Fishery Data Series No. 12-60

Steelhead Trout Production Studies at Sitkoh Creek, Alaska, 2007–2008

by

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October 2012

Alaska Department of Fish and Game **Divisions 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 trout *Oncorhynchus mykiss irideus* in Southeast Alaska prompted a multi-year study that began in 2003 at Sitkoh Creek. The long-term goal of this project is to estimate the number of steelhead smolts produced from a known escapement of adults. Adult escapement, smolt outmigration, and smolts-per-spawner estimates will be combined with data from a steelhead habitat carrying capacity project to lay the foundation for estimating escapement targets. An immigrant/emigrant weir was operated on Sitkoh Creek in spring 2007 and 2008. Using a modified Petersen model, the estimated escapement was 416 (Bayesian SE = 6.9) in 2007, and 511 (Bayesian SE = 6.5) in 2008. All untagged immigrant adult steelhead captured in 2007 and 2008 were implanted with passive integrated transponder (PIT) tags and released upstream. Approximately 82.5% of the kelts survived spawning in 2007, and 76.0% survived in 2008. In 2007 and 2008, all untagged kelts were PIT-tagged and released downstream. In 2007, 1,704 steelhead smolt, 2,011 sea-run cutthroat trout, and 27,534 sea-run Dolly Varden emigrated through the weir. In 2008, 1,751 steelhead smolt, 2,323 sea-run cutthroat trout, and 18,790 sea-run Dolly Varden emigrated. The 2007 smolt emigration was comprised of freshwater age-3 (18.6%) and age-4 (54.1%) fish. The 2008 smolt emigration was comprised of freshwater age-3 (26.8%) and age-4 (51.5%) fish. Combined freshwater age-3, -4, and -5 smolt (2,369 total) originating from the 2003 adult brood class (679 spawners) equated to 3.5 smolts-per-spawner. The total number of smolt produced by the 2004 adult brood class will be known upon completion of the 2009 field season, which will be the last field season.

Keywords: Steelhead trout, *Oncorhynchus mykiss irideus*, Sitkoh Creek, weir, escapement targets, passive integrated transponder tag, smolt and adult production, kelt survival, scale aging, ocean ages, freshwater ages, smolts-per-spawner, Dolly Varden char, cutthroat trout.

INTRODUCTION

Steelhead *Oncorhynchus mykiss* in Alaska are found in coastal streams from Dixon Entrance to the Alaska Peninsula. Southeast Alaska has 309 steelhead systems, most of which are believed to have escapements of 200 or fewer adults. Some of the larger systems, like the Naha, Karta and Thorne rivers once supported annual escapements greater than 1,000 adults. The largest steelhead system in the region, and possibly in Alaska, is the Situk River near Yakutat that produces between 3,000 and 15,000 adults. The smaller populations of steelhead in Southeast Alaska may be especially vulnerable to overexploitation if recreational or subsistence harvests significantly increase.

This project is designed to collect the data necessary to develop and support management decisions ensuring that adequate steelhead escapement exists to utilize the available freshwater habitat. The specific research emphasis of this project is to collect demographic parameters needed for evaluating steelhead smolt production relative to adult escapement. Estimates of smolt per spawner, combined with results from our companion steelhead carrying capacity project (Crupi and Nichols 2012), will provide the information necessary to approximate escapement targets for steelhead in Southeast Alaska.

Although the long-term objective of this project is to estimate smolt per spawner, several other demographic parameters will also be estimated. Researchers may ultimately be able to estimate repeat spawning rates and smolt-to-adult survival for Sitkoh Creek steelhead, as well as document scale patterns of known ocean-age adult steelhead returning to spawn. These estimates may prove useful in guiding management actions. This report summarizes the fifth and sixth years (2007 and 2008) of a 7-year study, and presents information on the steelhead immigration and emigration, length distributions, tagging, and preliminary scale aging at Sitkoh Creek. Emigrant counts and length frequency distributions of sea-run cutthroat trout and Dolly Varden char for Sitkoh Creek are also summarized.

OBJECTIVES

The objectives for this project during 2007 and 2008 were:

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) Estimate the age composition of all immigrant steelhead adults;
7) Enumerate all sea-run cutthroat trout and Dolly Varden passing the weir; and
8) Collect scales and otoliths from young-of-the-year steelhead for reference scale aging sample.

STUDY AREA

Sitkoh Creek was chosen for this long-term study because it has a moderately large population of steelhead, a history of successful weir studies, relatively intact habitat, serves as a steelhead index stream, and supports a valued sport fishery. 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) is approximately 6.4 km long, 10 to 30 m wide, 0.1 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 (USFS) maintains 2 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).

Steelhead trout from Sitkoh Creek were monitored 8 times prior to 2005 with weirs operated in 1936, 1937, 1982, 1990, 1993, 1996, 2003, 2004, 2005 and 2006 (Chipperfield 1938; Jones 1983; Jones et al. 1991; Harding and Jones 1994; Yanusz 1997; Love and Harding 2008, 2009). Escapement counts ranged from 395 to 1,108, and averaged approximately 705 fish (Table 1). On average, the Sitkoh system (creek and lake) ranked third highest in catch during 1997–2006 for all freshwater steelhead systems in Southeast Alaska, however, reported effort has been lower during recent years (Howe et al. 2001a-c; Walker et al. 2003; Jennings et al. 2004, 2006a-b, 2007, 2009a-b). Current angling regulations permit retention of steelhead ≥36 in (914 mm) TL, thus effectively protecting 96% of the steelhead in Sitkoh Creek.

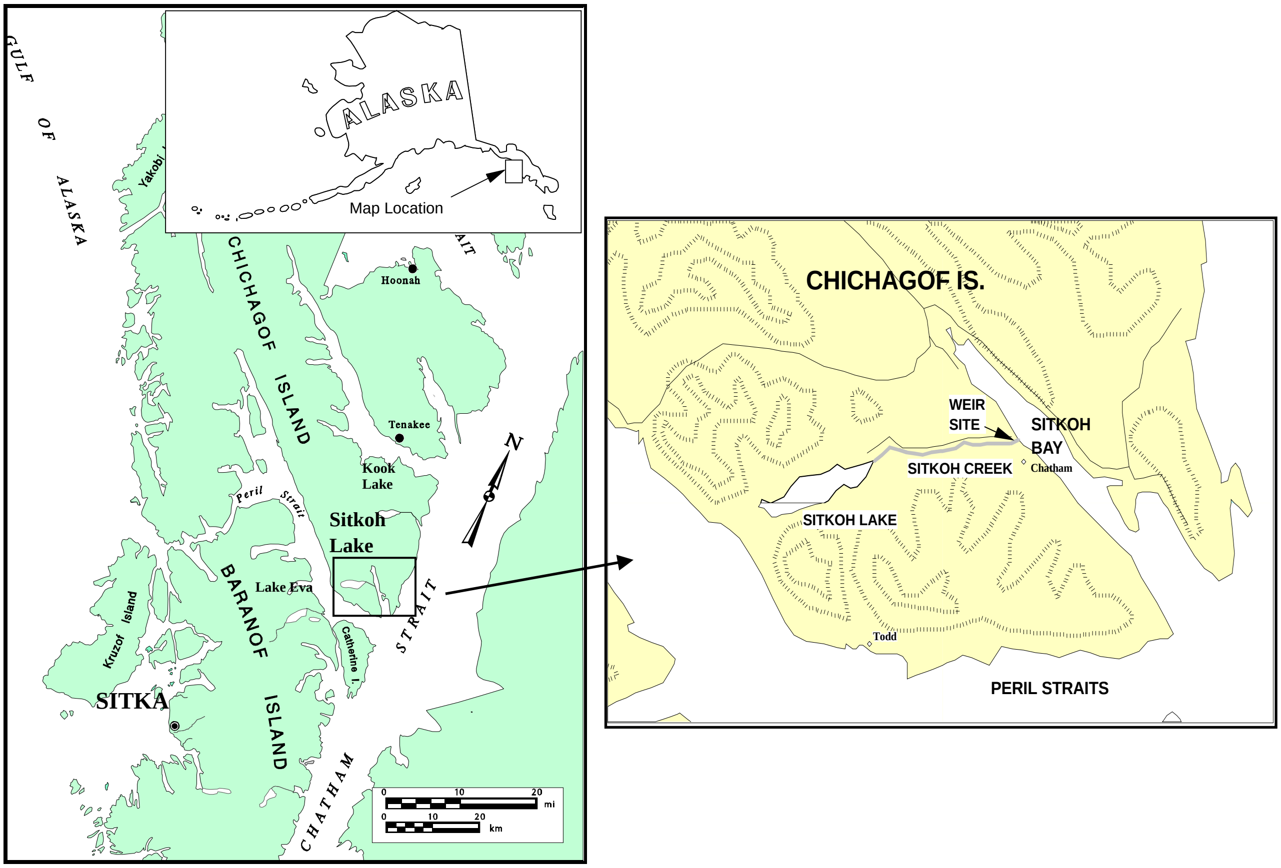


Figure 1.–Location of Sitkoh Lake, Sitkoh Creek, and weir site on Sitkoh Creek.

Table 1.–Historical escapements (based on weir census) and sex composition of immigrant steelhead at Sitkoh Creek. Numbers in parentheses are Chapman modified Petersen estimates.

Year	Escapement	Proportion female	Proportion male
1936[a]	760		
1937[a]	1,108		
1982[b]	690	0.5	0.5
1990[c]	661	0.61	0.39
1993[d]	520	0.63	0.37
1996[e]	926	0.62	0.38
2003[f]	679(682)	0.62	0.38
2004[f]	764(780)	0.60	0.40
2005[g]	543(574)	0.67	0.33
2006[g]	395(416)	0.65	0.35
Average	705		
2007	392(418)	0.66	0.33
2008	487(513)	0.68	0.32

[a] Chipperfield (1938).
[b] Jones (1983).
[c] Jones et al. (1991).
[d] Harding and Jones (1994).
[e] Yanusz (1997).
[f] Love and Harding (2008).
[g] Love and Harding (2009).

METHODS

An aluminum bipod weir was installed on Sitkoh Creek during May–June of 2007 and April–June of 2008. The weir contained separate emigrant-immigrant traps (2.5 m square), and was located approximately 400 m upstream from tidewater. The same site was used during previous studies in 1982, 1990, 1993, 1996, 2003, and 2004–2006. The weir was comprised of 18-mm diameter steel pickets spaced no more than 31 mm apart. The upstream face of the weir was overlaid with 1.2-m x 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 and the streambed was skirted with sandbags. Both the wire mesh and sandbags were believed to safely block the passage of fish ≥150 mm FL. Picket and channel holding pens were placed on both the upstream and downstream sides of the weir to hold captured fish entering and exiting the system. Again, vinyl-coated wire mesh was overlaid on both traps to create a barrier for fish ≥150 mm. The weir was scheduled to be operated from early April until to the last week of June during each sample year. During both years, 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 PM each day during 2007 and 2008.

ADULT STEELHEAD

All immigrating adult steelhead were counted, measured to the nearest 1 mm FL, and a subsample was measured for TL (current sport fish regulations are based on TL, and additional comparison between FL and TL was desired). Newly captured adults were sexed using secondary sexual characteristics as described by Morrow (1980) and Hart (1988), and tagged with 134 kHz passive integrated transponder (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. Detached adipose fins were collected from 50 adults sampled systematically throughout the course of immigration, and preserved in 70% ethanol for subsequent genetic analysis by the U.S. Fish and Wildlife Service Genetics Laboratory in Anchorage. In 2007 and 2008, all immigrating adult steelhead were checked for adipose clips and previously-implanted PIT tags, measured, and passed upstream through the weir.

To recapture previously scale-sampled smolts returning as adults in 2007, almost all (189 of 193 total) of the previously tagged immigrant adult steelhead were scale sampled. Untagged immigrants, tagged emigrants that were not seen as immigrants, and untagged emigrant kelts were not scale sampled. Downstream migrant fish were not scale sampled to minimize handling stress on the population as a whole. This means that 189 of a total immigrant population of 268 adult steelhead were scale sampled (71%), but scale sampling was biased towards previously-tagged immigrant adults. To minimize this bias in 2008, untagged adult immigrant steelhead were systematically sampled throughout the course of the upstream migration at a sample rate of about 1 in 3 (actual sample rate was 45 of 134 or 34%). Previously-tagged fish (identified by an adipose fin clip) were also sampled throughout the season at a scale sampling rate of approximately 1 in 3 (actual sample rate was 93 of 270 immigrants, or 34%). Of these 93 PIT-tagged fish that were scale sampled, 53 were identified a posteriori as repeat spawning adults that were then used to verify ocean aging results. Scales from untagged fish were removed from the left side and scales from previously tagged fish were removed from the right side of the fish from an area approximately 4–6 scale rows below and behind the dorsal fin, but above the lateral line. Scale samples were placed on labeled gum cards, and pressed flat in sequential order for storage.

All emigrating adult steelhead 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 in 2007 and 2008. All adult steelhead were measured during the periods the weir was operable, thus providing a length composition of immigrant steelhead passed through the weir.

The total abundance of immigrant steelhead was estimated using the Chapman modification of the Petersen estimator (Chapman 1951):

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

where:

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

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

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

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

Variance and the 95% credible interval for the estimator (equation 1) were estimated using Bayesian methods (Carlin and Louis 2000). Using Markov Chain Monte-Carlo techniques, a posterior distribution for $\hat{N}$ was generated by collecting 1,000,000 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 uniquely marked steelhead passed upstream through the weir that were not later observed passing downstream through the weir;

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

R = the number uniquely marked steelhead passed upstream 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 while passing fish either upstream or downstream from the weir.

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

$$\overline{N} = \frac{\sum_{b=1}^{1,000,000} \hat{N}_{(b)}}{1,000,000}; \text{ and} \quad (2)$$

$$\hat{var}(\hat{N}) = \frac{\sum_{b=1}^{1,000,000}(\hat{N}_{(b)} - \overline{N})^2}{1,000,000 - 1} \quad (3)$$

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

Mean lengths of adults and proportions occurring in different gender, size, age, and spawning history distributions were calculated using standard sample summary statistics (Cochran 1977).

STEELHEAD SMOLT

All emigrant steelhead smolt ≥150 mm were counted, examined for PIT tags, measured to the nearest 1 mm FL, and systematically scale sampled. Steelhead smolt were anesthetized using a buffered MS-222 solution prior to sampling. In 2007 and 2008, no smolts were implanted with PIT tags because this study was scheduled to be completed before these fish would have returned as adults.

Scales were collected from a systematic subsample of emigrant steelhead smolt. The subsample rate in 2007 was about 1 in 10, or 10.2%. In 2008, the subsample rate was 1 in 9, or 11.3%. Scales were removed from an area approximately 4–6 scale rows below and behind the dorsal fin, but above the lateral line. Untagged smolt were sampled on the left side, while previously-tagged smolt were sampled on the right. Between 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 likely retained by the vinyl-coated wire mesh used to cover the face of the weir, so a census was presumably obtained for the entire spring outmigration period that the weir was fished in 2007 and 2008. All smolt mortalities were counted, measured to the nearest 1 mm FL, and sampled for scales and otoliths. Because emigrant steelhead juveniles <150 mm FL could pass through the weir without being captured, these smaller steelhead represented an unknown percentage of the total emigration. Most were not considered to be smolt for this project. Because these smaller steelhead typically did not appear to have undergone smoltification and had the morphological characteristics of parr, they were counted as steelhead parr. All small steelhead juveniles <150 mm FL that appeared to have undergone smoltification were counted, measured to the nearest 1 mm FL, subsampled for scales, and released.

Mean lengths of smolt and proportions occurring in different size and age distributions were calculated using standard sample summary statistics (Cochran 1977).

STEELHEAD SCALE AGING AND ELECTRONIC IMAGING

Scale samples were imaged using an Indus International Microfiche[1] reader 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 D. E. Jones for steelhead trout (described in *Handbook for interpretation of steelhead trout scales in Southeast Alaska,* an unpublished document available through ADF&G, Division of Sport Fish, Douglas, Alaska). As

[1] This and subsequent product names are included for a complete description of the process and do not constitute product endorsement.

described in Erickson (1999), scale ages were determined primarily from the area of the scale lying 45o 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. As we did not have known-age samples, scale ages were considered to be estimated, not determined (Ericksen 1999).

Scale aging technicians made 3 independent readings of scale samples to estimate the age of each fish. Between readings, the scale images were randomized by the project biologist and scale aging results from the previous readings were not known during subsequent readings. The modal age of the 3 readings were taken as the estimated age. If none of the 3 reads agreed, the sample was considered unreadable and was omitted from the age composition estimation. Scales with regenerated foci (latinucleate) were unreadable and were also omitted. Assuming that a matching scale age, if not accurate, was the most consistent estimate, this final age was considered to be the best estimate. All reads that each technician made were archived for later assessment of aging errors. Juvenile and smolt scale aging criteria, including 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," were used to develop aging "rules" for smolt. These rules were incorporated into a scale aging methodology and then periodically re-evaluated as readers gained more experience aging scales from Sitkoh Creek. Adult scale aging was more complex because of the greater variation in freshwater and marine residency, latinucleate scales, variable and multiple spawning checks, variable freshwater, and variable saltwater residency for each fish. For example, a steelhead that spent 3 years in freshwater and 4 in the ocean could be variously aged as 3.4, 3.1s1s1s1, 3.2s1s1, 3.2s2, or 3.3s1. Age estimates refer to freshwater and saltwater ages including the use of "s" to indicate spawning checks in the format of X.XsX, wherein freshwater age precedes the decimal, saltwater follows the decimal and each "s" represents an observed spawning check. A 3.3s1 would be a fish that spent 3 years in freshwater, followed by 3 years in saltwater before it first returned to spawn (thus a spawning check), then a repeat spawning event the next year (when it was recaptured in the spring upstream migration) for a total age of 7 years.

In a future Fishery Data Series (FDS) report, tallies of the differences between true and estimated ocean ages will be compiled over time to determine bias in readings, and reproducibility of the repeated readings (i.e., precision) will be estimated using the CV (Campana 2001). Determining a mean CV for all adult and smolt scale ages from Sitkoh Creek scale samples will allow for comparison with the reviewed literature and from other systems in Southeast Alaska. Functionally significant differences between estimated ages of adults and smolts will be investigated to determine if the reading criteria based on scales can be modified to improve reading precision. Scale-based age estimates for both adult and smolt steelhead sampled during all years of the study, electronic imaging and archive methodology, and aging criteria will be summarized.

CUTTHROAT TROUT AND DOLLY VARDEN CHAR

All downstream-migrating Dolly Varden char and cutthroat trout were counted. No length information was collected in 2007 or 2008.

RESULTS

2007

Adult Steelhead - Immigration

Because of higher than normal snowfall and flooding in April of 2007, the Sitkoh Creek weir was not installed until 1 May, at which point it was fish tight until 30 May when the weir was overtopped for a 4 hour period at a 3 m section of the deepest panels. The weir was then operated continuously through 24 June 2007. Snorkel surveyors counted 6 adult steelhead upstream from the weir just prior to removal on 24 June. All of these fish were holding in the pool immediately above the weir. Presence/absence of adipose fins (i.e., tagged fish) was not noted. No adults were seen passing upstream over the top of the weir during the high, fast flows of 29 to 30 May, and previously had only been seen close to the bottom and along the edges of the stream during high flow events. Steelhead rheotaxis was along the bottom and nearest the stream banks, and fish were not observed passing upstream high in the water column against the strongest currents within the thalweg. This behavior has also been observed in migrating salmon (Webb and Hawkins 1989). It is believed that adult immigrants did not likely move upstream during the period the weir was overtopped, but could possibly have moved downstream. Downstream migrants were more passive in their behavior and were observed higher in the water column as they backed downstream. Although no movement upstream or down was observed during this period, some emigrant kelts could have been missed as they passed downstream over the weir during the night of May 29. A total of 269 adult steelhead were passed upstream through the Sitkoh Creek weir from 1 May until 16 June. Of these, 75 untagged adult immigrants received a new PIT tag and an adipose fin clip. The remaining 194 steelhead adults were previously tagged. Downstream migrating kelts totaled 345, of which 97 were PIT-tagged fish that had not been passed upstream (i.e., they likely passed the weir site in April prior to installation), 26 were untagged, and 222 were fish that had been tagged going upstream and were subsequently counted back downstream. The modified Petersen estimate of steelhead abundance was 418 (Bayesian SE = 7.0, 95% credible interval of 404.2 to 431.8).

The first adult steelhead was captured in the upstream trap on 6 May, and the last on 16 June, however, immigrant adults were seen moving into the creek in April prior to the weir installation. The peak daily count (44) occurred on 16 May, and the midpoint of the run occurred on 18 May. Upstream migration seemed to follow periods of increased stream discharge, and presumed increased precipitation (Figures 2 and 3). Females made up the majority of the run at 66%, while males represented 34%. The spawning immigration was largely complete by 8 June. Water temperatures increased steadily from between 1 and 3^{o} C during 14 to 16 April to a high of 13^{o} C by 24 June (Figure 3).

As in previous years, the overall immigrant sex ratio was skewed towards females (66%) in 2007 with equal numbers of males and females arriving early and more females in total (Figure 4). Emigrant tagged adult steelhead that were passed downstream, but not as upstream immigrants, were not included in sex ratios as there were relatively few of them. Gender-specific freshwater mortality was not known, and the decision was made not to subject kelts to additional handling stress. It appears that females that had previously been tagged or recorded as immigrants in 2007 were more prevalent as emigrants (74%, Table 2).

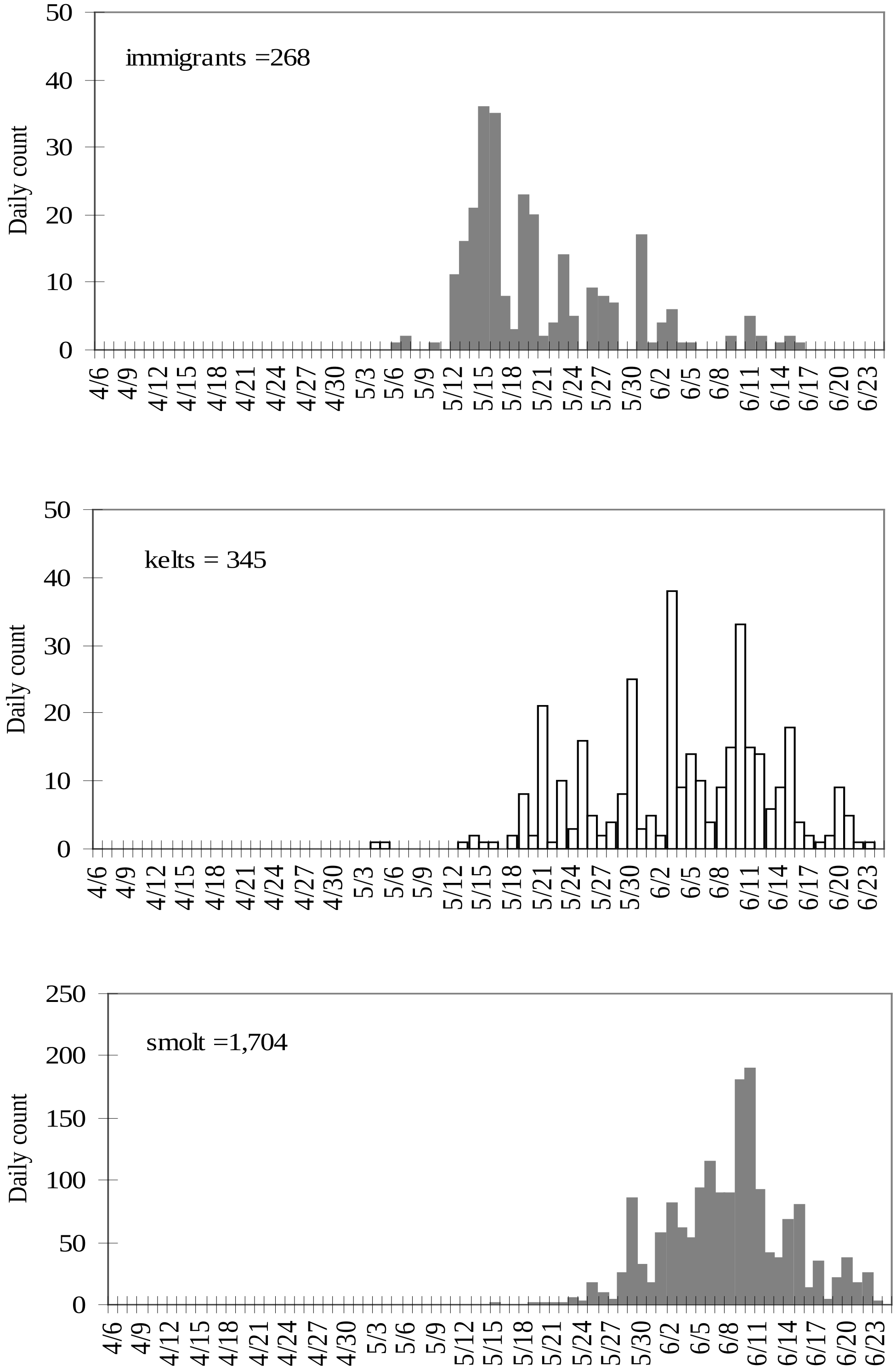


Figure 2.–Daily counts of immigrant steelhead (top panel) and emigrant kelts (center panel), emigrant steelhead smolt (bottom panel) at Sitkoh Creek, 2007.

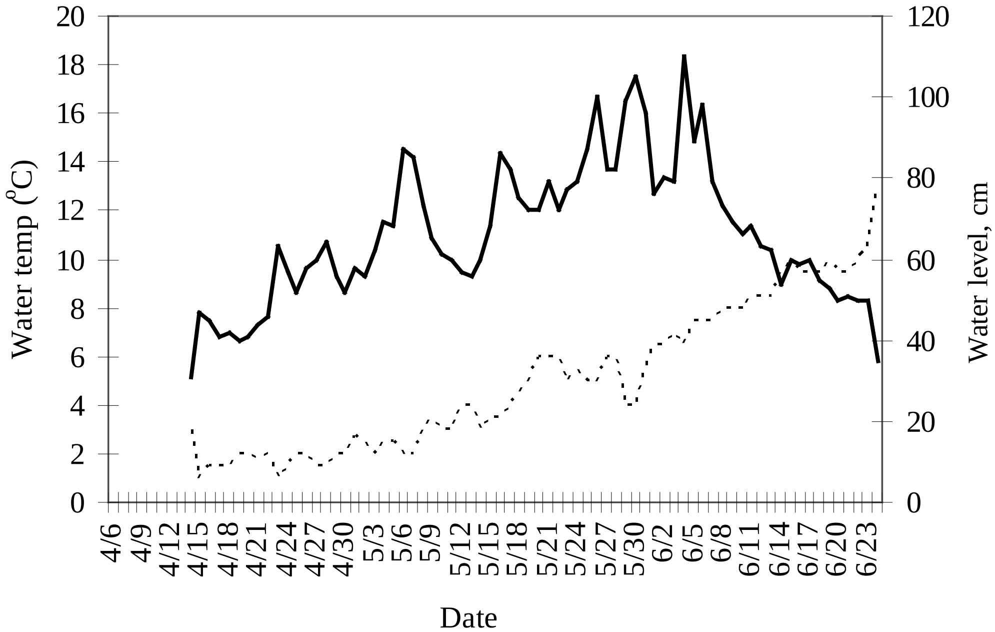


Figure 3.–Daily measurements of water level in cm (solid line), and water temperature in °C (stippled line) at Sitkoh Creek, 2007.

Table 2.–Escapements based on weir counts, Chapman modified Peterson estimates (in parentheses) and proportion female for immigrant and emigrant steelhead at Sitkoh Creek for 2003–2008.

Year	Escapement	Proportion immigrant female	Proportion emigrant female
2003[a]	679(682)	0.62	0.67
2004[a]	764(780)	0.60	0.68
2005[b]	543(574)	0.67	0.63
2006[b]	395(416)	0.65	0.69
2007	392(418)	0.66	0.74
2008	487(513)	0.68	0.73

[a] Love and Harding (2008).

[b] Love and Harding (2009).

The length measurements of all immigrant steelhead passed through the weir in 2007 averaged 742 mm FL and had a SD = 76.3 mm, and ranged from 465 to 915 mm (N= 268). Proportionately more fish >750 mm FL were females, and fish <750 mm were predominately males (Figure 5). The length for all males averaged 716 mm FL, and had SD = 94.7 mm (N = 85). Female lengths averaged 754 mm FL, and had SD = 63.0 mm (N = 184). In 2007, 5 fish (1.7 % of the total immigrant steelhead run) met the minimum length requirement of 36 inches (914 mm) for sport fish retention (Table 3).

Table 3.–Proportion of the total steelhead immigration >914 mm TL and proportion by sex for all fish >914 mm TL for all years during which a weir was operated.

Year	No. of fish ≥36 in TL[a]	Proportion of escapement ≥36 in TL[a]	Sex composition of steelhead ≥36 in TL	
			Proportion male (of fish ≥36 in)	Proportion female (of fish ≥36 in)
1982[b]	48	0.070 [c]	0.380	0.620
1990[d]	19	0.029 [c]	0.210	0.790
1993[e]	29	0.056 [f]	0.530	0.470
1996[g]	28	0.030 [c]	0.500	0.500
2003[h]	16	0.024 [c]	0.875	0.125
2004[h]	17	0.022 [c]	0.647	0.353
2005[i]	13	0.024 [c]	0.692	0.308
2006[i]	15	0.039 [c]	0.733	0.267
2007	5	0.013 [c]	0.664	0.336
2008	3	0.006 [c]	0.677	0.323

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

[b] Jones (1983).

[c] All fish examined.

[d] Jones et al. (1991).

[e] Harding and Jones (1994).

[f] Fish lengths sampled, SE = 0.00091, *N* = 303

[g] Yanusz (1997).

[h] Love and Harding (2008).

[i] Love and Harding (2009).

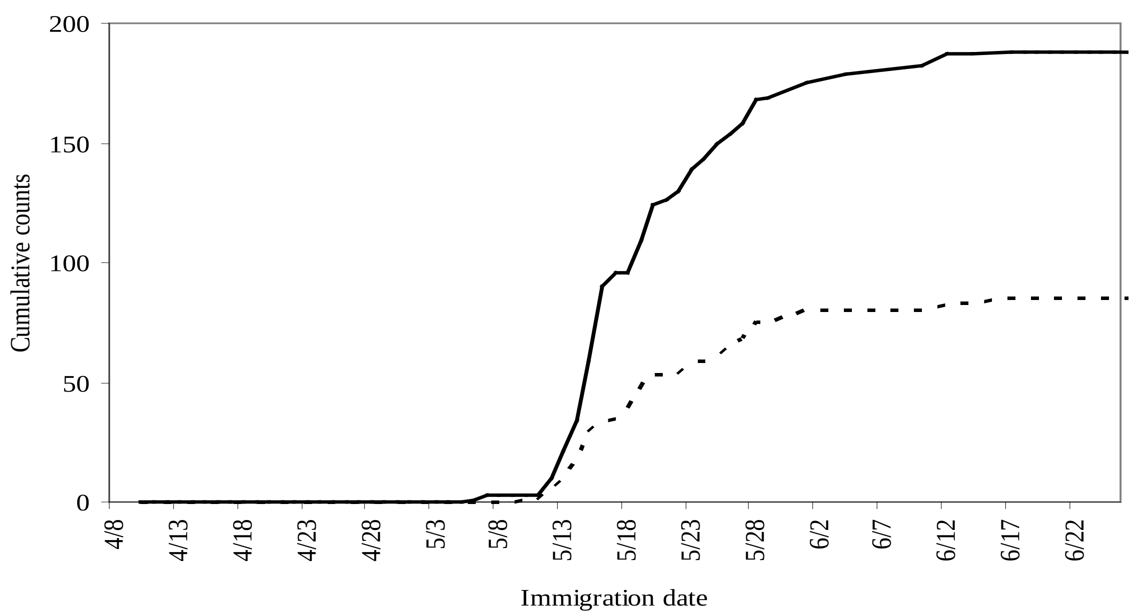


Figure 4.–Cumulative counts of adult male (stippled line) and female (solid line) steelhead immigrating through the Sitkoh Creek weir from May 1 to June 24, 2007. Note that because of record snowfall, heavy ice, and flooding during April, installation of the weir was delayed until 1 May.

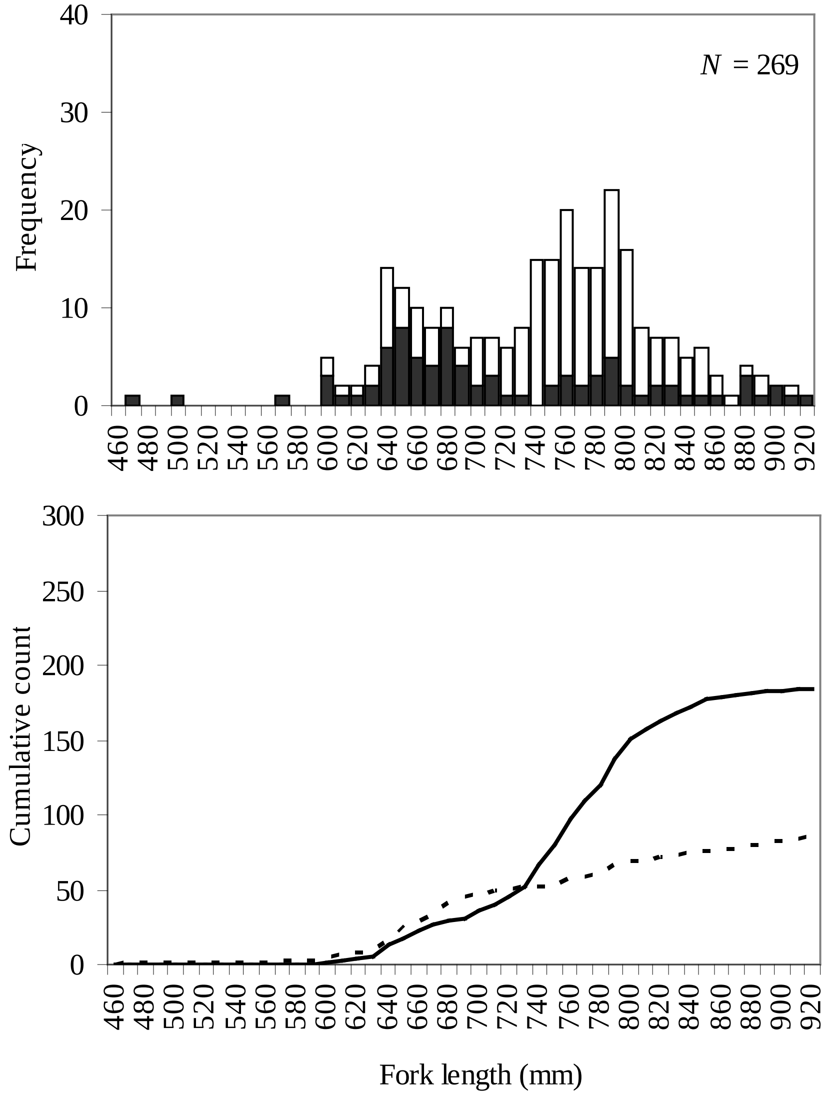


Figure 5.–Length-frequency distributions for male (filled bars) and female (clear bars) steelhead (top panel) and cumulative numbers by sex and length of adult male (stippled line) and female (solid line) steelhead immigrating into Sitkoh Creek during 2007 (bottom panel).

Of the 269 adult steelhead that were passed upstream, scale samples were taken from 189 previously PIT-tagged immigrant steelhead, representing 97% of the tagged upstream immigration of 194 fish. Untagged immigrants (75) were not sampled. Summary statistics reported here based on scale analyses (age and spawning history) are germane only to the previously-tagged component of the 2007 steelhead escapement. Data are not available to make similar inferences about the entire escapement. Predominant freshwater age estimates for the previously tagged component of the escapement (first-time and repeat spawning adults) during 2007 were 3- and 4-freshwater. Nine age classes were documented among first-time spawners: ages 3.3 (8.5%), 4.2 and 3.2 (both at 7.9%), and 4.3 (6.9%) were the dominant age classes.

Ocean-age-2 adults of all freshwater ages were about equally prevalent (21.6%), as ocean age 3 (20.2%). One fish returned as an adult the year after it was initially tagged as a smolt in 2006, the first "jack" steelhead to be captured at Sitkoh Creek (Table 4). Although not scale sampled in 2007, the untagged component of the immigration could have either been Sitkoh Creek fish that possibly outmigrated at times other than when the weir was in place, or they were strays. It seems unlikely that they were 5-year skip spawning adults or 5-year first-time spawners.

Table 4.–Age composition of Sitkoh Creek steelhead immigrant adults sampled in 2007 and 2008. Estimated ages based on 3 independent readings of each scale sample by the same scale aging technician.

	2007		2008	
Class	*n*	%	*n*	%
3.1	1	0.5	0	0.0
3.2	15	7.9	14	10.0
3.3	16	8.5	6	4.3
4.2	15	7.9	20	14.3
4.3	13	6.9	4	2.9
5.2	0	0.0	3	2.1
5.3	0	0.0	1	0.7
2.3s1	1	0.5	0	0.0
3.2s1	23	12.2	10	7.1
3.2s1s1	7	3.7	12	8.6
3.2s1s1s1	3	1.6	0	0.0
3.3s1	2	1.1	5	3.6
3.3s1s1	0	0.0	1	0.7
4.2s1	16	8.5	2	1.4
4.2s1s1	9	4.8	5	3.6
4.2s1s1s1	1	0.5	0	0.0
4.3s1	1	0.5	2	1.4
4.3s1s1	0	0.0	1	0.7
5.2s1	1	0.5	0	0.0
x.2	10	5.3	25	17.9
x.2s1	17	9.0	2	1.4
x.2s1s1	11	5.8	3	2.1
x.2s1s1s1	1	0.5	1	0.7
x.3	9	4.8	9	6.4
x.3s1	7	3.7	3	2.1
x.3s1s1	1	0.5	1	0.7
x.4	1	0.5	0	0.0
No match	6	3.2	7	5.0
Unreadable	2	1.1	3	2.1
Total	189		140	

Previously PIT-tagged steelhead (i.e., recaptured fish) that were captured at Sitkoh Creek weir were initially tagged either as emigrant smolts, or as immigrant or emigrant adults during previous years. Recaptured steelhead adults were either first-time (first recapture) or repeat spawners (multiple recaptures). First-time spawning, repeat spawning, and untagged adult steelhead of unknown origin were tallied from counts of adult steelhead upstream and downstream through the weir. The observed escapement count was the total of 269 fish (194 tagged and 75 untagged) that moved upstream from May to June, 97 tagged fish not seen upstream that were passed downstream, and 26 untagged fish that passed the weir before it was installed for a total of 392. Of this observed adult escapement, 290 (74%) were recaptured steelhead. The natal source stream and smolt emigrant year of the remaining 101 (26%) untagged adult fish seen in 2007 was not known. Recaptured adult steelhead identified as first-time spawners in 2007 were all initially tagged as smolts during 2003 to 2006. Ocean-age-1 (1 fish), ocean-age-2 (66 fish), ocean-age-3 (112 fish), and ocean-age-4 (3 fish), steelhead adults initially tagged as smolt were all recaptured for the first time in 2007 for a total of 182 (46%) of the total observed escapement that were first-time spawners (i.e., first-time recaptures). The three ocean-age-4 recaptured adults had no previous recapture history and were not scale sampled, so evidence of spawning could not be determined. However, they were likely repeat spawners that may have spawned elsewhere or entered Sitkoh Creek at a different time than when the weir was in place during 2004–2006.The remaining 109 (27%) recaptured steelhead were either repeat spawning adults tagged as smolt in 2003 and 2004 (42), repeat spawning adults tagged as adults (46), or had faulty tags (21) that could not be read (Table 5).

Adult Steelhead - Emigration

The first fish was captured leaving the system on 4 May, the last was captured on 23 June, and the midpoint of the emigration was on 4 June. The peak daily downstream count (38) occurred on 3 June (Figure 2). The lengths of all measured emigrant steelhead (n = 219) averaged 739 mm FL, had a SD of 71.6 mm and ranged from 499 to 900 mm. Emigrant females varied less in length, and were generally slightly larger than males. The length of females averaged 754 mm FL and had a SD of 62.2 mm, whereas the length of males averaged 696 mm FL and had a SD of 79.4 mm. More females (74.4%) emigrated than did males (25.6%). One moribund adipose-clipped fish captured in the downstream trap did not survive because of otter bites in the head. All untagged emigrant fish were PIT tagged and released.

Steelhead Smolt

A total of 1,704 steelhead smolt and 6 juvenile (parr) steelhead were captured emigrating through the weir during 2007. All 6 parr were too small to tag and were released downstream. Of the total of 1,704 steelhead smolt, 1,697 were measured for lengths (lengths were not taken on 7 fish that were tagged). Of the 1,704, 1,647 were released alive and received a PIT tag, and 57 were sacrificed for paired scale and otolith samples in order to verify scale aging methods. There were no other known smolt steelhead mortalities in 2007. One smolt was identified as a re-emigrant smolt that had been tagged in 2006 and then recaptured passing downstream through the weir in 2007. When first examined in 2006, it had physical characteristics similar to other emigrating smolt, having faint parr marks and a silvery coloration. When recaptured in 2007, it still looked like a smolt. This smolt must have moved upstream sometime after the weir was removed in 2006, possibly to overwinter somewhere in the Sitkoh Creek system.

Table 5.–Initial PIT tagging year, total number, and percentage of total escapement of adults recaptured during 2007 and 2008 in Sitkoh Creek. Numbers in parentheses are number of repeat spawners for recaptured steelhead that were initially tagged as smolt.

	Recaptured adult year			
	2007		2008	
Tag year and type	*n*	%	*n*	%
2003 smolts	32(29)[a]	8.2	13(11)[b]	2.7
2004 smolts	125(13)	32.0	40(40)[c]	8.2
2005 smolts	66	17.1	78(19)	16.0
2006 smolts	1	0.3	166	34.1
2003 adults	0	0.0	0	0.0
2004 adults	9	2.3	0	0.0
2005 adults	22	5.6	1	0.2
2006 adults	15	4.1	3	0.6
2007 adults	ND	ND	13	2.7
Faulty tags	21	4.6	15	3.1

[a] Nine smolt tagged in 2003 were recaptured for the first time as adults in 2007, 6 of which were determined to be repeat spawners based on scale sampling and 3 had no previous recapture history

[b] Three smolt tagged in 2003 were recaptured for the first time as adults in 2008, 1 of which was determined to be a repeat spawning adult.

[c] All 40 smolt tagged in 2004 that were recaptured for the first time as adults in 2008 were determined to be repeat spawning adults

The first smolt was captured at the weir on 15 May, the last on 23 June, and the midpoint of the run was 8 June. The peak daily count (269) occurred on 10 June (Figure 2). Of the downstream migrant smolt, all but 7 were sampled for length frequency, which equaled 99.6% of all steelhead smolt captured (*N* = 1,697). Mean fork length was 205 mm and SD = 40.4 mm (range = 121 mm to 448 mm FL); the mode of the length frequency distribution was centered at 200 mm. One in every 30 fish was sacrificed for paired scale and otolith samples for a total of 57 samples. More of the emigrant smolt that left Sitkoh Creek later in the season were smaller, but the range of sizes was similar throughout the smolt emigration (Figure 6). During the flood of 30 and 31 May, increasing numbers of steelhead smolt continued to be caught in the downstream trap. The range of sizes of smolt captured during the flood was similar to the range captured prior. Smolt were also observed to move downstream along the bottom of the streambed during high flows and were removed hourly to minimize stress. None were observed passing over top of the weir during the 4-hour period that the weir was breached, but this may have occurred. There was no reason to assume large numbers of smolt had passed unaccounted during the flood.

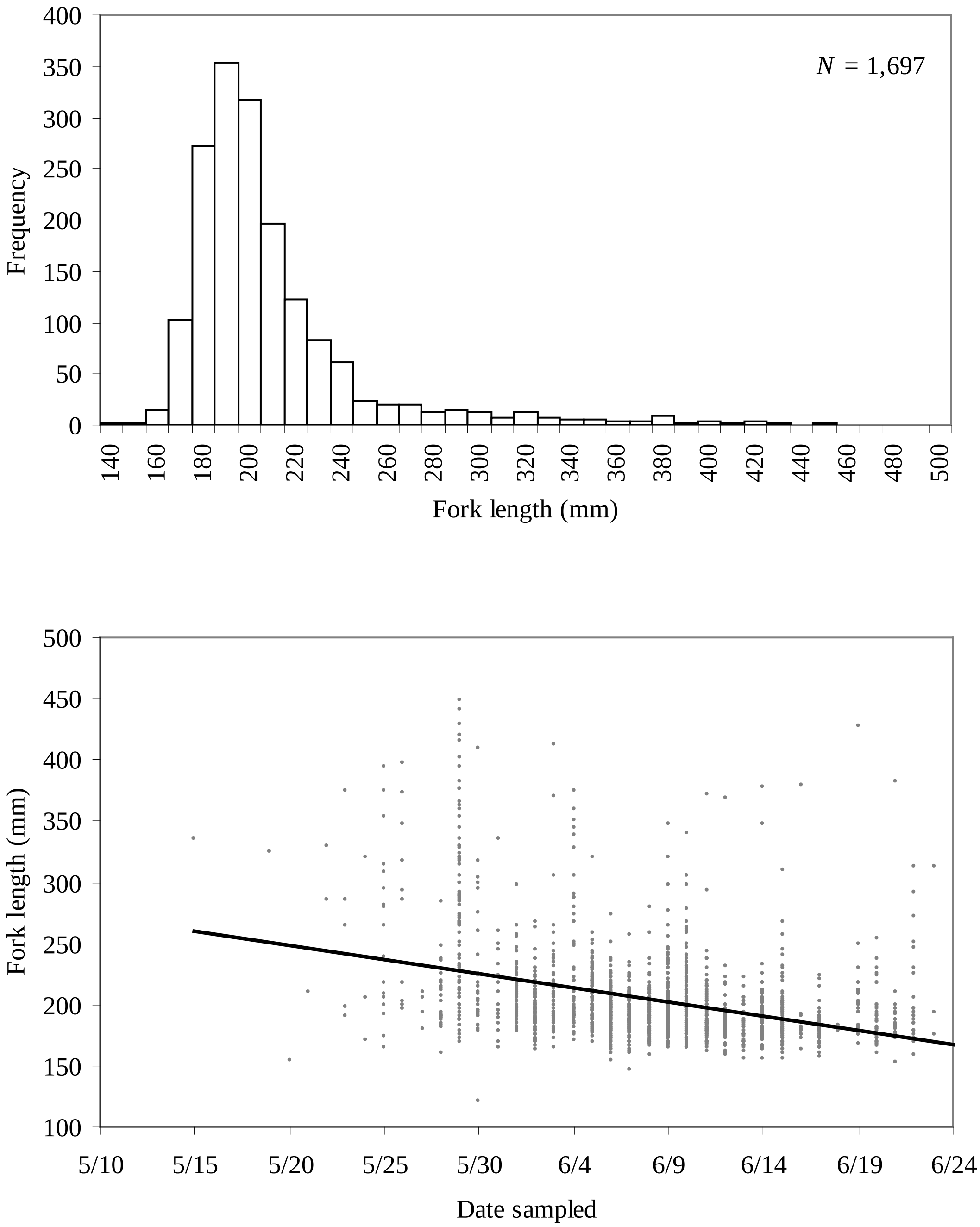


Figure 6.–Length-frequency distribution of steelhead smolt sampled emigrating out of Sitkoh Creek (top panel) and size (mm FL) of steelhead smolt by date captured at the weir during 2007 (bottom panel). Depicted trend line is best fit linear trend line (y = mx + b) of smolt size by sample date (bottom panel).

Table 6.–Freshwater ages for Sitkoh Creek steelhead smolt, 2007 and 2008 determined by scale analysis. Estimated ages were based on 3 independent readings of each scale sample by the same scale aging technician.

	2007		2008			
	Number	% Sampled	Number	% Sampled	Total number	Average % sampled
Sample (total emigration)	172 (1,704)	10.2	198 (1,751)	11.3	371 (3,455)	10.8
Age 2	0	0	0	0	0	0
Age 3	32	18.6	53	26.8	85	23.0
Age 4	93	54.1	102	51.5	195	52.7
Age 5	24	14.0	26	13.1	50	13.5
Age 6	7	4.1	3	1.5	10	2.7
ngs[a]	15	8.7	14	7.1	29	7.8
No match	0	0	0	0	0	0
Recaptured smolt	1	0.6	0	0	1	0.3

[a] ngs = no good scales, unusable for aging.

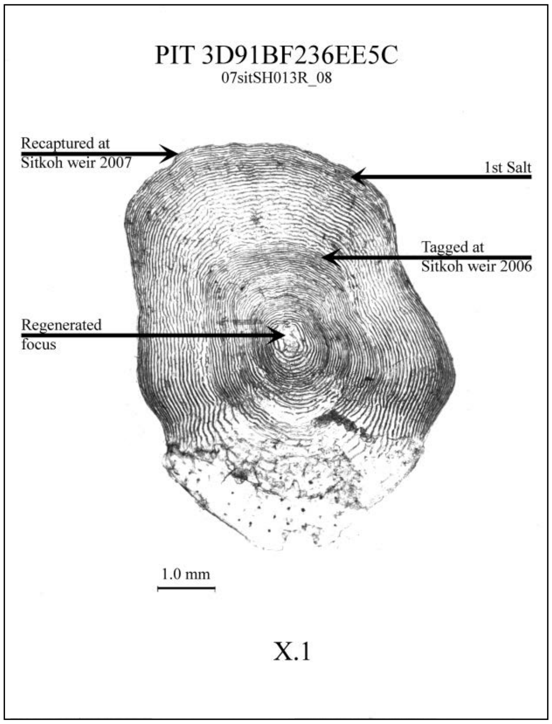
Scale samples were collected from 172 steelhead smolt (10.2%), and estimated freshwater ages ranged from age 3 to 6 years. Following aging protocol described earlier, most smolt (72%) were estimated to be 3 and 4 years old, and most (54%) were 4 years old. Approximately 14% were age 5, and 4% (7 fish) were age 6. Approximately 9% of the scale samples collected could not be read because of large, regenerated foci, damaged or dirty scales (Table 6). One smolt was recaptured in 2007 that had been tagged previously in 2006 (Figure 7). It was tagged as an emigrant smolt on 3 June, 2006 at 167 mm FL, then recaptured emigrating through the weir on 10 June, 2007 at 235 mm FL. It was aged at 3 freshwater years in 2006, and 4 freshwater years in 2007 with apparent good growth between the 3rd and 4th annuli in 2007.

Dolly Varden Char

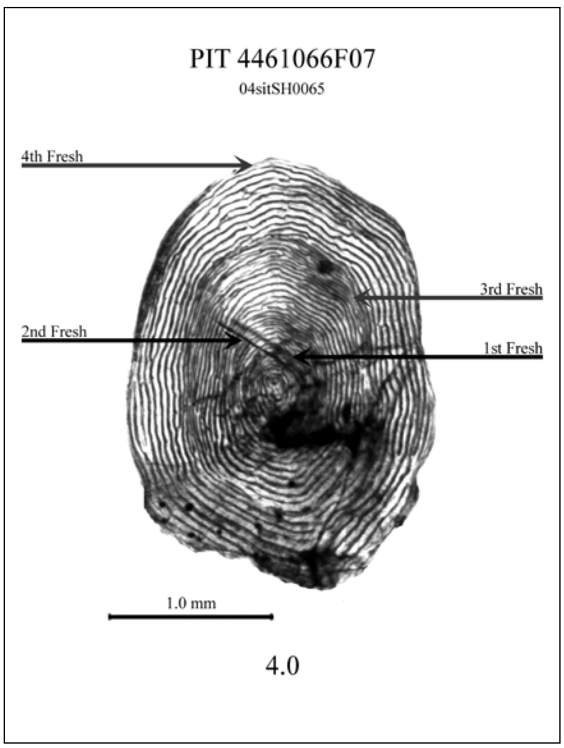
There were 27,534 Dolly Varden passed downstream through the weir in 2007. The first fish was counted on 18 April, and the peak daily count (4,455) occurred on 17 May (Figure 8), one day following the midpoint of the run. Because the weir was installed a month late, it is likely that some Dolly Varden passed downstream before installation. Dolly Varden were counted, but not measured, in 2007.

Cutthroat Trout

A total of 2,011 emigrant cutthroat trout were counted through the weir during the period that it was fished in 2007. The first trout was captured on 18 April, and the midpoint occurred 25 May. Cutthroat trout were still being caught in the downstream weir until the morning the weir was pulled. The peak count (250) was made on 3 May (Figure 8). Cutthroat trout were counted, but not measured, in 2007. As in previous years, many of the larger fish were observed to be in spawning condition, and left the Sitkoh system early in the outmigration. Overall size varied throughout the run, but more of the smaller fish were seen in 2007 than in previous years, possibly due to the later weir installation.



a)



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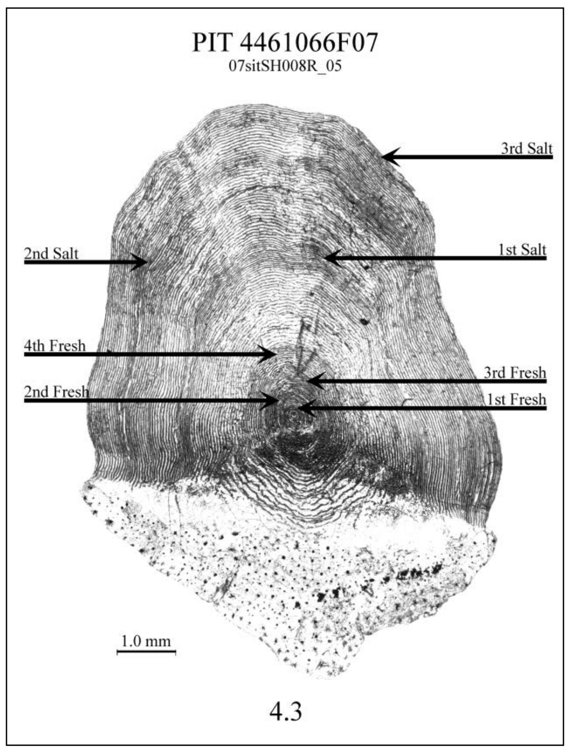

c)

Figure 7.–Steelhead recaptured adults: (a) 1-ocean adult tagged initially in 2006 then recaptured in 2007 moving upstream through the weir, (b) 3-ocean adult, tagged initially as a 4-freshwater smolt in 2004, and (c) recaptured in 2007 as a 3-ocean first-time spawning adult.

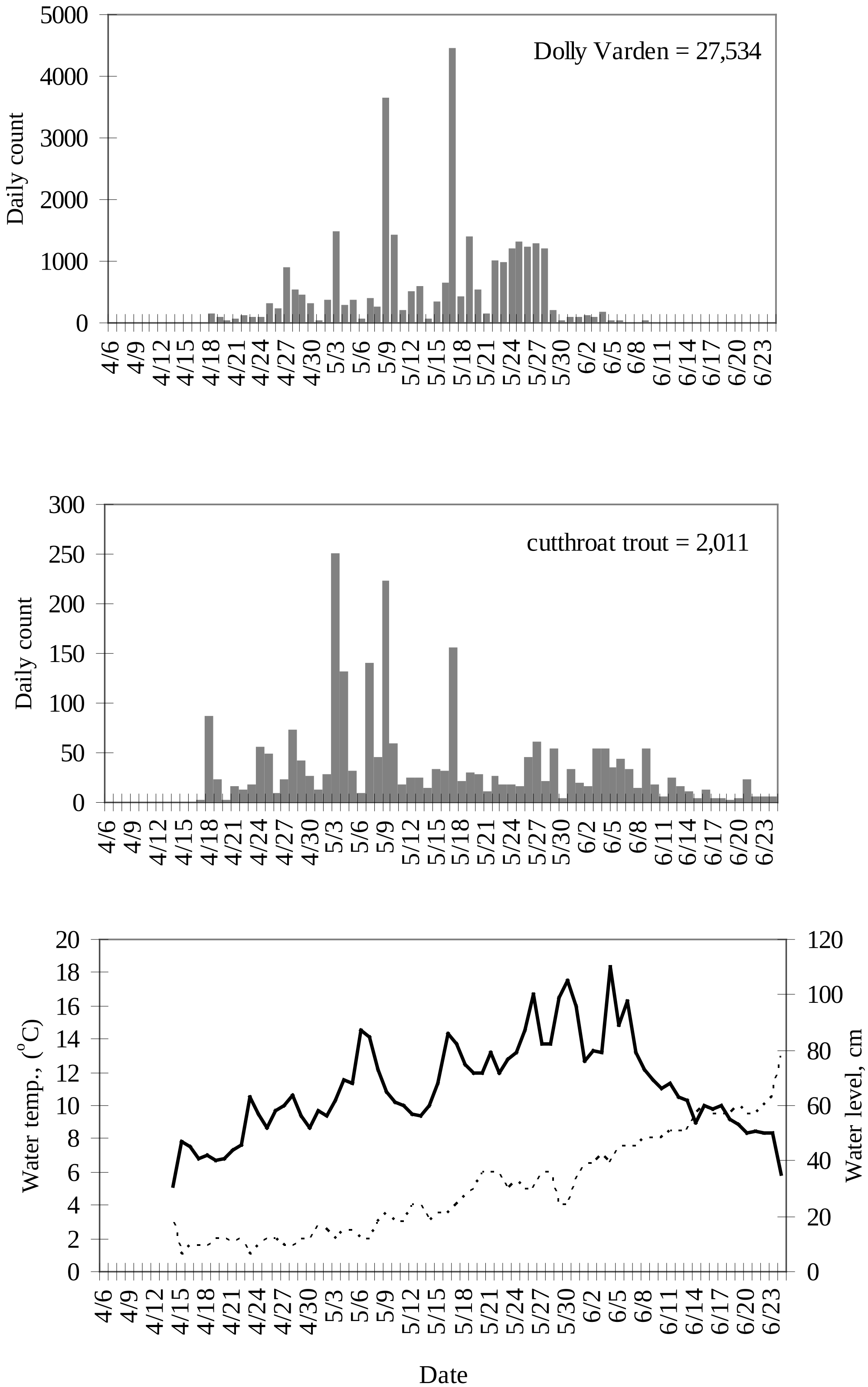

Figure 8.–Daily counts of emigrant Dolly Varden char (top panel) and emigrant cutthroat trout (center panel), and daily measurements of water level in cm (solid line) and water temperature in °C (stippled line) at Sitkoh Creek, 2007 (bottom panel).

Other Migrants

Emigrant rainbow trout and returning sockeye salmon were also passed through the Sitkoh Creek weir in 2007. There were 40 rainbow trout passed downstream between 14 May and 23 June. Of these, 4 were identified as emigrant rainbow trout from a group of 41 trout that were PIT tagged in 2006. Some of these recaptures had the physical characteristics of steelhead smolt when they were initially tagged, and some were initially identified as rainbow trout. One rainbow trout tagged in May 2006 measured 150 mm FL, and when it was recaptured in June of 2007 it measured 225 mm FL. Scale samples were not taken from this fish. There were also 38 returning sockeye salmon that passed through the weir between 27 May and 24 June. No pink salmon were observed in 2007.

2008

Adult Steelhead – Immigration

The weir was operated from 10 April to 23 June 2008. The first adult steelhead was caught on 14 April, 4 days after the weir was fish tight. The last fish was captured on 19 June, the high count (31 fish) occurred on 1 May, and the midpoint of the run was on 18 May (Figure 9). Although the weir was installed earlier in 2008, warm spring rainfall and meltwater from a heavy snowpack accumulated during the winter of 2007/2008 caused flooding conditions from April to mid-May. The weir was breached during one flood event from 12 May at 17:00 until 13 May at 12:00. During this event the upstream trap was closed to prevent mortalities of adults moving into the trap during high flows. The upstream trap was again closed on 14 May for 18 hours because of high flows, but the weir was not breached again. An unknown number of adult fish (one was observed) moved upstream past the weir during the flood on 12 to 13 May. Because an unknown number of adults passed upstream during this flood, total abundance of immigrant adult steelhead was estimated. To allow the weir to pass more water, the smolt mesh panels were removed during the 12 May flood. They were replaced 13 May by 19:00. Water temperatures increased steadily from 3°C on 12 April to 9°C by 22 June, and did not rise above 5°C until 18 May, later and cooler than in previous years (Figure 10).

A total of 404 adult steelhead were passed through the weir. Of this total, 134 untagged fish and 270 previously-tagged fish were passed upstream through the weir. Of the 390 emigrants examined for marks, 22 were untagged kelts, 61 emigrants that were not seen as immigrants were passed downstream, and 307 of those observed upstream were passed back down for a kelt survival rate of 76%. The modified Petersen estimate of adult steelhead abundance was 513 (Bayesian SE = 6.6, 95% credible interval = 500.0 to 526.0). All untagged fish were measured, sexed, PIT tagged, and marked with an adipose fin clip. All of the recaptured fish were measured and sexed, and the PIT tag number was recorded. Females comprised the majority of the total immigrant run at 68% (273 fish), while males comprised 32% (130 fish) (Table 1). No information was collected from 1 fish released upstream.

The length of immigrating steelhead averaged 731 mm FL and had SD = 66.4 mm (range = 590 to 940 mm). Proportionately fewer females than males immigrated into Sitkoh Creek prior to 10 May (Figure 11). Proportionately more fish >740 mm FL were females (Figure 12). The length of males averaged 751 mm FL and had SD = 70.6 mm (n = 130). The length of females averaged 757 mm FL, and had SD = 68.2 mm (n = 273). One fish was mistakenly not measured or sexed.

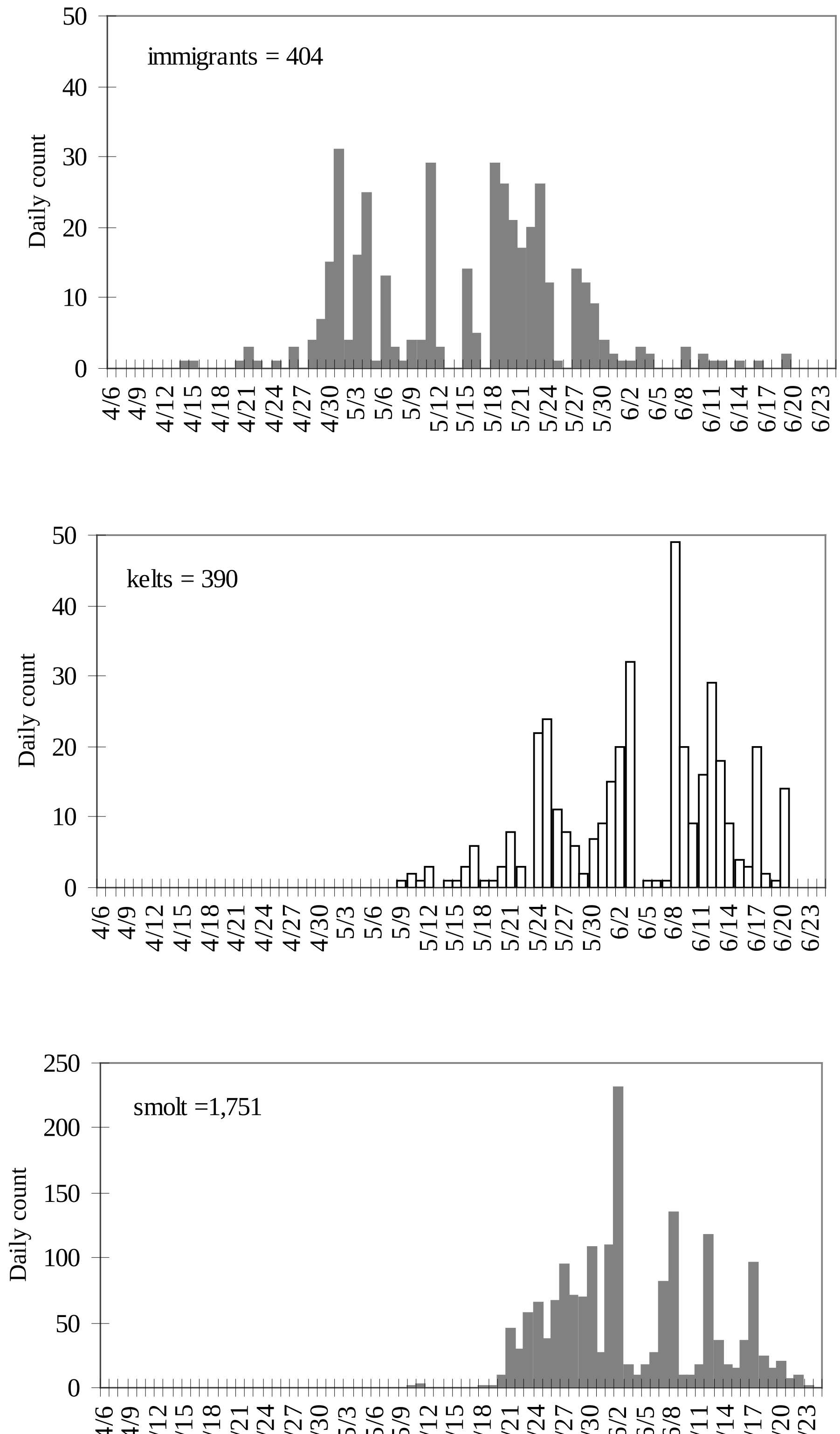

Figure 9.–Daily counts of adult upstream immigrant steelhead (top panel), downstream kelts (center panel), and emigrant steelhead smolt (bottom panel) at Sitkoh Creek weir, 2008

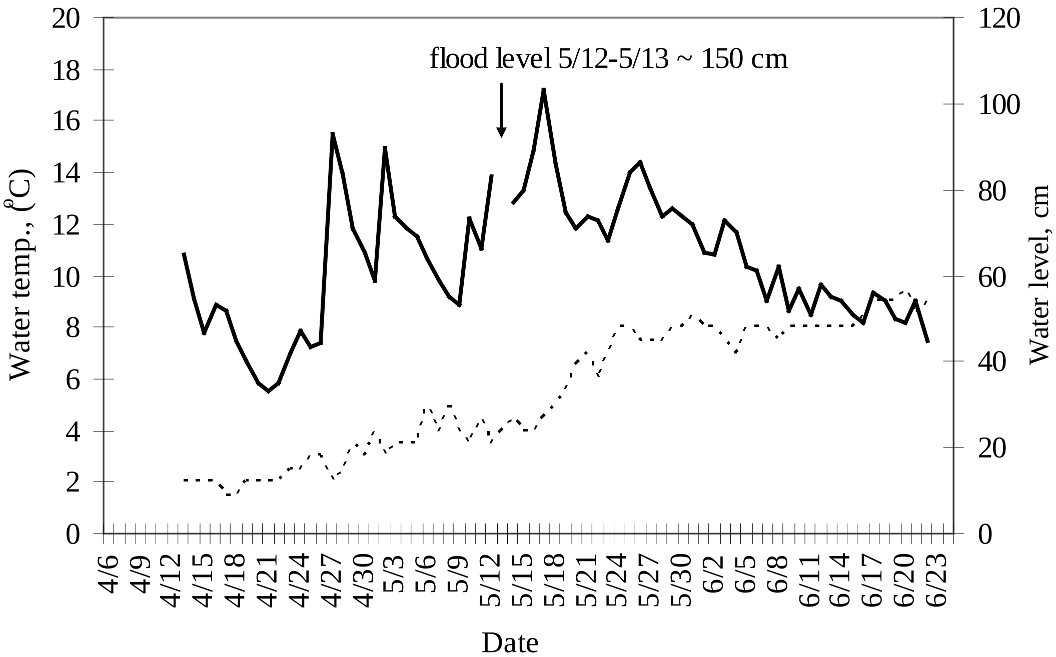

Figure 10.–Daily measurements of water level in cm (solid line), and water temperature in °C (stippled line) at Sitkoh Creek, 2008.

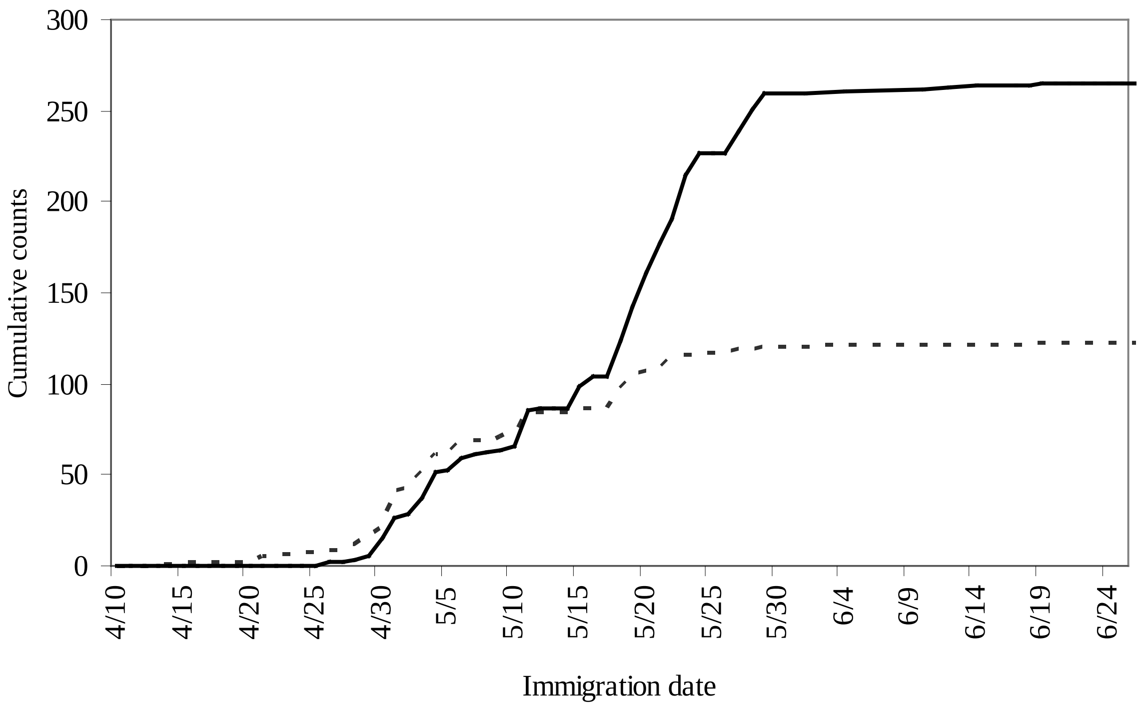

Figure 11.–Cumulative counts of adult male (stippled line) and female (solid line) steelhead immigrating through the Sitkoh Creek weir from April 10 to June 24, 2008

In 2008, 3 fish (0.7 % of the total immigrant steelhead run) met the minimum length requirement for sport fish retention (36 inches or 914 mm) (Table 3). In addition to length frequency measurements, spawning condition of 379 adult steelhead was recorded and categorized as bright (54%), or blush fish (46%). Seventy-two percent of all adult steelhead examined were green (not ripe or had immature gonads), and most of these were males. Thirty-six percent (145 fish) of the total adult steelhead passing upstream (404) had scars, of which approximately 33% were scratch or claw marks, whereas 2% had well delineated net marks. The remainder of the scarring was difficult to categorize as net or hook-and-line marking as some fish became scratched as they passed through the weir. Fishing lures were removed from a few fish.

Scale samples were taken from 140 steelhead adults, or approximately 35% of the immigrant population. Because sample rates of the two systematically sampled strata were the same, age frequency analysis should be representative of the entire immigrant population and should not be biased. Eight age classes were documented among first-time spawners, with ages x.2 (x indicating unknown age), 4.2, and 3.2 being the most common (Table 4). Ocean-age-2 first time spawners (62 fish, with all freshwater ages combined), were aged at x-, 3-, 4-, and 5-freshwater and represented about 44% of scale sampled adults. Ocean-age-3 first-time spawners (20 fish) were less prevalent and represented 14% of the all scale sampled adult steelhead (Table 4). Adult spawners lived variable years in saltwater (1 to 3 years) and in freshwater (2 to 5 years) before their first spawning event. Adult repeat spawners were estimated to have spawned 2–4 times, if their recapture during the spring 2008 spawning migration is included. Maximum age based on estimated scale aging was 9 years for 1 fish that was aged at 4.3s1s1.

Previously PIT-tagged steelhead that were recaptured at Sitkoh Creek weir were initially tagged either as emigrant smolts, or as immigrant or emigrant adults during previous years and were either first-time or repeat spawners. The adult escapement in 2008 was the combination of 404 total immigrants upstream, 22 untagged emigrants, and 61 tagged fish not seen as immigrants, for a total of 487. Of this 487, 68% (329) were recaptured fish that were initially PIT tagged as either emigrant smolts or as adults, and were either first-time or repeat spawners (Table 5). All of the ocean-age-2 adults recaptured were first-time spawners (166, or 34%). Fifty-nine of the 78 ocean age-3 fish were first time spawners and 19 were repeat spawners (total of 16%). All of the 40 ocean-age-4 recaptures (8%) were considered to be repeat spawners. However, 10 of these had not been recaptured previously, but scale samples indicating evidence of repeat spawning. All of the ocean-age-5 adults were assumed to be repeats (3%), but 2 had not been recaptured previously and were not scale sampled prior to 2008 and 1 was determined to be a repeat spawning adult. It may be that these fish strayed. It seems unlikely that they were ocean-age-5 first-time spawners. All adult steelhead returning to Sitkoh Creek that were known to be first-time spawners (55%) were initially tagged as smolts during 2006 (166 ocean-age 2), or tagged in 2005 (59 ocean-age 3). Repeat spawning adult steelhead tagged initially as adults were still numerous at 15% of the total adult escapement. Recaptured steelhead that had unreadable PIT tags, or tags that did not match archived PIT tag numbers, equaled 3% of escapement (Table 5). These fish were retagged with new tags.

Extrapolating PIT tag recaptures to the estimated total escapement of 513 for 2008, 68% (348 steelhead) of the total escapement were recaptured fish, of which 46% (235 steelhead) were first-time spawners, and 22% (113 steelhead) were repeat spawners. An estimated 164 steelhead (32%) of the total estimated escapement were untagged immigrants.

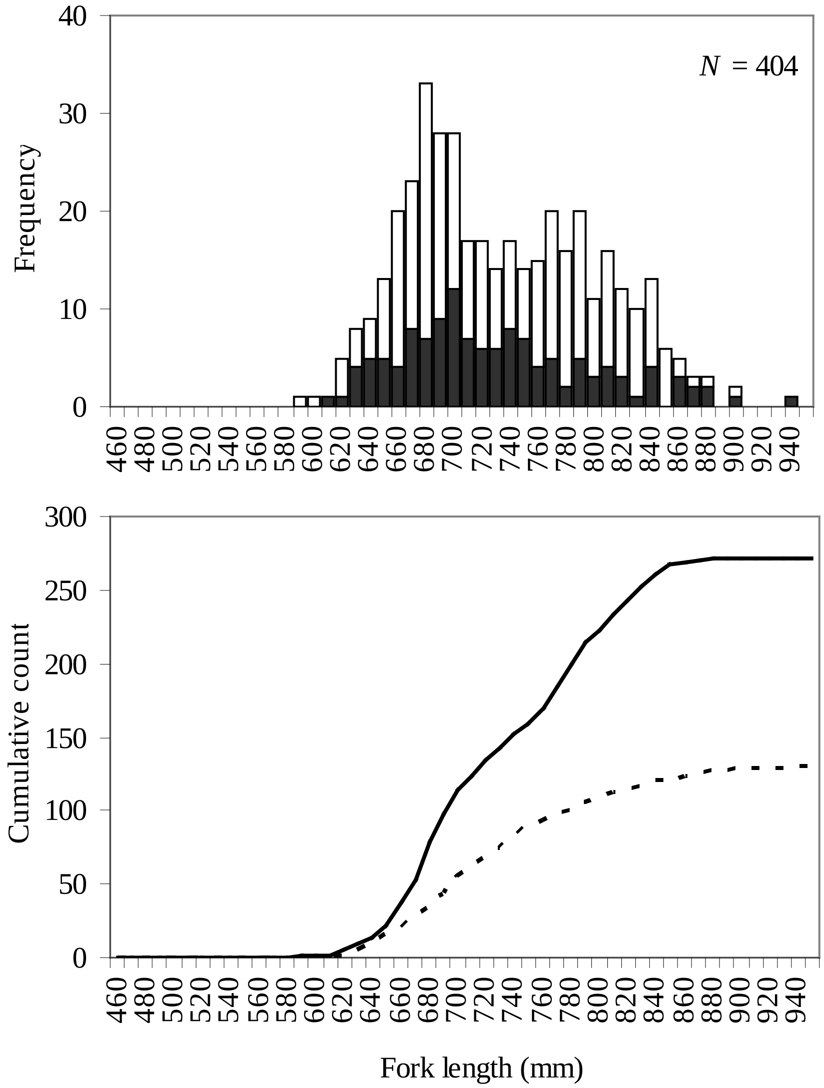

Figure 12.–Length-frequency distributions for male (filled bars) and female (clear bars) steelhead (top panel) and cumulative proportion by sex and length of adult male (stippled line) and female (solid line) steelhead immigrating into Sitkoh Creek during 2008 (bottom panel).

Adult Steelhead - Emigration

The first kelt was captured on 9 May, the last kelt was captured on 22 June, and the midpoint of the run was 8 June. The peak daily downstream count (49) also occurred on 8 June (Figure 9). The length of all measured emigrant steelhead averaged 734 mm FL and had a SD of 66.2 mm. The range was 615 to 940 mm (n = 283). Females varied slightly less in size, and were generally slightly larger than males, but this difference was not great. The length of females averaged 736 mm FL and had a SD of 65.8 mm. The length of males averaged 727 mm FL and had a SD of 67.7 mm. Proportionately more females (73%) emigrated from the system following spawning than did males.

Downstream migrating kelts totaled 390, of which 308 were previously tagged as immigrants, 58 were previously tagged but not seen as immigrants, and 24 were untagged. All untagged fish were PIT tagged and adipose finclipped before they were released downstream. Post-spawning survival was approximately 76.0% (307 tagged emigrants/404 immigrants).

Steelhead Smolt

A total of 1,751 steelhead smolt ≥150 mm FL emigrated through the weir, all of which survived to be released. No steelhead smolts were PIT tagged in 2008. A subsample of 198, or 11.3% of the emigrant population were measured, scale sampled and released downstream. Eighteen steelhead parr (<150 mm FL) were noted moving downstream through the weir trap. The first steelhead smolt was captured passing through the weir on 10 May 2008, and the last on 22 June 2008, 2 days before the weir was removed for the season. To allow the weir to pass more water, the smolt mesh panels were removed during the 12 May flood. They were replaced 13 May by 19:00 PM. Although 5 steelhead smolt had been counted through the downstream trap on 10 and 11 May, no smolts were captured from 13 May until 18 May. Although a few smolt could have been missed, the smolt outmigration had not likely begun because of colder water temperatures, therefore the emigrant smolt count was considered to be a census. The midpoint of the emigration occurred approximately 1 June to 2 June, and peak daily count (231 smolt) occurred on 2 June 2008 (Figure 9). This migration timing appeared to be very similar to previous years.

The length of steelhead smolt ≥150 mm averaged 196 mm FL and had a SD = 34.2 mm (140–459 mm FL) The length frequency distribution unimodal about the mode of 190 (Figure 13). Scale samples were collected from 198 smolt (11.3% of the fish encountered). Preliminary scale analysis indicated that most smolt (78.3%) were estimated to be age 3 and 4, and ages ranged from age 3 to 6 (Table 6). Approximately 7% (14 samples) of the scale samples collected could not be read because of large, regenerated foci, dirty scales, or an insufficient number of scales in the sample. No recaptured smolts (emigrant smolts PIT tagged in previous years) were caught in 2008.

Dolly Varden Char

There were 18,790 Dolly Varden passed downstream through the weir in 2008. The first fish was counted on 14 April. The peak daily count (3,315) occurred on 10 May (Figure 14) which was the same day of the midpoint of the run. Dolly Varden were counted, but not measured in 2008. As in previous years, fewer large fish were caught in the downstream trap later in the season.

Cutthroat Trout

A total of 2,323 emigrant anadromous cutthroat trout were counted through the weir in 2008. The first trout was captured on 14 April, and the midpoint of the weir count occurred on 25 May. The highest daily count (272) occurred on 10 May (Figure 14). Cutthroat trout were counted, but not measured in 2008. As in previous years, many of the larger fish were observed to be in spawning condition, and left the Sitkoh Creek system earlier in the outmigration than the smaller cutthroat. Although length measurements were not taken, size generally appeared to decrease with time. Cutthroat trout were caught in the downstream weir until the morning before the weir was pulled (23 June 2008).

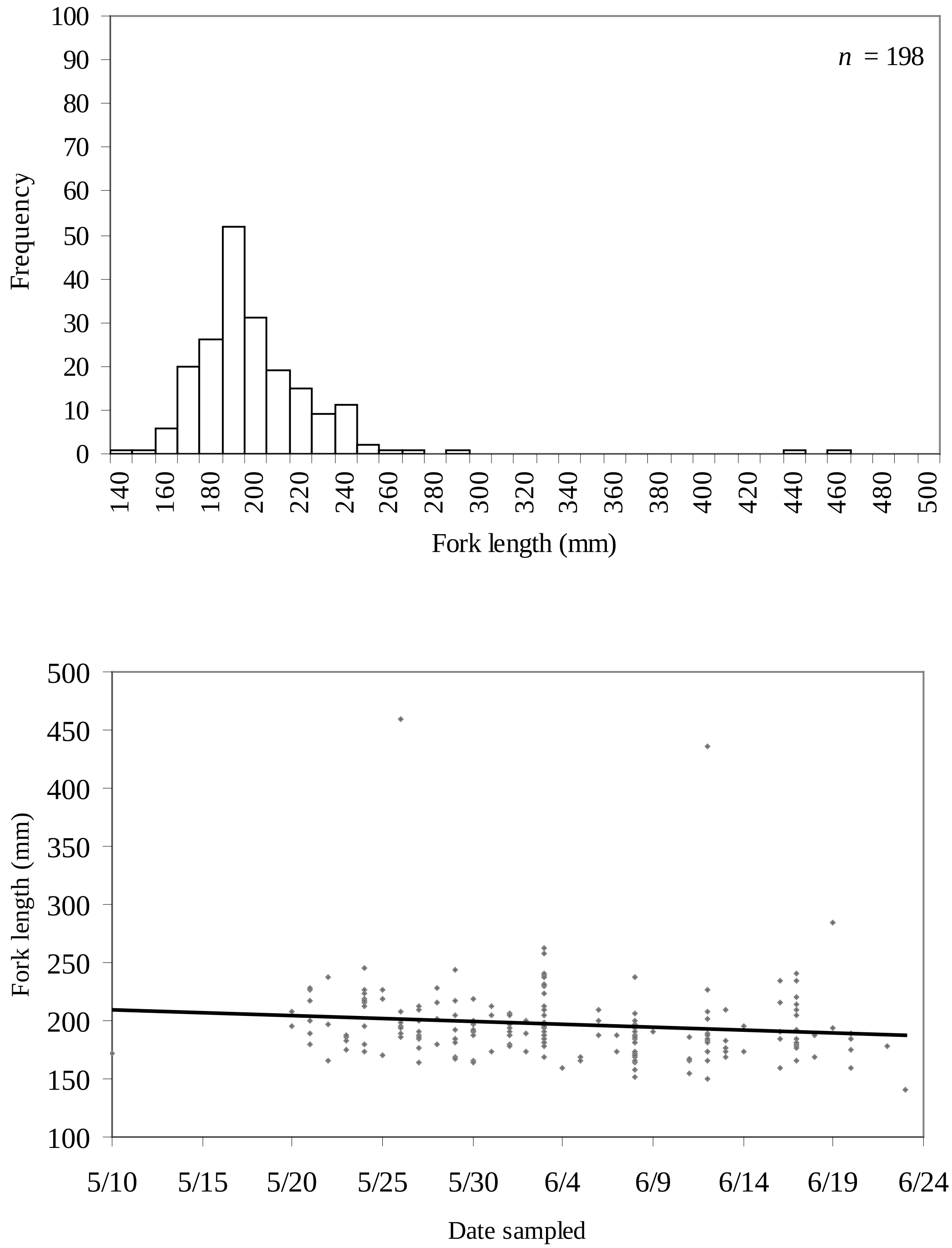

Figure 13.–Length-frequency distribution of steelhead smolts captured emigrating out of Sitkoh Creek (top panel) and the size (mm FL) of these smolts by date captured at the weir during 2008. Linear trend line (y = mx + b) of smolt size by sample date depicted (bottom panel).

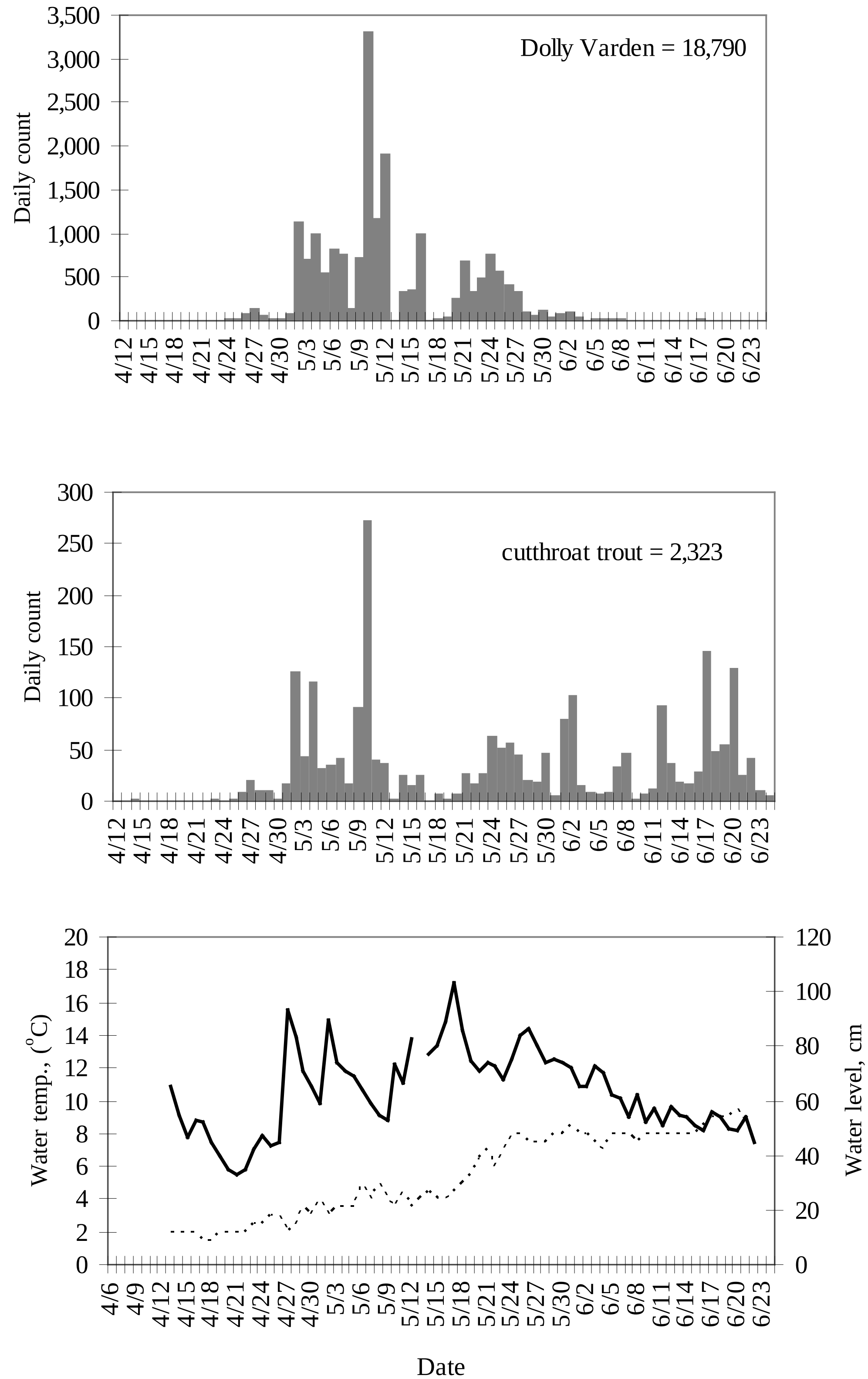

Figure 14.–Daily counts of emigrant Dolly Varden char (top panel) and emigrant cutthroat trout (center panel), and daily measurements of water level in cm (solid line), and water temperature in °C (stippled line) at Sitkoh Creek, 2008 (bottom panel).

Other Migrants

Emigrant rainbow trout and returning sockeye salmon were also passed through the Sitkoh Creek weir during 2008. There were 53 rainbow trout passed downstream between 6 May and 22 June. Of these, 2 trout were identified as emigrant rainbows from a group of 41 trout that were PIT tagged in 2006. Both of these fish were identified as rainbow trout in 2006 as they migrated past the weir in May of that year. There were also 5 returning sockeye salmon that passed through the weir between 18 June and 20 June. No pink salmon were passed in 2008 before the weir was removed for the season.

DISCUSSION

As originally conceived, this project had goals of obtaining a census each year over a 10-year period (from 2003–2012) of adult and smolt steelhead production, description of freshwater age structure of emigrant smolts, and preliminary estimates of production of smolts-per-spawner. Although too limited temporally to allow for the typical rigorous spawner-recruit analysis, the hope was that a census of steelhead through a weir, combined with PIT-tagging of individual fish, would provide fewer, but precise and accurate estimates of population parameters that could be used to estimate preliminary, but believable, production estimators. In addition to adult and smolt production, age information and smolt-per-spawner estimates, additional parameters such as freshwater and marine survivals, freshwater and marine growth, verification of marine age estimates and first-time and repeat spawning rates have also been collected from recapture of tagged individuals. Census of steelhead adults through the weir has allowed estimates of escapements based on expansion of snorkel surveys to known instream abundance above the weir (Love and Harding 2008, 2009). Enumeration of outmigrating smolts has 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). Although funding for research on Sitkoh Creek was cut prematurely in 2009, research results have made this project an unqualified success.

This study provides a short time series of adult escapement, smolt outmigration abundance, repeat spawning and tag recapture results for a steelhead system in northern Southeast Alaska that supports moderate sport fishing pressure and relatively little subsistence use. This project is unique, as no other multi-year PIT-tagging studies of a wild steelhead population in Southeast Alaska have been conducted. The baseline information collected may be useful for management action following future changes to regulations, use, or harvest.

The objectives of this project were to obtain counts and length frequency estimates of untagged immigrant and emigrant adult steelhead; counts, length frequencies and estimated ages of previously tagged adult immigrant and emigrant steelhead; counts and estimated ages of outmigrating steelhead smolt. The purposes behind these objectives were to estimate smolt and adult production for the steelhead habitat capability study (Crupi and Nichols 2012), and through scale aging and PIT tag recoveries, estimate freshwater age structure, marine survival of previously tagged smolts, and preliminary smolt-per-spawner estimates from these stock-recruit relationships. This research has also quantified repeat spawning rates, described possible steelhead/rainbow trout life history polymorphism in Sitkoh Creek, described straying outside of the study area (discussed below), and corroborated results reported in the literature for steelhead in Alaska, as well as elsewhere in their distributional range. Counts of Dolly Varden char, cutthroat trout, and sockeye salmon passed through the weir at Sitkoh Creek are also presented.

STEELHEAD SMOLT PRODUCTION AND LENGTH FREQUENCIES

The 2007 (*N* = 1,704) and 2008 (*N* = 1,751) steelhead smolt emigration counts were the lowest counts of the previous 6 years that Sitkoh Creek smolt have been counted (Yanusz 1997; Love and Harding 2008, 2009). Smolt abundance has varied from a high of 3,742 in 2004 to a low of 1,704 in 2007 in Sitkoh Creek. Although difficult to assess with such a short time series, lower smolt production in 2007 and 2008 (Table 7) may fall within a range of normal variation. Variations in smolt production have been reported for a long-term steelhead production study (30+ years) on the Keogh River, British Columbia, wherein smolt abundance averaged 2,390 annually during 1999–2007, yet only 965 smolts were counted in 2007 (McCubbing 2002; McCubbing and Ward 2003, 2007).

Table 7.–Summary of adult immigrant and emigrant counts and smolt steelhead counts at the Sitkoh Creek weir, 2003–2008.

Year	Number of adult immigrants	Number of emigrant kelts	Number of smolts
2003	679	460	3,162
2004	764	565	3,742
2005	543	363	2,230
2006	395	292	3,561
2007	392	345	1,704
2008	487	390	1,751

Although Sitkoh Creek steelhead smolt production was lower than previous years, the 2007 and 2008 smolt length frequency distributions were similar to the previous 4 years, and average sizes were slightly larger (Love and Harding 2008, 2009) at 205 mm FL in 2007 and 196 mm in 2008. Average lengths at emigration are larger than reported for the Keogh River, which ranged from 167 in 2006 to 185 in 2007 (McCubbing 2002; McCubbing and Ward 2003, 2007). As suggested by previous decade-long Keogh River research, Keogh River adult steelhead run size and age structure appeared to vary directly with smolt abundance and body size, which also influenced ocean survival (Ward and Slaney 1988, 1993; Carlin and Louis 2000 Ward et al. 1989). It remains unclear whether the smaller number of larger-sized smolts in the Keogh River in 2007 indicate competition for rearing habitat, food and/or space in earlier years. Nutrient fertilization projects in the Keogh River during 1997–2000 did produce greater numbers of larger smolt, possibly indicating competition for limited invertebrate production prior to fertilization (Ward et al. 2003). Invertebrate production estimates or nutrient fertilization experiments have not been conducted on Sitkoh Creek, but the larger average size of Sitkoh Creek smolts may confer a survival advantage. What influence food or habitat variations have had on smolt size and production is unknown. Decreasing outmigration abundance of Sitkoh Creek smolts could also be the related to density independent abiotic factors such as freezing winter temperatures, ice formation and dewatering (Huusko et al. 2007), or low summertime flows that resulted in dewatering of redds, or concentration of fry, thus exposing them to increased predation.

SMOLT FRESHWATER AGING AND SMOLTS-PER-SPAWNER ESTIMATES

The precision of Sitkoh Creek scale aging analysis was considered to be good for the 2007 and 2008 samples. These age estimates were then used to estimate smolts-per-spawner for the 2003–2008 period. Approximately, 90% of 3 independent scale aging reads matched. Accuracy will be verified pending paired scale/otolith sample comparisons from samples taken in 2006, 2007, and 2008. Independent, third-party age estimates for paired collections of otoliths and scales are currently being completed by the Alaska Department of Fish and Game's Mark, Tag and Age Laboratory in Juneau.

Freshwater age estimates for steelhead smolt appear to be greater for Sitkoh Creek when compared to stocks in British Columbia and farther south. A high proportion of steelhead smolt (78% of all sampled) in Sitkoh Creek appeared to be freshwater ages 3 and 4 in both 2007 and 2008 (Table 6). In 2007 and 2008, no scale-sampled smolts were aged younger than freshwater age 3, unlike scale aging results from the southern end of steelhead distribution. Steelhead in the Sacramento River were predominately freshwater age 1 (29%) and freshwater age 2 (70%), but only 1% freshwater age 3 (Hallock et al. 1961). Even when compared to smolt ages estimated for 2007 from the Keogh River, Sitkoh Creek smolt leaving freshwater were older in 2007 to 2008 (Ward and Slaney 1988; Love and Harding 2008, 2009). In 2007, the Keogh River produced more freshwater age-2 (48%) and age-3 (44%) smolt than Sitkoh Creek, where age estimates indicated that no freshwater age-2 and fewer freshwater age-3 (18.6%) smolt were produced (McCubbing and Ward 2007). Sitkoh Creek freshwater ages for outmigrant smolt in 2007 were predominately age 4 (>50%). Age estimates for the Keogh River for 2008 are not available, but Sitkoh Creek freshwater ages were estimated at 26.8% freshwater age 3, and 51.5% freshwater age 4 for outmigrant smolt. Scale-aged smolt in 1977–1983 for Keogh River smolt were generally younger, averaging 33% freshwater age 2 to 56% freshwater age 3, and fewer (11%) that were aged freshwater age 4+ (Ward and Slaney 1988). Such a shift towards older smolt with increasing latitude may not be unexpected because steelhead have been reported to spend more years in freshwater before smolting in colder northern streams (Withler 1966). As reported in Lohr and Bryant (1999), the most abundant freshwater age classes were estimated to be freshwater age 3 and 4 years for 5 other wild (excluding Klawock River and Ward Creek, which have hatchery fish) steelhead populations in Southeast Alaska.

The first estimate of Sitkoh Creek recruits per spawner (i.e., smolts-per-spawner) is less than the average calculated for the Keogh River. Assuming that scale aging methods used are unbiased, the production of smolt in 2006 (1,217 at freshwater age 3), 2007 (922 at freshwater age 4) and 2008 (229 at freshwater age 5) originating from the 2003 adult brood year class totaled 2,369 smolt. As related to the 2003 adult brood year class of 682, this equates to approximately 3.5 smolts-per-spawner for Sitkoh Creek. Smolts aged as freshwater age 2, 3, and 4 from the 2004 adult brood year class equaled 1,229 smolts, resulting in an incomplete (biased low) estimate of 1.6 smolts-per-spawner (Tables 8 and 9). The total smolts produced by the 2004 brood year class based on freshwater scale aging will be known upon completion of the 2009 field season. Year class analysis for wild steelhead stocks from the Keogh River estimated 16.6 smolts-per-spawner for the 2003 brood year class, an average of 4.8 smolts-per-spawner for 1986–1996 period, and an average 27 smolts-per-spawner for 1996 to 2002 (Ward et al. 2002,; McCubbing and Ward 2003, 2007; McCubbing 2002). The almost 6-fold difference in estimates for 1996 to 2002 was likely attributed to fertilization experiments conducted on the Keogh during this period, which enhanced invertebrate production.

Table 8.–Numbers of outmigrant smolts produced by adult brood year classes 2003–2008 based on freshwater scale aging of smolts.

Adult brood year class	Number of adults	Number of smolts	Number of smolt by emigration year						Number by adult brood year class
			2003	2004	2005	2006[a]	2007[b]	2008	
2003	682	3,166	– [c]	0	0	1,217	922	229	2,369
2004	780	3,742		– [c]	0	11	317	902	1,229
2005	574	2,230			– [c]	0	0	469	469
2006	416	3,549				– [c]	0	0	0
2007	418	1,704					– [c]	0	0
2008	513	1,751						– [c]	NA

[a] Love and Harding (2009).

[b] From Table 6.

[c] Smolt from brood year class *y* do not emigrate in year *y*.

Table 9.–Smolts-per-spawner for adult brood year classes 2003–2008 based on freshwater scale aging of smolt.

Adult brood year class	Number of adults	Number of smolts	Smolt-per-spawner by emigration year						Smolt-per-spawner (all fish)
			2003	2004	2005	2006	2007	2008	
2003	682	3,166	– [a]	0	0	1.785	1.352	0.336	3.47
2004	780	3,742		– [a]	0	0.014	0.406	1.156	1.58
2005	574	2,230			– [a]	0	0	0.818	0.82
2006	416	3,549				– [a]	0	0	0.00
2007	418	1,704					– [a]	0	0.00
2008	513	1,751						– [a]	NA

[a] Smolt from brood year class *y* do not emigrate in year *y*.

In the Keogh River there is continued concern for low smolt production by wild stocks (at smolts-per-spawner estimates that are higher than for Sitkoh Creek), declining steelhead abundance during the past 2 decades, and changing climactic effects, which are all cited as cause for conservation concerns. There may also be cause for concern in regards to Sitkoh Creek smolt production, however only 1 estimate of smolts-per-spawner has been obtained and without a long-term commitment to collecting production data at Sitkoh Creek, the current data series is too short to be useful for meaningful comparison or monitoring.

PIT TAG RETURNS AND OCEAN SURVIVAL

Recaptured adult steelhead in Sitkoh Creek were either previously tagged adults (recaptured as repeat spawners), or tagged smolts that had returned (one or more times) as adults. Of the total escapement, progressively more tagged steelhead have been recaptured at Sitkoh Creek since the project was initiated: 13.7% of total escapement in 2004, 24.3% in 2005, 63.2% in 2006, 74.2% in 2007 and 67.6% in 2008. Of those previously-tagged fish that were recaptured in 2007, 77% were initially tagged as smolts; during 2008, 90% were initially tagged as smolts.

Tagging-related ocean survival estimates for smolts returning to Sitkoh Creek for the first time in 2007 and 2008 were calculated for all smolt tagging years (a total of 14,025 smolts tagged and released in good condition from 2003–2007). Adult fish that had previously been tagged as smolts were recaptured in 2007 and 2008. Most of the recaptured adult steelhead (greater than 98% for 2007 and 2008) returned after 2 to 3 years in the ocean as first-time spawners (Table 10). This is consistent with the most abundant ocean-age classes reported for other Southeast Alaska streams such as the Karta, Thorne, Klawock, Petersburg, Peterson, Ward and Situk rivers (Lohr and Bryant 1999).

Table 10.–Number of annual and total PIT-tagged smolt that returned as first-time recaptured adult steelhead. Tag returns in percent for each smolt tagging year that were recaptured in 2003–2007.

		Unique returns as adults					
Smolt year	Number tagged	2005	2006	2007	2008	Total return by smolt year	% Tag return
2003	2,995	53	129	3	2	187	6.2
2004	3,608		49	112	0	161	4.5
2005	2,226			67	59	126	5.7
2006	3,549			1	166	167	4.7
2007	1,647						
Total	14,025						
2- and 3-ocean, %:		100	100	98	99		

Based on these tagging returns, an average of 5.3% of the 2003–2005 Sitkoh Creek smolt emigrations survived to return as adults in 2005, 2006, 2007 and 2008 (Table 10). Although the data only represent 4 years of tagging returns for ocean-age-2 and ocean-age-3 adults, marine survivals were within the range of 4.5% to 7.8% reported for the Keogh River during 2002 to 2003 (Ward and Slaney 1988; McCubbing 2002; McCubbing and Ward 2003), and were higher than the Keogh River in 2007 at 1.4% (McCubbing and Ward 2007). A regression of Sitkoh Creek smolt ocean survival on mean length of smolt for all years and ocean ages combined did not show a significant relationship ($r^2 = 0.1429$, $n = 6$).

Ocean-age-3 PIT-tagged adults (average = 209 mm FL) returning to spawn for the first time were not different in size on average when they left as smolts as compared to ocean-age-2 (average = 211 mm FL) fish. These size-at-age results are similar to those from the Keogh River (1975–1986), where no clear relationship was found between ocean age and mean smolt size (Ward and Slaney 1988).

ADULT PRODUCTION, SIZES, SEX RATIOS, REPEAT SPAWNING AND KELT SURVIVAL

Following 2 years of lower adult escapements during 2006 (N = 395) and 2007 (N = 391, the number of adult steelhead that returned during 2008 increased (N = 486). In spite of this increase, the escapement was still below the average (595) of the previous 4 years. The weir was installed later in the spring of 2007 (1 May), because of record snowpack and spring icing conditions. However, 93% of the estimated escapement during the spring period was still counted through the weir that year. In 2008, the weir was installed on schedule on April 10, and approximately 95% of the estimated escapement was censused through the weir by the end of June. An average of 96% of the estimated escapements were counted through the weir in 2003–2007. Weir integrity was compromised during 2007 for 4 hours when the weir was overtopped, but it was felt that no adults likely passed the weir. During 2008 the weir was not fish tight for about 19 hours during the mid-May flood, and an unknown number of adults passed the weir at that time. It appears that escapement into Sitkoh Creek is lower than average, but stable.

Proportionally more of the steelhead in Sitkoh Creek were females during 2007 and 2008, similar to what has been observed since this study was initiated in 2003. The mean proportion females during the 6 years of the study is 65% (Table 1). During 2007 and 2008, Sitkoh Creek female steelhead were larger and less variable in size than males, and appeared to survive the spawn better based on kelt counts. Adult female steelhead were also larger on average, and less variable in size during 2003–2008 (average FL = 761, SD = 61.1) when compared to males (average FL = 732, SD = 82.0). Females have also been reported to be larger than males in the Karta River, Petersburg Creek, Peterson Creek, Situk River, Anchor River, Karluk River, Crooked Creek and Nikolai Creek (Wallis et al. 1983; Lohr and Bryant 1999; Gates and Palmer 2006a-b).

Although females were proportionately more abundant overall, the sex composition of very large steelhead (>914 mm TL or ≥36 in TL) was predominately males (66% in 2007 and 68% in 2008). Prior to 2003, sex ratios of legal-sized fish were more equal or skewed towards large females. Since 2003, an increasing number of larger males are the only legal-sized fish in the population. However, average lengths of all adult steelhead in Sitkoh Creek has decreased from 753 mm FL to 731 mm FL since 2005, and the proportion of returning first-time spawners (which are younger and smaller), based on scale aging estimates, has increased (Love and Harding 2008, 2009). Only 5 fish (1.7%) in 2007 and 3 fish (0.7%) in 2008 were available for harvest during 2007–2008, and fewer legal large fish have been present in the population since 2003/2004 (Table 4). Sport fishing regulations in Southeast Alaska only allow harvest of trophy-sized steelhead greater than 36 inches total length, or 914 mm FL.

Post-spawning survival in Sitkoh Creek for both sexes combined was 82% in 2007 and 76% in 2008, compared to an average post-spawning survival of 69% in 2003–2006. Emigrant females composed an average of 67% in the 2003–2006 escapements, compared to 74% and 73% in 2007 and 2008, respectively, more than their immigration sex ratios in every year (Table 2). Post-spawning females also appeared to have higher survival rates than males as reported from the Karta River, Petersburg Creek, Peterson Creek, Situk River, Anchor River and Karluk River during 1971–1993 (Lohr and Bryant 1999), the Keogh River in 1988 (Ward and Slaney 1988), and in Crooked and Nikolai creeks in 2005 and 2006 (Gates and Palmer 2006a-b). PIT-tagged recaptures in 2007 and 2008 were similar to metrics (sex ratio) of the Sitkoh Creek steelhead escapements for all 6 years of study: females spent more time in the ocean and were larger on average, had higher post-spawning survivals, and were more abundant as repeat spawners compared to males (Love and Harding 2008, 2009). The percentage of outmigrating kelts from previous years that survived to spawn again in Sitkoh Creek during 2007 and 2008 equaled 20.3% for males and females combined, regardless of number of spawning events.

Although most spawners were first time spawners, a high proportion of the total escapement in Sitkoh Creek were repeat spawners in 2007 and 2008. Sitkoh Creek repeat-spawning rates (males and females combined) based on adult PIT tag returns of ocean ages-3, -4 and -5 adults recaptured in 2007 and 2008 averaged 20.6% of the escapement, which was higher than most years reported for the Keogh River. Based on scale analysis, repeat spawning rates for the Keogh River from 1976 to 1986 averaged 8.1% for males and 11.6% for females, but differed in 1988 and 2007 wherein 20% and 22%, respectively, were repeat spawners (Ward et al. 1989; McCubbing and Ward 2007). Sitkoh Creek repeat spawning rates were approximately twice those reported for Washington state rivers (Busby et al. 1996), but similar to or lower than reported repeat spawning rates (20–45%) for the Karta River, Situk River, Petersburg and Peterson Creeks in Southeast Alaska (Lohr and Bryant 1999). Higher repeat spawning rates for females may indicate good marine survival. Good survival combined with larger body size of older and larger repeat spawning females may mean higher average fecundity, greater egg numbers per female, and greater contribution to smolt production.

ADULT IMMIGRATION TIMING, SNOWMELT AND STRAYING

The run timing of steelhead at Sitkoh Creek in 2007 and 2008 appeared to be more similar to 2006, occurring later than previous observations from weir counts in the 1980s to 2004 (Jones et al. 1991; Harding and Jones 1994; Yanusz 1997; Love and Harding 2008, 2009). The midpoint of the immigration in 2006 occurred on 15 May. Because it is likely that fish were missed passing upstream during high water events in 2007 and 2008, adjusting the upstream counts upward in 2007 by about 35% (149), as estimated from downstream adults not passed upstream, and upwards in 2008 by about 21% (109), equates to a midpoint of about 14 May in 2007 and 10 May 10 in 2008, later than the average midpoint of 30 April in 2003–2005. The later years of this study (2006–2008) were more similar to that reported in the historical data from 1936 and 1937 (Jones et al. 1991; Chipperfield 1938; Figure 15). Heavy snowfall was observed at Sitkoh Creek during the 2006–2008 period. Using Juneau airport weather observations as a proxy, the 3-year average of total snowfall during 2003–2005 was 74.1 inches compared to the 3-year average for 2006–2008 of 130.8 inches (National Weather Service, Juneau Alaska, Alaska Climate Database http://pajk.arh.noaa.gov/cliMap/cli_out.php).

Not unlike the cold, snowy spring of 2006, record snowfall and extended snowmelt kept water temperatures colder later into the spring during both 2007 and 2008, and may have delayed immigration and emigration timing. Water temperatures in 2007 and 2008 (Figures 3 and 10) reached 10 ^{o}C in mid June, later than was recorded in 2003–2005 when the 10^{o}C threshold was reached during the 3rd and 4th week of May. The mean date that 95% of the immigrants passed the weir during 2003–2005 was 23 May, and 95% of the emigrant adults passed the weir on average by 14 June. During the spring seasons of 2006–2008, 95% of the immigrants passed the weir on average by 2 June, and 95% of the emigrants passed through by 18 June. By delaying migrations into, but not out of Sitkoh Creek, adult steelhead stayed in the stream for an average of only 16 days during 2006–2008, compared to 22 days on average during 2003–2005. The ability to detect changes in juvenile (fry and smolt) production attributed to changes in environment is hindered by the complexity of the lifecycle, and the likelihood that these events affect different age classes in different ways.

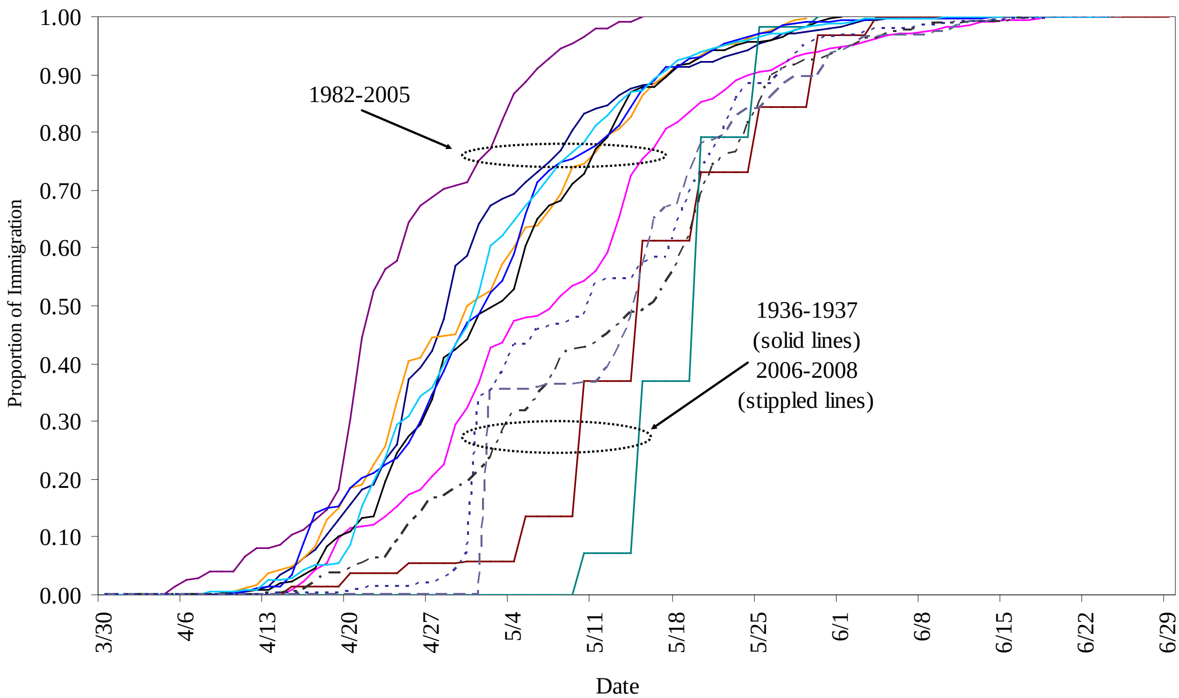

Figure 15.–Immigration timing of steelhead at Sitkoh Creek for all years during which a weir was operated. Data from Chipperfield (1938), Jones (1983), Jones et al. (1991), Harding and Jones (1994), and Yanusz (1997), Love and Harding (2008), Love and Harding (2009).

Straying from Sitkoh Creek to other systems has been documented for adult steelhead. In 2006 during a snorkel survey to nearby Sitkoh River, 6 of a total of 50 fish (12%) in a 2-mile section of stream were observed to be missing adipose fins indicating that fin-clipped steelhead, most likely from Sitkoh Creek, were present (Love and Harding 2009). Straying between Sitkoh Creek and the Situk River in Yakutat has also been documented. In 2007, a tagged kelt was sampled at the Situk River weir that did not match any of the PIT tags deployed in that stream. It was initially tagged as a smolt at 240 mm FL on 19 May 2006 in Sitkoh Creek before being recaptured at the Situk River weir on 14 June 2007 (Robert Johnson, ADF&G Division of Sport Fish biologist, retired, personal communication). This corroborates preliminary results of a principle component analysis of genetic data from 5 populations (3 in the Copper River, the Situk River, and Sitkoh Creek) that Situk River and Sitkoh Creek samples were clustered more closely together than they are to the Copper River stocks (Jeffrey Olsen, US Fish and Wildlife Service Conservation Genetics Laboratory, Anchorage, personal communication). Where sympatric anadromous (steelhead) and nonanadromous (resident) *O. mykiss* occur, it is possible that a single population exists, and genetic diversity is linked to combined abundance. This could mean that adjacent Southeast Alaska stocks may be part of a larger metapopulation, but extensive genetics sampling comparing diversity and gene flow between the various stocks would be needed to confirm the degree of this relationship.

LIFE HISTORY POLYMORPHISM

O. mykiss exhibit a variety of life histories ranging from nonmigratory to strongly migratory. These represent distinct life history strategies for this species, and in some areas where they interbreed may give rise to each of the forms present, i.e., resident fish giving rise to migratory and vice-versa (Thrower et al. 2004). This has been termed life history polymorphism (McEwan et al. 2005). Sitkoh Creek steelhead also appear to exhibit a range of life history strategies including: straying between steelhead systems, "re-emigrant" smolt ("half-pounders"), migratory rainbows and the (rare) occurrence of ocean-age-1 steelhead adults. Several smolts that were initially tagged in 2003, 2004, and 2006 have been recaptured as re-emigrants in 2004, 2005 and 2007, respectively. Increased circuli spacing and scale growth near the outer margin of the scale and greater size at recapture indicate these fish are utilizing richer feeding areas, possibly the nearshore estuarine environments, before returning to fresh water. None of these re-emigrant smolt have been observed to be in spawning condition. This life history type is similar to that for half-pounders, which are generally less than 400 mm FL and were originally described in the Rogue, Klamath, Mad and Eel rivers of southern Oregon and northern California (Snyder 1925; Kesner and Barnhart 1972; Everest 1973; Barnhart 1986). Upstream movements of "half-pounders" have also been observed elsewhere in Southeast Alaska. Half-pounders from Chuck Creek, Heceta Island (Steve McCurdy, ADF&G Division of Sport Fish, Craig, personal communication), and from near Petersburg (Douglas Fleming, ADF&G Division of Sport Fish, Petersburg Alaska, personal communication) have been sampled (Figure 16). Two half-pounders were sampled in Chuck Creek in October 2004 and September 2002, as they moved through an adult coho salmon weir, and measured 315 mm FL and 350 mm FL, respectively. The half-pounder captured in 2002 had a scale sample with scale growth characteristics similar to the re-emigrant smolt of Sitkoh Creek. Neither fish from Chuck Creek appeared to be sexually mature.

In 2007, a small 465 mm FL male steelhead adult (smaller than 22 inches) tagged as a smolt in 2006 was recaptured moving upstream through the weir. This was the first known ocean-age-1 precocious male to be recaptured at Sitkoh Creek (Figure 7 (a)). Populations in Oregon and California have higher frequencies of ocean-age-1 adults than populations to the north. In Southeast Alaska ocean-age-1 adults have also been reported in the Karta, Thorne, Klawock, Situk rivers, and Petersburg, and Peterson creeks (Lohr and Bryant 1999). Farther to the south in British Columbia, for the 1976–1986 period, an average of 3% of the escapement were ocean-age-1 adult males in the Keogh River (Ward and Slaney 1988). Generally, ocean-age-2 steelhead are considered the dominant adult age class in North America (Busby et al. 1996). This also appears to be true for Southeast Alaska stocks. Estimated ocean-age-2 fish (from scale samples) were generally more abundant than returning ocean-age-3 adults (Lohr and Bryant 1999), even though Withler (1966) found that ocean age at spawning (and mean adult length) generally increased with increasing latitude. Ocean age upon first return to spawn may instead be more variable for steelhead at higher latitudes than that reported for more southern stocks. While more ocean-age-3 PIT-tagged adults returned to Sitkoh Creek prior to 2007, returning ocean-age-2 adults were more abundant in 2008.

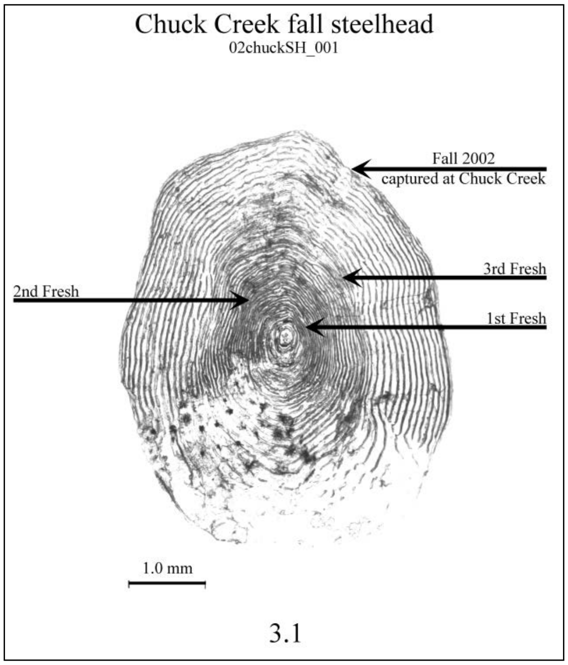

Figure 16.–Image of scale sample from a "half-pounder" steelhead sampled immigrating in fall of 2002 into Chuck Creek, Heceta Island, Alaska showing the first saltwater growth on outer margin of scale. Compare this to Figure 7 (a) of the 1-ocean adult recaptured

Small numbers of resident rainbow trout have also emigrated through the Sitkoh Creek weir each year of its operation. During 2007 and 2008, 40 and 53 resident rainbow trout were counted through the weir each year, respectively. Two recaptured rainbow trout were sampled each year that had been initially tagged in 2006. Early in the season, many of these resident rainbow trout were obviously ready to spawn and readily released milt and eggs when handled. It is not known if these fish were migrating to other stream systems to spawn, as documented for cutthroat trout (Yanusz 1997), or migrating to the lower portion of Sitkoh Creek. Some of the later resident rainbow trout emigrants appeared to be in post-spawning condition (fungus, abraded pelvic and caudal fins). These resident rainbows may have been moving into the lower river or estuary to recover and possibly to feed.

It is possible that the different life history forms of *O. mykiss* within Sitkoh Creek may be interbreeding given the overlap in spawn timing. Spawning groups of adult steelhead pairs with associated rainbow trout have been observed together in Sitkoh Creek. The author has seen these groups during snorkel surveys and has sampled a sexually mature male rainbow by hook and line from such a group. It is not known whether mature male rainbows were actively spawning with the steelhead or feeding on their eggs. Interbreeding of different life history forms is congruent with genetic analysis throughout the Pacific Rim (Busby et al. 1996; Docker and Heath 2003; McPhee et al. 2007). Sympatric populations (rainbows and steelhead) have been reported to occur together in the Copper River (Stark 1999), wherein comparisons of steelhead and conspecific rainbow stocks from 2 areas of the Copper River drainage suggest genetic similarity between resident rainbow trout and anadromous steelhead sampled (Wuttig et al. 2004). Where the two populations occur in sympatry, it is possible that a single population exists, and genetic diversity may be linked to combined abundance. Stream resident rainbow trout may contribute to sustaining this system's smolt production as in the Copper River and also in Sashin Creek

(Wuttig et al. 2004; Thrower et al. 2004), and possibly, yet undetermined, in Sitkoh Creek. Both ecotypes have been shown to be capable of producing both resident and anadromous offspring. In Sashin Creek, steelhead ecotypes have been produced from lake-source rainbows at the National Marine Fisheries Service Little Port Walter hatchery in Southeast Alaska (Thrower et al. 2004). Wuttig et al. (2004) suggest that to maintain genetic diversity in *O. mykiss* populations, conservative management may best be accomplished by attempting to maintain genetic diversity of rainbows that move genes within the system, as well as diversity of steelhead that stray to geographically distant stream systems. In addition to the influence of genetics, differing growth rates and survivals attributed to changing environmental influences may determine the life history strategy of steelhead. In turn, this type of selection may have resulted in steelhead maintaining the ability to respond to environmental conditions by adopting either resident or anadromous life-cycles, an ability known as state dependent or conditional life history strategy (Houston and McNamara 1992; Jonsson and Jonsson 1993). Life history polymorphism of rainbow trout and steelhead at Sitkoh Creek may allow for a greater variety of genetic diversity to be conserved if conditions change and may confer greater survival to the species as a whole (McEwan et al. 2005; Jonsson and Jonsson 1993; Shapovalof and Taft 1954).

On average, the variety of life history forms (half-pounder ocean-age-1 adults, and re-emigrant smolts) observed in Sitkoh Creek represent less than one-half of 1 % of the total smolt emigration during any given year. This plasticity in the life history strategies observed may indicate a lack of reproductive isolation within the Sitkoh Creek population. Because steelhead smolt and rainbow trout smolt can be very difficult to tell apart, it is possible that some downstream migratory rainbows made up a percentage of the outmigrant smolt counts. However, technicians were very careful to correctly identify steelhead smolt. During 2003–2008, only 1 smolt was subsequently recaptured as an "anadromous" rainbow trout that was mature and had spawning coloration. This recaptured rainbow trout had smolt characteristics when first tagged as an outmigrant. Based solely on estimated freshwater scale ages sampled from the smolt emigration, it appears that an average of approximately 13% of the emigrant smolts during the past 6 years were estimated to be 5 freshwater age or greater in scale age (i.e., possibly migratory rainbows). On average, since 2003, approximately 17% of the adults (first-time and repeat spawners combined) returning to Sitkoh Creek were estimated (based on PIT tag recaptures that were scale aged) to be 5 freshwater age or greater. Without knowing the adult brood source for outmigrant smolt as well as migratory rainbows it is not possible to precisely determine relative contribution of steelhead versus resident rainbow, unless stable isotope analysis of collected scale samples could distinguish between progeny of adult marine or freshwater origin as can be done with otoliths (Kalish 1990). Regardless of adult brood year class, estimates of smolt per unit of habitat (based on outmigrant numbers) for the steelhead habitat study (Crupi and Nichols 2012) would be unchanged but smolt-per-spawner estimates would have to be modified. Reducing the percentage of smolt estimated to be freshwater age 5 would reduce the number of smolts, which in turn would reduce the production estimates in Tables 8 and 9. Further study comparing relative genetic relationships between the two sympatric life history forms would be necessary to tease out relative contribution to smolt production. Regardless of resident rainbow contribution, maybe the use of smolts-per-steelhead female would be a more appropriate measure given their higher fecundity and likely greater contribution to anadromous smolt production.

DOLLY VARDEN CHAR, CUTTHROAT TROUT AND OTHER SPECIES

The number of Dolly Varden that emigrated through the weir in 2007 (27,534 fish) and 2008 (18,790 fish) continued on a downward trend from a high count of 62,409 outmigrants in 2004. However, emigrant Dolly Varden may have passed over or around the weir during the high water events in 2007 and 2008. In 2007, the date during which over half of the total emigration had passed downstream (23 May) was similar to the cold spring of 2006 (May 28), but later than 2005 (May 15).

The cutthroat trout emigrations in Sitkoh Creek in 2007 (2,011 fish) and 2008 (2,323 fish) were lower than the mean emigration abundance in 2003–2006 (3,490 fish). The highest emigration total reported is 4,588 in 2003. Because of the late weir installation in 2007 and heavy flow events in 2008, it is possible that some cutthroat emigrants were missed. Emigration timing was delayed, but similar to previous years. Ninety-five percent of the total cutthroat trout emigration was completed by early to mid-June in 2007 and 2008, compared to end of May in earlier years. It is unknown why Dolly Varden and cutthroat trout emigration abundance was lower than previous years, but both may have been delayed by colder spring water temperatures.

Counts of salmon species such as sockeye and pink salmon passed through the Sitkoh Creek weir are incomplete. Because these species typically migrate upstream later in the summer after the weir was already removed, no inferences can be made about escapements based on fish passed through the Sitkoh Creek weir.

SUMMARY OF OBSERVATIONS FOR SITKOH CREEK

Sitkoh Creek steelhead smolt production appears to have declined during this study, but varies similar to reported production for the Keogh River. Mean length and length frequency distributions of outmigrations in recent years do not appear to be different than previous years. Not unexpected for a more northern stock, estimated scale ages indicated that Sitkoh Creek steelhead spend approximately a year longer in freshwater prior to smolting, and returned as adults, on average, a year later after they went to sea. Marine survival of previously PIT-tagged smolts (including tagging-related handling stress) to returning adults appears to be relatively high for Sitkoh Creek, as compared to the Keogh River in recent years. Smolt-per-spawner estimates for Sitkoh Creek were similar to estimates obtained in recent years on the Keogh River when production was not altered by nutrient input. However, when compared to long-term research streams such as the Keogh River, these estimates are considered low. Whether or not the low smolt production on Sitkoh Creek is cause for conservation concern is not known.

Although steelhead production appears to be lower than when this study was initiated in 2003, the variation in production is within the range reported in the literature for more extensively studied systems like the Keogh River and may be mitigated by straying, high repeat spawning rates and possibly contribution by resident rainbow trout. Straying rates at Sitkoh Creek were not determined for 2007. In 2008, 45 untagged immigrant adults were systematically scale sampled at Sitkoh Creek. Of these, 11% (5 fish) were repeat spawners that might have strayed from elsewhere, returned to the creek at some time other than when the weir was in place, or were missed and had not been PIT tagged in previous years. The remaining 89% (40 fish) were likely first time spawners, although some could be repeat spawning adults that did not show circuli erosion at the spawning check of the scale. Mis-identifying repeat-spawning adults as first-time spawners if a spawning check is evident is less likely because the circuli erosion of a spawning check is distinctive (Figure 17b). Although repeat spawning rates were not estimated in 2007, in 2008 22% of the escapement was estimated to be repeat spawners.

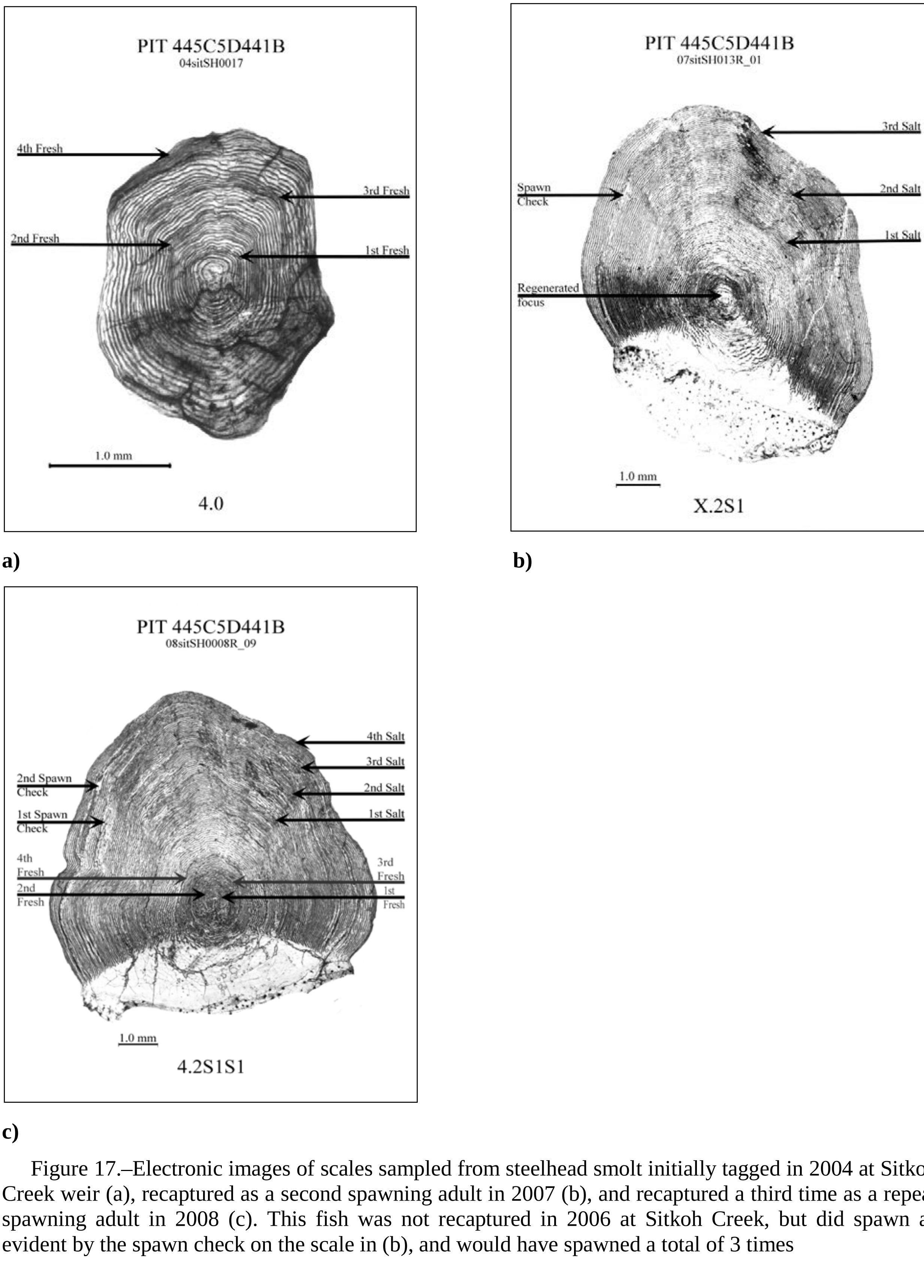

Figure 17.–Electronic images of scales sampled from steelhead smolt initially tagged in 2004 at Sitkoh Creek weir (a), recaptured as a second spawning adult in 2007 (b), and recaptured a third time as a repeat spawning adult in 2008 (c). This fish was not recaptured in 2006 at Sitkoh Creek, but did spawn as evident by the spawn check on the scale in (b), and would have spawned a total of 3 times

Lohr and Bryant (1999) report repeat spawning rates for 4 other Southeast Alaska streams of 25–70%. Repeat spawning adults from Snow Creek, Washington tend to produce more smolt that survive to return as adults than do first-time spawning adults. Over the lifetime of the adult steelhead, repeat spawning slows the rate of loss of genetic diversity and increases the rate of recovery in smaller populations (Seamons and Quinn 2010).

Kelt survivals in Sitkoh Creek also favor females, which may help preserve productivity and genetic contribution favoring anadromous steelhead. Sitkoh Creek also supports a healthy population of resident rainbow trout, which may contribute to maintaining genetic diversity and smolt production in years of low steelhead escapement. Sitkoh Creek appears to produce larger, older outmigrant smolts, stable but lower smolt production, good adult female spawner survival in marine and fresh waters, high repeat spawning rates, documented straying to other systems, and a large rainbow trout population which all may confer higher resilience to perturbation, maintain diversity and allow recovery following low abundance years. Nonetheless, a northern stock such as Sitkoh Creek may be slow-growing and slow to replace recruits. It may also be more vulnerable to overexploitation and experience declines due to lower productivity, slower growth, and older age-at-maturity, and thus should be managed cautiously.

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APPENDIX A: FILE DESCRIPTION

Appendix A1.–Contents of electronic files submitted with this report

File name	Software	Contents
0708FDS_Tables & Figs.xls	Excel 2003	Figures and tables and associated data and Appendices used to generate them for this report
07-08Sitkoh Rawdata.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 during 2007 and 2008
07Daily&Cumm counts.xls	Excel 2003	Daily weir counts in 2007 for all species at Sitkoh Creek
08Daily&Cumm counts.xls	Excel 2003	Daily weir counts in 2008 for all species at Sitkoh Creek
daily temp and level 2007.xls	Excel 2003	Daily temp and stage gauge at Sitkoh Creek in 2007
daily temp and level 2008.xls	Excel 2003	Daily temp and stage gauge at Sitkoh Creek in 2008