/16/08	05/05/08	261	0.00	164	76	560	2,770
3	05/06/08	05/07/08	94	0.00	83	17	442	9,481
4	05/08/08	05/09/08	110	0.00	100	57	192	404
5	05/10/08	05/12/08	148	0.00	128	48	391	2,506
6	05/13/08	05/18/08	727	750.41	139	84	1,198	9,361
7	05/19/08	05/21/08	114	0.00	78	24	362	4,160
8	05/22/08	06/22/08	399	51.40	313	209	597	968
		Total	1,860	801.82	1,010	516	3,769	29,817

TABLE 3-15. ─Production of steelhead and cutthroat smolts in Mill, Abernathy, and Germany creeks, 2008.

	Steelhead				Cutthroat			
Watershed	Production	Low 95% C.I.	High 95% C.I.	CV	Production	Low 95% C.I.	High 95% C.I.	CV
Mill	1,256	1,072	1,440	7.5%	1,180	985	1,375	8.4%
Abernathy	1,192	838	1,546	15.1%	310	193	428	19.3%
Germany	3,769	3,431	4,108	4.6%	184	157	211	7.4%

Body Size

In Mill Creek, steelhead smolts ranged from 122 to 209-mm FL (n = 88, Appendix C-10). Weekly average lengths ranged from 127 to 193-mm FL and were fairly consistent throughout the season, with the exception of an increase in the last three weeks of trap operation (Figure 3-8*a*). Cutthroat smolts ranged from 115 to 230-mm FL (n = 124, Appendix C-10). Weekly average lengths of cutthroat ranged from 126 to 192-mm FL and had an increasing trend over the trapping season (Figure 3-9*a*).

In Abernathy Creek, natural-origin steelhead smolts ranged from 112 to 210-mm FL (n = 85; Appendix C-11). Weekly average lengths ranged from 112 to 200-mm FL with no apparent trend throughout the season (Figure 3-8*b*). Cutthroat smolts ranged from 144 to 238-mm FL (n = 27; Appendix C-11) with weekly average lengths between 157 and 208-mm FL (Figure 3-9*b*).

In Germany Creek, steelhead smolts ranged from 118 to 232-mm FL (n = 107; Appendix C-12). Weekly average lengths ranged from 128 to 220-mm FL with no apparent trend throughout the season (Figure 3-8*c*). Cutthroat smolts ranged from 130 to 225-mm FL (n = 48; Appendix C-12) with weekly average lengths between 166 and 197-mm FL (Figure 3-9*c*).

Migration Timing

In Mill Creek, the steelhead outmigration was minimal until statistical week 16. Steelhead migration peaked on statistical week 18 (April 28–May 4) and declined to nearly zero by the end of the trapping season (Figure 3-10*a*). Fifty percent of the steelhead smolt migration had occurred by May 4 (Figure 3-11). Cutthroat migration occurred throughout the trapping period without any noticeable modality.

In Abernathy Creek, both natural-origin steelhead and cutthroat had a unimodal peak in their outmigration. Peak migration for both species occurred on statistical week 20 (May 12-18). Very few natural-origin steelhead or cutthroat migrated prior to statistical week 18 (Figure 3-10*b*). Median migration date for natural-origin steelhead and cutthroat was May 15 (Figure 3-11 and 3-12).

Germany, both steelhead and cutthroat had a unimodal peak in their outmigration. Peak migration for both species occurred during statistical week 20 (May 12-18). Migration of steelhead and cutthroat was minimal prior to statistical week 16 and after statistical week 24 (Figure 3-10*c*). Median migration date for steelhead was May 13 (Figure 3-11) and for cutthroat was May 23 (Figure 3-12).

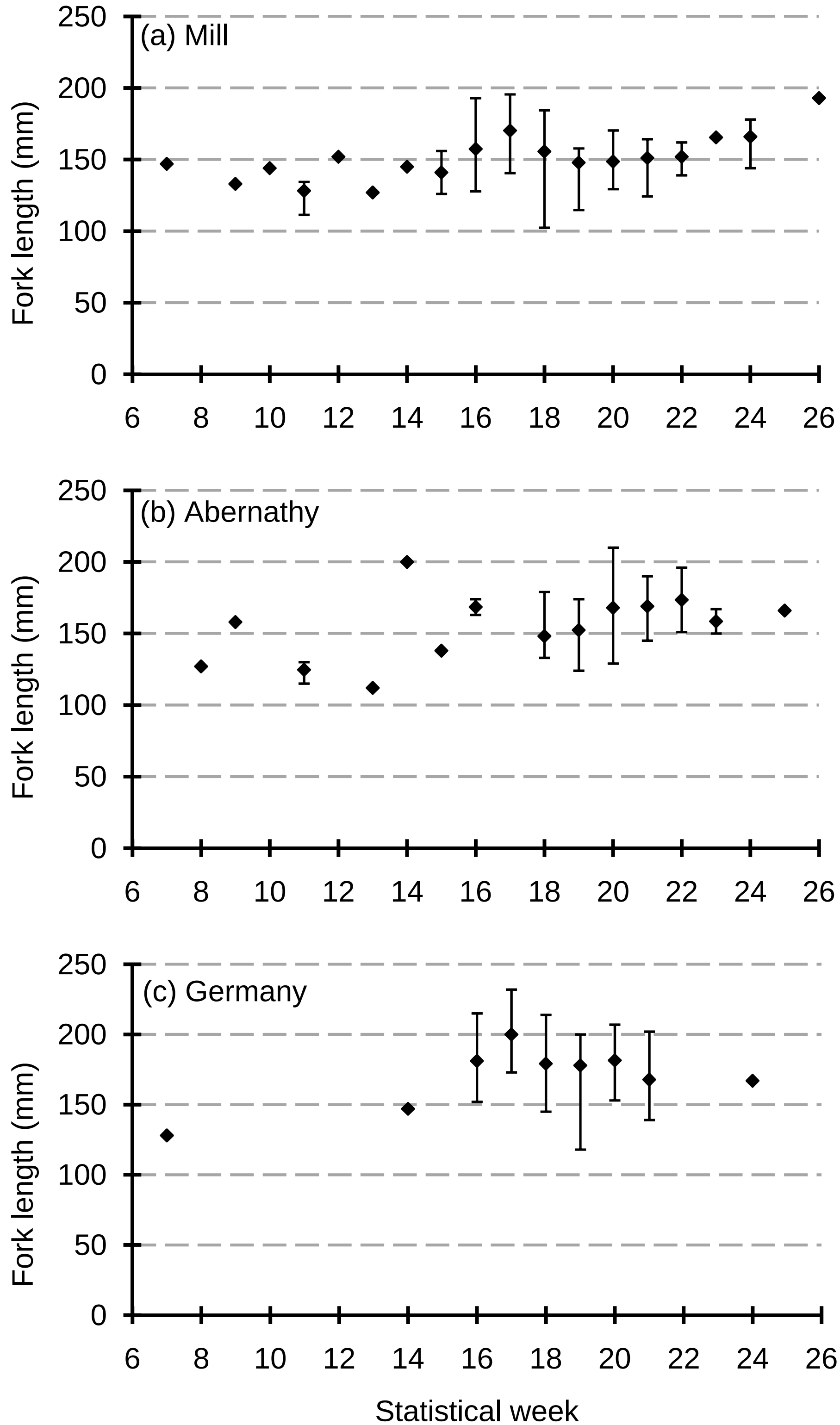

FIGURE 3-8.─Lengths of steelhead smolts captured on Mill (*a*), Abernathy (*b*), and Germany (*c*) creeks, 2008. Data are mean, minimum, and maximum fork lengths (mm) by statistical week.

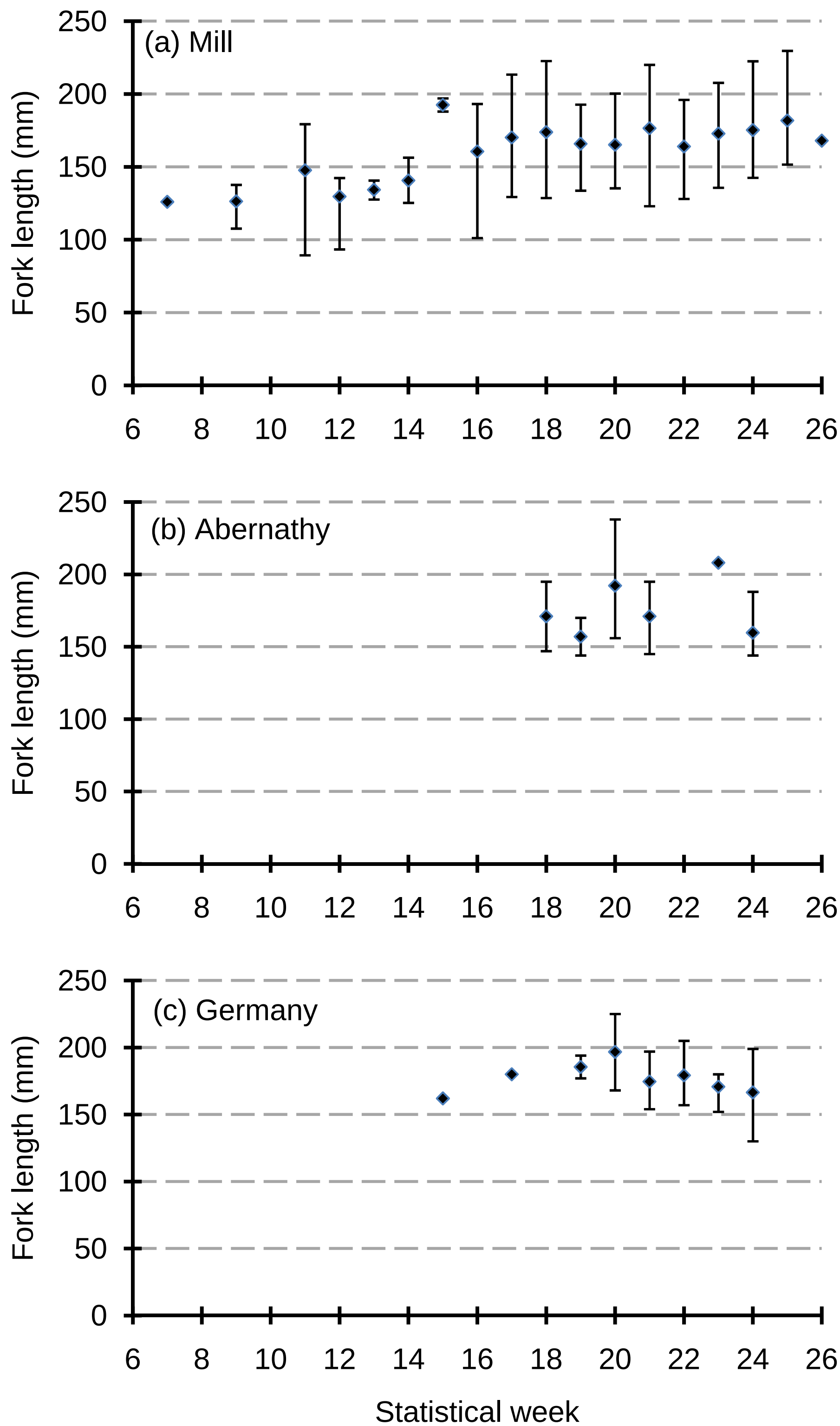

FIGURE 3-9. —Lengths of cutthroat smolts captured on Mill (*a*), Abernathy (*b*), and Germany (*c*) creeks, 2008. Data are mean, minimum, and maximum fork lengths (mm) by statistical week.

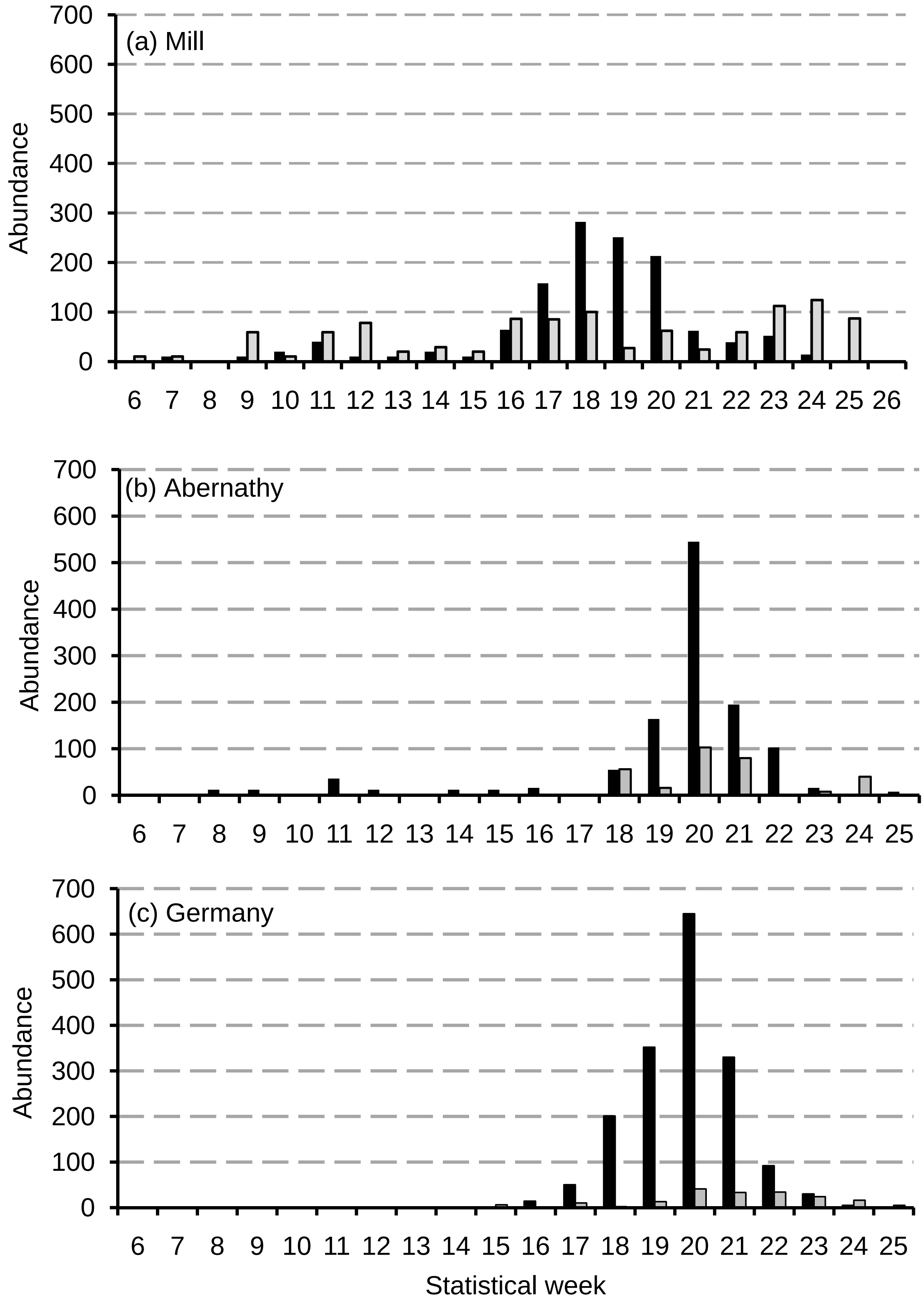

FIGURE 3-10. —Migration timing of natural-origin steelhead (black) and cutthroat (gray) smolt outmigration in Mill (*a*), Abernathy (*b*), and Germany (*c*) creeks, 2008. Data are abundance estimates by statistical week.

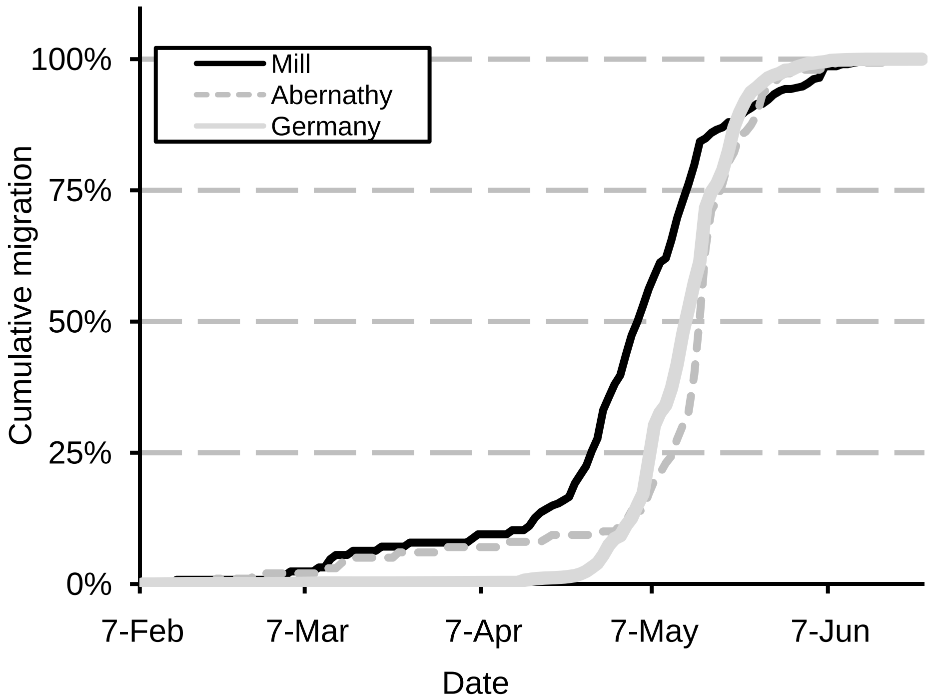

FIGURE 3-11. —Cumulative migration for steelhead in Mill (solid black), Abernathy (dashed gray), and Germany (solid gray) creeks, 2008. Data are percent cumulative migration on a daily basis.

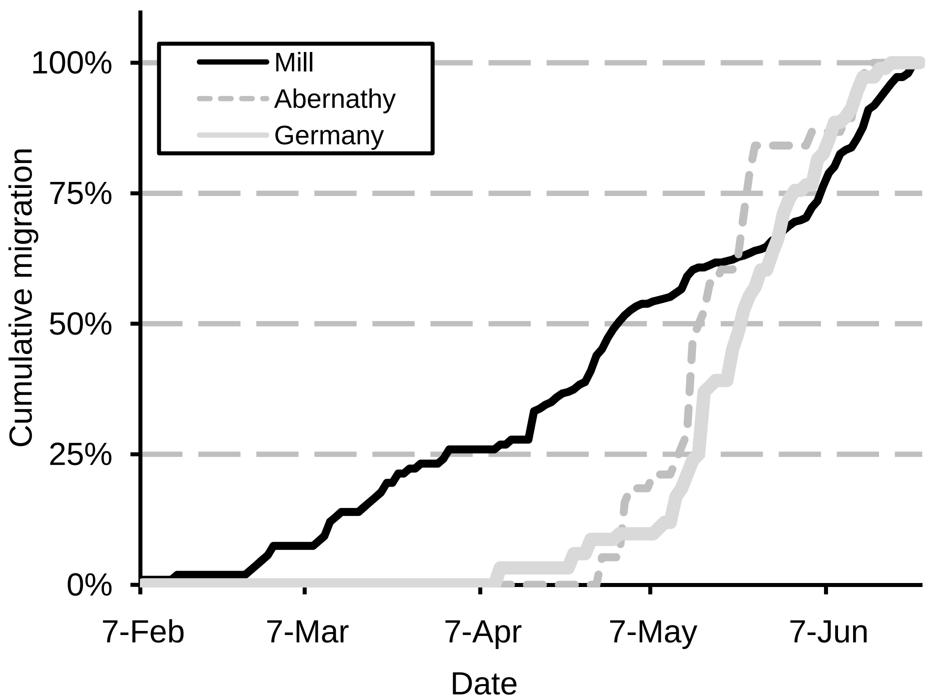

FIGURE 3-12. —Cumulative migration for cutthroat in Mill (solid black), Abernathy (dashed gray), and Germany (solid gray) creeks, 2008. Data are percent of cumulative migration on a daily basis.

Discussion

In 2008, production of Chinook, coho and cutthroat was highest in Mill Creek and production of steelhead was highest in Germany Creek. These trends are consistent with results from previous years. Over eight years of trapping, coho and cutthroat production have been highest in Mill and lowest in Germany Creek whereas steelhead production has been highest in Germany Creek and lowest in Mill Creek (Figure 3-13). Differences in production among these creeks may be influenced by stream gradient which is lowest in Mill Creek and highest in Germany Creek. Coho typically rear in pool habitat which is more abundant in low gradient streams such as Mill Creek. Steelhead prefer faster moving, mid-channel habitat which is more abundant in high gradient streams such as Germany Creek.

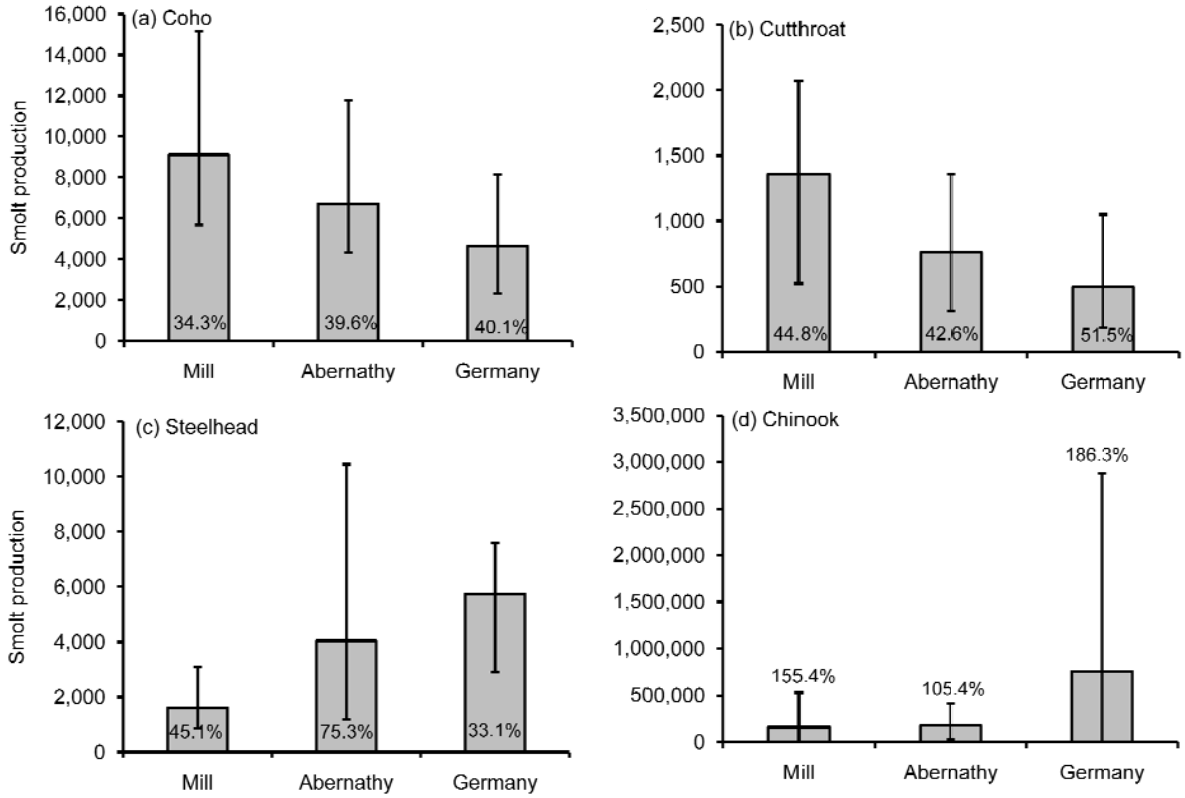

FIGURE 3-13. —Juvenile production of coho (*a*), cutthroat (*b*), steelhead (*c*), and Chinook (*d*) in Mill, Abernathy, and Germany creeks. Data are average, minimum, and maximum production, 2001-2008. Percentages (coefficient of variation) represent inter-annual variation in juvenile production.

In comparison to coho and steelhead, no trend in Chinook production has been apparent across watersheds (Figure 3-13). Inter-annual variation in Chinook production is much higher (CV = 105.4 to 186.3%) than inter-annual variation in coho (CV = 34.3% to 40.1%), cutthroat (CV = 42.6 to 51.5%), or steelhead production (CV = 33.1 to 75.3%). These results suggest that variables limiting Chinook production are less predictable than those limiting coho, cutthroat, or steelhead production. Chinook are distinct from these species in that juvenile migrants spend minimal time rearing in the creeks (maximum of 3-4 months). Variables limiting Chinook production may include escapement, spawning flows, and incubation flows. In comparison, coho, cutthroat, and steelhead rear for at least one year in freshwater. Juvenile production of these species may be limited by rearing conditions (e.g., low summer flows or high winter flows) that temper large variation in egg deposition and early life history survival.

In 2008, coho-to-cutthroat ratios ranged from 9.3 in Mill Creek, 18.4 in Abernathy, and 21.6 in Germany Creek. These ratios were consistent with the ratios measured in previous years. Average coho to cutthroat ratios over the eight years of evaluation has been 8.0 in Mill Creek, 10.0 in Abernathy Creek, and 12.0 in Germany Creek. These ratios are low compared to coho-to-cutthroat ratios between eight and 1,372 in other western Washington watersheds for the period between 1978 and 2001 (D. Seiler, personal communication). One hypothesis is that coho to cutthroat ratio decreases as stream gradient increases. This hypothesis may explain the low coho to cutthroat ratio in lower Columbia IMW streams (high gradient) relative to the Chehalis River basin (low gradient, 1978-2001 coho to cutthroat ratio = 713). However, this hypothesis is not supported within the IMW creeks. Coho to cutthroat ratios in Germany Creek (higher gradient; 2001-2008 average = 11.6) are higher than coho to cutthroat ratios in Mill Creek (low gradient; 2001-2008 average = 8.3). Another hypothesis is that coho to cutthroat ratios in Mill, Abernathy, and Germany creeks are influenced by low coho escapements. The lower Columbia River fisheries have historically been managed to maximize harvest of hatchery coho, a management approach that does not give priority to natural-origin escapements. The extent to which spawner escapements limit juvenile coho production in Mill, Abernathy, and Germany creeks is unknown. Spawner-smolt production curves for these creeks are limited by the logistical challenges associated with coho escapement estimates (see Adult Coho Evaluation section).

The combination of parr abundance, parr over-winter survival, and smolt production data demonstrates the importance of over-winter survival in determining smolt production for the BY 2006 coho. Although parr abundance in Mill Creek was less than half that of Abernathy or Germany creeks, coho smolt production in Mill Creek exceeded that of Abernathy by 5,231 smolts and Germany by 6,948 smolts. This difference resulted from a much higher overwinter survival in Mill Creek (14.4%) than Abernathy (2.8%) or Germany (1.8%) creeks (Table 3-3). These results suggest that habitat restoration projects aimed at increasing natural coho production should focus on enhancing habitat that increases over-winter survival (e.g., availability of sheltered areas during high winter flow events).

Assumptions

The mark-recapture approach used to derive juvenile production estimates was based on six assumptions (Hayes et al. 2007). Violation of an assumption has potential to bias estimates derived from the mark-recapture study. Consideration of assumptions and the accuracy of abundance and survival estimates are discussed below.

<u>Assumption 1. Population is geographically closed and no immigration or emigration has occurred.</u> This assumption is technically violated because all smolts are emigrating. However, the migration occurs over a defined time window and the time-stratified study design allows a more instantaneous measure of smolt abundance. The time-stratified study design does assume that all captured smolts are leaving the system. This assumption would be violated if some individuals establish residency within the creeks. Residency is unlikely for coho or Chinook but possible for cutthroat and steelhead. Estimates generated for these creeks reflect the migratory

production of all species and therefore underestimate total trout production (resident and anadromous).

Assumption 2. Population is demographically closed with no births or deaths. This assumption would be violated if new juveniles recruited into the cohort or if deaths occurred between the period of mark and recapture. With one exception, this assumption was met. Trapping occurred outside the spawning season (i.e., no births) and deaths between the period of mark and recapture were unlikely given the short time interval. A possible source of mortality was predation on juvenile fry in the live box of the trap. This bias is most likely to impact catch and recapture of Chinook fry (due to their small size) even though traps were checked regularly and every effort was made to minimize predation. If substantial predation occurred on maiden captures in the live box, catch and migration would be underestimated for this time period. If substantial predation occurred on recaptured fish in the live box, efficiency would be underestimated and migration overestimated for this time period.

Assumption 3. No marks are lost or missed. This assumption would be violated if dye or fin clips were not recognized on recaptured fish. This assumption was likely met. None of the marks used (clips, dye) were likely to be "lost" within the one to two day time frame between release and recapture. The frequency of undetected marks should also have been low given the highly trained staff performing both the marking procedure and collecting the recapture data. If marks were lost or undected, catch data would be inflated (individual would be recorded as maiden capture) and the recapture rate decreased. In combination, these errors would result in an underestimate of trap efficiency and an overestimate of migrant abundance.

Assumption 4. Marking does not change fish behavior or vulnerability to capture. This assumption would be violated if marked fish either avoided the trap or were more prone to capture than they were during the maiden capture event. Trap avoidance of marked fish would overestimate migrant abundance whereas trap attraction of marked fish would underestimate migrant abundance. Behavioral differences between maiden captures and recaptured fish are unknown. However, the ability to behaviorally avoid the trap under in-stream flows is more likely for coho or steelhead than the smaller subyearling Chinook.

Assumption 5. Marked fish mix at random with unmarked fish. This assumption would be violated if marked and unmarked fish were spatially or temporally distinct in their downstream movements. Spatial or temporal segregation could increase likelihood of recapture (underestimate migrant abundance) or decrease likelihood of capture (overestimate migrant abundance). Marked fish were generally released in the second riffle above the trap (approximately 100 m) and distributed across the creek during release. For this reason, we expect that random mixing did occur between marked and unmarked fish.

Assumption 6. All animals have an equal probability of capture that does not change over time. This assumption would be violated if trap efficiency changes over time or if some fish are not moving in a unidirectional downstream direction. Changes in trap efficiency are most likely to bias migration estimates if they occur during peak migration periods. Changes in trap efficiency are accommodated by stratifying the migration estimate into different time periods that incorporate time-specific mark and recapture data. Equal probability of capture would also be violated if a portion of the juvenile fish were caught because they were redistributing in the creek rather than in process of a downstream migration. Lack of unidirectional movement will result in an overestimate of migration because catch is overestimated and recaptures are underestimated. In this study, we believe that most if not all of the captured juvenile fish were in process of a downstream migration to the Columbia River. Marked fish were typically recaptured within a two day time frame; unique clip marks on the yearling fish indicate very few delayed recaptures occurred. Furthermore, juvenile traps are located just above the confluence with the Columbia River, and minimal river rearing habitat exists downstream of the traps.

Lower Columbia Adult Coho Evaluation

Authors: Patrick Hanratty and Mara Zimmerman

Methods

Abernathy Creek Weir

A resistance-board weir (RBW) was installed at RM 0.8 and began operation at 1600 hours on September 23, 2008. The trapping location was below all major tributaries and coho spawning sections of the stream. Throughout the season, weir integrity was compromised several times due to high flows. On November 8 and 9, high flows and heavy debris loads caused the weir panels to occasionally submerge, allowing fish to pass upstream undetected. After this period, the weir fished effectively for 1.5 days. On November 11, high flows following a heavy rainstorm fully collapsed the weir and inundated the live box by1000 hours. The weir was repaired on November 20 after flows dropped sufficiently. Between November 20 and December 24, the weir appeared to be fish tight and fishing well. On December 24, the weir blew out in response to extreme high flows caused by several days of heavy rain on existing snowpack. After this event, damage to the weir prevented its operation and continued high flows prevented safe access to make the needed repairs. The resistance-board weir did not operate after December 24, 2008.

The trap was checked at least daily and all coho were enumerated by sex, measured (FL), and checked for marks and tags (fin clips, coded-wire tags, and PIT tags). Scale samples were taken from all non-marked coho (adipose fin intact) and used to determine age and origin (natural versus hatchery). All adipose-clipped coho were assumed to be of hatchery origin. Fish were not lethally sampled for coded-wire tag recovery. All captured coho were marked with a left opercle punch prior to being released upstream.

Abernathy Fish Technology Center Electric Weir

Coho spawner escapement was sampled a second time at an electric weir operated by the USFWS Abernathy Fish Technology center (AFTC) at RM 3 (RKm 5). Coho sampled at this weir were those punched at the resistance board weir as well as non-punched coho that passed through the weir during high flow events. The AFTC electric weir trap began operation the week of October 17 and continued through mid-January 2009. Coho catch was enumerated by sex, origin (natural versus hatchery), and mark status (opercle punch or no punch). Coho were then transported a few hundred meters upstream into the upper watershed of Abernathy Creek.

Spawning Ground Surveys

Survey reaches for spawning ground surveys were previously delineated by habitat type using Ecosystem Diagnosis and Treatment model (EDT) reaches (IMWSOC 2005). In each watershed, survey reach delineation began at the top end of tidewater (EDT Reach 2), identified from vegetation and regular stage height changes. Within each EDT reach, a reference point (RP) was assigned every 100 meters. Within each EDT reach, RP 0 occurs at the downstream most end and RP values increase sequentially towards the upstream end of the reach. Flags and permanent markers serve as a marker for each RP and were placed on the nearest suitable site, usually a tree. In a few areas (e.g., Germany Creek Reach 6), RPs have not been marked due to landowner requests.

Bi-weekly surveys of spawning grounds were conducted on foot between mid-October and mid-December 2008 on each of the three creeks. Data from spawning ground surveys provided additional recaptures of opercle-punched coho on Abernathy Creek as well as spatial and temporal spawning distributions of coho spawning on all three creeks. Surveys were conducted in all main stem and tributary streams with known spawning habitat and in all areas found to contain coho spawners in previous years. Supplemental surveys were conducted on reaches outside this range if flows were high enough to provide access to coho spawners.

Surveys on all three creeks were conducted between the second week of October and the second week of December. After this time, access to roads in the upper watershed was prevented by storm damage that occurred in late December. One additional survey was conducted in Abernathy Creek on January 16, 2009.

During each survey, surveyors recorded the number of coho redds and the number of live and dead coho. Incidental observations of other species were also recorded. Redds were flagged and tails were cut from carcasses so that observations would not be recounted in subsequent surveys. Location of each redd was recorded as a latitude and longitude using a Garmin GPSMap76 unit. Precision of most coordinates was less than 100 ft and typically between five and 50 feet. In those cases where no signal was received, redd locations were assigned to the nearest known point, either another redd location or established reference points. These locations were generally within 50 m of the actual redd.

Coho Escapement into Abernathy Creek

A mark-recapture approach was used to estimate coho escapement into Abernathy Creek. A portion of the coho escapement was captured and punched at the resistance board weir. Coho escapement was resampled at the Abernathy Fish Technology Center (AFTC), on the resistance board weir, and on the spawning grounds. Spawning ground samples used in this analysis were restricted to the main stem and tributaries below the AFTC weir. Escapement estimate was stratified into six groups based on origin (natural versus hatchery) and sex and age class (females, males, jacks). Escapement was estimated using Chapman's modification of the Petersen estimate (Seber 1973):

Equation 3-12

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

and the variance was estimated by:

Equation 3-13

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

where:

$\hat{N}$ = Coho escapement into Abernathy Creek,

n_1 = Coho marked with opercle punch and released above the RBW,

n_2 = Coho sampled for marks at the RBW (fall backs), AFTC weir trap, and spawning grounds, and

m_2 = Punched coho recaptured at the RBW (fall backs), AFTC weir trap, and spawning grounds.

Survival-to-Return to Abernathy Creek

Survival to return of natural-origin coho to Abernathy Creek was calculated separately for jacks (BY 2006) and adults (BY 2005) because they represent different brood years. Survival-to-return was based on the number of smolts from the corresponding brood years that were marked (PIT tagged) and released during the downstream migration and the number of tagged coho that returned as spawners to the resistance board weir.

Survival to return ($\hat{s}$) was:

Equation 3-14

$$\hat{s} = \frac{\hat{m}_2}{n_{1adj}}$$

where:

$\hat{m}_2$ = Estimated return to Abernathy Creek of coho PIT-tagged and released from the smolt trap, and

n_{1adj} = Adjusted mark group of coho PIT-tagged and released from the smolt trap.

Estimated return of PIT-tagged coho ($\hat{m}_2$) was calculated by expanding the PIT-tagged coho recaptured at the RBW (m_2) by adult trap efficiency. Adult trap efficiency was the total coho caught in the RBW trap (n_2) divided by the total natural-origin escapement estimate of coho in Abernathy Creek ($\hat{N}_{NOR}$):

Equation 3-15

$$\hat{m}_2 = m_2 * \frac{\hat{N}_{NOR}}{n_2}$$

The adjusted release group of PIT tagged smolts (n_{1adj}) was adjusted by a rate of 63% in order to account for mortality and tag loss of marked fish. This percentage incorporates a 25% reduction rate due to general tag loss and mortality between smolt and adult (Knudsen et al. 2009) and a 16% reduction due to handling and tagging during the delicate smolt life stage (Blankenship and Hanratty 1990).

Variance of the survival-to-return estimate was calculated as the variance of an estimate and a constant (Appendix B-3).

Incidence of Natural-Origin Coho in Abernathy Creek Escapement

Incidence of natural-origin coho was calculated as:

Equation 3-16

$$\%NOR = \frac{\hat{N}_{NOR}}{\hat{N}_{NOR} + \hat{N}_{HOR}}$$

where:

$\%NOR$	=	Percent natural-origin coho calculated for Abernathy Creek,
$\hat{N}_{NOR}$	=	Natural-origin coho spawners estimated for Abernathy Creek, and
$\hat{N}_{HOR}$	=	Hatchery-origin coho spawners estimated for Abernathy Creek.

Variance of the percent natural-origin coho was estimated as the variance of the ratio of two estimates (Appendix B-5).

Coho Escapement into Mill and Germany Creeks

Natural-origin coho escapements into Mill and Germany creeks were calculated by applying survival to return at Abernathy Creek to smolt production in these creeks. Natural-origin escapement was calculated separately for jacks and adults as they represented two different brood years (2005 and 2006). Total escapement (natural and hatchery origin) into Mill and Germany creeks was the natural-origin estimate expanded by the incidence of natural-origin coho spawners in Abernathy Creek.

Natural-origin escapement ($\hat{N}_{NOR}$) in Mill or Germany creeks for a given brood year (*i*) was calculated as:

Equation 3-17

$$\hat{N}_{NOR} = \hat{P}_i * \hat{s}_i$$

where:

$\hat{N}_{NOR}$	=	Natural-origin coho escapement estimated for Mill or Germany creeks,
$\hat{P}_i$	=	Smolt production for brood year *i* from Mill or Germany creeks, and
$\hat{s}_i$	=	Survival-to-return of coho in brood year *i* to Abernathy Creek.

Variance of the natural-origin coho escapement was estimated as the variance of the product of two estimates (Appendix B-4).

Total coho escapement in Mill and Germany creeks was calculated as:

Equation 3-18

$$\hat{N}_T = \frac{\hat{N}_{NOR}}{\%NOR}$$

This total was summed for jack and adult coho. Variance of the total coho escapement was estimated as the variance of the ratio of two estimates (Appendix B-5).

Confidence intervals and coefficient of variation for all estimates were calculated (Appendix B-1 and B-2).

Spawner Distribution and Migration Timing

Spatial distribution of spawners was summarized by plotting redd locations for each of the three creeks. Spatial distribution was qualitatively described with respect to known landmarks (i.e., tributaries) and observed concentrations of redd deposition in each watershed. Spawning timing was evaluated from the density of redds observed per kilometer surveyed during each spawner survey period. Spawning timing could not be described from weir captures as an unknown number of coho passed the weir undetected during high flow events.

Results

Abernathy Creek Coho Escapement

The first adult coho was captured on October 3 and the last occurred on November 11, 2008. Over the season, a total of 204 (126 non-marked, 78 ad-marked) adult coho and 90 (20 non-marked, 70 ad-marked) jacks were captured (Table 3-16). One adult and one jack (both ad-marked) were moribund upon capture and released downstream. The remaining 203 adult coho (59 males, 63 females) and 89 jack coho were marked and released upstream in good condition.

In addition to coho, fourteen chinook (7 males, 5 females, 2 jacks) were captured and passed upstream between September 27 and October 29 (Table 3-16). Ten were non-marked and four were ad-marked. A total of nine steelhead adults (3 males, 6 females) were captured between October 3 and November 10, 2008. All but one female were ad-marked. One ad-marked male was PIT tagged and one ad-marked female had a CWT.

According to scale analysis, two non-marked coho were hatchery origin. Of the five non-marked coho with CWTs, two were hatchery origin (1 male, 1 jack) and three were natural origin (1 male, 2 females). The two hatchery coho were likely strays from a double index tag group released from Lewis River hatchery. The three natural-origin coho were likely coded-wire tags applied to smolts in Mill or Germany creeks.

Resampling of coho spawners occurred between early October and mid-January. A total of 170 adult and 73 jack coho were re-sampled (Table 3-17). Of the re-sampled adults, 108 (63.5%) were non-marked, and 62 (36.5%) were ad-marked. Of the re-sampled jacks, 30 (41%) were non ad-marked and 43 (59%) were ad-marked. The recapture sample included 68 adults (47 non-marked, 21 ad-marked,) and 34 jacks (12 non-marked, 22 ad-marked) that were opercle punched at the RBW. Coho marked with an opercle punch represented 40% of the adults and 46.6% of the jacks sampled.

Total coho escapement in Abernathy Creek was estimated to be 513 adults (CV = 8.5%) and 182 jacks (CV = 9.1%). (Table 3-18). Of the total escapement, 56% of adults and 27% of jacks were estimated to be of natural origin. (Table 3-19). Survival to return rate was estimated to be 1.85% for adults (BY 2005) and 0.37% for jacks (BY 2006, Table 3-20).

Coho Body Size in Abernathy Creek

For non-marked coho, adult male lengths ranged from 54 to 89-cm FL and females from 57 to 83-cm FL. For ad-marked coho, adult male lengths ranged from 56 to 90-cm FL and females from 60 to 82-cm FL. Jack lengths ranged from 32 to 49-cm FL(Table 3-21).

TABLE 3-16.—Disposition of adult and jack coho captured in the Abernathy resistance-board weir, 2008. Mark status refers to the presence or absence of an adipose fin on captured coho. Coho were either untagged, positive for coded-wire tags (CWT), or positive for PIT tags.

Mark status	Sex	Coho					Chinook	Steelhead
		Untagged	CWT	PIT	Total	Released upstream		
Non-marked	Male	58	2	1	61	61	4	3
	Female	59	2	4	65	65	5	6
	Jack	17	1	2	20	20	1	0
Ad-marked	Male	41	2	NA	43	42	3	0
	Female	34	1	NA	35	35	0	0
	Jack	69	1	NA	70	69	1	0
Subtotal	Male	99	4	1	104	103	7	3
	Female	93	3	4	100	100	5	6
	Jack	86	2	2	90	89	2	0
Total adults		192	7	5	204	203	12	9

TABLE 3-17.—Coho re-sampled on Abernathy Creek from the Abernathy Technology Center (AFTC) electric weir, spawner surveys, and fall back on the resistance board weir (RBW), 2008. Coho were marked (punched) when captured in the RBW upstream trap. Resample data were stratified by sex and age into male (M), female (F), and jack (J).

		AFTC				Spawner Survey				RBW			
Mark Status	Sex	Punched	No Punch	Total	%P	Punched	No Punch	Total	%P	Punched	No Punch	Total	%P
Non-marked	M	26	35	61	43%	3	2	5	60%	3	3	6	50%
	F	9	18	27	33%	0	2	2	0%	6	1	7	86%
	J	12	18	30	40%	0	0	0	-	0	0	0	-
Ad-marked	M	12	16	28	43%	1	1	2	50%	0	0	0	-
	F	3	21	24	13%	0	2	2	0%	5	1	6	83%
	J	14	19	33	42%	2	0	2	100%	6	2	8	75%
Subtotal	M	38	51	89	43%	4	3	7	57%	3	3	6	50%
	F	12	39	51	24%	0	4	4	0%	11	2	13	85%
	J	26	37	63	41%	2	0	2	100%	6	2	8	75%
Total Adults		50	90	140	36%	4	7	11	36%	14	5	19	74%

TABLE 3-18.─Coho escapement stratified by sex, age, and origin in Abernathy Creek, 2008.

Variable/Estimate	Non marked				Ad-Marked				Total	
	Male	Female	Adult	Jack	Male	Female	Adult	Jack	Adults	Jacks
Marks released (m)	61	65	126	20	42	35	77	69	203	89
Recaptures (r)	32	15	47	12	13	8	21	22	68	34
Catch (c)	72	36	108	30	30	32	62	43	170	73
N	136	152	288	49	94	131	225	133	513	182
V(N)	141	588	729	39	223	949	1172	238	1,901	277
95% C.I. (+/-)	23	48	53	12	29	60	67	30	85	33
CV	8.7%	16.0%	9.4%	12.7%	15.8%	23.5%	15.2%	11.6%	8.5%	9.1%

TABLE 3-19.─Estimate of natural and hatchery-origin coho adults and jacks in Abernathy Creek, 2008.

Estimate	Adult	Jacks
N_{NOR}	288	49
Var(N_{NOR})	729	39
N_{HOR}	225	133
Var (N_{HOR})	1,172	238
N_{TOTAL}	513	182
Var (N_{TOTAL})	1,901	277
% NOR	56.10%	26.90%
Var (% NOR)	0.51%	0.18%

TABLE 3-20.─Survival-to-return of jack and adult coho returning to Abernathy Creek, 2008.

Variable/Estimate	Jack	Adult
Brood Yr	2006	2005
Tag Year	2008	2007
# PITagged smolts	1,039	983
Adjusted # Tagged (m)	655	619
2008 Return	1	5
Adjusted 2008 return (r)	2	11
Var (r)	96	4,994
Survival to return (s)	0.37%	1.85%
Var (s)	0.02%	1.30%

TABLE 3-21.─Fork length (cm) mean, standard deviation (St. Dev.), and range of adult and jack coho captured at the Abernathy Creek resistance board weir, 2008.

	Non Marked			Ad-Marked		
	Male	Female	Jack	Male	Female	Jack
Average	72.0	72.8	41.4	76.6	74.5	41.0
St. Dev.	8.03	4.91	2.81	7.25	4.79	3.06
Range	54-89	57-83	35-48	56-90	60-82	32-49

Coho Escapement into Mill and Germany Creeks

Coho escapement into Mill Creek was estimated to be 306 adults and 150 jacks (Table 3-22). Coho escapement into Germany Creek was estimated to be 84 adults and 55 jacks. Coefficients of variation associated with these estimates were very high due to the number of estimates and their associated variances.

TABLE 3-22.─Coho escapement estimated for Mill and Germany creeks, 2008. Natural-origin coho were estimated from smolt production in Mill and Germany creeks and survival-to-return rate measured at Abernathy Creek. Total coho escapement was the natural-origin escapement expanded for hatchery strays.

Estimate	Mill Creek			Germany Creek		
	Jack	Adult	Total	Jack	Adult	Total
Brood year	2007	2006		2007	2006	
Smolt year	2008	2007		2008	2007	
Smolts (*P*)	10,930	9,289	N/A	3,982	2,556	N/A
V(P)	247,907	823,365	N/A	19,985	11,763	N/A
Survival (*s*)	0.37%	1.85%	N/A	0.37%	1.85%	N/A
V(s)	0.02%	1.30%	N/A	0.02%	1.30%	N/A
N_{NOR}	40	172	212	15	47	62
$V(N_{NOR})$	23,847	1,111,290	1,135,137	3,168	84,782	87,949
% NOR	26.90%	56.14%	N/A	26.90%	56.14%	N/A
V(% NOR)	0.18%	0.51%	N/A	0.18%	0.51%	N/A
N_{TOTAL}	150	306	456	55	84	139
$V(N_{TOTAL})$	321,918	3,470,780	3,792,698	42,760	264,790	307,550
95% C.I.	1,112	3,651	3,817	405	1,009	1,087
CV	377.40%	608.62%	426.70%	377.50%	610.90%	399.00%

Coho Spawner Distributions

Four spawner surveys were completed on all three creeks, and a fifth survey was completed in Abernathy Creek after the winter flooding event (Table 3-23). Surveys covered a cumulative distance of 285 kilometers (Table 3-24). A total of 201 live spawners and 270 redds were observed in the three watersheds. Average redd encounter rate was highest in Germany Creek (1.2 R/km), intermediate in Mill Creek (0.99 R/km), and lowest in Abernathy Creek (0.72 R/km).

TABLE 3-23.—Coho spawner survey periods and distance covered in Mill, Abernathy and Germany creeks, 2008-2009.

Survey Period No.	Mill		Abernathy		Germany	
	Dates	Distance (km)	Dates	Distance (km)	Dates	Distance (km)
1	10/ 13-10/21	22.3	10/21-10/22	17.8	10/23	14.9
2	10/ 27-10/29	21.5	10/30-11/3	24.0	11/7-11/10	22.0
3	11/11-11/18	25.5	11/18-11/21	31.6	11/24-11/26	22.6
4	12/ 1-12/3	24.7	12/3-12/9	33.2	12/9-12/11	22.4
5	NA	NA	1/ 16	2.5	NA	NA
Total	10/13 – 12/3	94	10/21-1/16	109.1	10/23-12/11	81.9

TABLE 3-24.—Live coho, redds, and carcasses observed during in spawning ground surveys on Mill, Germany, and Abernathy creeks, 2008.

Stream	Total km	Live	Live/km	Redds	Redds/km	Carcass	Carcass/km
Mill	94	87	0.93	93	0.99	19	0.20
Abernathy	109.1	59	0.54	79	0.72	18	0.16
Germany	81.9	55	0.67	98	1.20	38	0.46
Total	285	201	0.71	270	0.95	75	0.26

Spawning activity was unevenly distributed in each watershed (Figure 3-14). In Mill Creek, spawning activity was greatest just below the confluence of main stem Mill Creek and North Fork Mill Creek and in the upper most extent of Mill Creek. In Abernathy Creek, spawning was concentrated near the confluence of Abernathy and Cameron creeks and downstream of the AFTC electric weir. Coho spawning in the upper watershed of Abernathy Creek was dispersed with no defined areas of redd concentrations. In Germany Creek, spawning activity was concentrated in the lower 3 km of the creek and in the upper most extent of this watershed.

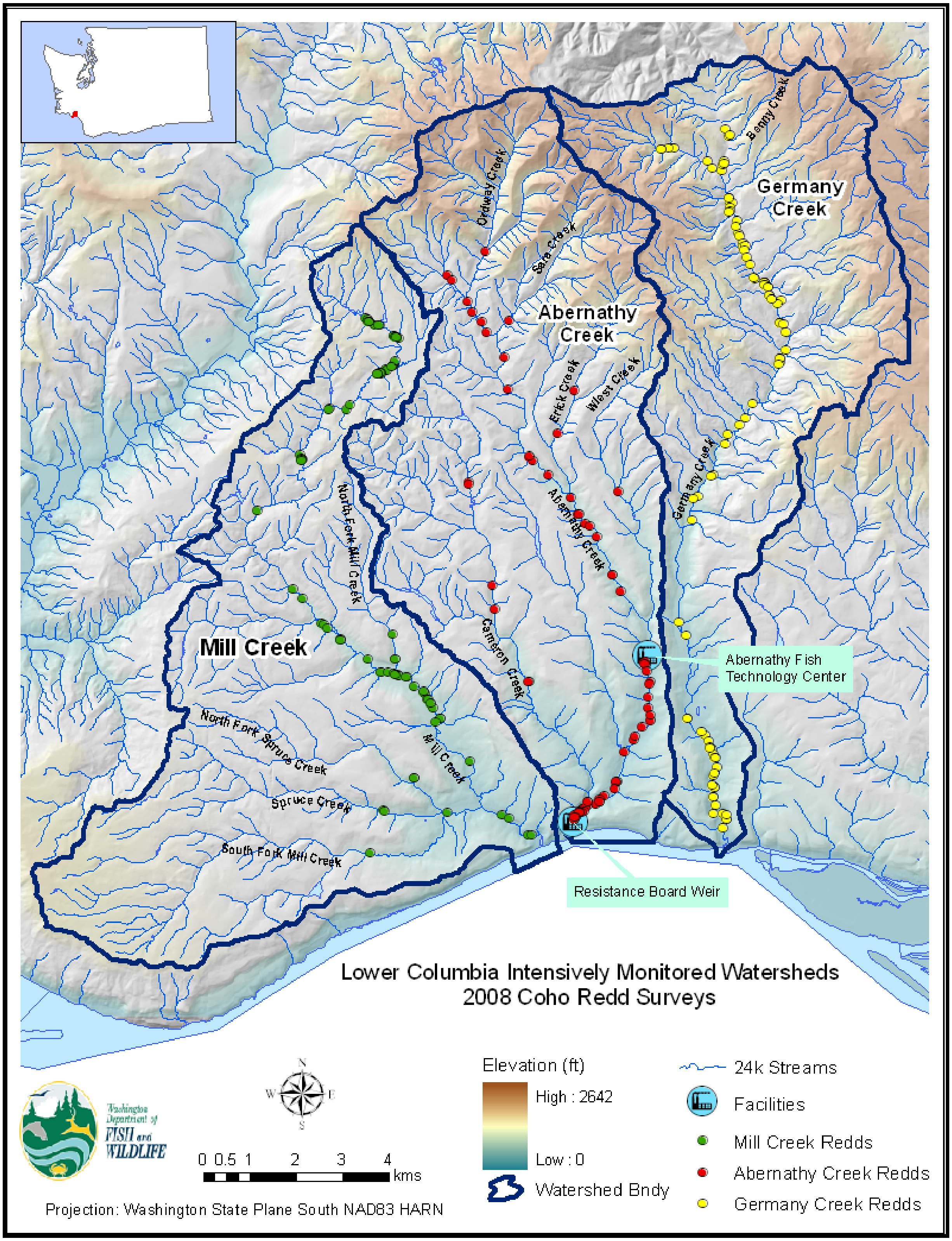

FIGURE 3-14.─Coho redds observed during spawner surveys on Mill, Abernathy, and Germany creeks, 2008. Data points are redd locations.

Coho Spawner Migration Timing

Coho redds were observed in the first survey of all three creeks (Figure 3-15). Over the four surveys completed on Mill and Germany creeks, new redd observations were low on the first survey and increased through mid-December (Figure 3-15*a* and *c*). Access to Mill and Germany creeks in late December or January was prevented by dangerous road conditions and high waters following the late December flooding event. Five surveys were completed on Abernathy Creek (Figure 3-15*b*). In Abernathy Creek, new redd encounter rates were similar among survey periods and no defined no peak in spawning activity was observed.

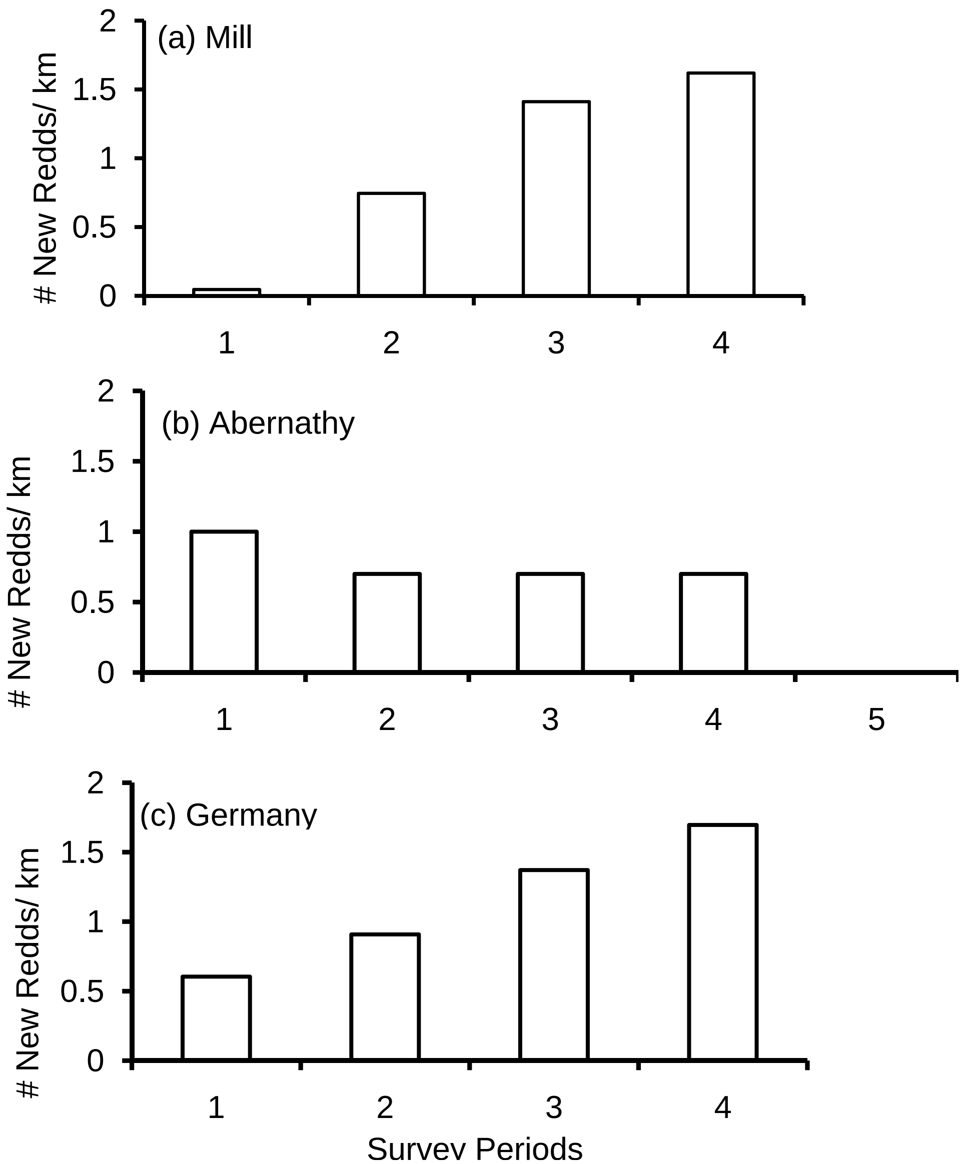

FIGURE 3-15.—New coho redds observed in bi-weekly spawner surveys of Mill (*a*), Abernathy (*b*), and Germany (*c*) creeks, 2008. Data are redds per kilometer. Dates for each survey period are found in Table 3-23.

Discussion

Mark-Recapture Estimate for Abernathy Creek

The mark-recapture study on Abernathy Creek was successful through mid-December. The weir remained fish tight under low to moderate flows. However, weir function was periodically compromised under high flows. The location of the Abernathy Creek weir was changed in 2008 in order to improve weir function. In 2008, the location was moved 100-m downstream from the previous location because new cuts in the stream channel had rendered the old site unsuitable. The stream channel was wider at the new site with the main flow spread over a larger area.

Mark and recapture escapement data was stratified by sex and age under the assumption that behavioral differences between male and female spawners and size differences between jack and adult males would impact the likelihood of recapturing marked fish. Another option would have been to stratify by the type of survey conducted to recover tags (i.e., electric weir, spawner survey, resistance board weir). However, we assumed that the incidence of tag recoveries would be comparable across survey types. This assumption could not be statistically tested in 2008 due to low numbers of recoveries in spawner surveys and on the resistance board weir.

The combined wild and hatchery escapement estimate of 695 adult and jack coho in Abernathy Creek may be biased low if a large number of coho moved upstream and spawned during the late December flooding. Redd surveys from mid-December indicated that spawning was occurring prior to the flood and coho typically move into headwater areas to spawn following a large pulse of water. However, only a few coho were caught in the AFTC weir trap between late December and mid-January and no new redds were observed during a spawner survey conducted in mid-January. This suggests that the coho spawning activity in Abernathy Creek was near completion by late December.

Incidence of natural-origin coho in the resample group (63.5%) was nearly identical to that initially marked at the RBW (62%). However, natural-origin jacks were a higher proportion of the re-sample group (41% natural) than the initial mark group of jacks at the RBW (22% natural). This difference should not influence jack escapement estimates because natural- and hatchery-origin estimates were derived independently. However, different recapture rates based on origin suggests that spawning distributions differed between natural- and hatchery-origin jack coho in Abernathy Creek. Resample data were heavily weighted by recaptures at the AFTC weir 48% of jack coho in the AFTC weir catch were of natural origin. In comparison, all jacks recovered on the spawning grounds or as fall back on the RBW were of hatchery origin. This suggests that natural-origin jacks were selecting spawning grounds higher in the Abernathy Creek watershed than hatchery-origin jacks.

Survival-to-Return Estimates for Mill and Germany Creeks

Although escapement estimates were derived for Mill and Germany creeks, these estimates were problematic. In the absence of a weir on these creeks, we applied survival-to-return rates for natural-origin coho in Abernathy to the relevant smolt production for Mill and Germany creeks and adjusted this number for the incidence of natural-origin coho in the Abernathy Creek spawning escapement.

The approach used to estimate escapement for Mill and Germany creeks included several assumptions which were met with limited success. The survival-to-return approach assumes that harvest and marine survival were similar for coho from each of the three creeks, an assumption we consider to be reasonable given the spatial proximity of the watersheds. The survival-to-return approach also assumed that coho return to the creek from which they emigrated and that minimal dispersal occurs among watersheds. This assumption is likely to be incorrect, although the extent of dispersal among watersheds is unknown. In 2008, three CWT natural-origin coho, likely from Mill or Germany creeks, were caught at the Abernathy weir. In order to maximize escapement into the watersheds, these coho were not sacrificed for CWT recovery and their exact origin is unknown. However, the close proximity of the three watersheds increases the possibility that returning spawners disperse to a non-natal watershed. In addition, the survival-to-return approach also assumed that the stray rate of hatchery-origin coho was comparable among watersheds. Although hatchery coho were not released from any of these watersheds, hatchery coho represented 44% of the adult spawner and 73% of the jack escapement into Abernathy Creek. The assumption that hatchery straying was comparable among the three watersheds could be tested by comparing natural and hatchery-origin recoveries from spawner surveys; however, low numbers of recovered carcasses precluded this comparison in 2008.

An additional uncertainty in the survival-to-return estimate is the adjustment applied to the tagged group of smolts released from the downstream trap. Tag loss and mortality of PIT tagged salmonids has been demonstrated to be high during the smolt to adult growth period (Knudsen et al. 2009; Prentice et al. 1994). However, both these studies marked fish as pre-smolts and therefore did not include mortality associated with handling during the smolt period. We have applied a 63% adjustment rate to the PIT tagged smolt group, encompassing the general tag retention and mortality of pre-smolts (Prentice et al. 1994) and mortality associated with handling smolts (Blankenship and Hanratty 1990). If tag-related mortalities were overestimated, survival-to-return may be overestimated for Abernathy Creek leading to an overestimate of coho escapement into Mill and Germany creeks. In 2008, survival-to-return estimate for adult coho in Abernathy Creek was among the lowest survivals observed in 30 years of study at adult monitoring sites in coastal Washington and Puget Sound. Further interpretation of survival-to-return estimates will require additional years of data from the Abernathy Creek site and a more comprehensive study on the impacts of PIT tags on coho smolt survival.

In addition to potential biases, the precision of the Mill and Germany creek escapement estimates was very low and reflected as high coefficients of variation. The survival-to-return estimate was based on the product or ratio of multiple estimates (i.e., smolt production, survival-to-return, percent natural-origin coho). These calculations resulted in the variance term being compounded with each calculation. Resulting coefficients of variation for the Mill and Germany creek escapement estimates reflected the high uncertainty of these numbers. We conclude that future application of survival-to-return based escapement estimates will be used for studies conducted at 100%-capture smolt and adult weirs.

Spawner Distributions

Spawner surveys are typically problematic for the purpose of estimating coho escapement because coho spawning usually extends to the upper reaches of each watershed, making redds more difficult to locate than those of main stem spawners such as Chinook. Coho spawning also occurs during the season of high water events that limit access to and visibility of stream channels. However, the data gathered on the bi-weekly surveys are useful for describing the timing and spatial distribution of spawning activity within the defined sampling area. The sampling area for this study was based on WDFW historical records of actual or presumed spawning activity as well as additional tributaries identified as potential spawning habitat.

In most cases, coho spawning was concentrated in areas with the most suitable spawning habitat. Suitable spawning habitat is defined as low gradient reaches with golf-ball sized substrate. The two areas of concentrated spawning activity in Mill Creek were characterized by this habitat. In comparison, the remainder of the Mill Creek watershed is characterized by higher gradient and larger substrate. In Abernathy Creek, spawning was concentrated near the confluence of Abernathy and Cameron creeks and downstream of the AFTC electric weir. While these areas provide coho with suitable spawning habitat, the high concentration below the AFTC electric weir may indicate a reluctance to enter the trapping facility. Coho that entered the AFTC trap were transported upstream. Coho spawning in upper Abernathy Creek (above AFTC) was broadly dispersed and much of the spawning habitat, presumed to be suitable, was not used in 2008. The two concentrated areas of spawning activity in Germany Creek occurred at the lowest and upper extents of the watershed. Germany Creek has the steepest gradient of the three watersheds, and redds in lower Germany Creek were primarily observed early in the season when flows were low and access to the upper watershed was limited. Thus, spatial distribution of spawners is likely impacted by the availability of suitable habitat and adequate flows to access these habitats.

The summary of new redd observations by survey period in each watershed indicated that coho spawning in Abernathy Creek occurs earlier than in Mill and Germany creeks. Spawning activity was already ongoing in Abernathy Creek during the first spawner survey and new redd observations (standardized to survey length) did not increase over subsequent surveys. These results contrasted with Mill and Germany creeks where few redds were observed the first survey and new redd observations increased in subsequent survey periods. These results suggest that. The first encounters of coho (three jacks) at the RBW occurred on September 30, a week after the trap began fishing. By October 6th, 51 adults and 19 jacks had arrived at the RBW trap, representing 25% and 20% of the total capture in 2008. Migration prior to trap installation is unlikely given the extremely low stream flow conditions during the late summer period. Therefore, spawning activity in Abernathy Creek would have been better described if surveys were conducted immediately following the first captured of coho at the RBW. In 2009, spawner survey protocols will be modified to address this issue.

Spawner survey results from Mill and Germany creeks indicated that coho spawning activity was near its peak in early to mid-December. Spawner surveys on Mill and Germany creeks were not conducted after mid-December because the roads and creeks could not be safely accessed. High flows and low water clarity prevented surveys of even the lower reaches of Mill and Germany creeks for the remainder of the coho spawning season. A survey successfully completed in mid-January on Abernathy Creek did not encounter any new coho redds, although visibility was somewhat limited by water clarity. The absence of new redds during the mid-January survey may indicate little spawning activity following the flooding event. In addition, timing of the late-December flooding event was simultaneous with peak in coho spawning activity and therefore likely to maximize disruption of existing redds and greatly reduce survival of coho eggs laid in the gravel. Although this study did not directly measure habitat characteristics, bed load transport during the flooding event was obvious and resulted in major changes to the stream channel. Pending flow conditions in 2009, coho spawner surveys in all watersheds will be conducted into mid-January or until the number of newly observed redds declines.

Lower Columbia Adult Chinook Evaluation

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Methods

Spawner Surveys

The initial Chinook survey sampling frame for this project was established in 2005 (Rawding et al. 2006b) based on previous surveys, a species distribution mapping project, and EDT reach delineation utilized in previous IMW coho surveys. EDT reference points and corresponding survey reaches were used where available. For tidal and other non-delineated EDT reaches, data were tallied for the entire reach length. The initial sampling frame included 97 reaches in Mill Creek (including 11 reaches in South Fork Mill Creek), 153 reaches in Abernathy Creek, and 102 reaches in Germany Creek. In 2008, Chinook spawner distribution was limited by low stream flows in all creeks and a large beaver dam in Germany Creek, reduced attraction water in the fish ladder above AFTC in Abernathy Creek, and shallow-water riffles in Mill Creek. The 2008 survey area was reduced to focus on spawning below these points after upstream surveys verified that the entire spawning distribution was encompassed by the abbreviated survey efforts. Figure 3-16 presents the initial 2005 sampling frame, the reduced 2008 survey area, and the uppermost detection of fish presence for Germany, Mill and Abernathy creeks. Stream discharge over the survey period was obtained from the Washington Department of Ecology (WDOE) stream gauges in Germany, Mill and Abernathy creeks (https://fortress.wa.gov/ecy/wrx/wrx/flows/station.asp?wria=25).

Weekly counts of live salmon and salmon carcasses commenced on September 5th and continued until November 5, 2008. Data were recorded for each survey reach. Live Chinook were identified as either spawning or holding. A fish was identified as holding if it was observed in an area not considered spawning habitat, such as pools or large cobble and boulder riffles (Parken et al. 2003). Salmon were classified as spawners if they were on redds or based on their relative location to appropriate spawning substrate.

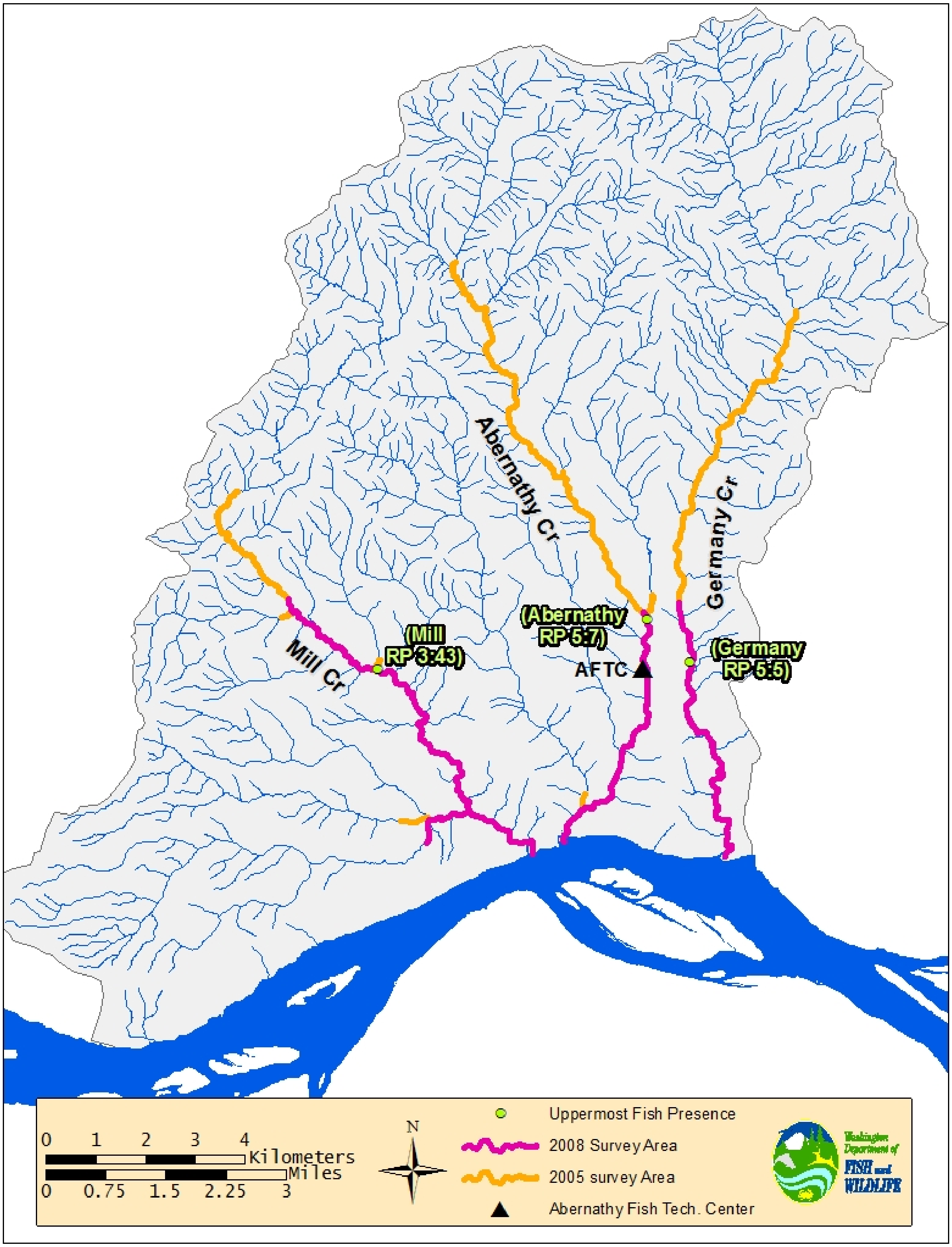

FIGURE 3-16.—Map of initial 2005 IMW sampling frame, the 2008 survey area, and the uppermost detection of fish presence in 2008 for fall Chinook Salmon in Germany, Abernathy, and Mill creeks.

Carcass Tagging

All carcasses that were not totally decomposed were tagged and biologically sampled for length, sex, fin marks, condition and scales (for age determination). Carcasses were tagged on both opercles with uniquely numbered plastic tags (McIssac 1977). Tags were placed on the inside of the opercle to limit predation and potential bias in recovery rates due to observation of brightly colored tags. Tagged carcasses were then placed into moving water to facilitate mixing with untagged carcasses (Sykes and Botsford 1986). On subsequent surveys, technicians recorded the tag numbers of recovered carcasses. When tagged carcasses were recovered, the tags were removed and fish were marked by removing the tail (denoted as loss on capture in the Jolly-Seber model). Experienced field personnel were employed for this project when possible; less experienced personnel were trained in adult salmon identification, redd identification, and sampling/tagging protocols.

Approach to Population and Distribution Estimates

Chinook spawner abundance and distribution was estimated in Germany, Abernathy and Mill creeks using three different methods: (1) the Jolly-Seber (JS) model, (2) the arrival/death model, and (3) trapezoidal Area-Under-the-Curve (AUC). Each method relies upon carcass tagging either directly for an estimate of abundance or indirectly to estimate residence time. Residence time is required to estimate abundance in the AUC methodology. The JS model was the primary method of estimating spawner abundance for this study. The arrival/death model provided an estimate of residence time needed for AUC estimates, the mean date of arrival for the spawning population, and a secondary estimate of abundance. Trapezoidal AUC abundance estimates were calculated by survey reach to represent the spatial distribution of the population. The sum of AUC reach estimates provided a tertiary estimate of spawner abundance.

(1) Jolly –Seber Model via Carcass Tagging

The Jolly-Seber model estimates population abundance in mark-recapture studies where the population is open (Jolly 1965; Seber 1965) and has been widely used in estimating Pacific salmon spawning escapement (Jones and McPherson 1997; McIssac 1977; Parker 1968; Rawding and Hillson 2003; Schwarz et al. 1993; Stauffer 1970). Among carcass tagging mark-recapture models, the JS model is accurate, precise, and robust method for estimating salmon spawning escapement (Boydstun 1994). The JS model utilized carcass tagging for mark-recapture and was the primary method of estimating escapement chosen for this study.

Seber (1982) and Pollock et al. (1990) provide details of study design, assumptions, and analysis of mark-recapture experiments using the JS model. The notation and equations used in this paper are from Schwarz et al. (1993) and are found in Table 3-25.

TABLE 3-25.─Notation used for Jolly Seber estimates from Schwarz et al. (1993).

Statistics	n_i	number of animals captured at sample time i, i=1…,k ($n_i = m_i + u_i$)
	m_i	number of animals captured at sample time i that were previously marked
	u_i	number of animals captured at sample time i that were unmarked
	l_i	number of animals lost on capture at time i
	R_i	number of animals that are released after the i[th] sample. R_i need not equal n_i if losses on capture or injections of new animals occur at sample time i.
	r_i	number of R_i animals released at sample time i that are recaptured at one or more future sample times
	z_i	number of animals captured before time i, not captured at time i, and captured after time i.
Fundamental Parameters	k	number of sample times
	p_i	probability of capture at sample time i, i=1…,k
	Φ_i	probability of an animal surviving between sample time i and sample time i+1 given it was alive at sample time i, i=1, …,k-1
	B_i	number of animals that enter after sample time i and survive to sample time i+1, i=0, …,k-1. The B_i are referred to as the net births. B_0 is defined as the number of animals alive just prior to the first sample.
	N	total number of animals that enter the system and survive until the next sample time. ($N = B_0 + B_1 + \ldots + B_{k-1}$).
	β_i	fraction of the total net births that enter the system between sample times i and i+1, i=0, …, k-1. We refer to these as the entry probabilities. $\beta_i=B_i/N$
	v_i	probability that an animal is captured at time i will not be released, i=1,…,k.
Functions of Parameters	λ_i	probability that an animal seen again after sample time i, i=1,…, k $\lambda_i = \Phi_i\ p_{i+1} + \Phi_i\ (1-p_{i+1})\ \lambda_{i+1}$, i=1,…,k-1; $\lambda_k = 0$
	τ_i	conditional probability that an animal is seen at sample time i given that it was seen at or after sample time i, i=1,…k. ($\tau_i = p_i/(p_i + (1-p_i)\ \lambda_i)$, i=1,…k)
	Ψ_i	probability that an animal enters the population and is not seen before time 1, i=1,…,k-1. ($\psi_1 = \beta 0$, $\psi_{i+1} = \psi_i(1-p_i)\ \Phi_i + \beta_i$)
	N_i	population size at time i. ($N_1 = B_0$, $N_{i+1} = (N_i-n_i+R_i)\ \Phi_i + B_i$)
	U_i	number of unmarked animals in the population at time i;. $U_1 = 0$; $U_{i+1} = U_i\ (1-p_i)\ \Phi_i + B_i$
	B^*_i	gross number of animals that enter between sampling occasion i and i+1. These include animals that enter and die before the next sampling occasion.

Assumptions to recruitment between sampling occasions are needed to estimate annual salmon escapement from the JS model. One assumption is that recruitment takes place at the mid-point (McIssac 1977; Stauffer 1970; Sykes and Botsford 1986); the adjustment factor for this assumption is (1/ sqrt(ϕ_i)), where ϕ_i = the probability that an animal alive at sampling occasion *i* will be alive at sampling occasion *(i*+1). An alternative assumption is uniform recruitment (Crosbie and Manly 1985; Schwarz et al. 1993) with an adjustment factor of (log ϕ_i / (ϕ_i -1)). Schwarz et al. (1993) conducted a sensitivity analysis to these and other distributions of adult recruitment. Adjustment factors are similar when survival is high because most fish survive to the next sampling occasion. When survival is low, the adjustment factors varied considerably. Schwarz et al. (1993) noted the actual distribution of recruitment is unknown and care should be taken in choosing a recruitment adjustment factor. In their analysis, the performance of the mid-point and uniform adjustment factors was similar and the uniform recruitment distribution was used in this analysis.

In the JS model, all recruitment parameters at the beginning and end of the sampling periods cannot be estimated without further assumptions. A well-designed mark-recapture study should commence before a significant number of fish enter the stream or spawning area, and extend until recruitment is completed. Therefore, if studies extend to the end of recruitment, Schwarz et al. (1993) suggest that net births (B_{s-1}) should approach zero, with little effect on the population estimate. At the start of the study, the JS model is not able to directly estimate births (B_0 and B_1) because the probability of capture is not identifiable without making further assumptions; however, it may be reasonable to assume that for the probability of capture $p(1) = 1$, $(p1) = (p2)$, or p = constant. Any of these assumptions makes it possible to estimate (B_0 and B_1) and these assumptions are discussed further in model selection. Our study was initiated before spawning and continued weeks after spawning was completed, meeting the recommendations from Schwarz et al. (1993) regarding a well-designed study.

Following the notation from Schwarz et al. (1993), escapement is the sum of fish immigrating between the first and last sampling occasions (called gross births, B^*_i), plus fish entering before the first sampling occasion (β^*_0) (Schwarz et al. 1993). Escapement was estimated as:

Equation 3-19

$$E = \beta_0 \phi_1 (\log \phi_1 / (\phi_1 - 1)) + \beta^*_i \ldots \beta^*_{s-2}$$

where:

E	=	Escapement,
B_i	=	Number of animals that enter the river after sampling occasion i and are still alive at i+1, (births)
B^*_i	=	Gross number of animals that enter between sampling occasion i and i+1 (gross births), and
ϕ_i	=	Probability that an animal alive at sampling occasion i will be alive at sampling occasion (i+1).

Escapement is calculated as the number present in the first sampling event plus new individuals immigrating prior to each sampling event $i = 2, \ldots, s-2$:

Equation 3-20

$$E = N_2 (\log \phi_1 / (\phi_1 - 1)) + B_2 (\log \phi_2 / (\phi_2 - 1)) + \ldots + B_{s-2} (\log \phi_{s-2} / (\phi_{s-2} - 1))$$

where:

N_i	=	Number of animals alive in the system at sampling occasion i, (abundance).

Asymptotic large sample variances were derived from the net recruitment (sum of B^*_i) using the Delta method (Schwarz and Arnason 1996). Standard parameter estimates with associated standard error (*SE*), and salmon escapement estimates with associated *SE* were derived using the methodology of Schwarz and Arnason (1996).

In mark-recapture experiments, 5-10 marked animals should be recovered per release group in order to produce unbiased estimates (Schwarz and Taylor 1998). Seven to ten recaptures per period are recommended (Bailey 1951; Chapman 1951; Seber 1973) for unbiased JS estimates. This number of recaptures is difficult to achieve during the initial and final sampling periods because few fish are present. If no marked fish were recovered in a sample ($m_i = 0$), the POPAN 7 Maximum Likelihood Estimator (MLE) of abundance (N_i) and consequently births (B_i) are infinite and the program will not converge on an abundance estimate. Therefore, when a sampling period had no recoveries, these data were pooled with adjacent periods. Pooling should result in nearly unbiased estimates if survival was greater than 50% for each of the pooled intervals (Hargrove and Borland 1995). Survival estimates in this study were greater than 70%, which indicated the population estimates should be unbiased. Regardless, a bias in the initial or final weeks should have little effect on the total abundance estimate because so few fish are present during this period.

Carcass Tagging Model Selection

When calculating abundance with the JS model in POPAN, capture (p_i), survival (Φ_i), and entrance (β_i) probabilities can be set as equal or variable among sample periods (carcass model selection followed Lebreton et al. 1992). A global model compatible with the biology of the species studied was selected and its fit assessed. POPAN 7 uses the model notation adopted by Lebreton et al. (1992) (Table 3-26). The initial global model selected was the full or unrestricted JS model, characterized by p_t, ϕ_t, and β_t, which implies that capture, survival, and entry probabilities vary over time periods, denoted by "t" (Schwarz and Arnason 1996). In this model, not all parameters are identifiable and constraints must be imposed on p_1 and p_s to produce an estimate of salmon escapement; these parameters are set equal to 1 in the full model. These same constraints must also be imposed when capture probabilities vary over time (p_t). Estimates of precision with the unrestricted model are usually poor because of the large number of parameters (Arnason et al. 1998).

The more parsimonious model was selected using Akaike Information Criteria (AIC) defined as:

Equation 3-21

$$AIC = -2 * \ln L + 2 * k$$

where $\ln L$ = the log likelihood model fit to the data and k = the number of parameters in the model (Akaike 1973). Constant parameter models, where some or all of the p_i and/or ϕ_i are assumed to be equal, may yield better estimates of precision and were explored. For example, in POPAN 7 notation, p_t implies that capture probabilities vary across time, while p_{same} implies that capture probabilities are constant across time. Models with AIC greater than 10 points above the lowest AIC value have little support but when model difference is less than a value of 2, they have substantial support (Burnham and Anderson 2002). Population estimates, *SE*, log-likelihoods, and parameters were obtained from POPAN 7 results.

TABLE 3-26.─Model notation used for JS carcass tagging (from Lebreton et al. 1992). Models names indicate whether capture, survival, or entrance probabilities were allowed to vary over time ("t") or were held constant ("same").

Model	Model Parameters		
	Probability of Capture (p_t)	Probability of Survival (ϕ_t)	Probability of Entrance (β_t)
1) t t t	Varies over periods	Varies over periods	Varies over periods
2) same t t	Equal over periods	Varies over periods	Varies over periods
3) t same t	Varies over periods	Equal over periods	Varies over periods
4) same same t	Equal over periods	Equal over periods	Varies over periods

Jolly-Seber Model Assumptions

Five assumptions of the Jolly Seber model must be met in order to obtain unbiased population estimates from the model (Seber 1973):

1. Equal Catchability: Every animal in the population whether tagged or untagged, has the same probability of being caught in the i^{th} sample (p_i) given that it is alive and in the population when the sample is taken;

2. Survival: Every tagged animal has the same probability of surviving (ϕ_i) from the i^{th} to the $(i+1)^{th}$ sample and of being in the population at the time of the $(i+1)^{th}$ sample, given that it is alive and in the population immediately after the i^{th} release;

3. Handling Mortality: Every animal caught in the i^{th} sample has the same probability of being tagged and returned to the population;

4. Tag Loss: Tagged animals do not lose their marks and all marks are recognized on recovery; and

5. Instantaneous Sampling: All samples are instantaneous, i.e., sampling time is negligible and each release is made immediately after the sample.

The individual capture history data was formatted into summary statistics using JOLLY (Pollock et al. 1990). This program also assesses model fit using a chi-square goodness of fit test based on a series of contingency tables (Pollock et al. 1985); however, due to the experimental design of carcass tagging in which all recoveries were treated as loss on capture, these chi-square tests were not available or were not applied to assess violations in assumptions 1 and 2. Population estimates should be made for homogeneous groups, but the probability of recovering salmon is often influenced by age and/or size, and sex (Boydstun 1994; Hahn et al. 2001; Schwarz and Arnason 1996; Zhou 2002). Seber (1982) recommends that homogeneity in length be tested by a comparison of those captured and not recovered to those captured and recovered using a Kolmogorov-Smirnov (KS) test. Similarly, a chi-squared test was used to test for different recovery rates for males and females.

Since this was a carcass tagging experiment handling mortality (assumption 3) was not relevant and was not assessed. Tag loss (assumption 4) was assessed through the application of two opercle tags. Tag loss and missing tags can bias mark-recapture experiments (Arnason and Mills 1981; Cowan and Schwarz 2005; McDonald et al. 2003). Tag loss was assumed to be due to physical loss from the fish and not from overlooking tags, as the field crew was well trained and experienced in sampling protocols. The purpose of the double tagging experiment was to estimate the number of fish that lost both tags (*mo*) to adjust m_i or R_i in the JS model as needed (evaluated using approach of Maselko et al. 2003). They indicated the probability of losing a single tag be noted by p, and the number of recaptures with no tags, one tag, and two tags be denoted by m_0, m_1, and m_2, respectively. The probability that a fish loses both tags is p^2 and the probability that a fish has at least 1 tag present is $1 - p^2$. Since m_0, m_1, and m_2 were available from the data the probability of losing one tag is:

Equation 3-22

$$p = (m_0 + m_1/2) / (m_0 + m_1 + m_2)$$

These recoveries are binomially distributed with $N = m_1 + m_2$, with respective probabilities $2p(1-p)/(1-p^2)$ and $(1-p)^2/(1-p^2)$. The maximum likelihood estimate of p is:

Equation 3-23

$$p = (m_1/2) / (m_1/2 + m_2)$$

Setting both estimates of p equal and solving for recoveries missing both tags is:

Equation 3-24

$$m_0 = (m_1^2) / (4m_2)$$

The instantaneous sampling assumption (5) was not seriously violated as overall the time necessary to complete surveys was relatively small compared to the weekly sampling interval (Schwarz et al. 1993). In 2008, carcass surveys on Abernathy and Mill creeks were completed in a single day for the entire sampling season. On Germany Creek, six of the 10 surveys were completed in a single day, three took 2 days, and one took 3 days.

(2) *Arrival/Death Model*

Hilborn et al. (1999) described a maximum likelihood (ML) approach that fit an arrival, death, observational, and statistical model to the periodic live counts of pink salmon to estimate escapement. The equations in this paper are directly from Hilborn et al. (1999) and for consistency the same notation was used (Table 3-27). The primary purpose of the ML approach is to estimate residence time or stream life *(s)* used in estimating the spawning population by reach, along with the mean date of arrival (*m)* and the standard deviation of arrival (σ_m). However, this approach also generates estimates of abundance useful for comparison to the JS carcass tagging model abundance estimates. The data used in the model are the weekly estimates of dead salmon obtained from the JS carcass tagging model using POPAN 7 and the weekly counts of spawners.

TABLE 3-27.—Notation used for arrival/death model from Hilborn et al. (1999).

Parameter	Description
s	residence time of spawners
N_t	number of spawners alive in the stream at day t
A_t	the cumulative number of spawners that arrived in the stream to day t
D_t	the cumulative number of dead salmon in the stream to day t
m	mean date of arrival for spawners
σ_m	standard deviation of the mean date of arrival for spawners
E	total escapement for the stream
x_t	total number of spawners observed in the stream on day t
C_t	number of live salmon predicted in the stream on day t
v	observer efficiency assumed to be 100%
d_t	The cumulative number of dead spawners observed in the stream to day t

The normal distribution is an appropriate distribution for the arrival and abundance of salmon on the spawning ground (Hill 1997; Su et al. 2001). If it is assumed that arrivals and deaths are normally distributed, then the predicted number of salmon that have arrived by day t is:

Equation 3-25

$$A_t = E\int_{i-0}^{t}\left[1/\sigma_m\sqrt{2\Pi}\exp\left(-\left(i-m\right)^2/2\sigma_d^2\right)\right]di$$

the predicted cumulative number of salmon that have died is,

Equation 3-26

$$D_t = E\int_{i-0}^{t-s}\left[1/\sigma_m\sqrt{2\Pi}\exp\left(-\left(i-m\right)^2/2\sigma_d^2\right)\right]di$$

and the predicted number of salmon alive on any given day t is:

Equation 3-27

$$\mathrm{N}_t = A_t - D_t$$

In the observational model, the predicted salmon observed on day t (C_t) are proportional to the number of salmon (N_t) scaled by observer efficiency, which is assumed to be 100%:

Equation 3-28

$$C_t = v\,\mathrm{N}_t$$

Hilborn et al. (1999) indicated that a goodness of fit criterion was required to determine which combination of parameters best fit the observations and assumptions about the error structure may have a major impact for the estimated parameters. Although process and observational errors are part of this model, Hilborn et al. (1999) recommended using a simple assumption that all error is assumed to be observational. The observed salmon on day t equals the observed error multiplied by the number of observed salmon on day t plus some error. In a standard additive normal model, e_t is normally distributed with a mean of zero and a standard deviation $\sigma_{n:}$

Equation 3-29

$$x_t = v\,N_t + e_t\,;\ d_t = v\,D_t + e_t$$

$$e_t = N(0,\ \sigma^2{}_n)$$

The likelihood of the observations given the parameters is:

Equation 3-30

$$L(x|C) = \Pi\ \ 1/\ \sigma_n\ \sqrt{2\Pi}\quad exp(\ \text{-}(\ x_t - C_t)^2\ /2\sigma^2{}_n)$$

Equation 3-31

$$L(d|D) = \Pi\ \ 1/\ \sigma_n\ \sqrt{2\Pi}\quad exp(\ \text{-}(\ d_t - D_t)^2\ /2\sigma^2{}_n)$$

In these salmon surveys, all live counts were recorded and the number of carcasses is estimated from the JS model. The live salmon count model is fitted to the number of salmon observed in the stream on day t (Equation 3-30) and the dead salmon model is fitted to the number of salmon that have died (Equation 3-31). The parameters of interest are estimated by solving both equations simultaneously. It should be noted in this approach that the standard deviation of the mean date of arrival, which controls the shape of the normal curve, is the same for the arrival and death models. Therefore, the residence time is constant during the entire spawning period.

The confidence intervals for stream life were estimated using likelihood profile methods (Hilborn and Mangel 1997). To construct a likelihood profile the ML estimates are found for the described parameters and the parameter for which a profile is required is evaluated over a range above and below the point estimate. At each step of the process, the ML estimate of the other parameters are calculated and the negative logarithm for that iteration is stored. For example, the confidence interval estimates for stream life *(s)* are based on the χ^2 distribution of the log-likelihood ratio:

Equation 3-32

$$2(L(s) - L(s)_{\min}) \approx \chi^2 \text{ with 1 degree of freedom}$$

(3) *Trapezoidal AUC model*

Overall spawner abundance and spawners per RP reach were estimated using the AUC method (Neilson and Geen 1981; Perrin and Irvine 1990). Spawners per reach may also be an alternative to the mapping of redds as a representation of spatial structure (Rawding et al. 2006a). Due to the sparseness of some reach data, the trapezoidal method was used to estimate the *AUC*.

Equation 3-33

$$AUC = \Sigma\ (t_i - t_{i-1}) * (x_i + x_{i+1})/2$$

where t = time and x = spawner count.

The point estimate for stream life (s) from the arrival/death model was divided into AUC to estimate escapement (E).

Equation 3-34

$$\hat{E} = AUC\,/\,s$$

Similarly, the lower and upper 95% confidence interval (*CI*) for stream life were divided into *AUC* to estimate the lower and upper bounds for the spawners per reach. Variance (*Var*) was approximated:

Equation 3-35

$$Var(\hat{E}) = (95\%CI_{upper} - 95\%CI_{lower})/(2*1.96))^2$$

Number of females was estimated from carcass tagging data. Females were identified by coloration, shape of the belly, kype, and teeth (Healey 1991). The proportion of male and female Chinook (p_k) salmon adults in each subwatershed was estimated as:

Equation 3-36

$$\hat{p}_k = n_k / n_t \, p_k = n_k / n_t$$

Where n_k = the number of male or female carcasses , and n_t = the number of total carcasses examined. The variance of the proportion was estimated as:

Equation 3-37

$$Var(\hat{p}_k) = (p_k(1 - p_k))/(n_t - 1)$$

Abundance and variance for each reach was estimated for each sex (*k*) within each stream section as:

Equation 3-38

$$\hat{E}_k = \hat{E} * \hat{p}_k$$

Equation 3-39

$$Var(\hat{E}_k) = Var(\hat{E}) * \hat{p}_k^2 + Var(\hat{p}_k) * \hat{E}^2 + Var(\hat{E}) * Var(\hat{p}_k)$$

where $\hat{E}_k$ = estimated AUC escapement by male or female and $Var(\hat{E}_k)$ = variance of the salmon escapement by male or female.

Comparison of Population Estimates

Estimates produced by the three approaches were compared using a z test statistic (Seber 1973):

Equation 3 - 40

$$z = (N_1 - N_2)/\sqrt{(Var_1 + Var_2)}$$

Jolly Seber model estimates (primary method) were compared to estimates from the Arrival/Death model and AUC in pairwise comparisons.

The following software was used in this analysis. The individual capture history data was formatted into summary statistics using JOLLY (Pollock et al. 1990). Fundamental parameters and functions of parameters including the JS estimate of salmon escapement and SE were calculated in an online version of POPAN-7 (http://www.stat.sfu.ca/~cschwarz/Carlan.online). The statistical package R was used for KS tests (Ihaka and Gentleman 1996). The remainder of the analysis used Microsoft Excel (Microsoft Corporation, Redmond, Washington) with an Excel add-in called PopTools (Hood 2005). The level of significance was set at α =0.05.

Results

Stream Flow

Stream flows remained at less than 50 cubic feet per second (cfs) for all three creeks through early October when a small freshet created a spike in flows; after which flows remained less than 100 cfs until the first major freshet of the fall in early November (Figure 3-17).

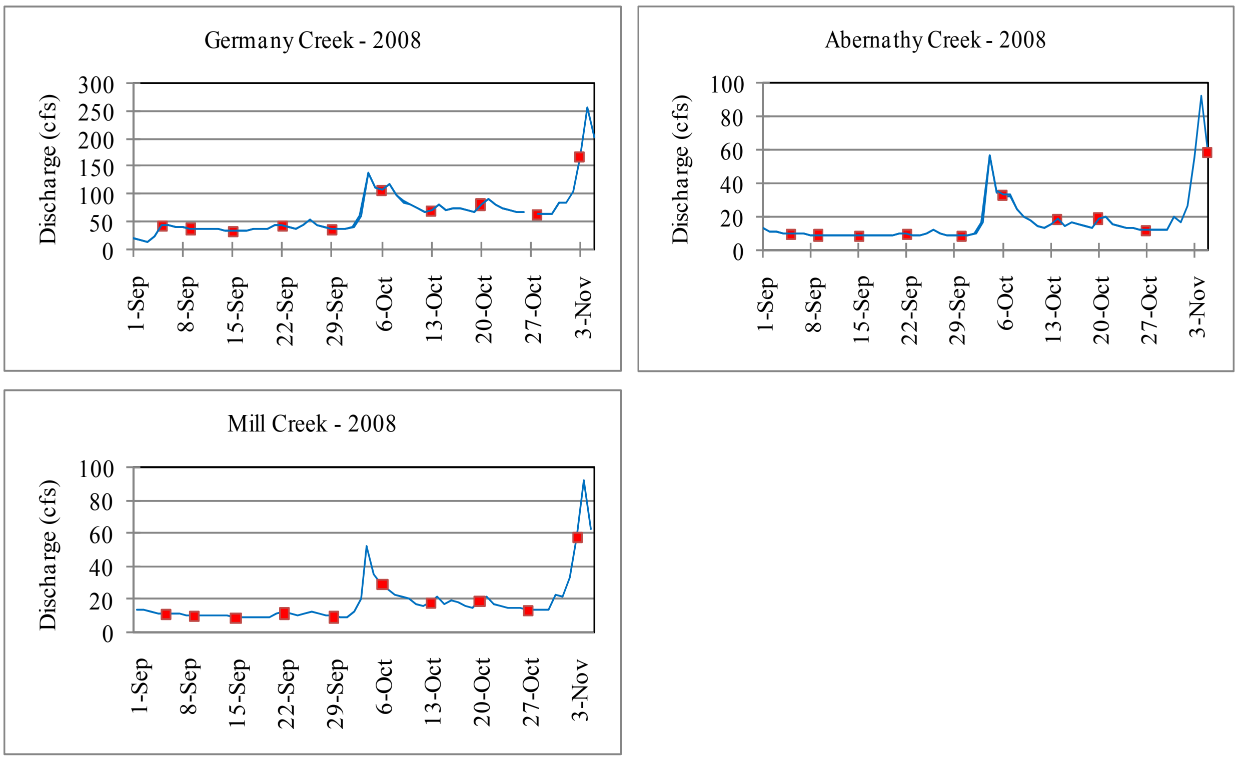

FIGURE 3-17.—Stream discharge in cubic feet per second (cfs) recorded at the Washington Department of Ecology (WDOE) gauging stations on Germany, Abernathy and Mill creeks – Fall 2008 (https://fortress.wa.gov/ecy/wrx/wrx/flows/station.asp?wria=25). Squares represent stream survey dates.

Jolly Seber Assumption 1: Sex and Size Bias

The null hypothesis of equal recovery rates between sexes could not be rejected (p-value > 0.05) (Table 3-28) and abundance in each creek was estimated for all adults (males and females combined). Adults are defined as individuals with fork lengths (FL) over 65cm. Small fish (FL < 65cm), typically have significantly different recovery rates when compared to fish with FL > 65cm. Insufficient numbers of tagged fish with FL < 65 cm were released and recovered to generate a population estimate for this group independently of larger adults. Therefore, live and carcass counts of small fish (recorded as jacks on stream survey cards) were also excluded from all population estimates.

The null hypothesis of equal recovery by size could not be rejected for males, females and adults (males and females combined) in Germany, Abernathy and Mill creeks ($p > 0.05$) (Table 3-29, Figure 3-18).

TABLE 3-28.─Recovery rates of tagged male and female Chinook salmon carcasses, 2008. Differences between sexes were evaluated with a chi-square test.

Basin	Group	Tag & Recovered	Tag & Not Recovered	$\chi 2$	df	*p*-value
Germany	Males	194	40	1.63	1	0.20
	Females	118	35			
Abernathy	Males	2	6	0.000692	1	0.98
	Females	4	7			
Mill	Males	43	38	0.74	1	0.39
	Females	28	35			

TABLE 3-29.─Number of tagged (recovered versus not recovered) male, female, and total adult Chinook salmon carcasses with associated length data, 2008. Differences in recovery by size between tagged fish recovered and tagged fish not recovered were evaluated with a Kolmogorov-Smirnov test.

Basin	Group	Tag & Recovered	Tag & Not Recovered	D statistic	p-value
Germany	Males	194	40	0.1760	0.2556
	Females	118	35	0.1559	0.5277
	Adults	312	75	0.1323	0.2404
Abernathy	Males	2	6	0.3333	0.9963
	Females	4	7	0.6071	0.3051
	Adults	6	13	0.4231	0.4544
Mill	Males	42	36	0.2738	0.1093
	Females	28	35	0.1143	0.9872
	Adults	70	71	0.0976	0.8904

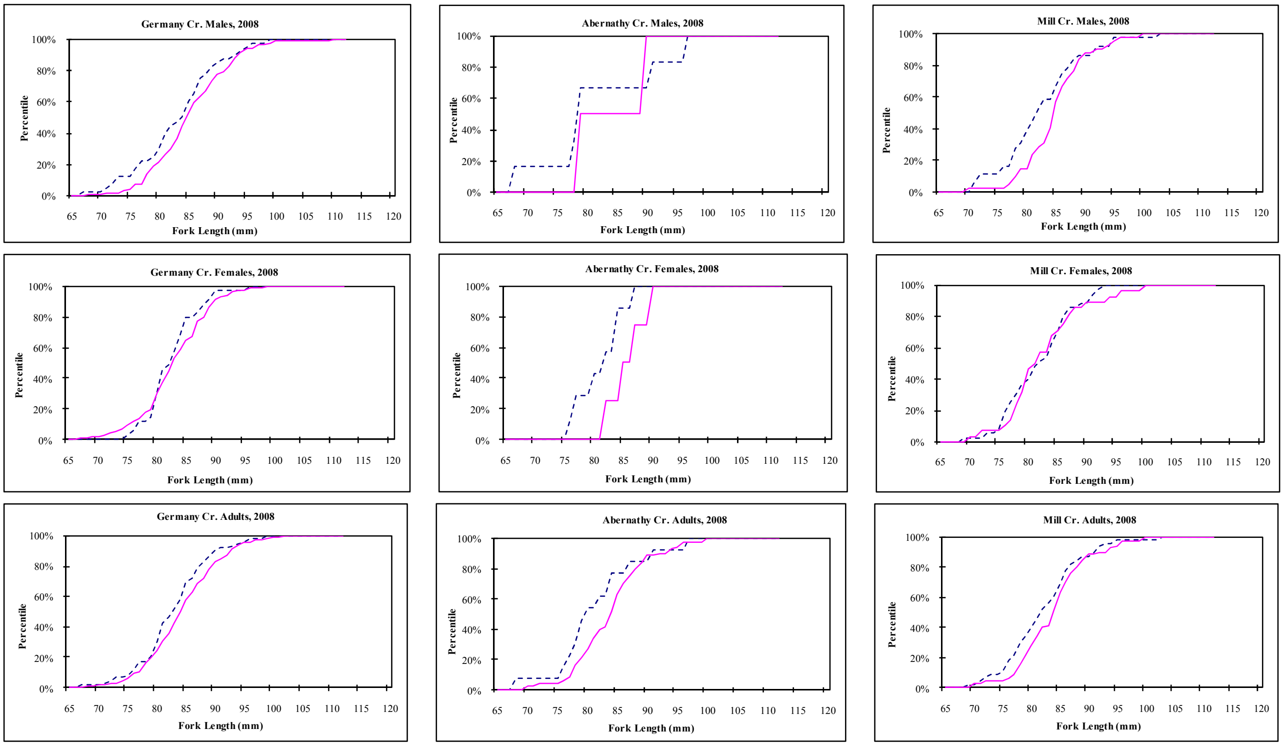

FIGURE 3-18.─Graph of KS test for differences in tagged Chinook recovered (solid line) versus tagged Chinook not recovered (dashed line) in Germany, Abernathy, and Mill creeks, 2008.

Jolly-Seber Assumption 4: Tag Loss

Tag loss was estimated from double tagging each salmon carcass recovered in each of the creeks. Excluding data on Abernathy Creek, where sample size was small (n = 6), the probability of a salmonid carcass losing two tags (p^2) ranged from 0.02% to 0.38% (Table 3-30). Conversely, the probability of retaining at least one tags (1-p^2) ranged from 99.62% to 99.98%. The number of expected recoveries which lost two tags (m_0) was less than 0.16 fish for all categories (excluding Abernathy males). No correction factor was applied in the JS model for the number of fish recovered that potentially lost both tags.

TABLE 3-30.─Estimated tag loss by group from double tagging experiments. Data include number of carcasses recovered with one tag (*m_1*), number of carcasses recovered with two tags (*m_2*), expected number of recoveries which lost two tags (*m_0*), probability of a fish losing one tag (*p*), and probability of a fish losing two tags (*p^2*).

Basin	Group	m_1	m_2	p	p^2	m_0
Germany	Males	5	187	1.32%	0.02%	0.0334
	Females	4	114	1.72%	0.03%	0.0351
	Adults	9	301	1.43%	0.02%	0.0651
Abernathy	Males	1	1	33.33%	11.11%	0.2500
	Females	0	4	0.00%	0.00%	0.0000
	Adults	1	5	9.09%	0.83%	0.0500
Mill	Males	5	38	6.17%	0.38%	0.1645
	Females	1	27	1.82%	0.03%	0.0093
	Adults	6	65	4.41%	0.19%	0.1385

Jolly Seber Estimates

Jolly Seber abundance estimates for Germany and Mill creeks were consistent regardless of the carcass tagging model used. Carcass tag recoveries per release group in Abernathy creek did not meet the recommended minimum number (generally 7) for unbiased estimates (Chapman 1951; Schwarz and Taylor 1998) in any sampling period and precluded estimating the Abernathy population using the JS model. Summary statistics for the JS data are provided for Germany, Abernathy, and Mill creeks in Table 3-31, Table 3-32, and Table 3-33, respectively. Population estimates from the JS carcass tagging models are found in Table 3-34. AIC criteria was used to select the best model for each basin. Spawner abundance in Germany creek (n = 444, model 2) was approximately twice that of Mill creek (n = 206, model 4).

TABLE 3-31. ─Germany Creek summary statistics used for Jolly-Seber estimate.

Period	n_i	m_i	R_i	r_i	z_i
1.43	11	0	11	9	0
2.14	15	9	6	2	0
3.14	23	2	19	16	0
4.14	133	12	121	111	4
5.14	245	107	138	103	8
6.14	130	91	39	31	20
7.00	77	42	35	29	9
8.00	55	35	18	11	3
9.14	14	14	0	0	0

TABLE 3-32.─Abernathy Creek summary statistics used for Jolly-Seber estimate.

Period	n_i	m_i	R_i	r_i	z_i
4.00	3	0	3	2	0
5.14	8	1	7	3	1
6.00	8	3	5	1	1
7.76	6	2	4	0	0

TABLE 3-33.─Mill Creek summary statistics used for Jolly-Seber estimate.

Period	n_i	m_i	R_i	r_i	z_i
3.00	10	0	10	5	0
4.00	28	4	24	18	1
5.00	75	17	58	32	2
6.00	58	30	25	9	4
7.00	29	11	18	7	2
8.00	17	9	8	0	0

TABLE 3-34.─Model selection for the four JS carcass tagging models, where * is the "best" model based on AIC selection criteria.

Basin	Model	-lnl	n	Dev	AIC	Pop. Est	SE	95% CI	
								Lower	Upper
Germany	1) t t t	-41.081	24	82	130.2	441	13.2	415	466
	2) same t t*	-46.398	18	93	128.8	444	14.6	416	473
	3) same same t	-52.644	17	105	139.3	445	9.6	426	464
	4) t same t	-59.592	11	119	141.2	439	7.1	425	453
Abernathy	1) t t t					N/A			
	2) same t t					N/A			
	3) same same t					N/A			
	4) t same t					N/A			
Mill	1) t t t	-24.804	15	50	79.6	199	12.4	175	224
	2) same t t	-25.091	12	50	74.2	200	12.4	176	225
	3) same same t	-29.711	11	59	81.4	205	12.5	181	230
	4) t same t*	-29.055	8	58	74.1	206	11.6	183	229

Arrival/Death Model Estimates

The primary purpose of the Arrival/Death model was to estimate the residence time of spawners in Mill and Germany creeks. This residence time was applied to estimate the spawner abundance by reach discussed in the next section. In addition, the average Mill and Germany residence time was used in the Arrival/Death model to estimate spawning escapement in Abernathy Creek because too few recoveries occurred to use the JS model. The Arrival/Death model estimates that escapement in Germany was 438 Chinook and Mill was 209 Chinook (Table 3-35). These are very similar to the JS model because the JS model results are used for the death curve in the Arrival/Death model. Residence time was 4.96 days in Germany Creek and 5.79 in Mill Creek. Live count data and weekly carcass population estimates generated by POPAN for Germany and Mill were combined to generate an average residence time (5.28 days) and this residence time was used to estimate escapement and other Arrival/Death parameters for Abernathy Creek. Using this approach the Abernathy Creek estimate was 85 adult Chinook salmon. The mean date of arrival (converted from Julian dates) for fish classified as spawners was September 19th for Germany Creek, September 25th for Abernathy Creek, and September 21st for Mill Creek. A graphical fit of the model to the data for each creek is found in Figure 3-19.

TABLE 3-35.─Parameter estimates from the Arrival/Death model.

Parameter	Germany	Abernathy	Mill
Escapement (Esc)	438	85	209
Esc 95% CI (lower - upper)	421 - 455	44 - 121	193 - 230
Residence Time	4.9632	Fixed at 5.28	5.7916
Sigma	14.3246	3.92278	9.7379
Mean date of arrival (Julian Date)	262.7752	268.5724	265.2911
S.D. of mean date of arrival	8.1691	11.6073	9.0307

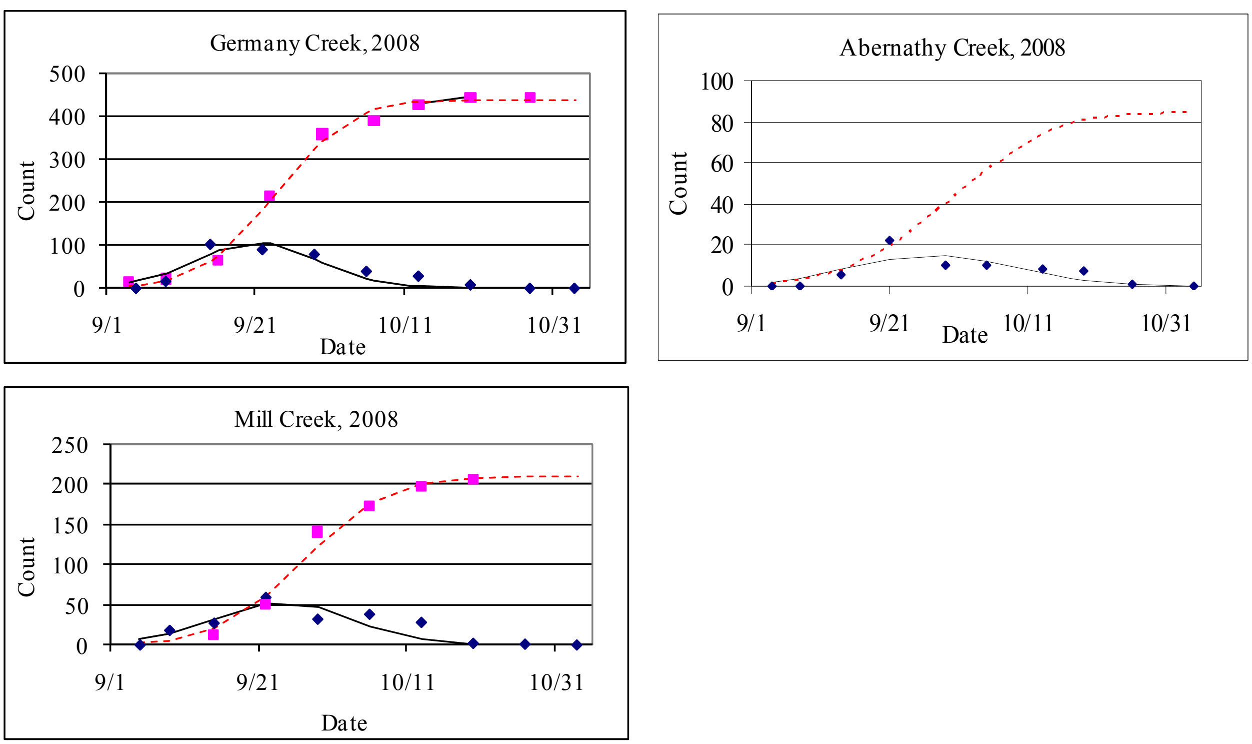

FIGURE 3-19.─Maximum Likelihood (ML) fits of the observed Chinook salmon live spawning counts (diamond) and carcass tagging population estimate of dead Chinook salmon (squares) to the predicted number of live Chinook salmon (solid line) and cumulative number of dead Chinook (dashed line) for Germany, Abernathy and Mill creeks, 2008.

AUC Estimates and Spatial Distribution

The trapezoidal AUC model estimated Chinook escapement to be 491, 86, and 239 Chinook in Germany, Abernathy, and Mill creeks, respectively (Table 3-36). To represent spatial distribution of adult fall Chinook spawners in Germany, Abernathy and Mill Creeks, independent AUC population estimates were calculated by RP reach (Appendix E).

In general, distribution was confined to the lower third of the drainage area in each creek. The uppermost point of Chinook presence was defined by the most upstream observation of a Chinook (live or dead) or a Chinook redd. For Germany, Abernathy and Mill creeks this point occurred in RP 5-5 (live fish), RP 5-7 (redd) and RP 3-43 (redd), respectively (Figure 3-16).The highest density of spawners was found in Germany Creek section RP 5-2, Abernathy Creek section RP 4-23, and Mill Creek 3-22 (Appendix E).

Sum of the independent AUC reach estimates within each basin equaled the overall AUC estimate in all three creeks (Table 3-36).

TABLE 3-36.─Population estimates and 95% confidence intervals (CI) of adult Chinook salmon using Area-Under-the-Curve for Germany, Abernathy and Mill creeks, 2008.

Location	AUC Estimate	Lower 95% CI	Upper 95% CI	Sum of Reach Estimates
Germany	491	409	609	491
Abernathy	86	73	105	86
Mill	239	188	324	239

Comparison of Estimates

Escapement estimates of adult Chinook (Table 3-37) did not differ significantly between the JS model and the arrival/death and AUC models ($p > 0.05$, Table 3-38) in Germany and Mill creeks. Compared to the JS model, estimates from the Arrival/Death model and AUC had a relative bias of -1.35% and 10.59%, respectively, for Germany Creek and 1.46% and 16.02% for Mill Creek (Table 3-38).

TABLE 3-37.─Chinook escapement estimates from the Jolly Seber model, Arrival/Death Model, and Trapezoidal Area-Under-the-Curve for Germany, Abernathy and Mill Creeks, 2008.

	Jolly Seber		Arrival/Death		AUC	
Location	Esc	95% CI	Esc	95% CI	Esc	95% CI
Germany	444	416 - 473	438	421 - 455	491	409 - 609
Abernathy	NA	NA	85	44 - 121	86	73 - 105
Mill	206	183 - 229	209	193 - 230	239	188 - 324

TABLE 3-38.─Results of z-test for pairwise comparison of abundance estimates from the Jolly Seber (JS) model versus the Arrival/Death (A/D) model and the Area-Under-the-Curve (AUC) model.

	JS vs. A/D model	JS vs. AUC	Relative Bias A/D model to JS	Relative Bias AUC to JS
Germany	p=0.72	p=0.38	-1.35%	10.59%
Abernathy	NA	NA	NA	NA
Mill	p=0.84	p=0.37	1.46%	16.02%

Sex Ratio and Age Composition

Adult male Chinook salmon represented 58.3%, 52.0%, and 55.2% of carcasses sampled in Germany, Abernathy and Mill creeks, respectively (Table 3-39). Age-3 fish were the dominant age class for males and females in all three creeks (Table 3-40).

TABLE 3-39.─Sex ratio of Chinook carcasses recovered in Germany, Abernathy, and Mill creeks, 2008. Jack and adult males were identified by scale aging.

	Jacks	Males	Females
Germany	14 (3.5%)	235 (58.3%)	154 (38.2%)
Abernathy	1 (4.0%)	13 (52.0%)	11 (44.0%)
Mill	2 (1.4%)	80 (55.2%)	63 (43.4%)

TABLE 3-40.─Age composition of Chinook carcasses recovered in Germany, Abernathy, and Mill creeks, 2008.

	Age-2	Age-3	Age-4	Age-5	Age-6
Germany					
Males	14 (6.0%)	189 (80.4%)	32 (13.6%)	0 (0.0%)	0 (0.0%)
Females	0 (0.0%)	85 (60.3%)	54 (38.3%)	2 (1.4%)	0 (0.0%)
Abernathy					
Males	1 (10.0%)	6 (60.0%)	3 (30.0%)	0 (0.0%)	0 (0.0%)
Females	0 (0.0%)	5 (50.0%)	5 (50.0%)	0 (0.0%)	0 (0.0%)
Mill					
Males	2 (2.7%)	62 (84.9%)	8 (11.0%)	1 (1.4%)	0 (0.0%)
Females	0 (0.0%)	39 (70.9%)	15 (27.3%)	1 (1.8%)	0 (0.0%)

Discussion

Stream Surveying and Stream Flows

Low stream flows in 2008 combined with a large beaver dam in Germany Creek, low attraction flow in the fish ladder above AFTC in Abernathy Creek, and a shallow-water riffle in Mill Creek limited spawner distribution to the lower portions of these watersheds. Surveys were conducted periodically throughout the spawning season above these points to verify Chinook were not passing these temporary barriers. A moderate freshet in early October increased stream flows, but surveys after this event confirmed fish did not move above temporary barriers. By the end of October, observations of live fall Chinook salmon had decreased to less than five live fish in each creek and no live fish were seen during the November survey, just prior to the first major freshet of the fall. This observation is consistent with Rawding et al. (2006) and suggests that Tule fall Chinook spawning is completed by late October/early November. Surveys were assumed to encompass the entire spatial and temporal spawning distribution for these creeks in 2008.

Evaluation of JS Model via Carcass Tagging

In addition to assumptions that were empirically tested, results of the carcass-tagging model were potentially impacted by mixing of carcasses, predation, and accuracy of residence time estimates. Equal recoveries of tagged and untagged carcasses (assumption 1) depend on complete mixing of tagged and untagged carcasses. To facilitate mixing, carcasses were returned to moving water so they would mix and redistribute with untagged carcasses; however, it was not possible to directly test this assumption in this study.

Animal predation on carcasses has potential to be selective on carcasses in a less decomposed state. Surveys are conducted once per week and an average of 3-4 days pass before new carcasses are tagged and counted on the subsequent survey. If fresh carcasses are consumed at a different rate than older carcasses, this would bias the results. Also, the survival of carcasses may be influenced by their age at initial recovery. The fresher a carcass is when initially tagged the higher its "survival" (Law 1994). JS population estimates to be robust, accurate, and precise when salmon counts at the Bogus Creek weir (California) were compared to population estimates obtained from the JS carcass tagging model (Sykes and Botsford 1986). Since the carcass tagging methods and recovery rates in this study were similar, it is expected that the results presented here would be similar.

Residence times of Chinook spawners in this study were comparable to a previous study of Chinook residence time (Parken et al. 2003). Parken et al. (2003) estimated the mean residence time of spring Chinook salmon spawners in the Nicola River, British Columbia between 1996 and 1999 to be 5.86 days (95% CI 5.39-6.62 days) (Table 3-41). In our study, mean residence time for Tule fall Chinook salmon (Germany and Mill creeks combined) was 5.28 days (95% CI 4.34 to 6.23 days) in 2008, similar to that observed on the Nicola River, and slightly lower than the mean residence time of 6.03 reported in 2005 from these same watersheds (Figure 3-20).

TABLE 3-41.―Estimated residence times and 95% confidence intervals for Chinook salmon classified as spawners – Germany, Abernathy and Mill creeks 2005 and 2008 (GAM 2005 is the average for Germany, Abernathy, and Mill Creeks for 2005), and the Nicola River 1996-1999.

Population	Mean Residence Time	95% Confidence Intervals	
		Lower	Upper
Germany Creek, 2005	5.47	4.57	6.37
Abernathy Creek, 2005	6.44	5.17	7.71
Mill Creek, 2005	6.17	5.24	7.10
GAM, 2005	6.03	5.23	6.83
Germany Creek, 2008	4.96	4.00	5.95
Mill Creek, 2008	5.79	4.27	7.36
Germany & Mill combined, 2008	5.28	4.34	6.23
Nicola River, 1996	5.69	5.01	6.37
Nicola River, 1997	5.83	5.12	6.54
Nicola River, 1998	6.37	4.22	8.52
Nicola River, 1999	5.57	4.99	6.15
Nicola River, 1996-99	5.86	5.25	6.47

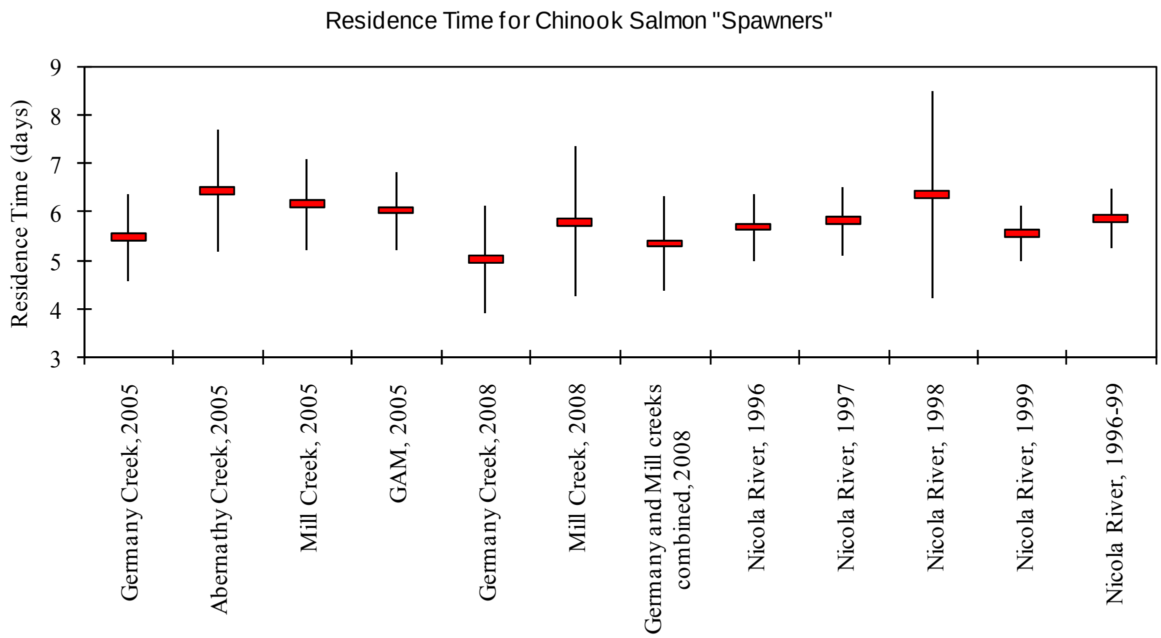

FIGURE 3-20.—Estimated residence times and 95% confidence intervals for Chinook salmon classified as spawners – Germany, Abernathy and Mill creeks 2005 and 2008 (GAM 2005 is the average for Germany, Abernathy, and Mill Creeks for 2005), and the Nicola River 1996-1999.

Evaluation of Arrival/Death Model

To estimate the residence time (stream life) using the arrival/death model, the following key assumptions were made:

1) Observer efficiency is 100%,
2) Arrival and death of Chinook salmon follow a normal distribution,
3) Residence time is constant, and
4) Observation errors are normally distributed.

Chinook salmon spawn in gravel riffles, glides, and tailouts, which are generally less than 4 feet deep under the flow conditions observed during this study; therefore, all spawning Chinook salmon should be visible under normal discharge. A series of environmental variables were estimated and recorded for each survey including visibility, weather conditions, and stream flow. Visibility was estimated, in reaches less than 4 feet deep, by wading into the water until the tip of the wading shoe was no longer visible. The depth of the water was measured at this point with a measuring stick. Visibility in water depths over 4 feet was estimated by surveyors. Visibility on all surveys was greater than 4 feet through the spawning period and all data was used when fitting the data to the timing model.

The normal distribution is used for modeling the arrival of salmon (Hill 1997; Su et al. 2001). It also appears to be a reasonable assumption for modeling the death of salmon (Figure 3-19); however, other arrival/death models such as the beta or mixture models (Hilborn et al. 1999) should be explored in future analysis with the "best" model selected using AIC (Burnham and Anderson 2002).

Some research suggests that residence time for salmon declines throughout the season (Ames 1984; Fukushima and Smoker 1997; Su et al. 2001) because early arrivals hold until factors are optimal for spawning and late arrivals spawn very soon after entry. To avoid this variable residence time, the approach used by Parken et al (2003) was followed, which calculated the residence time for spawners. It is reasonable to assume that residence time for spawners is constant throughout the season, if mate selection, nest construction, spawning, and nest protection by females is constant. The residence time in this analysis was constant (Ames 1984; Bue et al. 1998) and calculated using the spawner count data and weekly carcass estimates (English et al. 1992; Manske and Schwarz 2000; Parken et al. 2003).

A normal error structure was assumed for this model. This error structure may be appropriate when population densities are low, but as population densities increase it may be more difficult to obtain an accurate count. In this case, the lognormal or pseudo-Poisson error structure may be more appropriate (Hilborn et al. 1999). Since the true escapement and residence time are unknown, selection of the appropriate error structure for Chinook salmon is unclear; however, a sensitivity analysis of different error structures on the residence time should be considered in future reports.

Evaluation of AUC Model

Sources of error in the AUC reach-scale model population estimate include misclassification of holders and spawners, and fish movement during the survey period. Surveyor error in classifying fish as holders or spawners may bias the residence time estimate. Chinook salmon hold in pools and then move into glide, riffle and tailout habitats for spawning. Surveyor error would not affect the reach abundance estimates if holding and spawning occur in the same reach. However, if holding occurs primarily in lower reaches of these creeks and spawning in upstream reaches, the number of spawners would be overestimated in the lower reaches and underestimated in the upstream reaches.

Another potential source of error is the movement of fish between adjacent reaches as they are being counted. This can occur if fish are spooked by the surveyor and move to an adjacent section; however, this occurs infrequently. If this type of event occurs, surveyors attempt to track individual fish that move from one reach to another in order to avoid double counting.

Evaluation of Estimate Comparison

Jolly Seber escapement estimates for Germany (444, 95% CI 416-473) and Mill (206, 95% CI 183-229) creeks are considered the most robust and are the final abundance estimates for these creeks in 2008. Escapement estimates from the arrival/death model and AUC were both similar to the JS model (Table 3-38), indicating these methods also provide accurate and precise estimates of abundance. For Abernathy Creek, an escapement estimate from the JS model was not possible due to the low number of carcasses available for tagging and recapture. The Arrival/Death estimate (85, 95% CI 44-121), derived from the combined Germany and Mill creek residence time, is considered the best and final estimate for Abernathy Creek in 2008.

Recommendations

The current Chinook salmon monitoring program in these creeks is the only statewide Chinook monitoring program providing annual estimates of uncertainty in salmon escapement. The estimates appear to be unbiased and for the JS model precise, with CV less than 7%.

Estimates for Abernathy Creek were less precise due to very small population size (85 fish). The following minor recommendations will further improve this program.

Although these estimates are believed to be robust, precise, and accurate, they remain estimates. It is further recommended that a weir be installed in one of these streams for the duration of the fall Chinook salmon run. Given typical flows in these watersheds, a weir could be fished throughout the fall Chinook return time. The census of fall Chinook passed above the weir would be compared to the JS or AUC population estimates to assess the bias and precision of these methodologies in the lower Columbia River IMW streams. Weirs would also be very useful when escapement estimates are low as occurred on Abernathy Creek in 2008.

During initial surveys, some carcasses were observed prior to the first observed redds or fish spawning in Germany Creek. These fish are classified as pre-spawning mortalities and were used in the JS and Arrival/Death models. In future years, spawning success should be recorded on all carcasses and pre-spawning mortalities should not be used to develop escapement estimates. However, pre-spawning mortalities could be included in the estimate of total run size.

Estimates of residence time in this report assume the cumulative population of carcasses is known without error. This is not the case as this estimate obtained from POPAN-7. Rawding (2009) noted that this approach slightly underestimated variance of the residence time because the approach did not include the variance from the carcass tagging estimate. Future reports should consider these alternate calculations for residence time (presented in Rawding 2009).

The residence time used in Abernathy Creek to estimate escapement using the Arrival/Death model was the average of the Germany and Mill Creek estimates. In reality, the mean estimate of residence time also has a precision estimate (standard deviation), which is not incorporated into the model. Therefore, the reported confidence intervals for estimate of Abernathy Creek underestimate the variance. It is suggested that the AUC analysis and subsequent maximum likelihood estimates be updated using the equations from Hilborn et al. (1999) to more accurately reflect this uncertainty in residence time and escapement.

The reach specific AUC estimates use the trapezoiodal approximation method. Hierarchical approaches can be used in such circumstances (Newman 2009) and may be a better alternative when presented with sparse mark-recapture data (Rivot and Prevost 2002). In this case it could be assumed that the mean date of arrival (and its standard deviation) for each of the reaches is from a common distribution (Su et al. 2001). If the above assumptions are reasonable these modifications could improve the precision of the reach scale abundance estimates.

The current estimates of confidence intervals for JS estimates rely on asymptotic large sample variances estimated from POPAN-7. While these are likely to provide adequate coverage when sample sizes are large, salmon escapements in these creeks are often hundreds of fish or less. When populations are small, asymptotic large sample variance will not provide adequate coverage and other methods should be considered.

Given, the precise estimates of residence time for spawning Chinook salmon, WDFW should consider AUC as the primary method for estimating Chinook salmon escapement when precise estimates are required and there is insufficient funding for weirs or mark-recapture programs. This alternative has provided more precise estimates than peak count expansion (Parken et al. 2003).

Lower Columbia Adult Winter Steelhead Evaluation

Authors: Bryce Glaser, Steven Gray, Steve VanderPloeg, and Dan Rawding

Methods

Stream Surveys

Stream surveys to identify and enumerate steelhead redds were used to estimate adult wild winter-run steelhead abundance. Surveys were conducted within the general sampling frame established in 2005 (Rawding et al. 2006a). In 2008, slight adjustments to the sampling frame increased efficiency by emphasizing survey reaches used by steelhead in 2005-2007, and reducing surveys in areas with minimal to no usage. Complete surveys were initiated in all reaches in early March (statistical week 10) and continued through late May (statistical week 21, Appendix D). On February 21, 2008, a survey was conducted in lower Abernathy and Germany creeks to look for the presence of early spawners. Additional surveys were conducted into early June in select reaches where significant numbers of active redds were present. "Standard surveys" were conducted approximately every two weeks (9-20 days) in all sections identified as having a high potential for spawning (Table 3-42). "Supplemental" or "exploratory" surveys were conducted periodically throughout the season and near peak spawning time in late April in reaches with low probability for spawning. "Supplemental" surveys were those conducted in reaches with a history of surveying in previous years. "Exploratory" surveys were those conducted in reaches with no prior survey history. During each survey, newly identified steelhead redds were flagged and the location of each (latitudinal and longitudinal coordinates) was recorded. Redd locations were captured using recreational grade Garmin GPSMap76 units set in the NAD 83 coordinate system. GPS units were allowed to acquire satellite locations until an accuracy of $\pm$ 100 feet or less was obtained. Accuracies most often ranged from 5 to 50 feet. In subsequent surveys, previously flagged redds were inspected to determine if they should be classified as "still visible" or "not visible". A "still visible" redd would have been observed and identified without the flagging present. A "not visible" redd did not meet this criteria.

Redd counts were assumed to be a complete census of wild winter-run steelhead redd construction in these watersheds in 2008. To estimate wild winter steelhead escapement, the total number of redds was multiplied by 0.81, which was the average number of redds per female in Snow and Salmon Creeks between 1977 and 1980 (Freymond and Foley 1986). This calculation yielded an estimate of the number of female steelhead, which is then multiplied by two to provide a total escapement; based on the average winter steelhead sex ratio of 1:1 (Freymond and Foley 1986).

The methods of Hilborn et al. (1999) were modified and used to estimate redd life and the mean date of arrival (construction) for redds. Spawning time (redd construction) was assumed to be normally distributed (Hill 1997) and measurement errors were assumed to be normally distributed (Hilborn et al. 1999). Data analysis was performed in Microsoft Excel (Microsoft Corporation, Redmond, Washington) using an Excel add-in called PopTools (Hood 2005).

TABLE 3-42. —Steelhead redd survey reaches and survey schedule for Mill, Abernathy and Germany creeks in 2008. Standard surveys were sections with high potential for spawning. Supplemental surveys were sections with a prior history of surveying, but with low probability of spawning. Exploratory surveys were sections with low probability of spawning, but no prior survey history. In 2008, NF Ordway and NF Ordway Extended were combined into a single Standard section; the survey schedule for this reach is shown in the "NF Ordway Creek" row. In 2008, Germany Creek –Middle Extended A and GEE were combined into a single Standard section; the survey schedule for this reach is shown in the "Germany Creek – Middle Extended A" row.

							Statistical Week																
Basin	Reach Name	Description	Survey Type	Rmi (btm)	Rmi (top)	Distance (mi.)	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Mill	Mill Creek - Upper A	Trib put in (end of 7000 Rd) upstream to Mill Top (marker at IMW site 20)	Supplemental	10.2	12.2	2.0								X									
Mill	Mill Creek - Upper B	2700 Rd upstream to Trib put in (end of 7000 rd)	Standard	6.7	10.2	3.4			X		X		X	X			X						
Mill	Mill Creek - Middle	Girlscout Camp upstream to 2700 Rd	Standard	2.8	6.7	4.0			X		X	X		X			X						
Mill	Mill Creek - Lower	Mouth upstream to Girlscout Camp	Standard	0.0	2.8	2.8			X		X	X			X		X			X			
Mill	NF Mill Creek	Mouth upstream to top marker at road crossing	Supplemental	0.0	1.3	1.3								X									
Mill	SF Mill - Upper A	Marker 0.8 miles above midpoint bridge upstream to Top marker	No Survey	3.4	5.1	1.7																	
Mill	SF Mill - Upper B	Midpoint bridge (at Turkey Sign) upstream 0.8 miles to marker	Supplemental	2.6	3.4	0.8								X									
Mill	SF Mill - Middle	Spruce Cr (4 corners bridge) upstream to midpoint bridge (at Turkey Sign)	Standard	0.6	2.6	2.0					X		X		X		X			X			
Mill	SF Mill - Lower	Mouth upstream to Spruce Cr (4 corners bridge)	Standard	0.0	0.6	0.6			X		X		X		X		X			X			
Mill	Spruce Creek	Mouth upstream to markers at old road behind washout	Standard	0.0	1.4	1.4					X		X		X		X			X			
Abernathy	Abernathy Creek - Above Ordway	Ordway Cr upstream to forks	Standard	9.3	9.8	0.4			X		X		X	X			X		X				
Abernathy	Abernathy Creek - Upper Extended	Sara Cr bridge (470 rd) upstream to Ordway Cr	Standard	8.6	9.3	0.7			X		X		X	X			X		X				
Abernathy	Abernathy Creek - Upper	4 corners' bridge (450 Rd) upstream to Sara Cr bridge (470 Rd)	Standard	7.3	8.6	1.3			X		X		X	X			X		X				
Abernathy	Abernathy Creek - Middle Extended A	Abernathy Cr Rd bridge abv Wiest Cr Rd upstream to '4-corners' Bridge (450 Rd)	Standard	4.7	7.3	2.6			X		X		X	X			X		X			X	
Abernathy	Abernathy Creek - Middle	Wiest Cr Bridge upstream to Abernathy Cr Rd bridge abv Wiest Cr Rd	Standard	3.6	4.7	1.1			X		X		X	X			X		X			X	
Abernathy	Abernathy Creek - Middle Extended B	Hatchery Weir (electric) upstream to Wiest Cr Bridge	Standard	3.0	3.6	0.5			X		X		X	X			X		X			X	
Abernathy	Abernathy Creek - Lower Extended	Slide Cr Bridge upstream to Hatchery Weir (electric)	Standard	1.4	3.0	1.6	X		X		X		X	X			X		X			X	
Abernathy	Abernathy Creek - Lower	Mouth upstream to Slide Cr Bridge	Standard	0.0	1.4	1.4	X		X		X		X	X			X		X				
Abernathy	Cameron Creek	Mouth upstream to Cameron Top at markers	Standard	0.0	4.2	4.2			X				X	X			X		X				
Abernathy	Cameron Creek Trib	Mouth upstream 0.2 mile to markers	Standard	0.0	0.2	0.2			X				X	X			X						
Abernathy	Slide Creek	Mouth upstream to Slide Creek Rd Bridge	No Survey	0.0	1.0	1.0																	
Abernathy	Wiest Creek	Mouth upstream to DNR bridge	Standard	0.0	1.9	1.9			X		X		X	X			X		X				
Abernathy	Erick Creek	Mouth upstream to Top at markers	Standard	0.0	0.8	0.8			X		X		X	X			X		X				
Abernathy	Midway Creek	Mouth upstream to Top (4-corners (450 rd) bridge)	Standard	0.0	0.2	0.2			X		X		X	X			X		X				
Abernathy	Sara Creek	Mouth upstream to Forks	Standard	0.0	0.5	0.5			X		X		X	X			X		X				
Abernathy	SF Sara Creek Extended	Forks up 0.2 miles on South Fork Sara	Standard	0.5	0.7	0.2			X		X		X				X		X				
Abernathy	Ordway Creek	Mouth upstream to forks	Standard	0.0	0.7	0.7			X		X		X				X		X				
Abernathy	SF Ordway Creek	Forks upstream to top/log falls	Standard	0.0	0.1	0.1			X		X		X				X		X				
Abernathy	NF Ordway Creek	Forks upstream to old Road Crossing	Standard	0.7	0.9	0.2			X		X		X	X			X		X				
Abernathy	NF Ordway Creek Extended*	Old road crossing upstream to top/ log jam	Standard	0.9	1.0	0.1																	
Germany	Germany Creek - Upper Extended A	2nd 1000 Rd. crossing upstream to top marker of Germany (Forks @ 1000/1080 junctio	Standard	10.2	11.1	0.9			X		X	X		X			X			X		X	
Germany	Germany Creek - Upper	1st major LB Trib abv 1300 Rd (LLID...2986) upstream to 2nd 1000 Rd crossing	Standard	9.3	10.2	0.9			X		X	X		X			X			X		X	
Germany	Germany Creek - Upper Extended B	1300 Rd upstream to 1st major LB Trib (LLID...2986)	Standard	8.5	9.3	0.8			X		X	X		X			X			X		X	
Germany	Germany Creek - Middle Extended A	Top of Middle Extended Flagging to 1300 rd bridge	Standard	6.8	8.5	1.7			X		X	X		X			X			X		X	
Germany	Germany Creek (GEE)**	1100 rd br up 1/4 mi to flagging, trib	Standard	6.4	6.8	0.4																	
Germany	Germany Creek - Middle	County Gate upstream to 1100 Rd	Standard	5.9	6.4	0.5			X		X	X		X			X			X		X	
Germany	Germany Creek - Middle Extended B	Forest & Fish sign bridge upstream to County Gate	Standard	4.0	5.9	1.9			X		X	X		X			X			X		X	
Germany	Germany Creek - Lower Extended	Markers near Stella Chapel Rd/Yellow house upstream to Forest & Fish sign bridge	Standard	2.7	4.0	1.3			X		X	X		X			X			X			
Germany	Germany Creek - Lower	Mouth upstream to markers near Stella Chapel Rd/ Yellow house	Standard	0.0	2.7	2.7	X		X		X	X		X			X			X			
Germany	RB Trib of Germany Creek	RB trib below 1300 rd bridge - Exploratory for 2008	Exploratory	0	0.3	0.3								X									
Germany	Apple creek	Apple Creek (Germany Trib) - Mouth upstream 0.13 miles	Exploratory	0	0.13	0.13									X								
Germany	Germany Creek - WGEXX	Forks to upper GPS point - Exploratory	Exploratory	11.2	12	0.8								X									
Germany	Germany Creek - EGEXX	Forks to upper GPS point - Exploratory	Exploratory	11.2	12.12	0.92								X									

Snorkel Survey

A single snorkel survey was conducted on April 9, 2008 (statistical week 15) in Abernathy Creek to estimate the proportion of hatchery steelhead (marked with an adipose fin clip) below the USFWS AFTC. The survey was conducted downstream from the AFTC electric weir (RM 3.0) to Slide Creek Bridge (RM 1.4) (Reach – "Abernathy Creek Lower Extended", Table 3-42). A pair of snorkelers floated downstream, shoulder to shoulder, in a line perpendicular to the stream. Adult steelhead were enumerated, and the presence or absence of an adipose fin was recorded when possible.

Results

Abundance and Distribution

In 2008, 18.3, 18.9 and 13.2 river miles (RM) of main stem and tributary habitat were surveyed in Mill, Abernathy and Germany creeks, respectively. Spawner abundance was estimated to be 38, 248, and 244 wild winter-run steelhead for these creeks, respectively (Table 3-43).

A total of 23 redds were observed in the Mill Creek basin. Average redd density was lower in Mill Creek (1.25 redds/mile) than other surveyed watersheds (Table 3-43). Within Mill Creek, the highest observed redd density was in lower Mill Creek from RM 1 to 3 (Figure 3-21, Appendix F). In addition to mainstem Mill Creek, redds were observed in lower South Fork Mill and Spruce creeks.

A total of 153 redds were observed in the Abernathy Creek basin, with an average redd density of 8.08 redds/mile (Table 3-43). Redds in this creek were broadly distributed from the mouth to Ordway Creek but were heavily concentrated around the USFWS AFTC (located at RM 3) with the highest densities (> 40 redds/mile) between RM 2 and 4 (Figure 3-21, Appendix F). In addition to redds observed in main stem Abernathy Creek, redds were also observed in Cameron, Ordway, and Erick creeks.

A total of 150 redds were observed in the Germany Creek basin, representing an average redd density of 11.3 redds/mile – the highest of the three creeks in 2008 (Table 3-43). Distribution was confined to the mainstem and redds were broadly distributed throughout (Figure 3-21). The highest redd density observed in Germany Creek was 30.0 redds/mile between RM 8 and 9 (Figure 3-21, Appendix F).

TABLE 3-43.—Survey distance, upper-most spawning distribution, observed redds, redd densities, and estimated wild winter-run steelhead (WWSH) escapements for lower Columbia River IMW streams in 2008.

Basin	Survey distance (miles)	Upper-most redd (RM)	Observed redds	Redd density (redds/mile)	WWSH Abundance
Mill	18.3	9.6	23	1.25	38
Abernathy	18.9	12.3	153	8.08	248
Germany	13.2	11.7	150	11.3	244

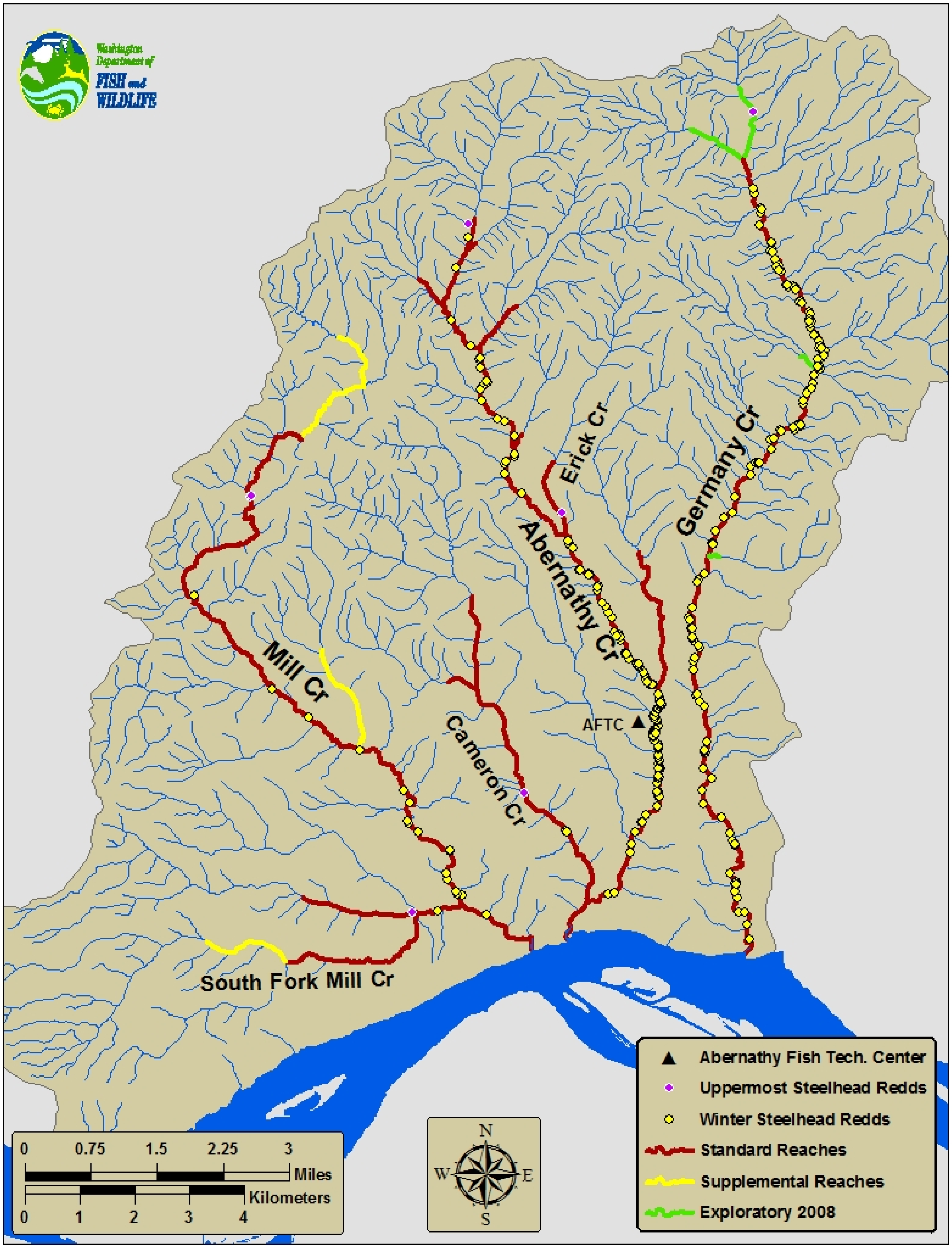

FIGURE 3-21. —Survey area and locations of observed winter steelhead redds in Germany, Abernathy, and Mill creeks, 2008.

Migration Timing

Few new redds were observed during the first surveys in late February and early March on Mill, Abernathy and Germany creeks (Figure 3-22). Redd abundance peaked in mid to late April then declined throughout the season. The timing of observed redd deposition, which approximates a normal distribution, indicates that surveys encompassed the temporal period of wild steelhead spawning. The mean date of arrival (construction) of new redds occurred between April 7 and 9, 2009 for all three creeks (Table 3-44). Average redd life (the number of days a redd was visible) ranged from 24.1 days on Mill Creek to 28.6 days on Germany Creek (Table 3-44).

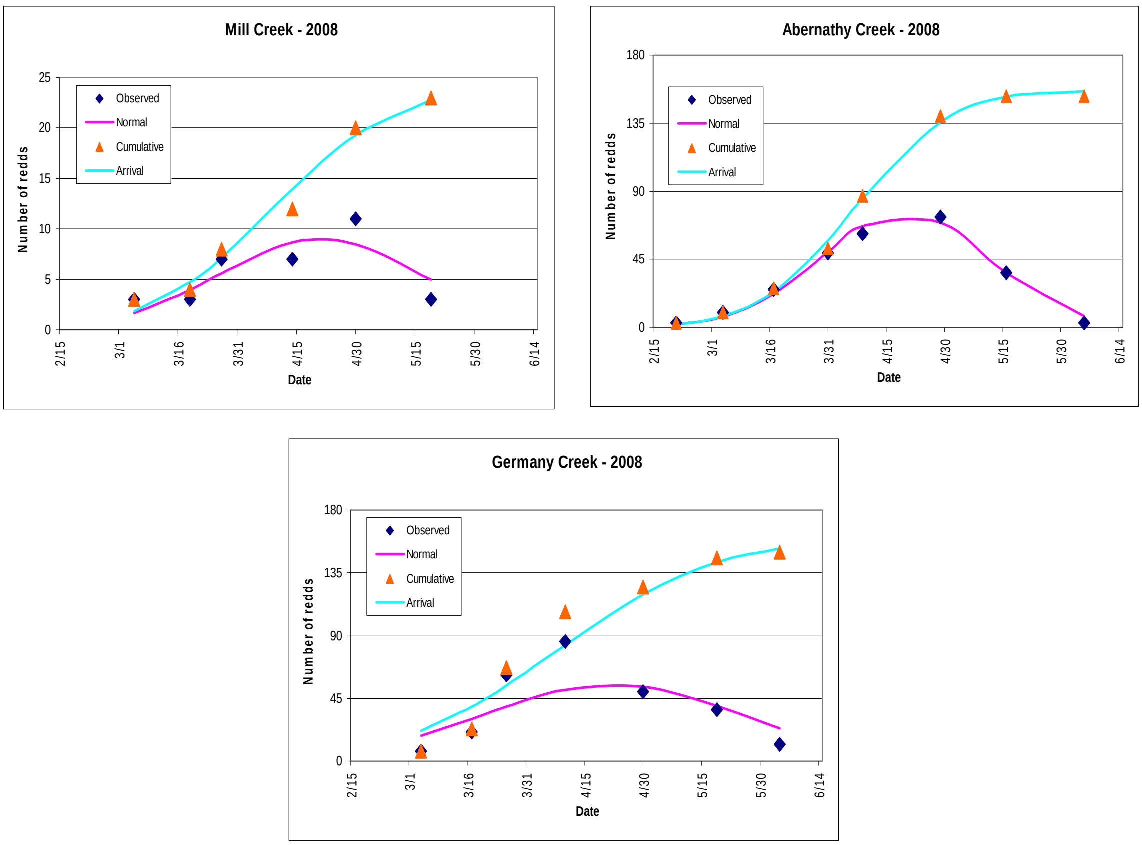

FIGURE 3-22. —Normal distribution fit to the number of visible redds observed on each survey (bold line and diamonds) and cumulative number of new redds (light line and triangles) for Mill, Abernathy and Germany creeks in 2008. Curve fit assumes normal observation errors (see Hilborn et al 1999).

TABLE 3-44.—Mean date of arrival (construction) and mean redd-life for new redds observed in Mill, Abernathy and Germany Creeks in 2008.

		Redd life		
Basin	Mean date of arrival	Mean (days)	95% CI lower	95% CI upper
Mill	4/9/08 (stat wk 15)	24.1	18.3	30.8
Abernathy	4/7/08 (stat wk 15)	26.1	24.4	27.9
Germany	4/8/08 (stat wk 15)	28.6	20.8	37.1

Snorkel Survey

A total of 48 adult steelhead were observed during the survey, with 32 identifiable as either adipose fin intact or adipose fin missing (Table 3-45). Of these, 53% (*n* = 17) were missing adipose fins, indicating hatchery origin.

TABLE 3-45.—Results of snorkel survey conducted April 9, 2009 in Abernathy Creek below the Abernathy Fish Technology Center.

Reach	Adipose Intact	Adipose Missing	Adipose Unknown	Total
Abernathy Creek - Lower Extended	15	17	16	48

Discussion

Assumptions

Key assumptions of redd surveys are that all redds are correctly identified and enumerated, standard reaches are representative of spawning time (especially if standard reaches are used to expand data from supplemental reaches), and percentages of visible redds in index (standard) reaches are accurately determined. For this project, surveys were assumed to provide a census count of redds and escapement estimates did not rely on expansion of supplemental surveys. Standard surveys covered the known steelhead spawning distribution within each watershed, and supplemental and exploratory surveys determined whether steelhead spawned outside the known distribution. In 2008, supplemental and exploratory surveys identified a single redd in an upper reach of Germany Creek (Figure 3-21) that lay outside the standard survey reaches. No other redds were found outside standard survey areas. The Germany Creek redd was included in data analysis, but no attempt was made to expand redd counts for this exploratory reach.

To address the assumption that all redds are correctly identified, experienced surveyors are hired for this project whenever possible because they are more likely to correctly identify redds (Dunham et al. 2001). Regardless of previous experience, new surveyors receive training in redd identification from experienced WDFW personnel. Training occurs in early March, prior to the start of the survey period, in the form of a redd identification criteria and photo review. For the first several surveys, new surveyors walk with an experienced surveyor and receive additional in-field training. After new surveyors are trained, they survey sections alone and their data are verified by a WDFW biologist who re-surveys a sub-sample of the same sections. Typically, re-surveys take place during the initial training period and in the first few weeks of the season, prior to the peak of spawning in mid to late April. Re-surveys are also conducted in the first part of May to ensure less experienced surveyors do not confuse steelhead redds with lamprey redds that typically begin to appear during this timeframe.

Even when redds are correctly identified, not all redds will be counted if redds constructed after a survey become undetectable (not visible) before the next survey. In 2008, mean redd life ranged from 24.1 days (95%CI 18.3 – 30.8) for Mill Creek to 28.6 days (95%CI 20.8 – 37.1) for Germany Creek (Table 3-44). These results corresponded well with a Puget Sound Chinook study that demonstrated redd life is typically close to 20 days (Hahn et al. 2001). Surveys were conducted approximately bi-weekly with a range of 9 to 20 days, indicating, on average, a redd was available for at least one and often two (or more) surveys.

Other factors that can affect redd life are the occurrence of freshets, rapid algae growth, and superimposition of redds. Occasionally, high water events remove algae and smooth out redd pockets and tailings, making redds deposited between surveys undetectable. In addition, new redds constructed after a significant freshet can be more difficult to identify because they lack the characteristic color change of a redd constructed in algae laden substrate. Currently, redd counts are not adjusted for the impact of these circumstances. In 2008, stream flows were punctuated by intermittent, moderate freshets that remained below 200 cubic feet per second (cfs) for the survey period (Figure 3-23). Algae growth and redd detectability may also vary throughout the season. Typically, streamflows decline and air/water temperatures increase as surveys progress throughout the spring. These conditions promote more rapid algae growth with the potential to decrease redd life. In addition to freshets and algal growth, redd detectability can be impacted by superimposition of redds. Superimposition reduces redd life and is generally more pronounced in areas of high spawning density where more fish are competing for suitable spawning areas.

To examine the influence of these factors on surveyors ability to detect redds, the percentage of new redds observed on one survey and then again on the subsequent survey was tracked. Redetection percentages ranged from 0 to 100%, 37% to 100%, and 29% to 86% for Mill, Abernathy and Germany creeks, respectively (Table 3-46, Fig. 3-24). High variability in Mill Creek is likely due to the small number of redds (n = 23) available for tracking. In Abernathy and Germany creeks more redds were available (n = 153, n = 150; Table 3-43) for assessment. From the initiation of surveys (statistical week 8) through statistical week 14, redetection percentages were greater than 69% in Abernathy and Germany creeks, indicating most redds were visible for at least two surveys. From statistical week 15 through the end of the season, redetection percentages for Abernathy and Germany creeks ranged from 28.6% to 38.5%. The decline in percentage of redetected redds between statistical weeks 14 and 15 (3/31/08 to 4/13/08) corresponds with the peak of redd construction (Figure 3-22). This period represents the greatest potential for redd superimposition, especially in reaches with high redd density. Small freshets occurring during this time period (Figure 3-23) may have also contributed to reduced redd visibility. A declining hydrograph from statistical week 16 (4/14/08) through the end of surveys (Figure 3-23) corresponds with increased algal growth associated with typical springtime warming of air and water temperatures and increasing day lengths. In combination, these factors likely produced the reduced percentage of redetected redds between surveys that occurred in the latter half of the survey season. These results reinforce the need to conduct surveys on a biweekly schedule, at a minimum. While percentages did decline mid-season, the fact that a third or more of redds were visible for more than one survey throughout the season suggests that early season freshets (Figure 3-23) were of insufficient magnitude to completely clean and smooth redds. While superimposition during peak redd construction may have prevented the detection of some redds, the likelihood of missed redds from this and other factors was assumed to be low.

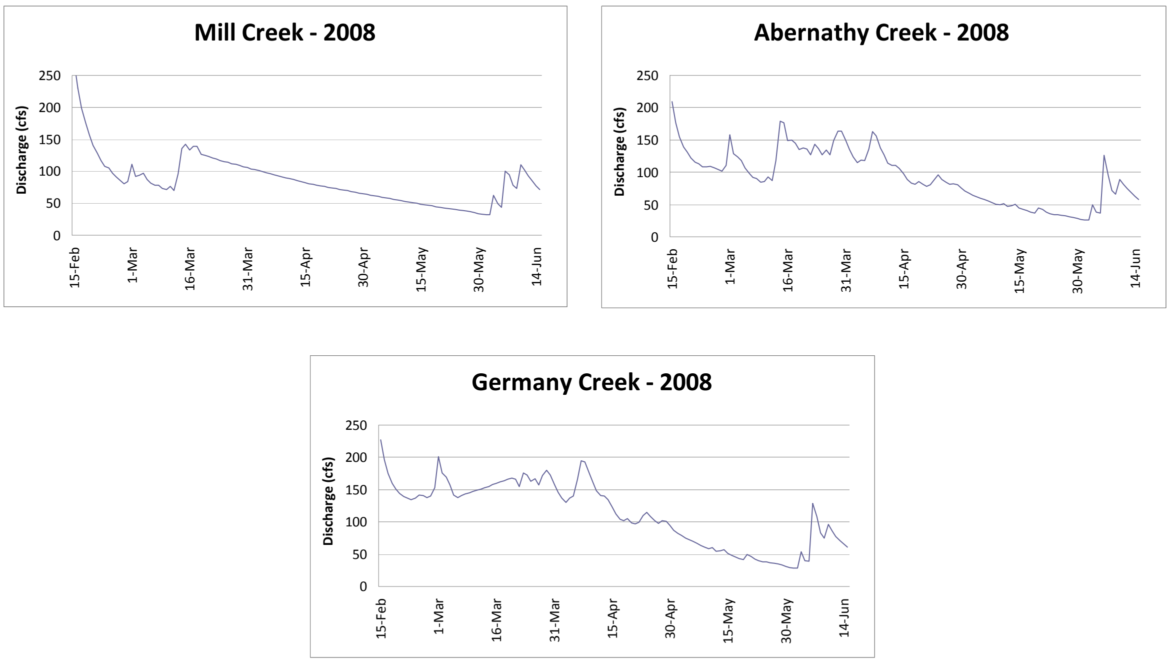

FIGURE 3-23. ─Stream discharge in cubic feet per second (cfs) recorded at the Washington Department of Ecology (WDOE) gauging stations on Mill, Abernathy and Germany creeks – Spring 2008 (https://fortress.wa.gov/ecy/wrx/wrx/flows/station.asp?wria=25).

TABLE 3-46.—Percentage of redds that were new (New) and still visible (SV) on the next survey by statistical week in Mill, Abernathy, and Germany creeks, 2008.

Stat	Mill Creek			Abernathy Creek			Germany Creek		
Week	New	SV	%SV	New	SV	%SV	New	SV	%SV
8				3	3	100.0%			
9									
10	3	3	100.0%	7	7	100.0%	7	6	85.7%
11									
12	1	1	100.0%	16	15	93.8%	16	14	87.5%
13	5	1	20.0%				44	32	72.7%
14				26	18	69.2%			
15				35	13	37.1%	39	15	38.5%
16	4	3	75.0%						
17									
18	8	0	0.0%	53	20	37.7%	18	6	33.3%
19									
20				13	5	38.5%			
21							21	6	28.6%

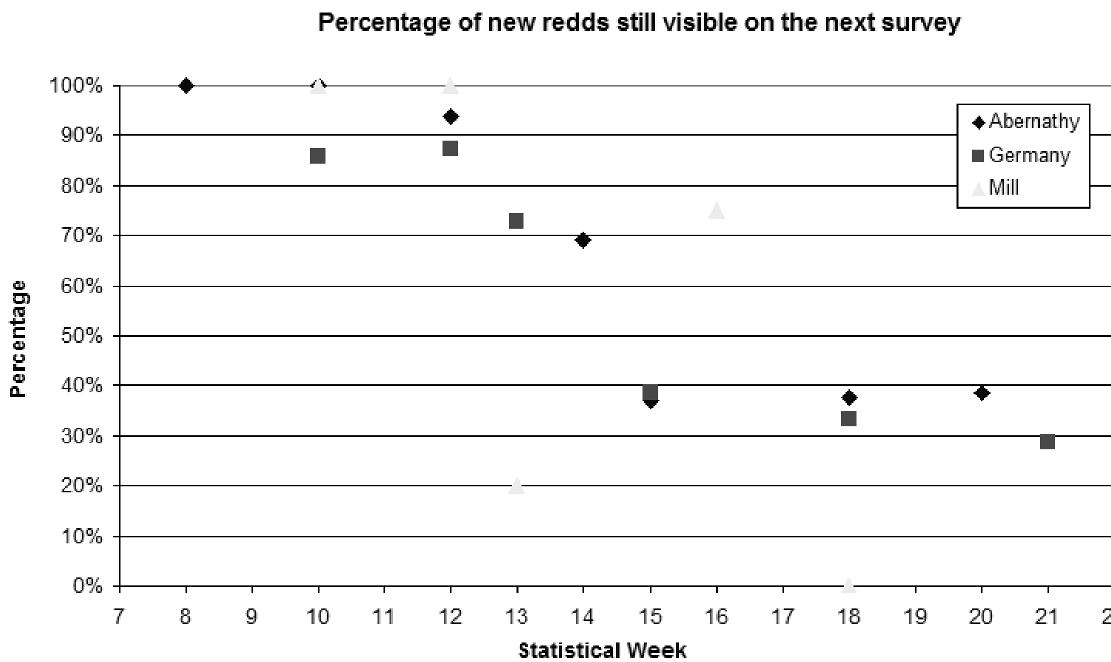

FIGURE 3-24.—Percentage of new redds in Mill, Abernathy, and Germany creeks still visible on the next survey by statistical week, 2008.

Hatchery Program Implications

Since escapement survey methodology for this project was based on redd observations and not fish counts, surveyors were not able to differentiate between hatchery and wild fish in these creeks. Therefore, our escapement estimates are likely a composite of both hatchery and wild fish spawning naturally after March 1. Historically, pronounced temporal spawning time differences between traditional summer and winter-run hatchery stocks and wild winter-run steelhead (Crawford 1979) has allowed successful use of redd survey methodology to estimate wild winter-run abundance. Adult hatchery fish from the USFWS winter-run steelhead broodstock program on Abernathy Creek have returned annually since 2005 (USFWS 2005; USFWS 2006; USFWS 2007; USFWS 2008). The intent of this program was to create a steelhead brood stock from natural origin juveniles collected in Abernathy Creek, with run and spawn timing similar to wild-winter run steelhead in the basin. If initial juvenile collections included offspring from stray hatchery steelhead (i.e., Chambers Creek stock) and Abernathy wild winter-run adults, their run and spawning time may reflect both origins. Steelhead in Mill, Abernathy and Germany creeks are considered a single population (LCFRB 2004). The level of exchange of individuals between basins is not known. Therefore, hatchery-origin steelhead from the integrated USFWS brood stock program may return to all three creeks as well, and this return likely contributed to the redd counts in this study.

Brood stock collection for the USFWS program occurs at the AFTC. In 2005, a new electric weir was installed to direct returning fish into the collection facility. More recently, the weir has been used in combination with an adult trap located in the fish ladder above the AFTC in response to concerns about altered spawning distribution in Abernathy Creek associated with electric weir operation (USFWS 2005, 2006, 2007, 2008). While much progress has been made, redd densities in the vicinity of the AFTC (~RM 3) electric weir and fish ladder trap remain high (> 40 redds/mile) (Figure 3-21, Appendix F). Most likely these increased densities are the result of weir/ladder trap effects (i.e. delayed passage and trap rejection) and an affinity of hatchery returns to spawn near their release location (AFTC). The relative effect of these variables is not resolved. A snorkel survey conducted in the reach below the AFTC near the peak of spawning confirmed a high proportion (53%) of the adult steelhead in the reach were of hatchery origin.

Full assessment of this program's effect on natural origin spawner abundance and distribution was beyond the scope of this project but should be explored.

Recommendations

While redd counts provide reasonably accurate estimates of salmonid escapement (Muhlfield et al. 2006), stream specific assumptions for redd surveys are difficult to verify. These assumptions include observer efficiency and unaccounted-for redds due to freshets and other factors in these watersheds. Numerous studies have concluded that weir or mark-recapture methods should be used to address assumption uncertainties in spawning ground surveys (Hilborn et al. 1999; Jones et al. 1998; Parken et al. 2003; Su et al. 2001). Rawding et al. (2006) recommended installation of a weir near the mouth of at least one of these creeks and that a mark-recapture study design be implemented to calibrate observer efficiencies for winter steelhead redds. Budget levels for this project were not sufficient to incorporate these tasks but these recommendations remain valid.

In a mark-recapture study design, steelhead could be captured at the weir, Floy tagged, and released above the weir. Recapture events would be the occurrence of tagged and untagged spawning steelhead observed during redds surveys (Jacobs 2002), through snorkeling or recapture of adults at an upstream facility such as the AFTC (Rawding and Cochran 2005), angling, or recapture of kelts as they emigrate past the weir (Begich 1995). This type of design would also allow for further assessment of potential hatchery program effects on natural origin spawner abundance through determination of hatchery and natural origin proportions of the escapement.

A weir operation would also provide in-basin sex ratios and redds per female, refining these key assumptions for the purpose of estimating spawning escapements. In this study, the number of redds per female was assumed to be 0.81 and the sex ratio assumed to be 1:1. Freymond and Foley (1986) reported that redds per female in Snow Creek ranged from 0.65 to over 1 and steelhead sex ratios in different river systems were variable. This variation, although derived using out-of-basin data, can be used to quantify uncertainty in the redd-based escapement estimates for Mill, Abernathy, and Germany creeks. In the absence of a lower river weir operation in these specific watersheds, variance from Snow Creek redds per female data and annual winter steelhead sex ratios from the Kalama and Toutle Rivers should be incorporated into the spawning ground escapement estimates of winter-run steelhead in future years. Additionally, as fish ladder trap operations by the USFWS above the AFTC in Abernathy Creek are refined, data should be used to develop sex ratios, redds per female, and hatchery origin proportions specific to upper Abernathy Creek.

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APPENDIX A

Variance of total unmarked smolt numbers, when the number of unmarked juvenile out-migrants, is estimated.

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APPENDIX A: Variance of total unmarked smolt numbers, when the number of unmarked juvenile out-migrants, is estimated.

NOTE: This derivation was written using a different notation than this report. Variable conversions are as follows:

Derivation = Report

$$\hat{U}_i = \hat{N}_j$$

$$\hat{u}_i = n_{2j}$$

$$M_i = n_{1j}$$

$$m_i = m_{2j}$$

****

The estimator for $\hat{U}_i$ is,

$$\hat{U}_i = \frac{\hat{u}_i\left(M_i+1\right)}{\left(m_i+1\right)}$$

the estimated variance of $\hat{U}_i$, $Var\left(U_i\right)$ is as follows,

$$Var\left(\hat{U}_i\right) = Var\left(\hat{u}_i\right)\left(\frac{\left(M_i+1\right)\left(M_i m_i+3M_i+2\right)}{\left(m_i+1\right)^2\left(m_i+2\right)}\right)+Var\left(\hat{U}_i\left|E\left(\hat{u}\right)\right.\right)$$

where $Var\left(\hat{U}_i\left|E\left(\hat{u}\right)\right.\right) = \dfrac{\left(M_i+1\right)\left(M_i-m_i\right)E\left(\hat{u}_i\right)\left(E\left(\hat{u}_i\right)+m_i+1\right)}{\left(m_i+1\right)^2\left(m_i+2\right)}$,

$E\left(\hat{u}_i\right)$ = the expected value of $\hat{u}_i$ either in terms of the estimator (equation for $\hat{u}_i$) or just substitute in the estimated value and, $Var\left(\hat{u}_i\right)$ depends on the sampling method used to estimate $\hat{u}_i$.

Derivation:

Ignoring the subscript i for simplicity, the derivation of the variance estimator is based on the following unconditional variance expression,

$$Var\left(\hat{U}\right) = Var\left(E\left(\hat{U}\left|u\right.\right)\right)+E\left(Var\left(\hat{U}\left|u\right.\right)\right).$$

The expected value and variance $\hat{U}$ given u is as before, respectively,

$$E\left(\hat{U}_i\left|u\right.\right) = \frac{u_i\left(M_i+1\right)}{\left(m_i+1\right)} \text{ and,}$$

$$Var\left(\hat{U}\left|u\right.\right) = \frac{u\left(u+m+1\right)\left(M+1\right)\left(M-m\right)}{\left(m+1\right)^2\left(m+2\right)}.$$

Substituting in $\hat{u}$ for u gives the following,

$$Var\left(\hat{U}\right) = Var\left(\frac{\hat{u}(M+1)}{(m+1)}\right) + E\left[\frac{(M+1)(M-m)\hat{u}(\hat{u}+m+1)}{(m+1)^2(m+2)}\right]$$

$$Var\left(\hat{U}\right) = \left(\frac{(M+1)}{(m+1)}\right)^2 Var(\hat{u}) + \frac{(M+1)(M-m)}{(m+1)^2(m+2)}\left[E\left(\hat{u}^2\right) + E(\hat{u})(m+1)\right]$$

Note that,

$$E\left(\hat{u}^2\right) = Var(\hat{u}) + (E\hat{u})^2$$

Substituting in this value for $E\left(\hat{u}^2\right)$,

$$Var\left(\hat{U}\right) = \left(\frac{(M+1)}{(m+1)}\right)^2 Var(\hat{u}) + \frac{(M+1)(M-m)}{(m+1)^2(m+2)}\left[Var(\hat{u}) + \left(E(\hat{u})\right)^2 + E(\hat{u})(m+1)\right]$$

$$= \left(\frac{(M+1)}{(m+1)}\right)^2 Var(\hat{u}) + \frac{(M+1)(M-m)}{(m+1)^2(m+2)}\left[Var(\hat{u}) + E(\hat{u})\left[E(\hat{u}) + m + 1\right]\right]$$

$$Var\left(\hat{U}\right) = \left(\frac{(M+1)}{(m+1)}\right)^2 Var(\hat{u}) + \frac{(M+1)(M-m)}{(m+1)^2(m+2)}Var(\hat{u}) + \frac{(M+1)(M-m)E(\hat{u})\left[E(\hat{u}) + m + 1\right]}{(m+1)^2(m+2)}$$

$$Var\left(\hat{U}\right) = Var(\hat{u})\left(\frac{(M+1)^2}{(m+1)^2} + \frac{(M+1)(M-m)}{(m+1)^2(m+2)}\right) + \frac{(M+1)(M-m)E(\hat{u})\left[E(\hat{u}) + m + 1\right]}{(m+1)^2(m+2)}$$

$$Var\left(\hat{U}\right) = Var(\hat{u})\left(\frac{(M+1)^2}{(m+1)^2} + \frac{(M+1)(M-m)}{(m+1)^2(m+2)}\right) + Var\left(\hat{U} \middle| E(\hat{u})\right)$$

$$Var\left(\hat{U}\right) = \frac{(M+1)}{(m+1)^2}Var(\hat{u})\left(\frac{(M+1)(m+2)}{(m+2)} + \frac{(M-m)}{(m+2)}\right) + Var\left(\hat{U} \middle| E(\hat{u})\right)$$

$$Var\left(\hat{U}\right) = \frac{(M+1)}{(m+1)^2}Var(\hat{u})\left(\frac{Mm + 2M + m + 2 + M - m}{(m+2)}\right) + Var\left(\hat{U} \middle| E(\hat{u})\right)$$

$$Var\left(\hat{U}\right) = Var(\hat{u})\left(\frac{(M+1)(Mm + 3M + 2)}{(m+1)^2(m+2)}\right) + Var\left(\hat{U} \middle| E(\hat{u})\right)$$

APPENDIX B

Variance, Confidence Intervals, and Coefficient of Variation

APPENDIX B: Variance, Confidence Intervals, and Coefficient of Variation

Equation B-1. Confidence interval for an estimate ($\hat{N}$) with variance [$V(\hat{N})$]:

$$\hat{N}_{95\%CI} = \hat{N} \pm 1.96\sqrt{V(\hat{N})}$$

Equation B-2. Coefficient of variation for an estimate ($\hat{N}$) with variance [$V(\hat{N})$]:

$$CV = \frac{\sqrt{V(\hat{N})}}{\hat{N}}$$

Equation B-3. Variance of the product of an estimate ($\hat{E}$) and a constant (*C*):

$$V(\hat{E} * C) = V(\hat{E}) * C^2$$

Equation B-4. Variance of the product of two estimates ($\hat{E}_A, \hat{E}_B$) that are independent of each other:

$$V(\hat{E}_A * \hat{E}_B) = Var(\hat{E}_A) * \hat{E}_B^{\ 2} + \hat{E}_A^{\ 2} * V(\hat{E}_B) - Var(\hat{E}_A) * V(\hat{E}_B)$$

Equation B-5. Variance of the ratio of two estimates ($\hat{E}_A, \hat{E}_B$) using the delta method:

$$V\left(\frac{\hat{E}_A}{\hat{E}_B}\right) = \frac{\hat{E}_A}{\hat{E}_B} * \left(\frac{V(\hat{E}_A)}{\hat{E}_A^{\ 2}} + \frac{V(\hat{E}_B)}{\hat{E}_B^{\ 2}}\right) - V(\hat{E}_A) * \frac{V(\hat{E}_B)}{\hat{E}_B^{\ 4}}$$

APPENDIX C

Lengths of juvenile migrants in Hood Canal and Lower Columbia streams

APPENDIX C: 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. Season total mean and standard deviation are weighted by catch.

Appendix C-1.─Fork lengths (mm) of coho smolts in Big Beef Creek, 2008.

					Range		Number	Sample
Statistical week	Begin	End	Mean	St. Dev.	Min	Max	Sampled	Rate
14	04/01/2008	04/07/2008	127.4	13.33	104	146	8	23.50%
15	04/08/2008	04/14/2008					0	0.00%
16	04/15/2008	04/21/2008	130.6	10.68	116	148	8	10.10%
17	04/22/2008	04/28/2008	122.0	11.67	104	156	31	8.60%
18	04/29/2008	05/05/2008	110.3	14.31	84	145	91	2.90%
19	05/06/2008	05/12/2008	107.4	10.67	87	152	166	2.10%
20	05/13/2008	05/19/2008	103.4	9.71	81	136	184	1.50%
21	05/20/2008	05/26/2008	95.7	5.85	87	109	15	0.90%
22	05/27/2008	06/02/2008	96.9	11.2	75	130	64	29.50%
23	06/03/2008	06/09/2008	105.2	11.82	95	125	5	1.90%
		Season total	105.3	10.36	75	156	572	

APPENDIX C-2.─Fork lengths (mm) of coho smolts in Little Anderson Creek, 2008.

					Range		Number	Sample
Statistical week	Begin	End	Mean	St. Dev.	Min	Max	Sampled	Rate
14	04/01/08	04/07/08					0	0.0%
15	04/02/08	04/08/08					0	
16	04/03/08	04/09/08					0	
17	04/04/08	04/10/08					0	0.0%
18	04/05/08	04/11/08					0	0.0%
19	04/06/08	04/12/08	96.0	4.58	91	100	3	14.3%
20	04/07/08	04/13/08	93.0	5.57	88	99	3	14.3%
21	04/08/08	04/14/08	90.0		90	90	1	4.5%
22	04/09/08	04/15/08	92.0		92	92	1	12.5%
23	04/10/08	04/16/08	104.0		104	104	1	14.3%
		Season total	93.8	2.70	88	104	9	9.7%

APPENDIX C-3.─Fork lengths (mm) of coho smolts in Seabeck Creek, 2008.

Statistical week	Begin	End	Mean	St. Dev.	Range Min	Max	Number Sampled	Sample Rate
13	03/25/08	03/31/08	108.3	10.34	98	121	4	15.4%
14	04/01/08	04/07/08					0	0.0%
15	04/08/08	04/14/08					0	0.0%
16	04/15/08	04/21/08					0	0.0%
17	04/22/08	04/28/08					0	0.0%
18	04/29/08	05/05/08	105.3	9.96	87	123	15	19.2%
19	05/06/08	05/12/08	105.9	9.05	89	123	20	13.5%
20	05/13/08	05/19/08	105.1	9.47	86	131	88	23.4%
21	05/20/08	05/26/08	100.2	10.12	86	118	14	10.3%
22	05/27/08	06/02/08	95.5	6.09	89	107	6	28.6%
		Season total	104.3	9.49	86	131	147	

APPENDIX C-4.─Fork lengths (mm) of coho smolts in Stavis Creek, 2008.

Statistical week	Begin	End	Mean	St. Dev.	Range Min	Max	Number Sampled	Sample Rate
14	04/01/08	04/07/08					0	0.0%
15	04/08/08	04/14/08					0	0.0%
16	04/15/08	04/21/08					0	0.0%
17	04/22/08	04/28/08	96.0		96	96	1	11.1%
18	04/29/08	05/05/08	103.0	10.38	89	118	12	16.4%
19	05/06/08	05/12/08	95.8	7.52	81	120	46	11.1%
20	05/13/08	05/19/08	96.9	8.18	78	118	109	15.4%
21	05/20/08	05/26/08	95.4	7.13	83	115	72	5.6%
22	05/27/08	06/02/08	94.0	9.43	78	115	46	22.2%
23	06/03/08	06/09/08	96.0		96	96	1	4.3%
		Season total	96.0	7.64	78	120	287	

APPENDIX C-5.—Fork lengths (mm) of juvenile Chinook in Mill Creek, 2008.

					Range		Number	
Statistical week	Begin	End	Mean	St.Dev.	Min	Max	Sampled	Caught
7	02/11	02/17	35.7	0.82	35	37	10	21
8	02/18	02/24	36.1	1.44	34	39	13	52
9	02/25	03/02	35.9	2.06	34	40	14	174
10	03/03	03/09	33.7	1.16	32	35	10	301
11	03/10	03/16	35.4	1.51	34	38	10	706
12	03/17	03/23	37.4	2.27	34	41	10	672
13	03/24	03/30	39.2	2.25	36	43	10	419
14	03/31	04/06					0	712
15	04/07	04/13	37.6	1.78	35	41	10	847
16	04/14	04/20	37.0	1.15	35	39	10	649
17	04/21	04/27	36.9	0.74	36	38	10	80
18	04/28	05/04	36.8	1.28	35	39	8	30
19	05/05	05/11	38.5	1.29	37	40	4	5
20	05/12	05/18	50.5	4.51	45	56	4	4
21	05/19	05/25	48.0		48	48	1	3
22	05/26	06/01	52.0	3.46	47	55	4	4
23	06/02	06/08	59.0	6.27	49	68	7	18
24	06/09	06/15	60.6	7.47	50	68	5	7
25	06/16	06/22	46.0		46	46	1	1
26	06/23	06/29	62.0	16.46	52	81	3	3
		Season total	37.0	1.72	32	81	144	4,708

APPENDIX C-6. ─Fork lengths (mm) of juvenile Chinook in Abernathy Creek, 2008.

Statistical week	Begin	End	Mean	St. Dev.	Range		Number sampled
					Min	Max	
9	02/25	03/02	35.1	0.88	34	36	10
10	03/03	03/09	35.2	0.92	34	37	10
11	03/10	03/16	36.3	0.95	35	38	10
12	03/17	03/23	37.5	1.20	36	39	8
13	03/24	03/30	36.3	1.95	34	41	10
14	03/31	04/06					0
15	04/07	04/13	37.8	1.40	36	40	10
16	04/14	04/20	38.5	1.57	36	41	11
17	04/21	04/27	37.0	2.05	34	40	10
18	04/28	05/04	35.9	0.88	35	37	10
19	05/05	05/11	38.6	2.88	36	43	5
20	05/12	05/18	43.3	9.71	35	63	8
21	05/19	05/25	49.0	10.04	38	68	11
22	05/26	06/01	52.5	7.19	46	62	4
23	06/02	06/08	54.7	9.17	46	78	17
24	06/09	06/15	55.8	7.41	48	65	4
25	06/16	06/22	64.7	10.69	58	77	3
		Season total	37.9	1.91	34	78	141

APPENDIX C-7. ─Fork lengths (mm) of juvenile Chinook in Germany Creek, 2008.

Statistical week	Begin	End	Mean	St. Dev.	Range Min	Range Max	Number Sampled	Number Caught
6	02/07	02/10	35.5	0.93	34	37	8	20
7	02/11	02/17	37.6	1.26	35	39	10	104
8	02/18	02/24	36.1	1.10	34	38	10	41
9	02/25	03/02	36.1	1.41	34	39	17	105
10	03/03	03/09	37.4	1.58	35	40	10	208
11	03/10	03/16	36.3	1.25	34	38	10	744
12	03/17	03/23	36.3	1.25	34	38	10	592
13	03/24	03/30	37.8	1.39	36	40	9	418
14	03/31	04/06	37.8	1.55	36	41	10	657
15	04/07	04/13	38.6	1.96	36	42	10	328
16	04/14	04/20	39.1	2.60	36	45	10	34
17	04/21	04/27	37.1	1.45	35	39	10	74
18	04/28	05/04	38.1	4.04	35	49	10	47
19	05/05	05/11	49.7	8.30	33	72	18	25
20	05/12	05/18	50.7	5.40	40	60	19	63
21	05/19	05/25	53.4	13.00	41	95	16	121
22	05/26	06/01	54.1	6.84	46	68	10	86
23	06/02	06/08	58.4	6.92	49	76	17	163
24	06/09	06/15	60.7	8.09	50	78	15	75
25	06/16	06/22	63.0	10.00	52	76	4	12
		Season total	39.8	2.43	33	95	233	3,917

APPENDIX C-8. —Fork lengths of coho smolts in Mill Creek, 2008.

					Range		Number	
Statistical week	Begin	End	Mean	St. Dev.	Min	Max	Sampled	Caught
6	02/07	02/10	93.0		93	93	1	8
7	02/11	02/17	78.3	5.56	70	87	16	31
8	02/18	02/24	81.3	5.80	70	89	11	11
9	02/25	03/02	78.8	10.19	65	97	12	19
10	03/03	03/09	81.0	7.79	72	88	4	6
11	03/10	03/16	85.1	11.59	66	110	16	66
12	03/17	03/23	85.4	10.22	74	100	12	79
13	03/24	03/30	92.6	6.63	84	103	18	56
14	03/31	04/06	87.1	6.62	76	98	18	41
15	04/07	04/13	88.5	10.35	76	105	11	39
16	04/14	04/20	94.2	5.42	87	104	13	49
17	04/21	04/27	109.1	22.15	80	185	16	114
18	04/28	05/04	103.4	5.02	94	109	10	270
19	05/05	05/11	105.1	6.50	93	118	34	473
20	05/12	05/18	105.6	8.61	84	123	37	851
21	05/19	05/25	112.7	9.09	95	128	22	745
22	05/26	06/01	109.9	7.38	96	121	11	517
23	06/02	06/08	94.0		94	94	1	507
24	06/09	06/15	107.0	10.51	97	125	10	248
25	06/16	06/22	111.6	10.48	98	128	9	19
26	06/23	06/29					0	4
	Season totals		104.2	7.48	65	185	405	4,153

APPENDIX C-9. —Fork lengths of coho smolts in Abernathy Creek, 2008.

					Range		Number
Statistical week	Begin	End	Mean	St. Dev.	Min	Max	Sampled
6	02/07	02/10	76.9	10.91	62	94	10
7	02/11	02/17	77.6	10.90	51	96	12
8	02/18	02/24	78.5	9.50	66	93	6
9	02/25	03/02					0
10	03/03	03/09					0
11	03/10	03/16	81.9	7.74	69	95	10
12	03/17	03/23	76.3	8.50	68	88	4
13	03/24	03/30	94.5	9.19	88	101	2
14	03/31	04/06	96.0		96	96	1
15	04/07	04/13	74.0		74	74	1
16	04/14	04/20	102.7	2.52	100	105	3
17	04/21	04/27	103.1	9.52	91	124	10
18	04/28	05/04	109.2	12.43	88	150	48
19	05/05	05/11	112.2	14.29	80	165	115
20	05/12	05/18	113.2	10.84	84	160	338
21	05/19	05/25	117.0	8.63	96	139	303
22	05/26	06/01	115.1	9.79	94	140	132
23	06/02	06/08	113.6	8.47	94	132	65
24	06/09	06/15	112.8	12.00	98	135	9
25	06/16	06/22	108.0		108	108	1
		Season totals	112.1	10.33	51	165	1,070

APPENDIX C-10. ─Fork lengths of coho smolts in Germany Creek, 2008.

					Range		Number	
Statistical week	Begin	End	Mean	St. Dev.	Min	Max	Sampled	Caught
6	02/07	02/10	80.0		80	80	1	1
7	02/11	02/17	97.4	25.28	66	151	8	9
8	02/18	02/24	85.0	6.28	75	92	5	5
9	02/25	03/02	88.5	0.71	88	89	2	4
10	03/03	03/09	82.0		82	82	1	2
11	03/10	03/16	89.1	5.87	83	98	7	8
12	03/17	03/23	96.5	3.85	92	102	8	8
13	03/24	03/30	93.3	12.54	77	114	10	11
14	03/31	04/06	88.3	13.01	75	101	3	4
15	04/07	04/13	96.7	4.16	92	100	3	3
16	04/14	04/20	114.6	7.02	105	125	9	14
17	04/21	04/27	121.5	20.55	101	154	10	20
18	04/28	05/04	111.7	6.42	97	120	11	66
19	05/05	05/11	112.1	9.97	102	136	20	105
20	05/12	05/18	116.1	7.09	94	128	34	466
21	05/19	05/25	117.4	8.58	101	133	24	798
22	05/26	06/01	118.0	0.00	118	118	2	466
23	06/02	06/08	110.9	7.38	100	121	11	258
24	06/09	06/15	106.0	10.28	90	120	6	39
25	06/16	06/22	115.5	4.95	112	119	2	4
		Season totals	115.3	5.46	66	154	177	2,291

APPENDIX C-10. ─Fork lengths of steelhead and cutthroat smolts in Mill Creek, 2008.

			Steelhead					Cutthroat				
					Range		Number			Range		Number
Statistical week	Begin	End	Mean	St.Dev.	Min	Max	Sampled	Mean	St.Dev.	Min	Max	Sampled
6	02/07	02/10										
7	02/11	02/17	147.0		147	147	1	126.0		126	126	1
8	02/18	02/24										
9	02/25	03/02	133.0		133	133	1	126.3	14.58	115	145	6
10	03/03	03/09	144.0		144	144	1					
11	03/10	03/16	128.2	9.71	122	145	5	147.7	38.48	116	206	6
12	03/17	03/23	152.0		152	152	1	129.7	18.12	117	166	6
13	03/24	03/30	127.0		127	127	1	134.3	6.24	128	141	4
14	03/31	04/06	145.0		145	145	1	140.7	15.50	125	156	3
15	04/07	04/13	141.0	21.21	126	156	2	192.5	6.36	188	197	2
16	04/14	04/20	157.4	19.48	122	187	14	160.6	28.61	128	220	12
17	04/21	04/27	170.3	17.13	145	200	11	170.2	30.35	127	211	12
18	04/28	05/04	155.7	24.41	127	209	10	173.8	26.57	125	219	11
19	05/05	05/11	147.9	13.24	138	181	10	165.9	20.19	139	198	7
20	05/12	05/18	148.7	12.84	127	168	12	165.2	21.88	130	195	12
21	05/19	05/25	151.1	14.22	138	178	7	176.5	32.44	133	230	6
22	05/26	06/01	152.0	9.62	142	165	5	164.0	29.25	132	200	6
23	06/02	06/08	165.5	0.71	165	166	2	172.8	19.00	138	210	12
24	06/09	06/15	166.0	19.08	154	188	3	175.3	22.69	128	208	12
25	06/16	06/22						181.8	31.268	134	212	5
26	06/23	06/29	193.0		193	193	1	168		168	168	1
		Season total	154.5	15.90	122	209	88	167.8	23.44	115	230	124

APPENDIX C-11. ─Fork lengths of steelhead and cutthroat smolts in Abernathy Creek, 2008.

			Steelhead					Cutthroat				
					Range		Number			Range		Number
Statistical week	Begin	End	Mean	St.Dev.	Min	Max	sampled	Mean	St.Dev.	Min	Max	sampled
6	02/07	02/10					0					0
7	02/11	02/17					0					0
8	02/18	02/24	127.0		127	127	1					0
9	02/25	03/02	158.0		158	158	1					0
10	03/03	03/09					0					0
11	03/10	03/16	124.7	8.39	115	130	3					0
12	03/17	03/23					0					0
13	03/24	03/30	112.0		112	112	1					0
14	03/31	04/06	200.0		200	200	1					0
15	04/07	04/13	138.0		138	138	1					0
16	04/14	04/20	168.5	7.78	163	174	2					0
17	04/21	04/27					0					0
18	04/28	05/04	148.2	17.26	133	179	6	171.0	33.94	147	195	2
19	05/05	05/11	152.4	15.87	124	174	11	157.0	18.38	144	170	2
20	05/12	05/18	168.0	20.06	129	210	35	192.2	24.99	156	238	13
21	05/19	05/25	169.0	11.7	145	190	18	171.0	17.57	145	195	6
22	05/26	06/01	173.5	31.82	151	196	2					0
23	06/02	06/08	158.5	12.02	150	167	2	208.0		208	208	1
24	06/09	06/15					0	159.7	24.58	144	188	3
25	06/16	06/22	166.0		166	166	1					0
		Season total	163.88	17.48	112	210	85	176.6	23.59	144	238	27

APPENDIX C-12. ─Fork lengths of steelhead and cutthroat smolts in Germany Creek, 2008.

			Steelhead					Cutthroat				
					Range		Number			Range		Number
Statistical week	Begin	End	Mean	St.Dev.	Min	Max	Sampled	Mean	St.Dev.	Min	Max	Sampled
6	02/07	02/10					0					0
7	02/11	02/17	128.0		128	128	1					0
8	02/18	02/24					0					0
9	02/25	03/02					0					0
10	03/03	03/09					0					0
11	03/10	03/16					0					0
12	03/17	03/23					0					0
13	03/24	03/30					0					0
14	03/31	04/06	147.0		147	147	1					0
15	04/07	04/13					0	162.0		162	162	1
16	04/14	04/20	181.2	20.48	152	215	12					0
17	04/21	04/27	200.0	19.54	173	232	10	180.0		180	180	1
18	04/28	05/04	179.2	16.67	145	214	25					0
19	05/05	05/11	177.9	20.89	118	200	14	185.5	12.02	177	194	2
20	05/12	05/18	181.5	14.21	153	207	19	196.7	19.75	168	225	7
21	05/19	05/25	167.8	16.35	139	202	24	174.6	13.68	154	197	15
22	05/26	06/01					0	179.3	17.81	157	205	12
23	06/02	06/08					0	170.8	12.69	152	180	4
24	06/09	06/15	167.0		167	167	1	166.5	24.45	130	199	6
25	06/16	06/22					0					0
		Season total	177.8	16.43	118	232	107	179.5	16.85	130	225	48

APPENDIX D

Statistical weeks and corresponding dates in 2008.

APPENDIX D: Statistical weeks and corresponding dates in 2008. Statistical weeks begin on Monday and end on Sunday of a given week. The first and last statistical week of each year are typically less than seven days.

2008 Statistical Week Listing

Week Number	First Day Monday	Last Day Sunday	Statistical Month
1	1-Jan	6-Jan	January
2	7-Jan	13-Jan	January
3	14-Jan	20-Jan	January
4	21-Jan	27-Jan	January
5	28-Jan	3-Feb	January
6	4-Feb	10-Feb	February
7	11-Feb	17-Feb	February
8	18-Feb	24-Feb	February
9	25-Feb	2-Mar	February*
10	3-Mar	9-Mar	March
11	10-Mar	16-Mar	March
12	17-Mar	23-Mar	March
13	24-Mar	30-Mar	March
14	31-Mar	6-Apr	March
15	7-Apr	13-Apr	April
16	14-Apr	20-Apr	April
17	21-Apr	27-Apr	April
18	28-Apr	4-May	April
19	5-May	11-May	May
20	12-May	18-May	May
21	19-May	25-May	May
22	26-May	1-Jun	May
23	2-Jun	8-Jun	June
24	9-Jun	15-Jun	June
25	16-Jun	22-Jun	June
26	23-Jun	29-Jun	June
27	30-Jun	6-Jul	June
28	7-Jul	13-Jul	July
29	14-Jul	20-Jul	July
30	21-Jul	27-Jul	July
31	28-Jul	3-Aug	July
32	4-Aug	10-Aug	August
33	11-Aug	17-Aug	August
34	18-Aug	24-Aug	August
35	25-Aug	31-Aug	August
36	1-Sep	7-Sep	September
37	8-Sep	14-Sep	September
38	15-Sep	21-Sep	September
39	22-Sep	28-Sep	September
40	29-Sep	5-Oct	September
41	6-Oct	12-Oct	October
42	13-Oct	19-Oct	October
43	20-Oct	26-Oct	October
44	27-Oct	2-Nov	October
45	3-Nov	9-Nov	November
46	10-Nov	16-Nov	November
47	17-Nov	23-Nov	November
48	24-Nov	30-Nov	November
49	1-Dec	7-Dec	December
50	8-Dec	14-Dec	December
51	15-Dec	21-Dec	December
52	22-Dec	28-Dec	December
53	29-Dec	31-Dec	December

* Leap Year

APPENDIX E

Population estimates of Chinook spawners in Mill, Abernathy, and Germany creeks

APPENDIX E: Population estimates of Chinook spawners in Mill, Abernathy, and Germany creeks

Appendix E-1. Population estimate of Chinook spawners for 102 reaches in Germany Creek beginning at the mouth based on trapezoidal approximation of the AUC. (Blank cells indicate reaches were not surveyed in 2008.)

Survey Reach	Reach Lgth (m)	Density Fish/m	All Pop. Est	All 95% CI Lower	All 95% CI Upper	Females Pop. Est	Females 95% CI Lower	Females 95% CI Upper	Males Pop. Est	Males 95% CI Lower	Males 95% CI Upper
1-0	234	0.00	0	0	0	0	0	0	0	0	0
2-0	100	0.00	0	0	0	0	0	0	0	0	0
2-1	100	0.00	0	0	0	0	0	0	0	0	0
2-2	83	0.00	0	0	0	0	0	0	0	0	0
3-0	100	0.00	0	0	0	0	0	0	0	0	0
3-1	100	0.00	0	0	0	0	0	0	0	0	0
3-2	100	0.00	0	0	0	0	0	0	0	0	0
3-3	100	0.00	0	0	0	0	0	0	0	0	0
3-4	100	0.00	0	0	0	0	0	0	0	0	0
3-5	100	0.07	7	6	9	3	2	4	4	3	5
3-6	100	0.00	0	0	0	0	0	0	0	0	0
3-7	100	0.00	0	0	0	0	0	0	0	0	0
3-8	100	0.03	3	2	4	1	1	2	2	1	2
3-9	100	0.07	7	6	9	3	2	4	4	3	5
3-10	100	0.00	0	0	0	0	0	0	0	0	0
3-11	100	0.06	6	5	7	2	2	3	3	2	4
3-12	100	0.00	0	0	0	0	0	0	0	0	0
3-13	100	0.10	10	8	12	4	3	6	6	4	7
3-14	100	0.03	3	2	3	1	1	2	2	1	2
3-15	100	0.03	3	2	3	1	1	2	2	1	2
3-16	100	0.00	0	0	0	0	0	0	0	0	0
3-17	100	0.14	14	12	17	6	4	8	8	6	10
3-18	100	0.19	19	16	24	8	6	11	11	8	14
3-19	100	0.01	1	1	2	1	0	1	1	1	1
3-20	100	0.00	0	0	0	0	0	0	0	0	0
3-21	100	0.03	3	2	4	1	1	2	2	1	2
3-22	100	0.07	7	6	9	3	2	4	4	3	5
3-23	55	0.00	0	0	0	0	0	0	0	0	0
4-0	100	0.04	4	4	5	2	1	2	2	2	3
4-1	100	0.03	3	2	4	1	1	2	2	1	2
4-2	100	0.00	0	0	0	0	0	0	0	0	0
4-3	100	0.21	21	17	26	9	6	12	12	8	15
4-4	100	0.22	22	19	28	10	7	13	13	9	16
4-5	100	0.03	3	2	3	1	1	2	2	1	2
4-6	100	0.01	1	1	2	1	0	1	1	1	1
4-7	100	0.01	1	1	2	1	0	1	1	1	1

Appendix E-1. Population estimate of Chinook spawners for 102 reaches in Germany Creek beginning at the mouth based on trapezoidal approximation of the AUC. (Blank cells indicate reaches were not surveyed in 2008.)

			All			Females			Males		
Survey Reach	Reach Lgth (m)	Density Fish/m	Pop. Est	95% CI Lower	95% CI Upper	Pop. Est	95% CI Lower	95% CI Upper	Pop. Est	95% CI Lower	95% CI Upper
4-8	100	0.07	7	6	9	3	2	4	4	3	5
4-9	100	0.00	0	0	0	0	0	0	0	0	0
4-10	100	0.12	12	10	15	5	4	7	7	5	9
4-11	100	0.04	4	3	5	2	1	2	2	2	3
4-12	100	0.10	10	8	12	4	3	6	6	4	7
4-13	100	0.11	11	9	13	5	3	6	6	4	8
4-14	100	0.10	10	8	12	4	3	6	5	4	7
4-15	100	0.04	4	4	5	2	1	2	2	2	3
4-16	72.5	0.27	20	16	24	9	6	11	11	8	14
5-0	100	0.38	38	32	48	17	12	22	21	15	27
5-1	100	0.29	29	24	35	13	9	16	16	11	20
5-2	100	1.14	114	95	141	50	35	66	64	46	82
5-3	100	0.30	30	25	37	13	9	17	17	12	21
5-4	100	0.31	31	26	38	14	9	18	17	12	22
5-5	100	0.35	35	29	43	15	11	20	19	14	25
5-6	100	0.00	0	0	0	0	0	0	0	0	0
5-7	100	0.00	0	0	0	0	0	0	0	0	0
5-8	100	0.00	0	0	0	0	0	0	0	0	0
5-9	100	0.00	0	0	0	0	0	0	0	0	0
5-10	100	0.00	0	0	0	0	0	0	0	0	0
5-11	100	0.00	0	0	0	0	0	0	0	0	0
5-12	100	0.00	0	0	0	0	0	0	0	0	0
5-13	100	0.00	0	0	0	0	0	0	0	0	0
5-14	100	0.00	0	0	0	0	0	0	0	0	0
5-15	100	0.00	0	0	0	0	0	0	0	0	0
5-16	100	0.00	0	0	0	0	0	0	0	0	0
5-17	100	0.00	0	0	0	0	0	0	0	0	0
5-18	100	0.00	0	0	0	0	0	0	0	0	0
5-19	100	0.00	0	0	0	0	0	0	0	0	0
5-20	100	0.00	0	0	0	0	0	0	0	0	0
5-21	100	0.00	0	0	0	0	0	0	0	0	0
5-22	100	0.00	0	0	0	0	0	0	0	0	0
5-23	110	0.00	0	0	0	0	0	0	0	0	0
5-24	100	0.00	0	0	0	0	0	0	0	0	0
5-25	100	0.00	0	0	0	0	0	0	0	0	0
5-26	100	0.00	0	0	0	0	0	0	0	0	0
5-27	66.6	0.00	0	0	0	0	0	0	0	0	0
Apple Cr Bridge- .41 miles below	661.6										

Appendix E-1. Population estimate of Chinook spawners for 102 reaches in Germany Creek beginning at the mouth based on trapezoidal approximation of the AUC. (Blank cells indicate reaches were not surveyed in 2008.)

			All			Females			Males		
Survey Reach	Reach Lgth (m)	Density Fish/m	Pop. Est	95% CI		Pop. Est	95% CI		Pop. Est	95% CI	
				Lower	Upper		Lower	Upper		Lower	Upper
Apple Cr Bridge-.54 mile above	882.6										
7-0	100										
7-1	100										
7-2	100										
7-3	100										
7-4	100										
7-5	100										
7-6	100										
7-7	100										
7-8	100										
7-9	100										
7-10	100										
7-11	100										
7-12	100										
7-13	100										
7-14	100										
7-15	100										
7-16	100										
7-17	100										
7-18	100										
7-19	100										
7-20	100										
7-21	100										
7-22	100										
7-23	79.6										
8-0	100										
8-1	115.2										
9 & 10	2317										

Appendix E-2.─Population estimates of Chinook spawners for 153 reaches in the Abernathy Creek beginning at the mouth based on trapezoidal approximation of the AUC. (Blank cells indicate reaches were not surveyed in 2008.)

Survey Reach	Reach Lgth (m)	Density Fish/m	All Pop. Est	All 95% CI Lower	All 95% CI Upper	Females Pop. Est	Females 95% CI Lower	Females 95% CI Upper	Males Pop. Est	Males 95% CI Lower	Males 95% CI Upper
1-0	341.5	0.01	4	4	5	2	1	3	2	1	3
2-0	100	0.04	4	3	5	2	1	3	2	1	3
2-1	100	0.00	0	0	0	0	0	0	0	0	0
2-2	100	0.00	0	0	0	0	0	0	0	0	0
2-3	100	0.01	1	1	2	1	0	1	1	0	1
2-4	83.8	0.04	4	3	4	2	1	3	2	1	3
3-0	100	0.05	5	5	7	3	1	4	3	2	4
3-1	100	0.00	0	0	0	0	0	0	0	0	0
3-2	100	0.00	0	0	0	0	0	0	0	0	0
3-3	100	0.00	0	0	0	0	0	0	0	0	0
3-4	100	0.01	1	1	2	1	0	1	1	0	1
3-5	100	0.00	0	0	0	0	0	0	0	0	0
3-6	100	0.01	1	1	2	1	0	1	1	0	1
3-7	100	0.00	0	0	0	0	0	0	0	0	0
3-8	100	0.00	0	0	0	0	0	0	0	0	0
3-9	100	0.00	0	0	0	0	0	0	0	0	0
3-10	100	0.00	0	0	0	0	0	0	0	0	0
3-11	100	0.00	0	0	0	0	0	0	0	0	0
3-12	100	0.00	0	0	0	0	0	0	0	0	0
3-13	100	0.00	0	0	0	0	0	0	0	0	0
3-14	100	0.00	0	0	0	0	0	0	0	0	0
3-15	100	0.00	0	0	0	0	0	0	0	0	0
3-16	100	0.00	0	0	0	0	0	0	0	0	0
3-17	47	0.00	0	0	0	0	0	0	0	0	0
4-0	100	0.00	0	0	0	0	0	0	0	0	0
4-1	100	0.00	0	0	0	0	0	0	0	0	0
4-2	100	0.00	0	0	0	0	0	0	0	0	0
4-3	100	0.02	2	2	3	1	1	2	1	1	2
4-4	100	0.00	0	0	0	0	0	0	0	0	0
4-5	100	0.00	0	0	0	0	0	0	0	0	0
4-6	100	0.00	0	0	0	0	0	0	0	0	0
4-7	100	0.01	1	1	2	1	0	1	1	0	1
4-8	100	0.03	3	2	3	1	1	2	1	1	2
4-9	100	0.00	0	0	0	0	0	0	0	0	0
4-10	100	0.00	0	0	0	0	0	0	0	0	0
4-11	100	0.00	0	0	0	0	0	0	0	0	0
4-12	100	0.00	0	0	0	0	0	0	0	0	0
4-13	100	0.00	0	0	0	0	0	0	0	0	0
4-14	100	0.05	5	4	6	2	1	4	3	2	4
4-15	100	0.04	4	3	5	2	1	3	2	1	3
4-16	100	0.05	5	4	6	2	1	4	3	2	4
4-17	100	0.01	1	1	2	1	0	1	1	0	1
4-18	100	0.01	1	1	2	1	0	1	1	0	1

Appendix E-2.—Population estimates of Chinook spawners for 153 reaches in the Abernathy Creek beginning at the mouth based on trapezoidal approximation of the AUC. (Blank cells indicate reaches were not surveyed in 2008.)

Survey Reach	Reach Lgth (m)	Density Fish/m	All			Females			Males		
			Pop. Est	95% CI Lower	95% CI Upper	Pop. Est	95% CI Lower	95% CI Upper	Pop. Est	95% CI Lower	95% CI Upper
4-19	100	0.01	1	1	2	1	0	1	1	0	1
4-20	100	0.04	4	3	5	2	1	3	2	1	3
4-21	100	0.03	3	2	3	1	1	2	1	1	2
4-22	100	0.01	1	1	2	1	0	1	1	0	1
4-23	80	0.36	29	25	35	13	7	20	16	9	23
5-0	100	0.01	1	1	1	1	0	1	1	0	1
5-1	100	0.00	0	0	0	0	0	0	0	0	0
5-2	100	0.00	0	0	0	0	0	0	0	0	0
5-3	100	0.00	0	0	0	0	0	0	0	0	0
5-4	100	0.00	0	0	0	0	0	0	0	0	0
5-5	100	0.00	0	0	0	0	0	0	0	0	0
5-6	100	0.01	1	1	2	1	0	1	1	0	1
5-7	31	0.00	0	0	0	0	0	0	0	0	0
6-0	NA										
7-0	70										
8-0	100										
8-1	100										
8-2	100										
8-3	100										
8-4	100										
8-5	100										
8-6	100										
8-7	100										
8-8	100										
8-9	100										
8-10	100										
8-11	100										
8-12	100										
8-13	100										
8-14	100										
8-15	100										
8-16	100										
8-17	100										
8-18	100										
8-19	100										
8-20	100										
8-21	100										
8-22	100										
8-23	100										
8-24	100										
8-25	100										
8-26	100										
8-27	100										

Appendix E-2.─Population estimates of Chinook spawners for 153 reaches in the Abernathy Creek beginning at the mouth based on trapezoidal approximation of the AUC. (Blank cells indicate reaches were not surveyed in 2008.)

Survey Reach	Reach Lgth (m)	Density Fish/m	All Pop. Est	All 95% CI Lower	All 95% CI Upper	Females Pop. Est	Females 95% CI Lower	Females 95% CI Upper	Males Pop. Est	Males 95% CI Lower	Males 95% CI Upper
8-28	100										
8-29	100										
8-30	100										
8-31	100										
8-32	100										
8-33	100										
8-34	100										
8-35	100										
9-0	100										
9-1	100										
9-2	100										
9-3	100										
9-4	100										
9-5	100										
9-6	100										
9-7	100										
9-8	100										
9-9	100										
9-10	100										
9-11	100										
9-12	100										
9-13	100										
9-14	100										
9-15	100										
9-16	100										
9-17	100										
9-18	100										
9-19	100										
9-20	100										
9-21	100										
9-22	100										
9-23	100										
9-24	100										
9-25	100										
9-26	100										
9-27	100										
9-28	100										
9-29	100										
9-30	100										
9-31	100										
9-32	100										
9-33	100										
9-34	100										

Appendix E-2.—Population estimates of Chinook spawners for 153 reaches in the Abernathy Creek beginning at the mouth based on trapezoidal approximation of the AUC. (Blank cells indicate reaches were not surveyed in 2008.)

Survey Reach	Reach Lgth (m)	Density Fish/m	All			Females			Males		
			Pop. Est	95% CI		Pop. Est	95% CI		Pop. Est	95% CI	
				Lower	Upper		Lower	Upper		Lower	Upper
9-35	100										
9-36	100										
9-37	100										
9-38	100										
9-39	100										
9-40	100										
9-41	100										
9-42	100										
9-43	100										
9-44	100										
9-45	100										
9-46	37										
10-0	100										
10-1	100										
10-2	100										
10-3	100										
10-4	100										
10-5	100										
10-6	100										
10-7	100										
10-8	100										
10-9	100										
10-10	100										
10-11	75										

Appendix E-3. ─Population estimates for Chinook spawners for 86 reaches in Mill Creek and 11 reaches in SF Mill Creek beginning at the mouth based on trapezoidal approximation of the AUC. (Blank cells indicate reaches were not surveyed in 2008.)

Survey Reach	Reach Lgth (m)	Density Fish/m	All			Females			Males		
			Pop. Est	95% CI Lower	95% CI Upper	Pop. Est	95% CI Lower	95% CI Upper	Pop. Est	95% CI Lower	95% CI Upper
1-0	374	0.00	0	0	0	0	0	0	0	0	0
2-0	100	0.00	0	0	0	0	0	0	0	0	0
2-1	100	0.00	0	0	0	0	0	0	0	0	0
2-2	100	0.01	1	1	2	1	0	1	1	0	1
2-3	100	0.00	0	0	0	0	0	0	0	0	0
2-4	100	0.00	0	0	0	0	0	0	0	0	0
2-5	100	0.00	0	0	0	0	0	0	0	0	0
2-6	100	0.00	0	0	0	0	0	0	0	0	0
2-7	100	0.01	1	1	2	1	0	1	1	0	1
2-8	100	0.00	0	0	0	0	0	0	0	0	0
2-9	100	0.02	2	1	2	1	0	1	1	1	1
2-10	100	0.00	0	0	0	0	0	0	0	0	0
2-11	100	0.00	0	0	0	0	0	0	0	0	0
2-12	100	0.00	0	0	0	0	0	0	0	0	0
2-13	100	0.00	0	0	0	0	0	0	0	0	0
2-14	100	0.00	0	0	0	0	0	0	0	0	0
2-15	37	0.00	0	0	0	0	0	0	0	0	0
3-0	100	0.00	0	0	0	0	0	0	0	0	0
3-1	100	0.00	0	0	0	0	0	0	0	0	0
3-2	100	0	0	0	0	0	0	0	0	0	0
3-3	100	0	0	0	0	0	0	0	0	0	0
3-4	100	0	0	0	0	0	0	0	0	0	0
3-5	100	1	1	2	1	0	1	1	0	1	1
3-6	100	0	0	0	0	0	0	0	0	0	0
3-7	100	1	1	2	1	0	1	1	0	1	1
3-8	100	0	0	0	0	0	0	0	0	0	0
3-9	100	5	4	7	2	1	3	3	2	4	5
3-10	100	0	0	0	0	0	0	0	0	0	0
3-11	100	8	7	11	4	2	5	5	3	6	8
3-12	100	30	23	40	13	8	18	17	10	23	30
3-13	100	1	1	2	1	0	1	1	0	1	1
3-14	100	2	2	3	1	1	1	1	1	2	2
3-15	100	0.01	1	1	2	1	0	1	1	0	1
3-16	100	0.02	2	2	3	1	1	1	1	1	2
3-17	100	0.00	0	0	0	0	0	0	0	0	0
3-18	100	0.04	4	3	5	2	1	2	2	1	3
3-19	100	0.06	6	5	8	3	2	4	3	2	5
3-20	100	0.16	16	13	22	7	4	10	9	6	13
3-21	100	0.24	24	19	33	11	6	15	13	8	19
3-22	100	0.47	47	37	63	21	12	29	26	16	36

Appendix E-3. ─Population estimates for Chinook spawners for 86 reaches in Mill Creek and 11 reaches in SF Mill Creek beginning at the mouth based on trapezoidal approximation of the AUC. (Blank cells indicate reaches were not surveyed in 2008.)

Survey Reach	Reach Lgth (m)	Density Fish/m	All Pop. Est	All 95% CI Lower	All 95% CI Upper	Females Pop. Est	Females 95% CI Lower	Females 95% CI Upper	Males Pop. Est	Males 95% CI Lower	Males 95% CI Upper
3-23	100	0.01	1	1	2	1	0	1	1	0	1
3-24	100	0.05	5	4	7	2	1	3	3	2	4
3-25	100	0.20	20	16	28	9	5	13	11	7	16
3-26	100	0.18	18	14	24	8	5	11	10	6	14
3-27	100	0.25	25	20	34	11	7	16	14	9	20
3-28	100	0.01	1	1	2	1	0	1	1	0	1
3-29	100	0.00	0	0	0	0	0	0	0	0	0
3-30	100	0.00	0	0	0	0	0	0	0	0	0
3-31	100	0.04	4	3	5	2	1	2	2	1	3
3-32	100	0.04	4	3	5	2	1	2	2	1	3
3-33	100	0.06	6	5	8	3	2	4	3	2	5
3-34	100	0.00	0	0	0	0	0	0	0	0	0
3-35	100	0.00	0	0	0	0	0	0	0	0	0
3-36	100	0.00	0	0	0	0	0	0	0	0	0
3-37	100	0.01	1	1	2	1	0	1	1	0	1
3-38	100	0.00	0	0	0	0	0	0	0	0	0
3-39	100	0.00	0	0	0	0	0	0	0	0	0
3-40	100	0.00	0	0	0	0	0	0	0	0	0
3-41	100	0.00	0	0	0	0	0	0	0	0	0
3-42	100	0.00	0	0	0	0	0	0	0	0	0
3-43	100	0.00	0	0	0	0	0	0	0	0	0
3-44	40	0.00	0	0	0	0	0	0	0	0	0
4-0	100	0.00	0	0	0	0	0	0	0	0	0
4-1	100	0.00	0	0	0	0	0	0	0	0	0
4-2	100	0.00	0	0	0	0	0	0	0	0	0
4-3	100	0.00	0	0	0	0	0	0	0	0	0
4-4	100	0.00	0	0	0	0	0	0	0	0	0
4-5	100	0.00	0	0	0	0	0	0	0	0	0
4-6	100	0.00	0	0	0	0	0	0	0	0	0
4-7	100	0.00	0	0	0	0	0	0	0	0	0
5-0	100	0.00	0	0	0	0	0	0	0	0	0
5-1	100	0.00	0	0	0	0	0	0	0	0	0
5-2	122.6	0.00	0	0	0	0	0	0	0	0	0
6-0	100	0.00	0	0	0	0	0	0	0	0	0
6-1	100	0.00	0	0	0	0	0	0	0	0	0
6-2	100	0.00	0	0	0	0	0	0	0	0	0
6-3	100	0.00	0	0	0	0	0	0	0	0	0
6-4	100	0.00	0	0	0	0	0	0	0	0	0
6-5	100	0.00	0	0	0	0	0	0	0	0	0
6-6	100	0.00	0	0	0	0	0	0	0	0	0

Appendix E-3. ─Population estimates for Chinook spawners for 86 reaches in Mill Creek and 11 reaches in SF Mill Creek beginning at the mouth based on trapezoidal approximation of the AUC. (Blank cells indicate reaches were not surveyed in 2008.)

Survey Reach	Reach Lgth (m)	Density Fish/m	All Pop. Est	All 95% CI Lower	All 95% CI Upper	Females Pop. Est	Females 95% CI Lower	Females 95% CI Upper	Males Pop. Est	Males 95% CI Lower	Males 95% CI Upper
6-7	100	0.00	0	0	0	0	0	0	0	0	0
6-8	100	0.00	0	0	0	0	0	0	0	0	0
6-9	100	0.00	0	0	0	0	0	0	0	0	0
6-10	100	0.00	0	0	0	0	0	0	0	0	0
6-11	100	0.00	0	0	0	0	0	0	0	0	0
6-12	63	0.00	0	0	0	0	0	0	0	0	0
SFM 1-0	100	0.00	0	0	0	0	0	0	0	0	0
SFM 1-1	100	0.00	0	0	0	0	0	0	0	0	0
SFM 1-2	100	0.00	0	0	0	0	0	0	0	0	0
SFM 1-3	100	0.00	0	0	0	0	0	0	0	0	0
SFM 1-4	100	0.00	0	0	0	0	0	0	0	0	0
SFM 1-5	100	0.00	0	0	0	0	0	0	0	0	0
SFM 1-6	100	0.00	0	0	0	0	0	0	0	0	0
SFM 1-7	100	0.00	0	0	0	0	0	0	0	0	0
SFM 1-8	100	0.00	0	0	0	0	0	0	0	0	0
SFM 1-9	67.2	0.00	0	0	0	0	0	0	0	0	0
SFM >Brg ~ 0.5 mi.	503.4	0.00	0	0	0	0	0	0	0	0	0

APPENDIX F

Steelhead redd locations in Mill, Abernathy, and Germany creeks.

APPENDIX F: Steelhead redd locations in Mill, Abernathy, and Germany creeks.

Appendix F-1.─Steelhead redds observed per river mile (RM) sections of Mill, Abernathy, and Germany creeks, 2008.

SubBasin	Stream Name	Rmi Section	# of Redds	Length (Mi)	Redds / Mi
Abernathy	Abernathy Creek	0 to 1	2	1.0	2
Abernathy	Abernathy Creek	1 to 2	6	1.0	6
Abernathy	Abernathy Creek	2 to 3	41	1.0	41
Abernathy	Abernathy Creek	3 to 4	46	1.0	46
Abernathy	Abernathy Creek	4 to 5	21	1.0	21
Abernathy	Abernathy Creek	5 to 6	9	1.0	9
Abernathy	Abernathy Creek	6 to 7	4	1.0	4
Abernathy	Abernathy Creek	7 to 8	7	1.0	7
Abernathy	Abernathy Creek	8 to 9	8	1.0	8
Abernathy	Abernathy Creek	9 to 9.8	1	0.8	1.3
Abernathy Tribs	Wiest Creek	0 to 1	0	1.0	0
Abernathy Tribs	Wiest Creek	1 to 1.9	0	0.9	0
Abernathy Tribs	Cameron Creek	0 to 1	2	1.0	2
Abernathy Tribs	Cameron Creek	1 to 2	2	1.0	2
Abernathy Tribs	Cameron Creek	2 to 3	0	1.0	0
Abernathy Tribs	Cameron Creek	3 to 4	0	1.0	0
Abernathy Tribs	Cameron Creek	4 to 4.2	0	0.2	0
Abernathy Tribs	Erick Creek	0 to 0.8	1	0.8	1.3
Abernathy Tribs	Midway Creek	0 to 0.2	0	0.2	0
Abernathy Tribs	Cameron RB Trib	0 to 0.2	0	0.2	0
Abernathy Tribs	Sara Creek	0 to 0.7	0	0.7	0
Abernathy Tribs	South Fork Ordway	0 to 0.1	0	0.1	0
Abernathy Tribs	Ordway Creek	0 to 1	2	1.0	2
Abernathy Tribs	Ordway Creek	1 to 1.1	1	0.0	27.1
Germany	Germany Creek	0 to 1	7	1.0	7
Germany	Germany Creek	1 to 2	9	1.0	9
Germany	Germany Creek	2 to 3	5	1.0	5
Germany	Germany Creek	3 to 4	11	1.0	11
Germany	Germany Creek	4 to 5	17	1.0	17
Germany	Germany Creek	5 to 6	8	1.0	8
Germany	Germany Creek	6 to 7	11	1.0	11
Germany	Germany Creek	7 to 8	18	1.0	18
Germany	Germany Creek	8 to 9	30	1.0	30
Germany	Germany Creek	9 to 10	24	1.0	24
Germany	Germany Creek	10 to 11	9	1.0	9
Germany	Germany Creek	11 to 11.1	0	0.1	0
Germany Tribs	Apple Creek	0 to 0.1	0	0.1	0
Germany Tribs	GURT3 [1)]	0 to 0.3	0	0.3	0
Germany Tribs	West Fork Germany Creek	0 to 0.7	0	0.7	0
Germany Tribs	East Fork Germany Creek	0 to 0.9	1	0.9	1.1
Mill	Mill Creek	0 to 1	1	1.0	1
Mill	Mill Creek	1 to 2	7	1.0	7
Mill	Mill Creek	2 to 3	5	1.0	5
Mill	Mill Creek	3 to 4	3	1.0	3
Mill	Mill Creek	4 to 5	1	1.0	1
Mill	Mill Creek	5 to 6	1	1.0	1
Mill	Mill Creek	6 to 7	1	1.0	1
Mill	Mill Creek	7 to 8	0	1.0	0
Mill	Mill Creek	8 to 9	2	1.0	2

SubBasin	Stream Name	Rmi Section	# of Redds	Length (Mi)	Redds / Mi
Mill	Mill Creek	9 to 10	0	1.0	0
Mill	Mill Creek	10 to 11	0	1.0	0
Mill	Mill Creek	11 to 12	0	1.0	0
Mill	Mill Creek	12 to 12.1	0	0.1	0
Mill Tribs	South Fork Mill Creek	0 to 1	1	1.0	1
Mill Tribs	South Fork Mill Creek	1 to 2	0	1.0	0
Mill Tribs	South Fork Mill Creek	2 to 3	0	1.0	0
Mill Tribs	South Fork Mill Creek	3 to 3.4	0	0.4	0
Mill Tribs	Spruce Creek	0 to 1	1	1.0	1
Mill Tribs	Spruce Creek	1 to 1.4	0	0.4	0
Mill Tribs	North Fork Mill Creek	0 to 1	0	1.0	0
Mill Tribs	North Fork Mill Creek	1 to 1.3	0	0.3	0

[1)] Germany Upper Right Trib # 3

Appendix F-2.─Steelhead redds observed per river kilometer (Rkm) sections of Mill, Abernathy, and Germany creeks, 2008.

SubBasin	Stream Name	Rkm Section	# of Redds	Length (Km)	Redds / Km
Abernathy	Abernathy Creek	0 to 1	0	1.0	0
Abernathy	Abernathy Creek	1 to 2	2	1.0	2
Abernathy	Abernathy Creek	2 to 3	5	1.0	5
Abernathy	Abernathy Creek	3 to 4	12	1.0	12
Abernathy	Abernathy Creek	4 to 5	36	1.0	36
Abernathy	Abernathy Creek	5 to 6	33	1.0	33
Abernathy	Abernathy Creek	6 to 7	18	1.0	18
Abernathy	Abernathy Creek	7 to 8	9	1.0	9
Abernathy	Abernathy Creek	8 to 9	7	1.0	7
Abernathy	Abernathy Creek	9 to 10	3	1.0	3
Abernathy	Abernathy Creek	10 to 11	2	1.0	2
Abernathy	Abernathy Creek	11 to 12	5	1.0	5
Abernathy	Abernathy Creek	12 to 13	5	1.0	5
Abernathy	Abernathy Creek	13 to 14	7	1.0	7
Abernathy	Abernathy Creek	14 to 15	1	1.0	1
Abernathy	Abernathy Creek	15 to 15.7	0	0.7	0
Abernathy Tribs	Cameron Creek	0 to 1	0	1.0	0
Abernathy Tribs	Cameron Creek	1 to 2	2	1.0	2
Abernathy Tribs	Cameron Creek	2 to 3	2	1.0	2
Abernathy Tribs	Cameron Creek	3 to 4	0	1.0	0
Abernathy Tribs	Cameron Creek	4 to 5	0	1.0	0
Abernathy Tribs	Cameron Creek	5 to 6	0	1.0	0
Abernathy Tribs	Cameron Creek	6 to 6.8	0	0.8	0
Abernathy Tribs	Cameron RB Trib	0 to 0.3	0	0.3	0
Abernathy Tribs	Erick Creek	0 to 1	1	1.0	1
Abernathy Tribs	Erick Creek	1 to 1.3	0	0.3	0
Abernathy Tribs	Midway Creek	0 to 0.3	0	0.3	0
Abernathy Tribs	Ordway Creek	0 to 1	1	1.0	1
Abernathy Tribs	Ordway Creek	1 to 1.8	2	0.7	3
Abernathy Tribs	Sara Creek	0 to 1	0	1.0	0
Abernathy Tribs	Sara Creek	1 to 1.1	0	0.1	0
Abernathy Tribs	South Fork Ordway	0 to 0.2	0	0.2	0
Abernathy Tribs	Wiest Creek	0 to 1	0	1.0	0
Abernathy Tribs	Wiest Creek	1 to 2	0	1.0	0
Abernathy Tribs	Wiest Creek	2 to 3	0	1.0	0
Abernathy Tribs	Wiest Creek	3 to 3.1	0	0.1	0
Germany	Germany Creek	0 to 1	4	1.0	4
Germany	Germany Creek	1 to 2	8	1.0	8
Germany	Germany Creek	2 to 3	4	1.0	4
Germany	Germany Creek	3 to 4	2	1.0	2
Germany	Germany Creek	4 to 5	7	1.0	7
Germany	Germany Creek	5 to 6	5	1.0	5
Germany	Germany Creek	6 to 7	8	1.0	8
Germany	Germany Creek	7 to 8	11	1.0	11
Germany	Germany Creek	8 to 9	3	1.0	3
Germany	Germany Creek	9 to 10	7	1.0	7
Germany	Germany Creek	10 to 11	9	1.0	9
Germany	Germany Creek	11 to 12	7	1.0	7
Germany	Germany Creek	12 to 13	13	1.0	13

SubBasin	Stream Name	Rkm Section	# of Redds	Length (Km)	Redds / Km
Germany	Germany Creek	13 to 14	18	1.0	18
Germany	Germany Creek	14 to 15	15	1.0	15
Germany	Germany Creek	15 to 16	17	1.0	17
Germany	Germany Creek	16 to 17	9	1.0	9
Germany	Germany Creek	17 to 17.9	2	0.9	2.2
Germany Tribs	Apple Creek	0 to 0.2	0	0.2	0
Germany Tribs	GURT3 [1)]	0 to 0.4	0	0.4	0
Germany Tribs	West Fork Germany Creek	0 to 1	0	1.0	0
Germany Tribs	West Fork Germany Creek	1 to 1.2	0	0.1	0
Germany Tribs	East Fork Germany Creek	0 to 1	1	1.0	1
Germany Tribs	East Fork Germany Creek	1 to 1.5	0	0.5	0
Mill	Mill Creek	0 to 1	1	1.0	1
Mill	Mill Creek	1 to 2	5	1.0	5
Mill	Mill Creek	2 to 3	3	1.0	3
Mill	Mill Creek	3 to 4	5	1.0	5
Mill	Mill Creek	4 to 5	0	1.0	0
Mill	Mill Creek	5 to 6	2	1.0	2
Mill	Mill Creek	6 to 7	1	1.0	1
Mill	Mill Creek	7 to 8	1	1.0	1
Mill	Mill Creek	8 to 9	0	1.0	0
Mill	Mill Creek	9 to 10	0	1.0	0
Mill	Mill Creek	10 to 11	1	1.0	1
Mill	Mill Creek	11 to 12	0	1.0	0
Mill	Mill Creek	12 to 13	0	1.0	0
Mill	Mill Creek	13 to 14	2	1.0	2
Mill	Mill Creek	14 to 15	0	1.0	0
Mill	Mill Creek	15 to 16	0	1.0	0
Mill	Mill Creek	16 to 17	0	1.0	0
Mill	Mill Creek	17 to 18	0	1.0	0
Mill	Mill Creek	18 to 19	0	1.0	0
Mill	Mill Creek	19 to 19.5	0	0.5	0
Mill Tribs	North Fork Mill Creek	0 to 1	0	1.0	0
Mill Tribs	North Fork Mill Creek	1 to 2	0	1.0	0
Mill Tribs	North Fork Mill Creek	2 to 2.1	1	0.1	9.4
Mill Tribs	South Fork Mill Creek	0 to 1	0	1.0	0
Mill Tribs	South Fork Mill Creek	1 to 2	0	1.0	0
Mill Tribs	South Fork Mill Creek	2 to 3	0	1.0	0
Mill Tribs	South Fork Mill Creek	3 to 4	0	1.0	0
Mill Tribs	South Fork Mill Creek	4 to 5	0	1.0	0
Mill Tribs	South Fork Mill Creek	5 to 5.6	1	0.6	1.8
Mill Tribs	Spruce Creek	0 to 1	0	1.0	0
Mill Tribs	Spruce Creek	1 to 2	0	1.0	0
Mill Tribs	Spruce Creek	2 to 2.2	0	0.2	0

[1)] Germany Upper Right Trib # 3

Appendix F-3.─Steelhead redds observed in Ecosystem Diagnosis and Treatment (EDT) model reaches of Mill, Abernathy, and Germany creeks, 2008.

Subbasin	EDT Reach	# of Redds	Length (Mi)	Length Surveyed (Mi)	Redds / Mi	Description
Abernathy	Abernathy-1	0	0.16	0.16	0	Columbia River to slack water
Abernathy	Abernathy-2	0	0.40	0.40	0	Slack water to Cameron Cr
Abernathy	Abernathy-3	4	1.03	1.03	4	Cameron Cr to Slide Cr
Abernathy	Abernathy-4	49	1.49	1.49	33	Slide Cr to Abernathy Salmon Technology Center
Abernathy	Abernathy-5	29	0.45	0.45	65	Abernathy Salmon Technology Center to Falls
Abernathy	Abernathy-6 (falls)	0	0.00	0.00	0	Abernathy Falls
Abernathy	Abernathy-7	0	0.05	0.05	0	Falls To Weist Cr
Abernathy	Abernathy-8	43	2.19	2.19	20	Weist Cr to Erick Cr
Abernathy	Abernathy-9	18	2.84	2.84	6	Erick Cr to Sarah Cr
Abernathy	Abernathy-10	2	0.80	0.80	3	Sarah Cr to Ordway Cr
Abernathy	Abernathy-11	0	0.85	0.42	0	Ordway Creek to end of presumed COHO/STWI
Abernathy	Cameron-1	4	3.13	3.13	1	Mouth to Trib-1231894462314
Abernathy	Cameron-2	0	1.41	1.11	0	Trib-1231894462314 to Trib-1231969462500
Abernathy	Erick-1	1	0.69	0.69	1	Mouth to Midway Cr
Abernathy	Erick-2	0	0.16	0.16	0	Midway Cr to end of known COHO/STWI/SRCT
Abernathy	Midway-1	0	0.61	0.20	0	Mouth to barrier culvert-3
Abernathy	Ordway-1	1	0.72	0.72	1	Ordway mouth to forks
Abernathy	Ordway-2	2	0.66	0.38	5	W Ordway mouth to Trib-1231932463127
Abernathy	Ordway-5	0	0.92	0.14	0	E Ordway mouth to end of known COHO/STWI
Abernathy	Sarah-1	0	0.49	0.49	0	Mouth to forks
Abernathy	Sarah-3	0	1.34	0.20	0	E Sarah Mouth to end of known COHO/STWI/SRCT
Abernathy	Weist-1	0	1.02	1.02	0	Mouth to end of presumed CHFA
Abernathy	Weist-2	0	1.17	0.87	0	End of presumed CHFA to Trib-1231566462579
Germany	Germany-1	0	0.16	0.16	0	Mouth to slack water
Germany	Germany-2	1	0.23	0.23	4	Slack water to lower canyon
Germany	Germany-3	14	1.51	1.51	9	Lower canyon
Germany	Germany-4	6	1.16	1.16	5	Lower canyon to end of presumed CHUM
Germany	Germany-5	23	1.64	1.64	14	End of presumed CHUM to end of known CHFA
Germany	Germany-6	8	0.85	0.85	9	End of known CHFA to Trib-1231363462545
Germany	Germany-7	16	1.47	1.47	11	Trib-1231363462545 to Trib-1231231462714
Germany	Germany-8	2	0.13	0.13	16	Trib-1231231462714 to Trib-1231221462726
Germany	Germany-9	19	1.14	1.14	17	Trib-1231221462726 to Trib-1231123462853
Germany	Germany-10	11	0.30	0.30	37	Trib-1231123462853 to Trib-1231107462883
Germany	Germany-11	29	1.04	1.04	28	Trib-1231107462883 to Trib-1231209463005
Germany	Germany-12	6	0.25	0.25	24	Trib-1231209463005 to end of presumed CHFA
Germany	Germany-13	8	0.57	0.57	14	End of presumed CHFA to Trib-1231264463102
Germany	Germany-14	6	0.49	0.49	12	Trib-1231264463102 to Trib-1231292463165
Germany	Germany-15	0	0.26	0.26	0	Trib-1231292463165 to Trib-1231282461874 (east Germany)
Germany	Germany-16	0	1.52	0.71	0	Trib-1231282461874 (east Germany) to end of presumed COHO

Subbasin	EDT Reach	# of Redds	Length (Mi)	Length Surveyed (Mi)	Redds / Mi	Description
Germany	Trib1231123462853	0	1.40	0.26	0	Mouth to end of presumed COHO/STWI/SRCT
Germany	Trib1231282461874-1	0	0.51	0.51	0	Mouth to Trib-1231287463265
Germany	Trib1231282461874-2	1	0.45	0.45	2	Trib-1231287463265 to end of presumed COHO/STWI/SRCT
Germany	Trib1231363462545-1	0	0.13	0.13	0	Mouth to barrier culvert-6
Germany	Trib1231894462314-1	0	1.65	0.38	0	Mouth to end of presumed COHO/STWI
Mill	Mill-1	0	0.06	0.06	0	Mouth (@Columbia R.) to slack water
Mill	Mill-2	1	1.08	1.08	1	Slack water to SF Mill Creek
Mill	Mill-3	15	2.79	2.79	5	SF Mill Creek to NF Mill Creek
Mill	Mill-4	0	0.49	0.49	0	NF Mill Creek to end of known anadromous
Mill	Mill-5	0	0.20	0.20	0	End of known anadromous to Trib1232255462243
Mill	Mill-6	2	0.83	0.83	2	Trib1232255462243 to Trib1232393462311
Mill	Mill-7_A	1	1.95	1.95	1	Trib1232393462311 to Trib1232458462630
Mill	Mill-7_B	2	1.66	1.66	1	Trib1232393462311 to Trib1232458462630
Mill	Mill-8	0	0.14	0.14	0	Trib1232458462630 to end of presumed CHFA
Mill	Mill-9	0	0.64	0.64	0	End of presumed CHFA to Trib1232392462718
Mill	Mill-10	0	0.65	0.65	0	Trib1232392462718 to Trib1232295462744
Mill	Mill-11	0	0.95	0.95	0	Trib1232295462744 to Trib1232190462807
Mill	Mill-12	0	0.66	0.66	0	Trib1232190462807 to Trib1231748461868
Mill	Mill-13	0	0.35	0.11	0	Trib1231748461868 to end of presumed COHO/STWI
Mill	NF Mill-1	0	1.26	1.26	0	Mouth to Trib1232266462364
Mill	SF Mill-1	1	0.57	0.57	2	Mouth to Spruce Creek
Mill	SF Mill-2	0	2.00	2.00	0	Spruce Creek to Trib1232308461855
Mill	SF Mill-3	0	1.62	1.06	0	Trib1232308461855 to Trib1232617461878
Mill	Spruce-1	0	0.02	0.02	0	Mouth to Trib1231995461938
Mill	Spruce-2	1	0.11	0.11	9	Trib1231995461938 to end of presumed CHFA
Mill	Spruce-3	0	2.67	1.26	0	End of presumed CHFA to Hunter Creek