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Steelhead Trout Production Studies at Sitkoh Creek, Alaska, 2003–2009, and 2009 Final Report

by

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and

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December 2012

Alaska Department of Fish and Game **Division of Sport Fish and Commercial Fisheries**

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$log_{2,}$ etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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ABSTRACT

The need for life history information on steelhead *Oncorhynchus mykiss* in Southeast Alaska prompted a multi-year study whereby steelhead adults and smolts were counted through a weir on Sitkoh Creek each spring from April-June, 2003–2009. The ultimate goal of this project was to estimate demographic parameters necessary for describing spawner-recruit relationships such as the number of steelhead smolt produced per spawner. This information could be combined at some later date with data from a habitat-based carrying capacity project to estimate escapement targets. This report summarizes the final year (2009) of the Sitkoh Creek production project and provides comparison to previous years (2003–2008). An immigrant-emigrant weir was operated each spring from 2003 to 2009. In 2009, a total of 402 adult steelhead were counted through the weir, compared to an average for 2003–2008 of 543. The Chapman estimate for the 2009 escapement was 408 (Bayesian SE = 1.1). First-time spawners identified by their previously implanted passive integrated transponder tags comprised 65% of the adult escapement in 2009, which was corroborated by scale ages. The remaining escapement was comprised of repeat spawners, strays, or fish that were not previously sampled. Approximately 88% of the kelts survived spawning during 2009 and were successfully passed downstream through the weir, the highest kelt survival during the entire study period. During 2009, 893 steelhead smolt, 2,610 sea-run cutthroat trout, and 20,372 sea-run Dolly Varden emigrated downstream. Of the total number of emigrant steelhead smolt, 153 were scale sampled. An estimated 40% of the 2009 smolts were age-3-freshwater fish, and 51% were age-4-freshwater fish.

Keywords: Steelhead trout, *Oncorhynchus mykiss*, Sitkoh Creek, sustainable yield, smolt and adult production, post-spawning mortality, length frequency distribution, weir, PIT tag, scale sampling, Dolly Varden char, cutthroat trout.

INTRODUCTION

Steelhead *Oncorhynchus mykiss* in Alaska are found in coastal streams from Dixon Entrance to the Alaska Peninsula. The highest density of steelhead stream systems in Alaska occurs in Southeast Alaska, which has 309 watersheds known to support annual escapements of steelhead. The largest known steelhead producer in Southeast Alaska is the Situk River near Yakutat, which has annual kelt counts that vary from 3,000 to just over 15,000 adults. Other stream systems, such as the Karta and Thorne rivers on Prince of Wales Island, may have annual escapements of about 1,000 adult steelhead or more. However, most of the remaining steelhead systems in Southeast Alaska are believed to support escapements of 200 or less. Little is known about these smaller steelhead populations in Southeast Alaska, which may be vulnerable to overexploitation if recreational use or subsistence harvests significantly increase. Thus, there is a need to better understand the population dynamics of the small populations of steelhead in Southeast Alaska in order to manage them conservatively. This project was designed to collect the data necessary to assist management in estimating the escapement needed to produce the numbers of smolt necessary to fully utilize available freshwater habitat.

Sitkoh Creek was chosen for the study site because it supports a small to moderately-sized population of spring steelhead, has a history of successful weir operations, has relatively intact habitat, is one of ADF&G's 10 regional steelhead snorkel index streams (Harding and Love 2005, 2008; Harding 2009, 2012; Coyle 2012), and supports a valued sport fishery. Located in northern Southeast Alaska (north of Frederick Sound), escapement (weir) counts on Sitkoh Creek ranged from 520 to 1,108 (mean = 778) prior to initiation of this project in 2003 (Chipperfield 1938; Jones 1983; Jones et al. 1991; Harding and Jones 1994; Yanusz 1997). For the 2003–2008 period escapements ranged from 395 to764 (Table 1) and averaged 543 fish (Love and Harding 2008, 2009; Love et al. 2012). Regionwide regulations established in 1994 permitted retention of only those steelhead ≥36 inches (914 mm) TL. This effectively protected 96–99% of the fish in Sitkoh Creek during the 2003–2008 period (Table 2). The Sitkoh Creek system (creek and lake) ranked third highest in angler catch from 1999 to 2004 for all freshwater steelhead systems in Southeast Alaska, and CPUE estimates (steelhead caught, but not harvested, per days fished) ranked second only to the Situk River (Howe et al. 1999, 2001a, 2001b; Jennings et al. 2004, 2006a, 2006b, 2007; Walker et al. 2003).

Table 1.–Historical steelhead escapement census and sex composition of steelhead escapement at Sitkoh Creek for weir counts made during 1936–37, 1982, 1990, 1993, 1996 and 2003–2009. Data for 1936 and 1937 from Chipperfield (1938); 1982 data from Jones (1983); 1990 data from Jones et al. (1991); 1993 data from Harding and Jones (1994); 1996 data from Yanusz (1997); 2003–2006 data from Love and Harding (2008, 2009); 2007–2008 data from Love et al. (2012).

Year	Escapement count	Petersen estimate (SE)	Total number of kelts	Proportion female	Proportion male
1936	760	–[a]	ND	ND	ND
1937	1,108	–[a]	ND	ND	ND
1982	690	–[a]	ND	0.50	0.50
1990	661	–[a]	ND	0.61	0.39
1993	520	–[a]	ND	0.63	0.37
1996	926	–[a]	ND	0.62	0.38
2003	679	682(2.0)	460	0.62	0.38
2004	764	780(4.0)	565	0.60	0.40
2005	543	574(4.7)	363	0.67	0.33
2006	395	416(3.5)	292	0.65	0.35
2007	392	418(7.0)	345	0.66	0.34
2008	487	513(6.6)	390	0.68	0.32
2009	402	408(1.1)	360	0.78	0.22
Average 03–08	543	564(4.9)	403	0.65	0.35
Average 03–09	523	542(4.6)	396	0.67	0.33

[a] Note estimated.

Table 2.–Proportion of the total steelhead escapement >914 mm TL (> 36 in) that were available for legal harvest by anglers, and proportion by sex for all fish >914 mm TL in years that a weir was operated at Sitkoh Creek. Data from Jones et al. (1991), Harding and Jones (1994), Yanusz (1997), Love and Harding (2008, 2009), and Love et al. (2012).

Year	No. of fish (≥ 914 mm in TL[a])	Proportion of escapement (≥ 914 mm in TL[a])	Proportion male (≥ 914 mm in TL[a])	Proportion female (≥ 914 mm in TL[a])
1982	48	0.070 [b]	0.380	0.620
1990	19	0.029 [b]	0.210	0.790
1993	29	0.056 [c]	0.530	0.470
1996	28	0.030 [b]	0.500	0.500
2003	16	0.024 [b]	0.875	0.125
2004	17	0.022 [b]	0.647	0.353
2005	13	0.024 [b]	0.692	0.308
2006	15	0.039 [b]	0.733	0.267
2007	5	0.017 [b]	0.664	0.336
2008	3	0.007 [b]	0.677	0.323
2009	5	0.013 [b]	0.400	0.600

[a] 914 mm TL (36 inches TL), assuming measurement error of 0.5 inches, the minimum size limit for sport harvest of steelhead in Southeast Alaska.

[b] All fish examined.

[c] Fish lengths were sampled, SE = 0.00091, N = 303.

Southeast Alaska spring-run steelhead typically return to their natal streams between March and early June, with the peak of the immigration occurring late April to early May. Fall-run steelhead also occur is some Southeast Alaska steelhead streams, as do occasional summer-run fish. Sitkoh Creek appears to support few fall-run steelhead and the existence of summer-run fish is not described. During years when the Sitkoh weir was installed just following ice breakup, fewer than 2% of the kelts captured emigrating through the weir were untagged. Because all adult immigrants were tagged as they passed upstream, these untagged kelts were of unknown origin or run timing. However, the steelhead population in Sitkoh Creek during the course of the study was considered to be predominantly spring-run and weirs operated during April to June were considered to sample the majority of the known steelhead escapement. In Southeast Alaska, steelhead smolt typically emigrate from streams about mid-May to the last week of June, and this was the case for Sitkoh Creek during all years of the study. According to scale analysis completed for the 2003–2008 Sitkoh Creek samples, predominant freshwater ages of smolts were three and four freshwater, with a range of two to six years. Most adult steelhead appeared to spend two to three years at sea before returning as first-time spawners and are known, based on scale samples, to repeat spawn up to five times in Sitkoh Creek. Most Sitkoh Creek adult steelhead were five to six years old upon the initiation of their first spawning migration. Adult steelhead that survive spawning (kelts) typically migrate back to the ocean from mid-May through June. Repeat-spawning steelhead compose 11–46% of the total adult return (Love et al. 2012; Lohr and Bryant 1999), and more than 60% are female.

The initial goals of the Sitkoh Creek steelhead production project were to obtain estimates of adult and smolt steelhead production (census of immigration and emigration through the weir verified with mark-recapture), describe freshwater age structure of emigrant smolts, and estimate numbers of smolts produced per adult spawners over the course of a 10-year period (from 2003 to 2012). A longer term study such as this would have allowed multiple smolt-per-spawner (SPS) estimates to be generated from known adult parent escapements, as well as at least triplicate estimates of smolt-to-adult returns. Due to funding limitations, the research at Sitkoh Creek was prematurely ended in 2009. Estimates of SPS were generated for the 2003, 2004 and 2005 parent brood years, and preliminary estimates for 2003–2004 smolt to 2008–2009 adult survivals were obtained. Known marine survival of smolts returning as adults based on PIT tag recaptures, and immigrant census combined with PIT-tagging of individual steelhead resulted in relatively precise and unbiased estimates of steelhead adult production (escapement). Because Sitkoh Creek is one of the regional snorkel survey index streams, census of steelhead adults through the Sitkoh Creek weir also allowed for validation of estimates of escapements from expansion of snorkel surveys to known instream abundance above the weir (Harding and Love 2008). Enumeration of outmigrating smolts provided the smolt abundance information necessary to extrapolate habitat use by juvenile steelhead identified during a separate study of steelhead habitat utilization in Sitkoh Creek (Crupi and Nichols 2012). Recapture of previously tagged steelhead also has allowed for estimates of kelt and smolt survivals, verification of marine ages, and first-time and repeat spawning rates.

No other multi-year studies of wild steelhead populations in Alaska have used standardized weir methods coupled with PIT-tagging techniques to estimate population parameters, making this project unique. More complete knowledge of the life history, abundance, survival, and other population characteristics observed at Sitkoh Creek during 2003–2009 should provide managers a better understanding of a Southeast Alaska steelhead stock that supports moderate sport fishing use and limited harvest. This type of baseline data may be valuable to managers for informing management decisions.

Spring emigrant cutthroat and rainbow trout, as well as emigrant Dolly Varden char, were also enumerated as they passed downstream through the weir. Counts of these emigrants are considered to be representative of only the spring component of the emigration for these species, and are presented here simply to record their prevalence; no inferences about population trends are made.

OBJECTIVES

The objectives for this project during 2009 were to:

1) Enumerate all downstream migrating steelhead smolt and estimate their length composition;
2) Estimate the age composition of downstream migrating steelhead smolt;
3) Enumerate all immigrant and emigrant adult steelhead and PIT tag all previously unmarked fish;
4) Recover PIT tag numbers from all previously tagged immigrant and emigrant steelhead passed through the weir;
5) Determine the length composition and sex ratio of all immigrant adult steelhead;
6) Determine the age composition of all immigrant steelhead adults; and
7) Enumerate all sea-run cutthroat trout and Dolly Varden passing the weir.

STUDY AREA

The Sitkoh Creek system is located on southeastern Chichagof Island in Southeast Alaska (Figure 1), and empties into Chatham Strait via Sitkoh Bay. Sitkoh Creek (ADF&G Anadromous Stream Catalog No. 113-59-10040; Johnson and Blanche 2012) is about 6.4 km long, 10 m to 30 m wide, 0.1 m to 3 m deep, and drains Sitkoh Lake. Sitkoh Lake has a surface area of 189 ha, a maximum depth of 42 m, and is located approximately 59 m above sea level. The U.S. Forest Service maintains two popular public-use cabins on Sitkoh Lake that are accessible by floatplane and logging roads. Sitkoh Creek is also accessible by boat from Sitka or Juneau, and attracts anglers from all urban centers of northern Southeast Alaska (Jones 1983).

METHODS

An aluminum bipod weir was installed on Sitkoh Creek on April 15 and operated through 22 June, 2009. The weir contained separate emigrant-immigrant traps (2.5 m^2) and was located approximately 400 m upstream from tidewater (Figure 1). This was the same site used during previous studies in 1982, 1990, 1993, 1996, and 2003–2008 (Chipperfield 1938; Jones 1983; Jones et al. 1991; Harding and Jones 1994; Yanusz 1997; Love and Harding 2008, 2009, Love et al. 2012). All immigrant adults, and emigrant kelts-smolt were processed through the upstream and downstream traps, respectively. Weir bipods and traps were first underlain with geotextile landscape fabric to prevent undercutting and erosion, then anchored with 18 mm diameter steel pipe at the bipods. Steel pickets spaced 31 mm apart were installed in the channels between bipods. The upstream face of the picket weir was then overlaid with 1.2 m by 1.8 m frames covered with vinyl-coated wire mesh (10 mm x 18 mm openings). The mesh and frames were attached to the weir with cable ties, and the entire interface of the mesh with the streambed was skirted with plastic fencing (18.75 mm^2 openings) and covered with sandbags. Both the wire mesh and plastic fencing were believed to safely block the passage of fish $\geq$150 mm FL. Picket and channel holding pens comprised the upstream (immigrant) and downstream (emigrant) traps used to hold captured fish entering and exiting Sitkoh Creek. Vinyl-coated wire mesh was overlaid on both traps to create a barrier for fish ≥150 mm. There were no adjustments made to the structure of the weir or its position in the creek during any period of its operation. Weir integrity was checked several times daily, and fish in each trap were processed whenever necessary to avoid crowding and mitigate stress. Water temperature and water depth were recorded at approximately 12:00 each day.

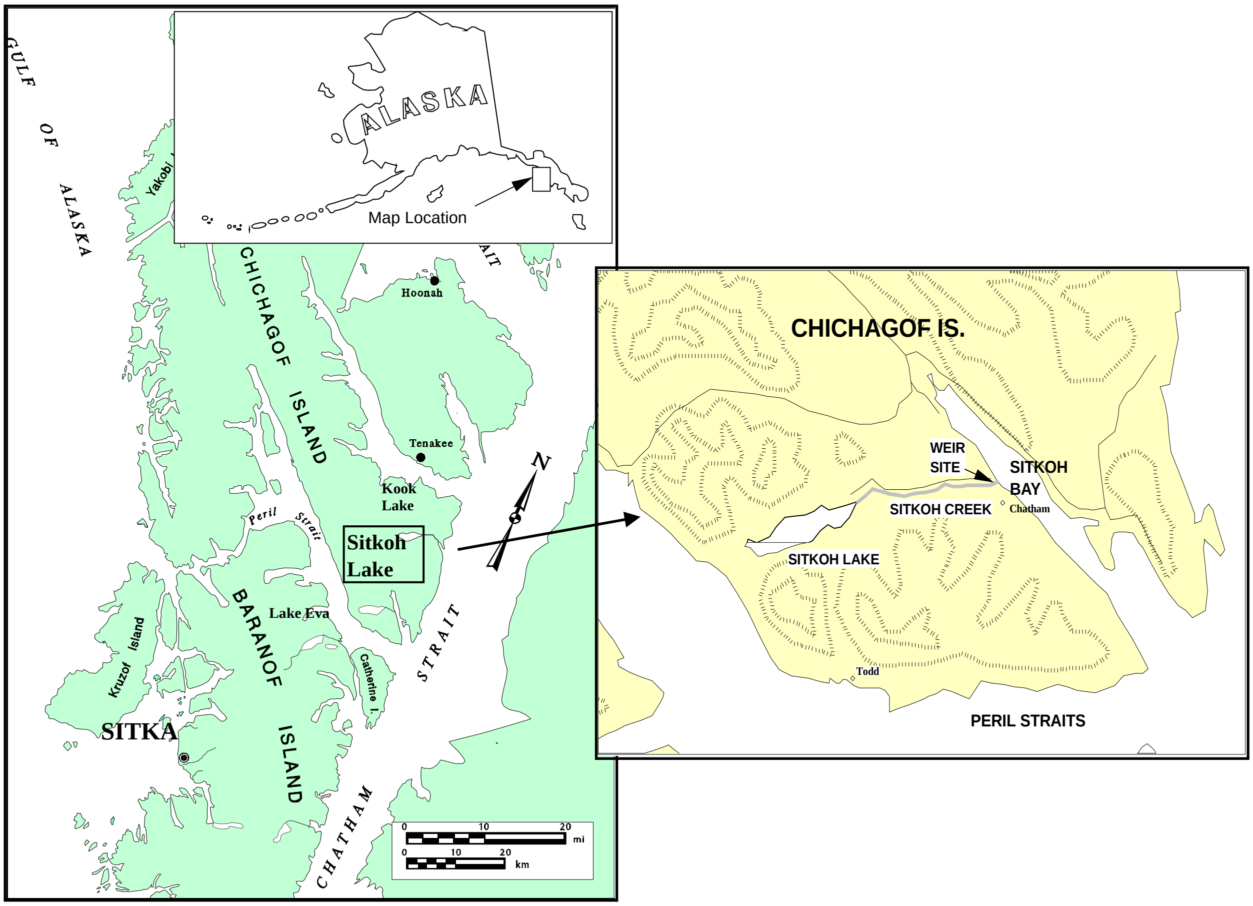

Figure 1.–Location of Sitkoh Lake, Sitkoh Creek, and weir site on Sitkoh Creek.

ADULT STEELHEAD

All immigrating adult steelhead were counted, measured to the nearest 1 mm FL, and a subsample was measured for TL. Newly captured immigrant adults were categorized by sex using secondary sexual characteristics, and tagged with 134 kHz PIT tags. PIT tags were implanted into the left side of the fish just under the skin and posterior to the cleithrum. Entrance wounds caused by PIT tag insertion were treated with iodophore and sealed with a drop of cyanoacrylate glue. Newly-tagged fish were secondarily marked by removing the adipose fin.

During 2009, all immigrating adult steelhead were checked for adipose clips and previously implanted PIT tags, measured, and passed upstream through the weir.

A systematic subsample of scales (every *n*th fish) was collected from immigrating adult steelhead (untagged and tagged). Scales were removed from an area approximately four to six scale rows below and behind the dorsal fin, but above the lateral line. Untagged immigrants had four to five scales removed from the left side, and scales from previously tagged fish were removed from the right side. Scale samples were placed on labeled gum cards and pressed flat in sequential order for storage. Detached adipose fins were collected from the first 50 systematically sampled untagged adults and preserved in 70% ethanol for later genetic sequencing by the U.S. Fish and Wildlife Service Genetics Laboratory in Anchorage.

All kelts were counted and checked for the presence of an adipose fin and PIT tag. If a tag was not present, the fish was PIT tagged, marked with an adipose fin clip, measured, and sexed. If a fish had a PIT tag but was not finclipped, the adipose fin was removed and this was noted on the data forms accordingly.

Daily and cumulative numbers of adult fish passing through the weir were recorded. For clarity in this report, all upstream migrating (immigration) adults will be denoted as immigrants and all downstream migrating (emigration) will be denoted as kelts. Because all adult steelhead were measured during the period the weir was operable, the length composition of immigrant steelhead passed through the weir was known. The weir was fish tight and was not breached during the sampling period. An estimate of total immigration was made using the Chapman modification to the Petersen estimator (Seber 1982):

$$\hat{N} = \frac{(C+1)(M+1)}{R+1} - 1 \tag{1}$$

where:

$\hat{N}$ = estimated abundance of steelhead;

M = the number uniquely marked steelhead passed upstream through the weir;

R = the number marked steelhead from *M* passed downstream through the weir; and,

C = the total number of steelhead passed downstream through the weir.

Variance and 95% credibility interval for the estimator (equation 1) were estimated using empirical Bayesian methods (Carlin and Louis 2000). Using Markov Chain Monte-Carlo techniques, a posterior distribution for $\hat{N}$ was generated by collecting 200,000 simulated values of $\hat{N}$ that were calculated using equation (1) from simulated values of equation parameters. Simulated values were modeled from observed data using a multinomial distribution for the proportions of the following classifications of steelhead in the spawning population:

M-R: the number of uniquely marked steelhead passed upstream (immigrants) through the weir that were not later observed passing downstream through the weir;

C-R: the number of steelhead kelts passed downstream through the weir that were not observed passing upstream through the weir;

R: the number uniquely marked steelhead passed upstream (immigrants) through the weir that were later observed passing downstream through the weir;

$\hat{N}$-M-C+R: the number of steelhead that were not observed passing either upstream or downstream through the weir.

At the end of the iterations, the following statistics were calculated:

$$\overline{N} = \frac{\sum_{b=1}^{200,000} \hat{N}_{(b)}}{200,000} \tag{2}$$

and

$$V\hat{a}r(\hat{N}') = \frac{\sum_{b=1}^{200,000} (\hat{N}_{(b)} - \overline{N})^2}{200,000 - 1} \tag{3}$$

where $\hat{N}_{(b)}$ is the bth simulated observation.

STEELHEAD SMOLT

All emigrant steelhead smolt $\geq$150 mm were captured, counted, examined for PIT tags from previous tagging, and systematically sampled for length (to the nearest 1 mm FL) and scales. Steelhead smolt were anesthetized using a buffered MS-222 solution prior to sampling. In 2009, no smolts were implanted with PIT tags because this study was scheduled to be terminated at the conclusion of this year's sampling. Note that all outmigrating (undergoing smoltification) steelhead smolts will be denoted in this paper as emigrants, and the outmigration as smolt emigration.

Scales were removed from an area approximately four to six scale rows below and behind the dorsal fin, but above the lateral line. Untagged fish were sampled on the left side, while previously tagged fish were sampled on the right. About 15 to 20 scales were removed from each sampled fish and were evenly spaced on clear glass slides. A second glass slide was secured over the first to protect the samples. Slides were stored inside a coin envelope inscribed with the sample number. Coin envelopes were stacked in sequential order and stored for aging.

All steelhead smolt >150 mm FL were presumably retained by the vinyl-coated wire mesh used to cover the face of the weir, so the count was considered a census. Length and age composition of subsampled steelhead smolt were estimated by:

$$\hat{p}_a = \frac{n_a}{n} \tag{4}$$

and

$$\text{v}\hat{\text{a}}\text{r}[\hat{p}_a] = \left(1 - \frac{n}{\text{N}}\right) \frac{\hat{p}_a(1 - \hat{p}_a)}{n - 1} \tag{5}$$

where n is the number of fish successfully measured for lengths or aged, n_a is the subset of n that belong to length or age group a, and N is the population size.

Emigrant steelhead juveniles <150 mm FL could pass through the weir without being captured. These smaller fish represented an unknown percentage of the total emigration and were not considered as smolt for this project. All juvenile steelhead <150 mm FL that were incidentally captured were counted, measured to the nearest 1 mm FL, subsampled for scales, and released. All smolt mortalities were counted, measured to the nearest 1 mm FL, and sampled for scales and otoliths.

STEELHEAD SCALE AGING AND ELECTRONIC IMAGING

Scale samples were imaged using an Indus International Microfiche reader[1] and electronic imaging software. Methodology used to estimate ages from electronic scale images was similar to that used by Ericksen (1999) for cutthroat trout, and by Jones (Undated/Unpublished handbook for interpretation of steelhead scales in Southeast Alaska, Alaska Department of Fish and Game, Division of Sport Fish, Douglas, Alaska) for steelhead trout. As described in Erickson (1999), scale ages were determined primarily from the area of the scale lying 45^o off either side of an imaginary reference line drawn along the longest axis of the scale, from the focus to the anterior edge. Patterns were often more evident in this area of the scale. Ideal scales were clean, mucus-free, and did not have a regenerated focus. Scale ages were considered to be estimated, not determined, because known-aged samples were not available for comparison (Ericksen 1999). To minimize error associated with variability between readers, only one scale aging technician has been employed to estimate ages of steelhead during 2003–2009. This scale-aging technician made three independent readings of each sampled scale to estimate age. If none of the three reads agreed, the sample was considered unreadable and was omitted from the age composition estimation. The modal age of the three scale-age readings was taken as the most consistent age and was reported. Assuming that a matching scale age, if not accurate, was the most consistent (precise) estimate, it was concluded that this final age was the best estimate. Between readings, the scale images were randomized by the project biologist and scale aging results from the previous reading(s) were not known during subsequent readings. All reads were archived and compiled for assessing precision of aging estimates. Criteria for aging juvenile and smolt scales included: rejection of latinucleate scales, overall scale size, average number of annual circuli relative to year of growth, identification of annuli, and identification of "plus growth." These criteria were used to develop aging "rules," which were incorporated into the scale-aging methodology of all fish and then periodically re-evaluated if warranted.

Age compositions of samples collected from immigrant adults and emigrant smolts in 2009 were compiled from all scales collected in the systematic samplings. Estimated steelhead ages were compiled using the methods described previously for scale aging. Reproducibility of scale reading techniques (i.e., precision) of these scale aging estimates for smolt scales were calculated using coefficient of variation (CV), expressed as the ratio of the standard deviation over the mean (Campana 2001) using:

$$CV_j = 100\% \times \frac{\sqrt{\frac{\sum_{i=1}^{R}\left(X_{ij} - X_j\right)^2}{R-1}}}{X_j} \qquad (6)$$

[1] Product names used in this report are included for scientific completeness, but do not constitute a product endorsement.

where CV_j is the age precision estimate for the *j*th fish, X_{ij} is the *i*th age determination of the *j*th fish, X_j is the mean age estimate of the *j*th fish, and *R* is the number of times each fish is aged. Averaging CV_j across all fish will give a mean CV for the method used. Mean CV was calculated for smolt scales. For adult scales, mean CV was calculated for total age, freshwater age, saltwater age and total number of spawning checks. The observed variability in scale readings was recorded and maintained to support future research efforts (e.g., fitting spawner-recruit curves) where modeling uncertainty in steelhead ages, and thus age structure of different populations, is critical. Because a known freshwater age reference collection (for determining relative bias of aging methods) for Sitkoh Creek was not available and would have required a juvenile rearing project beyond the scope and budget of this project, aging consistency (precision) was the best that could be accomplished.

CUTTHROAT TROUT AND DOLLY VARDEN CHAR

All emigrant cutthroat trout, rainbow trout and Dolly Varden char were counted as they passed downstream through the weir.

RESULTS

2009

Adult Steelhead-Immigration

The weir was continuously operated from 23 April to 25 June, 2009. The first adult was captured in the upstream trap on 5 May, and the last on 17 June. The peak daily count (60) occurred on 13 May, which was also the midpoint of the run. Upstream migration followed the initial higher runoff of rain-melted snow, and adults moved upstream almost a week later than in previous years (Figure 2). Water temperatures increased steadily from 1.5°C on 26 April to a peak of 13°C by 5 June, cooler than in years prior to 2006. Water temperatures in June of 2003 and 2005 reached 18°C (Love and Harding 2008, 2009).

A total of 397 adult steelhead were passed upstream through the weir. Of these, 120 untagged fish and 277 previously PIT-tagged fish were passed through the weir. All untagged immigrants were PIT-tagged before being released upstream. One additional untagged kelt was passed downstream, and four kelts that were tagged in previous years, but not seen as they passed upstream through the weir in 2009, were also captured as they migrated downstream. Adding these to the immigrant count (397) gives a minimum total known census of 402 adult steelhead for 2009. The Chapman estimate for Sitkoh Creek steelhead abundance was 408 (SE = 1.1). All untagged fish were measured, sexed, and PIT tagged; all recaptured fish were measured and sexed, and their PIT tag numbers were recorded.

Females made up the majority of the immigrants at 78% (218 fish), and males represented 22% (59 fish, Table 1). Unlike previous years, female immigrants were more abundant throughout the run (Figure 3). In previous years, roughly equal numbers of males and females moved upstream through the weir prior to 30 April. The spawning immigration was complete by 9 June.

Females were larger than males (Figure 4). The average length of all females was 753 mm FL and had a SD = 61.8 mm (N = 309); for males, length averaged 739 mm FL and had a SD = 81.7 mm (N = 88). The average fork length of all immigrant steelhead passed upstream through the weir was 750 mm FL (SD = 66.8 mm) and ranged from 560 to 920 FL mm (N = 397). In addition to fork length, total length was also measured on all fish and was incorporated into the Southeast Alaska regionwide regression model (see Harding et al. 2009). In 2009, five fish (three females, two males) met the minimum length requirements for retention in the sport fishery (1.3% of the total immigrant steelhead run, Table 2).

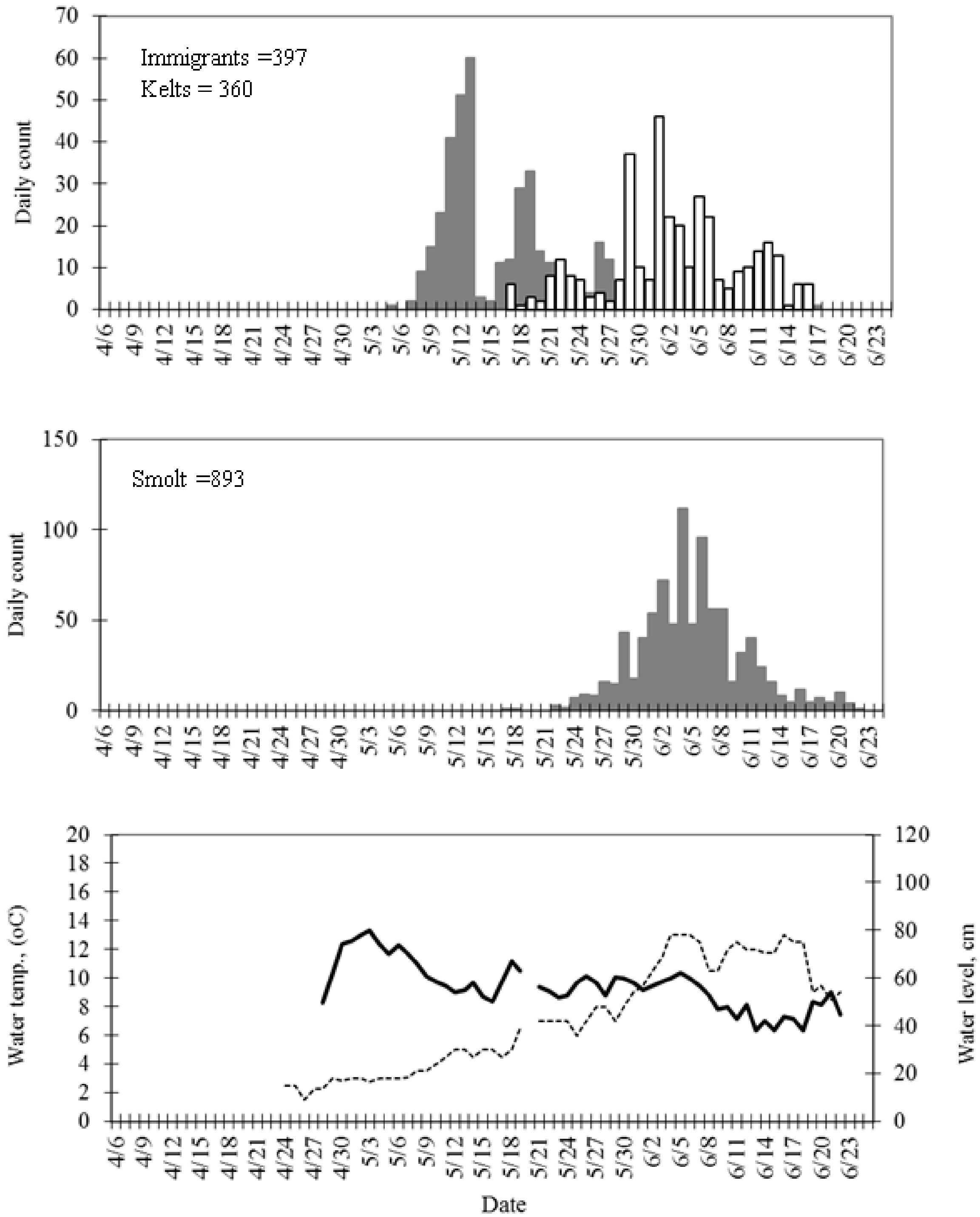

Figure 2.–Daily counts of immigrant steelhead (top panel solid bar graph) and kelts (top panel clear bar graph), emigrant steelhead smolt (center panel), and daily measurements of water level in cm (solid line), and water temperature in °C (stippled line) at Sitkoh Creek, 2009 (bottom panel).

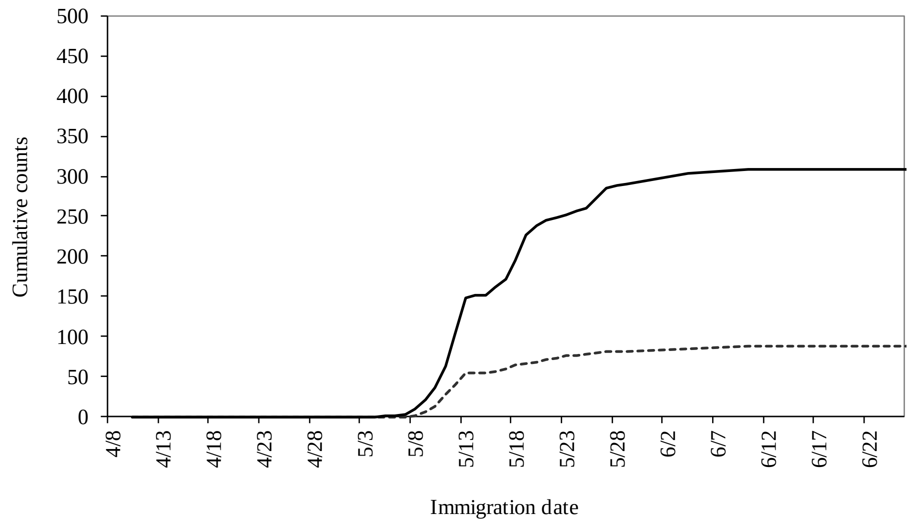

Figure 3.–Cumulative counts of adult male (stippled line) and female (solid line) steelhead immigrating through the Sitkoh Creek weir from 23 April to 25 June, 2009.

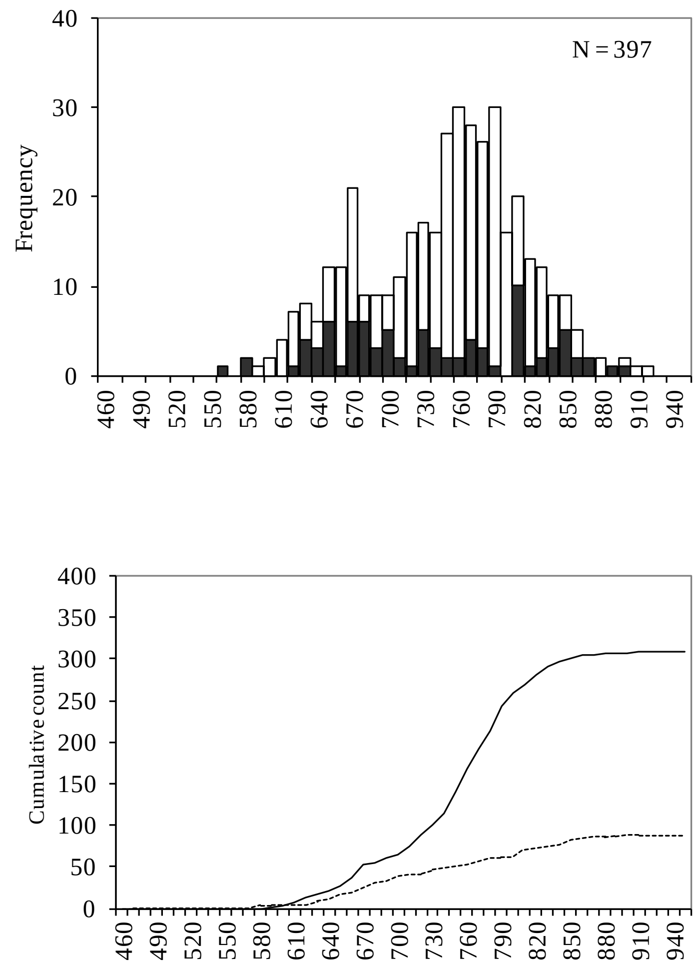

Figure 4.–Length-frequency distributions for male (filled bars) and female (clear bars) steelhead (top panel) and cumulative numbers by sex and length of adult male (stippled line) and female (solid line) steelhead immigrating into Sitkoh Creek during 2009 (bottom panel).

Scale samples were taken from 236 immigrant adult steelhead (recaptured and untagged fish combined) for a sampling ratio of 1.7:1, or from about 58% of the total escapement. Estimated ages were compiled for the freshwater and saltwater portions from each scale image to obtain total age. Total ages were estimated for 164 adults, or about 41% of the census count through the weir. Total age could not be determined for 72 samples because they were damaged, did not have readable freshwater or saltwater portion(s), or could not be assigned replicate ages in triplicate readings. Total ages ranged from five to nine, and averaged six years (Table 3). Freshwater ages ranged from three to six and averaged three years, while ocean ages ranged from two to five years and averaged three years for first-time and repeat spawners combined. About 61% (SE = 3%) of the steelhead adults passing through the weir were first-time spawners, and about 39% (SE = 3%) were repeat-spawners (Table 4). For recaptured fish (previously PIT tagged, n = 152) that were also scale sampled and aged, 75% were first-time spawners and 25% were repeat-spawners.

Of the 397 immigrant steelhead inspected at the weir, 280 (71%) were PIT-tagged fish that were recaptured (Table 5). About 86% (241) of the recaptured adults were initially PIT tagged as smolts during 2003–2007, 22 (8%) were initially tagged as adults during the previous two years, and 17 (6%) had faulty tags that could not be read. About 52% were identified as first-time spawners that were initially tagged as smolt in 2006 (i.e., three-ocean fish); total first-time spawners equaled about 65% of all recaptured fish. Repeat spawners (previously tagged either as smolts or adults) represented about 29% of the recaptured fish. The immigration total also included the 120 untagged steelhead that may have strayed into Sitkoh Creek or outmigrated as smolt at some time other than when the weir was operated during 2003–2008.

Table 3.–Minimum, maximum, mean, and mean CV of total age and freshwater and saltwater components of scale ages as determined by triplicate reads of adult steelhead scales from Sitkoh Creek sampled in 2009.

	# Aged	Minimum	Maximum	Mean	Mean CV
Total age	164	5	9	6.3	4.389
Freshwater component	164	3	6	3.4	6.709
Saltwater component	233	2	5	2.9	2.795
Not ageable	3	ND	ND	ND	ND
Total sampled	236				

Table 4.–Age composition of Sitkoh Creek steelhead adults sampled in 2009. Estimated ages based on three independent readings of a scale sample by the same scale-aging technician, the number of scales of that age class sampled (*n*), proportion by age class $(\hat{p}_a)$ and $SE(\hat{p}_a)$.

Age class	Number of steelhead sampled *(n)*	$\hat{p}_a$	SE($\hat{p}_a$)
3.2	35	0.167	0.026
3.3	23	0.110	0.022
4.2	14	0.067	0.017
4.3	15	0.071	0.018
5.2	2	0.010	0.007
5.3	1	0.005	0.005
3.2s1	17	0.081	0.019
3.2s1s1	7	0.033	0.012
3.2s1s1s1	2	0.010	0.007
3.3s1	2	0.010	0.007
3.3s1s1	1	0.005	0.005
3.3s1s1s1	1	0.005	0.005
4.2s1	15	0.071	0.018
4.2s1s1	2	0.010	0.007
5.2s1	1	0.005	0.005
5.2s1s1	1	0.005	0.005
5.3s1	1	0.005	0.005
x.2 [a]	18	0.086	0.019
x.2s1[a]	21	0.100	0.021
x.2s1s1[a]	1	0.005	0.005
x.2s1s1s1[a]	1	0.005	0.005
x.3 [a]	21	0.100	0.021
x.3s1[a]	5	0.024	0.011
x.3s1s1[a]	3	0.014	0.008
No match	23		
Not ageable	3		
Not aged	26		
First-time spawners	129	0.614	0.034
Repeat spawners	81	0.386	0.034
Total sampled	236		

[a] Freshwater age undetermined.

Table 5.–Initial passive integrated transponder (PIT) tagging year and number and percentage of adults recaptured during 2009 in Sitkoh Creek. Recaptured adults include all previously tagged immigrants plus all previously tagged kelts.

	Recaptured adults			
PIT tag year & type	*n*	%	Ocean ages	Spawning events
2003 smolts	3	1.1	6	3
2004 smolts	10	3.6	5	2–4
2005 smolts	20	7.1	4	1–3
2006 smolts	149	53	3	1–2
2007 smolts	63	22.4	2	1
2007 adults	2	0.7	4–5	2
2008 adults	18	6.4	3–4	2
Faulty tags	16	5.7		
Total	281			

Of the 397 immigrant steelhead inspected at the weir, 280 (71%) were PIT-tagged fish that were recaptured (Table 5). About 86% (241) of the recaptured adults were initially PIT tagged as smolts during 2003–2007, 22 (8%) were initially tagged as adults during the previous two years, and 17 (6%) had faulty tags that could not be read. About 52% were identified as first-time spawners that were initially tagged as smolt in 2006 (i.e., three-ocean fish); total first-time spawners equaled about 65% of all recaptured fish. Repeat spawners (previously tagged either as smolts or adults) represented about 29% of the recaptured fish. The immigration total also included the 120 untagged steelhead that may have strayed into Sitkoh Creek or outmigrated as smolt at some time other than when the weir was operated during 2003–2008.

Adult Steelhead-Emigration

A total of 360 kelts emigrated from Sitkoh Creek in 2009. Of these, 355 were sampled as spring 2009 immigrants that either had been previously PIT tagged or were PIT tagged during their upstream migration in 2009. One kelt was an untagged downstream migrant, and four were previously PIT tagged kelts that were passed downstream but had not been seen as immigrants. These five fish likely were in the system prior to weir installation. The first kelt was captured emigrating from Sitkoh Creek on 17 May, the last was captured on 22 June, and the midpoint of the emigration was on 1 to 2 June. The peak daily downstream kelt count (46) occurred on 1 June (Figure 2). The fork length of all kelt steelhead averaged 751 mm FL (SD = 66.5 mm) and ranged from 560 to 920 mm FL (N = 350). The four tagged kelts that had not been passed upstream through the weir and 1 untagged kelt passed downstream were not measured.

Emigrant females varied less in length and were generally slightly larger than males. The length of females averaged 756 mm FL and had a SD of 61.2 mm, versus the length of males, which averaged 731 mm FL and had a SD of 81.5 mm. From 17 May to 22 June, more females (78%) emigrated from the system following spawning than did males, similar to the sex ratio of the spawners entering the system (79% female). Post-spawning survival was approximately 88.2% (350 emigrants/397 immigrants) in 2009.

Steelhead Smolt

A total of 893 steelhead smolt and four juvenile (parr) steelhead were captured emigrating through the weir during 2009. Of these, 890 smolt and the four parr were released downstream and none were PIT-tagged as this was the last year of the project. There were three mortalities equaling about 0.3% (of the 893 smolt captured) of the total downstream migration. No recaptured smolt (re-emigrant smolt that had been tagged in previous years) were passed through the weir.

The first smolt emigrant was captured at the weir on 17 May, the last on 22 June, and the midpoint of the emigration was 4 June, which was also the day the peak daily count (112) occurred (Figure 2). Of 153 measured for fork length, the average was 189 mm FL (SD = 29.9 mm, range 158 mm to 448 mm FL); and the mode of the length frequency distribution was 188 mm (Table 6). The largest of the emigrants captured (approximately 350 mm FL) had all the physical characteristics of average-sized smolt, so it was regarded to be a steelhead and not rainbow trout. Most emigrant smolt that left Sitkoh Creek later in the season (after 10 June) were similar in size to earlier emigrants (Figure 5).

Scale samples were collected from 153 steelhead smolt (Table 7). Estimated freshwater ages ranged from two to five years. The majority of smolt (91%) were three or four years old, and age four was the predominate age class (51%). About 2% of the scale samples collected could not be read; they were either damaged, dirty, or had regenerated foci. The mean CV across all ages for all smolt scales aged was about 5%.

Table 6.–Length frequencies of Sitkoh Creek steelhead smolt sampled in 2009. Systematically sampled lengths including the number of lengths for that class sampled (*n*), proportion by length class $(\hat{p}_a)$, and $SE(\hat{p}_a)$.

Length class (mm FL)	Number of steelhead sampled *(n)*	$\hat{p}_a$	$SE(\hat{p}_a)$
150	5	0.033	0.014
160	8	0.052	0.018
170	14	0.092	0.023
180	23	0.150	0.029
190	36	0.235	0.034
200	41	0.268	0.036
210	15	0.098	0.024
220	5	0.033	0.014
230	4	0.026	0.013
240	0	0.000	0.000
250	0	0.000	0.000
260	0	0.000	0.000
270	0	0.000	0.000
280	0	0.000	0.000
290	0	0.000	0.000
300	0	0.000	0.000
310	0	0.000	0.000
320	0	0.000	0.000
330	1	0.007	0.007
340	0	0.000	0.000
350	0	0.000	0.000
360	0	0.000	0.000
370	0	0.000	0.000
380	0	0.000	0.000
390	0	0.000	0.000
400	0	0.000	0.000
410	0	0.000	0.000
420	0	0.000	0.000
430	0	0.000	0.000
440	0	0.000	0.000
450	1	0.007	0.007

Note: Total number sampled: 153; average length of all samples = 189 mm FL.

Table 7.–Estimated freshwater ages, based on scale analysis for Sitkoh Creek steelhead smolt, 2009, age composition or proportion ($\hat{p}_a$) and SE of age composition. Estimated ages based on three independent readings of a scale sample by the same scale-aging technician (total emigrant count for 2009 is in parenthesis). Mean CV is calculated as per Campana (2001) for all triplicate reads of collected smolt scales.

Scale age	# Sampled	$\hat{p}_a$	$SE(\hat{p}_a)$
Sample (total emigration)	153		
2	5	0.033	0.017
3	61	0.399	0.131
4	78	0.510	0.136
5	6	0.031	0.021
6	0	0.000	0.000
Not ageable	3		
No match	0		

Note: Mean CV (all triplicate reads combined) = 4.949.

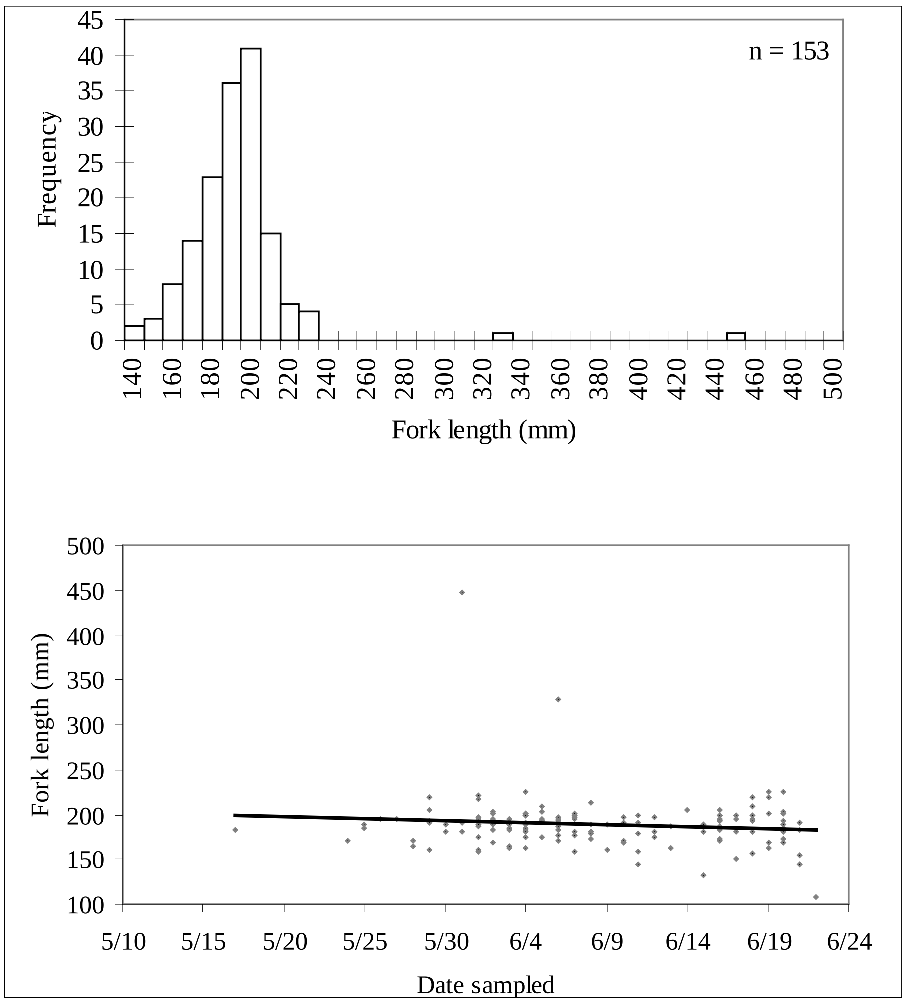

Figure 5.–Length-frequency distribution for systematic sample of the steelhead smolt that emigrated out of Sitkoh Creek (top panel) and size (mm FL) of sampled steelhead smolt by date captured at the weir during 2009 (bottom panel). Depicted trendline is the best fit linear trendline (y = mx + b) of smolt size by sample date (bottom panel).

Dolly Varden Char

There were 20,372 Dolly Varden emigrants captured and passed downstream through the weir during April to June. The first fish was captured on 26 April and the peak daily count (2,516) was on 17 May. The midpoint of the run also occurred on 17 May (Figure 6). Dolly Varden were captured until the day before the weir was pulled. Dolly Varden were not measured for length frequency analysis but, qualitatively, more smaller fish were passed in 2009 than any of the previous years since 2003. As in previous years, fork length generally decreased from April to June.

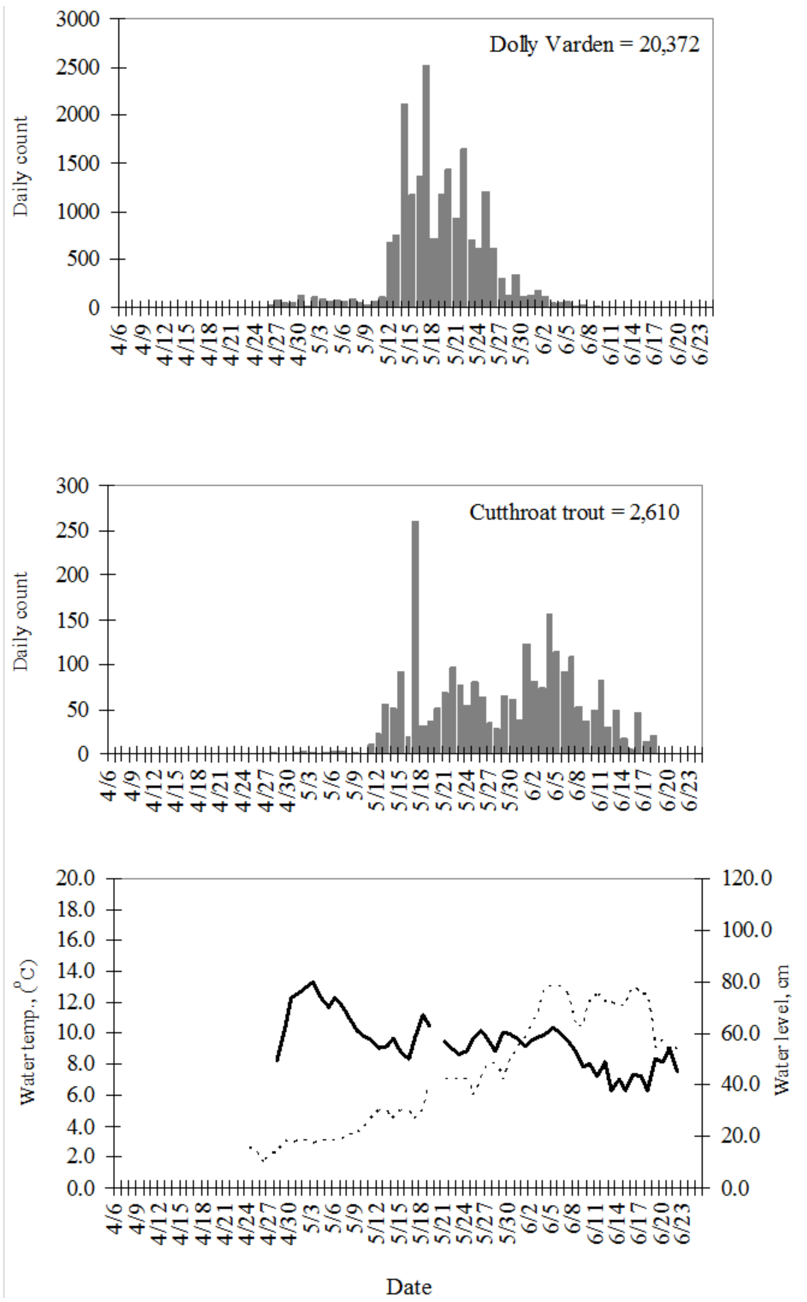

Figure 6.–Daily counts of emigrant Dolly Varden char (top panel), emigrant cutthroat trout (center panel), and daily measurements of water level in cm (solid line) and water temperature in °C (stippled line) at Sitkoh Creek, 2009 (bottom panel).

Cutthroat Trout

A total of 2,610 emigrant cutthroat trout were counted through the weir in 2009 during the period the weir was in place. The first trout was captured on 28 April and the midpoint occurred on 31 May. Emigrant cutthroat trout were captured until the morning the weir was pulled. The peak daily count (259) occurred on 17 May, and another high count (156) occurred on 4 June (Figure 6). Cutthroat were not measured for length frequency analysis but, qualitatively, more smaller fish were passed in 2009 than any of the previous years since 2003. The length of emigrants appeared to vary throughout the run, but generally fish length decreased through time.

Other Migrants

Emigrant rainbow trout and immigrant sockeye salmon were also captured and passed through the Sitkoh Creek weir during 2009. There were 29 rainbow trout emigrants passed downstream, one of which had been previously PIT tagged in 2006. This fish was tagged in May of 2006 at 210 mm FL as a juvenile, then recaptured initially in May of 2009 at 378 mm FL as a ripe male. A partial count was also made of salmon moving upstream through the weir to spawn in Sitkoh Creek. There were 55 immigrant adult sockeye salmon that passed through the weir between 14 June and 19 June. No pink salmon were passed through the weir in 2009.

DISCUSSION

The following discussion is organized in three parts: 1) a discussion of the 2009 Sitkoh Creek research results as compared to the previous six years of study, 2) comparison of Sitkoh Creek research to other research reported in the literature for the Pacific Northwest coast and, 3) recommendations for future research. Because 2009 was the last year of the Sitkoh Creek project, a chronological summary by month of steelhead weir operations was also included in Appendix A. Successful operation of the Sitkoh Creek weir using standardized capture and sampling methods to individually PIT-tag both adult and smolt steelhead proved that these methods could be used consistently to achieve research objectives. The 2003–2009 Sitkoh Creek steelhead project contributed to the understanding of steelhead demographics, population dynamics, and life history in Southeast Alaska. Censuses of escapement were obtained each year, as well as spring emigration counts of smolt, preliminary SPS estimates, estimated ages, length frequencies, sex ratios, migratory timing, smolt-adult and kelt survival rates, documentation of straying to nearby and distant streams, and observations of life history stages. This type of information is generally lacking from most of the 300+ Southeast Alaska steelhead populations.

Adult Escapements, Immigration and Stream Environments

Abundance estimates for all years of the study were similar to weir escapement counts, thus verifying weir counts as census. Weir counts averaged 97% of the Petersen estimates for all years sampled (Table 1). The adult steelhead escapement in 2009 was lower than the average of the 2003–2008 escapements (Tables 1 and 8), and annual escapements have generally declined since the initiation of this study. Similar escapement trends were also reported on the Keogh River, northern Vancouver Island, where escapements were the lowest in fall 2008/spring 2009 (n = 66 fish) since 1996–1999, and lower than the average of 119 for the 2000–2008 period (McCubbing 2010). Ten index streams located throughout Southeast Alaska that have been consistently snorkel surveyed since 1997 have also showed declines from 2007 onward, suggesting regionwide declines in escapements in recent years (Harding and Love 2008; Harding 2009, 2012). Reductions in estimated abundance based on test fishery data from the Skeena

River, British Columbia have also been reported for 2003–2007 fall steelhead, before increasing in fall 2009/spring 2010 (Mark Beere, B.C., Ministry of Environment, Fisheries Branch, personal communication). Based on these coastwide trends, reduced escapements in Sitkoh Creek in recent years may be within normal variation.

At Sitkoh Creek, during years of normal snowpack (2003–2005) adult steelhead began their immigration by about 11 April, and peaked (mid-point) during the last week of April or first week of May (Love and Harding 2008, 2009). In years with heavy snowpack, high stream discharge, or low spring temperatures during March and April, weir installation and steelhead immigration timing was delayed. In 2006–2008, heavy snowpack (2007), icing conditions (2006 and 2008), and low March and April temperatures (2006 and 2008) prolonged spring flooding and delayed weir installation by a week to about a month (Love and Harding 2009; Love et al. 2012). Adult immigrants arrived at the weir about a week (2006 and 2008) to about a month (2007) later than during years with milder temperatures and normal winter snow fall (Table 9). Although snowpack during the winter of 2008–2009 was only slightly greater than normal, immigration timing was still delayed compared to 2003–2005 due to colder spring water temperatures (National Weather Service, Juneau, Alaska. 2009. Alaska Climate Database. http://pajk.arh.noaa.gov/cliMap/cli_out.php; Love and Harding 2008, 2009; Love et al. 2012).

During all years, adult emigration timing did not vary greatly meaning that delayed immigration resulted in shorter time spent spawning.

Although difficult to assess with such a short time series, lower smolt production during 2007–2009 (Table 8) may fall within the range of normal variation. Sikoh Creek smolt abundance has varied from a high of 3,742 in 2004 to a low of 893 in 2009 (Yanusz 1997; Love and Harding, 2008, 2009; Love et al. 2012). Smolt production counts from the Keogh River weir varied similarly, averaging 2,390 annually during 1999–2007, with only 965 outmigrant smolts captured during 2007 (McCubbing 2002; McCubbing and Ward 2003, 2007) and fewer than 1,500 counted each year during 2008 and 2009 (McCubbing 2010). Although the quantity of smolts produced at Sitkoh Creek has declined, the size distribution has not changed. Sitkoh Creek smolt sizes have been very similar year-to-year during the 2003–2009 period (Table 9), with the mode of the unimodal length distributions between 189–210 mm FL (mostly freshwater ages three and four). Nutrient fertilization projects in the Keogh River during 1996–2002 appeared to have produced greater numbers of larger smolt, which suggests adequate rearing habitat and little competition for the enhanced invertebrate production (Ward et al. 2002, 2003). Analogously, Sitkoh Creek smolts in 2005–2009 may not have had food or habitat limitations based on consistent production of similar-aged fish and their consistent average size. Decreasing emigration abundance could instead have been related to density-independent abiotic factors that affected critical life history stages. The age of greatest vulnerability for Skeena River steelhead appeared to be at about two and three years of age, when most steelhead were probably parr (Hooten et al. 1987). Losses during critical life history stages of steelhead (fry, parr, and smolt) may contribute to highly variable ages and resultant variable adult returns (Ward 1996). Mechanisms capable of increasing juvenile trout mortality include freezing winter temperatures, ice formation and dewatering (Huusko et al. 2007), loss of low-velocity habitat associated with large woody debris (Mitro and Zale 2002; Shirvell 1990), and high freshwater discharge in July-November that can prematurely flush juveniles out of suitable habitat (Nehring and Anderson 1993; Latterell et al. 1998). Compared to more normal fall rain-on-snow events during most years studied on Sitkoh Creek, one event during the fall of 2005 was exceptional.

Table 8.–Summary of immigrant and emigrant steelhead counts from Sitkoh Creek weir, 2003–2009. Lengths, SD of lengths, and length ranges reported in mm FL. Numbers recaptured and survivals based on recovery of previously PIT-tagged fish.

	Sample year						
	2003[a]	2004[a]	2005[b]	2006[b]	2007[c]	2008[c]	2009[d]
Adult immigration							
Total immigration	679	764	543	395	392	487	402
Petersen estimate (SE)	682(2.0)	780(4.0)	574(4.7)	416(3.5)	418(7.0)	513(6.6)	408(1.1)
Average length (SD)	751(74.7)	740(69.5)	753(70.2)	749(73.2)	742(76.3)	731(70.6)	750(66.8)
Length range	555–910	576–930	550–935	548–923	465–915	590–940	560–920
No. recaptured (%)	0	110(14.4)	122(22.5)	248(62.8)	284(72.4)	327(67.1)	277(69.6)
No. scale sampled (%)	224(33.0)	325(42.5)	239(44.0)	200(50.6)	189(48.2)	143(29.4)	236(59.4)
% Female	62	60	67	65	66	68	78
Adult emigration							
Total emigration	460	565	363	292	345	390	360
Average length (SD)	743(74.0)	737(66.8)	760(53.9)	756(63.0)	739(71.6)	734(66.4)	751(66.5)
Length range	555–905	580–930	550–912	600–923	499–900	615–940	560–920
% Female	67	67	75	68	74	73	80
% Kelt survival	68	74	67	72	83	92	88
No. untagged down	6	5	5	9	26	22	9
Smolt emigration							
No. of smolt	3,162	3,742	2,230	3,561	1,704	1,751	893
Average length (SD)	196(24.6)	200(24.7)	197(27.7)	219(39.1)	205(40.4)	196(34.2)	189(29.9)
Freshwater age 3 & 4, %	77.7	87.6	70.9	75.5	72.7	78.3	90.9
Marine survival, %	6.2	4.4	5.7	7.9	ND	ND	ND
Emigration of other species							
No. of cutthroat trout	4,588	4,095	2,787	2,491	2,011	2,323	2,610
No. of Dolly Varden	52,884	62,409	38,422	29,820	27,534	18,790	20,372
No. of rainbow trout	28	40	9	41	40	53	29

[a] Data for 2003–2004 from Love and Harding (2008).

[b] Data for 2005–2006 from Love and Harding (2009).

[c] Data for 2007–2008 from Love et al. (2012).

Table 9.–Summary of adult and smolt steelhead counts and migratory timing for Sitkoh Creek, 2003–2009. Data are from Love and Harding (2008, 2009), Love et al. (2012).

	Adults				Smolt
Year	Number of immigrants	Midpoint of immigration	Number of kelts	Midpoint of emigration	Number of emigrants
2003	679	29-Apr	466	23-May	3,162
2004	764	2-May	565	26-May	3,742
2005	543	30-Apr	363	31-May	2,230
2006	395	16-May	301	4-Jun	3,561
2007	392	18-May	345	4-Jun	1,704
2008	487	18-May	390	8-Jun	1,751
2009	397	13-May	360	6-Jun	893

Over seven inches of rain (based on an Angoon weather station) fell during a one week rain-on-snow event in November 2005, over two times more rainfall than any other event ever recorded. During 2003–2004 and 2006–2009, normal fall flooding on Sitkoh Creek averaged about 700 cfs, compared to almost 2000 cfs in the fall of 2005 (Jarrod Sowa, ADF&G Aquatic Resources Group, personal communication). The following spring (2006), long-established pool habitats formed by stream channel large woody debris were washed out or pushed bankside. This single event dramatically changed pool and riffle habitats in Sitkoh Creek and could also have flushed juvenile steelhead, thus negatively affecting steelhead parr and smolt abundance during the following years.

Scale aging results indicated that in addition to Sitkoh Creek smolts being larger, they also appeared to be older. A high proportion of immigrant steelhead smolt (73% in 2007, 78% in 2008, and 91% in 2009) in Sitkoh Creek appeared to be freshwater ages three and four (Table 8), with age four being most prevalent. Matching triplicate reads for 95% of all scales aged, and mean CV < 5% for all smolt scales aged indicate precise ages and consistent, believable aging methods. In Southeast Alaska, freshwater ages three and four were also the most abundant age classes reported for five other steelhead populations, each having at least two years of data (Lohr and Bryant 1999). Although the 2009 smolt abundance in Sitkoh Creek was lower than previous years, smolt quality, in terms of average size and estimated age, was greater. By comparison, in 2009 at the Keogh River on Vancouver Island, freshwater ages two and three were the most prevalent ages, with age two composing 55% of all aged smolts. The average size of these younger Keogh smolt was 175 mm FL, less than for Sitkoh Creek during all years, 2003-2009 (McCubbing 2010; Love and Harding 2008, 2009; Love et al. 2012).

Good estimates of adult escapements, counts of smolt abundance, and precise estimates of age for all years of the study permitted assignment of smolt year classes to brood years and estimation of smolt-per-spawner (SPS). Based on scale-aging samples, the 2006–2009 smolt produced from the 2003 brood year totaled 2,363 smolt, which in turn equaled about 3.5 SPS (Tables 10 and 11). The 2004 brood year produced 1,273 smolts, for a SPS of 1.7. Incomplete estimates of SPS for 2005 smolts, not including 5-freshwater smolt outmigrants (n = 923 for 3- and 4-freshwater) also equaled 1.7. These estimates are low compared to the Keogh River stock, which produced a low average of about 5.0 SPS for 1986–1995 under natural conditions, and a high average of about 25 SPS for 1996–2009 following nutrient fertilization that enhanced stream invertebrate production (Ward et al. 2002, 2003; McCubbing 2002; McCubbing and Ward 2003, 2007; McCubbing 2010). Nonetheless, smolt emigration counts on the Keogh River were still below 1,500 in 2008 and 2009 and remain a cause for concern, especially because marine survival rates were less than 5% (McCubbing 2010). Although smolt counts each year at Sitkoh Creek were considered complete counts for the period that the weir was operated, it is possible that additional smolt emigrated from the stream when the weir was not in place, which would have resulted in a higher SPS.

Table 10.–Numbers of emigrant steelhead smolt produced in 2006–2009 by the 2003–2007 adult brood classes based on scale age estimates from smolt sampled emigrating from Sitkoh Creek.

			Emigrant smolt year (#)							# by adult brood class
Brood class year	Adult immigration	Smolt emigration	2003	2004	2005	2006[a]	2007[b]	2008[b]	2009	
2003	679	3,166				1,217	917	229	0	2,363
2004	764	3,742				11	325	902	35	1,273
2005	543	2,230						469	454	923
2006	395	3,549							355	355
2007	392	1,704							29	29
2008	487	1,751								
2009	397									
Average	522	2,434								

[a] From Love and Harding (2009).

[b] From Love et al. (2012).

Table 11.–Smolts-per-spawner (SPS) for 2003–2006 adult steelhead brood classes and 2006–2009 smolt emigrants based on scale age estimates from smolt sampled emigrating from Sitkoh Creek.

			Smolts-per-spawner (SPS) by emigrant year							
Brood class year	Adult immigration	Smolt emigration	2003	2004	2005	2006	2007	2008	2009	Overall SPS
2003	679	3,166				1.793	1.350	0.338	0.000	3.48
2004	764	3,742				0.014	0.426	1.180	0.046	1.67
2005	543	2,230						0.864	0.836	1.70
2006	395	3,549							0.898	0.90
2007	392	1,704							0.074	0.07
2008	487	1,751								
2009	397	893								
Average	522	2,434								

PIT Tag Returns: Marine Ages, Survival, Repeat Spawning and Straying

Although recent Sitkoh Creek smolt and adult counts appeared to be below average, the older, larger smolts returning as first-time spawning adults to Sitkoh Creek appeared to have good smolt-to-adult ocean survivals, relative to the Keogh River. Based on PIT tag returns, recaptured first-time spawning adults (tagged as smolt) sampled in 2005–2009 spent two or three years at sea and comprised about half (average = 49%) of the escapement in 2009. Ocean-age-2 and -3 fish (based on scale aging) were also the most abundant ocean-age classes found in the Karta, Thorne, Klawock, Ward, and Situk rivers; and Petersburg and Peterson creeks (Lohr and Bryant 1999). Marine survival of 2- and 3-ocean adults recaptured at Sitkoh Creek during 2005–2009 averaged 6.3% (Table 12), higher than smolt survivals for the Keogh River during 2001–2003 and 2005–2007, which were less than 4% (McCubbing 2002; McCubbing and Ward 2003), and during 2009 when survival was 5.0% (McCubbing 2010). Low adult returns to the Keogh River appeared to be related to these low marine survivals. Although Keogh River historically has produced higher SPS estimates than at Sitkoh Creek, the low number of returning adults to that system in recent years is well below the number of adults (500) previously thought necessary to produce a carrying capacity of 6,500 smolts (Ward 1996). Average escapement of wild steelhead in the Keogh River has not been above 250 adults since 1996 (McCubbing 2010), but Sitkoh Creek has averaged 574 since 1996.

Table 12.–Number of previously PIT-tagged 1-,2-,3-,4- and 5-ocean smolt that returned for the first time to spawn by year, total return by smolt tagging year, and overall marine survival (% tag return) by smolt tagging year (smolt-adult survival) for steelhead from Sitkoh Creek, 2003–2009.

		Unique adult returns of PIT-tagged smolt						
Smolt year	# Smolt tagged	2005	2006	2007	2008	2009	Total return by smolt year	Marine survival
2003	2,995	53	129	9	4	0	195	6.5
2004	3,608		49	112	11	0	172	4.8
2005	2,226			66	60	2	128	5.8
2006	3,549			1	164	115	280	7.9
2007	1,647					63	63	3.8

Immigrant and emigrant steelhead captured passing through the Sitkoh River weir were identified as either recaptured (PIT tagged initially as adults or smolt) or untagged adults. Progressively more tagged steelhead were recaptured at Sitkoh Creek annually since the project was initiated: from 14% of total escapement in 2004, to 70% in 2009. In 2009, 30% of immigrant adults passed through the weir were untagged. Systematic scale samples from these untagged fish showed evident spawn checks suggesting they had either spawned below the weir, or were possibly not from Sitkoh Creek. Several recaptured 4- and 5-ocean adults (previously tagged as smolts) with spawn checks on their scales were also sampled for the first time in 2009, indicating they had spawned somewhere other than above the weir prior to recapture. During a snorkel survey in 2006 on the nearby Sitkoh River, 6 of 50 observed adults (12%) were missing adipose fins, indicating straying to that system from Sitkoh Creek (Love and Harding 2009). In 2007, a kelt recaptured at the Situk River weir was discovered to have been tagged the year previous at Sitkoh Creek. Although exact rates are not known, stray steelhead appear to contribute to diversity, especially in the shorter stream systems of Southeast Alaska.

In addition to straying, repeat spawning contributes to sustaining populations in Southeast Alaska. Based on estimated ages from systematically collected scale samples from Sitkoh Creek in 2009, about 55% of all adults were first-time spawners, and 34% were repeat spawners. This compares to PIT tag recapture rates, which are considered to be more accurate, of 48% first-time spawners, and 21% repeat spawners. Lohr and Bryant (1999) report a range of repeat spawning rates of 33–51% for the Karta River, Petersburg Creek, Peterson Creek, and Situk River, based on scale aging. Keogh River repeat spawning rates were 17% and 14% in 2008 and 2009, respectively, which suggests that repeat spawners may survive well in the ocean and may play a significant role in sustaining Keogh River populations. This may also be the case for Sitkoh Creek repeat spawners.

Although there were fewer immigrants in 2009, kelt survival may be a mitigating factor. Average kelt survival at Sitkoh Creek between 2003–2008 was 73%, and ranged from 68% to 82%. In 2009, 88% of the adult immigrants were successfully passed back downstream through the weir as kelts. During three separate surveys in May and June 2009, snorkel surveyors observed 66–82% of all the fish in the lower survey reach immediately above the weir (Harding 2012). Kelt survival rates were likely higher than average in 2009 because the fish did not migrate as far upstream as in previous years, allowing more adults to rest in the pool within the 300 foot “no fishing” area upstream of the weir, thus exposing them to less overall predation by otters, or disturbance by fishermen. Average time that adult steelhead spent in the creek during 2009 (about one month) was similar to previous years.

Trout and Dolly Varden Production

Although weir counts of trout and char are considered only partial counts for the period the weir was in place at Sitkoh Creek, there appears to be declining numbers of cutthroat trout and Dolly Varden char emigrating during the spring period, April-June. This is similar to observed downward trends during the spring at Auke Creek weir from 1996–2008 (Echave 2009; Joyce et al. unpublished 2008 annual report, National Marine Fisheries Service, Ted Stevens Marine Research Institute, Juneau, Alaska). Causal factors for declines in these emigration numbers at Auke Creek are not known. Declines of emigrant steelhead smolt in the Keogh River have also occurred in recent years. Maybe Auke Creek and Sitkoh Creek char and trout have experienced low marine survival rates prior to 2009 as well. Emigrant counts for cutthroat trout and Dolly Varden char in Auke Creek in 2009 increased again, as observed in in 2009 at Sitkoh Creek (John Joyce, National Marine Fisheries Service, Ted Stevens Marine Research Institute, personal communication).

Summary

The results of the Sitkoh Creek project provide a preliminary baseline of seven years of production and demographic data. Spring steelhead weir counts provided accurate and precise estimates (census) of escapement at Sitkoh Creek during 2003–2009. Adult steelhead escapement during 2006 to 2009 was below the 2003–2009 average (Table 1; Love and Harding 2008, 2009), and annual escapements generally decreased throughout the project period (Table 8). In recent years lower escapements were also reported on the Skeena and Keogh rivers, and for snorkel surveys conducted on 10 Southeast Alaska index streams. As evidenced by the variation in annual escapement reported for the Keogh River, for which there is a 30+ year data set, changes in Sitkoh Creek steelhead abundance may be due to normal variability in marine survival. Length frequency of adult immigrants in 2009 appeared to be normally distributed and similar between males and females. Average length was not significantly different than the 2003–2008 average (Table 8; Love and Harding 2008, 2009; Love et al. 2012), and age estimation from scale sampling did not indicate changes in age structure. Because there were no size or age-related changes in stock composition, food supply or habitat limitations may not explain the low escapement in 2009. In 2009, marine survival rates for recaptured first-time spawning Sitkoh Creek adults were higher than in the Keogh River and Puget Sound streams (Bruce Ward, Ministry of Water, Land and Air Protection, British Columbia, University of British Columbia, personal communication). In 2009, kelt passage downstream was 88%, higher than the 2003–2008 average of 76% (Table 8). Based on PIT tag returns, repeat spawners composed at least 21% of the run in 2009. Good survival of females (78%), and the possibility that a high proportion of straying (30% of escapement were untagged) occurred in 2009, may help to sustain adult escapement. These various parameters may indicate that the tagging and handling stresses that adult (and smolt) steelhead were exposed to at the Sitkoh Creek weir may not have been exceedingly different from background stresses experienced elsewhere by other stocks, and that the Sitkoh steelhead population remains healthy.

Simple spawner-recruit relationships such as SPS may provide useful indicators for steelhead stock status, but should be considered in combination with marine survival, age and contribution by age of spawning adults, repeat spawning rates, straying, and contribution by other life history forms. As with adult production, the smolt emigration in 2009 was lower than previous years (Table 8; Love and Harding 2008, 2009). Survival of critical life history stages depends on stability of suitable habitat and lack of extreme abiotic events such as flooding during late summer/fall that may flush fry. Abiotic events such as the extreme flows during the fall of 2005 may have had negative effects on juvenile survival, smolt production, and subsequent returns of first-spawning adults. Variability in late summer or fall discharges may directly affect future production and should be considered alongside habitat-based production modeling such as were conducted on Sitkoh Creek (Crupi et al. 2010; Crupi and Nichols 2012). Habitat measurements taken prior to extreme flow events (50-year or 100-year) may make smolt production estimates by habitat type invalid if not repeated following changes to the habitat (removal of large woody debris and changes to pool-riffle ratios) that was surveyed.

Interannual abundance in Southeast Alaska smolt and adult steelhead populations such as Sitkoh Creek may be highly variable and subject to a host of biotic and abiotic events. Low smolt production (and resultant SPS estimates) in Sitkoh Creek during 2007–2009 appears to be coupled with consistently larger average size and greater marine survival compared to other research streams such as the Keogh River. Straying and high repeat spawning rates appear to be relatively high. These biotic characteristics of the population may balance extreme abiotic events such as extreme fall flooding/flushing of fry and parr and low stream productivity of northern latitude streams such as Sitkoh Creek. Given the variety of life history types observed in Sitkoh Creek, Southeast Alaska steelhead seem to be adaptable to changing abiotic events and exhibit variable life history strategies enabling them to persist following perturbation.

Recommendations for Future Research

Many steelhead populations throughout their native range have been listed as threatened or endangered under the Endangered Species Act. Southeast Alaska steelhead stocks remain productive and appear to be sustaining themselves through protection under current sport fishing regulations, relatively high repeat spawning rates and marine survival rates, high kelt survival rates, relatively pristine habitats, and contributions to the population by stray steelhead as well as resident rainbow trout. Nonetheless, small populations of steelhead may be vulnerable to overexploitation and in danger of losing genetic diversity. Currently, many of these systems are protected by their remoteness and the expense to reach them; however, a number of smaller systems are accessible and more vulnerable.

At a minimum, basic research should be continued on at least one stream each year in Southeast Alaska, preferably an index stream, in order to obtain abundance information, estimate marine survival rates, and calibrate snorkel counts. Weir projects, conducted in a standardized manner, would provide essentially a census of the steelhead population. Direct enumeration is the most accurate method. The expense of operating a weir that obtains a census appears to cost about as much as estimating population size by indirect methods such as Dual frequency IDentification SONar (DIDSON) and resistivity counters (Coyle and Reed 2012a, 2012b), once image processing and analysis time are included. Weir projects at systematic intervals would be useful monitoring tools for managers to track long-term production. Baseline genetic samples from index streams that are geographically distributed throughout Southeast Alaska may also be helpful for a better understanding of the degree of interrelatedness among the many small populations in Southeast Alaska. Knowledge of genetic relatedness would give managers a means to prioritize conservative management under differing scenarios of sport fishing use, subsistence harvest, and commercial interception.

Specific recommendations for future steelhead production studies:

1) Continue long-term weir studies of escapement and production estimates for adult and smolt steelhead in a variety of streams in Southeast Alaska.
2) Continue studies of habitat classification and habitat utilization by the different steelhead life history stages, coupled with weir studies, in a variety of streams in Southeast Alaska.
2) In further collaboration with the U.S. Fish and Wildlife Service Genetics Laboratory, collect representative, baseline genetics samples from a variety of steelhead streams in Southeast Alaska.
3) In collaboration with ADF&G, Division of Commercial Fisheries, initiate a sampling program of the Southeast Alaska commercial catches to quantify steelhead bycatch harvests.
4) Assist federal agencies in quantifying subsistence use of steelhead throughout Southeast Alaska.
5) In conjunction with weir studies, initiate a program of telemetry and archival tagging of steelhead, possibly in cooperation with the Pacific Ocean Shelf Tracking Project to better understand marine migratory behavior and the distributional range of steelhead.

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APPENDIX A: MONTH-TO-MONTH WEIR OPERATIONS FROM APRIL TO JUNE 2003–2009

April Weir Operations

During years with mild spring temperatures and normal snowpack, weir installation typically was completed by the first week of April. Weir personnel spent most of April installing the weir, measuring, scale sampling, PIT tagging adult immigrants, and setting up camp. To avoid unnecessary stress, adult steelhead were sampled as soon as they entered the trap. Each fish was typically handled for about a minute while being PIT-tagged, scale sampled, measured and sexed before being released. Immigrant sampling occurred predominantly in the evening to about midnight, and typically resumed as fish moved upstream again in the early morning. During the peak immigration periods, sampling occurred throughout the day.

Adult upstream movement was usually highest around the high spring tides, and following flood events when stream discharges began to drop. During years of normal snowpack, ice-free conditions and mild temperatures (2003–2005) adult steelhead began their immigration by about 11 April, and peaked (mid-point) during the last week of April or first week of May. In years with heavy snowpack, icing, prolonged high stream discharge, or low spring temperatures during March and April (2006-2008), weir installation and steelhead immigration timing was delayed. by a week to about a month. Adult immigrants arrived at the weir about a week (2006 and 2008) to about a month (2007) later than during years with milder temperatures and normal winter snowfall

The average fork length of immigrating adult steelhead during April was smaller when compared to the entire escapement. The smaller average size was primarily due to a higher proportion of smaller and younger males immigrating earlier in the spring. Larger immigrant females were typically more abundant beginning around mid-April to early May. If the Sitkoh Creek steelhead population required conservative management, the stream could be closed to spring steelhead fishing after the first week of May to protect these females. The female component of the population might actually be viewed as the effective population because females are more prevalent than males and have a higher repeat spawning rate. Temporal fishing closures would also limit additional stress for kelts because few (less than 5% of the total emigration) emigrate before the first week of May.

May Weir Activities

During May, weir personnel continued sampling adult immigrants, began sampling emigrant kelts, and PIT tagged smolt. The most time consuming activity was PIT tagging: most tagging occurred from late afternoon to evening, and also early in the morning. During the 2003–2009 study period, most (95%) of the immigrant adults passed the weir by the end of May or early June. In 2007, cold water and flooding appeared to delay adult immigration by about a week because the 95% threshold was not reached until 10 June. The kelt emigration usually began the first week of May and continued until about mid-June.

During years with normal stream discharge, the weir was modified by installing finer-meshed screening on the upstream face of the weir during the last week of April or the first week of May. This finer screening allowed safe capture of smolt during their emigration, which typically started about 10 May and continued for about a month. As with immigrant adults, cold water and high flows delayed smolt emigration by about a week (May 16 in 2007). In general the larger,

-continued-

more robust smolt emigrated first, and smaller smolts left the system later in the spring. Weir technicians identified the first outmigrant rainbows during the end of April or early May. These fish were typically larger (>300 mm FL) than smolt and often were in spawning condition and coloration. Dolly Varden and cutthroat trout emigrations began around mid-April.

June Weir Activities

The adult immigration was completed by about 15 June, and the emigration of kelts and smolts was completed by 24 June. During all years except 2007, water temperatures reached 13^{o}C by mid to late June. On average, 5% of the adult immigration was through the weir by late April when water temperatures were 3^{o}C, and was 95% complete by the time water temperatures reached 10.5^{o}C on about 10 June. The kelt emigration was about 95% complete by 15 June, or when water temperatures reached about 13^{o}C. Smolt emigration was 95% complete by about the same time and at about the same temperature as for adult emigrants. Cutthroat trout and Dolly Varden continued to leave the system until the weir was removed, but during warm water years would have largely completed their migration by mid to late June. Based on all years of weir operations on Sitkoh Creek, including 2007 when water temperatures were exceptionally cold, all steelhead migrations were complete by 24 June, when the weir was removed

APPENDIX B: FILE DESCRIPTIONS

Appendix B1.–Contents of electronic files submitted with this report.

FILE NAME	SOFTWARE	CONTENTS
09FDS_Tables & Figs.xls	Excel 2003	Figures and tables and associated data used to generate this report
03-09Sitkoh_Data.xls	Excel 2003	Sample and tag numbers, lengths, scale sample and genetic sample numbers, otolith sample number, dates samples collected for steelhead adults and juveniles at Sitkoh Creek weir, 2003–2009
09Daily_Cum_Counts.xls	Excel 2003	Daily weir counts in 2009 for all species at Sitkoh Creek
09Sitkoh_Temp_Level.xls	Excel 2003	Daily temp and stage gauge at Sitkoh Creek in 2009

Note: Located at Alaska Department of Fish and Game, Division of Sport Fish, Research and Technical Services, 333 Raspberry Rd, Anchorage AK 99518.